RCA

# Transistor Thyristor & Diode Manual

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RCA | Solid State Division | Somerville, NJ 08876

# Transistor Thyristor & Diode Manual

This Manual, like its preceding editions, is useful to engineers, educators, students, radio amateurs, hobbyists, and others who are technically interested in bipolar transistors, MOS field-effect transistors, thyristors, silicon rectifiers, and other solid-state diodes. It provides detailed information on the operation, technology, circuit applications, and testing of such devices, as well as definitive characteristics and ratings on all current RCA types.

This edition has been expanded and updated to cover the latest developments in solid-state device technology and applications. In addition, the technical data has been grouped according to product types to facilitate selection of the optimum device for a particular application. A complete index to specific devices is provided at the back of the Manual. The popular **Circuits** Section has also been augmented by several new types of circuits, and circuits previously included have been modified and updated as required to reflect current practices in circuit design and applications.

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# Contents

# Materials, Junctions, and Devices

SOLID-STATE devices are small but versatile units that can perform an amazing variety of control functions in electronic equipment. Like other electron devices, they have the ability to control almost instantly the movement of charges of electricity. They are used as rectifiers, detectors, amplifiers, oscillators, electronic switches, mixers, and modulators.

In addition, solid-state devices have many important advantages over other types of electron devices. They are very small and light in weight (some are less than an inch long and weigh just a fraction of an ounce). They have no filaments or heaters, and therefore require no heating power or warm-up time. They consume very little power. They are solid in construction, extremely rugged, free from microphonics, and can be made impervious to many severe environmental conditions. The circuits required for their operation are usually simple.

## SEMICONDUCTOR MATERIALS

Unlike other electron devices, which depend for their functioning on the flow of electric charges through a vacuum or a gas, solid-state devices make use of the flow of current in a solid. In general, all materials may be classified in three major categories—conductors, semiconductors, and insulators—depending upon their ability to conduct an electric current. As the name indicates, a semiconductor material has poorer conductivity than a conductor, but better conductivity than an insulator.

The materials most often used in semiconductor devices are germanium and silicon. Germanium has higher electrical conductivity (less resistance to current flow) than silicon, and is used in devices intended for applications that require low voltage drops at high currents and in some small-signal transistors. Silicon is more suitable for high-power devices than germanium. One reason is that it can be used at much higher temperatures. In general, silicon is preferred over germanium because processing techniques yield more economical devices. As a result, today, silicon tends to supersede germanium in almost every type of application, including the small-signal area, unless a very low device voltage drop is required.

### Resistivity

The ability of a material to conduct current (conductivity) is directly proportional to the number of free (loosely held) electrons in the material. Good conductors, such as silver, copper, and aluminum, have large numbers of free electrons; their resistivities are of the order of a few millionths of an ohm-centimeter. Insulators such as glass, rubber, and mica, which have very few loosely held electrons, have resistivities of several million ohm-centimeters.

Semiconductor materials lie in the range between these two extremes, as shown in Fig. 1. Pure germanium has a resistivity of 60 ohm-centimeters. Pure silicon has a considerably higher resistivity, in the order of 60,000 ohm-centimeters. As used in semiconductor devices, however, these materials contain carefully controlled amounts of certain impurities

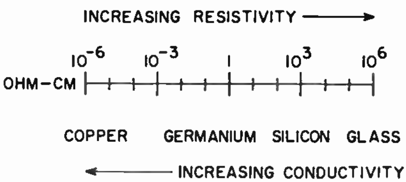



*Fig. 1—Resistivity of typical conductor, semiconductors, and insulator.*

which reduce their resistivity to about 2 ohm-centimeters at room temperature (this resistivity decreases rapidly as temperature rises).

## Impurities

Carefully prepared semiconductor materials have a crystal structure. In this type of structure, which is called a lattice, the outer or valence electrons of individual atoms are tightly bound to the electrons of adjacent atoms in electron-pair bonds, as shown in Fig. 2. Because such a

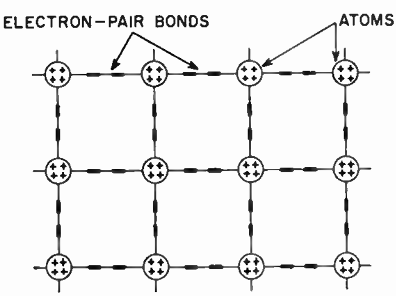



*Fig. 2—Crystal lattice structure.*

structure has no loosely held electrons, semiconductor materials are poor conductors under normal conditions. In order to separate the electron-pair bonds and provide free electrons for electrical conduction, it would be necessary to apply high temperatures or strong electric fields.

Another way to alter the lattice structure and thereby obtain free electrons, however, is to add small amounts of other elements having a different atomic structure. By the addition of almost infinitesimal amounts of such other elements, called "impurities", the basic electrical properties of pure semiconductor materials can be modified and controlled. The ratio of impurity to the semiconductor material is usually extremely small, in the order of one part in ten million.

When the impurity elements are added to the semiconductor material, impurity atoms take the place of semiconductor atoms in the lattice structure. If the impurity atoms added have the same number of valence electrons as the atoms of the original semiconductor material, they fit neatly into the lattice, forming the required number of electron-pair bonds with semiconductor atoms. In this case, the electrical properties of the material are essentially unchanged.

When the impurity atom has one more valence electron than the semiconductor atom, however, this extra electron cannot form an electron-pair bond because no adjacent valence electron is available. The excess electron is then held very loosely by the atom, as shown in Fig. 3, and

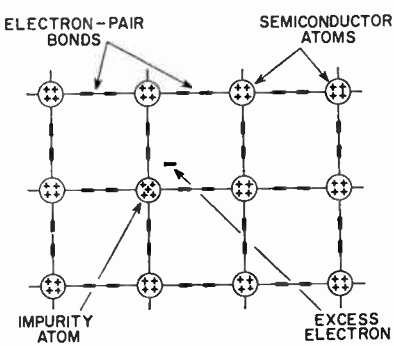



*Fig. 3—Lattice structure of n-type material.*

requires only slight excitation to break away. Consequently, the presence of such excess electrons makes the material a better conductor, i.e., its resistance to current flow is reduced.

Impurity elements which are added to germanium and silicon crystals to provide excess electrons include arsenic and antimony. When these elements are introduced, the resulting material is called **n-type** because the excess free electrons have a negative charge. (It should be noted, however, that the negative charge of the electrons is balanced by an equivalent positive charge in the center of the impurity atoms. Therefore, the net electrical charge of the semiconductor material is not changed.)

A different effect is produced when an impurity atom having one less valence electron than the semiconductor atom is substituted in the lattice structure. Although all the valence electrons of the impurity atom form electron-pair bonds with electrons of neighboring semiconductor atoms, one of the bonds in the lattice structure cannot be completed because the impurity atom lacks the final valence electron. As a result, a vacancy or "hole" exists in the lattice, as shown in Fig. 4. An electron from an adjacent electron-pair bond may then absorb enough energy to break its bond and move through the lattice to fill the hole. As in the case of excess electrons, the presence of "holes" encourages the flow of electrons in the semiconductor material; consequently, the conductivity is increased and the resistivity is reduced.

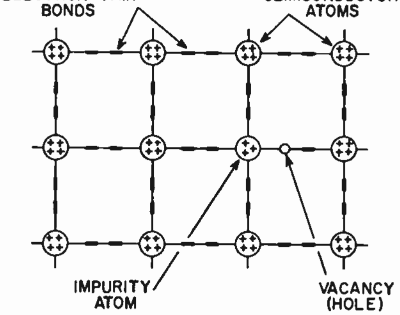



*Fig. 4—Lattice structure of p-type material.*

The vacancy or hole in the crystal structure is considered to have a positive electrical charge because it represents the absence of an electron. (Again, however, the net charge of the crystal is unchanged.) Semiconductor material which contains these "holes" or positive charges is called **p-type** material. P-type materials are formed by the addition of aluminum, gallium, or indium.

Although the difference in the chemical composition of n-type and p-type materials is slight, the differences in the electrical characteristics of the two types are substantial, and are very important in the operation of solid-state devices.

## P-N JUNCTIONS

When n-type and p-type materials are joined together, as shown in Fig. 5, an unusual but very important phenomenon occurs at the interface where the two materials meet (called the **p-n junction**). An interaction takes place between the two types of material at the junction as a result of the holes in one material and the excess electrons in the other.

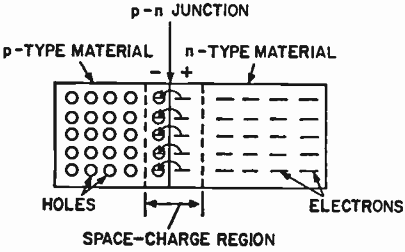



*Fig. 5—Interaction of holes and electrons at p-n junction.*

When a p-n junction is formed, some of the free electrons from the n-type material diffuse across the junction and recombine with holes in the lattice structure of the p-type material; similarly, some of the holes in the p-type material diffuse across the junction and recombine with free electrons in the lattice structure of the n-type material. This interaction or diffusion is brought into equilibrium by a small space-charge region (sometimes called the transition region or depletion layer). The p-type material thus acquires a slight negative charge and the n-type material acquires a slight positive charge.

Thermal energy causes charge carriers (electrons and holes) to diffuse from one side of the p-n junction to the other side; this flow of charge carriers is called diffusion current. As a result of the diffusion process, however, a potential gradient builds up across the space-charge region. This potential gradient can be represented, as shown in Fig. 6, by an imaginary battery connected across the p-n junction. (The battery symbol

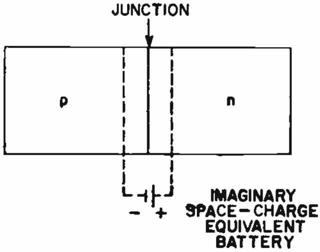



*Fig. 6—Potential gradient across space-charge region.*

is used merely to illustrate internal effects; the potential it represents is not directly measurable.) The potential gradient causes a flow of charge carriers, referred to as drift current, in the opposite direction to the diffusion current. Under equilibrium conditions, the diffusion current is exactly balanced by the drift current so that the net current across the p-n junction is zero. In other words, when no external current or voltage is applied to the p-n junction, the potential gradient forms an energy barrier that prevents further diffusion of charge carriers across the junction. In effect, electrons from the n-type material that tend to diffuse across the junction are repelled by the slight negative charge induced in the p-type material by the potential gradient, and holes from the p-type material are repelled by the slight positive charge induced in the n-type material. The potential gradient (or energy barrier, as it is sometimes called), therefore, prevents total interaction between the two types of materials, and thus preserves the differences in their characteristics.

## CURRENT FLOW

When an external battery is connected across a p-n junction, the amount of current flow is determined by the polarity of the applied voltage and its effect on the space-charge region. In Fig. 7(a), the positive terminal of the battery is connected to the n-type material and the negative terminal to the p-type material. In this arrangement, the free electrons in the n-type material are attracted toward the positive terminal of the battery and away from the junction. At the same time, holes from the

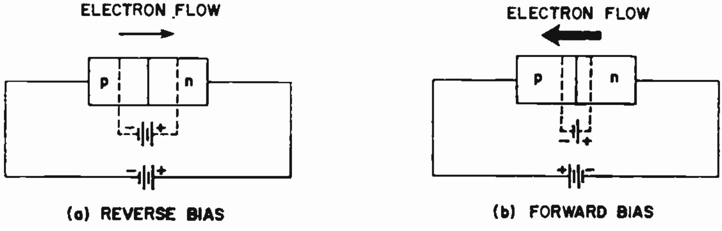



*Fig. 7—Electron current flow in biased p-n junctions.*

p-type material are attracted toward the negative terminal of the battery and away from the junction. As a result, the space-charge region at the junction becomes effectively wider, and the potential gradient increases until it approaches the potential of the external battery. Current flow is then extremely small because no voltage difference (electric field) exists across either the p-type or the n-type region. Under these conditions, the p-n junction is said to be reverse-biased.

In Fig. 7(b), the positive terminal of the external battery is connected to the p-type material and the negative terminal to the n-type material. In this arrangement, electrons in the p-type material near the positive terminal of the battery break their electron-pair bonds and enter the battery, creating new holes. At the same time, electrons from the negative terminal of the battery enter the n-type material and diffuse toward the junction. As a result, the space-charge region becomes effectively narrower, and the energy barrier decreases to an insignificant value. Excess electrons from the n-type material can then penetrate the space-charge region, flow across the junction, and move by way of the holes in the p-type material toward the positive terminal of the battery. This electron flow continues as long as the external voltage is applied. Under these conditions, the junction is said to be forward-biased.

The generalized voltage-current characteristic for a p-n junction in Fig. 8 shows both the reverse-bias and forward-bias regions. In the forward-bias region, current rises rapidly as the voltage is increased and is quite high. Current in the reverse-bias region is usually much lower. Excessive voltage (bias) in either direction should be avoided in normal applications because excessive currents and the resulting high temperatures may permanently damage the solid-state device.

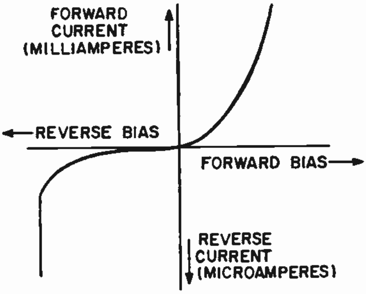



*Fig. 8—Voltage-current characteristic for a p-n junction.*

## TYPES OF DEVICES

The simplest type of solid-state device is the diode, which is represented by the symbol shown in Fig. 9. Structurally, the diode is basically a p-n junction similar to those shown in Fig. 7. The n-type material which serves as the negative electrode is referred to as the cathode, and the p-type material which serves as the positive electrode is referred to as the anode. The arrow symbol used for the anode represents the direction of "conventional current flow"; electron current flows in a direction opposite to the arrow.

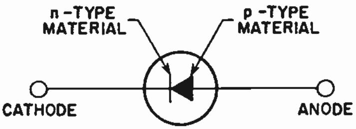



*Fig. 9—Schematic symbol for a solid-state diode.*

Because the junction diode conducts current more easily in one direction than in the other, it is an effective rectifying device. If an ac signal is applied, as shown in Fig. 10, electron current flows freely during the positive half cycle, but little or no current flows during the negative half cycle.

One of the most widely used types of solid-state diode is the silicon rectifier. These devices are available in a wide range of current

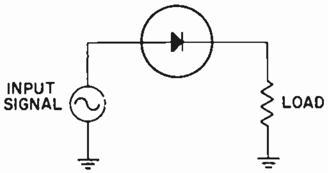



*Fig. 10—Simple diode rectifying circuit.*

capabilities, ranging from tenths of an ampere to several hundred amperes or more, and are capable of operation at voltages as high as 1000 volts or more. Parallel and series arrangements of silicon rectifiers permit even further extension of current and voltage limits. Characteristics and applications of these devices are discussed in detail in the section on Silicon Rectifiers.

Several variations of the basic junction diode structure have been developed for use in special applications. One of the most important of these developments is the **tunnel diode**, which is used for amplification, switching, and pulse generation. This diode and other special types (i.e., varactor, voltage-reference, and compensating diodes) are described in the section on Other Solid-State Diodes.

When another layer is added to a semiconductor diode to form three layers (two junctions), a device is produced which provides power or voltage amplification. The resulting device is called a **bipolar transistor**. The three regions of the device are called the **emitter**, the **base**, and the **collector**, as shown in Fig. 11(a). In normal operation, the emitter-to-base junction is biased in the forward direction, and the collector-to-base junction in the reverse direction.

Different symbols are used for n-p-n and p-n-p transistors to show the difference in the direction of current flow in the two types of devices. In the n-p-n transistor shown in Fig. 11(b), electrons flow from the emitter to the collector. In the p-n-p transistor shown in Fig. 11(c), electrons flow from the collector to the emitter. In other words, the direction of dc electron current is always opposite to that of the arrow on the emitter lead. (As in the case of semiconductor diodes, the arrow indicates the direction of "conventional current flow" in the circuit.)

The first two letters of the n-p-n and p-n-p designations indicate the respective polarities of the voltages applied to the emitter and the collector in normal operation. In

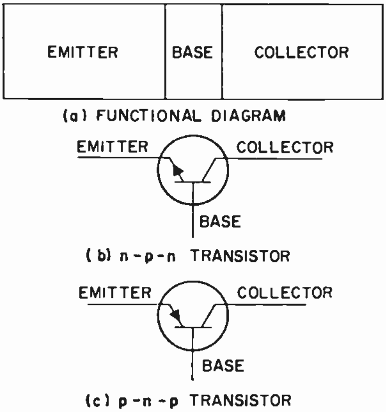



*Fig. 11—Functional diagram and schematic symbols for bipolar transistors.*

an n-p-n transistor the emitter is made negative with respect to both the collector and the base, and the collector is made positive with respect to both the emitter and the base. In a p-n-p transistor, the emitter is made positive with respect to both the collector and the base, and the collector is made negative with respect to both emitter and base.

The transistor, which is a three-element device, can be used for a wide variety of control functions, including amplification, oscillation, and frequency conversion. A complete description of the fabrication, electrical characteristics, and basic circuits of bipolar transistors is given in the section on Bipolar Transistors.

The **field-effect transistor** (FET) is another type of solid-state device that is becoming increasingly popular in electronic circuits. Functionally, this type of transistor differs from the bipolar transistor in that current flow through the device is controlled by variation of the electric field established by a control voltage rather than by variation of the current injected into the base terminal. Field-effect transistors exhibit many of the electrical characteristics of electron tubes, but still retain the inherent advantages of solid-state devices (e.g., small size, low power consumption, and mechanical ruggedness). On the basis of structural and functional differences, these devices are classified as either **junction-gate field-effect transistors** (JFET) or **metal-oxide-semiconductor field-effect transistors** (MOS/FET). Although in both types the conduction current is controlled by an electric field, the electrical characteristics of these devices differ significantly.

Fig. 12 shows the schematic symbols for both n-channel and p-channel junction-gate field-effect transistors. The gate, source, and drain electrodes of these devices are equivalent to the base, emitter, and collector electrodes, respectively, of bipolar transistors. A signal voltage applied to the gate electrode controls the conductivity of the semiconductor layer immediately below the gate, between the source and drain terminals. The n-channel type, which is analogous to an n-p-n bipolar transistor, is operated with the drain at a positive potential with respect to the source terminal. In the schematic symbol, this type is indicated by an arrow in the gate lead that points into the device. The drain potential for the p-channel type, which is analogous to a p-n-p bipolar transistor, is negative with respect to the source terminal. In the schematic symbol for this type, the arrow in the gate lead points away from the device.

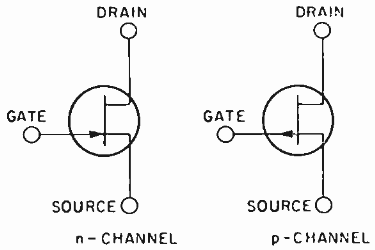



*Fig. 12—Schematic symbols for junction-gate field-effect transistors (JFET).*

Fig. 13 shows the schematic symbols for both n-channel and p-channel versions of the basic classes of MOS field-effect transistors, i.e., **enhancement types** and **depletion types**. The arrow used in the schematic symbol to indicate whether a device is an n-channel type (points inward) or a p-channel type (points outward) is shown in the lead from the substrate terminal. The substrate terminal is connected to the semiconductor substrate (also referred to as the active "bulk") on which the transistor is fabricated.

The technology for MOS field-effect transistors is more versatile than that for junction-gate types. Specific categories of MOS field-effect transistors have been designed with unique characteristics that make them ideal for linear (analog) and digital applications. For example, the depletion type is frequently used in linear applications, and the enhancement type is ideal for digital applications. An enhancement type of MOS field-effect transistor is equivalent to a "normally open" switch, as indicated in the schematic symbol by the gaps in the source-to-drain path. The depletion type, however, is normally conductive and its source-to-drain path is shown continuous in the schematic symbol. The enhancement-MOS/FET technology is being used increasingly in the fabrication of integrated circuits for digital application, particularly for large-scale-integration (LSI) circuits. A comprehensive description of MOS/FET devices is given in the section on **MOS Field-Effect Transistors.**

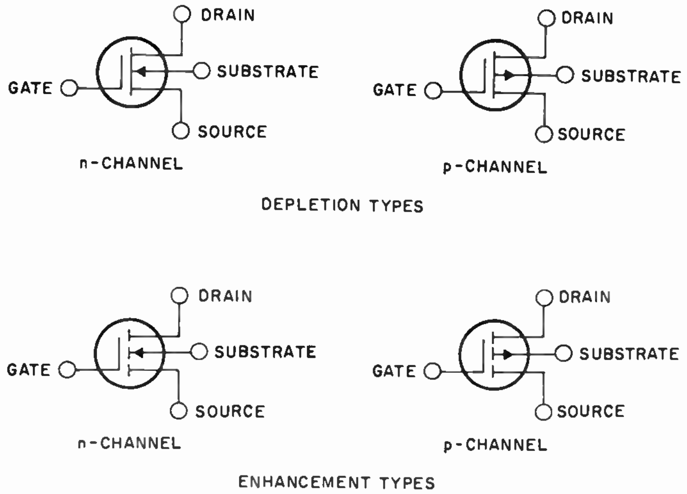



*Fig. 13—Schematic symbols for metal-oxide-semiconductor field-effect transistors (MOS/FET).*

When alternate layers of p-type and n-type semiconductor materials are arranged in a series array, various types of thyristors can be produced. The term thyristor is the generic name for solid-state devices that have electrical characteristics similar to those of thyratron tubes. The three basic types of thyristors are the bidirectional trigger diode called the diac, the reverse blocking triode called the silicon controlled rectifier or SCR, and the bidirectional triode thyristor, called the triac. The diac, shown in Fig. 14, is a two-electrode, three-layer device having the same doping level at both junctions and a "floating" base. The device conducts current in

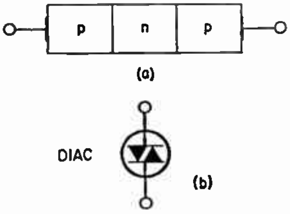



*Fig. 14—Junction diagram (a) and schematic symbol (b) for a diac.*

either direction after the applied voltage exceeds a certain value called the "breakover voltage." The SCR is a three-electrode, four-layer device, as shown in Fig. 15. The SCR

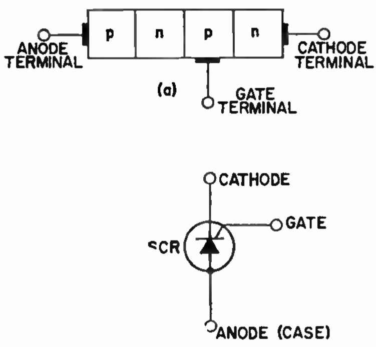



*Fig. 15—Junction diagram (a) and schematic symbol (b) for a silicon controlled rectifier or SCR.*

behaves as a conventional rectifier to block current flow in the reverse direction and as a transistor switch in the forward direction to first block current and then conduct through the device when a current pulse of sufficient magnitude is applied to the gate electrode. The triac is a three-electrode, five-layer device, as shown in Fig. 16, which exhibits the forward-blocking—forward-conducting voltage-current characteristic of the SCR structure for either direction of voltage applied to the main terminals. The schematic symbols for these thyristor devices are also shown in Figs. 14, 15, and 16. A complete description of these devices is given in the section on Thyristors.

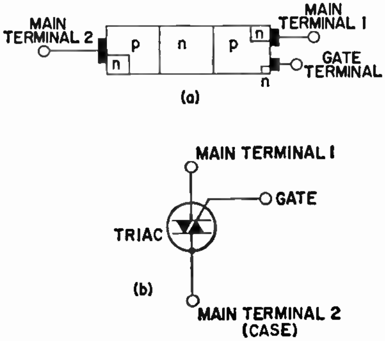



*Fig. 16—Junction diagram (a) and schematic symbol (b) for a triac.*

# Bipolar Transistors

A p-n junction biased in the reverse direction is equivalent to a high-resistance element (low current for a given applied voltage), while a junction biased in the forward direction is equivalent to a low-resistance element (high current for a given applied voltage). Because the power developed by a given current is greater in a high-resistance element than in a low-resistance element ($P = I^2R$), power gain can be obtained in a structure containing two such resistance elements if the current flow is not materially reduced. A device containing two p-n junctions biased in opposite directions is called a junction or bipolar transistor.

Such a two-junction device is shown in Fig. 17. The thick end layers are made of the same type of material (n-type in this case), and are separated by a very thin layer of the opposite type of material (p-type in the device shown). By means of the external batteries, the left-hand (n-p) junction is biased in the forward direction to provide a low-resistance input circuit, and the right-hand (p-n) junction is biased in the reverse direction to provide a high-resistance output circuit.

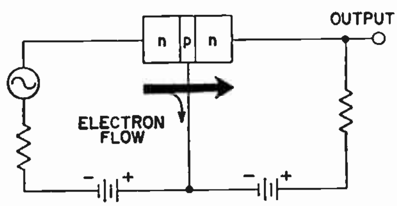



*Fig. 17—An n-p-n structure biased for power gain.*

Electrons flow easily from the left-hand n-type region to the center p-type region as a result of the forward biasing. Most of these electrons diffuse through the thin p-type region, however, and are attracted by the positive potential of the external battery across the right-hand junction. In practical devices, approximately 95 to 99.5 per cent of the electron current reaches the right-hand n-type region. This high percentage of current penetration provides power gain in the high-resistance output circuit and is the basis for transistor amplification capability.

The operation of p-n-p devices is similar to that shown for the n-p-n device, except that the bias-voltage polarities are reversed, and electron-current flow is in the opposite direction. (Many discussions of semiconductor theory assume that the "holes" in semiconductor material constitute the charge carriers in p-n-p devices, and discuss "hole currents" for these devices and "electron currents" for n-p-n devices. Other texts discuss neither hole current nor electron current, but rather "conventional current flow", which is assumed to travel through a circuit in a direction from the positive terminal of the external battery back to its negative terminal. For the sake of simplicity, this discussion will be restricted to the concept of electron current flow, which travels from a negative to a positive terminal.)

## DESIGN AND FABRICATION

The ultimate aim of all transistor fabrication techniques is the construction of two parallel p-n junctions with controlled spacing between the junctions and controlled impurity levels on both sides of each junction. A variety of structures has been developed in the course of transistor evolution.

The earliest transistors made were of the point-contact type. In this type of structure, two pointed wires were placed next to each other on an n-type block of semiconductor material. The p-n junctions were formed by electrical pulsing of the wires. This type has been superseded by junction transistors, which are fabricated by various alloy, diffusion, and crystal-growth techniques.

In grown-junction transistors, the impurity content of the semiconductor material is changed during the growth of the original crystal ingot to provide the p-n-p or n-p-n regions. The grown crystal is then sliced into a large number of small-area devices, and contacts are made to each region of the devices. Fig. 18(a) shows a cross-section of a grown-junction transistor.

In alloy-junction transistors, two small "dots" of a p-type or n-type impurity element are placed on opposite sides of a thin wafer of n-type or p-type semiconductor material, respectively, as shown in Fig. 18(b). After proper heating, the impurity "dots" alloy with the semiconductor material to form the regions for the emitter and collector junctions. The base connection in this structure is made to the original semiconductor wafer.

The drift-field transistor is a modified alloy-junction device in which the impurity concentration in the base wafer is diffused or graded, as shown in Fig. 18(c). Two advantages are derived from this structure: (a) the resultant built-in voltage or "drift field" speeds current flow, and (b) the ability to use a heavy impurity concentration in the vicinity of the emitter and a light concentration in the vicinity of the collector makes it possible to minimize capacitive charging times. Both these advantages lead to a substantial extension of the frequency performance over the alloy-junction device.

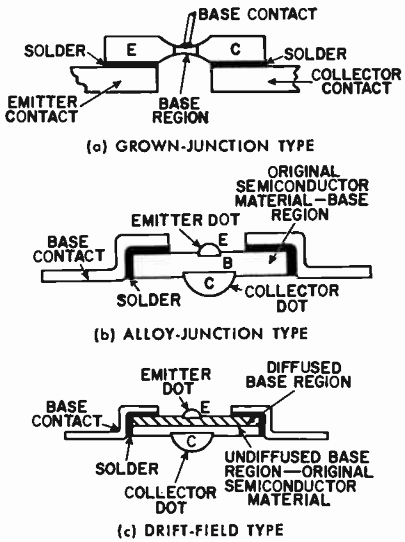



*Fig. 18—Cross-sections of junction transistors.*

The diffused-junction transistor represents a major advance in transistor technology because increased control over junction spacings and impurity levels makes possible significant improvements in transistor performance capabilities. A cross-section of a single-diffused "hometaxial" structure is shown in Fig. 19(a). Hometaxial transistors are fabricated by simultaneous diffusion of impurity from each side of a homogeneously doped base wafer. A mesa or flat-topped peak is etched on one side of the wafer in an intricate design to define the transistor emitter and expose the base region for connection of metal contacts. Large amounts of heat can be dissipated from a hometaxial structure through the highly conductive solder joint between the semiconductor material and the device package. This structure provides a very low collector resistance.

Double-diffused transistors have an additional degree of freedom for selection of the impurity levels and junction spacings of the base, emitter, and collector. This structure provides high voltage capability through a lightly doped collector region without compromise of the junction spacings which determine device frequency response and other important characteristics. Fig. 19(b) shows a typical double-diffused transistor; the emitter and base junctions are diffused into the same side of the original semiconductor wafer, which serves as the collector. A mesa is usually etched through the base region to reduce the collector area at the base-to-collector junction and to provide a stable semiconductor surface.

Double-diffused planar transistors provide the added advantage of protection or passivation of the emitter-to-base and collector-to-base junction surfaces. Fig. 19(c) shows a typical double-diffused planar transistor. The base and emitter regions terminate at the top surface of the semiconductor wafer under the protection of an insulating layer. Photolithographic and masking techniques are used to provide for diffusion of both base and emitter impurities in selective areas of the semiconductor wafer.

In triple-diffused transistors, a heavily doped region diffused from the bottom of the semiconductor wafer effectively reduces the thickness of the lightly doped collector region to a value dictated only by electric-field considerations. Thus, the thickness of the lightly doped or high-resistivity portion of the collector is minimized to obtain a low collector resistance. A section of a triple-diffused planar structure is shown in Fig. 19(d).

Epitaxial transistors differ from diffused structures in the manner in which the various regions are fabricated. Epitaxial structures are grown on top of a semiconductor wafer in a high-temperature reaction chamber. The growth proceeds atom by atom, and is a perfect extension of the crystal lattice of the wafer on which it is grown. In the epitaxial-base transistor shown in Fig. 20(a) a lightly doped base region is deposited by epitaxial techniques on a heavily doped collector wafer of opposite-type dopant. Photolithographic and masking techniques and

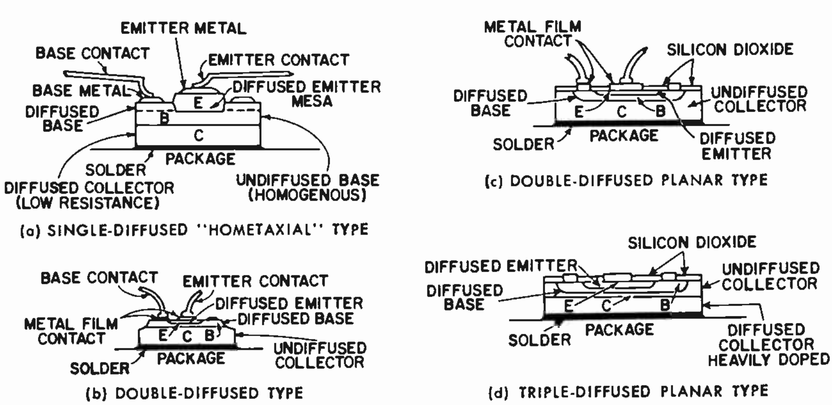



*Fig. 19—Cross-sections of diffused transistors.*

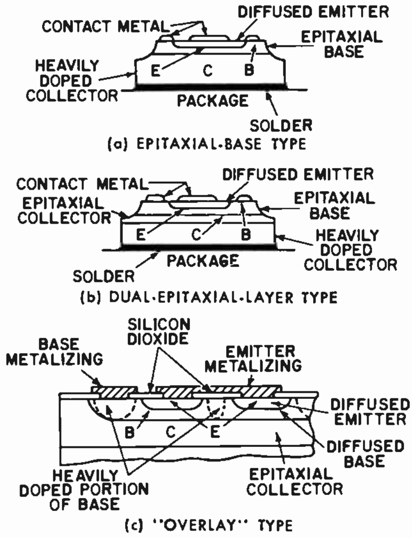



*Fig. 20—Cross-sections of epitaxial transistors.*

a single impurity diffusion are used to define the emitter region. This structure offers the advantages of low collector resistance and easy control of impurity spacings and emitter geometry. A variation of this structure uses two epitaxial layers. A thin lightly doped epitaxial layer used for the collector is deposited over the original heavily doped semiconductor wafer prior to the epitaxial deposition of the base region. The collector epitaxial layer is of opposite-type dopant to the epitaxial base layer. This structure, shown in Fig. 20(b), has the added advantage of higher voltage ratings provided by the epitaxial collector layer.

The overlay transistor is a double-diffused epitaxial device which employs a unique emitter structure. A large number of separate emitters are tied together by diffused and metalized regions to increase the emitter edge-to-area ratio and reduce the charging-time constants of the transistor without compromise of current- and power-handling capability. Fig. 20(c) shows a section through a typical overlay emitter region.

After fabrication, individual transistor chips are mechanically separated and mounted on individual headers. Connector wires are then bonded to the metalized regions, and each unit is encased in plastic or a hermetically sealed enclosure. In power transistors, the wafer is usually soldered or alloyed to a solid metal header to provide for high thermal conductivity and low-resistance collector contacts, and low-resistance contacts are soldered or metal-bonded from the emitter or base metalizing contacts to the appropriate package leads. This packaging concept results in a simple structure that can be readily attached to a variety of circuit heat sinks and can safely withstand power dissipations of hundreds of watts and currents of tens of amperes.

## BASIC CIRCUITS

Bipolar transistors are ideal current amplifiers. When a small signal current is applied to the input terminals of a bipolar transistor, an amplified reproduction of this signal appears at the output terminals. Although there are six possible ways of connecting the input signal, only three useful circuit configurations exist for current or power amplification: common-base, common-emitter, and common-collector. In the common-base (or grounded-base) connection shown in Fig. 21, the signal is introduced into the emitter-base circuit and extracted from the collector-base circuit. (Thus the base element of the transistor is common to both the input and output circuits). Because the input or emitter-base circuit has a low impedance (resistance plus reactance) in the order of 0.5 to 50 ohms, and the output or collector-base circuit has a high impedance in the order of 1000 ohms to one megohm, the voltage or power gain in this type of configuration may be in the order of 1500.

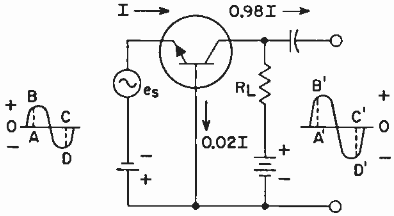



*Fig. 21—Common-base circuit configuration.*

The direction of the arrows in Fig. 21 indicates electron current flow. As stated previously, most of the current from the emitter flows to the collector; the remainder flows through the base. In practical transistors, from 95 to 99.5 per cent of the emitter current reaches the collector. The current gain of this configuration, therefore, is always less than unity, usually in the order of 0.95 to 0.995.

The waveforms in Fig. 21 represent the input voltage produced by the signal generator $e_s$ and the output voltage developed across the load resistor $R_L$. When the input voltage is positive, as shown at AB, it opposes the forward bias produced by the base-emitter battery, and thus reduces current flow through the n-p-n transistor. The reduced electron current flow through $R_L$ then causes the top point of the resistor to become less negative (or more positive) with respect to the lower point, as shown at A′B′ on the output waveform. Conversely, when the input signal is negative, as at CD, the output signal is also negative, as at C′D′. Thus, the phase of the signal remains unchanged in this circuit, i.e., there is no voltage phase reversal between the input and the output of a common-base amplifier.

In the common-emitter (or grounded-emitter) connection shown in Fig. 22 the signal is introduced into the base-emitter circuit and extracted from the collector-emitter circuit. This configuration has more moderate input and output impedances than the common-base circuit. The input (base-emitter) impedance is in the range of 20 to 5000 ohms, and the output (collector-emitter) impedance is about 50 to 50,000 ohms. Power gains in the order of 10,000 (or approximately 40 dB) can be realized with this circuit because it provides both current gain and voltage gain.

Current gain in the common-emitter configuration is measured between the base and the collector, rather than between the emitter and the collector as in the common-base circuit. Because a very small change in base current produces a relatively large change in collector current, the current gain is always greater than unity in a common-emitter circuit; a typical value is about 50.

The input signal voltage undergoes a phase reversal of 180 degrees in a common-emitter amplifier, as shown by the waveforms in Fig. 22.

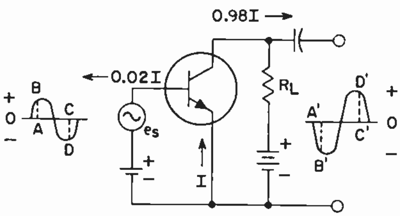



*Fig. 22—Common-emitter circuit configuration.*

When the input voltage is positive, as shown at AB, it increases the forward bias across the base-emitter junction, and thus increases the total current flow through the transistor. The increased electron flow through $R_L$ then causes the output voltage to become negative, as shown at A′B′. During the second half-cycle of the waveform, the process is reversed, i.e., when the input signal is negative, the output signal is positive (as shown at CD and C′D′.)

The third type of connection, shown in Fig. 23, is the common-collector (or grounded-collector) circuit. In this configuration, the signal is introduced into the base-collector circuit and extracted from the emitter-collector circuit. Because the input impedance of the transistor is high and the output impedance low in this connection, the voltage gain is less than unity and the power gain is usually lower than that obtained in either a common-base or a common-emitter circuit. The common-collector circuit is used primarily as

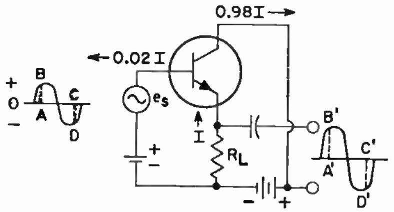



*Fig. 23—Common-collector circuit configuration.*

an impedance-matching device. As in the case of the common-base circuit, there is no phase reversal of the signal between the input and the output.

The circuits shown in Figs. 21 through 23 are biased for n-p-n transistors. When p-n-p transistors are used, the polarities of the batteries must be reversed. The voltage phase relationships, however, remain the same.

## CHARACTERISTICS

THE term "characteristic" is used to identify the distinguishing electrical features and values of a transistor. These values may be shown in curve form or they may be tabulated. When the characteristics values are given in curve form, the curves may be used for the determination of transistor performance and the calculation of additional transistor parameters.

Characteristics values are obtained from electrical measurements of transistors in various circuits under certain definite conditions of current and voltage. Static characteristics are obtained with dc potentials applied to the transistor electrodes. Dynamic characteristics are obtained with an ac voltage on one electrode under various conditions of dc potentials on all the electrodes. The dynamic characteristics, therefore, are indicative of the performance capabilities of the transistor under actual working conditions.

Published data for transistors include both electrode characteristic curves and transfer characteristic curves. These curves present the same information, but in two different forms to provide more useful data. Because transistors are used most often in the common-emitter configuration, characteristic curves are usually shown for the collector or output electrode. The collector-characteristic curve is obtained by varying collector-to-emitter voltage and measuring collector current for different values of base current. The transfer-characteristic curve is obtained by varying the base-to-emitter (bias) voltage or current at a specified or constant collector voltage, and measuring collector current. A collector-characteristic family of curves is shown in Fig. 24. Fig. 25 shows transfer-characteristic curves for the same transistor.

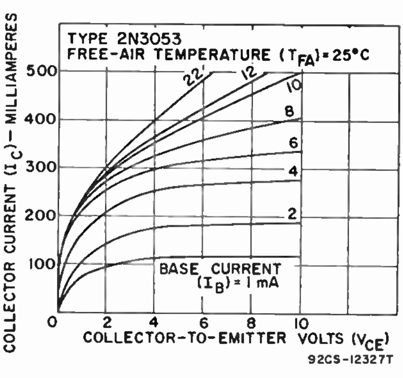



*Fig. 24—Collector-characteristic curves.*

A measure of the current gain of a transistor is its forward current-transfer ratio, i.e., the ratio of the current in the output electrode to the current in the input electrode. Because of the different ways in which transistors may be connected in circuits, the forward current-transfer ratio is specified for a

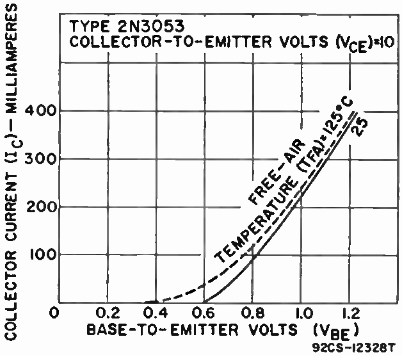



*Fig. 25—Transfer-characteristic curves.*

particular circuit configuration. The common-base forward current-transfer ratio is often called alpha (or $\alpha$), and the common-emitter forward current-transfer ratio is often called beta (or $\beta$).

In the common-base circuit shown in Fig. 21 the emitter is the input electrode and the collector is the output electrode. The dc alpha, therefore, is the ratio of the steady-state collector current $I_C$ to the steady-state emitter current $I_E$:

$$\alpha = \frac{I_C}{I_E} = \frac{0.98\ I}{I} = 0.98$$

In the common-emitter circuit shown in Fig. 22, the base is the input electrode and the collector is the output electrode. The dc beta, therefore, is the ratio of the steady-state collector current $I_C$ to the steady-state base current $I_B$:

$$\beta = \frac{I_C}{I_B} = \frac{0.98\ I}{0.02\ I} = 49$$

Because the ratios given above are based on steady-state currents, they are properly called dc alpha and dc beta. It is more common, however, for the current-transfer ratio to be given in terms of the ratio of signal currents in the input and output electrodes, or the ratio of a change in the output current to the input signal current which causes the change. Fig. 26 shows typical electrode currents in a common-emitter circuit (a) under no-signal conditions and (b) with a one-microampere signal applied to the base. The signal current of one microampere in the base causes a change of 49 microamperes (147-98) in the collector current. Thus the ac beta for the transistor is 49.

The cutoff frequency of a transistor is defined as the frequency at

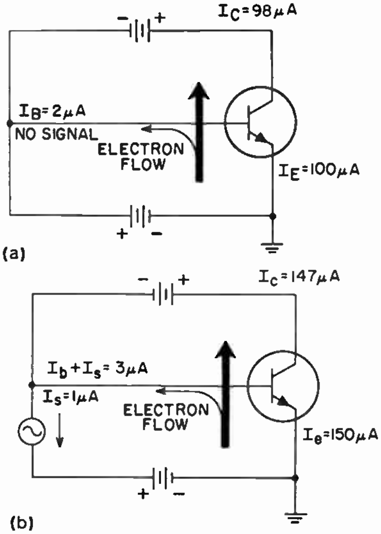



*Fig. 26—Electrode currents under (a) no-signal and (b) signal conditions.*

which the value of alpha (for a common-base circuit) or beta (for a common-emitter circuit) drops to 0.707 times its 1-kHz value. The gain-bandwidth product is the frequency at which the common-emitter forward current-transfer ratio (beta) is equal to unity. These characteristics provide an approximate indication of the useful frequency range of the device, and help to determine the most suitable circuit configuration for a particular application. Fig. 27 shows typical curves of alpha and beta as functions of frequency.

Extrinsic transconductance may be defined as the quotient of a small change in collector current divided

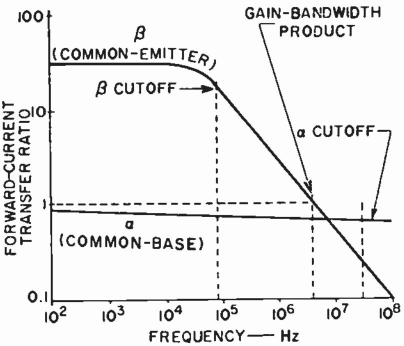



*Fig. 27—Forward current-transfer ratio as a function of frequency.*

by the small change in emitter-to-base voltage producing it, under the condition that other voltages remain unchanged. Thus, if an emitter-to-base voltage change of 0.1 volt causes a collector-current change of 3 milliamperes (0.003 ampere) with other voltages constant, the transconductance is 0.003 divided by 0.1, or 0.03 mho. (A "mho" is the unit of conductance, and was named by spelling "ohm" backward.) For convenience, a millionth of a mho, or a micromho ($\mu$mho), is used to express transconductance. Thus, in the example, 0.03 mho is 30,000 micromhos.

Cutoff currents are small steady-state reverse currents which flow when a transistor is biased into non-conduction. They consist of leakage currents, which are related to the surface characteristics of the semiconductor material, and saturation currents, which are related to the impurity concentration in the material and which increase with increasing temperatures. Collector-cutoff current is the steady-state current which flows in the reverse-biased collector-to-base circuit when the emitter-to-base circuit is open. Emitter-cutoff current is the current which flows in the reverse-biased emitter-to-base circuit when the collector-to-base circuit is open.

Transistor breakdown voltages define the voltage values between two specified electrodes at which the crystal structure changes and current begins to rise rapidly. The voltage then remains relatively constant over a wide range of electrode currents. Breakdown voltages may be measured with the third electrode open, shorted, or biased in either the forward or the reverse direction. For example, Fig. 28 shows a series of collector-characteristic curves for different base-bias conditions. It can

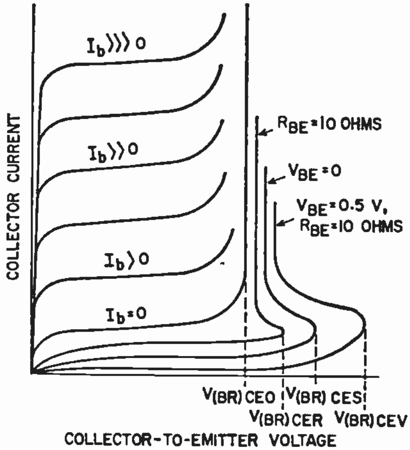



*Fig. 28—Typical collector-characteristic curves showing location of various breakdown voltages.*

be seen that the collector-to-emitter breakdown voltage increases as the base-to-emitter bias decreases from the normal forward values through zero to reverse values. The symbols shown on the abscissa are sometimes used to designate collector-to-emitter breakdown voltages with the base open $V_{(BR)CEO}$, with external base-to-emitter resistance $V_{(BR)CER}$, with the base shorted to the emitter $V_{(BR)CES}$, and with a reverse base-to-emitter voltage $V_{(BR)CEV}$.

As the resistance in the base-to-emitter circuit decreases, the collector characteristic develops two breakdown points, as shown in Fig. 28. After the initial breakdown, the collector-to-emitter voltage decreases with increasing collector current until another breakdown occurs at a lower voltage. This minimum collector-to-emitter breakdown voltage is called the **sustaining voltage.**

In large-area power transistors, there is a limiting mechanism referred to as "**second breakdown**". This condition is not a voltage breakdown, but rather an electrically and thermally regenerative process in which current is focused in a very small area of the order of the diameter of a human hair. The very high current, together with the voltage across the transistor, causes a localized heating that may melt a minute hole from the collector to the emitter of the transistor and thus cause a short circuit. This regenerative process is not initiated unless certain high voltages and currents are coincident for certain finite lengths of time.

In conventional transistor structures, the limiting effects of second breakdown vary directly with the amplitude of the applied voltage and inversely with the width of the base region. These effects are most severe in power transistors in which narrow base structures are used to achieve good high-frequency response. In RCA "overlay" power transistors, a special emitter configuration is used to provide greater current-handling capability and minimize the possibility of "hot spots" occurring at the emitter-base junction. This new design extends the range of power and frequency over which transistors can be operated before second breakdown begins to limit performance.

The curves at the left of Fig. 28 show typical collector characteristics under normal forward-bias conditions. For a given base input current, the collector-to-emitter saturation voltage is the minimum voltage required to maintain the transistor in full conduction (i.e., in the saturation region). Under saturation conditions, a further increase in forward bias produces no corresponding increase in collector current. Saturation voltages are very important in switching applications, and are usually specified for several conditions of electrode currents and ambient temperatures.

**Reach-through** (or **punch-through**) voltage defines the voltage value at which the depletion region in the collector region passes completely through the base region and makes contact at some point with the emitter region. This "reach-through" phenomenon results in a relatively low-resistance path between the emitter and the collector, and causes a sharp increase in current. Punch-through voltage does not result in permanent damage to a transistor, provided there is sufficient impedance in the power-supply source to limit transistor dissipation to safe values.

## BIASING

For most non-switching applications, the operating point for a particular transistor is established by the quiescent (dc, no-signal) values of collector voltage and emitter current. In general, a transistor may be considered as a current-operated device, i.e., the current flowing in the emitter-base circuit controls the current flowing in the collector circuit. The voltage and current values selected, as well as the particular biasing arrangement used, depend upon both the transistor characteristics and the specific requirements of the application.

As mentioned previously, biasing of a transistor for most applications consists of forward bias across the emitter-base junction and reverse bias across the collector-base junction. In Figs. 21, 22, and 23, two batteries were used to establish bias of the correct polarity for an n-p-n transistor in the common-base, common-emitter, and common-collector circuits, respectively. Many variations of these basic circuits can also be used. (In these simplified dc circuits, inductors and transformers are represented only by their series resistance.)

A simplified biasing arrangement for the common-base circuit is shown in Fig. 29. Bias for both the collector-base junction and the emitter-base junction is obtained from the single battery through the voltage-divider network consisting of resistors $R_2$ and $R_3$. (For the n-p-n transistor shown in Fig. 29(a) the emitter-base junction is forward-biased because the emitter is negative with respect to the base, and the collector-base junction is reverse-biased because the collector is positive with respect to the base, as shown. For the p-n-p transistor shown in Fig. 29(b), the polarity of the battery and of the electrolytic bypass capacitor $C_1$ is reversed.) The electron current I from the battery and through the voltage divider causes a voltage drop across resistor $R_2$ which biases the base. The proper amount of current then flows through $R_1$ so that the correct emitter potential is established to provide forward bias relative to the base. This emitter current establishes the amount of collector current which, in turn, causes a voltage drop across $R_4$. Simply stated, the voltage divider consisting of $R_2$ and $R_3$ establishes the base potential; the base potential essentially establishes the emitter potential; the emitter potential and resistor $R_1$ establish the emitter current; the emitter current establishes the collector current; and the collector current and $R_4$ establish the collector potential. $R_2$ is bypassed with capacitor $C_1$ so that the base is effectively grounded for ac signals.

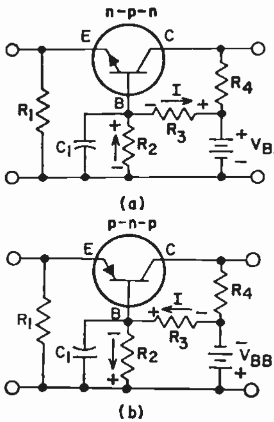



*Fig. 29—Biasing network for common-base circuit for (a) n-p-n and (b) p-n-p transistors.*

A single battery can also be used to bias the common-emitter circuit. The simplified arrangement shown in Fig. 30 is commonly called "fixed bias". In this case, both the base and the collector are made positive with respect to the emitter by means of the battery. The base resistance $R_B$ is then selected to provide the desired base current $I_B$ for the transistor (which, in turn, establishes the desired emitter current $I_E$), by means of the following expression:

$$R_B = \frac{V_{BB} - V_{BE}}{I_B}$$

where $V_{BB}$ is the battery supply voltage and $V_{BE}$ is the base-to-emitter voltage of the transistor.

In the circuit shown, for example, the battery voltage is six volts. The value of $R_B$ was selected to provide a base current of 27 microamperes, as follows:

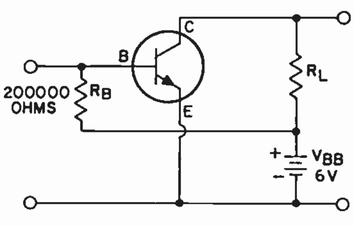



*Fig. 30—"Fixed-bias" arrangement for common-emitter circuit.*

$$R_B = \frac{6 - 0.6}{27 \times 10^{-6}} = 200{,}000 \text{ ohms}$$

The fixed-bias arrangement shown in Fig. 30, however, is not a satisfactory method of biasing the base in a common-emitter circuit. The critical base current in this type of circuit is very difficult to maintain under fixed-bias conditions because of variations between transistors and the sensitivity of these devices to temperature changes. This problem is partially overcome in the "self-bias" arrangement shown in Fig. 31.

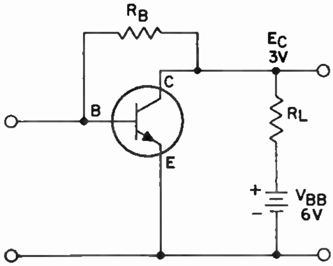



*Fig. 31—"Self-bias" arrangement for common-emitter circuit.*

In this circuit, the base resistor is tied directly to the collector. This connection helps to stabilize the operating point because an increase or decrease in collector current produces a corresponding decrease or increase in base bias. The value of $R_B$ is then determined as described above, except that the collector voltage $V_{CE}$ is used in place of the supply voltage $V_{BB}$:

$$R_B = \frac{V_{CE} - V_{BE}}{I_B}$$

$$= \frac{3 - 0.6}{27 \times 10^{-6}} = 90{,}000 \text{ ohms}$$

The arrangement shown in Fig. 31 overcomes many of the disadvantages of fixed bias, although it reduces the effective gain of the circuit.

In the bias method shown in Fig. 32 the voltage-divider network composed of $R_1$ and $R_2$ provides the

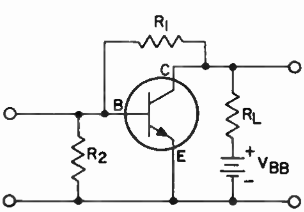



*Fig. 32—Bias network using voltage-divider arrangement for increased stability.*

required forward bias across the base-emitter junction. The value of the base bias voltage is determined by the current through the voltage divider. This type of circuit provides less gain than the circuit of Fig. 31, but is commonly used because of its inherent stability.

The common-emitter circuits shown in Figs. 33 and 34 may be used to provide stability and yet minimize loss of gain. In Fig. 33, a resistor

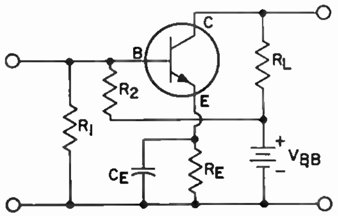



*Fig. 33—Bias network using emitter stabilizing resistor.*

$R_E$ is added to the emitter circuit, and the base resistor $R_2$ is returned to the positive terminal of the battery instead of to the collector. The emitter resistor $R_E$ provides additional stability. It is bypassed with capacitor $C_E$. The value of $C_E$ depends on the lowest frequency to be amplified.

In Fig. 34 the $R_2R_3$ voltage-divider network is split, and all ac feedback currents through $R_3$ are shunted to ground (bypassed) by capacitor $C_1$.

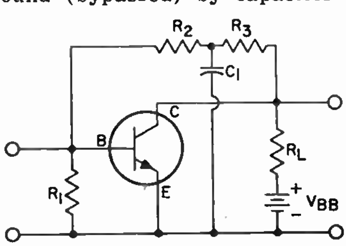



*Fig. 34—Bias network using split voltage-divider network.*

The value of $R_3$ is usually larger than the value of $R_2$. The total resistance of $R_2$ and $R_3$ should equal the resistance of $R_1$ in Fig. 32.

In practical circuit applications. any combination of the arrangements shown in Figs. 31, 32, 33, and 34 may be used. However, the stability of Figs. 31, 32, and 34 may be poor unless the voltage drop across the load resistor $R_L$ is at least one-third the value of the supply voltage. The determining factors in the selection of the biasing circuit are usually gain and bias stability (which is discussed later).

In many cases, the bias network may include special elements to compensate for the effects of variations in ambient temperature or in supply voltage. For example, the thermistor (temperature-sensitive resistor) shown in Fig. 35(a) is used to compensate for the rapid increase of collector current with increasing temperature. Because the thermistor resistance decreases as the temperature increases, the emitter-to-base bias voltage is reduced and the collector current tends to remain constant. The addition of the shunt and series resistances provides most effective compensation over a desired temperature range.

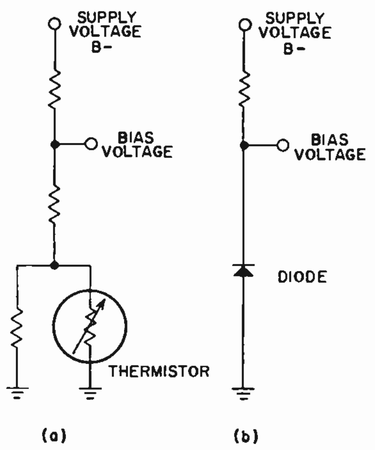


*Fig. 35—Bias networks including (a) a thermistor and (b) a voltage-compensating diode.*

The diode biasing network shown in Fig. 35(b) stabilizes collector current for variations in both temperature and supply voltage. The forward-biased diode current determines a bias voltage which establishes the transistor idling current (collector current under no-signal conditions). As the temperature increases, this bias voltage decreases. Because the transistor characteristic also shifts in the same direction and magnitude, however, the idling current remains essentially independent of temperature. Temperature stabilization with a properly designed diode network is substantially better than that provided by most thermistor bias networks. Any temperature-stabilizing element should be thermally close to the transistor being stabilized.

In addition, the diode bias current varies in direct proportion with changes in supply voltage. The resultant change in bias voltage is small, however, so that the idling current also changes in direct proportion to the supply voltage. Supply-voltage stabilization with a diode biasing network reduces current variation to about one-fifth that obtained when resistor or thermistor bias is used for a germanium transistor and one-fifteenth for a silicon transistor.

The bias networks of Figs. 30 through 34 are generally used in class A circuits. Class B circuits normally employ the bias networks shown in Fig. 35. The bias resistor values for class B circuits are generally much lower than those for class A circuits.

## BIAS STABILITY

Because transistor currents tend to increase with temperature, it is necessary in the design of transistor circuits to include a "stability factor" to keep the collector-current variation within tolerable values under the expected high-temperature operating conditions. The bias stability factor SF is expressed as the ratio between a change in steady-state collector current and the corresponding change in steady-state collector-cutoff current.

For a given set of operating voltages, the stability factor can be calculated for a maximum permissible rise in steady-state collector current from the room-temperature value, as follows:

$$SF = \frac{I_{Cmax} - I_{C1}}{I_{CBO2} - I_{CBO1}}$$

where $I_{C1}$ and $I_{CBO1}$ are measured at 25°C, $I_{CBO2}$ is measured at the maximum expected ambient (or junction) temperature, and $I_{Cmax}$ is the maximum permissible collector current for the specified collector-to-emitter voltage at the maximum expected ambient (or junction) temperature (to keep transistor dissipation within ratings).

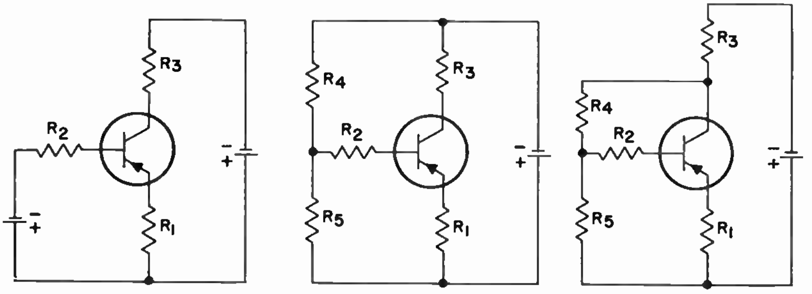
The calculated values of SF can then be used, together with the appropriate values of beta and $r_b'$ (base-connection resistance), to determine suitable resistance values for the transistor circuit. Fig. 36 shows equations for SF in terms of resistance values for three typical circuit configurations. The maximum value which SF can assume is the value of beta. Although this analysis was originally made for germanium transistors, in which the collector saturation current $I_{Co}$ is relatively large, the same type of analysis may be applied to interchangeability with beta for silicon transistors.

## COUPLING

Three basic methods are used to couple transistor stages: transformer, resistance-capacitance, and direct coupling.

The major advantage of transformer coupling is that it permits power to be transferred from one impedance level to another. A transformer-coupled common-emitter n-p-n stage is shown in Fig. 37. The voltage step-down transformer $T_1$ couples the signal from the collector of the preceding stage to the base of the common-emitter stage. The voltage loss inherent in this transformer is not significant in transistor circuits because, as mentioned previously, the transistor is a current-operated device. Although the voltage is stepped down, the available current is stepped up. The change in base current resulting from the presence of the signal causes an alternating collector current to flow in the primary winding of transformer $T_2$, and a power gain is obtained between $T_1$ and $T_2$.

This use of a voltage step-down transformer is similar to that in the output stage of an audio amplifier, where a step-down transformer is




$$SF = \frac{\beta(R_1 + R_2')}{R_2' + \beta R_1}$$

$R_2' = R_2 + r_b'$

$$SF = \frac{\beta(R_1 + Req)}{Req + \beta R_1}$$

$$Req = R_2' + \frac{R_4 R_5}{R_4 + R_5}$$

$R_2' = R_2 + r_b'$

$$SF = \frac{\beta(P + Q)}{Q + \beta P}$$

$Q = R_2'(R_3 + R_4 + R_5) + R_4 R_5$

$P = R_1 (R_3 + R_4 + R_5) + R_3 R_5$

$R_2' = R_2 + r_b'$

*Fig. 36—Bias-stability-factor equations for three typical circuit configurations.*

normally used to drive the loudspeaker, which is also a current-operated device.

The voltage-divider network consisting of resistors $R_1$ and $R_2$ in Fig. 37 provides bias for the transistor.

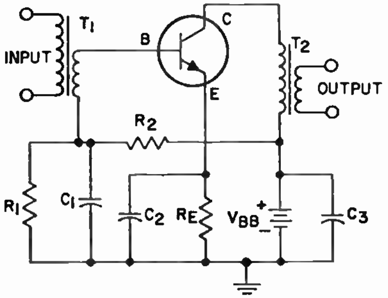



*Fig. 37—Transformer-coupled common-emitter stage.*

The voltage divider is bypassed by capacitor $C_1$ to avoid signal attenuation. The stabilizing emitter resistor $R_E$ permits normal variations of the transistor and circuit elements to be compensated for automatically without adverse effects. This resistor $R_E$ is bypassed by capacitor $C_2$. The voltage supply $V_{BB}$ is also bypassed, by capacitor $C_3$, to prevent feedback in the event that ac signal voltages are developed across the power supply. Capacitors $C_1$ and $C_2$ may normally be replaced by a single capacitor connected between the emitter and the bottom of the secondary winding of transformer $T_1$ with little change in performance.

The use of resistance-capacitance coupling usually permits some economy of circuit costs and reduction of size, with some accompanying sacrifice of gain. This method of coupling is particularly desirable in low-level, low-noise audio amplifier stages to minimize hum pickup from stray magnetic fields. Use of resistance-capacitance (RC) coupling in battery-operated equipment is usually limited to low-power operation. The frequency response of an RC-coupled stage is normally better than that of a transformer-coupled stage.

Fig. 38 shows a two-stage RC-coupled circuit using n-p-n transistors in the common-emitter configuration. The method of bias is similar to that used in the transformer-coupled circuit of Fig. 37. The major additional components are the collector load resistances $R_{L1}$ and $R_{L2}$ and the coupling capacitor $C_c$. The value of $C_c$ must be made fairly large, in the order of 2 to 10 microfarads, because of the small input and load resistances involved. (It should be noted that electrolytic capacitors are normally used for coupling in transistor audio circuits. Polarity must be observed, therefore, to obtain proper circuit operation. Occasionally, excessive leakage current through an electrolytic coupling capacitor may adversely affect transistor operating currents.)

Impedance coupling is a modified form of resistance-capacitance coupling in which inductances are used

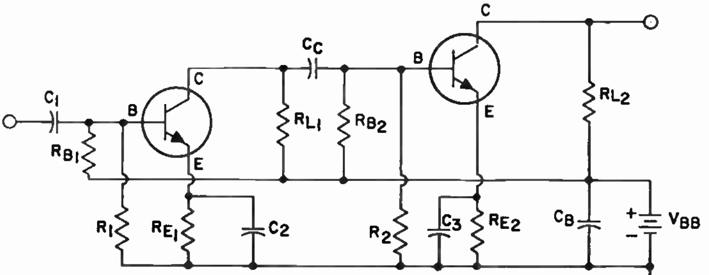



*Fig. 38—Two-stage resistance-capacitance coupled circuit.*

to replace the load resistors. This type of coupling is rarely used except in special applications where supply voltages are low and cost is not a significant factor.

Direct coupling is used primarily when cost is an important factor. (It should be noted that direct-coupled amplifiers are not inherently dc amplifiers, i.e., that they cannot always amplify dc signals. Low-frequency response is usually limited by other factors than the coupling network.) In the direct-coupled amplifier shown in Fig. 39, resistor $R_3$ serves as both the collector load resistor for the first stage and the bias resistor for the second stage. Resistors $R_1$ and $R_2$ provide circuit stability similar to that of Fig. 32 because the emitter voltage of transistor $Q_2$ and the collector voltage of transistor $Q_1$ are within a few tenths of a volt of each other.

a pronounced effect on the gain and power-output capabilities of transistors. As a result, physical aspects such as layout, type of chassis, shielding, and heat-sink considerations are important in the design of high-frequency amplifiers and oscillators.

### General Considerations

In general, high-frequency circuits are constructed on material such as brass or aluminum which is either silver-plated or machined to increase conductivity. The input and output circuits are "compartmentalized" by use of a milling operation. Copper-clad laminated or printed circuit boards facilitate soldering operations, and have been used satisfactorily at frequencies up to 400 MHz when the entire copper surface was kept intact and used for the ground plane.

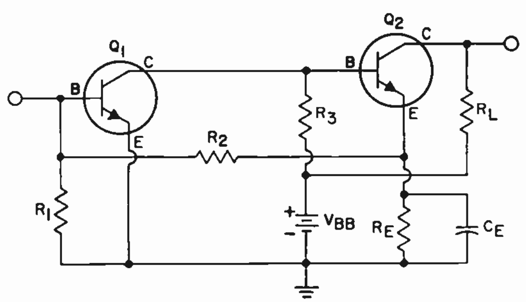



*Fig. 39—Two-stage direct-coupled circuit.*

Because so few circuit parts are required in the direct-coupled amplifier, maximum economy can be achieved. However, the number of stages which can be directly coupled is limited. Temperature variation of the bias current in one stage may be amplified by all the stages, and severe temperature instability may result.

## HIGH-FREQUENCY OPERATION

At frequencies of 100 MHz or more, the effects of stray capacitances and inductances, ground paths, and feedback coupling have

Because even a short lead provides a large impedance at high frequencies, it is necessary to keep all high-frequency leads as short as possible. This precaution is especially important for ground connections and for all connections to bypass capacitors and high-frequency filter capacitors. It is recommended that a common ground return be used for each stage, and that short, direct connections be made to the common ground point. The emitter lead especially should be kept as short as possible.

In many cases, problems of oscillation and regenerative feedback are caused by unwanted ground currents (i.e., ground-circuit feedback currents). An effective solution is to isolate the ac signal path from the dc path so that the signal does not pass through the power supply by way of the power leads. In a multistage amplifier, the power leads should enter the circuit at the highest power stage to minimize the amount of signal on the common power path. Lower-frequency oscillations can be minimized by use of a large capacitor across the power-supply terminals. High-quality feedthrough capacitors should also be used as the power-lead connections.

Particular care should be taken with the lead dress of the input and output circuits of high-frequency stages so that the possibility of stray coupling is minimized. Unshielded leads connected to shielded components should be dressed close to the chassis. (In high-gain audio amplifiers, these same precautions should be taken to minimize the possibility of self-oscillation.)

Feedback effects may occur in radio or television receivers as a result of coupling between stages through common voltage-supply circuits. Filters find an important use in minimizing such effects. They should be placed in voltage-supply leads to each transistor to provide isolation between stages.

Capacitors used in transistor rf circuits, particularly at high frequencies, should be mica or ceramic. For audio bypassing, electrolytic capacitors are required.

In high-frequency stages having high gain, undesired feedback may occur and produce harmful effects on circuit performance unless shielding is used. The output circuit of each stage is usually shielded from the input of the stage, and each high-frequency stage is usually shielded from other high-frequency stages. It is also desirable to shield separately each unit of the high-frequency stages. For example, each if and rf coil in a superheterodyne receiver may be mounted in a separate shield can. Baffle plates may be mounted on the ganged tuning capacitor to shield each section of the capacitor from the other section.

The shielding precautions required in a circuit depend on the design of the circuit and the layout of the parts. When the metal case of a transistor is grounded at the socket terminal, the grounding connection should be as short as possible to minimize lead inductance. Many transistors have a separate lead connected to the case and used as a ground lead; where present, these leads are indicated in the outline diagrams.

## Transistor Requirements

The important performance criteria in rf power-amplifier circuits are power output, power gain, and efficiency. Transistors to be used for power amplification must deliver power efficiently with sufficient gain in the frequency range of interest.

Power **Output**—The power-output capability of a transistor is determined by the current- and voltage-handling capabilities of the device in the frequency range of interest. The current-handling capability of the transistor is limited by its emitter periphery and the resistivity of the epitaxial layer. The voltage-handling capability of the device is limited by the breakdown voltages which are, in turn, limited by the resistivity of the epitaxial layer and by the penetration of the junction.

Fig. 40 shows a typical family of dc collector characteristics with base current as a parameter. The highest breakdown voltage is that of the collector-to-base junction $V_{(BR)CBO}$; the lowest voltage is that of the collector-to-emitter junction with the base open $V_{(BR)CEO}$. Breakdown voltages may vary anywhere between these two values depending on how the base is biased with respect to the emitter or on the resistance between the emitter and the base. The

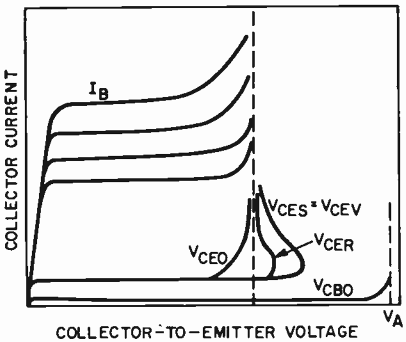



*Fig. 40—Collector current as a function of collector-to-emitter voltage for a typical rf transistor.*

static $V_{CEO}$ and $V_{CBO}$ values are related by the following equation:

$$V_{CEO} = \frac{V_{CBO}}{(1 + h_{FE})^{1/n}}$$

where $h_{FE}$ is the static forward-current transfer ratio and n is an empirical number that varies from 2.5 to 4 for n-p-n silicon transistors. When rf input is applied, the breakdown voltage is substantially higher than the dc or static value observed in the $V_{CEO}$ mode. Substitution of $f_T/f$ for $h_{FE}$ in the equation for $V_{CEO}$ yields the following result:

$$V_{CEO}(rf) = \frac{V_{CBO}}{[(f_T/f) + 1]^{1/n}}$$

where $f_T$ is the dynamic gain-bandwidth product and f is the frequency of operation. This equation indicates an increase in the breakdown characteristic from the $V_{CEO}$ value under dc conditions to a value that approaches $V_{CBO}$ at operating frequencies equal to or greater than $f_T$.

Another parameter which limits the power-handling capability of the transistor is the saturation voltage. The rf value of the saturation voltage $V_{CE(SAT)}$ is significantly greater than the dc value because the active area is less at high frequencies than at dc.

In general, all rf power transistors have operating voltage restrictions, and only current-handling capability differentiates power transistors from small-signal units. At high current levels, the emitter current of a transistor is concentrated at the emitter-base edge; therefore, transistor current-handling capability can be increased by the use of emitter geometries which have high emitter-periphery-to-emitter-area ratios and by the use of improved methods of growing collector substrate material. Transistors intended for large-signal applications should be designed so that the peak currents do not cause base widening, a condition that would limit the current-handling capability of the device. Base widening is severe in transistors in which the collector side of the collector-base junction has a lower carrier concentration and higher resistivity than the base side of the junction. However, the need for low-resistivity material in the collector to handle high currents without base widening severely limits the breakdown voltages. As a result, epitaxial layers of different resistivity are often used for different operational voltages.

Large-Signal Power Gain—The power gain of a transistor power amplifier is determined by the dynamic $f_T$, the dynamic input impedance, and the collector load impedance; the collector load impedance depends on the required power output and the collector voltage swing. The power gain, P.G., of a transistor power amplifier may be expressed in many forms. The simplest one is as follows:

$$P.G. = \frac{(f_T/f)^2 R_L}{4 R_e (Z_{in})}$$

where $R_L$ is the real part of the collector parallel-equivalent-load impedance determined by the required power output, and $Z_{in}$ is the dynamic input impedance when the collector load impedance is $Z_L$.

The equation for power gain shows that for high-gain operation large-signal or power transistors should have a high current gain which remains constant as the large-signal current level is varied. In other words, transistors suitable for large-signal operation must provide current gain under large-current-swing conditions. Constant current gain for varied current level can be achieved with shallow diffusion techniques.

The dynamic input impedance of the transistor pellet varies considerably under large-signal operation as compared to small-signal operation. The resistive part of the input impedance is inversely proportional to the area of the transistor and, therefore, to the power output of the device. The package parasitic inductance has a significant effect on the input impedance. A simple representation of a common-emitter equivalent transistor input circuit at uhf and microwave frequences is shown in Fig. 41. The large-signal $R_{in}$ and $L_{in}$ are different from the small-signal values; therefore, their exact quantitative analysis is difficult. The

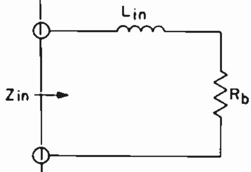



*Fig. 41—Equivalent input circuit of an rf power transistor.*

input impedance $Z_{in}$ can be expressed as follows:

$$Z_{in} = (r_b + \omega_T L_e) + j\left(\omega L_e - \frac{\omega_T}{\omega}\, r_e\right)$$

where $\omega_T = 2\pi f_T$, $\omega = 2\pi f$, and $L_e$ is the emitter parasitic inductance.

The parasitic emitter inductance also has a significant effect on power gain, as indicated by the following relation:

$$\text{P.G.} = \frac{(f_T/f)^2 R_L}{4\,(r_b + \omega_T L_e)}$$

The effect of the emitter parasitic inductance is to reduce the power gain.

**Efficiency**—Transistor efficiency is determined with the device operating under signal-bias conditions. The collector-to-base junction is reverse-biased, and the emitter-to-base junction is forward-biased partially with the input drive signal. The collector efficiency of a transistor rf amplifier is defined as the ratio of the rf power output at the frequency of interest to the dc input power. Therefore, high efficiency implies that circuit loss is minimum and that the ratio of the transistor output, the parallel equivalent resistance, and its collector load resistance are maximum. Thus, the transistor parameter which limits the collector efficiency is output admittance. The output admittance of a transistor pellet consists of two parts: an output capacitance $C_o$ and an equivalent parallel output resistance which approaches $1/\omega_T C_o$ at microwave frequencies under small-signal conditions. In a common-emitter circuit, $C_{ob}$ is essentially the output capacitance because the impedance level at the base is low relative to the impedance level at the transistor output. The output capacitance represents effectively the transistor junction capacitance in series with a resistance. If the collector resistivity is increased, the effective output capacitance and the collector-base breakdown voltage are both increased. In a power transistor, variations in junction and epitaxial thickness cause variations in $C_{ob}$ with $V_{CB}$, as shown in Fig. 42. Thus, the dynamic output capacitance is a function of voltage swing and power level. It can be shown that the average $C_o$ under maximum voltage swing is equal to $2C_{ob}$, where

$C_{ob}$ is measured at the voltage value of $V_{CB}$. For a first approximation, the large-signal output resistance can be assumed to be inversely proportional to $C_{ob}$. Because the ratio of the transistor output resistance to its collector load resistance determines the collector efficiency, a transistor with high output resistance and, therefore, low $C_{ob}$ is essential.

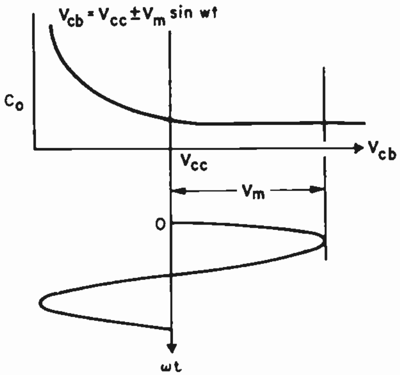



*Fig. 42—Collector-to-base capacitance as a function of collector-to-base voltage for a typical rf power transistor.*

Another transistor parameter that affects the efficiency of the device is the dissipation capability. The maximum power that can be dissipated before thermal runway occurs depends on how well internal transistor heat is removed. The amount of heat removed by conduction is an inverse function of the thermal resistance. The total thermal resistance is equal to the sum of several thermal drops in series: from the collector junction to the back of the pellet, at the pellet-solder interface, at the solder connection to the case, from the case to the heat sink, and from the heat sink to the atmosphere or ambient. These drops are usually divided into two major groups, junction-to-case thermal resistance $\theta_{J\text{-}C}$ and case-to-ambient thermal resistance $\theta_{C\text{-}A}$. Generally, power transistors are designed for minimum junction-to-case thermal resistance. The thermal resistance $\theta$, expressed in degrees C per watt of dissipation, may be calculated for the various sections of total heat-flow path as follows:

$$\theta = L/KA$$

where L is the distance that the heat travels in inches, A is the area of the path in square inches, and K is the material constant in W/°C-inches. K is equal to 2.12 for silicon, 5.2 for beryllium oxide, 9.7 for copper, and 3.1 for aluminum. For a given length and width, the thermal resistance can thus be calculated for most geometries. It has been common practice to characterize the transistor heat dissipation by the average device thermal resistance. The average junction-to-ambient thermal resistance $\theta_{J\text{-}A}$ of a device can be expressed as follows:

$$\theta_{J\text{-}A} = \frac{(T_J - T_a)}{P_{diss}} = \theta_{J\text{-}C} + \theta_{C\text{-}A} \ (^\circ C/W)$$

One of the problems in power dissipation is that of complete mounting of the pellet so that there is no discontinuity in the bond between pellet and mounting. Considerable care must be used in selection of the mounting system. At present, microwave power transistors are mounted with gold-silicon mounting systems. It should be pointed out that the dissipation of a microwave power transistor is considerably higher under rf operation than under dc operation. The junction temperature at radio frequencies is more a function of the average device dissipation than of the peak dissipation. The dissipation of a microwave power transistor is also a function of the thermal time constant.

## SWITCHING

Transistor switching applications are usually characterized by large-signal nonlinear operation of the devices. The switching transistor is generally required to operate in either of two states: on or off. In transistor switching circuits, the common-emitter configuration is by far the most widely used.

Typical output characteristics for an n-p-n transistor in the common-emitter configuration are shown in Fig. 43. These characteristics are divided into three regions of operation, i.e., cutoff region, active region, and saturation region.

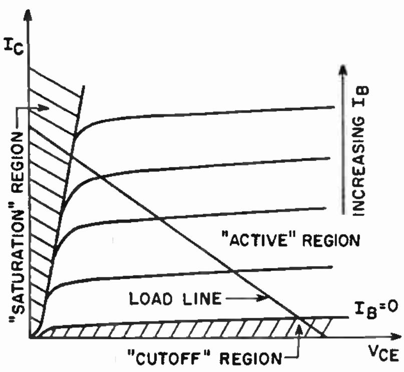



*Fig. 43—Typical collector characteristic of an n-p-n transistor showing three principal regions involved in switching.*

In the cutoff region, both the emitter-base and collector-base junctions are reverse-biased. Under these conditions, the collector current is very small, and is comparable in magnitude to the leakage current $I_{CEO}$, $I_{CEV}$, or $I_{CBO}$, depending on the type of base-emitter biasing used.

Fig. 44 is a sketch of the minority-carrier concentration in an n-p-n transistor. For the cutoff condition, the concentration is zero at both junctions because both junctions are reverse-biased, as shown by curve 1 in Fig. 44.

In the active region, the emitter-base junction is forward-biased and the collector-base junction is reverse-biased. Switching from the cutoff region to the active region is accomplished along a load line, as indicated in Fig. 43. The speed of transition through the active region is a function of the frequency-response characteristics of the device.

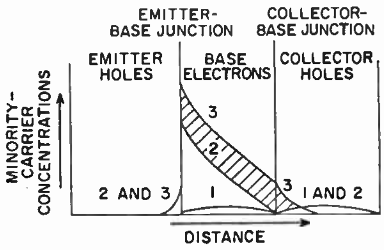



*Fig. 44—Minority-carrier concentrations in an n-p-n transistor: (1) in cutoff region, (2) in active region at edge of saturation region, (3) in saturation region.*

The minority-carrier concentration for the active region is shown by curve 2 in Fig. 44.

The remaining region of operation is the saturation region. In this region, the emitter-base and collector-base junctions are both forward-biased. Because the forward voltage drop across the emitter-base junction under this condition [$V_{BE}$(sat)] is greater than that across the collector-base junction, there is a net collector-to-emitter voltage referred to as $V_{CE}$(sat). It is evident that any series-resistance effects of the emitter and collector also enter into determining $V_{CE}$(sat). Because the collector is now forward-biased, additional carriers are injected into the base, and some into the collector. This minority-carrier concentration is shown by curve 3 in Fig. 44.

A basic saturated-transistor switching circuit is shown in Fig. 45. The voltage and current waveforms for this circuit under typical

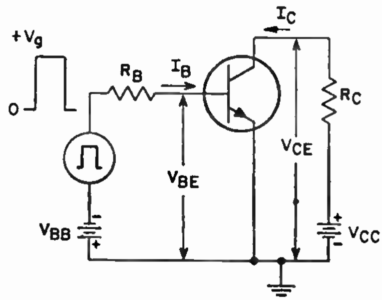



*Fig. 45—Basic saturated transistor switching circuit.*

base-drive conditions are shown in Fig. 46. Prior to the application of the positive-going input pulse, the emitter-base junction is reverse-biased by a voltage $-V_{BE}(\text{off}) = V_{BB}$. Because the transistor is in the cutoff region, the base current $I_B$ is the reverse leakage current $I_{BEV}$, which is negligible compared with $I_{B1}$, and the collector current $I_C$ is the reverse leakage current $I_{CEV}$, which is negligible compared with $V_{CC}/R_C$. When the positive-going input pulse $V_g$ is applied, the base current $I_B$ immediately goes positive.

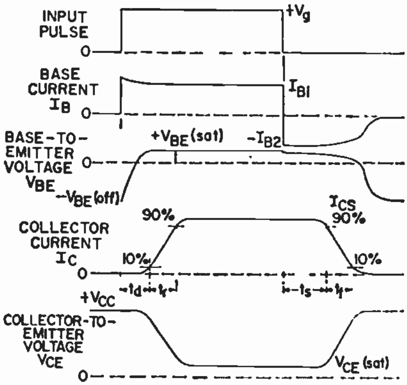



*Fig. 46—Voltage and current waveforms for saturated switching circuit shown in Fig. 45.*

The collector current, however, does not begin to increase until some time later. This delay in the flow of collector current ($t_d$) results because the emitter and collector capacitances do not allow the emitter-base junction to become forward-biased instantaneously. These capacitances must be charged from their original negative potential $[-V_{BE}(\text{off})]$ to a forward bias sufficient to cause the transistor to conduct appreciably. After the emitter-base junction is sufficiently forward-biased, there is an additional delay caused by the time required for minority carriers which are injected into the base to diffuse across the base and be collected at the collector. This delay is usually negligible compared with the delay introduced by the capacitive component. The collector and emitter capacitances vary with the collector-base and emitter-base junction voltages, and increase as the voltage $V_{BE}$ goes positive. An accurate determination of total delay time, therefore, requires knowledge of the nonlinear characteristics of these capacitances.

When the collector current $I_C$ begins to increase, the transistor has made the transition from the cutoff region into the active region. The collector current takes a finite time to reach its final value. This time, called rise time ($t_r$), is determined by the gain-bandwidth product ($f_T$), the collector-to-emitter capacitance ($C_C$), and the static forward current-transfer ratio ($h_{FE}$) of the transistor. At high collector currents and/or low collector voltages, the effect of this capacitance on rise time is negligible, and the rise time of collector current is inversely proportional to $f_T$. At low currents and/or high voltages, the effect of gain-bandwidth product is negligible, and the rise time of collector current is directly proportional to the product $R_C C_C$. At intermediate currents and voltages, the rise time is proportional to the sum $(\frac{1}{2}\pi f_T) + R_C C_C$. Under any of the above conditions, the collector current responds exponentially to a step of base current. If a turn-on base current ($I_{B1}$) is applied to the device, and the product $I_{B1}h_{FE}$ is less than $V_{CC}/R_C$, the collector current rises exponentially until it reaches the steady-state value $I_{B1}h_{FE}$. If $I_{B1}h_{FE}$ is greater than $V_{CC}/R_C$, the collector current rises toward the value $I_{B1}h_{FE}$. The transistor becomes saturated when $I_C$ reaches the value $I_{CS}$ ($\approx V_{CC}/R_C$). At this point, $I_C$ is effectively clamped at the value $V_{CC}/R_C$.

The rise time, therefore, depends on an exponential function of the ratio $I_{CS}/I_{B1} : h_{FE}$. Because the values of $h_{FE}$, $f_T$, and $C_C$ are not constant, but vary with collector voltage and current as the transistor is switching, the rise time as well as the delay time is dependent on nonlinear transistor characteristics.

After the collector current of the transistor has reached a steady-state value $I_{CS}$, the minority-charge distribution is that shown by curve 3 in Fig. 44. When the transistor is turned off by returning the input pulse to zero, the collector current does not change immediately. This delay is caused by the excess charge in the base and collector regions, which tends to maintain the collector current at the $I_{CS}$ value until this charge decays to an amount equal to that in the active region at the edge of saturation (curve 2 in Fig 44). The time required for this charge to decay is called the storage time ($t_s$). The rate of charge decay is determined by the minority-carrier lifetime in the base and collector regions, on the amount of reverse "turn-off" base current ($I_{B2}$), and on the overdrive "turn-on" current ($I_{B1}$) which determined how deeply the transistor was driven into saturation. (In non-saturated switching, there is no excess charge in the base region, so that storage time is negligible.)

When the stored charge ($Q_S$) has decayed to the point where it is equal to that at the edge of saturation, the transistor again enters the active region and the collector current begins to decrease. This fall-time portion of the collector-current characteristic is similar to the rise-time portion because the transistor is again in the active region. The fall time, however, depends on $I_{B2}$, whereas the rise time was dependent on $I_{B1}$. Fall time, like rise time, also depends on $f_T$ and $C_C$.

The approximate values of $I_{B1}$, $I_{B2}$, and $I_{CS}$ for the circuit shown in Fig. 45 are given by:

$$I_{B1} = \frac{V_G - V_{BB} - V_{BE}(sat)}{R_B}$$

$$I_{B2} = \frac{V_{BB} + V_{BE}(sat)}{R_B}$$

$$I_{CS} = \frac{V_{CC} - V_{CE}(sat)}{R_C}$$

## Switching Characteristics

The electrical characteristics for a switching transistor, in general, differ from that for a linear-amplifier type of transistor in several respects. The static forward current-transfer ratio $h_{FE}$ and the saturation voltages $V_{CE}(sat)$ and $V_{BE}(sat)$ are of fundamental importance in a switching transistor. The static forward current-transfer ratio determines the maximum amount of current amplification that can be achieved in any given circuit, saturated or non-saturated. The saturation voltages are necessary for the proper dc design of saturated circuits. Consequently, $h_{FE}$ is always specified for a switching transistor, generally at two or more values of collector current. $V_{CE}(sat)$ and $V_{BE}(sat)$ are specified at one or more current levels for saturated transistor applications. Control of these three characteristics determines the performance of a given transistor type over a broad range of operating conditions. For non-saturated applications, $V_{CE}(sat)$ and $V_{BE}(sat)$ need not be specified. For such applications, it is important to specify $V_{BE}$ at specific values of collector current and collector-to-emitter voltage in the active region.

Because the collector and emitter capacitances and the gain-bandwidth product influence switching time, these characteristics are specified for most switching transistors. The collector-base and emitter-base junction capacitances are usually measured at some value of reverse bias and are designated $C_{ob}$ and $C_{ib}$, respectively. The gain-bandwidth product ($f_T$) of the transistor is the frequency at which the small-signal forward current-transfer ratio ($h_{fe}$) is unity. Because this characteristic falls off at 6 dB per octave above the corner frequency, $f_T$ is usually controlled by specifying the $h_{fe}$ at a fixed frequency anywhere from 1/2 to 1/10 $f_T$. Because $C_{ob}$, $C_{ib}$, and $f_T$ vary nonlinearly over the operating range, these characteristics are generally more useful as figures of merit than as controls for determining switching speeds. When the switching speeds in a particular application are of major importance, it is preferable to specify the required switching speeds in the desired switching circuit rather than $C_{ob}$, $C_{ib}$, and $f_T$.

The storage time ($t_s$) of a transistor is dependent on the stored charge ($Q_s$) and on the driving current employed to switch the transistor between cutoff and saturation. Consequently, either the stored charge or the storage time under heavy overdrive conditions should be specified. Most recent transistor specifications require that storage time be specified.

Because of the dependence of the switching times on current and voltage levels, these times are determined by the voltages and currents employed in circuit operation.

## Dissipation, Current, and Voltage Ratings

Up to this point, no mention has been made of dissipation, current, and voltage ratings for a switching transistor. The maximum continuous ratings for dissipation and current are determined in the same manner as for any other transistor. In a switching application, however, the peak dissipation and current may be permitted to exceed these continuous ratings depending on the pulse duration, on the duty factor, and on the thermal time constant of the transistor.

Voltage ratings for switching transistors are more complicated. In the basic switching circuit shown in Fig. 45, three breakdown voltages must be considered. When the transistor is turned off, the emitter-base junction is reverse-biased by the voltage $V_{BE}$(off), (i.e., $V_{BB}$), the collector-base junction by $V_{CC} + V_{BB}$, and the emitter-to-collector junction by $+ V_{CC}$. To assure that none of the voltage ratings for the transistor is exceeded under "off" conditions, the following requirements must be met:

The minimum emitter-to-base breakdown voltage $V_{(BR)EBO}$ must be greater than $V_{BE}$(off).

The minimum collector-to-base breakdown voltage $V_{(BR)CBO}$ must be greater than $V_{CC} + V_{BE}$(off).

The minimum collector-to-emitter breakdown voltage $V_{(BR)CERL}$ must be greater than $V_{CC}$.

$V_{(BR)EBO}$ and $V_{(BR)CBO}$ are always specified for a switching transistor. The collector-to-emitter breakdown voltage $V_{(BR)CEO}$ is usually specified under open-base conditions. The breakdown voltage $BV_{CERL}$ (the subscript "RL" indicates a resistive load in the collector circuit) is generally higher than $V_{(BR)CEO}$. The requirement that $V_{(BR)CEO}$ be greater than $V_{CC}$ is overly pessimistic. The requirement that $V_{(BR)CERL}$ be greater than $V_{CC}$ should be used wherever applicable.

Coupled with the breakdown voltages are the collector-to-emitter and base-to-emitter transistor leakage currents. These leakage currents ($I_{CEV}$ and $I_{BEV}$) are particularly important considerations at high operating temperatures. The subscript "V" in these symbols indicates that these leakage currents are specified at a given emitter-to-base voltage (either forward or reverse). In the basic circuit of Fig. 41, these currents are determined by the following conditions:

$$\left.\begin{matrix} I_{CEV} \\ I_{BEV} \end{matrix}\right\} \quad \begin{matrix} V_{CE} = V_{CC} \\ V_{BE} = V_{BE}(\text{off}) = -V_{BB} \end{matrix}$$

In a switching transistor, these leakage currents are usually controlled not only at room temperature, but also at some higher operating temperature near the upper operational limit of the transistor.

## Inductive Switching

Most inductive switching circuits can be represented by the basic equivalent circuit shown in Fig. 47.

This type of circuit requires a rapid transfer of energy from the switched inductance to the switching mechan-

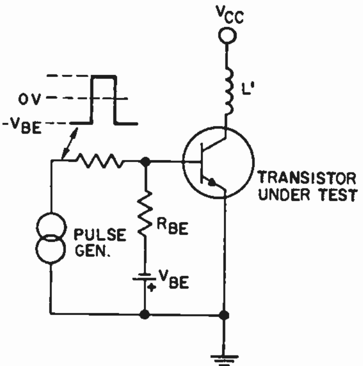



*Fig. 47—Basic equivalent circuit for inductive switching circuit.*

ism, which may be a relay, a transistor, a commutating diode, or some other device. Often an accurate calculation of the energy to be dissipated in the switching device is required, particularly if that device is a transistor. If the supply voltage is low compared to the sustaining breakdown voltage of the transistor

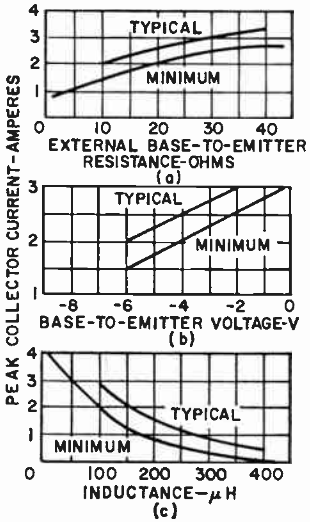



*Fig. 48—Typical reverse-bias second-breakdown ($E_s/_b$) rating curves.*

and if the series resistance of the inductor can be ignored, then the energy to be dissipated is ½ $LI^2$. This type of rating for a transistor is called "reverse-bias second breakdown." The energy capability of a transistor varies with the load inductance and base-emitter reverse bias. A typical set of ratings which now appears in RCA published data is shown on Fig. 48.

## SAFE-OPERATING-AREA RATINGS

During normal circuit operation, power transistors are often required to sustain high current and high voltage simultaneously. The capability of a transistor to withstand such conditions is normally shown by use of a safe-operating-area rating curve. This type of rating curve defines, for both steady-state and pulsed operation, the voltage-current boundaries that result from the combined limitations imposed by voltage and current ratings, the maximum allowable dissipation, and the second-breakdown ($I_s/_b$) capabilities of the transistor.

If the safe operating area of a power transistor is limited within any portion of the voltage-current characteristics by thermal factors (thermal impedance, maximum junction temperatures, or operating case temperature), this limiting is defined by a constant-power hyperbola ($I = KV^{-1}$) which can be represented on the log-log voltage-current curve by a straight line that has a slope of −1.

The energy level at which second breakdown occurs in a power transistor increases as the time duration of the applied voltage and current decreases. The power-handling capability of the transistor also increases with a decrease in pulse duration because the thermal mass of the power-transistor chip and associated mounting hardware imparts an inherent thermal delay to a rise in junction temperature.

Fig. 49 shows a forward-bias safe-area rating chart for a typical silicon power transistor, the RCA-2N3585. The boundaries defined by the curves in the safe-area chart indicate, for both continuous-wave and nonrepetitive-pulse operation, the maximum current ratings, the maximum collector-to-emitter forward-bias avalanche breakdown-voltage rating [$V\alpha M = 1$, which is usually approximated by $V_{CEO}$(sus)], and the thermal and second-breakdown ratings of the transistors.

As shown in Fig. 49, the thermal (dissipation) limiting of the 2N3585 ceases when the collector-to-emitter voltage rises above 100 volts during dc operation. Beyond this point, the safe operating area of the transistor is limited by the second-breakdown ratings. During pulsed operation, the thermal limiting extends to higher values of collector-to-emitter voltage before the second-breakdown region is reached, and as the pulse duration decreases, the thermal-limited region increases.

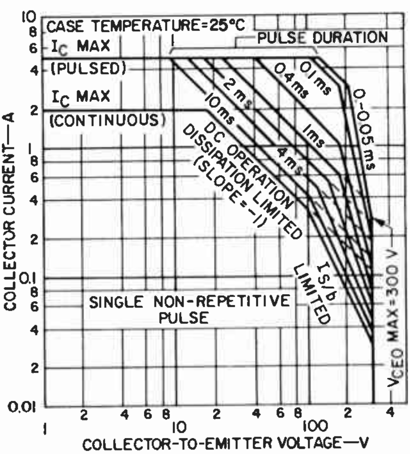



*Fig. 49—Safe-area rating chart for the 2N3585 silicon power transistor.*

If a transistor is to be operated at a pulse duration that differs from those shown on the safe-area chart, the boundaries provided by the safe-area curve for the next higher pulse duration must be used, or the transistor manufacturer should be consulted. Moreover, as indicated in Fig. 49, safe-area ratings are normally given for single nonrepetitive pulse operation at a case temperature of 25°C and must be derated for operation at higher case temperatures and under repetitive-pulse or continuous-wave conditions.

Fig. 50 shows temperature derating curves for the 2N3585 safe-area chart of Fig. 49. These curves show that thermal ratings are affected far more by increases in case temperature than are second-breakdown ratings. The thermal (dissipation-limited) derating curve decreases linearly to zero at the maximum junction temperature of the transistor [$T_J$(max) = 200°C]. The second-breakdown ($I_S/_b$-limited) temperature derating curve, however, is less severe because the increase in the formation of the high current concentrations that cause second breakdown is less than the increase in dissipation factors as the temperature increases.

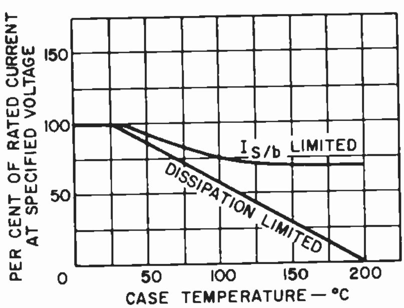



*Fig. 50—Safe-area temperature-derating curves for the 2N3585 silicon power transistor.*

Because the thermal and second-breakdown deratings are different, it may be necessary to use both curves to determine the proper derating factor for a voltage-current point that occurs near the breakpoint of the thermal-limited and second-breakdown-limited regions on the safe-area curve. For this condition, a derating factor is read from each derating curve. For one of the readings, however, either the thermal-limited section of the safe-area curve must be extrapolated upward in voltage or the second-breakdown-limited section must be extrapolated downward in voltage, depending upon which side of the voltage breakpoint the voltage-current point is located. The smaller of the collector-current values obtained from the thermal and second-breakdown deratings must be used as the safe rating.

For pulsed operation, the derating factor shown in Fig. 50 must be applied to the appropriate curve on the safe-area rating chart. For the derating, the effective case temperature $T_C(eff)$ may be approximated by the average junction temperature $T_J(av)$. The average junction temperature is determined as follows:

$$T_J(av) = T_C + P_{AV}\ (\theta_{J\text{-}C})$$

This approach results in a conservative rating for the pulsed capability of the transistor. A more accurate determination can be made by computation of actual instantaneous junction temperatures. (For more detailed information on safe-area ratings and temperature derating the reader should refer to the RCA Power Circuits Manual, Technical Series SP-51, pp. 94 to 105.)

## HANDLING CONSIDERATIONS

The generation of static charge in dry weather is harmful to all transistors, and can cause permanent damage or catastrophic failure in the case of high-speed devices. The most obvious precaution against such damage is humidity control in storage and operating areas. In addition, it is desirable that transistors be stored and transported in metal trays rather than in polystyrene foam "snow". During testing and installation, both the equipment and the operator should be grounded, and all power should be turned off when the device is inserted into the socket. Grounded plates may also be used for stockpiling of transistors prior to or after testing, or for use in testing ovens or on operating life racks. Further protection against static charges can be provided by use of partially conducting floor planes and non-insulating footwear for all personnel.

Environmental temperature also affects performance. Variations of as little as 5 per cent can cause changes of as much as 50 per cent in the saturation current of a transistor. Some test operators can cause marked changes in measurements of saturation current because the heat of their hands affects the transistors they work on. Precautions against temperature effects include air-conditioning systems, use of finger cots in handling of transistors (or use of pliers or "plug-in boards" to eliminate handling), and accurate monitoring and control of temperature near the devices. Prior to testing, it is also desirable to allow sufficient time (about 5 minutes) for a transistor to stabilize if it has been subjected to temperature much higher or lower than normal room temperature (25°C).

Although transient rf fields are not usually of sufficient magnitude to cause permanent damage to transistors, they can interfere with accurate measurement of characteristics at very low signal levels or at high frequencies. For this reason, it is desirable to check for such radiation periodically and to eliminate its causes. In addition, sensitive measurements should be made in shielded screen rooms if possible.

Care must also be taken to avoid the exposure of transistors to other ac or magnetic fields.

Many transistor characteristics are sensitive to variations in temperature, and may change enough at high operating temperatures to affect circuit performance. Fig. 51 illustrates the effect of increasing temperature on the common-emitter forward current-transfer ratio (beta), the dc collector-cutoff current, and the input and output impedances. To avoid undesired changes in circuit operation, it is recommended that transistors be located away from heat sources in equipment, and also that provisions be made for adequate heat dissipation and, if necessary, for temperature compensation.

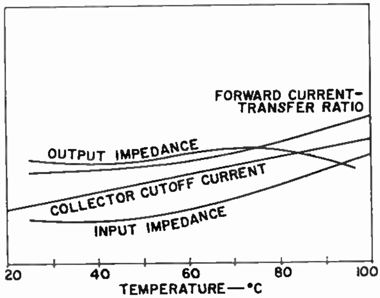



*Fig. 51—Variation of transistor characteristics with temperature.*

# MOS Field-Effect Transistors

FIELD-EFFECT transistors represent a unique and important category of electronic components. These devices combine many of the desirable characteristics of electron tubes with small size, low power consumption, mechanical ruggedness, and other advantages inherent in solid-state devices. For example, these devices can provide a square-law transfer characteristic that is especially desirable for amplification of multiple signals in rf amplifiers that are required to exhibit exceptionally low cross-modulation effects.

In this section, the basic operation and structure of the various types of field-effect transistors are briefly described and compared. The main emphasis, however, is placed on metal-oxide-semiconductor field-effect transistors, which are becoming increasily popular in electronic-circuit applications, particularly in receiver rf-amplifier and mixer circuits. The fabrication, electrical characteristics, biasing, and basic circuit configurations of these devices are discussed, and the integral gate-protection system developed for dual-gate types is explained.

## TYPES OF FIELD-EFFECT TRANSISTORS

Field-effect transistors (FET's) derive their name from the fact that current flow in them is controlled by variation of an electric field established by application of a voltage to a control electrode referred to as the gate. In contrast, current flow in bipolar transistors is controlled by variation of the current injected into the base terminal. Moreover, the performance of bipolar transistors depends on the interaction of two types of charge carriers (holes and electrons). Field-effect transistors, however, are unipolar devices; as a result, their operation is basically a function of only one type of charge carrier, holes in p-channel devices and electrons in n-channel devices.

A charge-control concept can be used to explain the basic operation of field-effect transistors. A charge on the gate (control electrode) induces an equal, but opposite, charge in a semiconductor layer, referred to as the channel, located directly beneath the gate. The charge induced in the channel controls the conduction of current through the channel and, therefore, between the source and drain terminals which are connected to opposite ends of the channel.

Discrete-device field-effect transistors are classified, on the basis of their control-gate construction, as either junction-gate types or metal-oxide-semiconductor types. Although both types operate on the basic principle that current conduction is controlled by variation of an electric field, the significant difference in their gate construction results in unique characteristics and advantages for each type.

## Junction-Gate Types

Junction-gate field-effect transistors, which are commonly referred to as JFET's or, in popular parlance, as JUG-FET's, may be either n-channel or p-channel devices. Fig. 52 shows the structure of an n-channel junction-gate field-effect transistor, together with the schematic symbols for both n-channel and p-channel versions of these devices. The structure for a p-channel device is identical to that of an n-channel device with the exception that n- and p-type semiconductor materials are replaced by p- and n-type materials, respectively.

In both types of junction-gate devices, a thin channel under the gate provides a conductive path between the source and drain terminals with zero gate-bias voltage. A p-n junction is formed at the interface of the gate and the source-to-drain layer. When this junction is reverse-biased, current conduction in the channel between the source and drain terminals is controlled by the magnitude of reverse-bias voltage, which if sufficient can virtually cut off the flow of current through the channel. If the junction becomes forward-biased, the input resistance (i.e., resistance between the gate and the source-to-drain layer) decreases sharply, and an appreciable amount of gate current flows. Under such conditions, the gate loading reduces the amplitude of the input signal, and a significant reduction in power gain results. This characteristic is a major disadvantage of junction-gate field-effect transistors. Another undesirable feature of these devices is that the leakage currents across the reverse-biased p-n junction can vary markedly with changes in ambient temperature. This latter factor tends to complicate circuit design considerations. Nonetheless, the junction-gate field-effect transistor is a very useful device in many small-signal-amplifier and chopper applications.

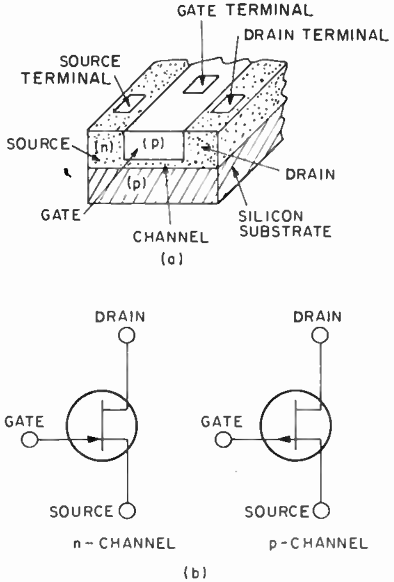



*Fig. 52—Junction-gate field-effect transistor (JFET): (a) side-view cross section of an n-channel device; (b) schematic symbols for n- and p-channel devices.*

## Metal-Oxide-Semiconductor Types

Figs. 53 and 54 show the structures and schematic symbols for both enhancement and depletion types of metal-oxide-semiconductor field-effect transistors (MOS/FET'S). In these devices, the metallic gate is electrically insulated from the semiconductor surface by a thin layer of silicon dioxide. These devices, which are commonly referred to as MOS field-effect transistors or, more simply, as MOS transistors, derive their name from the tri-layer construction of metal, oxide, and semiconductor material. Another name sometimes used for them is IGFET, which is an acronym for insulated-gate field-effect transistor. Insulation of the gate from the remainder of the

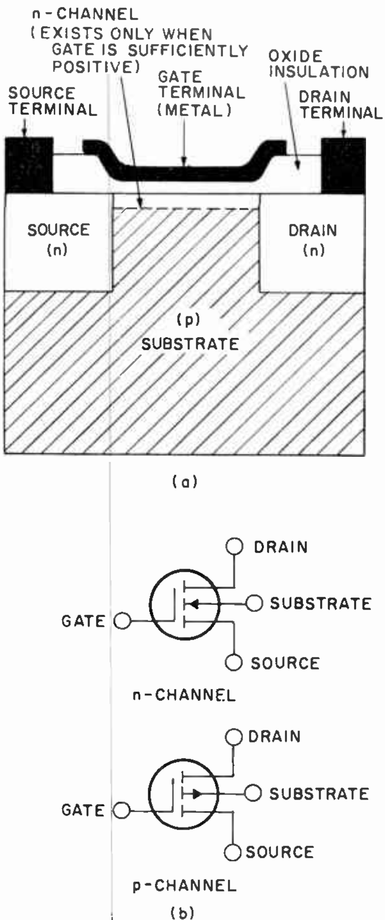



*Fig. 53—Enhancement-type metal-oxide-semiconductor field-effect transistor (MOS/FET): (a) side-view cross section of an n-channel device; (b) schematic symbols of n- and p-channel devices.*

transistor structure results in an exceedingly high input resistance (i.e., in the order of $10^{11}$ ohms). It should be realized that the metal gate and the semiconductor channel form a capacitor in which the oxide layer serves as the dielectric insulator.

The marked differences in the construction of enhancement and depletion types of MOS field-effect transistors, as is apparent from a comparison of Figs. 53(a) and 54(a), results in significant differences in the characteristics of these devices and, therefore, in the applications in which they are normally employed. (The differences in the

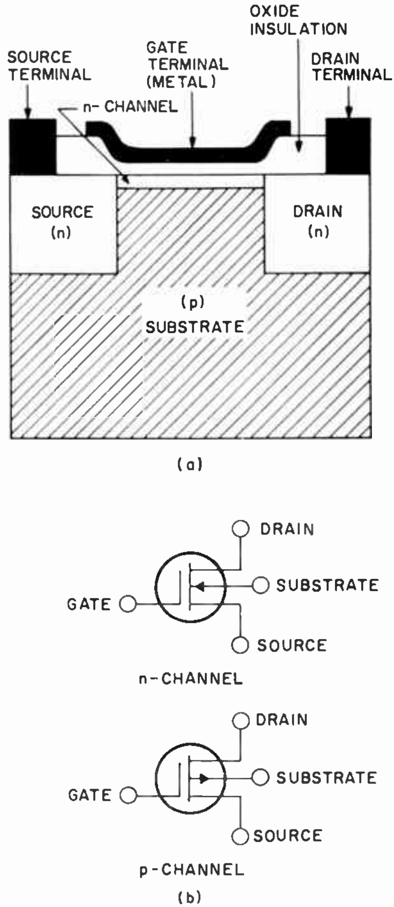



*Fig. 54—Depletion-type metal-oxide-semiconductor field-effect transistor (MOS/FET): (a) side-view cross section of an n-channel device; (b) schematic symbols for n- and p-channel devices.*

characteristics of the two types of MOS transistors are discussed subsequently in the section on Electrical Characteristics.)

Enhancement-Type Devices—As indicated by the interruptions in the channel line of the schematic symbols shown in Fig 53(b), enhancement-type MOS field-effect transistors are characterized by the fact that they have a "normally open" channel so that no useful channel conductivity exists for either zero or reverse gate bias. Consequently, this type of device is ideal for use in digital and switching applications. The gate of the enhancement type of MOS field-effect transistor must be forward-biased with respect to the source to produce the active charge carriers in the channel required for conduction. When sufficient forward-bias (positive) voltage is applied to the gate of an n-channel device, the region under the gate changes from p-type to n-type and provides a conduction path between the n-type source and drain regions. Similarly, in p-channel devices, application of sufficient negative gate voltage draws holes into the region below the gate so that this channel region changes from n-type to p-type to provide a source-to-drain conduction path.

The technology for enhancement-type MOS field-effect transistors is making its greatest impact in the fabrication of integrated circuits for digital applications, particularly in large-scale-integration (LSI) circuits.

Depletion-Type Devices—Depletion-type MOS field-effect transistors are characterized by the fact that, with zero gate bias, the thin channel under the gate region provides a conductive path between the source and drain terminals. In the schematic symbols for these devices, shown in Fig. 54(b), the channel line is drawn continuous to indicate this "normally on" condition. When the gate is reverse-biased (negative with respect to the source for n-channel devices, or positive with respect to the source for p-channel devices), the channel can be depleted of charge carriers; conduction in the channel, therefore, can be cut off if the gate potential is sufficiently high.

A unique characteristic of depletion-type MOS transistors is that additional charge carriers can be produced in the channel and, therefore, conduction in the channel can be increased by application of forward bias to the gate. No reduction in power gain occurs under these conditions, as is the case in junction-gate field-effect transistors, because the oxide insulation between the gate and the source-to-drain layer blocks the flow of gate current even when the gate is forward-biased.

The diagram shown in Fig. 54(a) illustrates the structure of a single-gate depletion-type MOS field-effect transistor. Depletion-type MOS field-effect transistors that have two independent insulated gate electrodes are also available. These devices offer unique advantages and represent the most important category of MOS field-effect transistors.

Fig. 55(a) shows a cross-sectional diagram of an n-channel depletion-type dual-gate MOS field-effect transistor. The transistor includes three terminating (n-diffused) regions connected by two conductive channels, each of which is controlled by its own independent gate terminal. For convenience of explanation, the transistor is shown divided into two units. Unit No. 1 consists of the source, gate No. 1, channel No. 1, and the central n-region which functions as drain No. 1. These elements act as a conventional single-gate depletion-type MOS field-effect transistor for which unit No. 2 functions as a load resistor. Unit No. 2 consists of the central n-region, which functions as source No. 2, gate No. 2, channel No. 2, and the drain. This unit may also be used as an independent single-gate transistor for which unit No. 1 acts as a source resistor. Fig. 55(b) shows the sche-

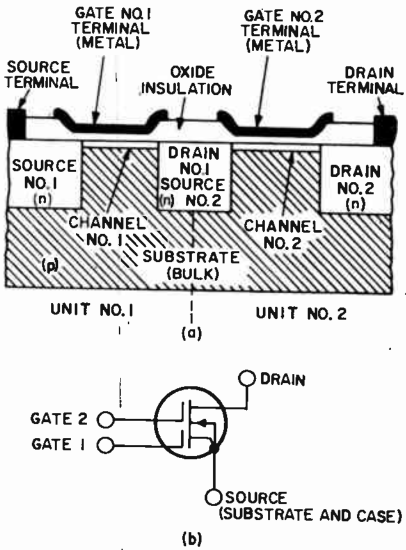



*Fig. 55—Dual-gate n-channel depletion-type metal-oxide-semiconductor field-effect transistor (MOS/FET): (a) side-view cross section; (b) schematic symbol.*

matic symbol for an n-channel dual-gate MOS field-effect transistor.

Equivalent-circuit representations of the two units in a dual-gate MOS transistor are shown in Fig. 56.

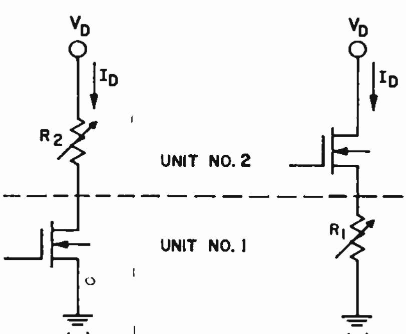



*Fig. 56—Equivalent-circuit representation of the two units in a dual-gate MOS field-effect transistor.*

Current can be cut off if either gate is sufficiently reverse-biased with respect to the source. When one gate is biased to cutoff, a change in the voltage on the other gate is equivalent to a change in the value of a resistor in series with a cut-off transistor.

The dual-gate MOS field-effect transistor is analogous to a multigrid electron tube in its versatility for circuit applications. The independent pair of gates makes this device attractive for use in rf amplifiers, gain-controlled amplifiers, mixers, and demodulators. In a gain-controlled amplifier, the signal is applied to gate No. 1, and the gain-control voltage is applied to gate No. 2. This arrangement is recommended because the forward transconductance obtained with gate No. 1 is higher than that obtained with gate No. 2. Moreover, unit No. 2 is very effective for isolation of the drain and gate No. 1. This unit provides sufficient isolation so that the dual-gate devices can be operated at frequencies into the uhf range without the need for neutralization. Examples of the use of dual-gate MOS field-effect transistors in circuit applications are shown in the Circuits section of this Manual.

A gate-protection system which can be incorporated as an integral part of the transistor structure has been developed for dual-gate MOS transistors. In devices that include this system, a set of back-to-back diodes is diffused directly into the semiconductor pellet and connected between each insulated gate and the source. (The low junction capacitance of the small diodes represents a relatively insignificant addition to the total capacitance that shunts the gate.) Fig. 57 shows a cross-sectional diagram and the schematic symbol for an n-channel dual-gate-protected depletion-type MOS field-effect transistor.

The back-to-back diodes do not conduct unless the gate-to-source voltage exceeds ± 10 volts typically. The transistor, therefore, can handle

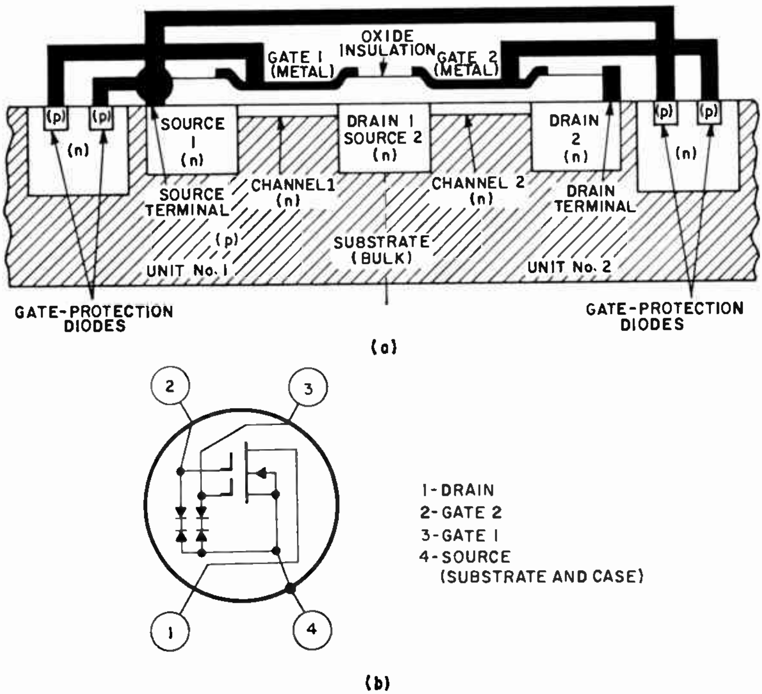


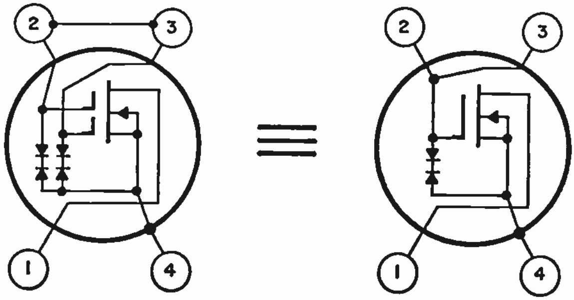

*Fig. 57—Dual-gate-protected n-channel depletion-type MOS field-effect transistor: (a) side-view cross section; (b) schematic symbol.*

a very wide dynamic signal swing without significant conductive shunting effects by the diodes (leakage through the "nonconductive" diodes is very low). If the potential on either gate exceeds + 10 volts typically, the upper diode [shown in Fig. 57(b)] of the pair associated with that particular gate becomes conductive in the forward direction and the lower diode breaks down in the backward (zener) direction. In this way, the back-to-back diode pair provides a path to shunt excessive positive charge from the gate to the source. Similarly, if the potential on either gate exceeds —10 volts typically, the lower diode becomes conductive in the forward direction and the upper diode breaks down in the reverse direction to provide a shunt path for excessive negative charge from the gate to the source. (The diode gate-protection technique is described in more detail in the following section on **Integral Gate Protection**).

Dual-gate-protected MOS transistors can be connected so that functionally they are directly equivalent to a single-gate type with gate protection. This method of connection is shown in Fig. 58.

## INTEGRAL GATE PROTECTION

The advent of an integral system of gate-protection in MOS field-effect transistors has resulted in a class of solid-state devices that exhibits ruggedness on a par with other solid-state devices that provide comparable performance. The gate-protection system mentioned in the preceding section offers protection against static discharge during handling operations without the need for external shorting mechanisms.




(a) (b)

*Fig. 58—Connection of a dual-gate-protected MOS field-effect transistor (a) so that it is functionally equivalent to a single-gate-protected MOS field-effect transistor (b).*

This system also guards against potential damage from in-circuit transients. Because the integral gate-protection system has provided a major impact on the acceptability of MOS field-effect transistors for a broad spectrum of applications, it is pertinent to examine the rudiments of this system.

Fig. 59 shows a simple equivalent circuit for a source of static electricity that can deliver a potential $e_0$ to the gate input of an MOS

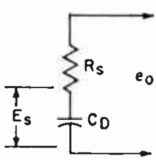



*Fig. 59—Equivalent circuit for a source of static electricity.*

transistor. The static potential $E_S$ stored in an "equivalent" capacitor $C_D$ must be discharged through an internal generator resistance $R_S$. Laboratory experiments indicate that the human body acts as a static (storage) source with a capacitance $C_D$ ranging from 100 to 200 picofarads and a resistance $R_S$ greater than 1000 ohms. Although the upper limits of accumulated static voltage can be very high, measurements suggest that the potential stored by the human body is usually less than 1000 volts. Experience has also indicated that the likelihood of damage to an MOS transistor as a result of static discharge is greater during handling than when the device is installed in a typical circuit. In an rf application, for example, static potential discharged into the antenna must traverse an input circuit that normally provides a large degree of attenuation to the static surge before it appears at the gate terminal of the MOS transistor. The ideal gate-protection signal-limiting circuit is a configuration that allows for a signal, such as that shown in Fig. 60(a), to be handled without clipping or distortion, but limits the amplitude of all transients that exceed a safe operating level, as shown in Fig. 60(b). An arrangement of back-to-back diodes, shown in Fig. 60(c), meets these requirements for protection of the gate insulation in MOS transistors.

Ideally, the transfer characteristic of the protective signal-limiting diodes should have an infinite slope at limiting, as shown in Fig. 61(a). Under these conditions, the static potential across $C_D$ in Fig. 61(b) discharges through its internal impedance $R_S$ into the load represented by the signal-limiting diodes. The ideal signal-limiting diodes, which have an infinite transfer slope, would then

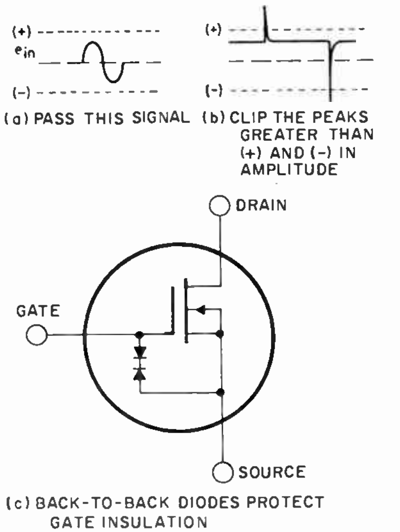



*Fig. 60—MOS gate-protection requirements and a solution.*

limit the voltage present at the gate terminal to its knee value, $e_d$. The difference voltage $e_s$ appears as an

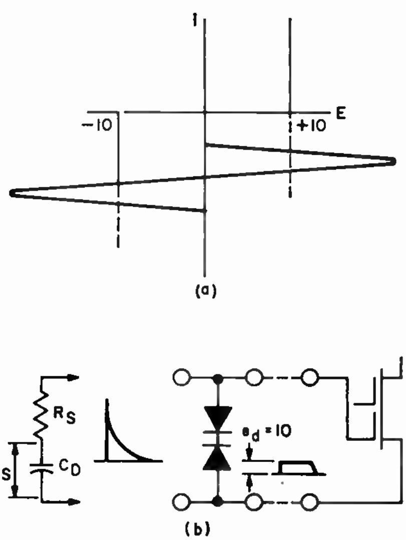



*Fig. 61—Transfer characteristic of protective diodes (a), and resulting waveforms in equivalent circuit (b).*

IR drop across the internal impedance of the source $R_s$, i.e., $e_s = E_s - e_d$ where $E_s$ is the potential in the source of static electricity and $e_d$ is the diode voltage drop. The instantaneous value of the diode current is then equal to $e_s/R_s$. During physical handling, practical peak values of currents produced by static-electricity discharges range from several milliamperes to several hundred milliamperes.

Fig. 62 shows a typical transfer characteristic curve measured on a typical set of back-to-back diodes used to protect the gate insulation in an MOS field-effect transistor that is nominally rated for a gate-to-source breakdown voltage of 20 volts.

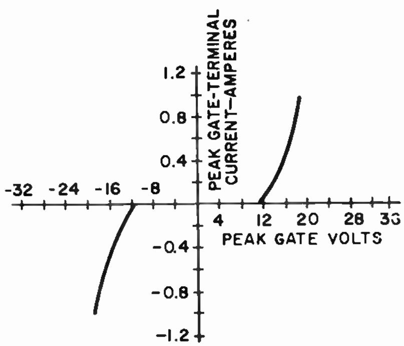



*Fig. 62—Typical diode transfer characteristic measured with 1-microsecond pulse width at a duty factor of 4 x $10^{-3}$.*

The transfer-characteristic curves show that the diodes will constrain a transient impulse to potential values well below the ±20 volt limit, even when the source of the transient surge is capable of delivering several hundred milliamperes of current. (These data were measured with 1-microsecond pulses applied to the protected gate at a duty-factor of 4 x $10^{-3}$).

## FABRICATION

The fabrication techniques used to produce MOS transistors are similar to those used for modern high-speed silicon bipolar transistors. The starting material for an n-channel transistor is a lightly doped p-type silicon wafer. (Reversal of p-type and n-type materials referred to in this description produces a p-channel transistor.) After the wafer is polished on one side and oxidized in a furnace, photolithographic techniques are used to etch away the oxide coating and expose bare silicon in the source and drain regions. The source and drain regions are then formed by diffusion in a furnace containing an n-type impurity (such as phosphorus). If the transistor is to be an enhancement-type device, no channel diffusion is required. If a depletion-type transistor is desired, an n-type channel is formed to bridge the space between the diffused source and drain.

The wafer is then oxidized again to cover the bare silicon regions, and a second photolithographic and etching step is performed to remove the oxide in the contact regions. After metal is evaporated over the entire wafer, another photolithographic and etching step removes all metal not needed for the ohmic contacts to the source, drain, and gate. The individual transistor chips are then mechanically separated and mounted on individual headers, connector wires are bonded to the metalized regions, and each unit is hermetically sealed in its case in an inert atmosphere. After testing, the external leads of each device are physically shorted together to prevent electrostatic damage to the gate insulation during branding and shipping.

## ELECTRICAL CHARACTERISTICS

The basic current-voltage relationship for an MOS transistor is shown in Fig. 63. With a constant gate-to-source voltage (e.g., $V_{GS} = 0$), the resistance of the channel is essentially constant, and current varies directly with drain-to-source voltage ($V_{DS}$), as illustrated in region A-B. The flow of drain current ($I_D$) produces an IR drop along the channel. The polarity of this drop is such as to oppose the field produced within the gate oxide by the gate bias. As the drain voltage is increased, a point is reached at which the IR drop becomes sufficiently high so that the capability of the gate field to attract enough carriers into the channel to sustain a higher drain-current is nullified. When this condition occurs (in the proximity of point B in Fig. 63), the channel is essentially depleted of carriers (i.e., becomes "constricted"), and drain current increases very much more slowly with further increases in drain-to-source voltage $V_{DS}$. This condition leads to the description of region B-C as the "pinch-off" region because the channel "pinches off" and the drain current ($I_{DS}$) tends to saturate at a constant value. Beyond point C, the transistor enters the "breakdown" region (also known as the "punch-through" region), in which unrestricted current flow and damage to the transistor result if current flow is not limited by the external circuit.

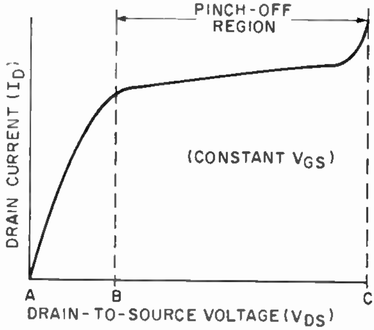



*Fig. 63—Basic current-voltage relationship for an MOS transistor.*

MOS transistors are especially useful in high-impedance voltage amplifiers when they are operated in the "pinch-off" region. The direct variation in their channel resistance (Region A-B in Fig. 63) makes them very attractive for use in voltage-controlled resistor applications, such as the chopper circuits used in connection with some types of dc amplifiers.

Typical output characteristic curves for n-channel MOS transistors are shown in Fig. 64. The resemblance of these curves to the basic curve shown in Fig. 63 should be noted. (For p-channel transistors, the polarity of the voltages and the direction of the current are reversed.) Typical transfer characteristics for n-channel single-gate MOS transistors are shown in Fig. 65. (Again, voltage polarities and current direction would be reversed for p-channel devices.) The threshold voltage ($V_{TH}$) shown in connection with the enhancement-type transistor illustrates the "normally-open" source-drain characteristic of the device. In these transistors, conduction does not begin until $V_{GS}$ is increased to a particular value. Fig. 66 shows typical drain-current curves

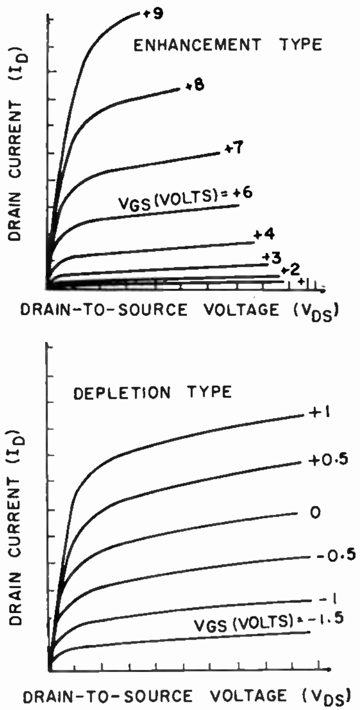



*Fig. 64—Typical output-characteristic curves for n-channel MOS transistors.*

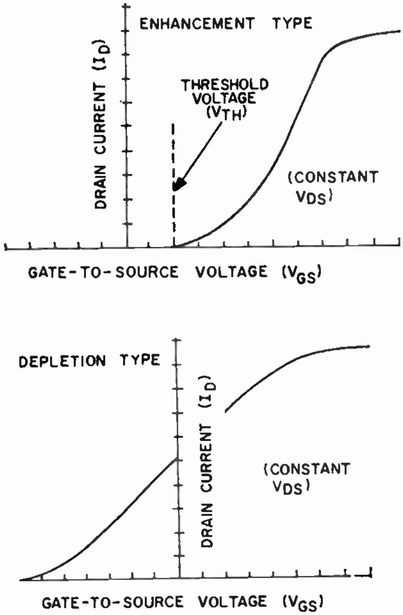



*Fig. 65—Typical transfer characteristics for n-channel MOS transistors.*

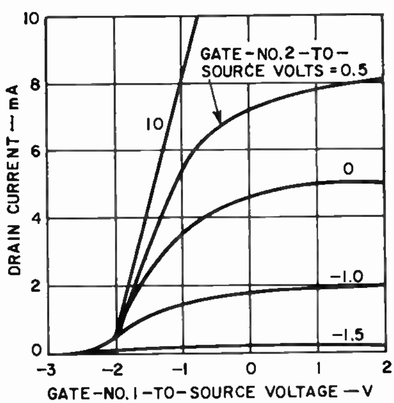



*Fig. 66—Drain current of a dual-gate MOS transistor as a function of gate-No. 1-to-source voltage for several values of gate-No. 2-to-source voltage.*

for a dual-gate device as a function of gate No. 1-to-source voltage for several values of gate No. 2-to-source voltage.

## BIASING TECHNIQUES FOR SINGLE-GATE MOS TRANSISTORS

The bias required for operation of a single-gate MOS transistor can be supplied by use of a self-bias (source-bias) arrangement, from a supply of fixed bias, or, preferably, by a combination of these methods. Fig. 67 illustrates each of the three biasing techniques.

The design of a self-bias circuit is relatively simple and straightforward. For example, if a 3N128 MOS transistor is to be operated with a drain-to-source voltage $V_{DS}$ of 15 volts and a small-signal transconductance $g_{fs}$ of 7400 micromhos, the drain current $I_D$ required for the specified value of transconductance is first obtained from published curves, such as those shown in Fig. 68(a). Next, the gate-to-source voltage required for this value of drain current is determined from another published curve, such as the solid-line curve shown in Fig. 68(b). These curves indicate that the drain current should be 5 milliamperes and that the gate-to-source voltage should be −1.1 volts for the specified values of drain-to-source voltage and transconductance. The source voltage $V_S$, the source resistance $R_S$, and the dc supply voltage $V_{DD}$ can then be readily calculated, as follows:

$$V_S = V_G - V_{GS} = 1.1 \text{ volts}$$
$$R_S = V_S/I_D = 1.1/5 = 220 \text{ ohms}$$
$$V_{DD} = V_{DS} + V_S = 15 + 1.1 = 16.1 \text{ volts}$$

The self-bias arrangement is satisfactory for some applications. A particular source resistance, however, must be selected for each device if a specified drain current is required because the drain-current characteristics of individual devices can vary significantly from the typical values. The dashed-line curves in Fig. 68(b) define the "high" and "low" limits for the characteristics of the 3N128 MOS transistor. For example, the zero-bias drain current $I_{DSS}$ can vary from a low value of 5 milliamperes to a high value of 25 milliamperes, a range of 20 milliamperes. Use of a source resistor of 220 ohms, as calculated in the preceding example, reduces the range of the drain current between "high" and "low" 3N128 transistors operated in self-bias circuits from 20 milliamperes to about 4 milliamperes. A reduction of about 5 to 1 in the range of $I_{DSS}$ values among individual devices can be achieved, therefore, by a judicious choice of the proper value of source resistance.

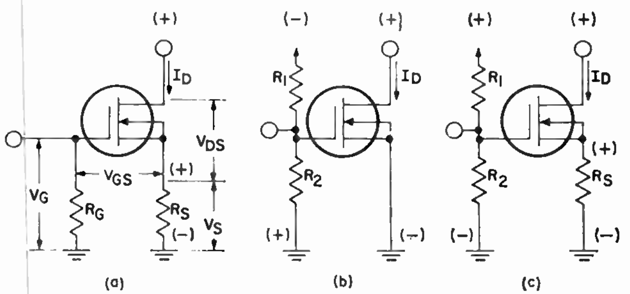



*Fig. 67—Biasing arrangements for single-gate MOS transistors: (a) self-bias circuit; (b) fixed bias supply; (c) combination of self bias and fixed bias.*

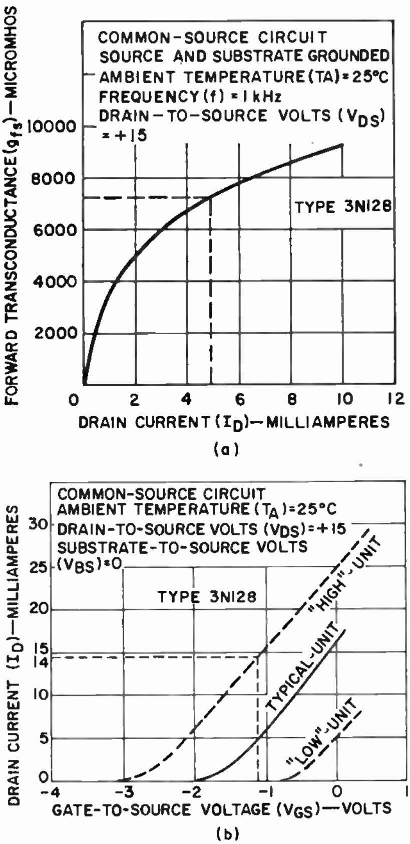



*Fig. 68—Operating characteristics for the RCA-3N128 MOS transistor: (a) forward transconductance as a function of drain current; (b) drain current as a function of gate-to-source voltage.*

Fixed-bias-supply systems, such as that shown in Fig. 68(b), are generally unattractive for use with MOS transistors for two main reasons. First, this type of system is undesirable because it requires the use of a separate, negative-voltage power supply. Second, as shown by the curves in Fig. 68(b), for a fixed bias supply of 1.1 volts, drain current would be 14 milliamperes for a "high" 3N128 transistor and would be cut off for a "low" device. Consequently, if an external bias system is used provisions must be made for adjustment of the bias voltage if a specific drain current is required for a particular device.

The combination bias system shown in Fig. 67(c) is the most effective arrangement when an application requires a specific drain current despite the range of drain-current characteristics encountered among individual devices. Fig. 69 shows two families of characteristic curves developed empirically for the combination bias system shown in Fig. 67(c). The family of curves on the left is pertinent for operation at a drain current of 5 milliamperes. For operation at a drain current of 10 milliamperes, the family of curves on the right should be used.

If a drain current of 5 milliamperes is desired, the pertinent curves in Fig. 69 show that, for a source resistance of 1000 ohms, a bias system can provide this value of current within 1 milliampere (as indicated by projections of lines a and b to the abscissa), despite a range of 5 to 25 milliamperes in the value of $I_{DSS}$ for individual devices. A drain current $I_D$ of 5 milliamperes, however, develops a self bias of —5 volts across the 1000-ohm source resistor $R_S$, and the transistor will be cut off unless sufficient positive bias is applied across the input resistors ($R_1$ and $R_2$) to establish the correct operating point. The positive bias voltage can be obtained from the positive drain supply $V_{DD}$ so that there is no need for a separate bias supply. For a drain-to-source voltage $V_{DS}$ of 15 volts, a drain current $I_D$ of 5 milliamperes, a gate-to-source voltage $V_{GS}$ of —1.1 volts, and a source resistance $R_S$ of 1000 ohms, the circuit parameters for the combination bias system shown in Fig. 67(c) can be calculated as follows:

$$V_S = I_D R_S = (0.005)(1000) = 5 \text{ volts}$$

$$V_G = V_{GS} + V_S = -1.1 + 5 = 3.9 \text{ volts}$$

$$V_{DD} = V_{DS} + V_S = 15 + 5 = 20 \text{ volts}$$

$$V_{DD}/V_G = (R_1 + R_2)/R_2 = 20/3.9 = 5.12$$

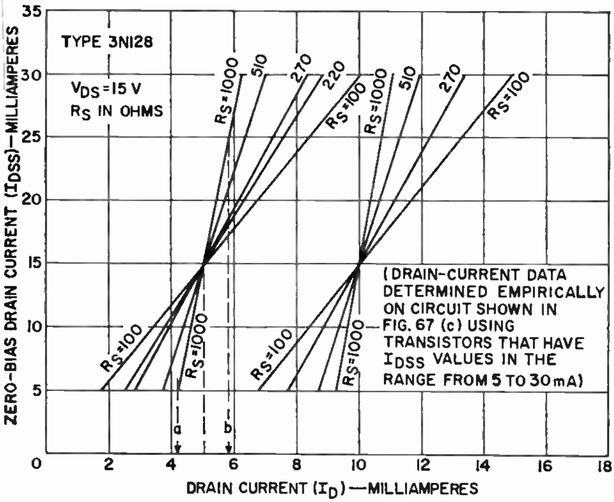



*Fig. 69—Drain current $I_D$ as a function of zero-bias drain current $I_{DSS}$ for several values of source resistance $R_S$.*

The lower limits for the values of the input resistors $R_1$ and $R_2$ are determined on the basis of the maximum permissible loading of the input circuit. The resistance that corresponds to this value is set equal to the equivalent value of the parallel combination of the two resistors. For example, if the total resistance in shunt with the input circuit is to be no less than 50,000 ohms, the values of $R_1$ and $R_2$ are calculated as follows:

$$R_1R_2/(R_1 + R_2) = 50{,}000$$
$$(R_1 + R_2)/R_2 = 5.12$$

Therefore, $R_1$ = 256,000 ohms and $R_2$ = 62,000 ohms.

In rf-circuit applications, the effects of input-circuit loading can be circumvented by use of the circuit arrangement shown in Fig. 70.

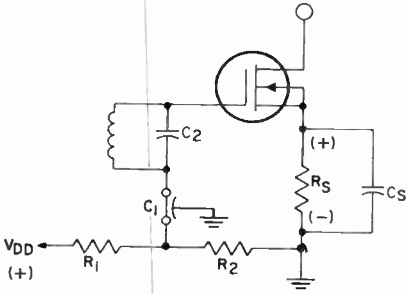



*Fig. 70—Circuit used to eliminate input-circuit loading in rf-amplifier applications.*

## BIASING TECHNIQUES FOR DUAL-GATE MOS TRANSISTORS

The following example illustrates the techniques used to provide the bias required for operation of a dual-gate MOS transistor. This example assumes a typical application in which a 3N140 dual-gate MOS transistor is required to operate with a drain-to-source voltage $V_{DS}$ of 15 volts and a forward transconductance $g_{fs}$ of 10,500 micromhos. (The techniques described for the 3N140 transistor are also applicable to dual-gate-protected MOS transistors.) The characteristic curves for the 3N140, shown in Fig. 71(a), indicate that the desired value of transconductance can be obtained for a gate No. 1-to-source voltage $V_{G1S}$ of −0.45

volt and a gate No. 2-to-source voltage $V_{G2S}$ of +4 volts. The curves in Fig. 71(b) show that for these conditions the drain current $I_D$ is 10 milliamperes.

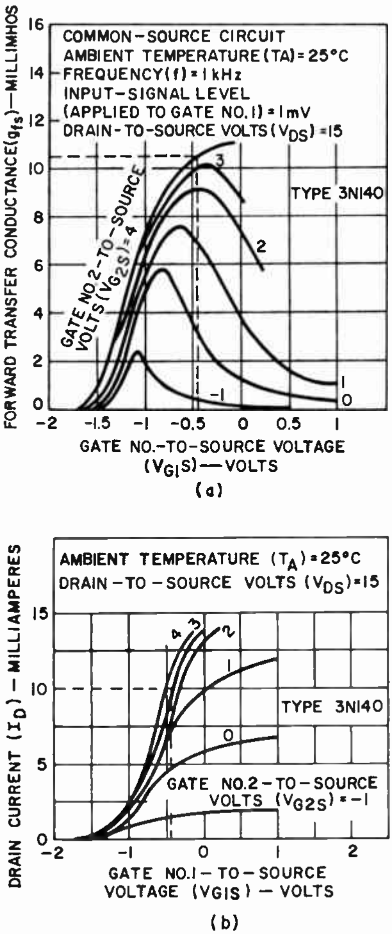



*Fig. 71—Operating characteristics for the RCA-3N140 dual-gate MOS transistor: (a) forward transconductance as a function of gate-No. 1-to-source voltage; (b) drain current as a function of gate-No. 1-to-source voltage.*

Fig. 72 shows a biasing arrangement that can be used for dual-gate MOS field-effect transistors. For the application being considered, the

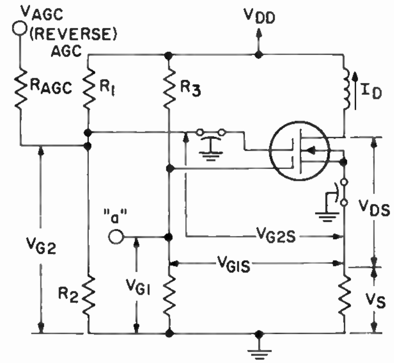



*Fig. 72—Typical biasing circuit for dual-gate MOS field-effect transistors.*

shunt resistance for gate No. 1 is assumed to be 25,000 ohms. Gate No. 2 is operated at rf ground (by means of adequate bypassing) and is biased with a fixed dc potential. Empirical experience with dual-gate MOS transistors has shown that a source resistance of approximately 270 ohms provides adequate self-bias for the transistor for operation from the proposed dc supply voltage. For this value of source resistance, the remaining parameters of the bias circuit are obtained from the following calculations:

$$V_S = I_D R_S = (0.010)(270) = +2.7 \text{ volts}$$

$$V_{G1} = V_{G1S} + V_S = (-0.45) + (+2.7) = +2.25 \text{ volts}$$

$$V_{G2} = V_{G2S} + V_S = (+4.0) + (+2.7) = +6.7 \text{ volts}$$

$$V_{DD} = V_{DS} + V_S = (+15) + (+2.7) = +17.7 \text{ volts}$$

The values of the voltage-divider resistances required to provide the appropriate voltage at each gate are determined in a manner similar to that described for single-gate MOS transistors. The value calculated for $R_3$ is 197,000 ohms, that for $R_1$ is 28,600 ohms, and the ratio $R_1/R_2$ is 11.67.

The circuit shown in Fig. 72 is normally used in rf amplifier applications. In this circuit, the signal voltage is applied at point "a" through appropriate input circuitry. If the agc feature is not employed, (e.g. in mixer circuits), the resistor $R_{agc}$ is disconnected at point "b." In a mixer application, the local oscillator signal is injected at point "b."

## GENERAL CIRCUIT CONFIGURATIONS

There are three basic single-stage amplifier configurations for MOS transistors: common-source, common-gate, and common-drain. Each of these configurations provides certain advantages in particular applications.

The **common-source** arrangement shown in Fig. 73 is most frequently used. This configuration provides a

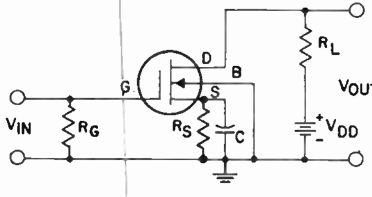



*Fig. 73—Basic common-source circuit for MOS field-effect transistors.*

high input impedance, medium to high output impedance, and voltage gain greater than unity. The input signal is applied between gate and source, and the output signal is taken between drain and source. The voltage gain without feedback, A, for the common-source circuit may be determined as follows:

$$A = \frac{g_{fs}\, r_{os}\, R_L}{r_{os} + R_L}$$

where $g_{fs}$ is the gate-to-drain forward transconductance of the transistor, $r_{os}$ is the common-source output resistance, and $R_L$ is the effective load resistance. The addition of an unbypassed source resistor to the circuit of Fig. 73 produces negative voltage feedback proportional to the output current. The voltage gain with feedback, A′, for a common-source circuit is given by

$$A' = \frac{g_{fs}\, r_{os}\, R_L}{r_{os} + (g_{fs}\, r_{os} + 1)\, R_S + R_L}$$

where $R_S$ is the total unbypassed source resistance in series with the source terminal. The common-source output impedance with feedback, $Z_o$, is increased by the unbypassed source resistor as follows:

$$Z_o = r_{os} + (g_{fs}\, r_{os} + 1)\, R_S$$

The **common-drain** arrangement, shown in Fig. 74, is also frequently referred to as a **source-follower**. In this configuration, the input impedance is higher than in the common-source configuration, the output impedance is low, there is no polarity reversal between input and output, the voltage gain is always less than unity, and distortion is low. The source-follower is used in applications which require reduced input-circuit capacitance, downward impedance transformation, or increased input-signal-handling capability. The input signal is effectively injected between gate and drain, and the output is taken between source and drain. The circuit inherently has 100-per-cent negative

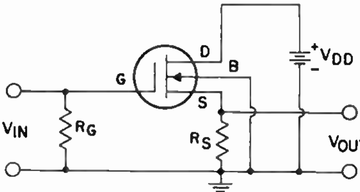



*Fig. 74—Basic common-drain (or source-follower) circuit for MOS transistors.*

voltage feedback; its gain A′ is given by

$$A' = \frac{R_S}{\dfrac{\mu + 1}{\mu} R_S + \dfrac{1}{g_{fs}}}$$

Because the amplification factor ($\mu$) of an MOS transistor is usually much greater than unity, the equation for gain in the source-follower can be simplified as follows:

$$A' = \frac{g_{fs} R_S}{1 + g_{fs} R_S}$$

For example, if it is assumed that the gate-to-drain forward transconductance $g_{fs}$ is 2000 micromhos ($2 \times 10^{-3}$ mho) and the unbypassed source resistance $R_S$ is 500 ohms, the stage gain A' is 0.5. If the same source resistance is used with a transistor having a transconductance of 10,000 micromhos ($1 \times 10^{-2}$ mho), the stage gain increases to 0.83.

When the resistor $R_G$ is returned to ground, as shown in Fig. 74, the input resistance $R_i$ of the source-follower is equal to $R_G$. If $R_G$ is returned to the source terminal, however, the effective input resistance $R_i'$ is given by

$$R_i' = \frac{R_G}{1 - A'}$$

where A' is the voltage amplification of the stage with feedback. For example, if $R_G$ is one megohm and A' is 0.5, the effective resistance $R_i'$ is two megohms.

If the load is resistive, the effective input capacitance $C_i'$ of the source-follower is reduced by the inherent voltage feedback and is given by

$$C_i' = c_{gd} + (1 - A')\, c_{gs}$$

where $c_{gd}$ and $c_{gs}$ are the intrinsic gate-to-drain and gate-to-source capacitances, respectively, of the MOS transistor. For example, if a typical MOS transistor having a $c_{gd}$ of 0.3 picofarad and a $c_{gs}$ of 5 picofarads is used, and if A' is equal to 0.5, then $C_i'$ is reduced to 2.8 picofarads.

The effective output resistance $R_o'$ of the source-follower stage is given by

$$R_o' = \frac{r_{os} R_S}{(g_{fs} r_{os} + 1) R_S + r_{os}}$$

where $r_{os}$ is the transistor common-source output resistance in ohms. For example, if a unit having a gate-to-drain forward transconductance $g_{fs}$ of 2000 micromhos and a common-source output resistance $r_{os}$ of 7500 ohms is used in a source-follower stage with an unbypassed source resistance $R_S$ of 500 ohms, the effective output resistance $R_o'$ of the source-follower stage is 241 ohms.

The source-follower output capacitance $C_o'$ may be expressed as follows:

$$C_o' = c_{ds} + c_{gs} \left(\frac{1 - A'}{A'}\right)$$

where $c_{ds}$ and $c_{gs}$ are the intrinsic drain-to-source and gate-to-source capacitances, respectively, of the MOS transistor. If A' is equal to 0.5 (as assumed for the sample input-circuit calculations), $C_o'$ is reduced to the sum of $c_{ds}$ and $c_{gs}$.

The common-gate circuit, shown in Fig. 75, is used to transform from a low input impedance to a

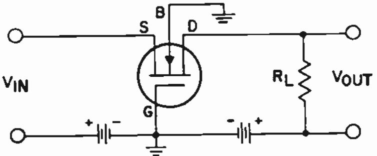



*Fig. 75—Basic common-gate circuit for MOS transistors.*

high output impedance. The input impedance of this configuration has approximately the same value as the output impedance of the source-follower circuit. The common-gate circuit is also a desirable configuration for high-frequency applications because its relatively low voltage gain makes neutralization unnecessary in most cases. The common-gate voltage gain, A, is given by

$$A = \frac{(g_{fs} r_{os} + 1) R_L}{(g_{fs} r_{os} + 1) R_G + r_{os} + R_L}$$

where $R_G$ is the resistance of the input-signal source. For a typical MOS transistor ($g_{fs}$ = 2000 micromhos, $r_{os}$ = 7500 ohms) and with $R_L$ = 2000 ohms and $R_G$ = 500 ohms, the common-gate voltage gain is 1.8. If the value of $R_G$ is doubled, the voltage gain is reduced to 1.25.

## TECHNICAL FEATURES

It is apparent from the preceding discussions that MOS field-effect transistors exhibit a number of technical features that result in unique performance advantages in circuit applications such as mixers, product detectors, remote gain-control circuits, balanced modulators, choppers, clippers, and gated amplifiers. These features include:

1. An extremely high input resistance and a low input capacitance—as a result, MO transistors impose virtually no loading on an agc voltage source (i.e., virtually no agc power is required) and have a wide agc range capability.
2. A wide dynamic range—MOS transistors, therefore, can handle positive and negative input-signal excursions without diode-current loading.
3. Cross-modulation effects and spurious response that are substantially less than those of other types of electronic devices—the cross-modulation characteristics of dual-gate transistors actually improve as the device approaches cutoff.
4. Zero offset voltage—this feature is especially desirable for chopper applications.
5. An exceptionally high forward transconductance.
6. Negative temperature coefficient for the drain current—"thermal runaway," therefore, is virtually impossible.
7. A very low gate leakage current that is relatively insensitive to temperature variations.
8. Very low oscillator feed-through in dual-gate mixer circuits.
9. Dual-gate transistors can provide good gain in common-source amplifiers into the uhf range without neutralization.

## HANDLING CONSIDERATIONS

MOS field-effect transistors, like high-frequency bipolar transistors, can be damaged by exposure to excessive voltages. The gate oxide insulation is susceptible to puncture when subjected to voltage in excess of the rated value. The very high resistance of the oxide insulation imposes a negligible load on electrostatically generated potentials and, therefore, provides an ineffective discharge path for sources of static electricity. As discussed earlier, the integral gate-protection system incorporated into some types of dual-gate MOS transistors is highly effective in the protection of these devices against the effects of electrostatic charges. Special precautions, however, must be taken in the handling and application of other types of MOS transistors that do not contain the integral gate protection. The discussion of MOS Transistors in the section on Testing and Mounting outlines the special handling procedures recommended for such devices.

# Thyristors

THE term **thyristor** is the generic name for solid-state devices that have characteristics similar to those of thyratron tubes. Basically, this group includes bistable solid-state devices that have two or more junctions (three or more semiconductor layers) and that can be switched between conducting states (from OFF to ON or from ON to OFF) within at least one quadrant of the principal voltage-current characteristic. Reverse-blocking triode thyristors, commonly called silicon controlled rectifiers (SCR's), and bidirectional triode thyristors, usually referred to as triacs, have three electrodes and are switched between states by a current pulse applied to the gate terminal. The bidirectional trigger diode, commonly called a diac, has only two electrodes. This device has no gate electrode but may be switched from an OFF state to an ON state for either polarity of applied voltage. The discussions in this section deal primarily with the SCR and the triac, their operation, electrical characteristics, and ratings. A brief description is also given of the operation of the diac and its chief function in triac phase-control circuits.

## SILICON CONTROLLED RECTIFIERS

A silicon controlled rectifier (SCR) is basically a four-layer p-n-p-n device that has three electrodes (a cathode, an anode, and a control electrode called the gate). Fig. 76 shows the junction diagram, principal voltage-current characteristic, and schematic symbol for an SCR.

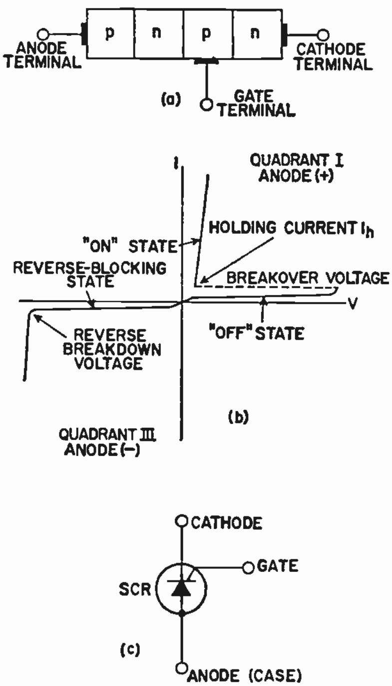



*Fig. 76—(a) Junction diagram, (b) principal voltage-current characteristic, and (c) schematic symbol for an SCR thyristor.*

Fig. 76(b) shows that under forward-bias conditions (anode positive with respect to cathode) the SCR has two states. At low values of forward bias, the SCR exhibits a very high impedance; in this forward-blocking or OFF state, a small forward current, called the forward OFF-state current, flows through the device. As the forward bias is increased, however, a voltage point is reached at which the forward current increases rapidly and the SCR switches to the ON state. This value of voltage is called the breakover voltage. When the SCR is in the ON state, the forward current is limited primarily by the impedance of the external circuit.

Under reverse bias (anode negative with respect to cathode), the SCR exhibits a very high internal impedance, and only a small amount of current, called the reverse blocking current, flows through the device. This current remains very small and the device remains in this OFF state unless the reverse voltage exceeds the reverse-breakdown-voltage limitation. At this point, the reverse current increases rapidly, and the SCR undergoes thermal runaway, a condition that normally causes irreversible damage to the device. The value of reverse breakdown voltage differs for individual SCR types, but is approximately 100 volts greater than the forward breakover voltage for most types. Under forward-bias conditions, the breakover voltage of the SCR can be controlled or varied by application of a current pulse to the gate electrode, as shown in Fig. 77. As the amplitude of the gate current pulse is increased, the breakover voltage for the SCR decreases until the curve closely resembles that of a rectifier. In normal operation, the SCR is operated with critical values well below the breakover voltage and is made to switch on by gate signals of sufficient magnitude to assure that

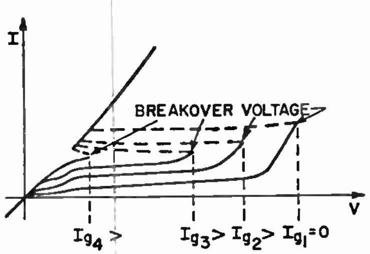



*Fig. 77—Curves showing the forward-voltage characteristics of a thyristor for different values of gate current.*

the device is switched to the ON state at the instant desired.

After the SCR is triggered by the gate signal, the current through the device is independent of the gate voltage or gate current. The SCR remains in the ON state until the principal current is reduced to a level below that required to sustain conduction.

Construction details of a typical SCR pellet are shown in Fig. 78.

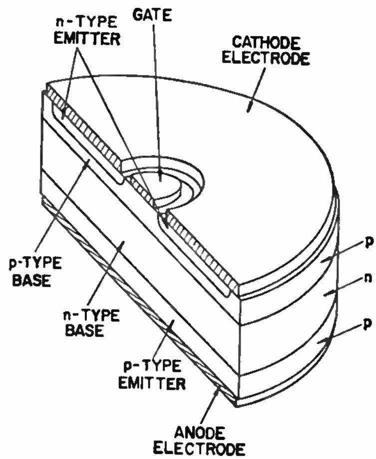



*Fig. 78—Cross-section of a typical SCR pellet.*

The shorted-emitter construction used in RCA SCR's can be recognized by the metallic cathode electrode in direct contact with the p-type base layer around the periphery of the pellet. The gate, at the center of the pellet, also makes direct metallic contact to the p-type base so that the portion of this layer under the n-type emitter acts as an ohmic path for current flow between gate and cathode. Because this ohmic path is in parallel with the n-type emitter junction, current preferentially takes the ohmic path until the IR drop in this path reaches the junction threshold voltage of about 0.8 volt. When the gate voltage exceeds this value, the junction current increases rapidly, and injection of electrons by the n-type emitter reaches a level high enough to turn on the device.

In addition to providing a precisely controlled gate current, the shorted-emitter construction also improves the high-temperature and dv/dt (maximum allowable rate of rise of OFF-state voltage) capabilities of the device.

The center-gate construction of the SCR pellet provides fast turn-on and high di/dt capabilities. In an SCR, conduction is initiated in the cathode region immediately adjacent to the gate contact and must then propagate to the more remote regions of the cathode. Switching losses are influenced by the rate of propagation of conduction and the distance conduction must propagate from the gate. With a central gate, all regions of the cathode are in close proximity to the initially conducting region so that propagation distance is significantly decreased; as a result, switching losses are minimized.

## TRIACS

Fig. 79 shows the junction diagram, voltage-current characteristic, and schematic symbol for a triac. The triac, like the SCR, has three electrodes; they are designated as main terminal No.1, main terminal No.2, and the gate. As shown in Fig. 79(b), the triac exhibits the same forward-blocking, forward-conducting voltage-current characteristic of the SCR, but for either polarity of voltage applied to the main terminals. Under forward bias (main terminal No.2 positive with respect to main terminal No.1) or reverse bias (main terminal No.2 negative with respect to main terminal No.1), the triac exhibits first a forward-blocking (OFF) state, then a forward-conducting (ON) state. The point at which the device switches states is the breakover voltage. Again like the SCR, the breakover voltage of the triac can be controlled or varied by application of a positive or negative current pulse to the gate electrode. As the amplitude of the current pulse is

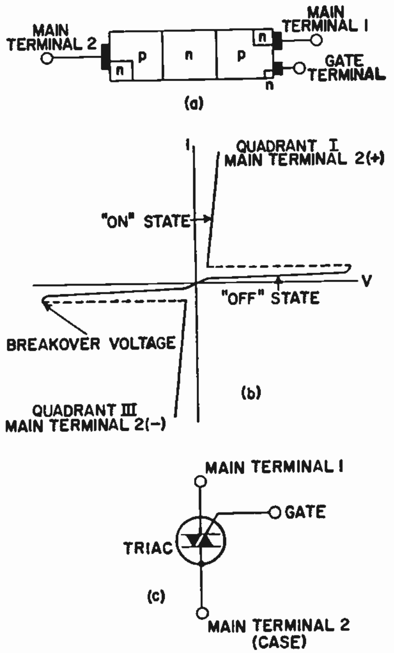



*Fig. 79—(a) Junction diagram, (b) principal voltage-current characteristic, and (c) schematic symbol for a triac thyristor.*

increased, the breakover point of the triac is decreased. The triac can therefore be considered as two SCR's connected in parallel and oriented in opposite directions, as shown in Fig. 80.

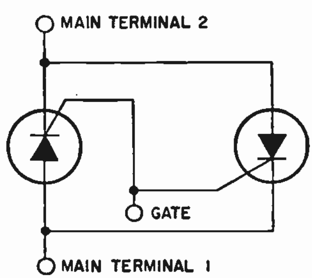



*Fig. 80—A triac equivalent circuit: two SCR's in parallel and oriented in opposite directions.*

Construction of a typical RCA triac pellet is shown in Fig. 81. In this device, the main-terminal-No. 1 electrode makes ohmic contact to a p-type emitter as well as to an n-type emitter. Similarly, the main-terminal-No. 2 electrode also makes ohmic contact to both types of emitters, but the p-type emitter of the main-terminal-No. 2 side is located opposite the n-type emitter of the main-terminal-No. 1 side, and the main-terminal-No. 2 n-type emitter is opposite the main-terminal-No. 1 p-type emitter. The net result is two four-layer switches in parallel, but oriented in opposite directions, in one silicon pellet. This type of construction makes it possible for a triac either to block or to conduct current in either direction between main terminal No. 1 and main terminal No. 2.

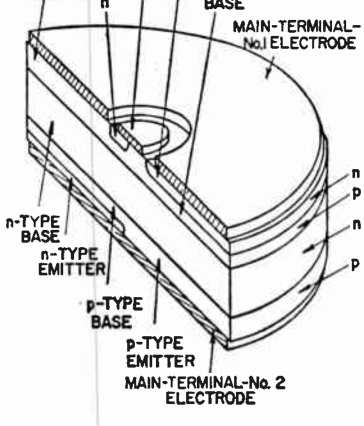



*Fig. 81—Cross-section of a typical triac pellet.*

## DIACS

A diac is a two-electrode, three-layer bidirectional avalanche diode which can be switched from the OFF state to the ON state for either polarity of applied voltage. Fig. 82 shows the junction diagram, voltage-current characteristic, and schematic symbol for a diac.

This three-layer trigger diode is similar in construction to a bipolar

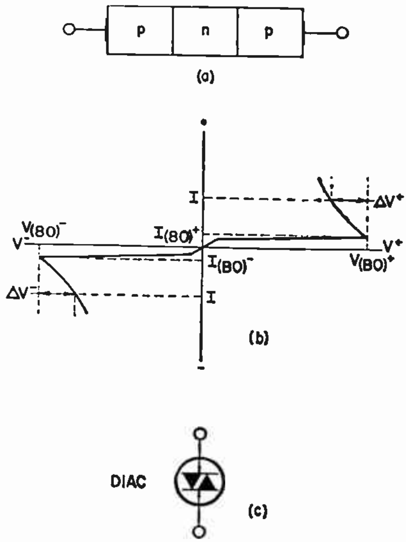



*Fig. 82—(a) Junction diagram, (b) voltage-current characteristic, and (c) schematic symbol for a diac.*

transistor. A diac differs from a bipolar transistor in that the doping concentrations at the two junctions are approximately the same and there is no contact made to the base layer. The equal doping levels result in a symmetrical bidirectional switching characteristic, as shown in Fig. 82(b). When an increasing positive or negative voltage is applied across the terminals of the diac, a minimum (leakage) current $I_{(BO)}$ flows through the device until the voltage reaches the breakover point $V_{(BO)}$. The reverse-biased junction then undergoes avalanche breakdown and, beyond this point, the device exhibits a negative-resistance characteristic, i.e., current through the device increases substantially with decreasing voltage.

Diacs are primarily used as triggering devices in triac phase-control circuits used for light dimming, universal motor-speed control, heat control, and similar applications. Fig. 83 shows the general circuit diagram for a diac/triac phase-control circuit. The magnitude and

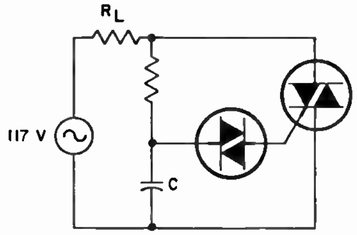



*Fig. 83—General circuit diagram for a diac/triac phase-control circuit.*

duration of the current pulse applied to the gate of the triac are determined by the value of phase-shift capacitance C, the change in voltage across and the dynamic impedance of the diac, and the triac gate impedance. The interaction of all circuit impedances and the phase-shift capacitance can best be represented by the curve of peak current as a function of the capacitance shown in Fig. 84.

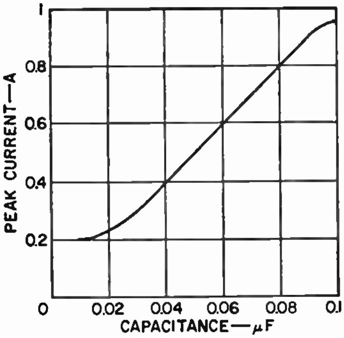



*Fig. 84—Peak current as a function of capacitance in a triac.*

## SCR AND TRIAC GATE CHARACTERISTICS

Silicon controlled rectifiers and triacs are ideal for switching applications. When the working voltage of the thyristor is below the breakover point, the device is essentially an open switch; above the breakover voltage, the thyristor switches to the ON state and is effectively a closed switch. The breakover voltage can be varied or controlled by injections of a signal at the gate terminal.

The manufacturer's specifications indicate the magnitude of gate current and voltage required to turn on these devices. Gate characteristics, however, vary from device to device even among devices within the same family. For this reason, manufacturer's specifications on gating characteristics provide a range of values in the form of characteristic diagrams. A diagram such as that shown in Fig. 85 is given to define the limits of gate currents and voltages that may be used to trigger any given device of a specific family. The boundary lines of maximum and minimum gate impedance on this characteristic diagram represent the loci of all possible triggering points for thyristors in this family. The curve OA represents the gate characteristic of a specific device that is triggered within the shaded area.

The magnitude of gate current and voltage required to trigger a thyristor varies inversely with junction temperature. As the junction temperature increases, the level of gate signal required to trigger the thyristor becomes smaller. Worst-case triggering conditions occur, therefore, at

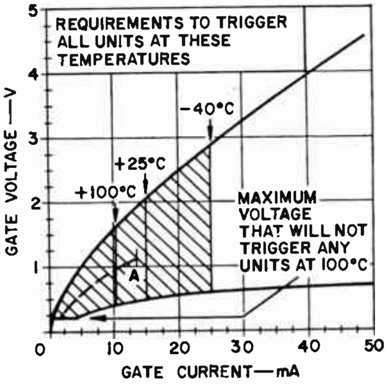



*Fig. 85—Gate-characteristics curves for a typical RCA SCR.*

the minimum operating junction temperature.

The gate nontrigger voltage $V_{gnt}$ is the maximum dc gate voltage that may be applied between gate and cathode of the thyristor for which the device can maintain its rated blocking voltage. This voltage is usually specified at the rated operating temperature (100°C) of the thyristor. Noise signals in the gate circuit should be maintained below this level to prevent unwanted triggering of the thyristor.

When very precise triggering of a thyristor is desired, the thyristor gate must be overdriven by a pulse of current much larger than the dc gate current required to trigger the device. The use of a large current pulse reduces variations in turn-on time, minimizes the effect of temperature variations on triggering characteristics, and makes possible very short switching times.

The coaxial gate structure and the "shorted-emitter" construction techniques used in RCA thyristors have greatly extended the range of limiting gate characteristics. As a result, the gate-dissipation ratings of RCA thyristors are compatible with the power-handling capabilities of other elements of these devices. Advantage can be taken of the higher peak-power capability of the gate to improve dynamic performance, increase di/dt capability (maximum allowable rate of rise of ON-state current), minimize interpulse jitter, and reduce switching losses. This higher peak-power capability also allows greater interchangeability of thyristors in high-performance applications.

The forward gate characteristics for thyristors, shown in Fig. 86, indicate the maximum allowable pulse widths for various peak values of gate input power. The pulse width is determined by the relationship that exists between gate power input and the increase in the temperature of the thyristor pellet that results from the application of gate power. The curves shown in Fig. 86(a) are for RCA SCR's that have relatively small current ratings (2N4101, 2N4102, and 40379 families), and the curves shown in Fig. 86(b) are for RCA SCR's that have larger current ratings (2N4103, 2N3873, and 2N3899 families). Because

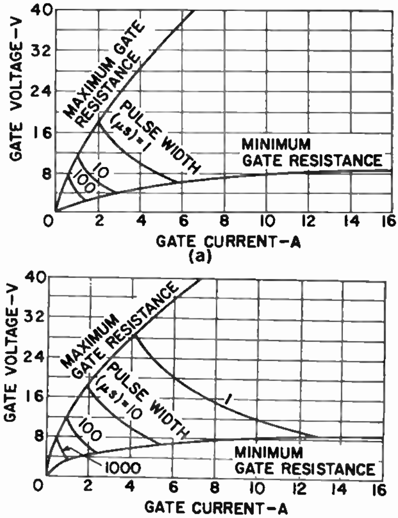



*Fig. 86—Forward gate characteristics for pulse triggering of RCA SCR's: (a) low-current types; (b) high-current types.*

the higher-current thyristors have larger pellets, they also have greater thermal capacities than the smaller-current devices. Wider gate trigger pulses can therefore be used on these devices for the same peak value of gate input power.

Because of the resistive nature of the "shorted-emitter" construction, similar volt-ampere curves can be constructed for reverse gate voltages and currents, with maximum allowable pulse widths for various peak-power values, as shown in Fig. 87. These curves indicate that reverse dissipations do not exceed the maximum allowable power dissipation for the device.

The total average dissipation caused by gate-trigger pulses is the sum of the average forward and reverse dissipations. This total dissipation should be less than the Maximum Gate Power Dissipation $P_{GM}$ shown in the published data for the selected SCR. If the average gate dissipation exceeds the maximum published value, as the result of high forward gate-trigger pulses and transient or steady-state reverse gate biasing, the maximum allowable forward-conduction-current rating of the device must be reduced to compensate for the increased rise of junction temperature caused by the increased gate power dissipation

The triac can be triggered in any of four operating modes, as summarized in Table I. The quadrant designations refer to the operating quadrant on the principal voltage-current characteristics, shown in Fig. 79 (either I or III), and the polarity symbol represents the gate-to-main-terminal-No. 1 voltage.

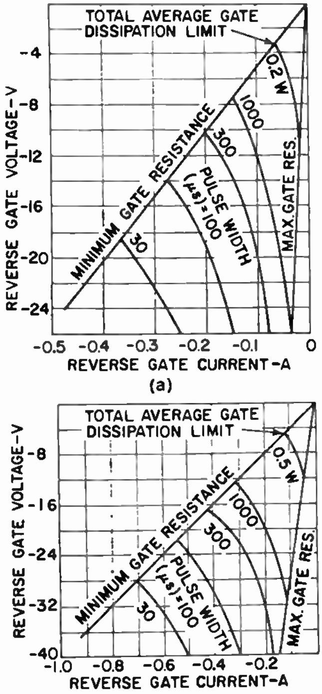



*Fig. 87—Reverse gate characteristics of RCA SCR's: (a) low-current types; (b) high-current types.*

Table I—Triac Triggering Modes

| Gate-to-Main-Terminal-No. 1 Voltage | Main-Terminal-No. 2-to-Main-Terminal-No. 1 Voltage | Operating Quadrant |
|---|---|---|
| Positive | Positive | I(+) |
| Negative | Positive | I(−) |
| Positive | Negative | III(+) |
| Negative | Negative | III(−) |

The gate-trigger requirements of the triac are different in each operating mode. The I(+) mode (gate positive with respect to main terminal No. 1 and main terminal No. 2 positive with respect to main terminal No. 1), which is comparable to equivalent SCR operation, is usually the most sensitive. The smallest gate current is required to trigger the triac in this mode. The other three operating modes require larger gate-trigger currents. For RCA triacs, the maximum trigger-current rating in the published data is the largest value of gate current that is required to trigger the selected device in any operating mode.

## Gate Trigger Circuits

The gate signal used to trigger an SCR or triac must be of sufficient strength to assure sustained forward conduction. Triggering requirements are usually stated in terms of dc voltage and current. Because it is common practice to pulse-fire thyristors, it is also necessary to consider the duration of firing pulse required. A trigger pulse that has an amplitude just equivalent to the dc requirements must be applied for a relatively long period of time (approximately 30 microseconds) to ensure that the gate signal is provided during the full turn-on period of the thyristor. As the amplitude of the gate-triggering signal is increased, the turn-on time of the thyristor is decreased, and the width of the gate pulse may be reduced. When highly inductive loads are used, the inductance controls the current-rise portion of the turn-on time. For this type of load, the width of the gate pulse must be made long enough to assure that the principal current rises to a value greater than the latching-current level of the device. The latching current of RCA thyristors is always less than twice the holding current.

The application usually determines whether a simple or somewhat sophisticated triggering circuit should be used to trigger a given thyristor. Triggering circuits can be as numerous and as varied as the applications in which they are used; this text discusses the basic types only.

Many applications require that a thyristor be switched full ON or full OFF in a manner similar to the operation of a relay. Although higher currents are handled by the thyristor, only small trigger or gate currents are required from the control circuit or switch. The simplest method of accomplishing this type of triggering is illustrated in Fig. 88.

Each circuit shows a variable resistor in the gate circuit to control the conduction angle of the thyristor.

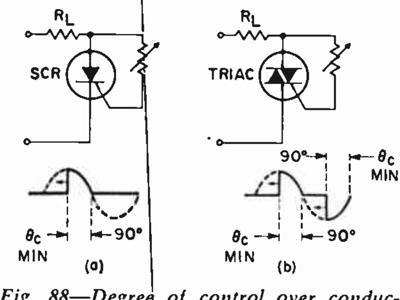



*Fig. 88—Degree of control over conduction angles when ac resistive network is used to trigger SCR's and triacs.*

The waveforms indicating the degree of control exercised by the variable resistance are also shown in Fig. 88. With maximum resistance in either circuit, the thyristor is OFF. As the resistance is reduced in the SCR circuit, a point is reached at which sufficient gate trigger current is provided at the positive peak of the voltage wave (90 degrees) to trigger the SCR ON. The SCR conducts from the 90-degree point to the 180-degree point for a total conduction angle of (180 − 90), or 90 degrees. In the triac circuit, as the resistance is reduced, the gate current increases until the triac is triggered at both the peak positive (90 degrees) and peak negative (270 degrees) points on the voltage wave. The triac then conducts between 90 degrees and 180 degrees, and between 270 degrees and 360 degrees for a total conduction angle of 180 degrees. The conduction angles of both the SCR and the triac can be increased by further reduction of the resistance in the gate circuits. For the SCR, the firing point is moved back from 90 degrees toward zero for a total conduction angle approaching 180 degrees. The triac firing points can also be moved back from 90 degrees toward zero for the positive half-cycle and from 270 degrees toward 180 degrees for the negative half-cycle to obtain a total conduction angle approaching 360 degrees. The resistor in the gate circuit assures that the gate current decreases to a negligible value after the thyristor is fired.

An easier method of obtaining a phase angle greater than 90 degrees for half-wave operation is to use a resistance-capacitance triggering network. Fig. 89 shows the simplest form of such networks for use with an SCR and a triac. The thyristor is in series with the load and in parallel with the RC network. At the beginning of each half-cycle (positive half-cycle only for the SCR), the thyristor is in the OFF state. As a result, the ac voltage appears across the thyristor and essentially none appears across the load. Because the thyristor is in parallel with the potentiometer and capacitor, the voltage across the thyristor drives current through the

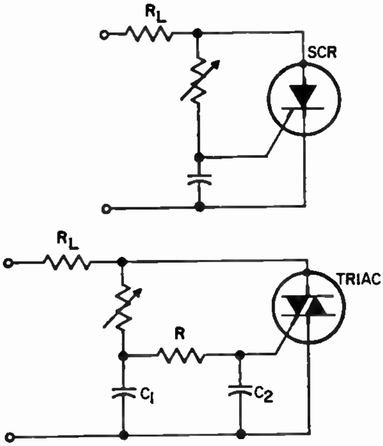



*Fig. 89—RC triggering networks used for phase-control triggering of thyristors.*

potentiometer and charges the capacitor. When the capacitor voltage reaches the breakover voltage of the thyristor, the capacitor discharges through the gate circuit and turns the thyristor on. At this point, the ac voltage is transferred from the thyristor to the load $R_L$ for the remainder of the half-cycle. If the potentiometer resistance is reduced, the capacitor charges more rapidly, and the breakover voltage is reached earlier in the cycle; as a result, the power applied to the load is increased.

The gate trigger voltage can be more closely controlled in simple resistance or resistance-capacitance circuits by use of a variety of special triggering devices. These triggering devices, including the diac, have a smaller range of characteristics, and are less temperature-sensitive. Basically, a thyristor triggering device exhibits a negative resistance after a critical voltage is reached, so that the gate-current requirement of the thyristor can be obtained as a pulse from the discharge of the phase-shift capacitor. Because the gate pulse need be only microseconds in duration, the gate-pulse energy and the size of the triggering components are relatively small. Triggering circuits of this type employ elements such as neon bulbs, diacs, unijunction transistors, and two-transistor switches.

Fig. 90 shows a light-dimming circuit in which a diac is used to trigger a triac. The voltage-current

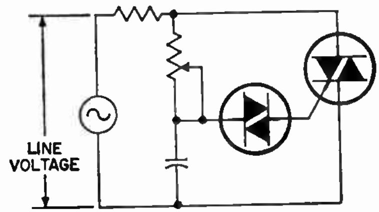



*Fig. 90—A light-dimmer circuit in which a diac is used to trigger a triac.*

characteristic for the diac in this circuit is shown in Fig. 91. The magnitude and duration of the gate-current pulse are determined

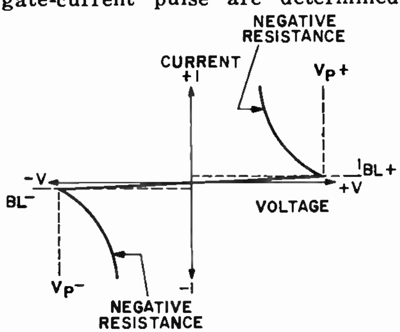



*Fig. 91—Voltage-current characteristic for triggering device shown in Fig. 90.*

by the interaction of the capacitor $C_1$, the diac characteristics, and the impedance of the thyristor gate. Fig. 92 shows the typical shape of the gate-current pulse that is produced.

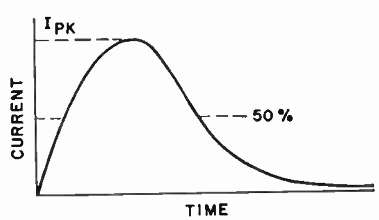



*Fig. 92—Typical gate-current waveform for circuit shown in Fig. 90.*

## SWITCHING CHARACTERISTICS

The ratings of thyristors are based primarily upon the amount of heat generated within the device pellet and the ability of the device package to transfer the internal heat to the external case. For high-frequency applications in which the peak-to-average current ratio is high, or for high-performance applications that require large peak values but narrow current pulses, the energy lost during the turn-on process may be the main cause of heat generation within the thyristor. The switching properties of the device must be known, therefore, to determine power dissipation which may limit the device performance.

When a thyristor is triggered by a gate signal, the **turn-on** time of the device consists of two stages, a delay time $t_d$ and a rise time $t_r$, as shown in Fig. 93. The total turn-on time $t_{gt}$ is defined as the time interval between the initiation of the gate signal and the time when the resulting current through the thyristor reaches 90 per cent of its maximum value with a resistive load. The delay time $t_d$ is defined as the time interval between the 10-per-cent point of the leading edge of the gate-trigger voltage and the 10-per-cent point of the

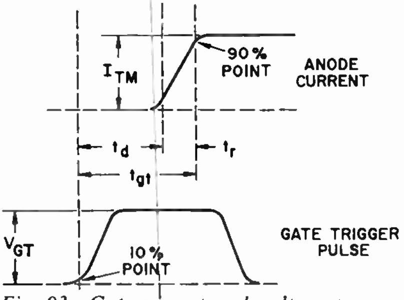



*Fig. 93—Gate-current and voltage turn-on waveforms for a thyristor.*

resulting current with a resistive load. The rise time $t_r$ is the time interval required for the principal current to rise from 10 to 90 per cent of its maximum value. The total turn-on time, therefore, is the sum of both the delay and rise times of the thyristor.

Although the turn-on time is affected to some extent by the peak OFF-state voltage and the peak ON-state current level, it is influenced primarily by the magnitude of the gate-trigger current pulse. Fig. 94 shows the variation in turn-on time with gate-trigger current for the RCA-2N3873 SCR.

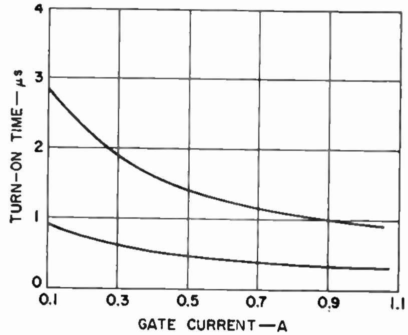



*Fig. 94—Range of turn-on time as a function of gate current for the 2N3873 SCR.*

To guarantee reliable operation and provide guidance for equipment designers in applications having short conduction periods, the voltage drop across RCA thyristors, at a given instantaneous forward current and at a specified time after turn-on from an OFF-state condition, is given in the published data. The waveshape for the initial ON-state voltage for the RCA-2N3873 SCR is shown in Fig. 95. This initial voltage, together with the time required for reduction of the dynamic forward voltage drop during the spreading time, is an indication of the current-switching capability of the thyristor.

When the entire junction area of a thyristor is not in conduction, the current through that fraction of the pellet area in conduction may result in large instantaneous power losses. These turn-on switching losses are proportional to the current and the voltage from cathode to anode of the device, together with the repetition rate of the gate-trigger pulses. The instantaneous power dissipated in a

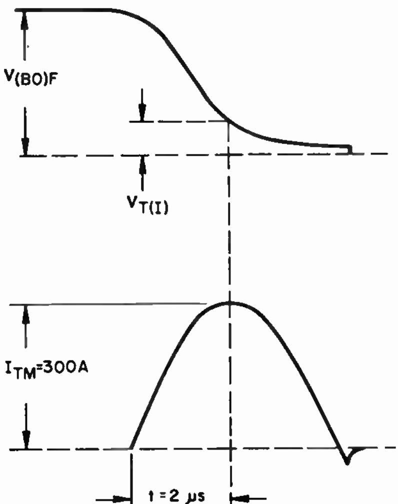



*Fig. 95—Initial on-state voltage and current waveforms for the 2N3873 SCR.*

thyristor under such conditions is shown in Fig. 96. The curves shown in this figure indicate that the peak

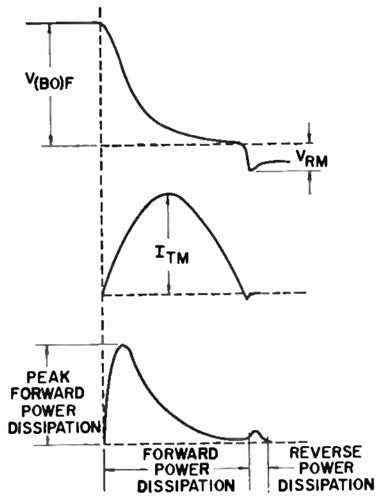



*Fig. 96—Instantaneous power dissipation in a thyristor during turn-on.*

power dissipation occurs in the short interval immediately after the device starts to conduct, usually in the first microsecond. During this time interval, the peak junction temperature may exceed the maximum operating temperature given in the manufacturer's data; in this case, the thyristor should not be required to block voltages immediately after the conduction interval. If the thyristor must block voltages immediately following the conduction interval, the junction-temperature rating must not be exceeded.

The turn-off time of an SCR also consists of two stages, a reverse-recovery time and a gate-recovery time, as shown in Fig. 97. When the

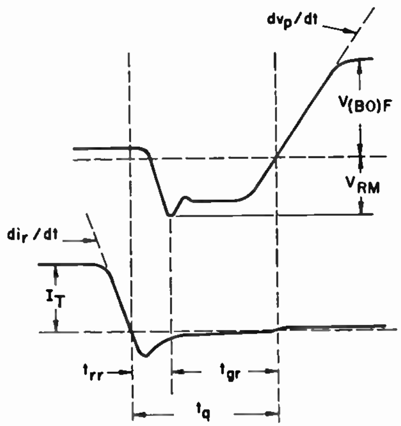



*Fig. 97—Circuit-commutated turn-off voltage and current waveforms for a thyristor.*

forward current of an SCR is reduced to zero at the end of a conduction period, application of reverse voltage between the anode and cathode terminals causes reverse current to flow in the SCR until the reverse-blocking junction establishes a depletion region. The time interval between the application of reverse voltage and the time that the reverse current passes its peak value to a steady-state level is called the reverse-recovery time $t_{rr}$. A second recovery period, called the gate-recovery time $t_{gr}$, must then elapse for the forward-blocking junction to establish a forward-depletion region so that forward-blocking voltage can be reapplied and successfully blocked by the SCR.

The gate-recovery time of an SCR is usually much longer than the reverse-recovery time. The total time from the instant reverse-recovery current begins to flow to the start of the re-applied forward-blocking voltage is referred to as the circuit commutated turn-off time $t_g$. The turn-off time is dependent upon a number of circuit parameters, including the ON-state current prior to turn-off, the rate of change of current during the forward-to-reverse transition, the reverse-blocking voltage, the rate of change of the re-applied forward voltage, the gate trigger level, the gate bias, and the junction temperature. The junction temperature and the ON-state current, however, have a more significant effect on turn-off time than any of the other factors. Because the turn-off time of an SCR depends upon a number of circuit parameters, the manufacturer's turn-off time specification is meaningful only if these critical parameters are listed and the test circuit used for the measurement is indicated.

Thyristors must be operated within the maximum ratings specified by the manufacturer to assure best results in terms of performance, life, and reliability. These ratings define limiting values, determined on the basis of extensive tests, that represent the best judgment of the manufacturer of the safe operating capability of the device.

## VOLTAGE RATINGS

The voltage ratings of thyristors are given for both steady-state and transient operation and for both forward- and reverse-blocking conditions. For SCR's, voltages are considered to be in the forward or positive direction when the anode is positive with respect to the cathode. Negative voltages for SCR's are referred to as reverse-blocking voltages. For triacs, voltages are considered to be positive when main terminal No. 2 is positive with respect to main terminal No. 1. Alternatively, this condition may be referred to as operation in the first quadrant.

### OFF-State Voltages

The repetitive peak OFF-state voltage $V_{DRM}$ is the maximum value of OFF-state voltage, either transient or steady-state, that the thyristor should be required to block under the stated conditions of temperature and gate-to-cathode resistance. If this voltage is exceeded, the thyristor may switch to the ON state. The circuit designer should insure that the $V_{DRM}$ rating is not exceeded to assure proper operation of the thyristor.

Under relaxed conditions of temperature or gate impedance, or when the blocking capability of the thyristor exceeds the specified rating, it may be found that a thyristor can block voltages far in excess of its repetitive OFF-state voltage rating $V_{DRM}$. Because the application of an excessive voltage to a thyristor may produce irreversible effects, an absolute upper limit should be imposed on the amount of voltage that may be applied to the main terminals of the device. This voltage rating is referred to as the peak OFF-state voltage $V_{DM}$. It should be noted that the peak OFF-state voltage has a single rating irrespective of the voltage grade of the thyristor. This rating is a function of the construction of the thyristor and of the surface properties of the pellet; it should not be exceeded under either continuous or transient conditions.

### Reverse Voltages (SCR's only)

Reverse voltage ratings are given for SCR's to provide operating guidance in the third quadrant, or reverse-blocking mode. There are two voltage ratings for SCR's in the reverse-blocking mode: repetitive peak reverse voltage ($V_{RRM}$) and nonrepetitive peak reverse voltage ($V_{RSM}$).

The repetitive peak reverse voltage is the maximum allowable value of reverse voltage, including all repetitive transient voltages, that may be applied to the SCR. Because reverse power dissipation is small at this voltage, the rise in junction temperature because of this reverse dissipation is very slight and is accounted for in the rating of the SCR.

The nonrepetitive peak reverse voltage is the maximum allowable value of any nonrepetitive transient reverse voltage which may be applied to the SCR. These nonrepetitive transient voltages are allowed to exceed the steady-state ratings, even though the instantaneous power dissipation can be significant. While the transient voltage is applied, the junction temperature may increase, but removal of the transient voltage in a specified time allows the junction temperature to return to its steady-state operating temperature before a thermal runaway occurs.

## ON-State Voltages

When a thyristor is in a high-conduction state, the voltage drop across the device is no different in nature from the forward-conduction voltage drop of a semiconductor diode, although the magnitude may be slightly higher. As in diodes, the ON-state voltage-drop characteristic is the major source of power losses in the operation of the thyristor, and the temperatures produced become a limiting feature in the rating of the device.

## CURRENT RATINGS

The current ratings for SCR's and triacs define maximum values for normal or repetitive currents and for surge or nonrepetitive currents. These maximum ratings are determined on the basis of the maximum junction-temperature rating, the junction-to-case thermal resistance, the internal power dissipation that results from the current flow through the thyristor, and the ambient temperature. The effect of these factors in the determination of current ratings is illustrated by the following example.

Fig. 98 shows curves of the maximum average forward power dissipation for the RCA-2N3873 SCR as a

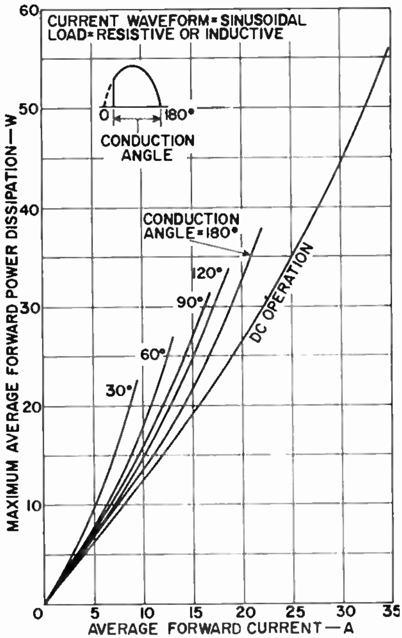



*Fig. 98—Power-dissipation rating chart for the 2N3873 SCR.*

function of average forward current for dc operation and for various conduction angles. For the 2N3873, the junction-to-case thermal resistance $\theta_{J-C}$ is 0.92°C per watt and the maximum operating junction temperature $T_J$ is 100°C. If the maximum case temperature $T_{C(max)}$ is assumed to be 65°C, the maximum average forward power dissipation can be determined as follows:

$$P_{AVG(max)} = \frac{T_{J(max)} - T_{C(max)}}{\theta_{J-C}}$$

$$= \frac{(100 - 65)\,°C}{0.92\,°C/watt}$$

$$= 38 \text{ watts}$$

The maximum average forward current rating for the specified conditions can then be determined from the rating curves shown in Fig. 98. For example, if a conduction angle of 180 degrees is assumed, the average forward current rating for a maximum dissipation of 38 watts is found to be 22 amperes.

These calculations assume that the temperature is uniform throughout the pellet and the case. The junction temperature, however, increases and decreases under conditions of transient loading or periodic currents, depending upon the instantaneous power dissipated within the thyristor. The current rating takes these variations into account.

The ON-state current ratings for a thyristor indicate the maximum values of average, rms, and peak (surge) current that should be allowed to flow through the main terminals of the device, under stated conditions, when the thyristor is in the ON state. For heat-sink-mounted thyristors, these maximum ratings are based on the case temperature; for lead-mounted thyristors, the ratings are based on the ambient temperature.

The maximum average ON-state current rating is usually specified for a half-sine-wave current at a particular frequency. Fig. 99 shows curves of the maximum allowable average ON-state current $I_{TF(avg)}$ for the RCA-2N3873 SCR family as a function of case temperature. Because peak and rms currents may be high for small conduction angles, the curves in Fig. 99 also show maximum allowable average currents as a function of conduction angle. The maximum operating junction temperature for the 2N3873 is 100°C. The rating curves indicate, for a given case temperature, the maximum average ON-state current for which the average temperature of the pellet will not exceed the maximum allowable value. The rating curves may be used for only resistive or inductive loads. When capacitive loads are used, the currents produced by the charge or discharge of the capacitor through the thyristor may be excessively high, and a resistance should be used in series with the capacitor to limit the current to the rating of the thyristor.

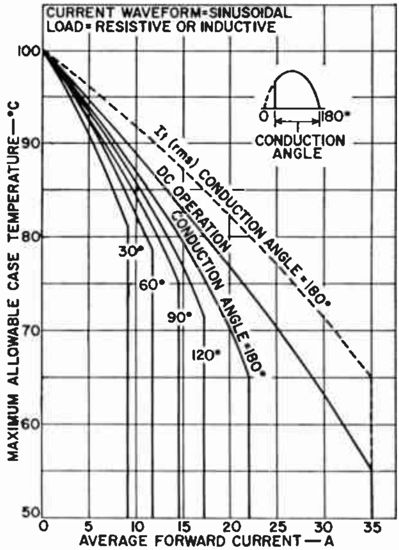



*Fig. 99—Current rating chart for the 2N3873 SCR.*

The ON-state current rating for a triac is given only in rms values because these devices normally conduct alternating current. Fig. 100 shows an rms ON-state current rating curve

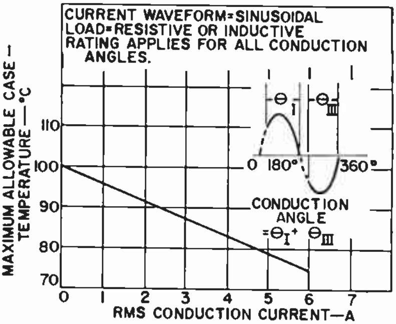



*Fig. 100—Current rating curve for a typical RCA triac.*

for a typical triac as a function of case temperature. As with the SCR, the triac curve is derated to zero current when the case temperature rises to the maximum operating junction temperature. Triac current ratings are given for full-wave conduction under resistive or inductive loads. Precautions should be taken to limit the peak current to tolerable levels when capacitive loads are used.

The surge ON-state current rating $I_{TF(surge)}$ indicates the maximum peak value of a short-duration current pulse that should be allowed to flow through a thyristor during one ON-state cycle, under stated conditions. This rating is applicable for any rated load condition. During normal operation, the junction temperature of a thyristor may rise to the maximum allowable value; if the surge occurs at this time, the maximum limit is exceeded. For this reason, a thyristor is not rated to block OFF-state voltage immediately following the occurrence of a current surge. Sufficient time must be allowed to permit the junction temperature to return to the normal operating value before gate control is restored to the thyristor. Fig. 101 shows a surge-current rating curve for the 2N3873 SCR. This curve shows peak values of half-sine-wave forward (ON-state) current as a function of overload duration measured in cycles of the 60-Hz current. Fig. 102 shows a surge-current rating curve for a typical triac. For triacs, the rating curve shows peak values for a full-sine-wave current as a function of the number of cycles of overload duration. Multicycle surge curves are the basis for the selection of circuit breakers and fuses that are used to prevent damage to the thyristor in the event of accidental short-circuit of the device. The number of surges permitted over the life of the thyristor should be limited to prevent device degradation.

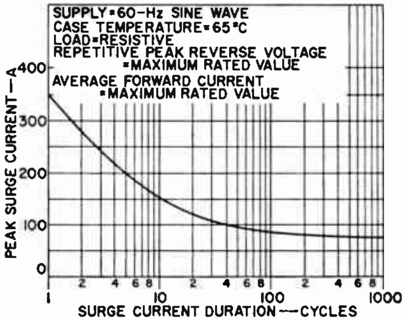



*Fig. 101—Surge-current rating curve for the 2N3873 SCR.*

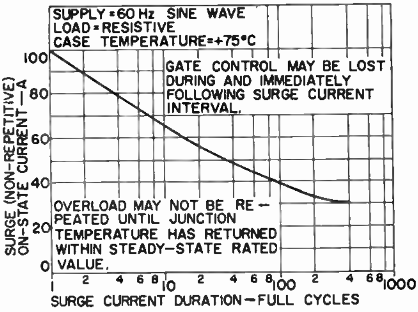



*Fig. 102—Surge-current rating curve for a typical triac.*

## CRITICAL RATE OF RISE OF ON-STATE CURRENT (di/dt)

In an SCR or triac, the load current is initially concentrated in the small area of the pellet where load current first begins to flow. This small area effectively limits the amount of current that the device can handle and results in a high voltage drop across the pellet in the first microsecond after the thyristor is triggered. If the rate of rise of current is not maintained within the rating of the thyristor, localized hot spots may occur within the pellet and permanent damage to the device may result. The waveshape for testing the di/dt capability of the RCA 2N3873 is shown in Fig. 103. The critical rate of rise of ON-state current is dependent upon the size of the cathode area that begins to conduct initially, and the size of this area is increased for larger values of gate trigger current. For this reason, the di/dt rating is specified for a specific value of gate trigger current.

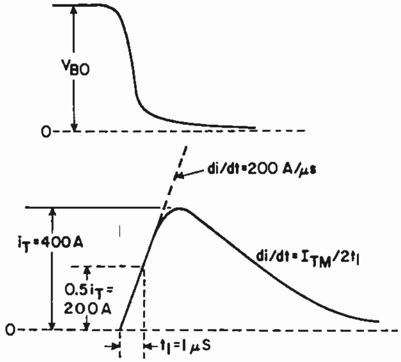



*Fig. 103—Voltage and current waveforms used to determine di/dt rating of the 2N3873 SCR.*

## HOLDING AND LATCHING CURRENTS

After an SCR or triac has been switched to the ON-state condition, a certain minimum value of anode current is required to maintain the thyristor in this low-impedance state. If the anode current is reduced below this critical holding-current value, the thyristor cannot maintain regeneration and reverts to the OFF or high-impedance state. Because the holding current ($I_H$) is sensitive to changes in temperature (increases as temperature decreases), this rating is specified at room temperature with the gate open.

The latching-current rating of a thyristor specifies a value of anode current, slightly higher than the holding current, which is the minimum amount required to sustain conduction immediately after the thyristor is switched from the OFF state to the ON state and the gate signal is removed. Once the latching current ($I_L$) is reached, the thyristor remains in the ON, or low-impedance, state until its anode current is decreased below the holding-current value. The latching-current rating is an important consideration when a thyristor is to be used with an inductive load because the inductance limits the rate of rise of the anode current. Precautions should be taken to insure that, under such conditions, the gate signal is present until the anode current rises to the latching value so that complete turn-on of the thyristor is assured.

## CRITICAL RATE OF RISE OF OFF-STATE VOLTAGE (dv/dt)

Because of the internal capacitance of a thyristor, the forward-blocking capability of the device is sensitive to the rate at which the forward voltage is applied. A steep rising voltage impressed across the main terminals of a thyristor causes a capacitive charging current to flow through the device. This charging current ($i = Cdv/dt$) is a function of the rate of rise of the OFF-state voltage.

If the rate of rise of the forward voltage exceeds a critical value, the capacitive charging current may become large enough to trigger the thyristor. The steeper the wavefront of applied forward voltage, the smaller the value of the thyristor breakover voltage becomes.

The use of the shorted-emitter construction in SCR's has resulted in a substantial increase in the dv/dt capability of these devices by providing a shunt path around the gate-to-cathode junction. Typical units can withstand rates of voltage rise up to 200 volts per microsecond under worst-case conditions. The dv/dt capability of a thyristor decreases as the temperature rises and is increased by the addition of an external resistance from gate to reference terminal. The dv/dt rating, therefore, is given for the maximum junction temperature with the gate open, i.e., for worst-case conditions.

## TRANSIENT PROTECTION

Voltage transients occur in electrical systems when some disturbance disrupts the normal operation of the system. These disturbances may be produced by various sources (such as lighting surges, energizing transformers, and load switching) and may generate voltages which exceed the rating of the thyristors. In addition, transients generally have a fast rate of rise that is usually greater than the critical value for the rate of rise of the thyristor OFF-state voltage (static dv/dt).

If transient voltages have magnitudes far greater than the device rating, the thyristor may switch from the OFF state to the ON state, and energy is then transferred from the thyristor to the load. Because the internal resistance of the thyristor is high during the OFF state, the transients may cause considerable energy to be dissipated in the thyristor before breakover occurs. In such instances, the transient voltage exceeds the maximum allowable voltage rating, and irreversible damage to the thyristor may occur.

Even if the magnitude of a transient voltage is within the maximum allowable voltage rating of the thyristor, the rate of rise of the transient may exceed the static dv/dt capability of the thyristor and cause the device to switch from the OFF state to the ON state. This condition also results in transfer of energy from the thyristor to the load. In this case, thyristor switching from the OFF state to the ON state does not occur because the maximum allowable voltage is exceeded but, instead, occurs because of the fast rate of rise of OFF-state voltage (dv/dt) and the thyristor capacitance, which result in a turn-on current $i = C dv/dt$. Thyristor switching produced in this way is free from high-energy dissipation, and turn-on is not destructive provided that the current that results from the energy transfer is within the device capability.

In either case, transient suppression techniques are employed to minimize the effects of turn-on because of overvoltage or because the thyristor dv/dt capability is exceeded.

One of the obvious solutions to insure that transients do not exceed the maximum allowable voltage rating is to provide a thyristor with a voltage rating greater than the highest transient voltage expected in a system. This technique, however, does not represent an economical solution because, in most cases, the transient magnitude, which is dependent on the source of transient generation, is not easily defined. Transient voltages as high as 2600 volts have resulted from lighting disturbances on a 120-volt residential power line. Usually, the best solution is to specify devices that can withstand voltage from 2 to 3 times the steady-state value. This technique provides a reasonable safety factor. The effects of voltage transients can further be minimized by use of external circuit elements, such as RC snubber networks across the thyristor terminals, as shown in Fig. 104. The rate at which the voltage rises at the thyristor terminal is a function of the load

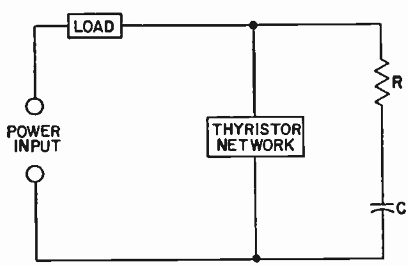



*Fig. 104—Minimizing effects of voltage transients in thyristor circuit by means of an RC snubber network.*

impedance and the values of the resistor R and the capacitor C in the snubber network. Because the load impedance is usually variable, the preferred approach is to assume a worst-case condition for the load and, through actual transient measurement, to select a value of C that provides the minimum rate of rise at the thyristor terminals. The snubber resistance should be selected to minimize the capacitor discharge currents during turn-on.

For applications in which it is necessary to minimize false turn-on because of transients, the addition of a coil in series with the load, as shown in Fig. 105, is very effective for suppression of transient rise times at the thyristor terminals. For example, if a transient of

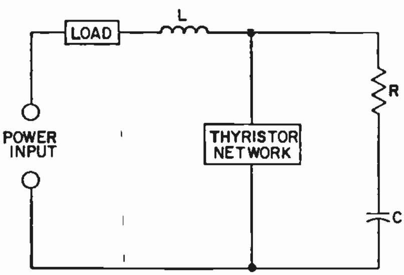



*Fig. 105—Suppression of transient rise times at the terminals of a thyristor by means of a coil in series with the load.*

infinite rise time is assumed to occur at the input terminals and if the effects of the load impedance are neglected, the rise time of the transient at the thyristor terminals is approximately equal to $E_{pk}/\sqrt{LC}$. If the value of the added inductor L is 100 microhenries and the value of the snubber capacitor C is 0.1 microfarad, the infinite rate of rise of the transient at the thyristor terminals is reduced by a factor of 3. For a filter network consisting of L = 100 microhenries, C = 22 microfarads, and R = 47 ohms, a 1000-volt-per-microsecond transient that appears at the input terminals is suppressed by a factor of 6 at the thyristor terminals.

## COMMUTATING dv/dt CAPABILITY

In ac power-control applications, a triac must switch from the conducting state to the blocking state at each zero-current point, or twice each cycle, of the applied ac power. This action is called commutation. If the triac fails to block the circuit voltage (turn off) following the zero-current point, this action is not damaging to the triac, but control of the load power is lost. Commutation for resistive loading presents no special problems because the voltage and current are essentially in phase. For inductive loading, however, the current lags the voltage so that, following the zero-current point, an applied voltage opposite to the current and equal to the peak of the ac line voltage occurs across the thyristor. The maximum rate of rise of this voltage which can be blocked without the triac reverting to the ON state is termed the critical rate of rise of commutation voltage, or the commutating dv/dt capability, of the triac.

SCR's do not experience commutation limitations because turn-on is not possible for the polarity of voltage opposite to current flow.

The commutating dv/dt is a major operating characteristic used to describe the performance capability of a triac. The characteristic can be more easily understood if the triac pellet, shown in Fig. 106, is considered to be divided into two halves.

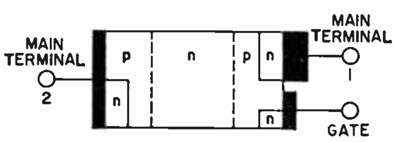



*Fig. 106—Junction diagram for a triac pellet.*

One half conducts current in one direction, the other half conducts in the opposite direction. The main blocking junctions and a lightly doped n-type base region in which charge can be stored are common to both halves of the triac pellet. (The base region is the section shown between the dotted lines in Fig. 106.)

Charge is stored in the base when current is conducted in either direction. The amount of charge stored at the end of each half-cycle of conduction depends on the commutating di/dt, i.e., the rate of decrease of load current as commutation is approached. The junction capacitance of the triac at commutation is a function of the remaining charge at that time. The greater the di/dt, the more remaining charge, and the greater the junction capacitance. When the voltage changes direction, the remaining charge diffuses into the opposite half of the triac structure. The rate of rise of this voltage (commutating dv/dt) in conjunction with the junction capacitance results in a current flow which, if large enough, can cause the triac to revert to the conducting state in the absence of a gate signal.

The commutating dv/dt capability is specified in volts per microsecond for the following conditions:

1. the maximum rated on-state current [$I_T$(RMS)];
2. the maximum case temperature for the rated value of on-state current;
3. the maximum rated off-state voltage ($V_{DROM}$);
4. the maximum commutating di/dt (where di/dt $= I_{pk} \sin \omega t$ and $\omega = 2\pi f$).

It is apparent, therefore, that the frequency (f) of the applied ac power is an important factor in determination of the commutating dv/dt capability of a triac.

Fig. 107 indicates how the commutating dv/dt capability of a triac depends on current and frequency. A particular triac has a specific commutating dv/dt capability at the rated 60-Hz on-state current. If this 60-Hz on-state current is reduced (dashed-line), then its associated commutating dv/dt capability is increased. It should be noted that although the sine-wave current is decreased in magnitude, the commutating di/dt is also decreased. For a 400-Hz on-state current of the same magnitude, it is evident that the commutating di/dt is much greater than at 60 Hz and, therefore, the commutating dv/dt capability is greatly reduced. These relationships indicate that a triac capable of 400-Hz operation must have an extremely high commutating capability.

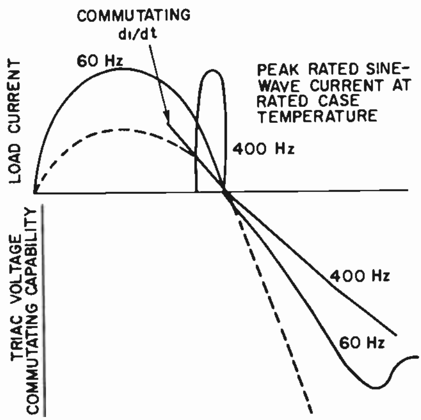



*Fig. 107—Dependence of triac commutating capability on current and frequency.*

RCA offers a complete line of triacs rated for 400-Hz operation. Applications of such devices are described in the section on Power Switching and Control.

It should be evident that 400 Hz is not an upper limit on frequency capability for triacs; 400 Hz is a characterization point simply because it is a standard operating frequency. Figs. 108 and 109 indicate how the frequency capability of a typical RCA 400-Hz triac can be increased. Fig. 108 shows that reduction of load current increases frequency capability. Maximum rated junction temperature and minimum rated commutating dv/dt are held constant for this test of capability. Fig. 109 shows the effects of junction temperature on frequency capability. For this test, rated current and minimum rated dv/dt are held constant. Therefore, if a typical

400-Hz triac is used at less than its maximum rated junction temperature and less than its rated current, its frequency capability is greatly enhanced.

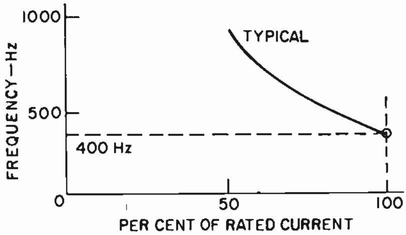



*Fig. 108—Frequency capability of a 400-Hz triac as a function of load current.*

One other factor that greatly affects commutating capability is temperature. All commutating characteristic data are specified for maximum operating case temperature at maximum rated steady-state current. If the operating case temperature is below the rated value, the commutating capability is increased.

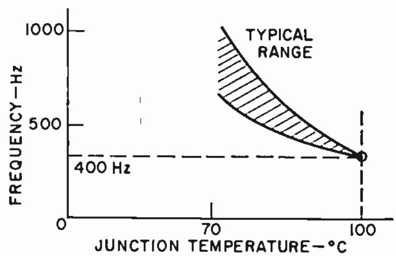



*Fig. 109—Frequency capability of a 400-Hz triac as a function of junction temperature.*

## RADIO-FREQUENCY INTERFERENCE

The fast switching action of triacs when they turn on into resistive loads causes the current to rise to the instantaneous value determined by the load in a very short period of time. Triacs switch from the high- to the low-impedance state within 1 or 2 microseconds; the current must rise from essentially zero to full-load value during this period. This fast switching action produces a current step which is largely composed of higher-harmonic frequencies of several megahertz that have an amplitude varying inversely as the frequency. In phase-control applications, such as light dimming, this current step is produced on each half-cycle of the input voltage. Because the switching occurs many times a second, a noise pulse is generated into frequency-sensitive devices such as AM radios and causes annoying interference. The amplitude of the higher frequencies in the current step is of such low levels that they do not interfere with television or FM radio. In general, the level of radio-frequency interference (RFI) produced by the triac is well below that produced by most ac/dc brush-type electric motors; however, some type of RFI suppression network is usually added.

There are two basic types of radio-frequency interference (RFI) associated with the switching action of triacs. One form, radiated RFI, consists of the high-frequency energy radiated through the air from the equipment. In most cases, this radiated RFI is insignificant unless the radio is located very close to the source of the radiation.

Of more significance is conducted RFI which is carried through the power lines and affects equipment attached to the same power lines. Because the composition of the current waveshape consists of higher frequencies, a simple choke placed in series with the load increases the current rise time and reduces the amplitude of the higher harmonics. To be effective, however, such a choke must be quite large. A more effective filter, and one that has been found adequate for most light-dimming applications, is shown in Fig. 110. The LC filter provides adequate attenuation of the high-frequency harmonics and reduces

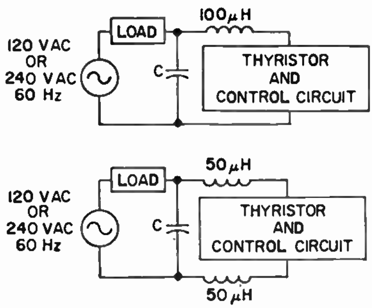



*Fig. 110—RFI-suppression networks (C = 0.1 μF, 200 V at 120 V ac; 0.1 μF, 400 V at 240 V ac).*

the noise interference to a low level. The capacitor connected across the entire network bypasses high-frequency signals so that they are not connected to any external circuits through the power lines.

Fig. 111 shows a triac control circuit that includes RFI suppression for the purpose of minimizing high-frequency interference. The values indicated are typical of those used in lamp-dimmer circuits.

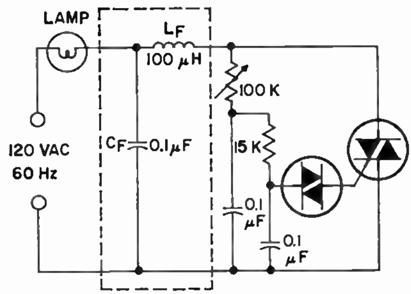



*Fig. 111—Lamp-control circuit incorporating RFI suppression.*

# Silicon Rectifiers

SILICON rectifiers are essentially cells containing a simple p-n junction. As a result, they have low resistance to current flow in one (forward) direction, but high resistance to current flow in the opposite (reverse) direction. They can be operated at ambient temperatures up to 200°C and at current levels as high as hundreds of amperes, with voltage levels greater than 1000 volts. In addition, they can be used in parallel or series arrangements to provide higher current or voltage capabilities.

Because of their high forward-to-reverse current ratios, silicon rectifiers can achieve rectification efficiencies greater than 99 per cent. When properly used, they have excellent life characteristics which are not affected by aging, moisture, or temperature. They are very small and light-weight, and can be made impervious to shock and other severe environmental conditions.

## THERMAL CONSIDERATIONS

Although rectifiers can operate at high temperatures, the thermal capacity of a silicon rectifier is quite low, and the junction temperature rises rapidly during high-current operation. Sudden rises in junction temperature caused by either high currents or excessive ambient-temperature conditions can cause failure. (A silicon rectifier is considered to have failed when either the forward voltage drop or the reverse current has increased to a point where the crystal structure or surrounding material breaks down.) Consequently, temperature effects are very important in the consideration of silicon rectifier characteristics.

## REVERSE CHARACTERISTICS

When a reverse-bias voltage is applied to a silicon rectifier, a limited amount of reverse current (usually measured in microamperes, as compared to milliamperes or amperes of forward current) begins to flow. As shown in Fig. 112, this reverse current flow increases slightly as the bias voltage increases, but then tends

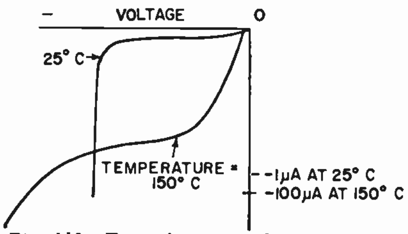



*Fig. 112—Typical reverse characteristics in a silicon rectifier.*

to remain constant even though the voltage continues to increase significantly. However, an increase in operating temperature increases the reverse current considerably for a given reverse bias.

At a specific reverse voltage (which varies for different types of diodes), a very sharp increase in reverse current occurs. This voltage is called the breakdown or avalanche (or zener) voltage. In many applications, rectifiers can operate safely at the avalanche point. If the reverse voltage is increased beyond this point, however, or if the ambient temperature is raised sufficiently (for example, a rise from 25 to 150°C increases the current by a factor of several hundred), "thermal runaway" results and the diode may be destroyed.

## FORWARD CHARACTERISTICS

A silicon rectifier usually requires a forward voltage of 0.4 to 0.8 volt (depending upon the temperature and the impurity concentration in the p-type and n-type materials) before significant current flow occurs. As shown in Fig. 113, a slight rise in voltage beyond this point increases the forward current sharply. Because of the small mass of the silicon rectifier, the forward voltage drop must be carefully controlled so that the specified maximum value of dissipation for the device is not exceeded. Otherwise, the diode may be seriously damaged or destroyed.

Fig. 113 shows the effects of an increase in temperature on the forward-current characteristic of a silicon

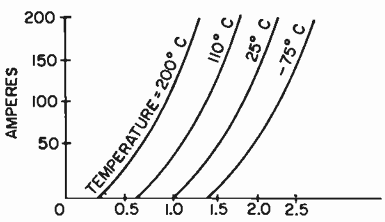



*Fig. 113—Typical forward characteristics in a silicon rectifier.*

rectifier. In certain applications, close control of ambient temperature is required for satisfactory operation. Close control is not usually required, however, in power circuits.

## RATINGS

Ratings for silicon rectifiers are determined by the manufacturer on the basis of extensive reliability testing. One of the most important ratings is the maximum peak reverse voltage (PRV), i.e., the highest amount of reverse voltage which can be applied to a specific rectifier before the avalanche breakdown point is reached. PRV ratings range from about 50 volts to as high as 1000 volts for some single-junction diodes. As will be discussed later, several junction diodes can be connected in series to obtain the PRV values required for very-high-voltage power-supply applications.

Because the current through a rectifier is normally not dc, current ratings are usually given in terms of average, rms, and peak values. The waveshapes shown in Fig. 114 and 115 help to illustrate the relationships among these ratings. For example, Fig. 114 shows the current variation with time of a sine wave

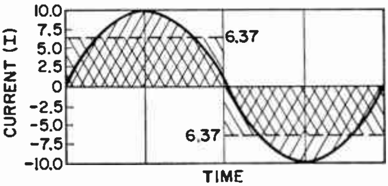



*Fig. 114—Variation of current of a sine wave with time.*

that has a peak current $I_{peak}$ of 10 amperes. The area under the curve can be translated mathematically into an equivalent rectangle that indicates the average value $I_{av}$ of the sine wave. The relationship between the average and peak values of the total sine-wave current is then given by

$$I_{av} = 0.637\ I_{peak}$$

or

$$I_{peak} = 1.57\ I_{av}$$

However, the power P consumed by a device (and thus the heat generated within it) is equal to the square of the current through it times its finite electrical resistance R (i.e., $P = I^2R$). Therefore, the power is proportional to the square of the current rather than to the peak or average value. Fig. 115 shows the square of the current for the sine wave of Fig. 114. A horizontal line drawn through a point halfway up the $I^2$ curve indicates the average (or mean) of the squares, and the square root of the $I^2$ value

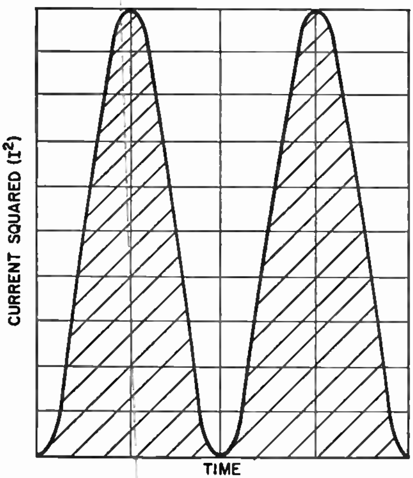


*Fig. 115—Variation of the square of sine-wave current with time.*

at this point is the root-mean-square (rms) value of the current. The relationship between rms and peak current is given by

$$I_{rms} = 0.707\ I_{peak}$$

or

$$I_{peak} = 1.414\ I_{rms}$$

Because a single rectifier cell passes current in one direction only, it conducts for only half of each cycle of an ac sine wave. Therefore, the second half of the curves in Figs. 114 and 115 is eliminated. The average current $I_{av}$ then becomes half of the value determined for full-cycle conduction, and the rms current $I_{rms}$ is equal to the square root of half the mean-square value for full-cycle conduction. In terms of half-cycle sine-wave conduction (as in a single-phase half-wave circuit), the relationships of the rectifier currents can be shown as follows:

$$I_{peak} = \pi \times I_{av} = 3.14\ I_{av}$$
$$I_{av} = (1/\pi)\ I_{peak} = 0.32\ I_{peak}$$
$$I_{rms} = (\pi/2)\ I_{av} = 1.57\ I_{av}$$
$$I_{av} = (2/\pi)\ I_{rms} = 0.64\ I_{rms}$$
$$I_{peak} = 2\ I_{rms}$$
$$I_{rms} = 0.5\ I_{peak}$$

For different combinations of rectifier cells and different circuit configurations, these relationships are, of course, changed again. Current (and voltage) relationships have been derived for various types of rectifier applications and are given in the section on DC Power Supplies.

Published data for silicon rectifiers usually include maximum ratings for both average and peak forward current. As shown in Fig. 116, the **maximum average forward current** is the maximum average value of current which is allowed to flow in the forward direction during a full ac cycle at a specified ambient or case temperature. Typical average current outputs range from 0.5 ampere to as high as 100 amperes for single silicon diodes. The **peak recurrent forward current** is the maximum repetitive instantaneous forward current permitted under stated conditions.

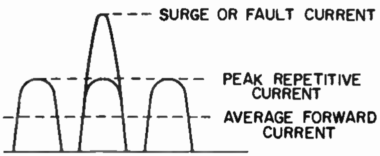


*Fig. 116—Representation of rectifier currents.*

In addition, ratings are usually given for non-repetitive surge, or fault, current. In rectifier applications, conditions may develop which cause momentary currents that are considerably higher than normal operating current. These increases (current surges) may occur from time to time during normal circuit operation as a result of normal load variations, or they may be caused by abnormal conditions or faults in the circuit. Although a rectifier can usually absorb a limited amount of additional heat without any effects other than a momentary rise in junction temperature, a sufficiently high surge can drive the junction temperature high enough to destroy the rectifier. Surge ratings indicate the amount of current overload or surge that the rectifier can withstand without detrimental effects.

Fig. 117 shows universal surge

rating charts for families of rectifiers having average current ratings up to 40 amperes. The rms currents shown in these charts are incremental values which add to the normal rms forward current during surge periods. The charts indicate maximum current increments that can be safely handled by the rectifiers for given lengths of time. These charts can be used by designers to determine whether circuit modifications are necessary to protect the rectifiers. If the value and duration of expected current surges are greater than the ratings for the rectifier, impedance should be added to capacitive-load circuits or fuses or circuit breakers to variable-load circuits for surge protection.

The fusing requirements for a given circuit can be determined by use of a coordination chart such as that shown in Fig. 118. Two characteristics are plotted on the coordination chart initially: (A) the surge rating curve for the rectifier, and

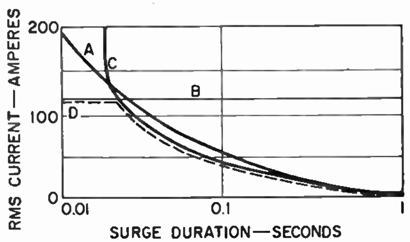


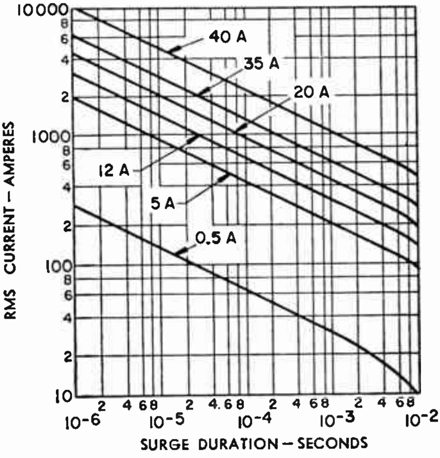

*Fig. 118—Typical coordination chart for determining fusing requirements (A = surge-rating chart for 20-ampere rectifier; B = expected surge current in half-wave circuit; C = opening characteristics of protective device; D = resulting surge current in modified circuit).*

(B) the maximum surge (fault current) expected in the circuit. In Fig. 118, curve A is the surge rating curve for a 20-ampere rectifier, and curve B is the maximum surge expected to occur in a single-phase half-wave rectifier circuit that has an input voltage of 600 volts and is subject to overload conditions in which the load resistance can decrease to 2 ohms. The maximum rms current which can flow under these conditions is given by

$$I_{rms} = E_{in}/2R_L = 600/4$$
$$= 150 \text{ amperes}$$

The incremental portion of this current is determined by subtracting the normal rms current of the 20-ampere rectifier ($I_{rms} = 1.57\ I_{av} = 1.57 \times 20 = 31.4$ amperes; $I_{surge} = 150 - 31.4 = 118.6$ amperes). The straight line of curve B is then drawn at an rms value of 118.6 amperes in Fig 118.

The intersection of curves A and B indicates that the 20-ampere rectifier can safely support an incremental rms surge current of 118.6 amperes for a maximum duration of about 40 milliseconds. Therefore, the circuit must be modified to include a protective element that has an



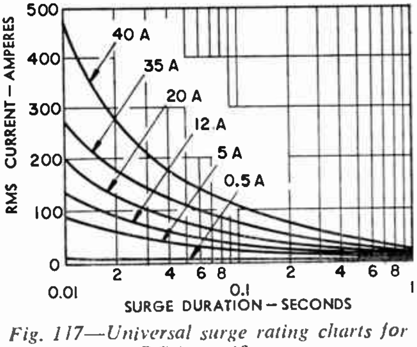




*Fig. 117—Universal surge rating charts for RCA rectifiers.*

"opening" characteristic that falls below the rectifier surge rating curve for all times greater than 40 milliseconds. The opening characteristic of such a protective element is shown in Fig. 118 as curve C. Surge current in the modified circuit is then limited by the circuit resistance for periods up to 40 milliseconds and by the protective element for surges of longer duration, as shown by curve D.

Surge currents generally occur when the equipment is first turned on, or when unusual voltage transients are introduced in the ac supply line. Protection against excessive currents of this type can be provided in various ways, as will be discussed later.

Because these maximum current ratings are all affected by thermal variations, ambient-temperature conditions must be considered in the application of silicon rectifiers. Temperature-rating charts are usually provided to show the percentage by which maximum currents must be decreased for operation at temperatures higher than normal room temperature (25°C).

## OVERLOAD PROTECTION

In the application of silicon rectifiers, it is necessary to guard against both over-voltage and over-current (surge) conditions. A voltage surge in a rectifier arrangement can be caused by dc switching, reverse recovery transients, transformer switching, inductive-load switching, and various other causes. The effects of such surges can be reduced by the use of a capacitor connected across the input or the output of the rectifier. In addition, the magnitude of the voltage surge can be reduced by changes in the switching elements or the sequence of switching, or by a reduction in the speed of current interruption by the switching elements.

In all applications, a rectifier having a more-than-adequate peak reverse voltage rating should be used. The safety margin for reverse voltage usually depends on the application. For a single-phase half-wave application using switching of the transformer primary and having no transient suppression, a rectifier having a peak reverse voltage three or four times the expected working voltage should be used. For a full-wave bridge using load switching and having adequate suppression of transients, a margin of 1.5 to 1 is generally acceptable.

Because of the small size of the silicon rectifier, excessive surge currents are particularly harmful to rectifier operation. Current surges may be caused by short circuits, capacitor inrush, dc overload, or failure of a single cell in a multiple arrangement. In the case of low-power cells, fuses or circuit breakers are often placed in the ac input circuit to the rectifier to interrupt the fault current before it damages the rectifier. When circuit requirements are such that service must be continued in case of failure of an individual diode, a number of cells can be used in parallel, each with its own fuse. Additional fuses should be used in the ac line and in series with the load for protection against dc load faults. In high-power cells, an arrangement of circuit breakers, fuses, and series resistances is often used to reduce the amplitude of the surge current. Fusing requirements can be determined by use of coordination charts for the particular circuits and rectifiers used.

## SERIES AND PARALLEL ARRANGEMENTS

Silicon rectifiers can be arranged in series or in parallel to provide higher voltage or current capabilities, respectively, as required for specific applications.

A parallel arrangement of rectifiers can be used when the maximum average forward current required is larger than the maximum current rating of an individual rectifier cell. In such arrangements, however, some means must be provided to assure proper division of current through the parallel rectifier cells. Parallel rectifier arrangements are not in general use. Designers normally use a polyphase arrangement to provide higher currents, or simply substitute the readily available higher-current rectifier types.

Series arrangements of silicon rectifiers are used when the applied reverse voltage is expected to be greater than the maximum peak reverse voltage rating of a single silicon rectifier (or cell). For example, four rectifiers having a maximum reverse voltage rating of 200 volts each could be connected in series to handle an applied reverse voltage of 800 volts.

In a series arrangement, the most important consideration is that the applied voltage be divided equally across the individual rectifiers. If the instantaneous voltage is not uniformly divided, one of the rectifiers may be subjected to a voltage greater than its specified maximum reverse voltage, and, as a result, may be destroyed. Uniform voltage division can usually be assured by connection of either resistors or capacitors in parallel with individual cells. Shunt resistors are used in steady-state applications, and shunt capacitors in applications in which transient voltages are expected. Both resistors and capacitors should be used if the circuit is to be exposed to both dc and ac components. When only a few diodes are in series, multiple transformer windings may be used, each winding supplying its own assembly consisting of one series diode. The outputs of the diodes are then connected in series for the desired voltage.

RCA rectifier stacks (CR101, CR201, and CR301 series) are designed to provide equal reverse voltage across the individual rectifier cells in the assembly under both steady-state and transient conditions. The CR101 and CR301 series stacks include an integral resistance-capacitance network to equalize the reverse voltage across the series-connected rectifier cells. The CR201 series stacks use precisely matched rectifier cells for internal voltage equalization. Extended life tests have shown that these rectifier stacks are capable of operating for many thousands of hours without noticeable degradation of performance.

# Other Solid-State Diodes

IN addition to the silicon rectifiers described in the preceding section, a number of other types of solid-state diode devices are available for use in a broad variety of circuit applications. For example, low-level rectifying diodes are widely used in signal-mixing, detector, and balanced-modulator applications. Such diodes, although they have significantly lower voltage and current ratings, operate essentially the same as the silicon rectifiers and are not discussed further. The emphasis in this section is on specialized types (i.e., tunnel, varactor, voltage-reference, and compensating diodes) that are used primarily to provide functions other than rectification.

## TUNNEL DIODES

A tunnel diode is a small p-n junction device having a very high concentration of impurities in the p-type and n-type semiconductor materials. This high impurity density makes the junction depletion region (or space-charge region) so narrow that electrical charges can transfer across the junction by a quantum-mechanical action called "tunneling." This tunneling effect provides a negative-resistance region on the characteristic curve of the device that makes it possible to achieve amplification, pulse generation, and rf-energy generation.

### Characteristics

Typical current-voltage characteristics for a tunnel diode are shown in Fig. 119. Conventional diodes do not conduct current under conditions of reverse bias until the breakdown voltage is reached; under forward bias they begin to conduct at approximately 300 millivolts. In tunnel diodes, however, a small reverse bias

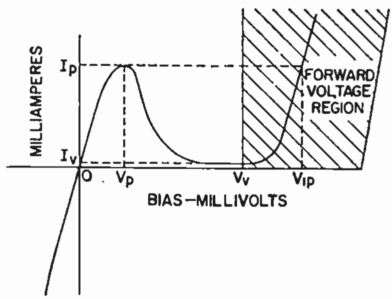



*Fig. 119—Typical current-voltage characteristic of a tunnel diode.*

causes the valence electrons of semiconductor atoms near the junction to "tunnel" across the junction from the p-type region into the n-type region; as a result, the tunnel diode is highly conductive for all reverse biases. Similarly, under conditions of small forward bias, the electrons in the n-type region "tunnel" across the junction to the p-type region and the tunnel-diode current rises rapidly to a sharp maximum peak $I_p$. At intermediate values of forward bias, the tunnel diode exhibits a negative-resistance characteristic and the current drops to a deep minimum valley point $I_v$. At higher values of forward bias, the tunnel diode exhibits the diode characteristic associated with conventional semiconductor current flow. The decreasing current with increasing forward bias in the negative-resistance region of the characteristic provides the tunnel diode with its ability to amplify, oscillate, and switch.

## Equivalent Circuit

In the equivalent circuit for a tunnel diode shown in Fig. 120, the n-type and p-type regions are shown as

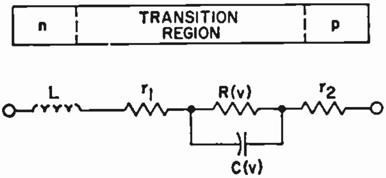



*Fig. 120—Equivalent circuit for a tunnel diode.*

pure resistances $r_1$ and $r_2$. The transition region is represented as a voltage-sensitive resistance R(v) in parallel with a voltage-sensitive capacitance C(v) because tunneling is a function of both voltage and junction capacitance. This capacitance is similar to that of a parallel-plate capacitor having plates separated by the transition region.

The dashed portion L in Fig. 120 represents an inductance which results from the case and mounting of the tunnel diode. This inductance is unimportant for low-frequency diodes, but becomes increasingly important at high frequencies (above 100 MHz).

Fig. 121 shows the form of the equivalent circuit when the diode is biased so that its operating point is in the negative-resistance region; dynamic characteristics of tunnel diodes are defined with respect to this circuit. $L_S$ represents the total series inductance, and $R_S$ the total series resistance. $C_D$ is the capacitance and $-R_D$ is the negative resistance of the diode. For small signal variations, both the resistance $R_D$ and the capacitance $C_D$ are constant.

The figure of merit F of a tunnel diode is equal to the reciprocal of $2\pi RC$, where R and C are the equivalent values $-R_D$ and $C_D$, respectively, shown in Fig. 121. This expression has two very useful interpretations:

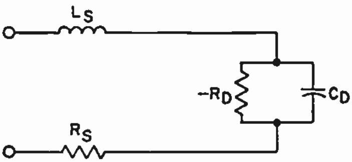



*Fig. 121—Equivalent circuit for a tunnel diode biased in the negative-resistance region.*

(1) it is the diode gain-bandwidth product for circuits operating in the linear negative-resistance region of the characteristic, and (2) its reciprocal is the diode switching time when the device is used as a logic element.

## Operating Point

When the tunnel diode is used in circuits such as amplifiers and oscillators, the operating point must be established in the negative-resistance region. The dc load line, shown as a solid line in Fig. 122, must be very steep so that it intersects the static characteristic curve at only one point A. The ac load line can be either steep with only one intersection B, as in the case of an amplifier, or relatively flat with three intersections C, D, and E, as in the case of an oscillator. The location of the operating point is determined by the anticipated signal swing, the required signal-to-noise ratio, and the operating temperature of the device. Biasing at the center of the linear portion

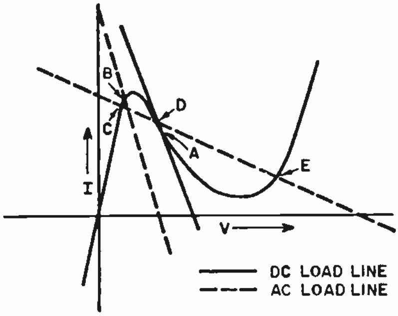



*Fig. 122—Typical load lines for tunnel-diode circuits.*

of the negative-resistance slope permits the greatest signal swing. For high-temperature operation, a higher operating current is chosen; for low noise, the device is operated at the lowest possible bias current.

### Radiation and Thermal Considerations

One of the most important features of the tunnel diode is its resistance to nuclear radiation. Experimental results have shown tunnel diodes to be at least ten times more resistant to radiation than transistors. Because the resistivity of tunnel diodes is so low initially, it is not critically affected by radiation until large doses have been applied. In addition, tunnel diodes are less affected by ionizing radiation because they are relatively insensitive to surface changes produced by such radiation.

In general, the tunnel-diode voltage-current characteristic is relatively independent of temperature. Specific tunnel-diode applications may be affected, however, by the relative temperature dependence of the various circuit components. In such applications, negative feedback or direct (circuit) compensation may be required.

## TUNNEL RECTIFIERS

In addition to its negative-resistance properties, the tunnel diode has an efficient rectification characteristic which can be used in many rectifier applications. When a tunnel diode is used in a circuit in such a way that this rectification property is emphasized rather than its negative-resistance characteristic, it is called a tunnel rectifier. In general, the peak current for a tunnel rectifier is less than one milliampere.

The major differences in the current-voltage characteristics of tunnel rectifiers and conventional rectifiers are shown in Fig. 123. In conventional rectifiers, current flow is substantial in the forward direction, but extremely small in the reverse direction (for signal voltages less than the breakdown voltage for the device). In tunnel rectifiers, however, substantial reverse current flows at very low voltages, while forward current is relatively small. Consequently, tunnel rectifiers can provide rectification at smaller signal voltages than conventional rectifiers, although their polarity requirements are opposite. (For this reason, tunnel rectifiers are sometimes called "back diodes.")

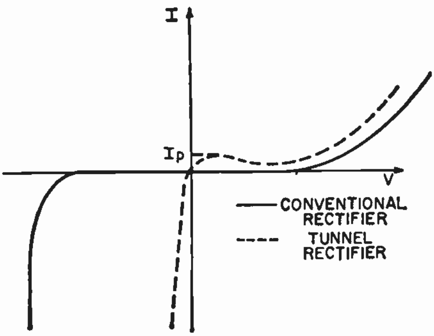



*Fig. 123—Current-voltage characteristics of tunnel rectifier and conventional rectifier.*

Because of their high-speed capability and superior rectification characteristics, tunnel rectifiers can be used to provide coupling in one direction and isolation in the opposite direction. Fig. 124 shows the use of tunnel rectifiers to provide directional coupling in a tunnel-diode logic circuit.

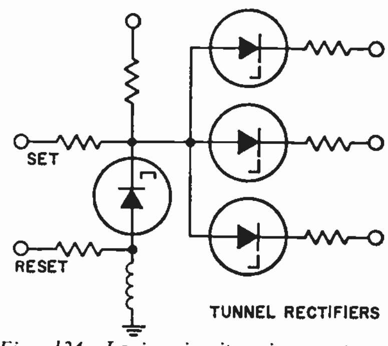



*Fig. 124—Logic circuit using a tunnel diode and three tunnel rectifiers.*

## VARACTOR DIODES

A varactor or variable-reactance diode is a microwave-frequency p-n junction solid-state device in which the depletion-layer capacitance bears a nonlinear relation to the junction voltage, as shown in Fig. 125(a). When biased in the reverse direction, a varactor diode can be represented by a voltage-sensitive capacitance C(v) in series with a resistance $R_s$, as shown in Fig. 125(b). This nonlinear capacitance and low series resistance, which permit the device to perform frequency-multiplication, oscillation, and switching functions, result from a very high impurity concentration outside the depletion-layer region and a relatively low concentration at the junction. Very low noise levels are possible in circuits using varactor diodes because the dominant current across the junction is reactive and shot-noise components are absent.

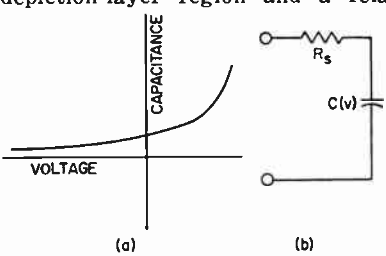



*Fig. 125—(a) Capacitance-voltage relation and (b) equivalent circuit for a varactor diode.*

Reactive nonlinearity, without an appreciable series resistance component, enables varactor diodes to generate harmonics with very high efficiency in circuits such as the shunt-type frequency multiplier shown in Fig. 126. The circuit is driven by a sinusoidal voltage source $V_s$ having a fundamental frequency f and an internal impedance $Z_s$. Because the ideal input filter is an open circuit for all frequencies except the fundamental frequency, only the fundamental component of current $i_f$ can flow in the input loop. A second-harmonic current $i_{2f}$ is generated by the varactor diode and flows toward the load $Z_L$; another ideal filter is used in the output loop to block the fundamental-frequency component of the input current.

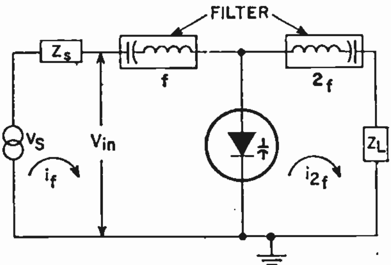



*Fig. 126—Varactor-diode frequency multiplier*

Varactor diodes can amplify signals when their voltage-dependent capacitance is modulated by an alternating voltage at a different frequency. This alternating voltage supply, which is often referred to as the "pump", adds energy to the signal by changing the diode capacitance in a specific phase relation with the stored signal charge so that potential energy is added to this charge. An "idler" circuit is generally used to provide the proper phase relationship between the signal and the "pump."

## VOLTAGE-REFERENCE DIODES

Voltage-reference or zener diodes are silicon rectifiers in which the reverse current remains small until the breakdown voltage is reached and then increases rapidly with little further increase in voltage. The breakdown voltage is a function of the diode material and construction, and can be varied from one volt to several hundred volts for various current and power ratings, depending on the junction area and the method of cooling. A stabilized supply can deliver a constant output (voltage or current) unaffected by temperature, output load, or input voltage, within given limits. The stability provided by voltage-reference diodes makes them useful as stabilizing devices and as reference sources capable of supplying extremely constant current loads.

## COMPENSATING DIODES

Excellent stabilization of collector current for variations in both supply voltage and temperature can be obtained by the use of a compensating diode operating in the forward direction in the bias network of amplifier or oscillator circuits. Fig. 127 shows the transfer characteristics of a transistor; Fig. 128 shows the forward characteristics of a compensating diode. In a typical circuit, the diode is biased in the forward direction; the operating point is represented on the diode characteristics by the dashed horizontal line. The diode current at this point determines a bias voltage which establishes the transistor idling current. This bias voltage shifts with varying temperature in the same direction and magnitude as the transistor characteristic, and thus provides an idling current that is essentially independent of temperature.

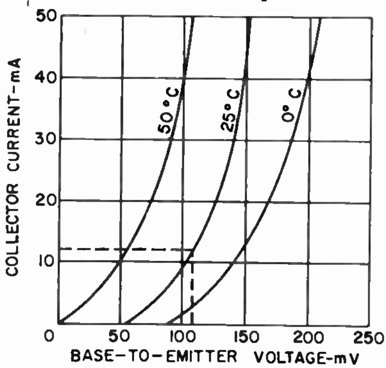


*Fig. 127—Transfer characteristics of transistor.*

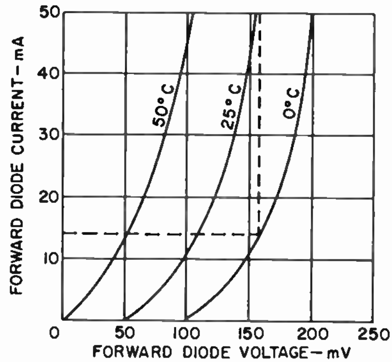


*Fig. 128—Forward characteristics of compensating diode.*

The use of a compensating diode also reduces the variation in transistor idling current as a result of supply-voltage variations. Because the diode current changes in proportion with the supply voltage, the bias voltage to the transistor changes in the same proportion and idling-current changes are minimized. (The use of diode compensation is discussed in more detail under "Biasing" in the section on Bipolar Transistors.

# Receiver Tuner-Circuit Applications

WHEN speech, music, or video information is transmitted from a radio or television station, the station radiates a modulated radio-frequency (rf) carrier. The function of a radio or television receiver is simply to reproduce the modulating wave from the modulated carrier.

As shown in Fig. 129, a superheterodyne radio receiver picks up the transmitted modulated rf signal, amplifies it and converts it to a modulated intermediate-frequency (if) signal, amplifies the modulated if signal, separates the modulating signal from the basic carrier wave, and amplifies the resulting audio signal to a level sufficient to produce the desired volume in a speaker. In addition, the receiver usually includes some means of producing automatic gain control (agc) of the modulated signal before the audio information is separated from the carrier.

The transmitted rf signal picked up by the radio receiver may contain either amplitude modulation (AM) or frequency modulation (FM). (These modulation techniques are described later under the heading Detection.) In either case, amplification prior to the detector stage is performed by tuned amplifier circuits designed for the proper frequency and bandwidth. Frequency conversion is performed by mixer and oscillator circuits or by a single converter stage which performs both mixer and oscillator functions. Separation of the modulating signal is normally accomplished by one or more diodes in a detector or discriminator circuit. Amplification of the audio signal is then performed by one or more audio amplifier stages. (Audio amplifiers are discussed in the section on Low-Frequency Amplification.)

The operation of a television receiver (shown in block-diagram form in Fig. 130) is more complex

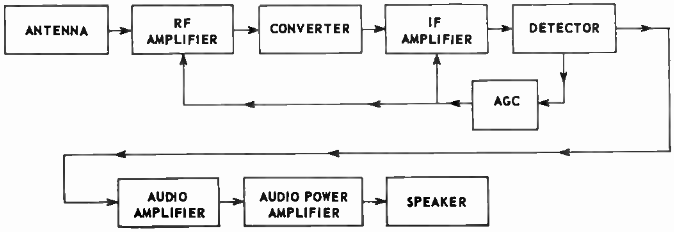



*Fig. 129—Simplified block diagram for a broadcast-band receiver.*

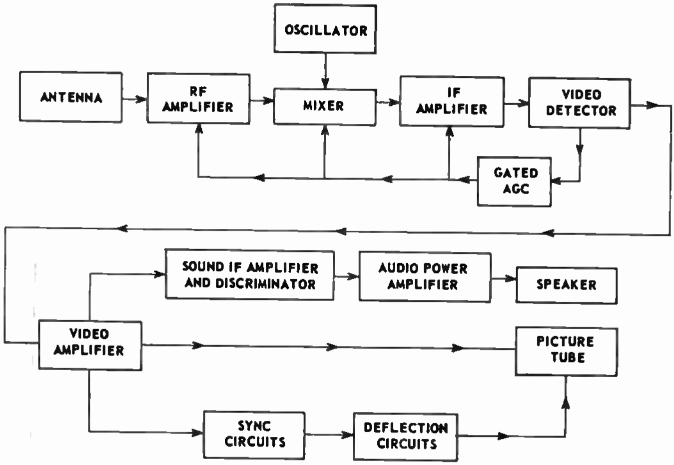



*Fig. 130—Simplified block diagram for a television receiver.*

than that of a radio receiver, as shown by a comparison of Figs. 129 and 130.

The tuner section of the television receiver selects the proper rf signals for the desired channel frequency, amplifies them, and converts them to a lower intermediate frequency. As in a radio receiver, these functions are accomplished in rf-amplifier, mixer, and local-oscillator stages. The if signal is then amplified in if-amplifier stages which provide the additional gain required to bring the signal level to an amplitude suitable for detection.

After if amplification, the detected signal is separated into sound and picture information. The sound signal is amplified and processed to provide an audio signal which is fed to an audio amplifier system. The picture (video) signal is passed through a video amplifier (discussed in the section on Low-Frequency Amplifiers) which conveys beam-intensity information to the television picture tube and thus controls instantaneous "spot" brightness. At the same time, deflection circuits cause the electron beam of the picture tube to move the "spot" across the faceplate horizontally and vertically. Special "sync" signals derived from the video signal assure that the horizontal and vertical scanning are timed so that the picture produced on the receiver exactly duplicates the picture being viewed by the camera or pickup tube. (The sync and deflection circuits are described in the section on TV Deflection.)

In a television receiver, the video signal contains a dc component, and therefore the average carrier level varies with signal information. As a result, the agc circuit is designed to provide a control voltage proportional to the peak modulated carrier level rather than the average modulated carrier level. The time constant of the agc detector circuit is made large enough so that the picture content of the composite video signal does not influence the magnitude of the agc voltage. In addition, an electronic switch is often included in the circuit so that it can be operated only during the retrace portion of the scanning cycle. This "gated agc" technique prevents noise peaks from affecting agc operation.

## DETECTION

The circuit of a radio, television, or communications receiver in which the modulation is separated from the carrier is called the demodulator or detector stage. Transmitted rf signals may be modulated in either of two ways. If the frequency of the carrier remains constant and its amplitude is varied, the carrier is called an amplitude-modulated (AM) signal. If the amplitude remains essentially constant and the frequency is varied, the carrier is called a frequency-modulated (FM) signal.

The effect of amplitude modulation (AM) on an rf carrier wave is shown in Fig. 131. The audio-

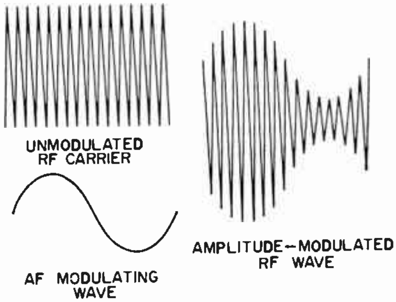



*Fig. 131—Waveforms showing effect of amplitude modulation on an rf wave.*

frequency (af) modulation can be extracted from the amplitude-modulated carrier by means of a simple diode detector such as that shown in Fig. 132(a). This circuit eliminates alternate half-cycles of the waveform, and detects the peaks of the remaining half-cycles to produce the output voltage shown in Fig. 132(b). In this figure, the rf voltage applied to the circuit is shown in light line; the output voltage across the capacitor C is shown in heavy line.

Between points a and b of Fig. 132(b), capacitor C charges up to the peak value of the rf voltage. Then, as the applied rf voltage falls away from its peak value, the capacitor holds the cathode of the diode at a potential more positive than the voltage applied to the anode. The capacitor thus temporarily cuts off current through the diode. While the

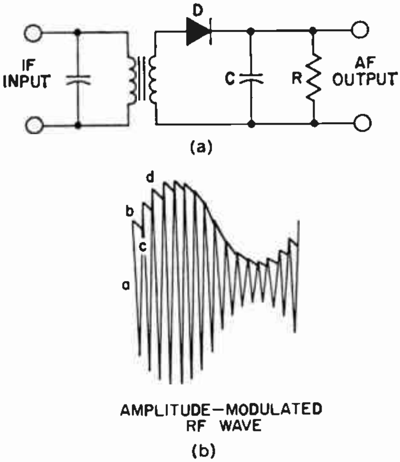



*Fig. 132—(a) Basic diode detector circuit and (b) waveform showing modulated rf input (light line) and output voltage (heavy line) of diode-detector circuit.*

diode current is cut off, the capacitor discharges from b to c through the diode load resistor R.

When the rf voltage on the anode rises high enough to exceed the potential at which the capacitor holds the cathode, current flows again, and the capacitor charges up to the peak value of the second positive half-cycle at d. In this way, the voltage across the capacitor follows the peak value of the applied rf voltage and reproduces the af modulating signal. The jaggedness of the curve in Fig. 132(b), which represents an rf component in the voltage across the capacitor, is exaggerated in the drawing. In an actual circuit, the rf component of the voltage across the capacitor is small. When the voltage across the capacitor is amplified, the output of the amplifier reproduces the speech or music that originated at the transmitting station.

Another way to describe the action of a diode detector is to consider the circuit as a half-wave rectifier. When the signal on the anode swings positive, the diode conducts and the rectified current flows. The dc voltage across the capacitor C varies in accordance with the rectified amplitude of the carrier and thus reproduces the af signal. Capacitor C should be large enough to smooth out rf or if variations, but should not be so large as to affect the audio variations. (Although two diodes can be connected in a circuit similar to a full-wave rectifier to produce full-wave detection, in practice the advantages of this connection generally do not justify the extra circuit cost and complication.)

In the circuit shown in Fig. 132(a), it is often desirable to forward-bias the diode almost to the point of conduction to improve performance for weak signal levels. It is also desirable that the resistance of the ac load which follows the detector be considerably larger than the diode load resistor to avoid severe distortion of the audio waveform at high modulation levels.

The basic diode detector may also be adapted to provide video-signal detection in black-and-white and color television receivers. Fig. 133 shows an example of a diode type of video detector for a color television receiver.

The video detector demodulates the if signal so that the luminance, chrominance, and sync signals are available at the output of the detector circuit. A crystal diode with an

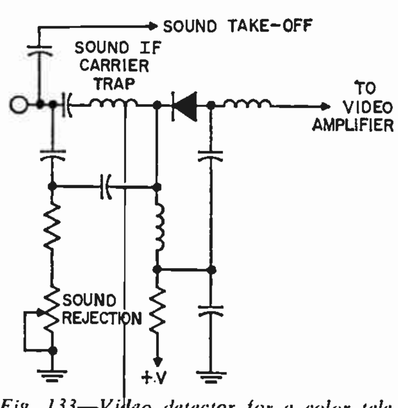



*Fig. 133—Video detector for a color television receiver.*

if filter is commonly used for this purpose. The video detector in a color receiver may employ a sound-carrier trap in its input. This trap attenuates the sound carrier and insures against the development of an undesirable 920-kHz beat frequency which is the frequency difference between the sound carrier and the color subcarrier. When the sound carrier is attenuated in this manner, the sound take-off point is located ahead of the video detector.

The effect of **frequency modulation** (FM) on the waveform of an rf carrier wave is shown in Fig. 134. In

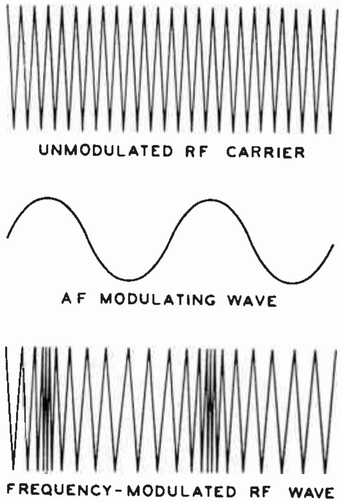



*Fig. 134—Waveforms showing effect of frequency modulation on an rf wave.*

this type of transmission, the frequency of the rf carrier deviates from the mean value at a rate proportional to the audio-frequency modulation and by an amount (determined in the transmitter) proportional to the amplitude of the af modulating signal. That is, the number of times the carrier frequency deviates above and below the center frequency is a measure of the frequency of the modulating signal; the amount of frequency deviation from the center frequency is a measure of the loudness (amplitude) of the modulating signal. For

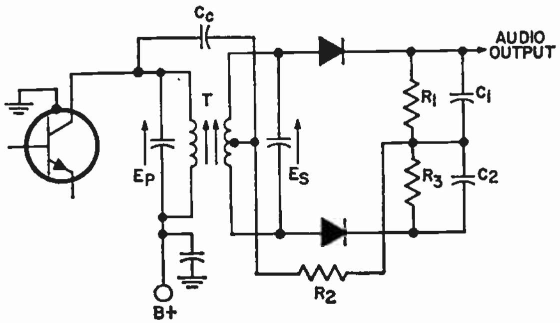



*Fig. 135—Balanced phase-shift discriminator circuit.*

this type of modulation, a detector is required to discriminate between deviations above and below the center frequency and to translate these deviations into a voltage having an amplitude that varies at audio frequencies.

The FM detector shown in Fig. 135 is called a balanced phase-shift discriminator. In this detector, the mutually coupled tuned circuits in the primary and secondary windings of the transformer T are tuned to the center frequency. A characteristic of a double-tuned transformer is that the voltages in the primary and secondary windings are 90 degrees out of phase at resonance, and that the phase shift changes as the frequency changes from resonance. Therefore, the signal applied to the diodes and the RC combinations for peak detection also changes with frequency.

Because the secondary winding of the transformer T is center-tapped, the applied primary voltage $E_p$ is added to one-half the secondary voltage $E_s$ through the capacitor $C_c$. The addition of these voltages at resonance can be represented by the diagram in Fig. 136; the resultant voltage $E_1$ is the signal applied to one peak-detector network consisting of one diode and its RC load. When the signal frequency decreases (from resonance), the phase shift of $E_s/2$ becomes greater than 90 degrees, as shown at (a) in Fig. 137, and $E_1$ becomes smaller. When the signal frequency increases (above resonance), the phase shift of $E_s/2$ is less than 90 degrees, as shown at (b), and $E_1$ becomes larger. The curve of $E_1$ as a function of frequency in Fig. 138 is readily identified as the response curve of an FM detector.

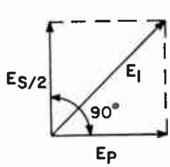



*Fig. 136—Diagram illustrating phase shift in double-tuned transformer at resonance.*

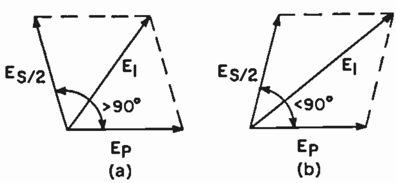



*Fig. 137—Diagrams illustrating phase shift in double-tuned transformer (a) below resonance and (b) above resonance.*

Because the discriminator circuit shown in Fig. 135 uses a push-pull configuration, the diodes conduct on alternate half-cycles of the signal frequency and produce a plus-and-minus output with respect to zero rather than with respect to $E_1$. The primary advantage of this arrangement is that there is no output at resonance. When an FM signal is applied to the input, the audio output voltage varies above and below zero as the instantaneous frequency varies above and below resonance.

The frequency of this audio voltage is determined by the modulation frequency of the FM signal, and the amplitude of the voltage is proportional to the frequency excursion from resonance. (The resistor $R_2$ in the circuit provides a dc return for the diodes, and also maintains a load impedance across the primary winding of the transformer.)

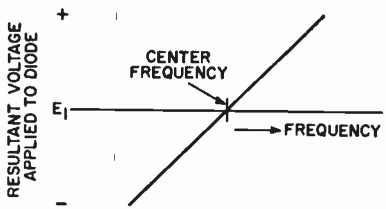



*Fig. 138—Diagram showing resultant voltage $E_1$ in Fig. 136 as a function of frequency.*

One disadvantage of the balanced phase-shift discriminator shown in Fig. 135 is that it detects amplitude modulation (AM) as well as frequency modulation (FM) in the if signal because the circuit is balanced only at the center frequency. At frequencies off resonance, any variation in amplitude of the if signal is reproduced to some extent in the audio output.

The ratio-detector circuit shown in Fig. 139 is a discriminator circuit which has the advantage of being relatively insensitive to amplitude variations in the FM signal. In this circuit, $E_p$ is added to $E_s/2$ through the mutual coupling $M_2$ (this voltage addition may be made by either mutual or capacitive coupling). Because of the phase-shift relationship of these voltages, the resultant detected signals vary with frequency variations in the same manner as described for the phase-discriminator circuit shown in Fig. 135. However, the diodes in the ratio detector are placed "back-to-back" (in series, rather than in push-pull) so that both halves of the circuit operate simultaneously during one-half of the signal frequency cycle (and are cut off on the other half-cycle). As a result, the detected voltages $E_1$ and $E_2$ are in series, as shown for the instantaneous polarities that occur during the conduction half-cycle. When the audio output is taken between the equal capacitors $C_1$ and $C_2$, therefore, the output voltage is equal to $(E_2-E_1)/2$ (for equal resistors $R_1$ and $R_2$).

The dc circuit of the ratio detector consists of a path through the secondary winding of the transformer, both diodes (which are in series), and resistors $R_1$ and $R_2$. The value of the electrolytic capacitor $C_3$ is selected so that the time constant of $R_1$, $R_2$, and $C_3$ is very long compared to the detected audio signal. As a result, the sum of the detected voltages $(E_1 + E_2)$ is a constant, and the AM components on the signal frequency are suppressed. This feature of the ratio detector provides improved AM rejection as compared to the phase-shift discriminator circuit shown in Fig. 135.

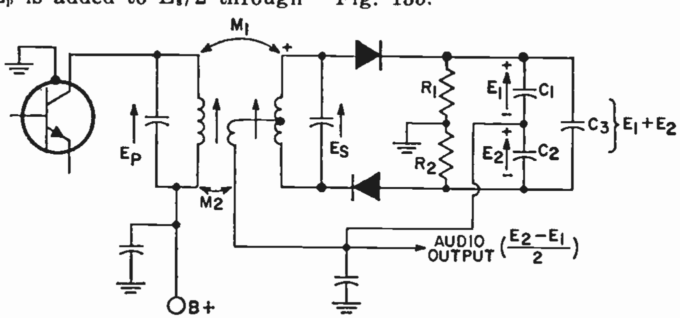



*Fig. 139—Ratio-detector circuit.*

# TUNED AMPLIFIERS

In radio-frequency (rf) and intermediate-frequency (if) amplifiers, the bandwidth of frequencies to be amplified is usually only a small percentage of the center frequency. Tuned amplifiers are used in these applications to select the desired bandwidth of frequencies and to suppress unwanted frequencies. The selectivity of the amplifier is obtained by means of tuned interstage coupling networks.

## Resonant-Circuit Characteristics

The properties of tuned amplifiers depend upon the characteristics of resonant circuits. A simple parallel resonant circuit (sometimes called a "tank" because it stores energy) is shown in Fig. 140. For practical purposes, the resonant frequency of such a circuit may be considered independent of the resistance R, provided R is small compared to the inductive reactance $X_L$. The resonant frequency $f_r$ is then given by

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

For any given resonant frequency, the product of L and C is a constant; at low frequencies LC is large; at high frequencies it is small.

The Q (selectivity) of a parallel resonant circuit alone is the ratio of the current in the tank ($I_L$ or $I_C$) to the current in the line (I). This unloaded Q, or $Q_o$, may be expressed in various ways, for example:

$$Q_o = \frac{I_C}{I} = \frac{X_L}{R_S} = \frac{R_p}{X_C}$$

where $X_L$ is the inductive reactance ($= 2\pi fL$), $X_c$ is the capacitive reactance ($= 1/[2\pi fC]$), and $R_p$ is the total impedance of the parallel resonant circuit (tank) at resonance. The Q varies inversely with the resistance of the inductor $R_S$. The lower the resistance, the higher the Q and the greater the difference between the tank impedance at frequencies off resonance compared to the tank impedance at the resonant frequency.

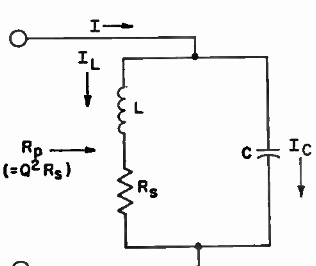



*Fig. 140—Simple parallel resonant circuit.*

The Q of a tuned interstage coupling network also depends upon the impedances of the preceding and following stages. The output impedance of a transistor can be considered as consisting of a resistance $R_o$ in parallel with a capacitance $C_o$, as shown in Fig. 141. Similarly, the input impedance can be considered as consisting of a resistance $R_i$ in parallel with a capacitance $C_i$. Because the

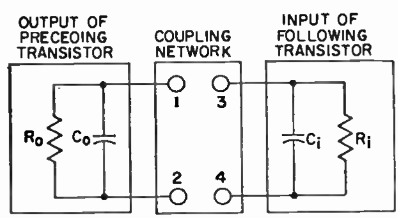



*Fig. 141—Equivalent output and input circuits of transistors connected by a coupling network.*

tuned circuit is shunted by both the output impedance of the preceding transistor and the input impedance of the following transistor, the effective selectivity of the circuit is the loaded Q (or $Q_L$) based upon the total impedance of the coupled network, as follows:

$$Q_L = \frac{\begin{Bmatrix}\text{total loading on} \\ \text{coil at resonance}\end{Bmatrix}}{X_L \text{ or } X_C}$$

The capacitances $C_o$ and $C_i$ in Fig. 141 are usually considered as part of the coupling network. For example, if the required capacitance between terminals 1 and 2 of the coupling network is calculated to be 500 picofarads and the value of $C_o$ is 10 picofarads, a capacitor of 490 picofarads is used between terminals 1 and 2 so that the total capacitance is 500 picofarads. The same method is used to allow for the capacitance $C_i$ at terminals 3 and 4.

When a tuned resonant circuit in the primary winding of a transformer is coupled to the nonresonant secondary winding of the transformer, as shown in Fig. 142(a), the effect of the input impedance of the following stage on the Q of the tuned circuit can be determined by considering the values reflected (or referred) to the primary circuit by transformer action. The reflected resistance $r_i$ is equal to the resistance $R_i$ in the secondary circuit times the square of the effective turns ratio between the primary and secondary windings of the transformer T:

$$r_i = R_i\,(N_1/N_2)^2$$

where $N_1/N_2$ represents the electrical turns ratio between the primary winding and the secondary winding of T. If there is capacitance in the secondary circuit ($C_s$), it is reflected to the primary circuit as a capacitance $C_{sp}$, and is given by

$$C_{sp} = C_p \div (N_1/N_2)^2$$

The loaded Q, or $Q_L$, is then calculated on the basis of the inductance $L_p$, the total shunt resistance ($R_o$ plus $r_i$ plus the tuned-circuit impedance $Z_t = Q_oX_c = Q_oX_L$), and the total capacitance ($C_p + C_{sp}$) in the tuned circuit.

Fig. 142(b) shows a coupling network which consists of a single-tuned circuit using mutual inductive coupling. The capacitance $C_t$ includes the effects of both the output capacitance of the preceding transistor and the input capacitance of the following transistor (referred to the primary of transformer $T_1$). The bandwidth of a single-tuned transformer is determined by the half-power points on the resonance curve (−3 dB or 0.707 down from

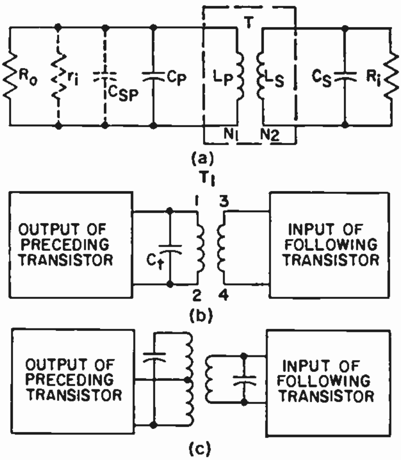



*Fig. 142—Equivalent circuits for transformer-coupling networks: (a) having tuned primary winding; (b) using inductive coupling; (c) using tap on primary winding.*

the maximum). Under these conditions, the band pass $\Delta f$ is equal to the ratio of the center or resonant frequency $f_r$ divided by the loaded (effective) Q of the circuit, as follows:

$$\Delta f = f_r/Q_L$$

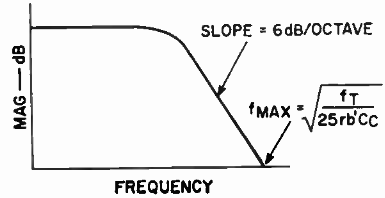
The inherent internal feedback in transistors can cause instability and oscillation as the gain of an amplifier stage is increased (i.e., as the load and source impedances are increased from zero to matched conditions). At low radio frequencies, therefore, where the potential gain of transistors is high, it is often desirable to keep the transistor load impedance low. Relatively high capacitance values in the tuned collector circuit can then be avoided by use of a tap on the primary winding of the coupling transformer, as shown in Fig. 142(c). At higher frequencies, the gain potential of the transistor decreases, and impedance matching is permissible. However, lead inductance becomes significant at higher frequencies, particularly in the emitter circuit. All lead lengths should be kept short, therefore, and especially the emitter lead, which not only degrades performance but is also a mutual coupling to the output circuit.

## Gain and Noise Figure

In the design of low-level tuned rf amplifiers, careful consideration must be given to the transistor and circuit parameters which control circuit stability, as well as those which maintain adequate power gain. The power gain of an rf transistor must be sufficient to provide a signal that will overcome the noise level of succeeding stages. In addition, if the signals to be amplified are relatively weak, it is important that the transistor and its associated circuit provide low noise figure at the operating frequency. In communication receivers, the noise figure of the rf stage determines the absolute sensitivity of the receiver and is, therefore, one of the most important characteristics of the device used in the rf stage.

The relative power-gain capabilities of transistors at high frequencies are indicated by their theoretical maximum frequency of oscillation $f_{max}$. At this frequency, the unilateralized matched power gain, or **maximum available gain** MAG, is 0 dB. As shown in Fig. 143, the curve of MAG as a function of frequency for a typical rf transistor rises approximately 6 dB per octave below $f_{max}$.

Because most practical rf amplifiers are not individually unilateralized, the power gain that can be obtained is somewhat less than the MAG because of internal feedback in the circuit. This feedback is greater in unneutralized circuits than in neutralized circuits, and therefore gain is lower when neutralization is not used. From a practical consideration, the feedback capacitance which must be considered is the total feedback capacitance between collector and base, including both stray and socket capacitances. In neutralized circuits, stray capacitances, socket capacitance, and the typical value of device capacitance can generally be neutralized. At a given frequency, therefore, the **maximum usable power gain** MUG of a neutralized circuit depends on the transconductance $g_m$ and the amount of internal feedback capacitance $C_f$. In unneutralized circuits, however, both socket and stray capacitances are involved in the determination of gain and must be included in the value of $C_f$. The ratio of $g_m$ to $C_f$ should be high to provide high power gain. Fig. 146 shows typical curves of MAG and MUG (for both the neutralized and the unneutralized case) for a low-level rf transistor used in a common-emitter circuit.



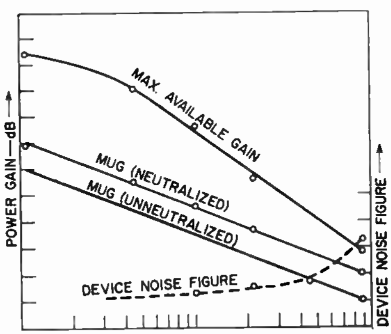




*Fig. 143—Maximum available gain MAG, maximum usable gain MUG, and noise figure NF as functions of frequency.*

The transistor requirements for high power gain and low noise figure are essentially the same. Published data for transistors intended for low-level rf applications generally indicate a minimum power gain and a maximum noise figure in a circuit typical of the intended use. A curve of noise figure NF as a function of frequency is also shown in Fig. 143. Circuit design factors for lowest noise figure include use of a low-noise transistor, choice of optimum bias current and source resistance, and use of low-loss input circuits. Optimum low-noise bias current for most low-level rf transistors is about 1 milliampere, or slightly higher in the uhf range. Optimum source resistance is a function of operating frequency and bias current for a given transistor.

Although maximum theoretical power gain cannot be achived in practical circuits, the gain of MOS transistors at high frequencies closely approximates the theoretical limit except for some losses in the input and output matching circuits.

Power gain is essentially independent of channel width, which is a determining factor in the size of MOS transistors. For example, if the width of the transistor is reduced by one half (and the steady-state drain current is similarly reduced to maintain a constant current density in the device), power gain remains the same because the transconductance, the input conductance, and the output conductance are all reduced by one half. Consequently, the frequency capability of MOS transistors can be increased by a reduction in their size.

The input circuit to the first stage of the amplifier should have as little loss as possible because such loss adds directly to the otherwise attainable noise figure. In other words, if the loss at the input to the first stage is 2 dB, the amplifier noise figure will be 2 dB higher than could be achieved with no loss at the input. To minimize such loss, it is generally desirable that the ratio of unloaded Q ($Q_o$) to loaded Q ($Q_L$) of the input circuit be high and that the bias resistors be isolated from the input by chokes or tuned circuits.

In practical rf-amplifier circuits using MOS transistors, the best possible noise figures are obtained when the input impedance of the transistor is slightly mismatched to that of the source. With this technique, noise figures as low as 1.9 dB have been obtained. Dual-gate MOS transistors typically exhibit a noise figure of 3.5 dB in the vhf range and of 4.5 dB in the uhf range.

In high-frequency tuned amplifiers, in which the input impedance is typically low, mutual inductive coupling may be impractical because of the small number of turns in the secondary winding. It is extremely difficult in practice to construct a fractional part of a turn. In such cases, capacitance coupling may be used, as shown in Fig. 144. This arrangement, which is also called capacitive division, is similar to tapping down on a coil at or near resonance. Impedance transformation in this network is determined by the ratio between capacitors $C_1$ and $C_2$. Capacitor $C_1$ is normally much smaller than $C_2$; thus the capacitive reactance $X_{C1}$ is normally much larger than $X_{C2}$. Provided the input resistance of the following transistor is much greater than $X_{C2}$, the effective turns ratio from the top of the coil to the input of the following transistor is $(C_1 + C_2)/C_1$. The total capacitance $C_t$ across the inductance L is given by

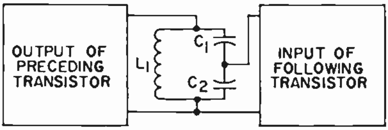



*Fig. 144—Single-tuned coupling network using capacitive division.*

$$C_t = \frac{C_1 C_2}{C_1 + C_2}$$

The resonant frequency $f_r$ is then given by

$$f_r = \frac{1}{2\pi\sqrt{L_1 C_t}}$$

Double-tuned interstage coupling networks are often used in preference to single-tuned networks to provide flatter frequency response within the pass band, a sharper drop in response immediately adjacent to the ends of the pass band, or more attenuation at frequencies far removed from resonance. In synchronous double-tuned networks, both the resonant circuit in the input of the coupling network and the resonant circuit in the output are tuned to the same resonant frequency. In "stagger-tuned" networks, the two resonant circuits are tuned to slightly different resonant frequencies to provide a more rectangular band pass with sharper selectivity at the ends of the pass band. Double-tuned or stagger-tuned networks may use capacitive, inductive, or mutual inductance coupling, or any combination of the three.

## Automatic Gain Control

Automatic gain control (agc) is often used in rf and if amplifiers in AM radio and television receivers to provide lower gain for strong signals and higher gain for weak signals. (In radio receivers, this gain-compensation network may also be called automatic volume control or avc.) When the signal strength at the antenna changes, the agc circuit modifies the receiver gain so that the output of the last if-amplifier stage remains nearly constant and consequently maintains a nearly constant speaker volume or picture contrast.

The agc circuit usually reduces the rf and if gain for a strong signal by varying the bias on the rf-amplifier and if-amplifier stages when the signal increases. A simple reverse agc circuit is shown in Fig. 145. On each positive half-cycle of the signal voltage, when the diode anode is positive with respect to the cathode, the diode passes current. Because of the flow of diode current through $R_1$, there is a voltage drop across $R_1$ which makes the upper end of the resistor negative with respect to ground. This voltage drop across $R_1$ is applied, through the filter $R_2$ and C, as reverse

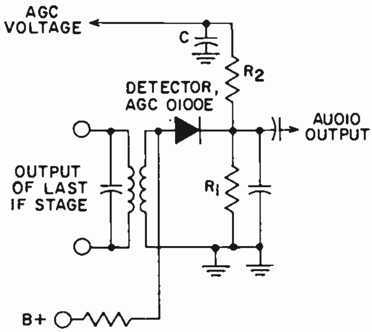



*Fig. 145—Simple reverse agc circuit.*

bias on the preceding stages. When the signal strength at the antenna increases, therefore, the signal applied to the agc diode increases, the voltage drop across $R_1$ increases, the reverse bias applied to the rf and if stages increases, and the gain of the rf and if stages is decreased. As a result, the increase in signal strength at the antenna does not produce as much increase in the output of the last if-amplifier stage as it would without agc.

When the signal strength at the antenna decreases from a previous steady value, the agc circuit acts in the opposite direction, applying less reverse bias and thus permitting the rf and if gain to increase.

The filter composed of C and $R_2$ prevents the agc voltage from varying at an audio frequency. This filter is necessary because the voltage drop across $R_1$ varies with the modulation of the carrier being received. If agc voltage were taken directly from $R_1$ without filtering, the audio variations in agc voltage would vary the receiver gain so as to smooth out the modulation of the carrier. To avoid this effect, the agc voltage is taken from the capacitor C. Because of the resistance $R_2$ in series with C, the capacitor can charge and discharge at only a comparatively slow rate. The agc voltage therefore cannot vary at frequencies as high as the audio range, but can vary rapidly at frequencies high enough to compensate for most changes in signal strength.

There are two ways in which automatic gain control can be applied to a transistor. In the reverse agc method shown in Fig. 145, agc action is obtained by decreasing the collector or emitter current of the transistor, and thus its transconductance and gain. The use of forward agc provides improved cross-modulation characteristics and better signal-handling capability than reverse agc. For forward agc operation, however, the transistor used must be specially designed so that transconductance decreases with increasing emitter current. In such transistors, the current-cutoff characteristics are designed to be more remote than the typical sharp-cutoff characteristics of conventional transistors. (All transistors can be used with reverse agc, but only specially designed types with forward agc.)

Reverse agc is simpler to use, and provides less bandpass shift and tilt with signal-strength variations. The input and output resistances of a transistor increase when reverse agc is applied, but the input and output capacitances are not appreciably changed. The change in the loading of tuned circuits is minimal, however, because considerable mismatch already exists and the additional mismatch caused by agc has little effect.

In forward agc, however, the input and output resistances of the transistor are reduced when the collector or emitter current is increased, and thus the tuned circuits are damped. In addition, the input and output capacitances change drastically, and alter the resonant frequency of the tuned circuits. In a practical circuit, the bandpass shift and tilt caused by forward agc can be compensated to a large extent by the use of passive coupling circuits.

## Cross-Modulation Distortion

Cross-modulation, an important consideration in the evaluation of transistorized tuner circuits, is produced when an undesired signal within the pass band of the receiver input circuit modulates the carrier of the desired signal. Such distortion occurs when third- and higher-odd-order nonlinearities are present in an rf-amplifier stage. In general, the severity of cross-modulation is independent of both the semiconductor material and the construction of the transistor (provided gain and noise factor are not sacrificed). At low frequencies, cross-modulation is also independent of the amplitude of the desired carrier, but varies as the square of the amplitude of the interfering signal.

To measure cross-modulation distortion, it is necessary to determine the amplitude of the undesired signal which transfers one per cent of its modulation to the desired signal. In most cases, a value of 100 millivolts or more over the complete agc range is considered good. The cross-modulation characteristics of MOS transistors are as good as those of bipolar transistors in the high-attenuation region, and are as much as ten times better in the low-attenuation region (when the incoming signal is weak). This low cross-modulation distortion should ultimately lead to extensive use of MOS transistors in the rf stages of all types of communications receivers.

In most rf circuits, the undesirable effects of cross-modulation can be minimized by good selectivity in the antenna and rf interstage coils. Minimum cross-modulation can best be achieved by use of the optimum circuit Q with respect to bandwidth and tracking considerations, which implies minimum loading of the tank circuits.

In rf circuits where selectivity is limited by the low unloaded Q's of the coils being used, improved cross-modulation can be obtained by mismatching the antenna circuit (that is, selecting the antenna primary-to-secondary turns ratio such that the reflected antenna impedance at the base of the rf amplifier is very low compared to the input impedance). This technique is commonly used in automobile receivers, and causes a slight degradation in noise figure. At high frequencies, such as in television, where low source impedances are difficult to obtain because of lead inductance or the impracticality of putting a tap on a coil having one or two turns, an unbypassed emitter resistor having a low value of resistance (e.g., 22 ohms) may be used to obtain the same effect.

Cross-modulation may occur in the mixer or rf amplifier, or both. Accordingly, it is important to analyze the entire tuner as well as the individual stages. Cross-modulation is also a function of agc. At sensitivity conditions where the rf stage is operating at maximum gain and the interfering signal is far removed from the desired signal, cross-modulation occurs primarily in the rf stage. As the desired signal level increases and agc is applied to the rf stage, the rf transistor gain decreases and provides improved cross-modulation. If the interfering signal is close to the desired signal, it is the rf gain at the undesired signal frequency which determines whether the rf stage or mixer stage is the prime contributor of cross-modulation. For example, it is possible that the rf stage gain (including selectivity of tuned circuits) at the undesired frequency is greater than unity. In this case, the undesired signal at the mixer input is larger than that at the rf input; thus the contribution of the mixer is appreciable. Intermediate and high signal conditions may be analyzed similarly by considering rf agc.

If adequate limiting is employed, cross-modulation does not occur in an FM signal.

Spurious-response characteristics are an important consideration in the evaluation of transistorized FM tuner circuits. Like cross-modulation, spurious response, an effect caused by the mixture of unwanted signals with the desired carrier, can occur in either the rf stage or the mixer. MOS field-effect transistors are especially suitable for use in FM rf-amplifier and mixer stages because of their inherently superior spurious-response rejection properties and signal-handling capabilities.

When spurious response is created in the rf amplifier, it may be removed by improved filtering between the rf amplifier and the mixer. The output of an MOS-transistor rf amplifier is low in harmonics. As a result, the need for a double-tuned rf interstage transformer is reduced and acceptable performance can usually be achieved with single-tuned circuits in both the antenna and rf interstage sections.

The dynamic-range capability of MOS field-effect transistors is about 25 times greater than that of bipolar transistors. In an actual tuner circuit, this large intrinsic dynamic range is reduced by a factor proportional to the square of the circuit source impedances. The net result is a practical dynamic range for MOS tuner circuits about five times that for bipolar types.

With MOS field-effect transistors, as contrasted with either bipolar transistors or junction-gate field-effect transistors, there is no loading of the input signal, nor drastic change of input capacitance even under extreme overdrive conditions.

In junction-gate field-effect transistors, a large incoming signal can have sufficiently high positive swing to drive the gate into conduction by a momentary forward bias; power is then drawn from the input signal just as if a resistance were placed across the input circuit. In bipolar transistors, there is a gradual change of both input impedance and input capacitance as a function of large signal excursions. These changes are undesirable because they can result in detuning of tuned circuits and widening of the input selectivity curve.

Fig. 146 shows the basic circuit configuration for the "front-end"

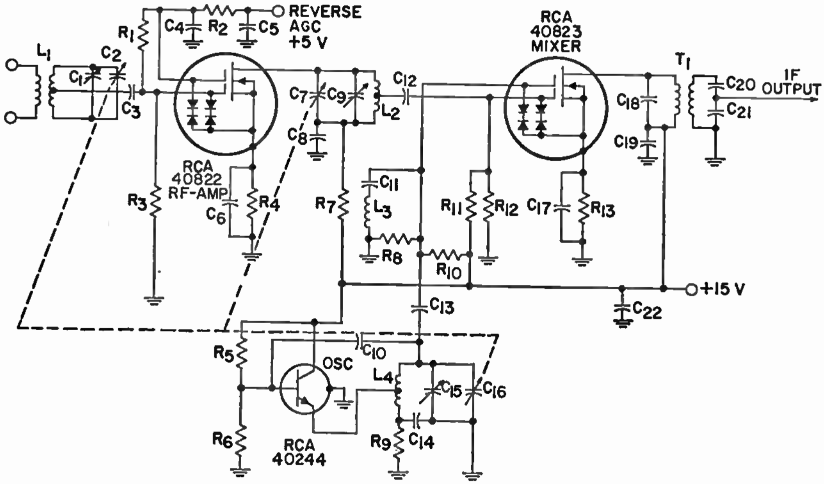



*Fig. 146—Circuit diagram of FM tuner using dual-gate MOS transistors in the rf amplifier and mixer stages.*

stages of an FM tuner that uses dual-gate-protected MOS field-effect transistors in both the rf-amplifier and mixer stages. A bipolar transistor is used in the local-oscillator stage. The detailed schematic diagram and functional description of a practical circuit of this type are given in the Circuits section at the back of this Manual.

Selection of appropriate source and load impedances for the rf stage should also take into consideration the fact that achievement of a low spurious response requires that the gate of the MOS transistor be tapped as far down on the antenna coil as gain and noise considerations permit. This arrangement makes possible optimum use of the available dynamic range of the MOS transistor.

The dual-gate MOS transistor is very attractive for use in mixer service because the two signals to be mixed are applied to separate gate terminals. This arrangement is an effective technique for reduction of oscillator radiation. In the circuit shown in Fig. 146, the signal frequency is applied to gate No. 1 of the mixer transistor and the local-oscillator input to gate No. 2.

Figs. 147 and 148 show FM tuner circuits that use bipolar transistors only. The n-p-n silicon transistors used are characterized by very low feedback capacitance, low noise, and high useful power gain, and feature a terminal arrangement in which the base and emitter terminals are interchanged to provide maximum isolation between the base and collector terminals. Although this basing configuration does not appreciably change the measured device-feedback capacitance, it does allow reduction of the collector-to-base capacitance due to external circuitry.

Laboratory results indicate that although tuners using three tuned circuits (including the oscillator tank) perform extremely well with regard to gain, noise, and rejection of certain higher-order spurious responses, the addition of another tuned circuit provides truly superior performance with regard to the attenuation of all spurious responses including image and the troublesome "half-if."

Figs. 147 and 148 each show the schematic diagram of a four-coil tuner designed around bipolar transistors. The dc conditions of both circuits are identical. The rf-stage transistor operates in the common-emitter configuration at an emitter current of 1.5 milliamperes. This configuration offers the highest stable gain at FM frequencies; the operating point specified was chosen as a compromise between noise, gain, and spurious response rejection. The mixer transistor operates in a common-emitter configuration at 1.5 milliamperes. The oscillator transistor operates in the common-collector configuration at approximately 2.5 milliamperes and provides approximately 28 millivolts of injection voltage to the mixer base. The common-collector configuration was chosen because it offers the greatest frequency stability with respect to changes in voltage and temperature. Also, if recommended wiring practices are adhered to, the use of the common-collector oscillator minimizes higher-order spurious responses.

In Fig. 147, the antenna coil is double-tuned, and thus provides better selectivity characteristics ahead of the rf stage than a single-tuned transformer under the same impedance-matching condition. By using coils with unloaded, mounted Q's of 100, sufficient selectivity is realized so that at signal levels up to 200 millivolts there are no spurious responses within the FM frequency band. One disadvantage of double-tuned transformers is the coupling loss associated with them. Noise performance is degraded from that obtained when single tuning is employed in the antenna coil by exactly the coupling loss of the double-tuned coil.

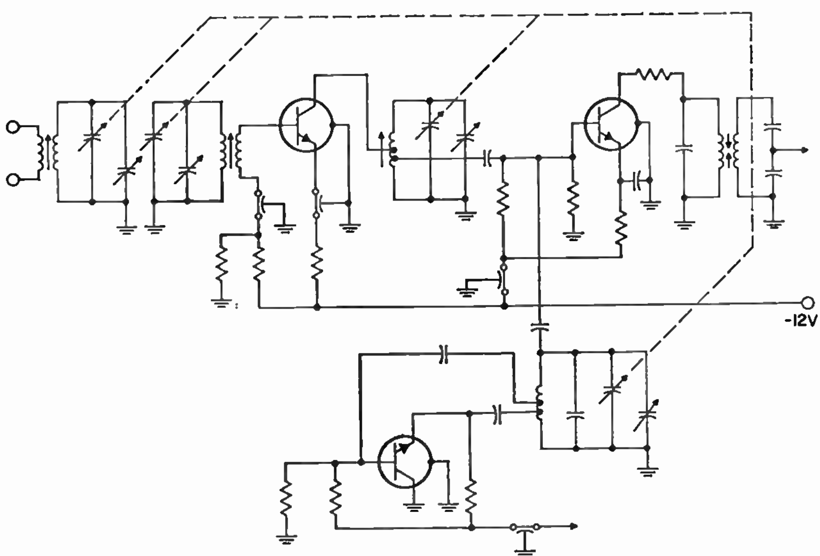



*Fig. 147—Four-coil FM tuner with double-tuned antenna transformer.*

Because the IHF (Institute of High Fidelity) sensitivity has developed into an important requirement and because a low value of IHF sensitivity is determined in part by noise performance, a circuit, Fig. 148, has been designed that improves the noise performance and yet maintains a high degree of rejection of spurious responses. It is felt that although high selectivity ahead of the rf stage is desirable, it is not essential. Laboratory tests indicate that the mixer is primarily responsible for spurious generation and that it is more important to maintain low drive to the mixer base and to have adequate selectivity ahead of it. Because the over-all gain from antenna to mixer base must be kept low enough for spurious immunity, and sufficiently high (10 to 15 dB) to mask mixer noise, it is clear that all of the available maximum usable gain is not needed. At a sacrifice of some gain, therefore, the selectivity characteristics of the double-tuned rf transformer can be improved by decreasing the coupling. It is assumed that if harmonics are generated in the rf stage, they will be adequately attenuated by the rf transformer. With a single-tuned antenna coil, circuit noise performance is improved for the reasons described.

Neither of the four-coil tuner circuits shown in Figs. 147 and 148 uses a 10.7-MHz if trap because the need for such a trap is eliminated with the use of the inductively tapped transformer.

A choice of first if transformer is offered. One version employs a capacitance-tapped secondary, as shown in Figs. 147 and 148; the other has an inductively tapped secondary. Electrically, both transformers are identical.

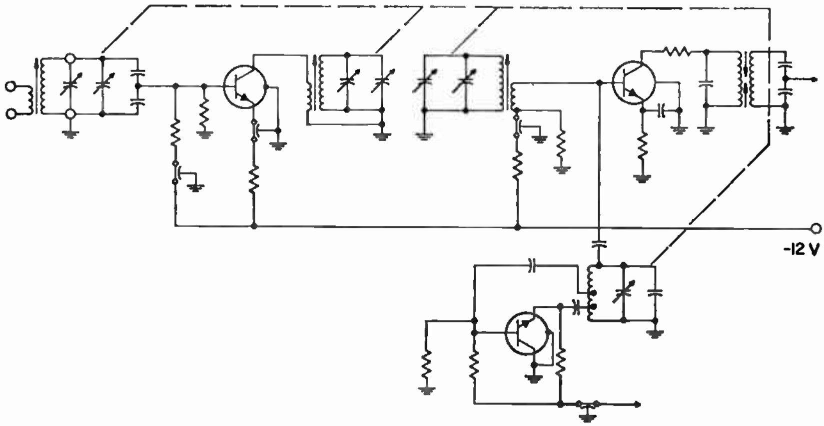



*Fig. 148—Four-coil FM tuner with double-tuned rf transformer.*

A limiter circuit is essentially an if-amplifier stage designed to provide clipping at a desired signal level. Such circuits are used in FM receivers to remove AM components from the if signal prior to FM detection. The limiter stage is normally the last stage prior to detection, and is similar to preceding if stages. At low input rf signal levels, it amplifies the if signal in the same manner as preceding stages. As the signal level increases, however, a point is reached at which the limiter stage is driven into saturation (i.e., the peak currents and voltages are limited by the supply voltage and load impedances and increases in signal produce very little increase in collector current). At this point, the if signal is "clipped" (or flattened) and further increases in rf signal level produce no further output in if signal to the detector.

Limiter stages may be designed to provide clipping at various input-signal levels. A high-gain FM tuner is usually designed to limit at very low rf input signal levels, and possibly even on noise signals. Additional AM rejection may be obtained by use of a ratio detector for the frequency discriminator.

## OSCILLATION

Bipolar and field-effect transistor oscillator circuits are similar in many respects to the tuned amplifiers discussed previously, except that a portion of the output power is returned to the input network in phase with the starting power (regenerative or positive feedback) to sustain oscillation. DC bias-voltage requirements for oscillators are similar to those discussed for amplifiers.

The maximum operating frequency of an oscillator circuit is limited by the frequency capability of the transistor used. The maximum frequency of oscillation of a transistor is defined as the frequency at which the power gain is unity. Because some power gain is required in an oscillator circuit to overcome losses in the feedback network, the operating frequency must be some value below the transistor maximum frequency of oscillation.

For sustained oscillation in a transistor oscillator, the power gain of the amplifier network must be equal to or greater than unity. When the amplifier power gain becomes less than unity, oscillations become smaller with time (are "damped") until they cease to exist. In practical oscillator circuits, power gains greater than unity are required because the power output is divided between the load and the feedback network, as shown in Fig. 149. The feedback power must be equal to the input power plus the losses in the feedback network to sustain oscillation. (A number of the oscillator circuits shown in the following sections on LC Resonant Feedback Oscillators and Crystal Oscillators employ MOS field-effect transistors. Although only single-gate types are shown in these circuits, the configurations are equally applicable for use with dual-gate devices. In such applications, the dual-gate MOS transistor is connected as shown in Fig. 58 to provide performance substantially equivalent to that provided by the single-gate device.)

### LC Resonant Feedback Oscillators

The frequency-determining elements of an oscillator circuit may consist of an inductance-capacitance (LC) network, a crystal, or a resistance-capacitance (RC) network. An LC tuned circuit may be placed in either the base circuit or the collector circuit of a common-emitter transistor oscillator. In the tuned-base oscillator shown in Fig. 150, one

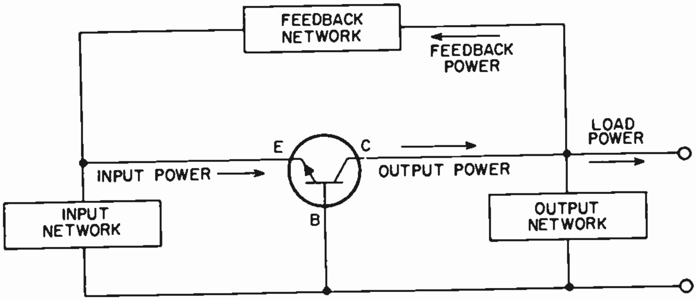



*Fig. 149—Block diagram of transistor oscillator showing division of output power.*

battery is used to provide all the dc operating voltages for the transistor. Resistors $R_1$, $R_3$, and $R_4$ provide the necessary bias conditions. Resistor $R_2$ is the emitter stabilizing resistor. The components within the dotted lines comprise the transistor amplifier. The collector shunt-feed arrangement prevents dc current flow through the tickler

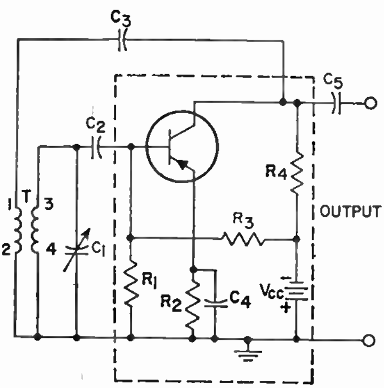



*Fig. 150—Tuned-base oscillator.*

(primary) winding of transformer T. Feedback is accomplished by the mutual inductance between the transformer windings.

The tuned circuit consisting of the secondary winding of transformer T and variable capacitor $C_1$ is the frequency-determining element of the oscillator. Variable capacitor $C_1$ permits tuning through a range of frequencies. Capacitor $C_2$ couples the oscillation signal to the base of the transistor, and also blocks dc. Capacitor $C_4$ bypasses the ac signal around the emitter resistor $R_3$ and prevents degeneration. The output signal is coupled from the collector through coupling capacitor $C_5$ to the load.

A tuned-collector transistor oscillator is shown in Fig. 151. In this circuit, resistors $R_1$ and $R_3$ establish the base bias. Resistor $R_2$ is the emitter stabilizing resistor. Capacitors $C_1$ and $C_2$ bypass ac around resistors $R_1$ and $R_2$, respectively. The

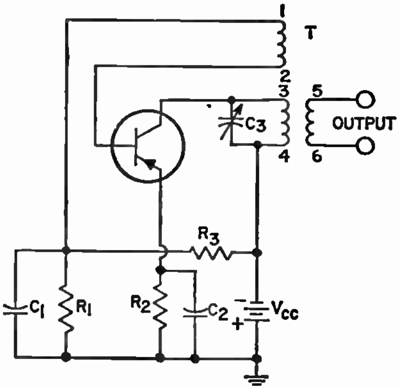



*Fig. 151—Tuned-collector oscillator.*

tuned circuit consists of the primary winding of transformer T and the variable capacitor $C_3$. Regeneration is accomplished by coupling the feedback signal from transformer winding 3-4 to the tickler coil winding 1-2. The secondary winding of the transformer couples the signal output to the load.

Another form of LC resonant feedback oscillator is the Hartley oscillator. This oscillator makes use of split inductance to obtain feedback and may be either shunt or series fed. In the shunt-fed circuit of Fig. 152, $R_1$, $R_2$, and $R_3$ are the biasing resistors; the frequency-determining network consists of

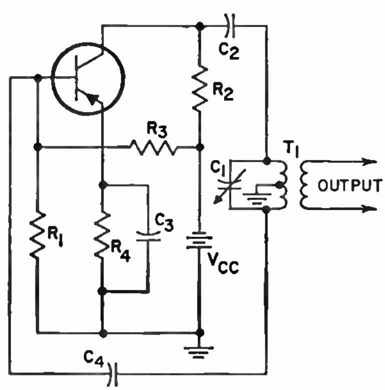



*Fig. 152—Shunt-fed Hartley oscillator.*

variable capacitor $C_1$ in series with the windings of $T_1$. The frequency of the oscillator is varied by $C_1$; $C_2$ is the dc blocking capacitor and $C_3$ is an ac bypass capacitor.

The circuit inductance functions in the manner of an auto transformer and provides the regenerative feedback signal obtained from the voltage induced in the lower half of the transformer winding and coupled through $C_4$ to the transistor base. No dc current flows through the primary of $T_1$ because the collector is shunt fed through $R_2$.

In the series-fed Hartley circuit shown in Fig. 153, the base-emitter circuit is biased through $R_1$ and $R_2$;

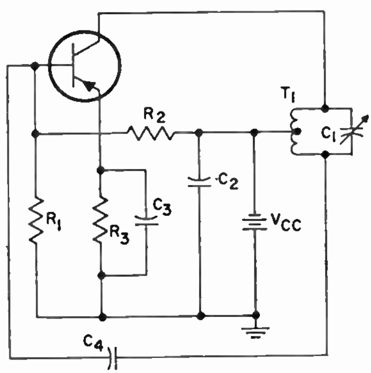



*Fig. 153—Series-fed Hartley oscillator.*

the collector is biased through the upper half of the transformer windings. Again, as in the shunt-fed circuit, $C_3$ provides an ac bypass. Feedback in the series-fed Hartley circuit is obtained from the lower-half of the transformer winding and is coupled through $C_4$ to the base of the transistor. The center-tap of the transformer winding is maintained at ac ground potential by $C_2$.

Fig. 154 shows two arrangements of a Hartley oscillator circuit using MOS field-effect transistors. Circuit (a) uses a bypassed source resistor to provide proper operating conditions; circuit (b) uses a gate-leak resistor and biasing diode. The amount of feedback in either circuit is dependent on the position of the tap on the coil. Too little feedback results in a feedback signal voltage at the gate insufficient

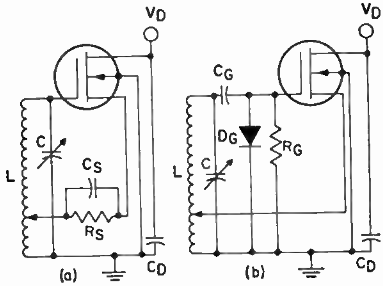



*Fig. 154—Hartley oscillator circuits using MOS transistors.*

to sustain oscillation; too much feedback causes the impedance between source and drain to become so low that the circuit becomes unstable. Output from these circuits can be obtained through inductive coupling to the coil or through capacitive coupling to the gate.

Another form of LC resonant feedback oscillator is the transistor version of the Colpitts oscillator, shown in Fig. 155. Regenerative feedback is obtained from the tuned circuit consisting of capacitors $C_2$

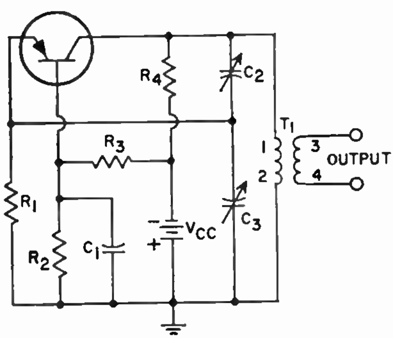



*Fig. 155—Transistor Colpitts oscillator.*

and $C_3$ in parallel with the primary winding of the transformer, and is applied to the emitter of the transistor. Base bias is provided by resistors $R_2$ and $R_3$. Resistor $R_4$ is the collector load resistor. Resistor

$R_1$ develops the emitter input signal and also acts as the emitter stabilizing resistor. Capacitors $C_2$ and $C_3$ form a voltage divider; the voltage developed across $C_3$ is the feedback voltage. The frequency and the amount of feedback voltage can be controlled by adjustment of either or both capacitors. For minimum feedback loss, the ratio of the capacitive reactance between $C_2$ and $C_3$ should be approximately equal to the ratio between the output impedance and the input impedance of the transistor.

Fig. 156 shows the field-effect transistor in use in two forms of the Colpitts oscillator circuit. These circuits are more commonly used in vhf and uhf equipment than the Hartley circuits because of the mechanical difficulty involved in making the tapped coils required at these frequencies by the Hartley circuits. Feedback is controlled in the Colpitts oscillator by the ratio of the capacitance of C′ to C″.

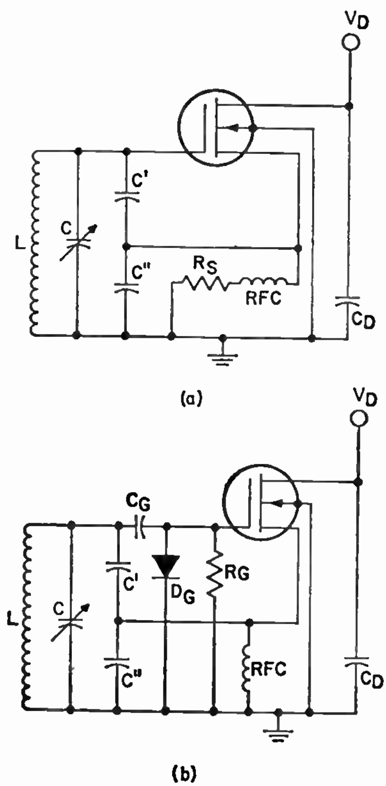



*Fig. 156—Colpitts oscillator circuits using MOS transistors.*

Fig. 157, the gate-tickler-feedback oscillator circuit, and Fig. 158, the drain-tickler-feedback oscillator

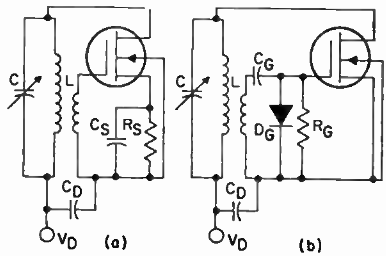



*Fig. 157—Gate-tickler-feedback oscillator circuits.*

circuit, have no particular advantages over the Hartley and Colpitts circuits except that in some designs

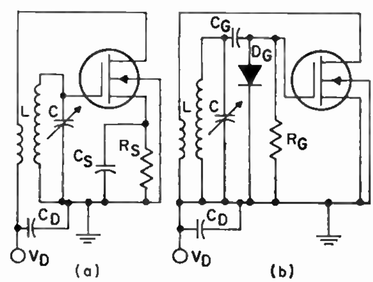



*Fig. 158—Drain-tickler-feedback oscillator circuits.*

it may be more economical to provide a tickler winding than the tapped coil or capacitive divider required in the Hartley or Colpitts circuits, respectively.

A Clapp oscillator is a modification of the Colpitts circuit shown in Fig. 155 in which a capacitor is added in series with the primary winding of the transformer to improve frequency stability. When the added capacitance is small compared to the series capacitance of $C_3$ and $C_4$, the oscillator frequency is determined by the series LC combination of the transformer primary and the added capacitor.

## Crystal Oscillators

A quartz crystal is often used as the frequency-determining element in a transistor oscillator circuit because of its extremely high Q (narrow bandwidth) and good frequency stability over a given temperature range. A quartz crystal may be operated as either a series or parallel resonant circuit. As shown in Fig. 159, the electrical equivalent of the mechanical vibrating characteristic of the crystal can be represented by a resistance R, an inductance L, and a capacitance $C_s$ in series. The lowest impedance of the crystal occurs at the series resonant frequency of $C_s$ and L; the resonant frequency of the circuit is then determined only by the mechanical vibrating characteristics of the crystal.

The parallel capacitance $C_p$ shown in Fig. 159 represents the electrostatic capacitance between the crystal electrodes. At frequencies above the

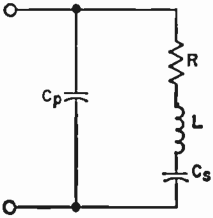



*Fig. 159—Equivalent circuit of quartz crystal.*

series resonant frequency, the combination of L and $C_s$ has the effect of a net inductance because the inductive reactance of L is greater than the capacitive reactance of $C_s$. This net inductance forms a parallel resonant circuit with $C_p$ and any circuit capacitance across the crystal. The impedance of the crystal is highest at the parallel resonant frequency; the resonant frequency of the circuit is then determined by both the crystal and externally connected circuit elements.

Increased frequency stability can be obtained in the tuned-collector and tuned-base oscillators discussed previously if a crystal is used in the feedback path. The oscillation frequency is then fixed by the crystal. At frequencies above and below the series resonant frequency of the crystal, the impedance of the crystal increases and the feedback is reduced. Thus, oscillation is prevented at frequencies other than the series resonant frequency.

The parallel mode of crystal resonance is used in the Pierce oscillator shown in Fig. 160. (If the crystal were replaced by its equivalent cir-

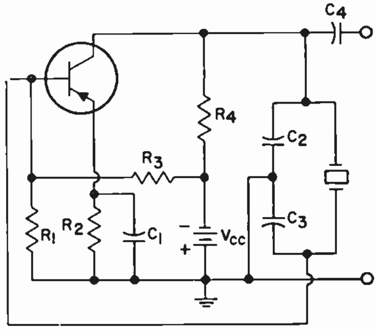



*Fig. 160—Pierce-type transistor crystal oscillator.*

cuit, the functioning of the oscillator would be analogous to that of the Colpitts oscillator shown in Fig. 155.) The resistances shown in Fig. 160 provide the proper bias and stabilizing conditions for the common-emitter circuit. Capacitor $C_1$ is the emitter bypass capacitor. The required 180-degree phase inversion of the feedback signal is accomplished through the arrangement of the voltage-divider network $C_2$ and $C_3$. The connection between the capacitors is grounded so that the voltage developed across $C_3$ is applied between base and ground and a 180-degree phase reversal is obtained. The oscillating frequency of the circuit is determined by the crystal and the capacitors connected in parallel with it.

The field-effect transistor also operates well in crystal oscillator circuits such as the Pierce-type oscillators shown in Fig. 161. Pierce oscillator are extremely popular because

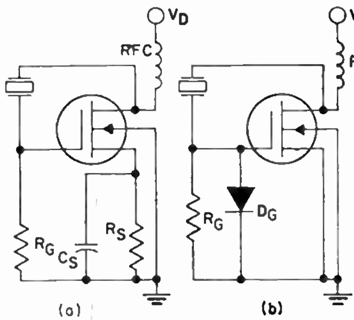



*Fig. 161—Pierce-type crystal oscillator circuits using MOS transistors.*

of their simplicity and minimum number of components. At frequencies below 2 MHz, a capacitive voltage divider may be required across the crystal. The connection between the voltage-divider capacitors must be grounded so that the voltage developed across the capacitors is reversed in phase by 180 degrees.

It is frequently desirable to operate crystals in communications equipment at their harmonic or overtone frequencies; Fig. 162 shows two circuits designed for this purpose. Additional feedback is obtained for the overtone crystal by the use of a capacitive divider as the tuned-circuit bypass. Most third-overtone crystals operate satisfactorily without this additional feedback, but the extra feedback is required for the 5th and 7th harmonics. The tuned circuit in Figs. 162(a) and 162(b) is not fully bypassed and produces a voltage that aids oscillation. The crystal in both circuits is connected to the junction of the capacitors $C_d'$ and $C_d''$; the ratio of these capacitors should be approximately 1:3.

The circuit of Fig. 163 operates well with low-frequency quartz bars. The crystal is located in the feedback circuit between the sources of

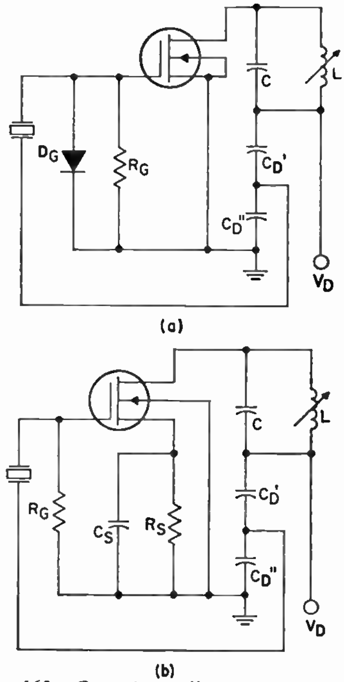



*Fig. 162—Crystal oscillator circuits permitting operation at overtone or harmonic frequencies.*

the two field-effect transistors and operates in the series mode. Capacitor $C_2$ is normally used for precise adjustment of the frequency of the

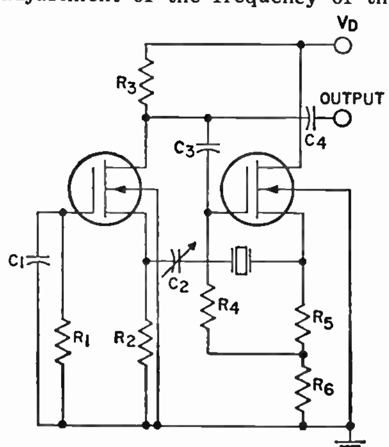



*Fig. 163—Low-frequency crystal oscillator circuit using MOS transistors.*

oscillator; a reduction in the capacitance increases the frequency slightly.

## RC Feedback Oscillators

A resistance-capacitance (RC) network is sometimes used in place of an inductance-capacitance network in a transistor oscillator. In the phase-shift oscillator shown in Fig. 164, the RC network consists of three sections ($C_1R_1$, $C_2R_2$, and $C_3R_3$), each of which contributes a phase shift of 60 degrees at the frequency of oscillation. Because the capacitive reactance of the network increases or decreases at other frequencies, the 180-degree phase shift required for the common-emitter oscillator occurs only at one frequency; thus, the output frequency of the oscillator is fixed. Phase-shift oscillators may be

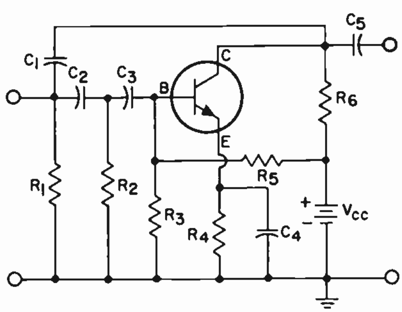



*Fig. 164—Transistor RC phase-shift oscillator.*

made variable over particular frequency ranges by the use of ganged variable capacitors or resistors in the RC networks. Three or more sections must be used in the phase-shifting networks to reduce feedback losses. The use of more sections contributes to increased stability.

## FREQUENCY CONVERSION

Transistors can be used in various types of circuits to change the frequency of an incoming signal. In radio and television receivers, frequency conversion is used to change the frequency of the rf signal to an intermediate frequency. In communications transmitters, frequency multiplication is often used to raise the frequency of the developed rf signal.

In a radio or television receiver, the oscillating and mixing functions are performed by a nonlinear device such as a diode or a transistor. As shown in the diagram of Fig. 165,

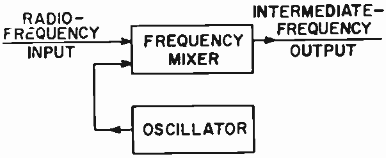



*Fig. 165—Block diagram of simple frequency-converter circuit.*

two voltages of different frequencies, the rf signal voltage and the voltage generated by the oscillator, are applied to the input of the mixer. These voltages "beat," or heterodyne, within the mixer transistor to produce a current having, in addition to the frequencies of the input voltages, numerous sum and difference frequencies.

The output circuit of the mixer stage is provided with a tuned circuit which is adjusted to select only one beat frequency, i.e., the frequency equal to the difference between the signal frequency and the oscillator frequency. The selected output frequency is known as the intermediate frequency, or if. The output frequency of the mixer transistor is kept constant for all values of signal frequency by tuning of the oscillator circuit.

In AM broadcast-band receivers, the oscillator and mixer functions are often accomplished by use of a single transistor called an "autodyne converter". In FM receivers, stable oscillator operation is more readily obtained when a separate transistor is used for the oscillator function. In such a circuit, the oscillator voltage is applied to the mixer by inductive coupling, capacitive coupling, or a combination of the two.

## AUTOMATIC FREQUENCY CONTROL

An automatic frequency control (afc) circuit is often used to provide automatic correction of the oscillator frequency of a superheterodyne receiver when, for any reason, it drifts from the frequency which produces the proper if center frequency. This correction is made by adjustment of the frequency of the oscillator. Such a circuit automatically compensates for slight changes in rf carrier or oscillator frequency, as well as for inaccurate manual or push-button tuning.

An afc system requires two sections: a frequency detector and a variable reactance. The detector section may be essentially the same as the FM detector illustrated in Fig. 120. In the afc system, however, the output is a dc control voltage, the magnitude of which is proportional to the amount of frequency shift. This dc control voltage is used to control the bias on a transistor or diode which comprises the variable reactance.

Automatic frequency control is also used in television receivers to keep the horizontal oscillator in step with the horizontal-scanning frequency at the transmitter. A widely used horizontal afc circuit is shown in Fig. 166. This circuit, which is often referred to as a balanced-phase-detector or phase-discriminator circuit, is usually employed to control the frequency of the horizontal-oscillator circuit. The detector diodes supply a dc control voltage to the horizontal-oscillator circuit which counteracts changes in its operating frequency. The magnitude and polarity of the control voltages are determined by phase relationships in the afc circuit.

The horizontal sync pulses obtained from the sync-separator circuit are fed through a phase-inverter or phase-splitter circuit to the two diode detectors. Because of the action of the phase-inverter circuit, the signals applied to the two diode units are equal in amplitude but 180 degrees out of phase. A reference sawtooth voltage obtained from the horizontal output circuit is also applied simultaneously to both units. The diodes are biased so that conduction takes place only during the tips of the sync pulses. Any change in the oscillator frequency alters the phase relationship betwen the reference sawtooth and the incoming horizontal sync pulses, and thus causes one of the diodes to conduct more heavily than the other so that a correction signal is produced. The system remains unbalanced at all times, therefore, because momentary changes in oscillator frequency are instantaneously corrected by the action of this control voltage. The network between the diodes and the horizontal-oscillator circuit is essentially a low-pass filter which prevents the horizontal sync pulses from affecting the horizontal-oscillator performance.

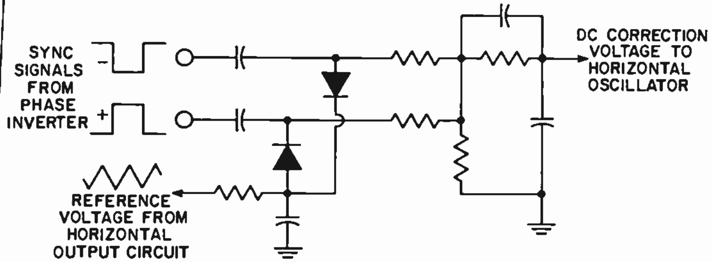



*Fig. 166—Balanced-phase-detector or phase-discriminator circuit for horizontal afc.*

# Low-Frequency Amplification

THE amplifying action of a transistor can be used in various ways in electronic circuits, depending on the results desired. The four recognized classes of amplifier service can be defined for transistor circuits as follows:

A class A amplifier is an amplifier in which the base bias and alternating signal are such that collector current in a transistor flows continuously during the complete electrical cycle of the signal, and even when no signal is present.

A class AB amplifier is an amplifier in which the base bias and alternating signal are such that collector current in a transistor flows for appreciably more than half but less than the entire electrical cycle.

A class B amplifier is an amplifier in which the base is biased to approximately collector-current cutoff, so that collector current is approximately zero when no signal is applied, and so that collector current in a transistor flows for approximately one-half of each cycle when an alternating signal is applied.

A class C amplifier is an amplifier in which the base is biased to such a degree that the collector current in a transistor is zero when no signal is applied, and so that collector current in a transistor flows for appreciably less than one-half of each cycle when an alternating signal is applied.

For radio-frequency (rf) amplifiers which operate into selective tuned circuits, such as the Tuned Amplifiers discussed in the section on Receiver Tuner-Circuit Applications, or for other amplifiers in which distortion is not a prime factor, any of the above classes of amplification may be used with either a single transistor or a push-pull stage. For audio-frequency (af) amplifiers in which distortion is an important factor, single transistors can be used only in class A amplifiers. For class AB or class B audio-amplifier service, a balanced amplifier stage using two transistors is required. A push-pull stage can also be used in class A audio amplifiers to obtain reduced distortion and greater power output. Class C amplifiers cannot be used for audio or AM applications.

## AUDIO AMPLIFIERS

Audio amplifier circuits are used in radio and television receivers, public address systems, sound recorders and reproducers, and similar applications to amplify signals in the frequency range from 20 to 20,000 Hz. Each transistor in an audio amplifier can be considered as either a current amplifier or a power amplifier. The type of circuit configuration selected is dictated by the requirements of the given application. The output power to be supplied, the required sensitivity and frequency response, and the maximum distortion limits, together with the capabilities and limitations of available devices, are the main criteria used to determine the circuit that will provide the desired performance most efficiently and economically.

In addition to the consideration that must be given to the achievement of performance objectives and the selection of the optimum circuit configuration, the circuit designer must also take steps to assure reliable operation of the audio amplifier under varying conditions of signal level, frequency, ambient temperature, load impedance, line voltage, and other factors which may subject the transistors to either transient or steady-state high stress levels. Low-cost, low-power audio systems (such as those used in mobile and TV output stages), in which high operating efficiency is not an important consideration, usually employ a single-ended, class A, transformer-coupled output stage such as that shown in Fig. 167.

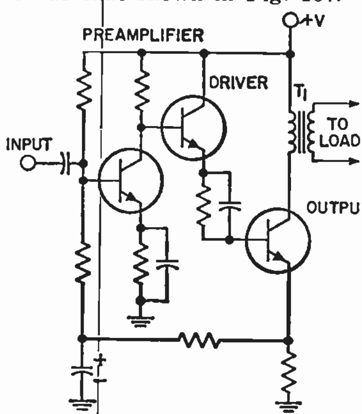



*Fig. 167—Typical low-power audio-amplifier circuit.*

The input to an audio amplifier is a low-power-level audio signal from the phonograph or magnetic-tape pickup head or, in a radio receiver, from the detector stage as indicated in Fig. 129. This signal is usually amplified through a preamplifier stage, one or more low-level (pre-driver or driver) audio stages, and an audio power amplifier. The system may also include frequency-selective circuits which act as equalization networks and/or tone controls.

## Low-Level Audio Stages

Simple class A amplifier circuits are normally used in low-level audio stages such as preamplifiers and drivers. Preamplifiers usually follow low-level output transducers such as microphones, hearing-aid and phonograph pickup devices, and recorder-reproducer heads.

Noise Figure—One of the important characteristics of a low-level amplifier circuit is its signal-to-noise ratio, or noise figure. The input circuit of an amplifier inherently contains some thermal noise contributed by the resistive elements in the input device. All resistors generate a predictable quantity of noise power as a result of thermal activity. This power is about 160 dB below one watt for a bandwidth of 10 kHz.

When an input signal is amplified, therefore, the thermal noise generated in the input circuit is also amplified. If the ratio of signal power to noise power (S/N) is the same in the output circuit as in the input circuit, the amplifier is considered to be "noiseless" and is said to have a noise figure of unity, or zero dB.

In practical circuits, however, the ratio of signal power to noise power is inevitably impaired during amplification as a result of the generation of additional noise in the circuit elements. A measure of the degree of impairment is called the noise figure (NF) of the amplifier, and is expressed as the ratio of signal power to noise power at the input ($S_i/N_i$) divided by the ratio of signal power to noise power at the output ($S_o/N_o$), as follows:

$$NF = \frac{S_i/N_i}{S_o/N_o}$$

The noise figure in dB is equal to ten times the logarithm of this power ratio. For example, an amplifier with a 1-dB noise figure decreases the signal-to-noise ratio by a factor of 1.26, a 3-dB noise figure by a factor of 2, a 10-dB noise figure by a factor of 10, and a 20-dB noise figure by a factor of 100.

In audio amplifiers, it is desirable that the noise figure be kept low. In general, the lowest value of NF is obtained by use of an emitter current of less than one milliampere and a collector voltage of less than two volts for a signal-source resistance between 300 and 3000 ohms. If the input impedance of the transistor is matched to the impedance of the signal source, the lowest value of NF that can be attained is 3 dB. Generally, the best noise figure is obtained by use of a transistor input impedance approximately 1.5 times the source impedance. However, this condition is often not realizable in practice because many transducers are reactive rather than resistive. In addition, other requirements such as circuit gain, signal-handling capability, and reliability may not permit optimization for noise.

In the simple low-level amplifier stage shown in Fig. 168, resistor $R_1$

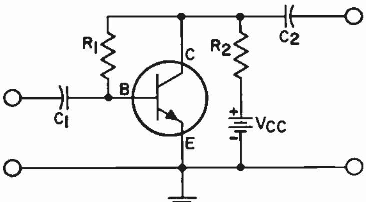



*Fig. 168—Simple low-level class A amplifier.*

determines the base bias for the transistor. The output signal is developed across the load resistor $R_2$. The collector voltage and the emitter current are kept relatively low to reduce the noise figure. If the load impedance across the capacitor $C_2$ is low compared to $R_2$, very little voltage swing results on the collector. Therefore, ac feedback through $R_1$ does not cause much reduction in gain.

Equalization—In many cases, low-level amplifier stages used as pre-amplifiers include some type of frequency-compensation network to enhance either the low-frequency or the high-frequency components of the input signal. The frequency range and dynamic range* which can be recorded on a phonograph record or on magnetic tape depend on several factors, including the composition, mechanical characteristics, and speed of the record or tape, and the electrical and mechanical characteristics of the recording equipment. To achieve wide frequency and dynamic range, manufacturers of commercial recordings use equipment which introduces a nonuniform relationship between amplitude and frequency. This relationship is known as a "recording characteristic". To assure proper reproduction of a high-fidelity recording, therefore, some part of the reproducing system must have a frequency-response characteristic which is the inverse of the recording characteristic. Most manufacturers of high-fidelity recordings use the RIAA characteristic for discs and the NARTB characteristic for magnetic tape.

The simplest type of equalization network is shown in Fig. 169. Because the capacitor C is effectively an open circuit at low frequencies, the low frequencies must be passed through the resistor R and are attenuated. The capacitor has a lower reactance at high frequencies, however, and bypasses high-frequency components around R so that they

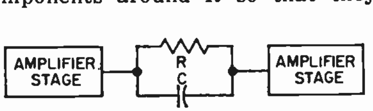



*Fig. 169—Simple RC frequency-compensation network.*

receive negligible attenuation. Thus the network effectively "boosts" the high frequencies. This type of equalization is called "attenuative."

Some typical preamplifier stages are shown in the Circuits section. The location of the frequency-compensation network or "equalizer" in the reproducing system depends on the types of recordings which are to

* The dynamic range of an amplifier is a measure of its signal-handling capability. The dynamic range expresses in dB the ratio of the maximum usable output signal (generally for a distortion of about 10 per cent) to the minimum usable output signal (generally for a signal-to-noise ratio of about 20 dB). A dynamic range of 40 dB is usually acceptable; a value of 70 dB is exceptional for any audio system.

be reproduced and on the pickup devices used. All commercial pickup devices provide very low power levels to a transistor preamplifier stage.

A ceramic high-fidelity phonograph pickup is usually designed to provide proper compensation for the RIAA recording characteristic when the pickup is operated into the load resistance specified by its manufacturer. Usually, a "matching" resistor is inserted in series with the input of the preamplifier transistor. However, this arrangement produces a fairly small signal current which must then be amplified. If the matching resistor is not used, equalization is required, but some improvement can be obtained in dynamic range and gain.

A magnetic high-fidelity phonograph pickup, on the other hand, usually has an essentially flat frequency-response characteristic. Because a pickup of this type merely reproduces the recording characteristic, it must be followed by an equalizer network, as well as by a preamplifier having sufficient gain to satisfy the input requirements of the tone-control amplifier and/or power amplifier. Many designs include both the equalizing and amplifying circuits in a single unit.

A high-fidelity magnetic-tape pickup head, like a magnetic phonograph pickup, reproduces the recording characteristic. This type of pickup device, therefore, must also be followed by an equalizing network and preamplifier to provide equalization for the NARTB characteristic.

Feedback networks may also be used for frequency compensation and for reduction of distortion. Basically, a feedback network returns a portion of the output signal to the input circuit of an amplifier. The feedback signal may be returned in phase with the input signal (positive or regenerative feedback) or 180 degrees out of phase with the input signal (negative, inverse, or degenerative feedback). In either case, the feedback can be made proportional to either the output voltage or the output current, and can be applied to either the input voltage or the input current. A negative feedback signal proportional to the output current raises the output impedance of the amplifier; negative feedback proportional to the output voltage reduces the output impedance. A negative feedback signal applied to the input current decreases the input impedance; negative feedback applied to the input voltage increases the input impedance. Opposite effects are produced by positive feedback.

A simple negative or inverse feedback network which provides high-frequency boost is shown in Fig. 170.

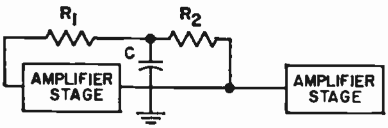



*Fig. 170—Negative-feedback frequency-compensation network.*

This network provides equalization comparable to that obtained with Fig. 169, but is more suitable for low-level amplifier stages because it does not require the first amplifier stage to provide high-level low frequencies. In addition, the inverse feedback improves the distortion characteristics of the amplifier.

Input Impedance—As mentioned previously, it is undesirable to use a high-resistance signal source for a transistor audio amplifier because the extreme impedance mismatch results in high noise figure. High source resistance cannot be avoided, however, if an input device such as a ceramic pickup is used. In such cases, the use of negative feedback to raise the input impedance of the amplifier circuit (to avoid mismatch loss) is no solution because feedback cannot improve the signal-to-noise ratio of the amplifier. A more practical method is to increase the input impedance somewhat by operating the transistor at the lowest practical current level and by using a transistor which has a high forward current-transfer ratio.

**Volume and Tone Controls**—Some preamplifier or low-level audio amplifier circuits include variable resistors or potentiometers which function as volume or tone controls. Such circuits should be designed to minimize the flow of dc currents through these controls so that little or no noise will be developed by the movable contact during the life of the circuit. Volume controls and their associated circuits should permit variation of gain from zero to maximum, and should attenuate all frequencies equally for all positions of the variable arm of the control. Several examples of volume controls and tone controls are shown in the Circuits section.

A tone control is a variable filter (or one in which at least one element is adjustable) by means of which the user may vary the frequency response of an amplifier to suit his own taste. In radio receivers and home amplifiers, the tone control usually consists of a resistance-capacitance network in which the resistance is the variable element.

The simplest form of tone control is a "treble cut" network such as that shown in Fig. 171. As $R_1$ is made smaller, the capacitor $C_2$ bypasses more of the high audio frequencies; therefore, the output of the network is decreased by an amount dependent upon the value of $R_1$. The resistance of $R_1$ should be very large in comparison to the reactance of $C_2$ at the highest audio frequency.

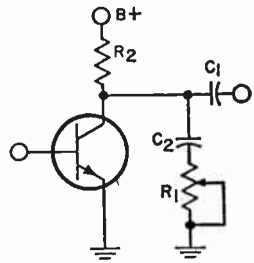



*Fig. 171—Simple tone-control network for fixed tone compensation or equalization.*

The tone-control network shown in Fig. 172 has two stages with completely separate bass and treble controls. Fig. 173 shows simplified representations of the bass control when the potentiometer is turned to its extreme variations (labeled BOOST and CUT). At very high frequencies, $C_1$ and $C_2$ are effectively short circuits and the network becomes the simple voltage divider $R_1$ and $R_2$. In the bass-boost position, $R_3$ is inserted in series with $R_2$ so that there is less attenuation to very low frequencies than to very high frequencies. Therefore, the bass is said to be "boosted". In the bass-cut position, $R_3$ is inserted in series with $R_1$ so that there is more attenuation to very low frequencies.

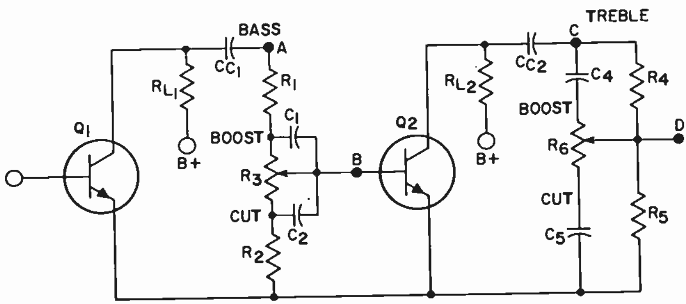



*Fig. 172—Two-stage tone-control circuit incorporating separate bass and treble controls.*

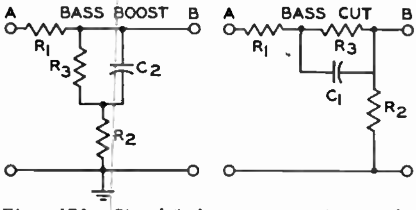



*Fig. 173—Simplified representations of bass-control circuit at extreme ends of potentiometer.*

Fig. 174 shows extreme positions of the treble control. $R_6$ is generally much larger than $R_4$ or $R_5$ and may be treated as an open circuit in the extreme positions. In both the boost and cut positions, very low frequencies are controlled by the voltage divider $R_4$ and $R_5$. In the boost position,

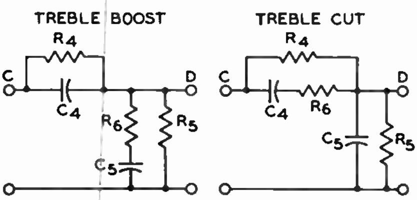



*Fig. 174—Simplified representations of treble-control circuit at extreme ends of potentiometer.*

$R_4$ is bypassed by the high frequencies and the voltage-divider point D is placed closer to C. In the cut position, $R_5$ is bypassed and there is greater attenuation of the high frequencies.

The frequencies at which boost and cut occur in the circuit of Fig. 172 are controlled by the values of $C_1$, $C_2$, $C_4$, and $C_5$. Both the output impedance of the driving stage (generally $R_{L1}$) and the loading of the driven stage affect the response curves and must be considered. This tone-control circuit, like the one in Fig. 171, is attenuative. Feedback tone controls may also be employed.

The location of a tone-control network is of considerable importance. In a typical preamplifier, it may be in the collector circuit of the final low-level stage or in the input circuit of the first stage. If the amplifier incorporates negative feedback, the tone control must be inserted in a part of the amplifier which is external to the feedback loop, or must be made a part of the feedback network. The over-all gain of a well designed tone-control network should be approximately unity. The system dynamic range should be adequate for all frequencies anticipated with the tone controls in any position. The high-frequency gain should not be materially affected as the bass control is varied, nor should the low-frequency gain be sensitive to the treble control.

## Driver and Output Stages

Driver stages in audio amplifiers are located immediately before the power-output stage. When a single-ended class A output stage is used, the driver stage is similar to a preamplifier stage. When a push-pull output stage in which both transistors are the same type (n-p-n or p-n-p) is used, however, the audio driver must provide two output signals, each 180 degrees out of phase with the other. This phase requirement can be met by use of a tapped-secondary transformer between a single-ended driver stage and the output stage, as shown in Fig. 175.

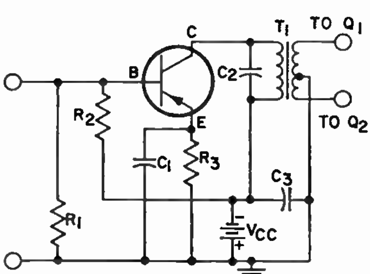



*Fig. 175—Driver stage for push-pull output circuit.*

The transformer $T_1$ provides the required out-of-phase input signals for the two transistors $Q_1$ and $Q_2$ in the push-pull output stage.

Transistor audio power amplifiers may be class A single-ended stages, or class A, class AB, or class B push-pull stages. A simple class A single-ended power amplifier is shown in Fig. 176. Component values which will provide the desired power output can be calculated from the

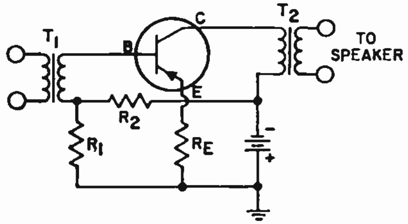



*Fig. 176—Class A power-amplifier circuit.*

transistor characteristics and the supply voltage. For example, an output of four watts may be desired from a circuit operating with a supply voltage of 14.5 volts (this voltage is normally available in automobiles which have a 12-volt ignition system). If losses are assumed to be negligible, the power output ($P_o$) is equal to the peak collector voltage ($e_c$) times the peak collector current ($i_c$), each divided by the square root of two to obtain rms values. The peak collector current can then be determined as follows:

$$P_o = \frac{e_c}{(2)^{1/2}} \times \frac{i_c}{(2)^{1/2}}$$

$$i_c = P_o (2)^{1/2} \times \frac{(2)^{1/2}}{e_c}$$

$$= 4 (2)^{1/2} \times \frac{(2)^{1/2}}{14.5}$$

$$= 0.55, \text{ or approximately } 0.6 \text{ ampere}$$

In class A service, the dc collector current and the peak collector swing are about the same. Thus, the collector voltage and current are 14.5 volts and 0.6 ampere, respectively.

The voltage drop across the resistor $R_E$ in Fig. 176 usually ranges from 0.3 to 1 volt; a typical value of 0.6 volt can be assumed. The value of $R_E$ must equal the 0.6-volt drop divided by the 0.6-ampere emitter current, or one ohm. (The emitter current is assumed to be nearly equal to the 0.6-ampere collector current.)

The current through resistor $R_2$ should be about 10 to 20 per cent of the collector current; a typical value is 15 per cent of 0.6, or 90 milliamperes.

The voltage from base to ground is equal to the base-to-emitter voltage (determined from the transistor transfer-characteristics curves for the desired collector or emitter current; normally about 0.4 volt for a germanium power transistor operating at an emitter current of 600 milliamperes) plus the emitter-to-ground voltage (0.6 volt as described above), or one volt. The voltage across $R_2$, therefore, is 14.5 minus 1, or 13.5 volts. The value of $R_2$ must equal 13.5 divided by 90, or about 150 ohms.

Because the voltage drop across the secondary winding of the driver transformer $T_1$ is negligible, the voltage drop across $R_1$ is one volt. The current through $R_1$ equals the current through $R_2$ (90 milliamperes) minus the base current. If the dc forward current-transfer ratio (beta) of the transistor selected has a typical value of 60, the base current equals the collector current of 600 milliamperes divided by 60, or 10 milliamperes. The current through $R_1$ is then 90 minus 10, or 80 milliamperes, and the value of $R_1$ is 1 volt divided by 80 milliamperes, or about 12 ohms.

The transformer requirements are determined from the ac voltages and currents in the circuit. The peak collector voltage swing that can be used before distortion occurs as a result of clipping of the output voltage is about 13 volts. The peak collector current swing available before current cutoff occurs is the dc current of 600 milliamperes. Therefore, the collector load impedance should be 13 volts divided by 600 milliamperes, or about 20 ohms, and the output transformer $T_2$ should be designed to match a 20-ohm primary impedance to the desired speaker impedance. If a 3.2-ohm speaker is used, for example, the impedance values for $T_2$ should be 20 ohms to 3.2 ohms.

The total input power to the circuit of Fig. 176 is equal to the voltage required across the secondary winding of the driver transformer $T_1$ times the current. The driver signal current is equal to the base current (10 milliamperes peak, or 7 milliamperes rms). The peak ac signal voltage is nearly equal to the sum of the base-to-emitter voltage across the transistor (0.4 volt as determined above), plus the voltage across $R_E$ (0.6 volt), plus the peak ac signal voltage across $R_1$ (10 milliamperes times 12 ohms, or 0.12 volt). The input voltage, therefore, is about one volt peak, or 0.7 volt rms. Thus, the total ac input power required to produce an output of 4 watts is 0.7 volt times 7 milliamperes, or 5 milliwatts, and the input impedance is 0.7 volt divided by 7 milliamperes, or 100 ohms.

Higher power output can be achieved with less distortion in class A service by the use of a **push-pull amplifier.** One of the disadvantages of a transistor class A amplifier (single-ended or push-pull), however, is that collector current flows at all times. As a result, transistor dissipation is highest when no ac signal is present. This dissipation can be greatly reduced by use of class B push-pull operation. When two transistors are connected in class B push-pull, one transistor amplifies half of the signal, and the other transistor amplifies the other half. These half-signals are then combined in the output circuit to restore the original waveform in an amplified state.

Ideally, transistors used in class B push-pull service should be biased to collector cutoff so that no power is dissipated under zero-signal conditions. At low signal inputs, however, the resulting signal would be distorted, as shown in Fig. 177, because of the low forward current-transfer ratio of the transistor at very low currents. This type of distortion, called cross-over distortion, can be suppressed by the use of a bias voltage which permits a small collector current flow at zero signal level. Any residual distortion can be further reduced by the use of negative feedback.

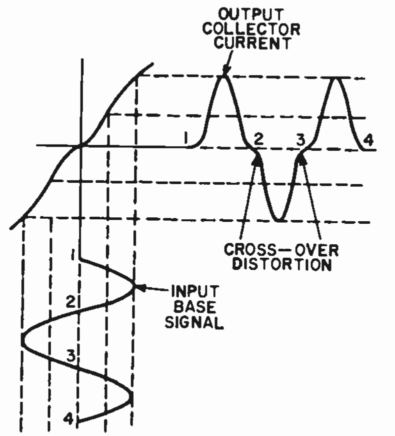



*Fig. 177—Waveforms showing cause of cross-over distortion.*

A typical class B push-pull audio amplifier is shown in Fig. 178. Resistors $R_{E1}$ and $R_{E2}$ are the emitter stabilizing resistors. Resistors $R_1$ and $R_2$ form a voltage-divider network which provides the bias for the transistors. The base-emitter circuit is biased near collector cutoff so that

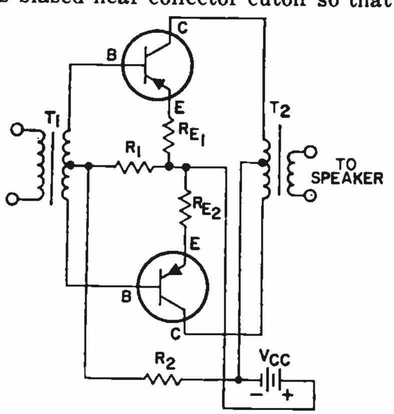



*Fig. 178—Class B push-pull audio-amplifier circuit.*

very little collector power is dissipated under no-signal conditions. The characteristics of the bias network must be very carefully chosen so that the bias voltage will be just sufficient to minimize cross-over distortion at low signal levels. Because the collector current, collector dissipation, and dc operating point of a transistor vary with ambient temperature, a temperature-sensitive resistor (such as a thermistor) or a bias-compensating diode may be used in the biasing network to minimize the effect of temperature variations.

The advantages of class B push-pull operation can be obtained without the need for an output transformer by use of a circuit such as that shown in Fig. 179. In this circuit, the secondary windings of the driver transformer $T_1$ are phased so that a negative signal from base to emitter of one transistor is accompanied by a positive signal from

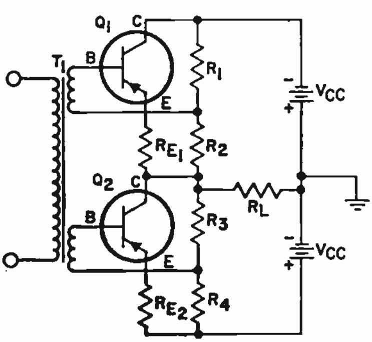



*Fig. 179—Single-ended class B circuit.*

base to emitter of the other transistor. When a negative signal is applied to the base of transistor $Q_1$, for example, $Q_1$ draws current. This current must flow through the load because the accompanying positive signal on the base of transistor $Q_2$ cuts $Q_2$ off. When the signal polarity reverses, transistor $Q_1$ is cut off, while $Q_2$ conducts current. The resistive dividers $R_1R_2$ and $R_3R_4$ provide a dc bias which keeps the transistors slightly above cutoff under no-signal conditions and thus minimizes cross-over distortion. The emitter resistors $R_{E1}$ and $R_{E2}$ help to compensate for differences between transistors and for the effects of ambient-temperature variations.

The secondary windings of any class B driver transformer should be bifilar-wound (i.e., wound together) to obtain tighter coupling and thereby minimize leakage inductance. Otherwise, "ringing" may occur in the cross-over region as a result of the energy stored in the leakage inductance.

Because junction transistors can be made in both p-n-p and n-p-n types, they can be used in complementary-symmetry circuits to obtain all the advantages of conventional push-pull amplifiers plus direct coupling. The arrows in Fig. 180 indicate the direction of electron current flow in the terminal leads of p-n-p and n-p-n transistors. When these

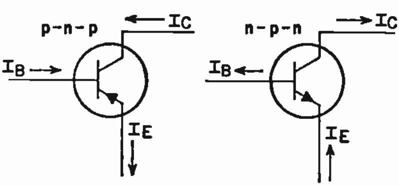



*Fig. 180—Electron-current flow in p-n-p and n-p-n transistors.*

two transistors are connected in a single stage, as shown in Fig. 181, the steady-state electron current path in the output circuit is completed through the collector-emitter

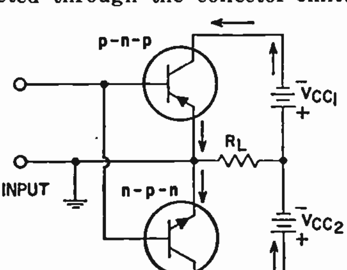



*Fig. 181—Basic complementary-symmetry circuit.*

circuits of the transistors. In the circuits of Figs. 179 and 181, essentially no steady-state current flows through the load resistor $R_L$. Therefore, the voice coil of a loudspeaker can be connected directly in place of $R_L$ without excessive speaker cone distortion.

The true complementary amplifier, shown in Fig. 182, is the simplest of all complementary circuits. Its features include a single

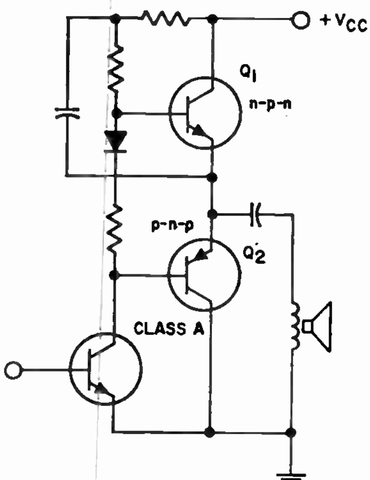



*Fig. 182—True-complementary amplifier.*

driver transistor, a single diode for bias, and the application of turn-off drive to the output devices. Because it requires a class A driver and both p-n-p and n-p-n output devices and has high standby current, the true-complementary design is seldom used for power-output levels in excess of 25 watts rms.

The class A driver stage shown in Fig. 182 requires the use of a large heat sink. The p-n-p power device in the complementary output stage is more expensive and has lower safe-area ratings than its n-p-n equivalent. Because control of base diffusion is more difficult in p-n-p devices, these types are generally 25-per-cent costlier than comparable n-p-n types.

One way to avoid the high cost of power p-n-p transistors is to employ a quasi-complementary circuit such as that shown in Fig. 183. In this type of circuit, a low-current

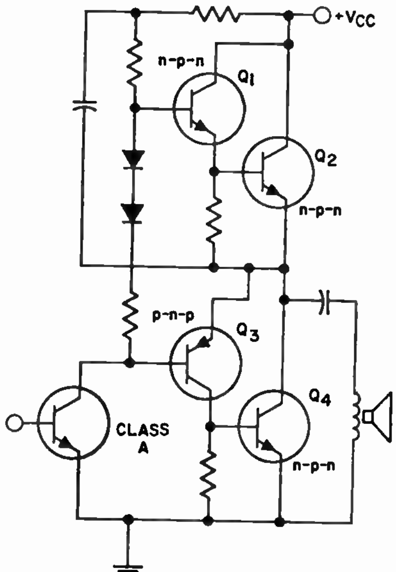



*Fig. 183—Quasi-complementary amplifier.*

p-n-p transistor is directly coupled to a high-current n-p-n transistor to simulate a high-current transistor, as shown in Fig. 184.

The advantages of quasi-complementary amplifiers include improved safe area for the n-p-n output transistor, lower cost, and the use of class B drivers. The major disadvantages are the need for two driver transistors and two bias diodes, and the absence of turn-off drive to the output transistors. Because the advantages far outweigh the disadvantages for high-power amplifiers, quasi-complementary circuits are generally used at power levels above 25 watts rms. The high-frequency response of such circuits can be improved by use of bleeder resistors in the base circuits of the output transistors.

In both true-complementary and quasi-complementary circuits, the output devices do not need to be well matched for beta. These circuits are essentially voltage amplifiers used in an emitter-follower configuration that has a voltage gain of nearly unity which varies only slightly with transistor beta. In the higher-power quasi-complementary amplifier, the effect of beta is even less important because a Darlington-connected stage is used. The basic requirement is that a minimum current gain be maintained from minimum to maximum drive.

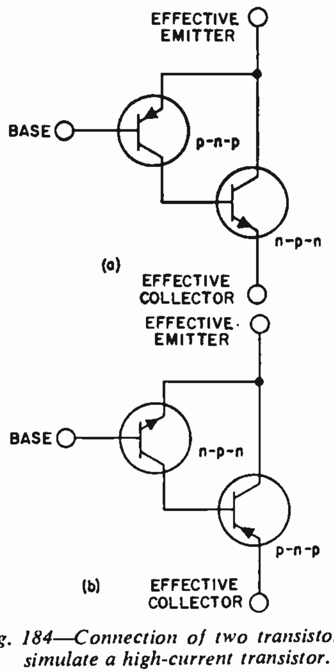



*Fig. 184—Connection of two transistors to simulate a high-current transistor.*

Several **high-fidelity amplifiers** are shown in the Circuits section. The performance capabilities of such amplifiers are usually given in terms of frequency response, total harmonic distortion, maximum power output, and noise level. To provide high-fidelity reproduction of audio program material, an amplifier should have a **frequency response** which does not vary more than 1 dB over the entire audio spectrum. General practice is to design the amplifier so that its frequency response is flat within 1 dB from a frequency well below the lowest to be reproduced to one well above the upper limit of the audible region.

**Harmonic distortion** and **intermodulation distortion** produce changes in program material which may have adverse effects on the quality of the reproduced sound. Harmonic distortion causes a change in the character of an individual tone by the introduction of harmonics which were not originally present in the program material. For high-fidelity reproduction, total harmonic distortion (expressed as a percentage of the output power) should not be greater than about 0.5 per cent at the desired listening level.

Intermodulation distortion is a change in the waveform of an individual tone as a result of interaction with another tone present at the same time in the program material. This type of distortion not only alters the character of the modulated tone, but may also result in the generation of spurious signals at frequencies equal to the sum and difference of the interacting frequencies. Intermodulation distortion should be less than 2 per cent at the desired listening level. In general, any amplifier which has low intermodulation distortion will have very low harmonic distortion.

The **maximum power output** which a high-fidelity amplifier should deliver depends upon a complex relation of several factors, including the size and acoustical characteristics of the listening area, the desired listening level, and the efficiency of the loudspeaker system.

The noise level and maximum output power determine the range of volume the amplifier is able to reproduce, i.e., the difference (usually expressed in dB) between the loudest and softest sounds in program material. Because the greatest volume range utilized in electrical program material at the present time is about 60 dB, the noise level of a high-fidelity amplifier should be at least 60 dB below the signal level at the desired listening level.

The design of audio equipment for direct operation from the ac power line normally requires the use of either a power transformer or a large voltage-dropping resistor to reduce the 120-volt ac line voltage to a level that is appropriate for transistors. Both of these techniques have disadvantages. The use of a transformer adds cost to the system. The use of a dropping resistor places restrictions on the final packaging of the instrument because the resistor must dissipate power. In addition, low-voltage supplies are usually more expensive to filter than high-voltage supplies.

The use of high-voltage silicon transistors eliminates the need for either a power transformer or a high-power voltage-dropping resistor, and permits the use of economical circuits and components in line-operated audio equipment. Several ac/dc circuits using these high-voltage transistors are shown in the Circuits section. The basic class A audio output stage shown in Fig. 185 is essentially of the same design as the class A amplifier discussed previously. Because the supply voltage is much higher, however, the currents are about one-tenth as high and the impedances about 100 times as high.

The use of a voltage-dependent resistor (VDR) as a damping resistor across the primary winding of the output transformer in Fig. 185 protects the output circuit against the destructive effects of transient voltages that can occur under abnormal conditions. If the VDR were not used, the peak collector voltage under transient conditions could be as high as five to ten times the supply voltage, or far in excess of the breakdown-voltage rating for the transistor. Because the resistance of the VDR varies directly with voltage, its use limits the transient voltage to safe levels but does not degrade overall circuit performance.

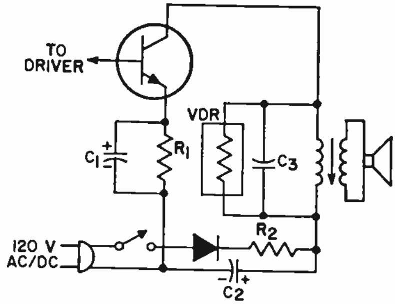



*Fig. 185—Basic audio-output stage for line-operated equipment.*

Fig. 186 shows another effective method for protection against transient voltages. In this arrangement, the output transformer is replaced by a center-tapped transformer and a silicon rectifier that has a peak-reverse-voltage rating of 300 to 400 volts. The peak voltage across the output is thus limited to a value which does not exceed twice the magnitude of the supply voltage. As the collector voltage approaches a value equal to twice the supply voltage, the voltage at the diode end of the transformer becomes sufficiently negative to forward-bias the diode and thus clamp the collector voltage. The required transformer primary impedance is generally about 10,000 ohms center-tapped; in addition, it is recommended that a bifilar winding be used to minimize leakage inductance. Because the arrangement

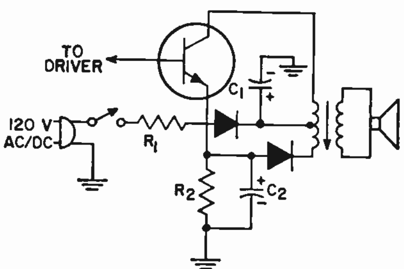



*Fig. 186—Alternate method for protection against transient voltages.*

shown in Fig. 186 provides more reliable protection against transients than that of Fig. 185, a higher supply voltage and a higher transformer impedance can be used.

It should be noted that special precautions are required in the construction of circuits for line-voltage operation. Because these circuits operate at high ac and dc voltages, special care must be exercised to assure that no metallic part of the chassis or output transformer is exposed to touch, accidental or otherwise. The circuits should be installed in non-metallic cabinets, or should be properly insulated from metallic cabinets. Insulated knobs should be used for potentiometer shafts and switches.

A phase inverter is a type of class A amplifier used when two out-of-phase outputs are required. In the split-load phase-inverter stage shown in Fig. 187, the output current of transistor $Q_1$ flows through both the

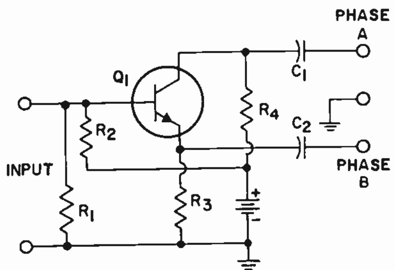



*Fig. 187—Split-load phase-inverter stage.*

collector load resistor $R_4$ and the emitter load resistor $R_3$. When the input signal is negative, the decreased output current causes the collector side of resistor $R_4$ to become more positive and the emitter side of resistor $R_3$ to become more negative with respect to ground. When the input signal is positive, the output current increases and opposite voltage polarities are established across resistors $R_3$ and $R_4$. Thus, two output signals are produced which are 180 degrees out of phase with each other. This circuit provides the 180-degree phase relationship only when each load is resistive and constant throughout the entire signal swing. It is not suitable as a driver stage for a class B output stage.

## DC AMPLIFIERS

Direct-coupled amplifiers are normally used in transistor circuits to amplify small dc or very-low-frequency ac signals; they can amplify signals having a frequency of zero hertz. The upper frequency limit of such an amplifier may range from a few hundred hertz in general-purpose electrometer applications to several megahertz in other applications. In general, dc amplifiers are used to amplify the output of transducers which produce quantitative information relative to heat, vibration, pressure, speed, and distance. Other applications include the output stages of series-type and shunt-type regulating circuits, chopper-type circuits, differential amplifiers, and pulse amplifiers.

Direct-coupled amplifiers are also used in chopper-type circuits to amplify low-level dc signals, as illustrated by the block diagram in Fig. 188. The dc signal modulates an ac carrier wave, usually a square wave, and the modulated wave is then amplified to a convenient level. The series of amplified pulses can then be detected and integrated into the desired dc output signal.

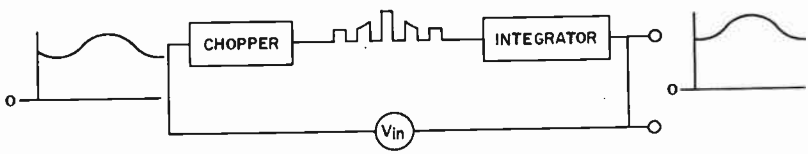



*Fig. 188—Block diagram showing action of "chopper" circuit.*

Chopper amplifiers consist of three basic sections. The first section converts the low-level input signal into a modulated ac signal, the second section amplifies this ac signal, and the third section demodulates the amplified signal.

The first section of a chopper amplifier is fundamentally a continuously operated ON-OFF switch. Ideally, this switch would have zero ON resistance, infinite OFF resistance, zero shunt capacitance, and zero switching time. It would also require no driving power and have infinite life. In actual practice, it is possible to achieve satisfactory performance with a switch that does not have these ideal characteristics.

The two basic circuit configurations for chopping are the series chopper and the shunt chopper. The shunt chopper is the more popular of the two because it can be capacitively coupled to an ac amplifier without the need for either a choke or a transformer. The series chopper has the disadvantage that it requires a dc return path for the input current. This path can be provided by an additional resistor at the expense of over-all circuit efficiency.

The basic series chopper circuit using an MOS transistor is shown in Fig. 189. This circuit has the characteristics of a simple L-pad attenuator in which the transistor is the variable series resistor. In the

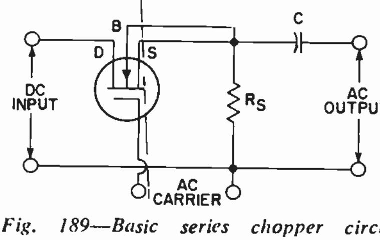



*Fig. 189—Basic series chopper circuit using an MOS transistor.*

ON condition, the value of the dc return resistance $R_S$ must be large compared to the load resistance $R_L$ to minimize resistive losses; $R_L$, in turn, must be large compared to the intrinsic drain resistance $r_d$(ON) so that the voltage $V_L$ across the load approaches the value of the dc input voltage $V_G$. In the OFF condition, the dc return resistance $R_S$ must be small compared to $r_d$(OFF). Because of these restrictions, the series chopper is seldom used except when the fixed resistance $R_S$ can be made variable by replacing it with a shunt chopper arranged to be OFF when the series chopper is ON, and vice versa.

Fig. 190 shows a shunt chopper circuit using an MOS transistor. In

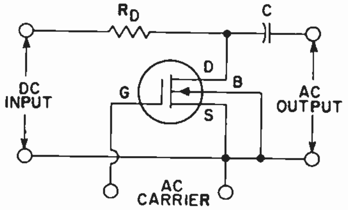



*Fig. 190—Basic shunt copper circuit using an MOS transistor.*

this circuit, the intrinsic drain resistance $r_d$ of the transistor must be small compared to the load resistance $R_L$ in the ON condition, but must be large compared to the fixed series resistance $R_D$ in the OFF condition. The requirement for $r_d$(ON) to have a very small value is minimized if $R_L$ is the high input impedance of an MOS transistor amplifier stage. Because of their high ON-to-OFF resistance ratio, negligible gate-leakage currents, and low feedthrough capacitance, MOS transistors considerably improve the level of solid-state chopper performance.

Differential amplifiers can be used to provide voltage regulation, or to compensate for fluctuations in current due to signal, component, or temperature variations. Typical differential-amplifier circuits, such as those shown in Fig. 191, may also include an output stage which supplies current to the load resistor R, and the necessary number of direct-coupled cascaded stages to provide the required amount of gain for a given condition of line-voltage or load-current regulation. The reference-voltage source $V_R$ is placed in one of the cascaded stages in such a manner that an error or difference signal between $V_R$ and some portion of the output voltage $V_O$ is developed and amplified. Some form of temperature compensation is usually included to insure stability of the direct-coupled amplifier.

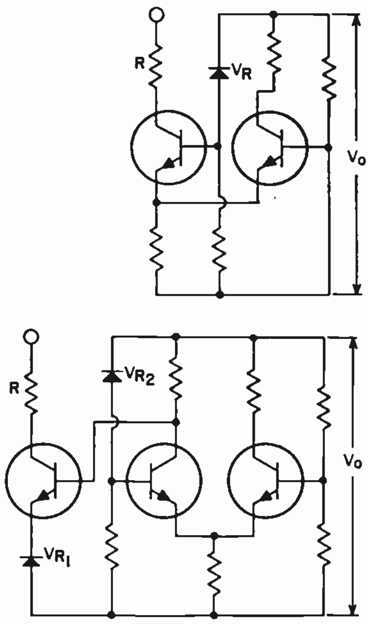



*Fig. 191—Typical differential-amplifier circuits.*

MOS-transistor dc amplifiers may take several different forms, including single-ended input to single-ended output, differential input to single-ended output, and differential input to differential output. Normally dc amplifiers require direct coupling of all stages (no coupling capacitors). In some versions of dc amplifiers, this requirement is circumvented by conversion of the low- or zero-frequency input signal into a modulated ac signal, amplification of this signal by means of capacitor-coupled stages, and then demodulation of the amplified signal to restore it to the original dc form. The necessary modulation may be accomplished by a number of different techniques, including electrically actuated mechanical switches, electronic switches, photo-optical switches, magnetic modulators, and diode bridge modulators. Input devices which function as switches are generally referred to as "choppers" because, as described above, they divide the input signal into segments in the form of square waves or pulses having an amplitude proportional to the amplitude of the input signal.

Single-ended dc amplifiers which do not employ "choppers" have a continuous ohmic current path between the input and the output as the result of direct coupling of all stages (i.e., the omission of all capacitive or inductive forms of coupling). In this configuration, the steady-state voltage at the output of one stage appears at the input of the next stage. In a typical cascade arrangement using MOS field-effect transistors, the signal progresses from the drain of the first unit to the gate of the next and so on to the last stage, as shown in Fig. 192. In this circuit configuration, the source terminal is generally placed at a potential equal to or greater than the drain-to-source voltage of the preceding stage. In the arrangement of Fig. 192, the gate is at a net zero voltage or is reverse-biased relative to the source.

Although MOS transistors are not optimized for direct-coupled applications, they can be used in such circuits because they have low gate leakage current (typically fractions of a picoampere), total input capacitance of about 5 picofarads, and an appreciable value of forward transconductance. In addition, tight production control limits the spread of drain current between individual transistors to a variation of approximately two to one for a high degree of interchangeability.

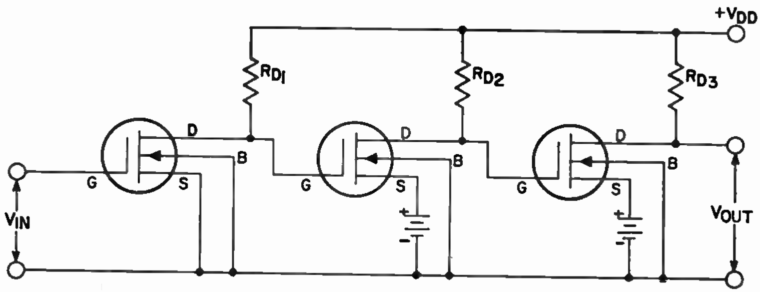



*Fig. 192—DC amplifier circuit in which n-channel depletion-type MOS transistors are direct-coupled by use of dc level shifting.*

For a fixed value of supply voltage, there are only three ways to increase the stage voltage gain A in a single-ended amplifier: (1) use of a transistor having a higher ratio of gate-to-drain forward transconductance $g_{fs}$ to drain current $I_D$; (2) use of a higher value of load resistance $R_L$ (if $R_L$ is less than the common-source output resistance $r_{os}$); and (3) use of a transistor having a higher value of $r_{os}$. The load resistance $R_L$ can only be increased to the point where the product of $I_D$ and $R_L$ is equal to approximately one-half the supply voltage. In general, the ratio of transconductance to drain current increases as drain current is decreased by negative gate bias. As a result, the stage voltage gain may be increased and power consumption decreased at the same time.

The increased voltage gain of an MOS transistor at reduced values of drain current may be accompanied by a relatively large drift in the operating point if there are wide excursions in ambient temperature. Many field-effect transistors have a point on their forward-transfer characteristic which is relatively insensitive to temperature variations. If this point does not coincide with the operating point which provides the desired voltage gain, a design compromise is required. As shown in Fig. 193, the zero-temperature-coefficient point may be identified by measurement of the forward-transfer characteristic at different ambient temperatures.

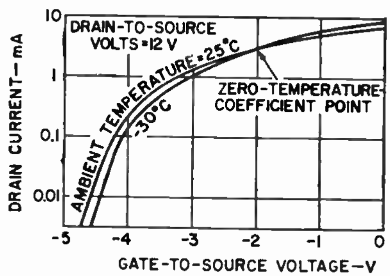



*Fig. 193—Forward-transfer characteristics of MOS transistor at 25°C and −30°C.*

## VOLTAGE-CONTROLLED ATTENUATORS

Because the drain current-voltage characteristic of MOS transistors remains linear at low drain-to-source voltages, these devices can be used as low-distortion voltage-controlled attenuators. The principal advantages of MOS transistors in this application are negligible gate-power requirements and large dynamic range.

Fig. 194 shows drain resistance as a function of gate-to-source voltage for a typical n-channel depletion-type insulated-gate transistor. Transistors having higher pinch-off voltages accept correspondingly greater peak signal-voltage swings before wave-shape distortion occurs.

However, the higher-pinch-off-voltage transistors require higher gate-voltage excursions to cover the resistance range from minimum to

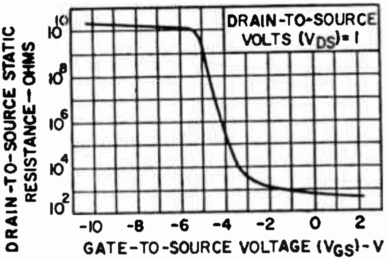



*Fig. 194—Drain resistance as a function of gate voltage for typical n-channel depletion-type MOS transistor.*

maximum. A typical n-channel MOS transistor produces total harmonic distortion of less than two per cent in a 100-millivolt 400-Hz sine wave. Fig. 195 shows an attenuator circuit using an MOS transistor and the output signal of the circuit as a function of gate-to-source voltage.

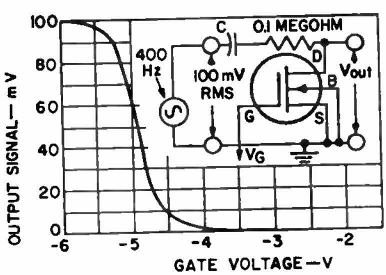



*Fig. 195—Output signal as a function of gate voltage for MOS transistor in circuit shown.*

Figs. 196 and 197 show two possible attenuator circuit configurations which use MOS transistors as voltage-variable resistors. The circuit in Fig. 196 is desirable for use at high signal levels because at such levels the thermal noise of the one-megohm series resistor does not degrade the signal-to-noise ratio of the system to an objectionable degree.

This circuit is a simple L-pad configuration in which the transistor serves as the variable-resistive element in the low side of the attenuator. The maximum attenuation obtainable is generally between 60 and 70 dB; minimum attenuation is 1 to 2 dB. This circuit must be followed by a high-impedance load such as a common-source amplifier stage.

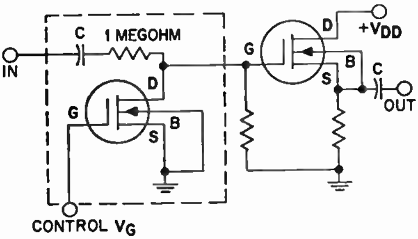



*Fig. 196—Attenuator circuit in which MOS transistor serves as variable-resistive element in low side.*

The circuit shown in Fig. 197 is the inverse of that in Fig. 196; i.e., the transistor serves as the variable-resistive element in the high side of the attenuator. Maximum attenuation in this circuit is also between 60 and 70 dB; minimum attenuation is between 1 and 6 dB. This circuit is

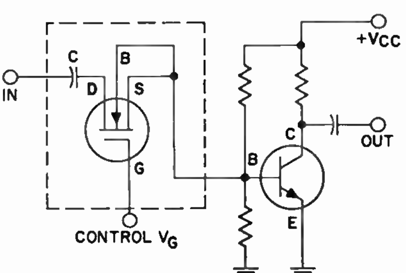



*Fig. 197—Attenuator circuit in which MOS transistor serves as variable-resistive element in high side.*

usually followed by a low-impedance load such as a common-emitter bipolar transistor amplifier stage.

The following design considerations are important for effective use of MOS field-effect transistors as linear attenuators:

(a) The gate(s) must be adequately decoupled to prevent the introduction of unwanted signals.

(b) The transistor attenuator must be inserted at a point in the system where the signal level is as high as the transistor can accept without excessive distortion.

(c) In ac systems, the direct-current flow through the transistor must be minimized by the use of suitable blocking capacitors.

(d) In ac systems, proper layout must be used to minimize stray shunt capacitance.

(e) In ac systems, the effects of the capacitive elements of the transistor must be considered.

## WIDE-BAND (VIDEO) AMPLIFIERS

In television camera chains as well as in ac voltmeters and vertical amplifiers for oscilloscopes, it is necessary for a transistor circuit to amplify signals ranging from very low frequencies (several hertz) to high frequencies (tens of megahertz) with a minimum of frequency and time-delay distortion. In response to these demands, circuit compensation techniques have been developed to minimize the amplitude and time-delay variation as the upper or lower frequency limits of the amplifier are approached.

The need for such compensation is evident when many identical stages of amplification are employed. If ten cascaded stages are used, a variation of 0.3 dB per stage results in a total variation of 3 dB. In an uncompensated amplifier, this total variation occurs two octaves (a frequency ratio of four) prior to the half-power point. Because two octaves are lost from both the high and low frequencies, the bandwidth of ten cascaded uncompensated amplifier stages is only one-sixteenth that of a single amplifier stage. Fig. 198 shows the amplitude response characteristics of various numbers of identical uncompensated amplifiers.

In general, the output of an amplifier may be represented by a current generator $i_{out}$ and a load resistance $R_L$, as shown in Fig. 199(a). Because the signal current is shunted by various capacitances at high frequencies, as shown in Fig. 199(b), there is a loss in gain at these frequencies. If an inductor L is placed in series with the load resistor $R_L$, as shown in Fig. 199(c), a low-Q circuit is formed which somewhat suppresses the capacitive loading. This method of gain compensation, called shunt peaking, can be very effective for improving high-frequency response. Fig. 199

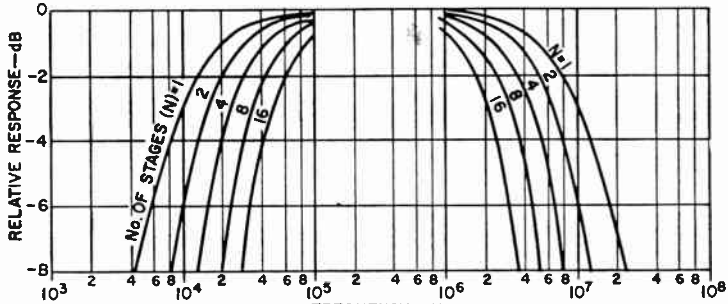



*Fig. 198—Amplitude response characteristics of various numbers (N) of identical uncompensated amplifiers.*

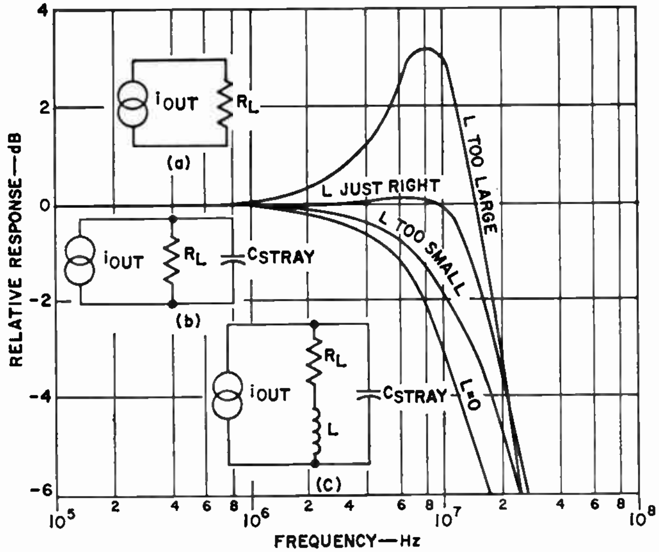



*Fig. 199—Equivalent circuits and frequency response of uncompensated and shunt-peaked amplifiers.*

shows the frequency response for the circuits shown in Figs. 199(a), (b), and (c). If the inductor L shown in Fig. 199(c) is made self-resonant approximately one octave above the 3-dB frequency of the circuit of Fig. 199(b), the amplifier response is extended by about another 30 per cent.

If the stray capacitance C shown in Fig. 199(b) is broken into two parts C′ and C″ and an inductor $L_1$ is placed between them, a heavily damped form of series resonance may be employed for further improvement. This form of compensation, called series peaking, is shown in Fig. 200(a). If C′ and C″ are within a factor of two of each other, series peaking produces an appreciable improvement in frequency response as compared to shunt peaking. A more complex form of compensation embodying both self-resonant shunt peaking and series peaking is shown in Fig. 200(b).

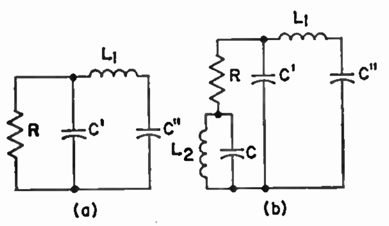



*Fig. 200—Circuits using (a) series peaking, and (b) both self-resonant shunt peaking and series peaking.*

The effects of various high-frequency compensation systems can be demonstrated by consideration of an amplifier consisting of three identical stages. If each of the three stages is down 3 dB at 1 MHz, and if a total gain variation of plus 1 dB and minus 3 dB is allowed, the bandwidth of the amplifier is 0.5 MHz without compensation. Shunt peaking raises the bandwidth to 1.3 MHz. Self-resonant shunt peaking raises it to 1.5 MHz. An infinitely complicated system could raise it to 2 MHz. If the distribution of capacitance permits it, series peaking alone can provide a bandwidth of about 2 MHz, while a combination of shunt and series peaking can provide a bandwidth of approximately 2.8 MHz. If the capacitance is perfectly distributed, and if an infinitely complex network of shunt and series peaking is employed, the ultimate capability is about 4 MHz.

The frequency response of a wideband amplifier is influenced greatly by variations in component values due to temperature effects, variation of transistor parameters with voltage and current (normal large-signal excursions), changes of stray capacitance due to relocated lead wires, or other variations. A change of 20 per cent in any of the critical parameters can cause a change of 0.7 dB in gain per stage over the last half-octave of the response for the most simple case of shunt peaking. As the bandwidth is extended by more complex peaking, a circuit becomes substantially more critical. (Measurement probes generally alter circuit performance because of their capacitance; this effect should be considered during frequency-response measurements.)

In the design of wideband amplifiers using many stages of amplification, it is necessary to consider time-delay variations as well as amplitude variation. When feedback capacitance is a major contributor to response limitation, the more complex compensating networks may produce severe ringing or even sustained oscillation. If feedback capacitance is treated as input capacitance produced by the Miller effect, the added input capacitance $C_f'$ caused by the feedback capacitor $C_f$ is given by

$$C_f' = C_f\ (1 - VG)$$

where VG is the input-to-output voltage gain. The gain VG, however, has a phase angle that varies with frequency. The phase angle is 180 degrees at low frequencies, but may lead or lag this value at high frequencies; the magnitude of VG then also varies. In the design of very wideband amplifiers (20 MHz or more), the phase of the transconductance $g_m$ must be considered.

Fig. 201(a) shows three stages of a multistage wideband amplifier. The resistors $R_3$ merely provide a high-impedance bias path for the collectors of the transistors. The ac collector current of each transistor normally flows almost exclusively into the relatively low impedance offered by the base of the next stage through the coupling capacitor $C_1$. The resistive network $R_1$ and $R_2$ provides a stable dc bias for the transistor base.

The mid-frequency gain of each stage is approximately equal to the common-emitter current-transfer ratio (beta) of the transistor if the component values are properly chosen. The high-frequency response is limited primarily by the transistor gain-bandwidth product $f_T$, the transistor feedback capacitance, and sometimes the stray capacitance. The low-frequency response is limited primarily by the value of the coupling capacitor $C_1$.

Fig. 201(b) illustrates the use of high-frequency shunt peaking and low-frequency peaking at the expense of stage gain in the three stages of the wideband amplifier to extend the high- and low-frequency response. The emitter resistors $R_6$ are made as small as possible, yet large enough to mask the variation of transconductance, and thus voltage gain, as a function of signal-current variation. For very small ratios of peak ac collector current to dc collector current, this variation is not substantial. The resistors $R_6$ also partially mask the effect of the intrinsic base-lead resistance $r_b'$.

The base-bias resistors $R_1$ of Fig. 201(a) are split into two resistors $R_4$ and $R_5$ in Fig. 201(b), with $R_4$ well bypassed. The mid-frequency gain is then reduced to a value approximating $R_5$ divided by $R_6$. At this point, however, the high-frequency response is increased by the same factor. Shunt peaking is provided by $L_1$ and $C_2$ for additional high-frequency improvement.

When the reactance of the bypass capacitor $C_3$ is large compared to $R_5$, the low-frequency gain is increased because the resistor no longer heavily shunts the transistor input. Selection of the proper value for $C_3$ exactly offsets the loss of low-frequency gain caused by $C_1$. When the reactance of $C_3$ approaches $R_4$, however, the low-frequency peaking is no longer effective.

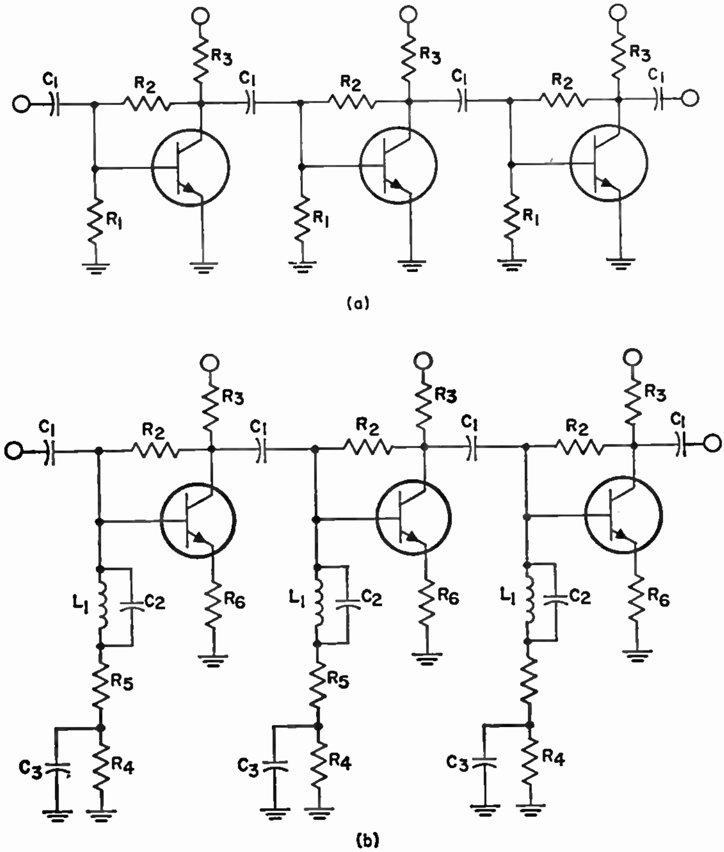



*Fig. 201—(a) Uncompensated and (b) compensated versions of three stages of a multistage wideband amplifier.*

# RF Power Amplification and Generation

RECENT significant improvements in the design and technology for high-frequency power transistors have resulted in the increasingly widespread application of transistors in the amplification and generation of rf power. Previously, cost considerations and performance limitations restricted the use of high-frequency power transistors to only a limited number of special circuits in which small size and light weight were the overriding requirements. As a result of the progress that has been made in design and processing, today, high-frequency transistors are often used in place of low- and medium-power tubes in many new equipment designs for operation at frequencies up to 2000 MHz. In addition to small size and light weight, other unique circuit advantages, such as greater reliability and significant increases in over-all circuit efficiency and bandwidth capability, have made possible this penetration of transistors into a very great number of different high-frequency applications.

## FEATURES OF RF POWER TRANSISTORS

The performance of an rf power transistor is critically dependent on the structure and geometry of the device. Such factors as the length of the emitter and base peripheries, the emitter-to-collector spacing (i.e., base width), the length of the collector-base junction, and parasitic inductances and resistive losses in the transistor package significantly affect power output, frequency response, thermal resistance, stability, and other important performance characteristics.

### Power Output

In early transistors, power outputs were in the milliwatt region, and increased power capability could be achieved only at the expense of frequency response. The power output of a transistor is limited by the current-handling capability and dissipation of the device. The maximum dc input power to a transistor is largely determined by the current-handling ability because the dc operating voltages of power transistors have been fairly well standardized at either 28 volts for military systems or 12.6 volts for mobile applications.

The current-handling ability of any transistor is proportional to the length of the edge of the emitter, i.e., the emitter periphery. The base current results in a voltage drop that causes the portion of the emitter most remote from the base contact to be least forward-biased. Little or no current, therefore, is injected from this region. This condition results even when the emitter strip is exceedingly narrow. In present transistors, the emitter is only 10,000 angstroms wide, but the emitter current is still limited by the total length of the emitter edge. The current-handling capability is approximately 1 milliampere per mil of emitter length; a transistor required to handle a current of up to 1 ampere, therefore, should have an emitter periphery of 1 inch.

## Frequency Response

The frequency response of a transistor is inversely proportional to the square of the emitter-to-collector spacing and to the capacitance of the transistor. For a given base width, therefore, the power-output/frequency capability is determined by the length of emitter periphery that can be concentrated into a given area. One figure of merit of a power-transistor design is the ratio of emitter periphery to base area. The 2N3375 transistor has a ratio of 0.82 mil of emitter edge per square mil of base area and can produce 4 watts of output power at 400 MHz. The 2N5921 transistor in which the ratio of emitter periphery to base area is increased to 3.1 mils per square mil can produce 6 watts of output power at 2 GHz. The 2N5921 pellet uses 180 emitters only 20,000 angstroms wide, and has a base width of approximately 1200 angstroms and an over-all length of 40 mils.

## Thermal Resistance

The thermal resistance of a transistor is proportional to the length of the collector-base junction, i.e., the base periphery. For this reason the base regions (the heat-generation area) of modern power transistors are made in the form of long, narrow rectangles to maximize the spreading of the heat in the silicon, which is a reasonably good conductor of heat (about 20 per cent of the conductivity of copper). In addition, power transistors are usually mounted on beryllium oxide to provide further spreading of the heat and electrical insulation of the devices from the chassis. Use of these techniques allows transistor dissipation of about $10^5$ watts per square centimeter.

## RF Power-Transistor Packages

The package is an integral part of an rf power transistor. A transistor package designed for use in rf power applications should have good thermal properties and low parasitic reactance. Parasitic inductances and resistive losses of the package significantly affect circuit performance characteristics, such as power gain, bandwidth, and stability. The most critical parasitics are the emitter- and base-lead inductances. Fig. 202 shows several popular commercially available rf power-transistor packages, and Table II indicates the parasitic inductances of each type. The TO-60 and TO-39 packages were first used for devices such as the 2N3375 and the 2N3866. The base and emitter parasitic inductances of these packages are in the order of 3 nanohenries; this value of inductance corresponds to a reactance of 7.5 ohms at 400 MHz. If the emitter is grounded internally to a TO-60 package (as in the 2N5016), the emitter lead inductance can be reduced to 0.6 nanohenry. Hermetically sealed, low-inductance radial-lead packages, such as the HF-19 package introduced by RCA, employ ceramic-to-metal seals and have good rf performance characteristics. The parasitic inductances can be reduced further by use of a hermetically sealed coaxial package, such as the HF-11, used for the 2N5470. This package has parasitic inductances in order of 0.1 nanohenry.

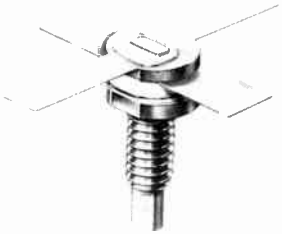

JEDEC
TO-39


JEDEC
TO-60

HF-12
Molded-Silicone Plastic
Package (Isolated
Electrodes)


HF-11

Coaxial Package



HF-19
Hermetic Strip-Line Type
Ceramic-to-Metal Package
(Isolated Electrodes)


HF-21

Coaxial Package

Studless HF-19

Package

*Fig. 202—Commercially available rf power-transistor packages.*

Table II—Summary of Packaged-Transistor Inductances

| Package | Inductance (nH) Emitter | Base |
|---|---|---|
| TO-39 (2N3866) | 3 | 3 |
| TO-60 (isolated emitter) (2N3375) | 3 | 3 |
| TO-60 (ground emitter) (2N5016) | 0.6 | 2 |
| Hermetic Strip-line (2N5919) | 0.4 | 0.6 |
| Coaxial case (2N5470) | 0.1 | 0.1 |

# DESIGN CONSIDERATIONS FOR RF POWER AMPLIFIERS

In the design of silicon-transistor rf power amplifiers for use in transmitting systems, several fundamental factors must be considered. As with any rf power amplifier, the class of operation has an important bearing on the power output, linearity, and operating efficiency. The modulation requirements of transistor rf power amplifiers differ slightly from those for tube amplifiers. The matching characteristics of input and output terminations significantly affect power output and frequency stability and, therefore, are particularly important considerations in the design of either transistor or vacuum-tube power amplifiers. The selection of the proper transistor for a given circuit application is also a major consideration, and the circuit designer must realize the significance of the various transistor parameters to make a valid evaluation of different types.

## Class of Operation

The class of operation of an rf amplifier is determined by the circuit performance required in the given applications. Class A power amplifiers are used when extremely good linearity is required. Although power gain in this class of service is considerably higher than that in class B or class C service, the operating efficiency of a class A power amplifier is usually only about 25 per cent. Moreover, the standby drain and thermal dissipation of a class A stage are high, and care must be exercised to assure thermal stability.

In applications, such as single-sideband transmitters, that require good linearity, class B push-pull operation is usually employed because the transistor dissipation and standby drain are usually much smaller and operating efficiency is higher. Class B operation is characterized by a collector conduction angle of 180 degrees. This conduction is obtained by use of only a slight amount of forward bias in the transistor stage. In this class of service, care must be taken to avoid thermal runaway.

In a class C transistor stage, the collector conduction angle is less than 180 degrees. The gain of the class C stage is less than that of a class A or class B stage, but is entirely usable. In addition, in the class C stage, standby drain is virtually zero, and circuit efficiency is the highest of the three classes. Because of the high efficiency, low collector dissipation, and negligible standby drain, class C operation is the most commonly used mode in rf power transistor applications.

For class C operation, the base-to-emitter junction of the transistor must be reverse-biased so that the collector quiescent current is zero during zero-signal conditions. Fig. 203 shows four methods that may be used to reverse-bias a transistor stage.

Fig. 203(a) shows the use of a dc supply to establish the reverse bias. This method, although effective, requires a separate supply, which may not be available or may be difficult to obtain in many applications. In addition, the bypass elements required for the separate supply increase the circuit complexity.

Figs. 203(b) and 203(c) show methods in which reverse bias is developed by the flow of dc base current through a resistance. In the case shown in Fig. 203(b), bias is developed across the base spreading resistance. The magnitude of this bias is small and uncontrollable because of the variation in $r_{bb}'$ among different transistors. A better approach, shown in Fig. 203(c), is to develop the bias across an external resistor $R_B$. Although the bias level is predictable and repeatable, the size of $R_B$ must be carefully chosen to avoid reduction of the collector-to-emitter breakdown voltage.

The best reverse-bias method is illustrated in Fig. 203(d). In this method, self-bias is developed across an emitter resistor $R_E$. Because no

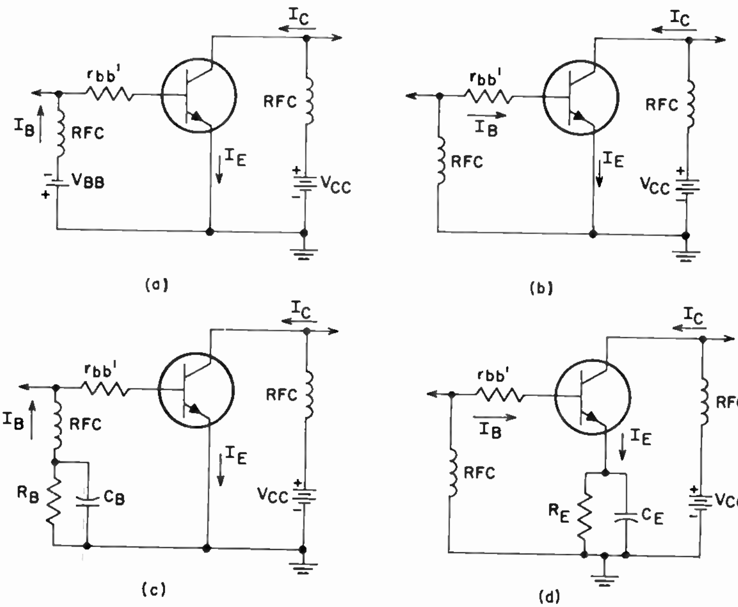



*Fig. 203—Methods for obtaining class C reverse bias: (a) by use of fixed dc supply $V_{BB}$; (b) by use of dc base current through the base spreading resistance $r_{bb}'$; (c) by use of dc base current through an external base resistance $R_B$; (d) by use of self bias developed across an emitter resistor $R_E$.*

external base resistance is added, the collector-to-emitter breakdown voltage is not affected. An additional advantage of this approach is that stage current may be monitored by measurement of the voltage drop across $R_E$. This technique is very helpful in balancing the shared power in paralleled stages. The bias resistor $R_E$ must be bypassed to provide a very-low-impedance rf path to ground at the operating frequency to prevent degeneration of stage gain. In practice, emitter bypassing is difficult and frequently requires the use of a few capacitors in parallel to reduce the series inductance in the capacitor leads and body. Alternatively, the lead-inductance problem may be solved by formation of a self-resonant series circuit between the capacitor and its leads at the operating frequency. This method is extremely effective, but may restrict stage bandwidth.

## Modulation (AM, FM, SSB)

Amplitude modulation of the collector supply of a transistor output stage does not result in full modulation. During down-modulation, a portion of the rf drive feeds through the transistor. Better modulation characteristics can be obtained by modulation of the supply to at least the last two stages in the transmitter chain. On the downward modulation swing, drive from the preceding modulated stages is reduced, and less feed-through power in the output results. Flattening of the rf output during up-modulation is reduced because of the increased drive from the modulated lower-level stages.

The modulated stages must be operated at half their normal voltage levels to avoid high collector-voltage swings that may exceed transistor collector-to-emitter breakdown ratings. RF stability of the modulated stages should be checked for the entire excursion of the modulating signal.

Amplitude modulation of transistor transmitters may also be obtained by modulation of the lower-level stages and operation of the higher-level stages in a linear mode. The lower efficiencies and higher heat dissipation of the linear stages override any advantages that are derived from the reduced audio-drive requirements; as a result, this approach is not economically practical.

Frequency modulation involves a shift of carrier frequency only. Carrier deviations are usually very small and present no problems in amplifier bandwidth. For example, maximum carrier deviations in the 50-MHz and 150-MHz mobile bands are only 5 kHz. Because there is no amplitude variation, class C rf transistor stages have no problems handling frequency modulation.

Single-sideband (SSB) modulation requires that all stages after the modulator operate in a linear mode to avoid intermodulation-distortion products near the carrier frequency. In many SSB applications, channel spacing is close, and excessive distortion results in adjacent-channel interference. Distortion is effectively reduced by class B operation of the rf stages, with close attention to biasing the transistor base-to-emitter junction in a near-linear region.

## Characterization of Large-Signal RF Power Transistors

The values of large-signal transistor parameters, such as the S and Y parameters, are different from those of small-signal transistors because (1) the values of transistor parameters change with power levels, and (2) the harmonic-frequency components that exist in a large-signal rf power amplifier must be considered in addition to the fundamental-frequency sinusoidal component in a small-signal amplifier. RF power-transistor characteristics are normally specified for a given circuit in a specific application.

The design of rf power-amplifier circuits involves the determination of dynamic input and load impedances. Before the input circuit is designed, the input impedance at the emitter-to-base terminals of the packaged transistor must be known at the drive-power frequency. Before the output circuit is designed, the load impedance presented to the collector terminal must be known at the fundamental frequency. These dynamic impedances are difficult to calculate at microwave frequencies because transistor parameters such as $S_{11}$ and $S_{22}$ vary considerably under large-signal operation and also change with the power level. Small-signal equations that might serve as useful guides for transistor design cannot be applied rigorously to large-signal circuits. Because large-signal representation of rf power transistors has not yet been developed, transistor dynamic impedances are best determined experimentally with slotted-line or vector voltmeter measurement techniques.

The system used for determination of transistor impedances under operating conditions is shown in Fig. 204. This system consists of a well-padded power signal generator, a directional coupler (or reflectometer) for monitoring the input reflected power, an input triple-stub tuner, an input low-impedance line section, the transistor holder (or test jig), an output line section, a bias tee, an output triple-stub tuner, another directional coupler for monitoring the output waveform or frequency, and an output power meter. For a given frequency and input power level, the input and output tuners are adjusted for maximum power output and minimum input reflected power. Once the system has been properly tuned, the impedance across terminals 1-1 (with the transistor disconnected) is measured at the same frequency in a slotted-line set-up or with the vector voltmeter. The conjugate of this impedance is

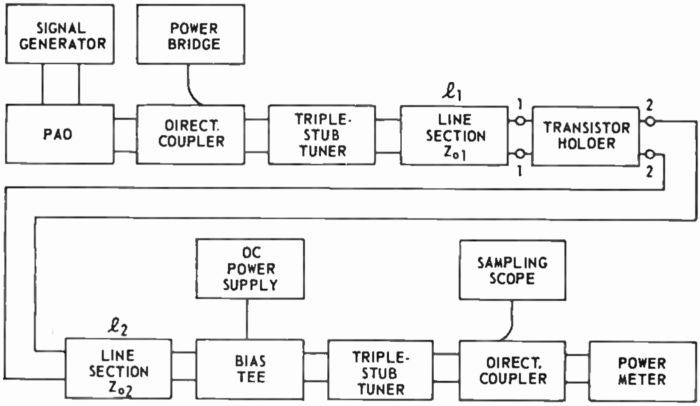



*Fig. 204—Set-up for measurement of rf transistor dynamic impedances.*

the dynamic input impedance of the transistor. Similarly, the impedance across terminals 2-2 (with the transistor disconnected) is the collector-load impedance presented to the transistor collector. Such measurements are performed at each frequency and power level. It should be noted that the circuit arrangement of Fig. 204 is also useful for testing the performance of the transistor. Thus, power output, power gain, and efficiency are readily determined.

## RF Amplifier Circuit Design

When the dynamic input impedance and the load impedance of a packaged transistor have been established, either from direct measurements as described previously, or from the manufacturer's data, the input and output matching circuits can be properly designed.

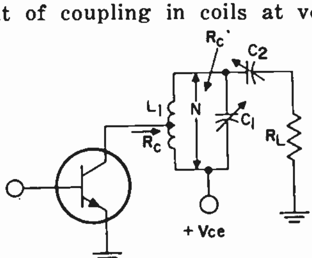
Output-Circuit Design—When the dc supply voltage and power output are specified, the circuit designer must determine the load for the collector circuit [$R_L = (V_{CE})^2/2P_o$]. Because an rf power amplifier is usually designed to amplify a specific frequency or band of frequencies, tuned circuits are normally used as coupling networks. The choice of the output tuned circuit must be made with due regard to proper load matching and good tuned-circuit efficiency.

As a result of the large dynamic voltage and current swings in a class C rf power amplifier, the collector current contains a large amount of harmonics. This effect is caused primarily by the nonlinearity in the transfer characteristics of the transistor. The tuned coupling networks selected must offer a relatively high impedance to these harmonic currents and a low impedance to the fundamental current.

Class C rf power amplifiers are reverse-biased beyond collector-current cutoff; harmonic currents are generated in the collector which are comparable in amplitude to the fundamental component. However, if the impedance of the tuned circuit is sufficiently high at the harmonic frequencies, the amplitude of the harmonic currents is reduced and the contribution of these harmonic currents to the average current flowing in the collector is minimized. The collector power dissipation is therefore reduced, and the collector-circuit output efficiency is increased.

Figs. 205 and 206 illustrate the use of parallel tuned circuits to couple the load to the collector circuit. The collector electrode of the transistor is tapped down on the output coil. Capacitor $C_1$ provides tuning for the fundamental frequency, and capacitor $C_2$ provides load matching of $R_L$ to the tuned circuit. The transformed $R_L$ across the entire tuned circuit is stepped down to match the collector by the proper turns ratio of the coil $L_1$. If the value of the inductance $L_1$ is chosen properly and the portion of the output-coil inductance between the collector and ground is sufficiently high, the harmonic portion of the collector current in the tuned circuit is small. Therefore, the contribution of the harmonic current to the dc component of current in the circuit is minimized. The use of a tapped-down connection of the collector to the coil maintains the loaded Q of the circuit and minimizes variation in the bandwidth of the output circuit with changes in the output capacitance of the transistor.

Although the circuits shown in Figs. 205 and 206 provide coupling of the load to the collector circuit with good harmonic-current suppression, the tuned-circuit networks have a serious limitation at very high frequencies. Because of the poor coefficient of coupling in coils at very high frequencies, the tap position is usually established empirically so that proper collector loading is achieved. Fig. 207 shows several suitable output coupling networks that provide the required collector loading and also suppress the circulation of collector harmonic currents. These networks are not dependent upon coupling coefficient for load-impedance transformation.




(a)

FOR N:1 TURN RATIO

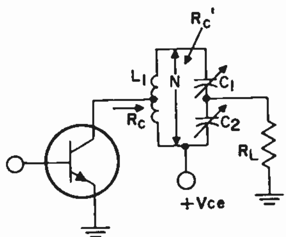
$$(1)\ R_c = \frac{V_{ce}^2}{2P_O}\ \text{(FOR CLASS C)}$$

$$(2)\ X_{L1} = \frac{R_c'}{Q_L} = \frac{N^2R_c}{Q_L}$$

$$(3)\ X_{C2} = R_L\sqrt{\frac{N^2R_c}{R_L}-1}$$

$$(4)\ X_{C1} = \frac{N^2R_c}{Q_L}\cdot\frac{1}{\left(1-\frac{X_{C2}}{Q_LR_L}\right)}$$

*Fig. 205—Tuned-circuit output coupling method and design equations in which output is transferred to load by a series coupling capacitor.*




(b)

FOR N:1 TURN RATIO

$$(1)\ R_c = \frac{V_{ce}^2}{2P_O}\ \text{(FOR CLASS C)}$$

$$(2)\ X_{L1} = \frac{N^2R_c}{Q_L}$$

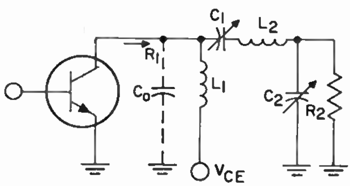
$$(3)\ X_{C1} = \frac{N^2R_cQ_L}{(Q_L^2+1)}\left[1-\frac{R_L}{Q_LX_{C2}}\right]$$

$$(4)\ X_{C2} = \frac{R_L}{\sqrt{\frac{(Q_L^2+1)R_L}{N^2R_c}-1}}$$

*Fig. 206—Tuned-circuit output coupling method and design equations in which output to the load is obtained from a capacitive voltage divider.*

The collector output capacitance for the networks shown in Fig. 207 is included in the design equations. The collector output capacitance of a transistor varies considerably with the large dynamic swing of the collector-to-emitter voltage and is dependent upon both the collector supply voltage and the power output.

Input-Circuit Design—The input circuit of most transistors can be represented by a resistor $r_{bb}'$ in series with a capacitor $C_{in}$. The input network must tune out the capacitance $C_{in}$ and provide a purely resistive load to the collector of the driver stage. Fig. 208 shows several networks capable of coupling the base

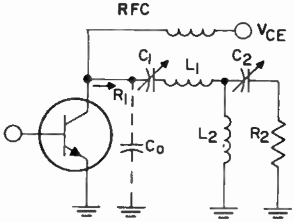


(a) FOR $R_1 < R_2$

(1) $X_{C_1} = Q_L R_1$ (2) $X_{C_2} = \dfrac{R_2}{\sqrt{\dfrac{R_2(Q_L^2+1)}{R_1 Q_L^2}-1}}$

(3) $X_{L_1} = \dfrac{Q_L R_1}{\left[\dfrac{Q_L R_1}{X_{C_O}}+1\right]}$

(4) $X_{L_2} = Q_L R_1\left[1+\dfrac{R_2}{Q_L X_{C_2}}\right]$



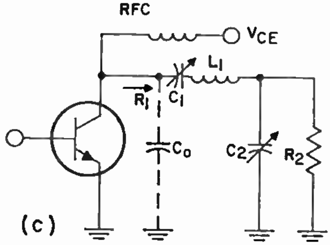
(b) FOR $\dfrac{Q_L X_{C_O}}{\sqrt{R_1 R_2}} > 1$

(1) $X_{L_1} = \dfrac{Q_L X_{C_O}^2}{R_1}\left[1-\dfrac{\sqrt{R_1 R_2}}{Q_2 X_{C_O}}\right]$

(2) $X_{L_2} = X_{C_O}\sqrt{R_2/R_1}$

(3) $X_{C_1} = \dfrac{Q_L X_{C_O}^2}{R_1}\left[1-\dfrac{R_1}{Q_L X_{C_O}}\right]$

(4) $X_{C_2} = \dfrac{R_2}{Q_L}\left[\dfrac{Q_L X_{C_O}}{\sqrt{R_1 R_2}}-1\right]$

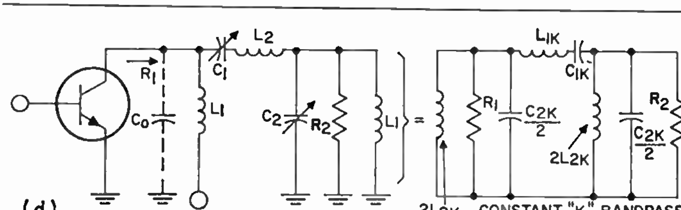


(c)

(1) $X_{C_1} = \dfrac{Q_L X_{C_O}^2}{R_1}\left[1-\dfrac{R_1}{Q_L X_{C_O}}\right]$

(2) $X_{C_2} = \dfrac{R_2}{\sqrt{\dfrac{(Q_L^2+1)}{Q_L^2}\,\dfrac{R_1 R_2}{X_{C_O}^2}-1}}$

(3) $X_{L_1} = \dfrac{Q_L X_{C_O}^2}{R_1}\left[1+\dfrac{R_2}{Q_L X_{C_2}}\right]$



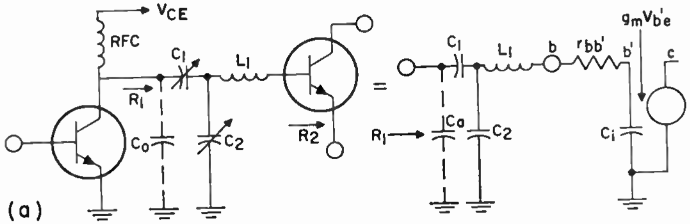
(d) CONSTANT "K" BANDPASS FILTER

LET $C_{2K} = 2\,C_{OUT}$; $R_1 = R_2$; $f_1$ = LOW FREQ. CUTOFF; $f_2$ = HI-FREQ. CUTOFF

(1) $(f_2 - f_1) = \dfrac{1}{2\pi C_O R_L}$ (2) $L_2 = L_{1K}\,\dfrac{R_1}{\pi(f_2-f_1)}$ (3) $L_1 = 2L_{2K} = \dfrac{(f_2-f_1)R_1}{2\pi f_1 f_2}$

(4) $C_1 = C_{1K} = \dfrac{f_2-f_1}{4\pi f_1 f_2 R_1}$ (5) $C_2 = C_o = \dfrac{C_{2K}}{2}$

*Fig. 207—Additional transistor output-coupling networks including transistor output capacitance.*

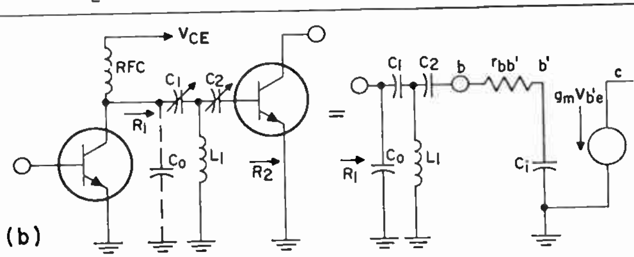



FOR $X_{L_1} >> X_{C_i}; R_1 > R_2 = r_{bb'}$

(1) $X_{L_1} = Q_L R_2 = Q_L r_{bb'}$

(2) $X_{C_1} = X_{co}\left[\sqrt{\frac{(Q_L^2+1)\, r_{bb'}}{R_1}} - 1\right]$

(3) $X_{C_2} = \frac{r_{bb'}(Q_L^2+1)}{Q_L} \cdot \frac{1}{\left[1-\sqrt{\frac{R_1 r_{bb'}(Q_L^2+1)}{X_{co}^2 Q_L^2}}\right]}$

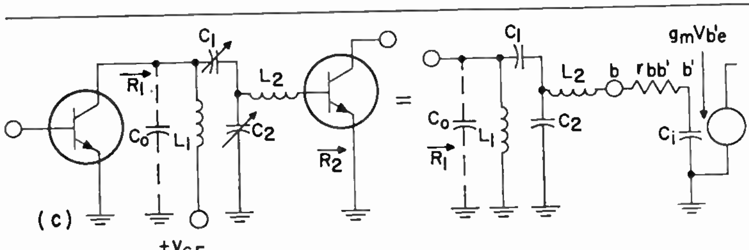



FOR $X_{C_2} >> X_{C_i}; R_1 > R_2 = r_{bb'}$

(1) $X_{L_1} = \frac{R_2(Q_L^2+1)}{Q_L} \cdot \frac{1}{\left[1+\sqrt{\frac{R_1 R_2}{X_{co}^2} \cdot \frac{(Q_L^2+1)}{Q_L^2}}\right]} = \frac{r_{bb'}(Q_L^2+1)}{Q_L} \cdot \frac{1}{\left[1+\sqrt{\frac{R_1 r_{bb'}}{X_{co}^2} \cdot \frac{(Q_L^2+1)}{Q_L^2}}\right]}$

(2) $X_{C_1} = X_{co}\left[\sqrt{\frac{r_{bb'}(Q_L^2+1)}{R_1}} - 1\right]$

(3) $X_{C_2} = Q_L R_2 = Q_L r_{bb'}$




FOR $R_1 > R_2;\ R_2 = r_{bb'};\ X_{L_2} \gg X_{C_i}$

(1) $X_{L_1} = \frac{R_1}{Q_L}$

(2) $X_{L_2} = \frac{R_2}{Q_L} \cdot \frac{\left[\sqrt{\frac{R_1}{R_2}} - 1\right]}{\left[1 - \frac{R_1}{Q_L X_{co}}\right]}$

(3) $X_{C_1} = \frac{R_1}{Q_L} \cdot \frac{\left[1-\sqrt{\frac{R_2}{R_1}}\right]}{1 - \frac{R_1}{Q_L X_{co}}}$

(4) $X_{C_2} = \frac{R_1}{Q_L} \cdot \frac{\sqrt{\frac{R_2}{R_1}}}{\left[1 - \frac{R_1}{Q_L X_{co}}\right]}$

*Fig. 208—Transistor input-circuit coupling networks.*

to the output of the driver stage and tuning out the input capacitance $C_{in}$. In the event that the transistor used has an inductive input, the reactance $X_{c_1}$ is made equal to zero, and the base inductance is included as part of inductor $L_1$ for networks such as that shown in Fig. 208(a) and is included as part of $L_2$ for networks of the type shown in Fig. 208(c). In Fig. 208(a), the input circuit is formed by the T network consisting of $C_1$, $C_2$, and $L_1$. If the value of the inductance $L_1$ is chosen so that its reactance is much greater than that of $C_{in}$, series tuning of the base-to-emitter circuit is obtained by $L_1$ and the parallel combination of $C_2$ and $(C_1 + C_o)$. Capacitors $C_1$ and $C_o$ provide the impedance matching of the resultant input resistance $r_{bb}'$ to the collector of the driving stage. Fig. 208(b) shows a T network in which the location of $L_1$ and $C_2$ is chosen so that the reactance of the capacitor is much greater than that of $C_{in}$; $C_2$ can then be used to step up $r_{bb}'$ to an appropriate value across $L_1$. The resultant parallel resistance across $L_1$ is transformed to the required collector load value by capacitors $C_1$ and $C_o$. Parallel resonance of the circuit is obtained by $L_1$ and the parallel combination $(C_1 + C_o)$ and $C_2$.

The circuits shown in Fig. 208(a) and 208(b) require the collector of the driving transistor to be shunt-fed by a high-impedance rf choke. Fig. 208(c) shows a coupling network that eliminates the need for a choke. In this circuit, the collector of the driving transistor is parallel tuned, and the base-to-emitter junction of the output transistor is series tuned. Fig. 209 shows several other forms of coupling networks that can be used in rf power-amplifier designs.

Line-section matching networks—In most microwave circuit applications, either air-line, strip-line, or lumped-element circuit arrangements are used; some useful circuit design techniques are discussed below.

Eighth-wave line sections: One of the properties of an eighth-wave section is that it has a real input impedance when it is terminated in a reactive impedance having a magnitude equal to $Z_o$. Therefore, for an eighth-wave line section, $Z_{in}$ is real if the following condition is met:

$$Z_o = |Z_L| = (R_L^2 + X_L^2)^{1/2}$$

where $R_L$ and $X_L$ are the real and imaginary parts of the complex impedance $Z_L$. The real impedance $Z_{in}$ can be determined from a Smith chart of the following relation:

$$Z_{in} = (R_L) \Big/ \left(1 - \frac{X_L}{|Z_L|}\right)$$

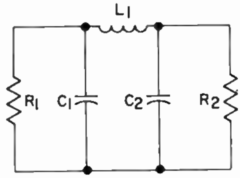
Eighth-wave transformers are useful for microwave power transistor matching, as shown in Fig. 210, because the small complex impedances of these devices can be matched directly, without the need for tuning-out mechanisms. In a typical power-amplifier circuit, the device input impedance R + jX ohms is the terminating impedance $Z_L$ of the eighth-wave line section. If the characteristic impedance of the line $Z_{o1}$ is made equal to the magnitude of $Z_L$, then the input impedance $Z_s$ of this line is a real impedance. Matching to the output is accomplished in a similar manner.

The real impedance of an eighth-wave section of uniform line is thus predetermined by the complex terminating impedance. Therefore, it is necessary to use additional transformations in cascade to match to a real impedance which is different from this predetermined real impedance.

Quarter-wave line sections: Quarter-wave lines are also useful as impedance transformers between real impedances. If quarter-wave transformers are used to match a real impedance to an active device, as shown in Fig. 211, the reactive component of the complex impedance (the admittance) of the active device must be tuned out. For example, in the input circuit of a power-transistor amplifier circuit, the quarter-

(a)

$R_1 > R_2$



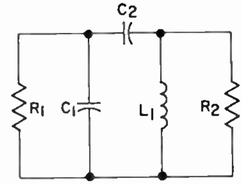

(1) $X_{C1} = \frac{R_1}{Q_L}$

(2) $X_{C2} = \frac{R_2}{\sqrt{\frac{R_2}{R_1}(Q_L^2+1)-1}}$

(3) $X_{L1} = \frac{Q_L R_1}{Q_L^2+1}\left[1+\frac{R_2}{Q_L X_{C2}}\right]$

(b)

$R_1 < R_2$



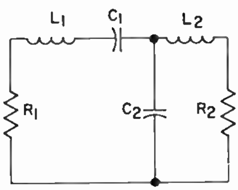

(1) $X_{C1} = \frac{R_1}{Q_L}$

(2) $X_{C2} = \frac{Q_L R_1}{(Q_L^2+1)}\left[\frac{R_2}{Q_L X_{L1}} - 1\right]$

(3) $X_{L1} = \frac{R_2}{\sqrt{\frac{R_2}{R_1}(Q_L^2+1)-1}}$

(c)

$R_1 > R_2$




(1) $X_{L1} = Q_L R_1$

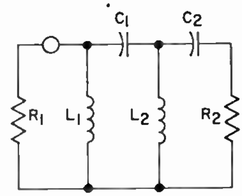
(2) $X_{L2} = \frac{R_2}{Q_L}\left[\sqrt{\frac{R_1(Q_L^2+1)}{R_2}} - 1\right]$

(3) $X_{C1} = \frac{R_1(Q_L^2+1)}{Q_L}\left[1 - \sqrt{\frac{R_2}{R_1(Q_L^2+1)}}\right]$

(4) $X_{C2} = \frac{R_1}{Q_L}\sqrt{\frac{R_2(Q_L^2+1)}{R_1}}$

(d)

$R_1 > R_2$




(1) $X_{L1} = \frac{Q_L R_1}{\left[1+\sqrt{\frac{R_1}{R_2}}\right]}$

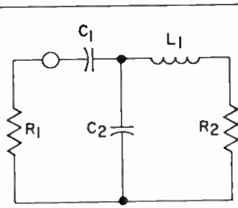
(2) $X_{L2} = \frac{Q_L R_2}{\left[1+\sqrt{\frac{R_2}{R_1}}\right]}$

(3) $X_{C1} = Q_L R_1 \sqrt{\frac{R_2}{R_1}}$

(4) $X_{C2} = Q_L R_2$

(e)

$R_1 > R_2$

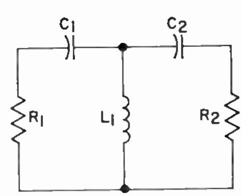



(1) $X_{L1} = Q_L R_2$

(2) $X_{C1} = R_1\sqrt{\frac{R_2(Q_L^2+1)}{R_1} - 1}$

(3) $X_{C2} = \frac{R_2(Q_L^2+1)}{Q_L} \cdot \frac{1}{\left[1 - \frac{X_{C1}}{Q_L R_1}\right]}$

(f)




(1) $X_{C1} = R_1\sqrt{\frac{R_2(Q_L^2+1)}{R_1} - 1}$

(2) $X_{C2} = Q_L R_2$

(3) $X_{L1} = \frac{R_2(Q_L^2+1)}{Q_L} \cdot \frac{1}{\left[1 + \frac{X_{C1}}{Q_L R_1}\right]}$

*Fig. 209—Other suitable rf-amplifier coupling networks for maximum power transfer.*

wave transformer matches the resistive component of the complex admittance of the device. An external capacitance $C_o$ or a stub provides the necessary susceptance needed to cancel the reactive component of the device. In the output portion of the circuit, a stub or a lumped element at the collector is used to bring the impedance to a real value and then to a quarter-wave line that goes to the actual load.

Direct transformation between the transistor (complex impedance) and a given source or load (real resistance) is also possible. The characteristic impedance $Z_o$ and length $l$ of the transmission line required to provide direct transformation from a pure resistance $R_1$ to an impedance $Z_2 = R_2 + jX_2$ can be determined by use of the following equations:

$$Z_o = \sqrt{R_1 R_2} \times \sqrt{1 - \frac{X_2^2}{R_2 (R_1 - R_2)}}$$

$$\tan \beta l = Z_o \left( \frac{R_1 - R_2}{R_1 X_2} \right)$$

If the impedance $Z_2$ is a resistance (i.e., $X_2 = 0$), the expression for $Z_o$ reduces to the quarter-wave transformer equation, and $l = \lambda/4$.

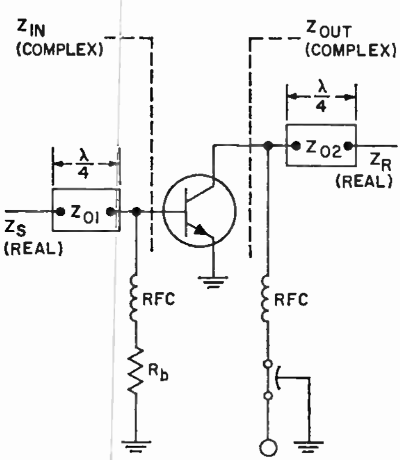



*Fig. 210—Eighth-wave transformer in a typical rf power-amplifier circuit.*

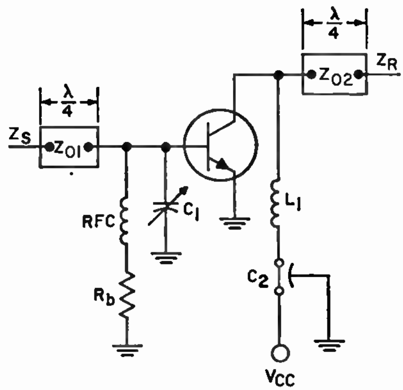



*Fig. 211—Quarter-wave transformers for rf power-transistor amplifiers.*

## MOBILE RADIO

In the United States, three frequency bands have been assigned to two-way mobile radio communications by the Federal Communications Commission. These frequency bands are 25 to 50 MHz, 148 to 174 MHz, and 450 to 470 MHz. The low-frequency band for overseas mobile communications is 66 to 88 MHz.

Frequency modulation (FM) is practiced in mobile radio communications in the United States and most overseas countries. The modulation is achieved by phase-modulation of the oscillator frequencies (usually the 12th or 18th submultiple of the operating frequency). In vhf bands, the frequency deviation is ±5 kHz and channel spacing is 25 kHz. In uhf bands, at present, the modulation deviation is ±15 kHz and channel spacing is 50 kHz. In the United Kingdom, AM as well as FM is used in mobile communications.

Typical mobile-transmitter power-output levels in the United States are 50 watts in the 50-MHz band, 30 watts in the 174-MHz band, and 25 watts in the 470-MHz band. Some of the transmitters used in the United States have power-output ratings as high as 100 watts. Overseas, power-output requirements are much more moderate; the most common power-output levels are in the 10-watt range.

All-solid-state mobile transmitters can be divided into two basic types: transmitters that operate from 24-to-28-volt collector supply voltages, obtained from dc-to-dc converters, and transmitters that operate directly from the 12-volt electrical system of a vehicle.

Both types have advantages and disadvantages. The advantages of 24- to 28-volt operation include higher power gains per stage, good transient suppression, and fairly simple current and voltage limiting. The disadvantages are the additional cost of dc-to-dc converters and the somewhat higher power consumption and increased size of the radio. Direct operation from a 12-volt system permits savings in cost and size, as well as higher efficiency. Because 12-volt operation produces less gain per stage, however, additional rf stages are often needed. Transient suppression and voltage and current limiting are also somewhat more difficult.

Because of the two discrete voltage ranges used for mobile radios, the transistor must be designed specifically for either 24-to-28-volt operation or 12-volt operation. Devices designed for 24-to-28-volt operation have substantially higher collector-breakdown voltages. In addition, all elements are usually isolated from the case to permit access to the emitter.

Fig. 212(a) shows a 175-MHz amplifier chain that operates directly from a 12-volt dc supply. An amplifier chain of this type can deliver 12 watts of output power with an input of 125 milliwatts and has an over-all efficiency of 60 per cent. The chain consists of three cascaded stages that provide power outputs of 1, 4, and 12 watts, respectively. For applications such as base stations in which higher output power levels are required, three overlay power transistors can be operated in parallel as shown in Fig. 212(b). In this arrangement, the transistors can supply as much as 35 watts at 175 MHz when driven from the three-stage amplifier chain shown in Fig. 220(a). Fig. 213 shows a 25-watt, 175-MHz amplifier chain that uses 2N5995 and 2N5996 stripline-package transistors. Fig. 214 shows a 6-watt, 470-MHZ amplifier chain that employs 2N2914 and 2N2915 transistors.

The requirements of rf power transistors operated in mobile-radio applications are extremely severe. The transistors must withstand the load-mismatch conditions created by objects near the transmitting antenna or by a break in the transmission line anywhere between zero and one-half wavelength. Under such conditions, the transistors must handle not only the increased dissipation, but also sudden energy surges that can destroy them in just a few microseconds. The development of transmitters that are immune to these failures is a result of a joint effort between solid-state-device and mobile-radio manufacturers. To avoid excessive junction temperatures, the equipment manufacturer must select transistors of sufficiently low thermal resistance. If a transistor lacks enough dissipation capability, two should be used—even though one could deliver the required rf output power. The use of adequately sized heat sinks is essential to protect devices operated under high-ambient-temperature conditions. Current limiting should also be employed to prevent excessive rise in junction temperature under mismatched load conditions. As an added precaution, a thermostat can be mounted on the heat sink to reduce the transmitter power in the event that the temperature becomes excessive.

The protection of the devices from "instantaneous" failure is more difficult because the time response of current or voltage limiters is not fast enough. Fig. 215 shows a circuit which has a sufficiently fast response time to protect the power transistors from "instantaneous" failures that result from mismatched-load conditions. The circuit operates on the principle of reflected power. Under

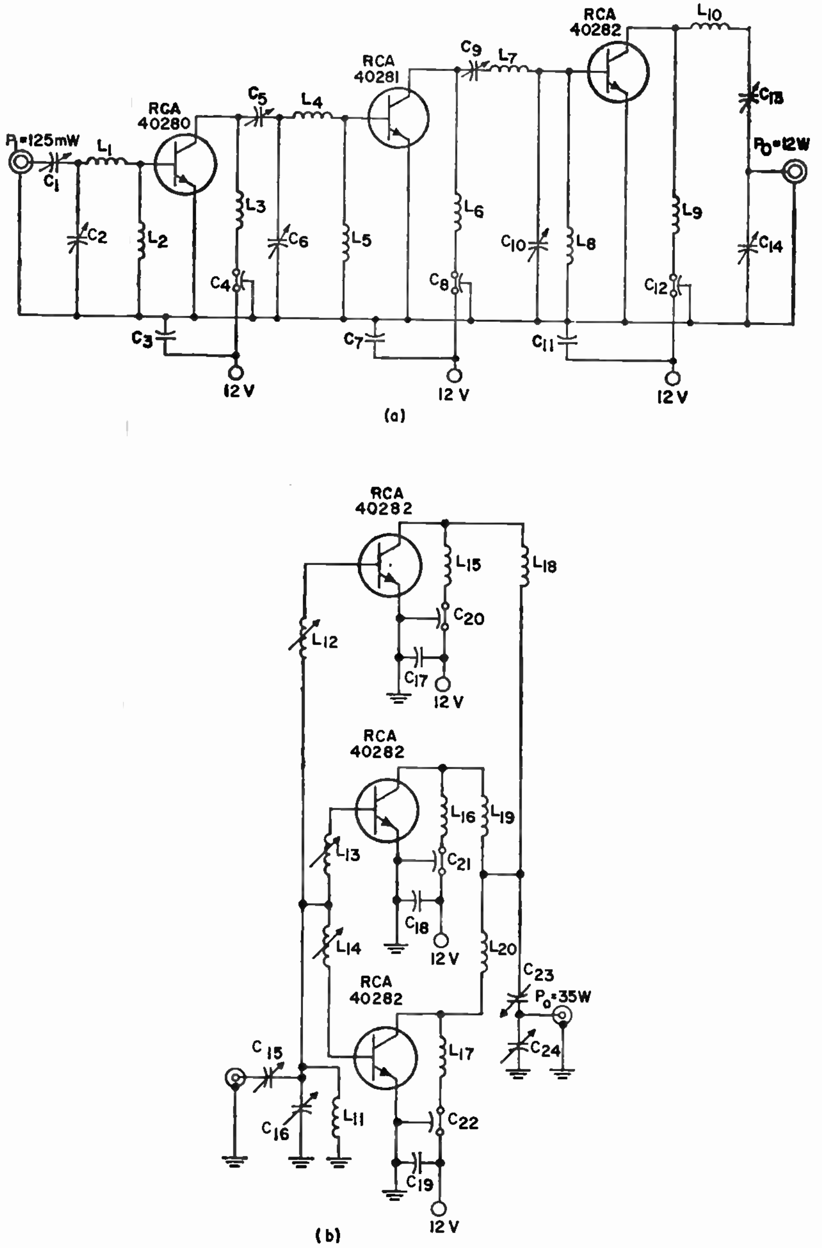



*Fig. 212—175-MHz transistor power amplifier: (a) 3-stage input amplifier; (b) output stage.*

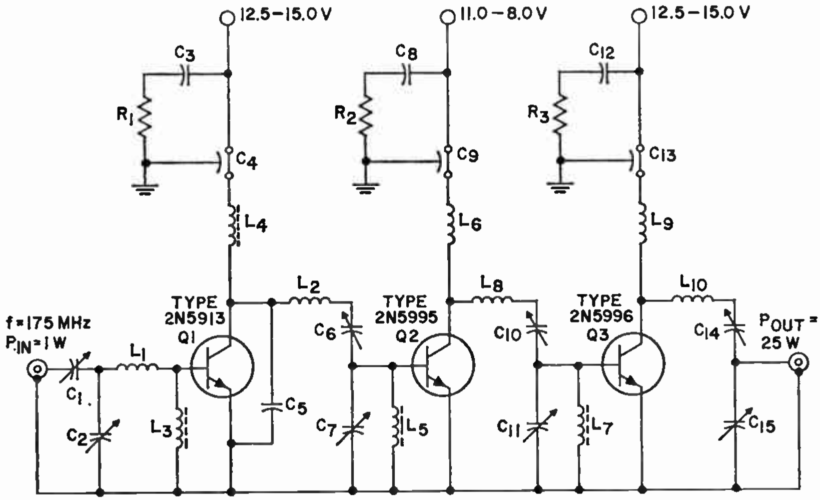



*Fig. 213—Three-stage 25-watt, 175-MHz amplifier chain.*

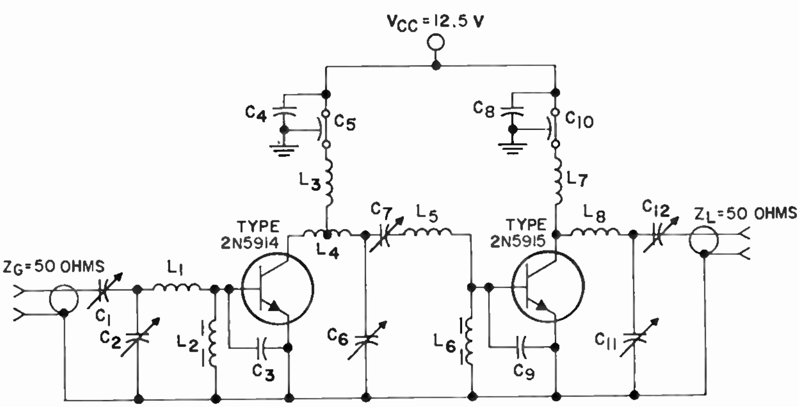



*Fig. 214—Typical 470-MHz amplifier with 0.4-watt input and 6-watt output.*

matched load conditions, there is no output from the VSWR detector. The control amplifier is saturated, and the gain-controlled rf amplifier operates at maximum gain. The power amplifier, therefore, is operated at maximum power output. If a mismatch occurs, a negative voltage from the VSWR bridge brings the control amplifier out of saturation, which, in turn, reduces the gain in the gain-controlled rf amplifier. Gain is reduced because the base of the rf amplifier becomes more negative with respect to the emitter, and because the unsaturated control

## Linear System Applications

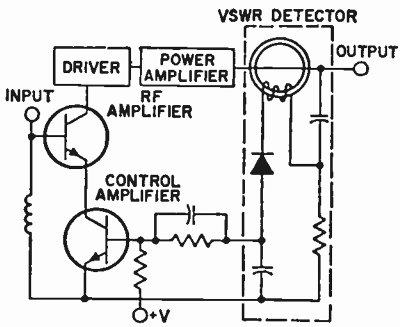



*Fig. 215—Load-mismatch protection circuit.*

amplifier has a degenerative effect on the rf amplifier. With the reduction in the gain of the gain-controlled rf amplifier, the drive to the power amplifier is decreased to safe levels. Once the load mismatch is removed, the system returns instantaneously to normal operating conditions.

## SINGLE-SIDEBAND TRANSMITTERS

The increase in communication traffic, especially in the hf and vhf ranges, necessitates more effective use of the frequency spectrum so that more channels can be assigned to a given spectrum. It has been shown that one of the more efficient methods of communication is through the use of single-sideband (SSB) techniques. In the past, the power-amplifier stages of an SSB transmitter invariably employed tubes because of the lack of suitable high-frequency power transistors. Recent transistor developments, however, have made it feasible and practical to design and construct all-solid-state single-sideband equipment for both portable and vehicular applications.

Unlike most commercially available rf power transistors, which are normally designed primarily for class C operation, an SSB transistor is designed for linear applications and should have a flat beta curve for low distortion, and emitter ballast resistance for stability and degeneration. In high-power amplifiers, transistor junctions experience wide excursions in temperature and a means must be provided to sense the collector-junction temperature so that an external circuit can be used to provide bias compensation to prevent an excessive shift in operating point and to avoid catastrophic device failure as a result of thermal runaway.

### Advantages of SSB Transmission

Single-sideband communication systems have many advantages over AM and FM systems. In areas in which reliability of transmission as well as power conservation are of prime concern, SSB transmitters are usually employed. The main advantages of SSB operation include reduced power consumption for effective transmission, reduced channel width to permit more transmitters to be operated within a given frequency range, and improved signal-to-noise ratio.

In a conventional 100-per-cent modulated AM transmitter, two-thirds of the total power delivered by the power amplifier is at the carrier frequency, and contributes nothing to the transmission of intelligence. The remaining third of the total radiated power is distributed equally between the two sidebands. Because both sidebands are identical in intelligence content, the transmission of one sideband would be sufficient. In AM, therefore, only one-sixth of the total rf power is fully utilized. In an SSB system, no power is transmitted in the suppressed sideband, and power in the carrier is greatly reduced or eliminated; as a result, the dc power requirement is substantially reduced. In other words, for the same dc input power, the peak useful output power of an SSB transmitter, in which the carrier is completely suppressed is theoretically six times that of a conventional AM transmitter.

Another advantage of SSB transmission is that elimination of one sideband reduces the channel width required for transmission to one-half that required for AM transmission. Theoretically, therefore, two SSB transmitters can be operated within a frequency spectrum that is normally required for one AM transmitter.

In a single-sideband system, the signal-to-noise power ratio is eight times as great as that of a fully modulated double-sideband system for the same peak power.

## Linearity Test

For an amplifier to be linear, a relationship must exist such that the output voltage is directly proportional to the input voltage for all signal amplitudes. Because a single-frequency signal in a perfectly linear single-sideband system remains unchanged at all points in the signal path, the signal cannot be distinguished from a cw signal or from an unmodulated carrier of an AM transmitter. To measure the linearity of an amplifier, it is necessary to use a signal that varies in amplitude. In the method commonly used to measure nonlinear distortion, two sine-wave voltages of different frequencies are applied to the amplifier input simultaneously, and the sum, difference, and various combination frequencies that are produced by nonlinearities of the amplifier are observed. A frequency difference of 1 to 2 kHz is used widely for this purpose. A typicla two-tone signal without distortion, as displayed on a spectrum analyzer, is shown in Fig. 216. The resultant signal envelope varies continuously between zero and maximum at an audio-frequency rate. When the signals are in phase, the peak of the two-frequency envelope is limited by the voltage and current ratings of the transistor to the same power rating as that for the single-frequency case. Because the amplitude of each two-tone frequency is equal to one-half the cw amplitude under peak power condition, the average power of one tone of a two-tone signal is one-fourth the single-frequency power. For two tones, conversely, the PEP rating of a single-sideband system is two times the average power rating.

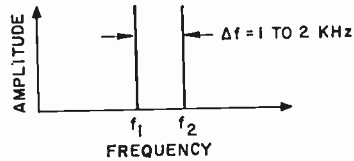



*Fig. 216—Frequency spectrum for a typical two-tone signal without distortion.*

## Intermodulation Distortion

Nonlinearities in an amplifier generate intermodulation (IM) distortion. The important IM products are those close to the desired output frequency, which occur within the pass band and cannot be filtered out by normal tuned circuits. If $f_1$ and $f_2$ are the two desired output signals, third-order IM products take the form of $2f_1 - f_2$ and $2f_2 - f_1$. The matching third-order terms are $2f_1 + f_2$ and $2f_2 + f_1$, but these matching terms correspond to frequencies near the third harmonic output of the amplifier and are greatly attenuated by tuned circuits. It is important to note that only odd-order distortion products appear near the fundamental frequency. The frequency spectrum shown in Fig. 217 illustrates the frequency relationship of some distortion

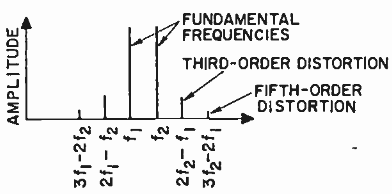



*Fig. 217—Frequency spectrum showing the frequency relationship of some distortion products to two test signals $f_1$ and $f_2$.*

products to the test signals $f_1$ and $f_2$. All such products are either in the difference-frequency region or in the harmonic regions of the original frequencies. Tuned circuits or filters following the nonlinear elements can effectively remove all products generated by the even-order components of curvature. Therefore, the second-order component that produces the second harmonic does not produce any distortion in a narrow-band SSB linear amplifier. This factor explains why class AB and class B rf amplifiers can be used as linear amplifiers in SSB equipment even through the collector-current pulses contain large amounts of second-harmonic current. In a wideband linear application, however, it is possible for harmonics of the operating frequency to occur within the pass band of the output circuit. Biasing the output transistor further into class AB can greatly reduce the undesired harmonics. Operation of two transistors in the push-pull configuration can also result in cancellation of even harmnics in the output.

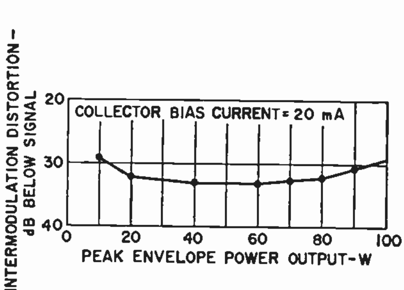



*Fig. 218—Typical intermodulation distortion in an RCA-40675 transistor at various output power levels.*

The signal-to-distortion ratio (in dB) is the ratio of the amplitude of one test frequency to the amplitude of the strongest distortion product. A signal-to-distortion specification of −30 dB means that no distortion product will exceed this value for a two-tone signal level up to the PEP rating of the amplifier. A typical presentation of IM distortion for a 40675 transistor at various output-power levels is shown in Fig. 218.

## Transistor Requirements

Most high-frequency power transistors are designed for class C operation. Forward biasing of such devices for class AB operation places them in a region where second breakdown may occur. The susceptibility of a transistor to second breakdown is frequency-dependent. Experimental results indicate that the higher the frequency response of a transistor, the more severe the second-breakdown limitation becomes. For an rf power transistor, the second-breakdown energy level at high voltage (greater than 20 volts) becomes a small fraction of its rated maximum power dissipation. This behavior is one of the reasons that vacuum tubes have traditionally been used in single-sideband applications.

A power transistor designed especially for use as a linear amplifier is required to perform satisfactorily when forward-biased for class AB operation, as well as to exhibit the desired high-frequency response. The ability of the transistor to withstand second breakdown is improved by subdividing the emitter into many small sites and resistively ballasting the individual sites. The RCA 2N5070 and 40675 transistors are designed specifically for linear-amplifier service in SSB applications. Current-limiting resistors are placed in series with each emitter site between the metalizing and the emitter-to-base junction.

## Bias Control

Operation of the transistor in a class AB amplifier to improve linearity requires the use of a positive base voltage for an n-p-n silicon transistor. The magnitude of the positive voltage must be large enough to bias the transistor to a point slightly beyond the threshold of collector-current conduction. The class AB bias condition must be maintained over a wide temperature range to prevent an increase in idling current to the level at which the transistor can be destroyed as a result of thermal runaway and to minimize distortion that results from a shift in the quiescent point.

It is particularly difficult to maintain the bias current of a transistor high-power class AB amplifier at a constant level. As the drive increases, the dissipation increases and the junction temperature rises. If the conventional biasing technique is employed (an ac-bypassed emitter resistor and a constant voltage supply to the base), the varying emitter current that results from the varying drive changes the voltage drop across the emitter resistor and causes the bias to shift with drive. If a constant-current base-bias supply is used, the drive power is rectified and the bias point is changed.

The problem of maintaing a stable quiescent current is caused by a reduction in the $V_{BE}$ of the transistor when the temperature rises. The base-to-emitter voltage decreases at a rate of approximately 2 millivolts per °C rise in temperature. Unless this condition is compensated for (i.e., bias voltage made to vary according to the $V_{BE}$ decrease), the transistor is destroyed by the thermal effects.

Bias-point control for the 40675 SSB transistor is accomplished by use of a diode placed next to the transistor pellet in the same package. The cathode of the diode is connected internally to the emitter lead. The anode of the diode is connected to a fourth terminal, as shown in Fig. 219. The diode is forward-biased between 1 to 5 milliamperes to provide a forward-voltage drop that is temperature-sensitive. At such a low current, the diode operates in the low-conductance region where it does not provide the stiff voltage necessary for the transistor bias. In this case, the

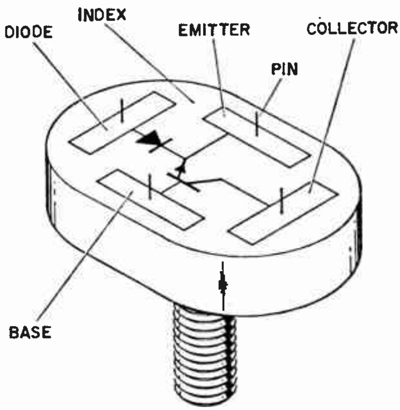



*Fig. 219—Package outline for the RCA-40675 SSB transistor showing internal-package diode used for transistor bias-point control.*

diode acts merely as a thermometer; an external amplifier must be used for current amplification. Compensation is achieved because the diode has approximately the same temperature coefficient for its forward-voltage drop as does the base-emitter junction of the transistor. Good tracking is obtained by mounting the diode and transistor pellets in the same case in very close proximity to minimize any thermal time lag. Temperature coefficient depends, to a large extent, upon the operating current. If the diode current can be adjusted so that it is approximately equal to the base current, good compensation can be achieved. The block diagram of a current amplifier that uses a low-conductance diode is shown in Fig. 220.

The schematic diagram of the current (bias-control) amplifier is shown in Fig. 221. The current amplifier employs a dc differential amplifier. The output voltage is the bias source for the power transistor. The use of a differential amplifier makes the entire amplifier relatively insensitive to temperature variations. Two additional stages are used for current amplification with negative feedback for stability.

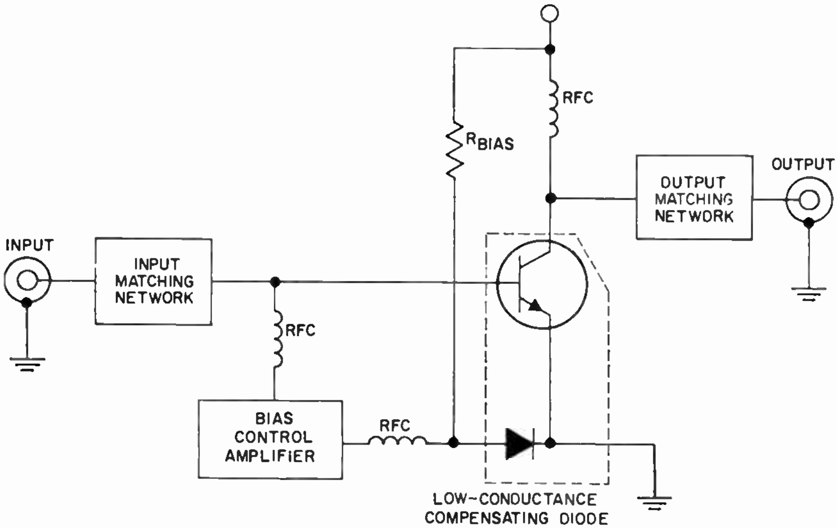



*Fig. 220—Block diagram of 30-MHz amplifier that uses a low-conductance diode for temperature compensation.*

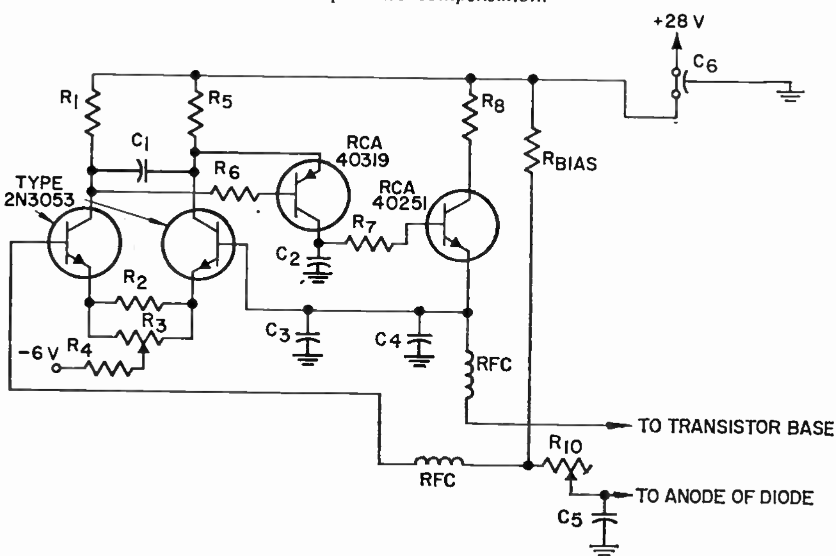



*Fig. 221—Bias-control stages for linear 30-MHz amplifier with temperature-compensating circuit.*

Transistor collector-bias current can be adjusted by varying the potentiometer connected in series with the temperature-compensating diode. The diode current established by $R_{bias}$ determines the degree of compensation. Overcompensation occurs when diode current is greater than the base current. Fig. 222(a) shows collector quiescent current, intially biased at 10 milliamperes, as a function of case temperature. With compensation, the transistor is thermally stable even for case temperature as high as 150°C. Without compensation, however, the transistor tends toward thermal runaway at a case temperature of approximately 75°C.

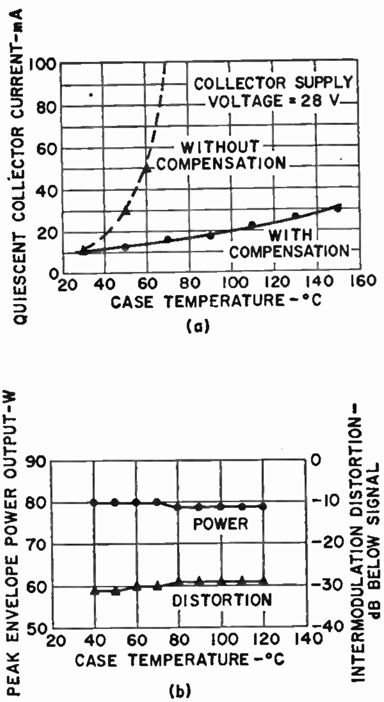



*Fig. 222—Performance characteristics for the 30-MHz amplifier: (a) collector current as a function of case temperature with and without temperature compensation; (b) output power and intermodulation distortion as a function of case temperature.*

Because both input and output are isolated through rf chokes, the external circuit provides compensation without degrading the rf performance of the power amplifier. Fig. 222(b) shows that no appreciable decrease in output power nor much increase in the third-order IM distortion occurs with increasing case temperature up to $T_C = 120°C$. The slight decrease in distortion, together with a decrease in collector efficiency, can be attributed to a rise in rf saturation voltage and a decrease in transistor beta at high temperature.

Despite the extra circuit needed to achieve temperature stabilization, the approach provides a practical solution for achievement of reliable operation of a class AB amplifier over a wide temperature range. The use of a small diode as a temperature-sensing element offers the following advantages:

(a) Diode and transistor pellets need not be matched for forward-voltage drop.

(b) Transistor quiescent current can be either overcompensated or undercompensated against changes in temperature by variation of the diode current.

(c) A diode idling current as low as 1 to 5 milliamperes can be used.

(d) Current of less than 50 milliamperes at 28 volts is needed to operate the external compensating circuit.

## Typical Linear Amplifier

The common-emitter configuration should be used for the power amplifier because of its stability and high power gain. Tuning is less critical, and the amplifier is less sensitive to variations in parameters among transistors. The class AB mode is used to obtain low intermodulation distortion. Neither resistive loading nor neutralization is used to improve linearity because of the resulting drastic reduction in power gain; furthermore, neutralization is difficult for large signals because parameters such as output capacitance and output and input impedances vary nonlinearly over the limits of signal swing.

In low-power linear amplifiers, the use of temperature-compensating circuits is sometimes not necessary provided that the transistor output power is less than 50 per cent of its maximum cw power rating. The RCA-2N5070 transistor is useful in such application. This transistor is specified for SSB applications without temperature compensation as follows:

Frequency = 30 MHz
$P_o$ (PEP) at 28 V = 25 W
Power Gain = 13 dB (min.)
Collector Efficiency =
40 % (min.)

Fig. 223 shows a 2-to-30-MHz wideband linear amplifier that uses other types of RCA rf transistors. At 5 watts (PEP) output, IM distortion products are more than 40 dB below one tone of a two-tone signal. Power gain is greater than 40 dB.

Fig. 224 shows a 150-watt 2-to-30-MHz push-pull amplifier that

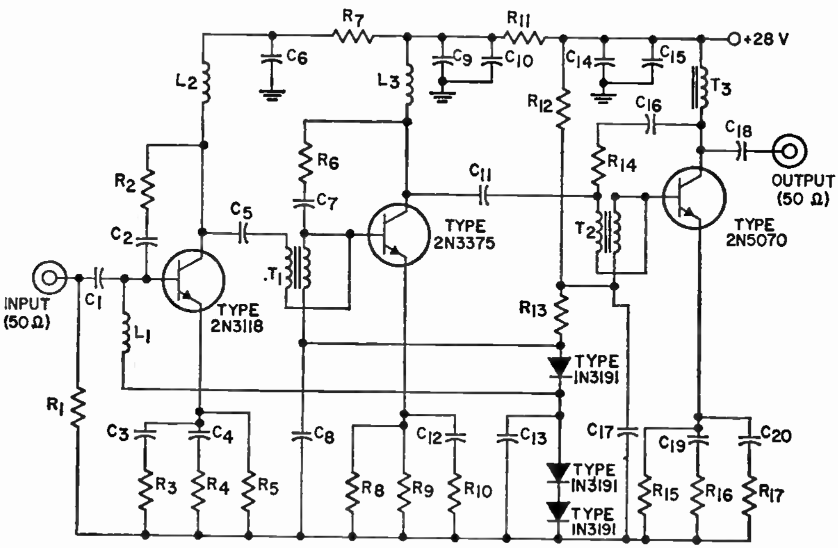



*Fig. 223—2-to-30-MHz linear power amplifier.*

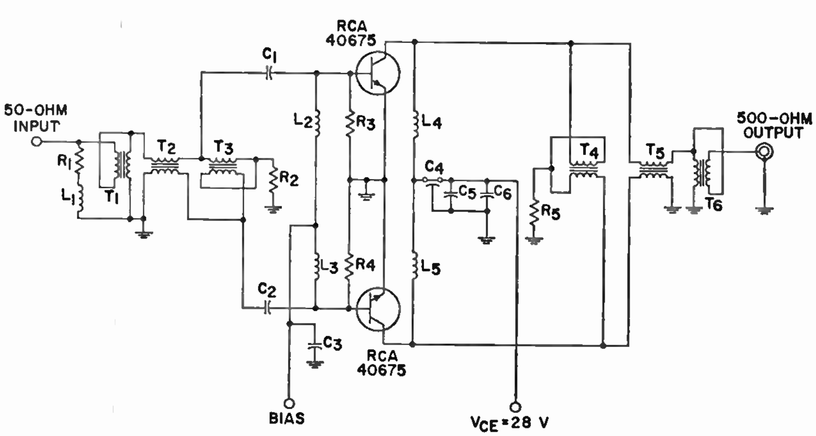



*Fig. 224—2-to-30-MHz, 130-watt (PEP) push-pull linear amplifier.*

uses a pair of 40675 transistors. Typical performance curves for this amplifier are shown in Fig. 225.

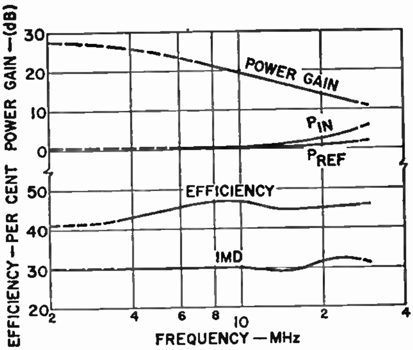



*Fig. 225—Typical performance curves for amplifier shown in Fig. 224.*

## AIRCRAFT RADIO

The aircraft radios discussed in this section are of the type used for communication between the pilot and the airport tower. The transmitter operates in an AM mode on specific channels between 118 and 136 MHz. Radios of this type are regulated by both the FCC and the FAA (Federal Aeronautics Administration). The FCC assigns frequencies to airports and places some requirements on the transmitters, particularly as regards spurious radiation and interference. The FAA sets minimum requirements on radio performance which are based on the maximum authorized altitudes for the plane, whether paying passengers are carried, and on the authorization for instrument flying. The FAA gives a desirable TSO certification to radio equipment that satisfies their standards of airworthiness.

The FCC checks aircraft-radio transmitter designs for interference and other electrical characteristics (as it does all transmitters). Additional requirements are specified for radios intended for use by scheduled airlines by a corporation supported by the airlines themselves.

Fig. 226 shows a broadband amplifier that can supply 15 watts of carrier power for aircraft transmitters.

## VHF AND UHF MILITARY RADIO

Military radios, which operate in the vhf and uhf ranges, vary greatly in requirements. Telemetering devices may operate with as little output as 0.25 watt, while communication systems may require outputs of 50 watts and more. Modulation may be AM, FM, PM (pulse modulation), or PCM (pulse-code modulation). Equipment may be designed for fixed, mobile, airborne, or even space applications. Although the circuits described in this section apply

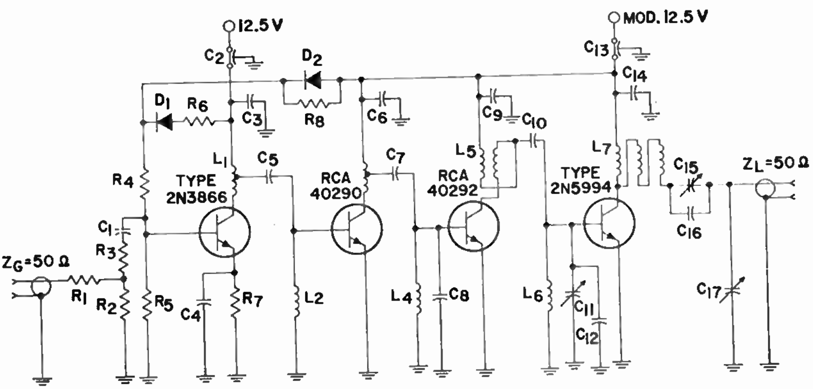



*Fig. 226—Amplitude-modulated broadband amplifier for 118-to-136-MHz operation.*

only to specific military applications, they are representative of the general design techniques used in all military vhf and uhf radio equipment.

## Sonobuoy Transmitters

A sonobuoy is a floating submarine-detecting device that incorporates an underwater sound detector (hydrophone). The audio signals received are converted to a frequency-modulated rf signal which is transmitted to patrolling aircraft or surface vessels. The buoy is battery-operated and is designed to have a very limited active life.

Typical requirements for the rf-transmitter section of the sonobuoy are as follows:

Frequency = 165 MHz
Supply Voltage = 8 to 15 volts
CW Output = 0.25 to 1.5 watts
Over-all Efficiency = 50 per cent
Harmonic Output = 40 dB down from carrier

Figure 227 shows the circuit configuration of an experimental sonobuoy transmitter designed to produce a power output of 2 watts at 160 MHz. Only three stages, including the crystal-controlled oscillator section, are required. Efficiency is greater than 50 per cent (overall) with a battery supply of 12 to 15 volts.

The 2N3866 or 2N4427 transistor can be used in a class A oscillator-quadrupler circuit which is capable of delivering 40 milliwatts of rf power at 80 MHz. Narrow-band frequency modulation is accomplished by "pulling" of the crystal oscillator. The crystal is operated in its fundamental mode at 20 MHz. The oscillator is broadly tuned to 20 MHz in the emitter circuit and is sharply tuned to 80 MHz in the collector circuit. The supply voltage to the oscillator section is regulated at 12 volts by means of a zener diode. Spectrum-analyzer tests indicate that this stage is highly stable even though rather high operating levels are used.

The oscillator-quadrupler section is followed by a 2N3553 class C doubler stage. This stage delivers a power output of 250 milliwatts at 160 MHz from a 12- to 15-volt supply. The over-all output of the sonobuoy can be adjusted by varying the emitter resistance of this stage.

The final power output is developed by an RCA-2N2711 transistor which operates as a straight-through class C amplifier at 160 MHz. A pi

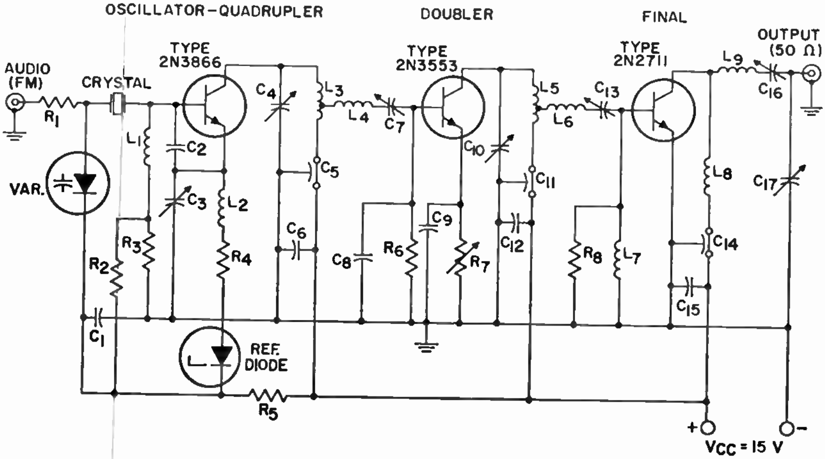



*Fig. 227—2-watt (rf power output) sonobuoy transmitter.*

network matches this output to the 50-ohm line. The spurious output (measured directly at the output port) is more than 35 dB down from the carrier. This suppression is achieved by means of series resonant trap circuits between stages and the use of the pi network in the output.

Many sonobuoy systems require power outputs in the range of only 0.25 to 0.5 watt, preferably with a supply voltage of 8 to 12 volts. The 2N4427 transistor is suitable for use as the doubler and also the final output device in such low-power applications. Fig. 228 shows a diagram of an output stage which uses the 2N4427 as a straight-through 175-MHz class C amplifier. This circuit can deliver output power of more than 500 milliwatts with a supply voltage of 10 volts and a drive power of 60 milliwatts.

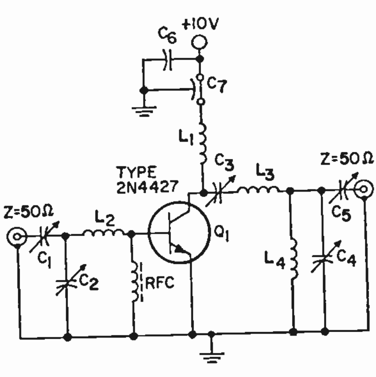



*Fig. 228—0.5-watt 175-MHz sonobuoy rf power output stage.*

For the lower power-output requirement at low supply voltages, the oscillator-quadrupler stage should use lower-power transistors such as the 2N1491 or 2N914. Only 10 to 15 milliwatts of fourth harmonic power is required in this case. The bias-network resistors ($R_2$ and $R_3$) should be adjusted for reliable oscillator starting conditions at these lower supply voltages.

Sonobuoy circuits, in general, must be reliable, simple, and low in cost. The three-stage transmitter circuit shown in Fig. 227 is intended to be representative of the general design techniques used in these systems. However, four-stage sonobuoy transmitter systems are also in common use at the present time. Typically, a four-stage arrangement consists of an oscillator-tripler stage, a second tripler stage, a buffer stage, and a final amplifier stage. Most present-day sonobuoy applications require CW power output between 0.25 and 0.5 watt.

## Air-Rescue Beacon

The air-rescue beacon is intended to aid rescue teams in locating airplane crew members forced down on land or at sea. The beacons are amplitude-modulated or continuous-tone line-of-sight transmitters. They are battery-operated and small enough to be included in survival gear.

Typical requirements for rescue beacons are as follows:

Frequency = 243 MHz (fixed)
Power Output = 300 milliwatts (carrier)
Efficiency = greater than 50 per cent
Supply Voltage = 6 to 12 volts
Modulation = AM, up to ±100 per cent

The 2N4427 transistor is especially suited for this service. A general circuit for the driver and output stages is shown in Fig. 229. Collector modulation, as well as some driver modulation, is used to achieve good down-modulation of the final amplifier. Conventional transformer-coupled modulation is used; however, a separate power supply and resistor network in the driver circuit are provided to adjust the modulation level of this stage independently of the output stage.

The rf-amplifier design is conventional; pi- and T-matching networks are used; simpler circuits (e.g.,

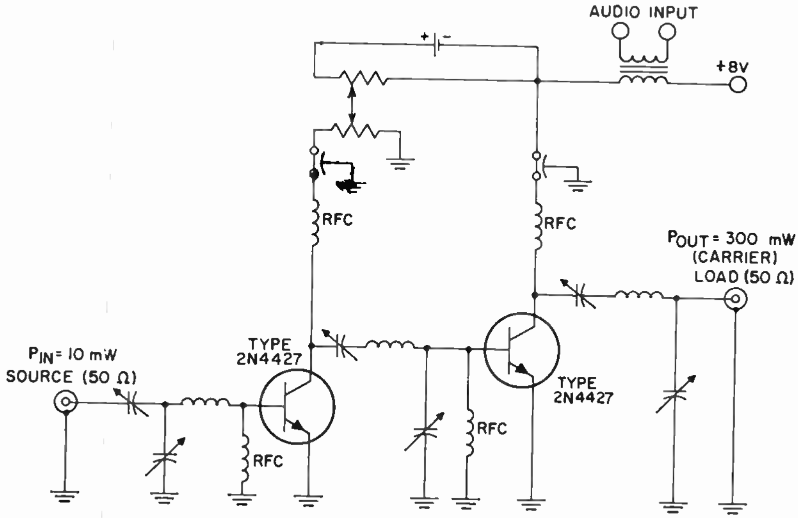



*Fig. 229—Driver and output stage for a 243-MHz beacon transmitter.*

device-resonated tapped coils), however, could be used. The T-matching network at the driver input is used to match the amplifier to a 50-ohm source for test purposes. A 10-to-20-milliwatt input signal is needed to develop a 300-to-400-milliwatt carrier output level.

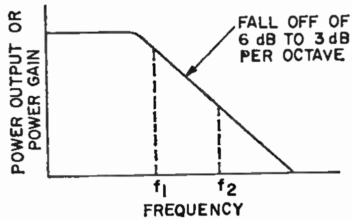
## Broadband Power Amplifier

RF power transistors are often used in broadband amplifier circuits for commercial and military applications. Transistor transmitters are superior to tube transmitters with respect to broadband capability, reliability, size, and weight. The aircraft communication bands of 116 to 152 MHz (discussed in previous section) and 225 to 400 MHz are of interest for both military and commercial applications. Another area of interest is ECM (electronic counter-measures equipment) applications. Transistors suitable for broadband applications must be capable of providing both the required power output within the entire frequency range of interest and constant gain within the pass band. The bandwith of a transistor power amplifier is limited by the following three factors: (1) intrinsic transistor structure, (2) transistor parasitics, and (3) external circuits such as input and output circuits.

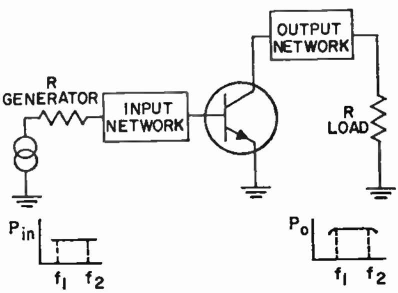
Transistor Structure—The parameters which determine the bandwidth of a transistor structure are the emitter-to-collector transit time, the collector depletion-layer capacitance, and the base-spreading resistance. The emitter-to-collector transit time, which represents the sum of the emitter capacitance charging delay, the base transit time, and the collector depletion-layer transit time, affects the over-all time of response to an input signal. The emitter-to-collector transit time is inversely proportional to the gain-bandwidth product $f_T$ of the transistor. A high $f_T$ is essential for broadband operation; in addition, a constant $f_T$ with current level is required for large-signal operation. The ratio of the $f_T$ to the product of the base-spreading resistance and the collector depletion-layer capacitance ($r_bC_c$) comprises the gain function of a transistor.

Under conjugate-matched input and output conditions, the power gain, which is equal to $f_T/8\pi f^2 r_b C_c$, falls off at a rate of 6 dB per octave. In a power amplifier, the power gain is usually decreased by less than 6 dB per octave, as shown in Fig. 230(a), because the load resistance $R_L$ presented to the collector is not equal to the output resistance of the transistor but is dictated by the required power output and the collector voltage swing. The curve in Fig. 230(a) indicates that one approach to achieving a broadband transistor amplifier is to optimize the matching at the higher end of the frequency band and to introduce mismatch in the input or output, or both, at the lower end of the band so that a constant power output is obtained from $f_1$ to $f_2$; this latter approach is shown in Fig. 230(b). The power output that can be obtained with a transistor broadband amplifier is comparable to that measured at the high end of the band in a narrowband amplifier; efficiency and power gain are slightly lower than in a narrowband amplifier because the load and source impedance cannot be ideally matched to the transistor over a broad frequency band. The disadvantage of this approach to producing a broadband transistor amplifier is the resultant relatively high input VSWR at the low end of the band.

A more sophisticated approach to achieving broadband performance is to consider the transistor structure, the transistor parasitic elements, and the external circuits as part of the over-all band-pass structure, in which the input and output circuits are coupled together by the transistor feedback capacitance. This combined structure reproduces the power-output or power-gain curve of Fig. 230(a) from $f_1$ to $f_2$. External feedback is then applied to control the input drive and flatten the power output over a broad frequency band.




(a)




(b)

*Fig. 230—(a) Output power as a function of frequency in an amplifier with conjugate-matched input and output conditions; (b) a method of correcting the decrease in power gain shown in (a).*

**Parasitic Limitation**—Every discrete transistor contains parasitic elements which impose further limitations on bandwidth. The most critical parasitics are the emitter-lead inductance $L_e$ and the base inductance $L_b$. These parasitic inductances range from 0.1 to 3 nanohenries in commercially available rf power transistors. In the simple equivalent circuit of a common-emtter transistor input circuit at high frequency shown in Fig. 231, the inductance $L_{in}$ represents the sum of the base parasitic inductance and the reflected emitter parasitic inductance; $R_{in}$ is the dynamic input resistance. The real part of the impedance, $R_{in}$, is inversely proportional to the collector area and the power-output capability of the device; i.e., the higher the power output, the lower the value of $R_{in}$. A low ratio of the reactance of $L_{in}$ to $R_{in}$ is important as the first step in broadband amplifier design. Unless the reactance of $L_{in}$ is appreciably lower than the input resistance $R_{in}$, the reactance must be tuned out and thus the bandwidth limited.

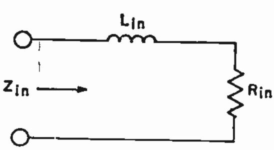



*Fig. 231—Equivalent input circuit of an rf power transistor.*

External Circuits—For a broadband amplifier circuit to deliver constant power output over the frequency range of interest, a proper collector load must be maintained to provide the necessary voltage and current swings. In addition, the input matching network must be capable of transforming the low input impedance of the transistor to a relatively high source impedance.

Suitable output circuits for broadband amplifiers includes constant-K low-pass filters, Chebyshev filters (both transmission-line and lumped-constant types), baluns, and tapered lines. Fig. 232(a) shows a conventional constant-K low-pass filter. The input impedance $Z_{11}$ is substantially constant at frequencies below the cut-off frequency $\omega_c = (L_K C_K)^{1/2}$. A constant collector load resistance can be obtained if the shunt arm (1-1) of $C_K$ is split into two capacitances, as shown in Fig. 232(b). Part of the capacitance represents the output capacitance of the transistor, $C_o$; the other part has a value which makes the total capacitance equal to $C_K$. Further improvement of bandwidth can be obtained by the cascading of more sections.

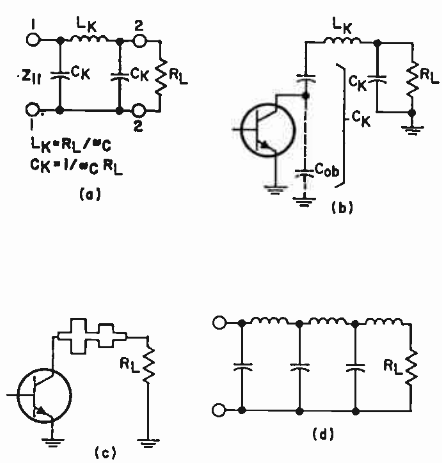



*Fig. 232—A conventional constant-K lowpass filter (a), a method of obtaining a constant collector load resistance (b), a short-step microstrip impedance transformer (c), a lumped equivalent Chebyshev impedance transformer (d).*

Fig. 232(c) shows a short-step microstrip impedance transformer which consists of short lengths of relatively high-impedance transmission line alternating with short lengths of relatively low-impedance transmission line. The sections of transmission line are all of the same length (i.e., $\lambda/16$). A constant load resistance can be maintained across the collector-emitter terminals over a wide frequency band if the circuit is designed to include a Chebyshev transmission characteristic. Fig. 232(d) shows a lumped-element Chebyshev impedance transformer which consists of a ladder network of series inductances and shunt capacitances. Transmission-line as well as strip-line baluns with different stepdown ratios (4 to 1, 9 to 1, and 16 to 1) can also be used in the output to provide the broadband impedance transformation.

One difficulty encountered in broadband transistor-power-amplifier design involves the attainment of the desired bandwidth in an input circuit which provides the required impedance transformation from the extremely low input impedance of a transistor to a relatively high source impedance. The design of the input circuit depends on the approach chosen: optimization of the match at the high end only, or the use of transistor parasitic elements as part of a low-pass structure. A simple way of optimizing the match at the high end is to introduce a capacitance between the base and the emitter terminals of the transistor to tune out the reactive part of the parallel equivalent input impedance of the transistor. The networks in Fig. 233 show that the lower the inductance $L_{in}$ or $Q_{in}$, the less frequency-sensitive is the equivalent parallel resistance $R_{eq}$. The networks shown provide a first step-up transformation for the real part of the input impedance of the transistor. When a capacitor is connected to the network of Fig. 233(a), the circuit has the same form as a half-section of a constant-K low-pass filter. If the cutoff frequency $\omega_c = 1/(L_{in}C)^{1/2}$ is high compared to the frequency of interest ($f_2$ in Fig. 230), the total combined input impedance of the transistor input and the capacitance C is approximately $R_{in}/(1 - \omega^2/\omega_c^2)$ and is constant if $(\omega^2/\omega_c^2) << 1$.

The remaining step in broadband transistor power amplifier design is the design of a network to provide the necessary impedance transformation over the entire frequency band. Circuits suitable for the input include multisection constant-K filters, Chebyshev filters, and tapered lines. A more sophisticated approach to obtaining a broadband transformation in the input is to treat the parasitic inductance $L_{in}$ of Fig. 233 as part of the transformation network. For example, $L_{in}$ can be considered as one arm of the Chebyshev low-pass filter of Fig. 232(d). For a given bandpass characteristic, the number of sections increases with the value of $L_{in}$. Again, therefore, low package parasitic inductance is important.

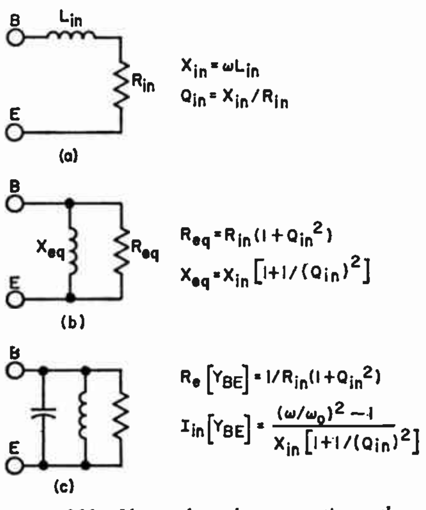



*Fig. 233—Networks demonstrating the effect of inductance $L_{in}$, or $Q_{in}$ on equivalent parallel resistance $R_{eq}$.*

Fig. 234 shows a 225-to-400-MHz broadband amplifier that uses

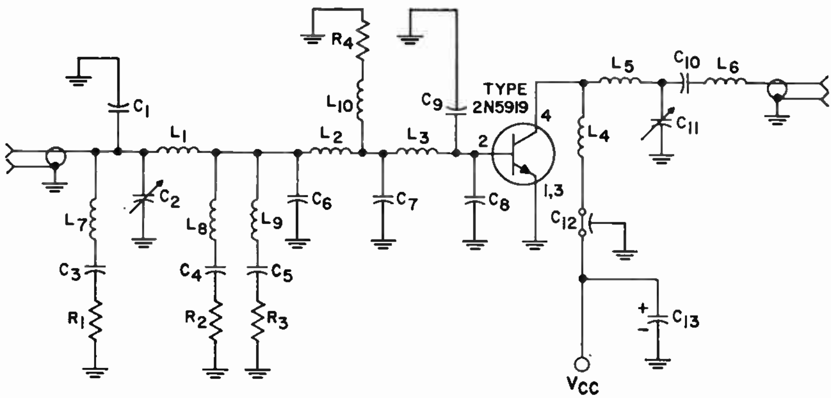



*Fig. 234—225-to-400-MHz broadband amplifier using 2N5919.*

an RCA 2N5919 transistor in conjunction with a Chebyshev input and output. Fig. 235 shows typical performance curves for this circuit. With an input of 4 watts, the circuit is capable of a minimum power output of 15 watts with a variation of 1.5 dB from 225 to 400 MHz; the collector efficiency is greater than 70 per cent.

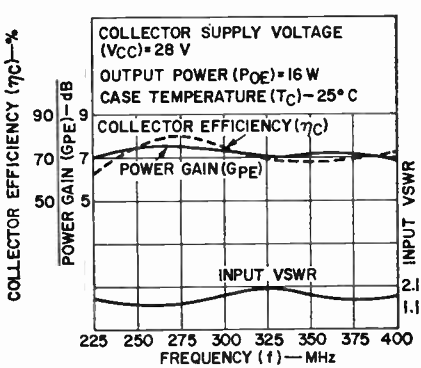



*Fig. 235—Typical broadband performance of the 225-to-400-MHz amplifier circuit shown in Fig. 234.*

## MICROWAVE POWER AMPLIFIERS

The power-output and frequency capabilities of rf power transistors have been increased many-fold during recent years so that the frequency spectrum over which these devices can provide useful power output now extends well into the microwave region.

In comparisons of transistor performances, gain and efficiency, as well as power output and frequency, are important considerations. The use of more than one low-gain transistor to obtain the same gain as one high-gain transistor results in reduced collector efficiency. For example, Fig. 236 illustrates the use of two transistors which have the same power output, but different gain and collector efficiency. The high-gain unit shown in Fig. 236(a) is capable of delivering an output of 10 watts at 1 GHz with a gain of 10 dB and a collector efficiency of 50 per cent. The low-gain unit shown in Fig. 236(b) is also capable of 10 watts output at 1 GHz, but with a gain of only 5 dB and a collector efficiency of only 30 per cent.

As shown in Fig. 236, two low-gain transistors are required to provide the same performance as one high-gain, high-efficiency unit. Besides using an additional transistor, the system of Fig. 236(b) requires twice as much dc power as that of Fig. 236(a); the additional 5 dB of gain required to match the high-gain transistor can be achieved only at the expense of 24 watts of dc power.

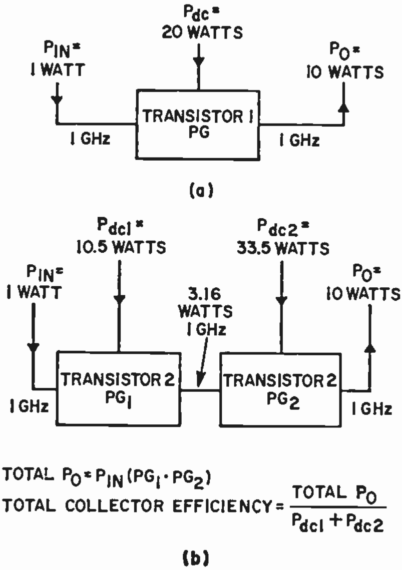



*Fig. 236—Comparison of one and two-transistor systems with the same power output but different gain and collector efficiencies.*

From the practical point of view, the system of Fig. 236(b) is more complex, and the higher dissipation of the output transistor is undesirable.

The 2N5108 transistor can be used in the common-emitter amplifier mode at L-band frequencies. A typical circuit configuration capable of operation in the 1-to-1.5-GHz range is shown in Fig. 237. This circuit can provide an output power of 1 watt at 1 GHz with a 28-volt power supply. The transistor emitter is directly grounded to the ground plane of the strip-line circuit board. The input circuit consists of capacitors $C_1$ and $C_2$ and the parasitic lead inductance of the 2N5108 transistor.

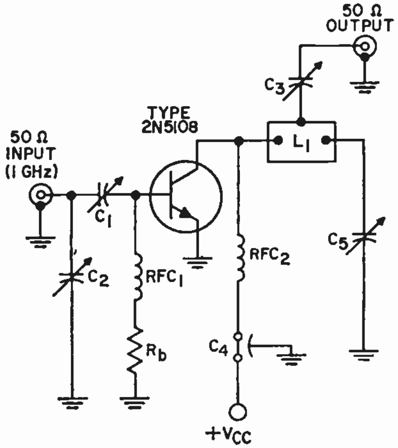



*Fig. 237—1-GHz power amplifier using 2N5108 transistor.*

The output circuit uses a capacitively loaded 50-ohm section of strip-line which is resonant at the operating frequency. The amplifier power gain is in the order of 6 dB; collector efficiency is about 35 per cent.

The RCA-2N5921 coaxial transistor is designed for operation at high L-band or low S-band frequencies. Fig. 238(a) shows a coaxial-line amplifier circuit which can provide 6 watts of output power at 2 GHz with a 28-volt power supply. In this circuit, the coaxial transistor is placed in series with the center conductors of the coaxial lines, and the base is properly grounded to separate the input and output cavities. The input line $L_1$, in conjunction with capacitance $C_1$ and $C_2$, transforms the complex input impedance to 50 ohms of real resistance.

The transistor output load impedance required for a 6-watt output

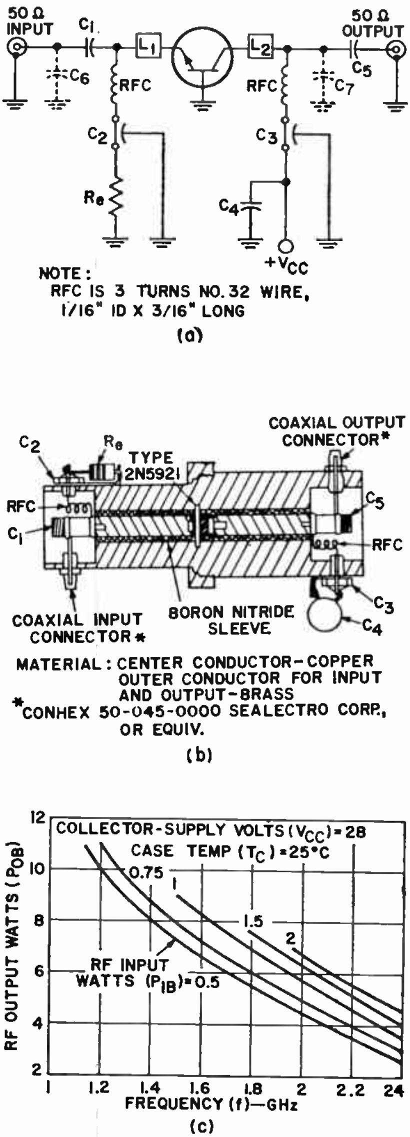



*Fig. 238—A coaxial-line amplifier circuit that can provide 6 watts of output power at 2 GHz with a 28-volt supply: (a) circuit diagram; (b) the hardware required for the circuit in (a); (c) rf power output as a function of frequency for the 2N5921 transistor.*

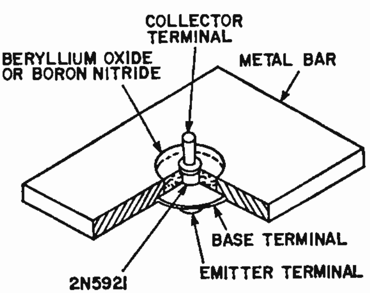
is 2.5 + j2.4 ohms at 2 GHz; the combination of a 7.8-ohm line $L_2$ (1-inch long) and capacitors $C_7$ and $C_6$ provides the transformation from 50 ohms to this value.

The hardware required in the circuit of Fig. 238(a) is shown in Fig. 238(b). A heat sink is provided by pressing the flange of the transistor to the outside conductor of the cavities. Additional heat flow is obtained through the use of a boron nitride cylinder which makes direct contact between the coaxial-line conductors over the entire length of the cavity. This arrangement improves heat conduction and thus is more suitable for high-power microwave transistors. In addition, the boron nitride, which has electrical and thermal properties comparable to aluminum oxide, is readily machineable and nontoxic. As a result of the use of the boron-nitride cylinder, coaxial-line lengths are substantially reduced.

When operated at 28 volts, the circuit of Fig. 238(a) can deliver cw power output of 6 watts at a gain of 7 dB; collector efficiency is greater than 45 per cent. Because of the excellent input and output circuit isolation (within the 2N5921 transistor as well as in this coaxial circuit design), the common-base circuit configuration shown in Fig. 238 is extremely stable. Fig. 238(c) shows the power output as a function of frequency of a 2N5921 transistor at 28 volts.

It has been established that a well-designed coaxial transistor package (such as the 2N5921) generally outperforms other transistor packages (including strip-line packages) at microwave frequencies. This performance can be related to the low values of the parasitic elements and the excellent isolation between the input and output circuits which is possible in the coaxial configuration. Coaxial transistors can also be used in microstrip or strip-line amplifier circuits which have thermal and electrical performance equal to that of the coaxial-line circuits.

Fig. 239(a) shows the circuit mounting arrangement of the 2N5921 coaxial transistor. The transistor is mounted vertically in a hole through a metal block. The cross-sectional view of the metal block can also be seen in Fig. 239(a). The bottom side of the metal block is counter-bored so that the base flange of the transistor can be placed flush with the metal block. The hole through the metal block has a somewhat larger diameter than that of the ceramic portion of the transistor which separates the base flange and the collector stud. A cylinder of beryllium oxide or boron nitride is press-fit between the transistor and the metal block to provide an additional heat-conducting path from the collector stud to the metal block; the block also serves as both a heat sink and a ground. The diameters of the holes through the metal block and the cylinder of beryllium oxide (or boron nitride) are determined by the desired characteristic impedance of the short coaxial-line section which is formed by this mounting technique. The beryllium oxide and boron nitride have excellent heat conductivity and low electrical losses and thus provide satisfactory heat dissipation from the coaxial transistor without adversely affecting the rf performance.



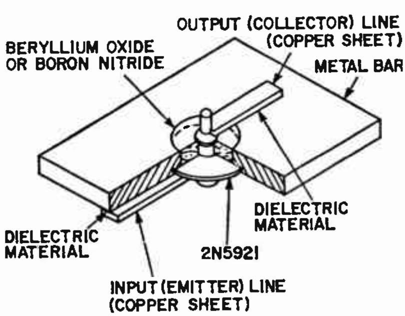




*Fig. 239—(a) Circuit mounting arrangement of the RCA-2N5921 coaxial transistor, and (b) a microstrip-line circuit making use of the arrangement in (a).*

The arrangement shown in Fig. 239(a) is suitable for use in microstrip, strip-line, and lumped-element circuits. The output circuit can be constructed on the top portion of the metal block and the input circuit on the bottom portion. This arrangement provides excellent isolation between the input and output circuits. For example, Fig. 239(b) shows the construction of the microstrip-line circuit. The output circuit is constructed of standard microstrip line mounted on the top surface of the metal block. The input circuit is constructed of another microstrip line placed directly over the bottom surface of the metal block. A strip-line circuit can be formed by placing another strip of dielectric material and ground plane above the conductor strips of Fig. 239(b).

In the microstrip amplifier circuit shown in Fig. 240, a 2N5921 transistor is mounted in a 0.350-inch-ID hole in a 0.210-inch-thick aluminum block. The base flange is mounted flush to one surface of this block. The collector section, however, is mounted through the hole in the block; a boron-nitride sleeve in the hole serves as an additional heat sink for the transistor.

The input and output lines are thin (5-mil) copper strips that are taped down on 5-mil Dupont H-Film,*

* Registered trademark, Dupont DeNemours & Co.

which serves as the dielectric medium of the microstrip circuit. The circuits are fixed-tuned at about 2 GHz. The ceramic capacitors $C_1$ and $C_5$ (used for dc isolation at the input and output ports) are slightly inductive at 2 GHz. The electrical performance of the circuit is equal to that of the coaxial-cavity circuit shown in Fig. 238.

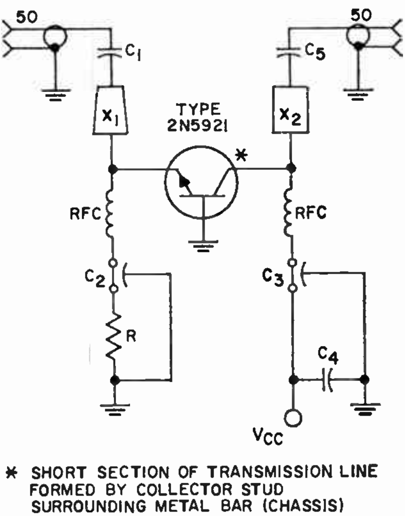
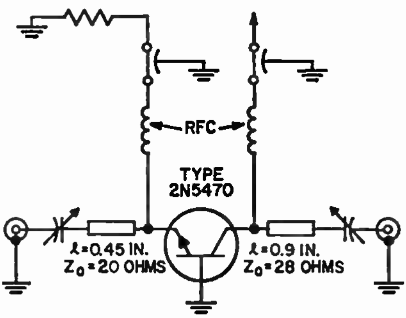



*Fig. 240—Typical 2-GHz grounded-base microstrip-line power amplifier circuit.*

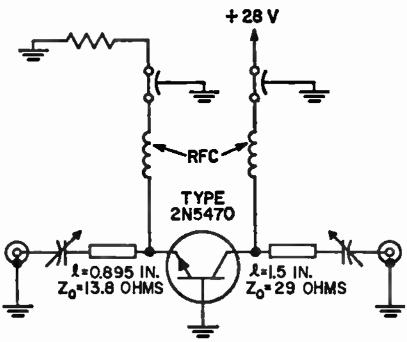
Fig. 241(a) shows the configuration for a 2-GHz amplifier that uses the same layout as that shown in Fig. 239. The metal block is aluminum. The input and output circuits are constructed on 1/32-inch Teflon* fiberglass board which is mounted atop the aluminum so that the input and output lines are on opposite sides of the aluminum block.

When operated at 28 volts with a typical 2N5470 transistor in the circuit, the 2-GHz amplifier can deliver a power output of 1.2 watts with a gain of 6 dB. The collector efficiency is 43 per cent, and the 3-dB bandwidth is 12 per cent. The performance of this microstrip-line amplifier is equivalent to that of a cavity or coaxial-line amplifier circuit.

A similar 1.5-GHz amplifier is shown in Fig. 241(b). The output circuit of this amplifier is constructed on 1/32-inch Teflon fiberglass board which is mounted on one surface of an aluminum block. The input line is constructed on the opposite side of the aluminum block; the block serves as the ground plane of the line. The input line is formed by mounting a 5-mil copper sheet over a 5-mil dielectric sheet (DuPont H-film) which is placed directly over




(a)




(b)

*Fig. 241—(a) A 2-GHz, and (b) a 1.5-GHz stripline amplifier using the type 2N5470 transistor.*

* Registered trademark, Dupont DeNemours & Co.

the aluminum block surface. This amplifier circuit, when operated at 28 volts with a typical 2N5470 transistor included, can provide output power of 1.5 watts with a gain of 8.5 dB and a collector efficiency of 50 per cent.

## MICROWAVE POWER GENERATION

Microwave power can be generated by operation of a power transistor as a fundamental-frequency oscillator or as an amplifier incorporated with a low-power, crystal-controlled multiplier chain. Both modes of operation are important in microwave applications. Fundamental-frequency oscillators are now widely used in local oscillators and sonde oscillators, and for backward-wave oscillator (BWO) replacement.

### Fundamental-Frequency Oscillators

Transistors capable of power amplification are also suitable for power oscillation. The most important part of every oscillator is an element of amplification. It is then necessary only to provide a path that feeds back a part of the power output to the input in the proper phase and a source of dc power. The maximum frequency of oscillation, which is related to $f_{max}$ in a small-signal transistor, is usually difficult to define in a microwave power transistor because of the added parasitic elements. The circuit-design for an oscillator circuit is similar to that discussed previously for amplifier circuits.

Fig. 242 shows Colpitts, Hartley, and Clapp transistor oscillators suitable for use in microwave applications. The inductances and the capacitances of the oscillator shown in Fig. 242(a) can sometimes be considered as the parasitic elements of the package. Such parasitic elements can be used to form a transistor oscillator capable of operation at microvave frequencies provided the frequency of oscillation can be controlled. Although the transistor configuration is not too well defined in these oscillator circuits, the device can be grounded in high-frequency operation at the collector, the base, or the emitter without affecting its performance.

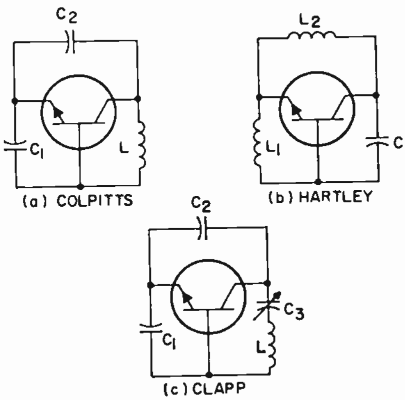



*Fig. 242—Basic transistor oscillator circuits: (a) Colpitts, (b) Hartley, and (c) Clapp.*

**L-Band Oscillators**—Fig. 243 shows the circuit configuration of a 1.68-GHz fundamental-frequency oscillator which uses the 2N5108 transistor. This transistor is packaged in a TO-39 case, and its collector is grounded to the ground plane of a 1/16-inch Teflon-fiberglass microstripline board. Power output is taken from the base through a 0.75-inch section of 50-ohm microstripline and the capacitor network composed of $C_1$ and $C_2$. Power output greater than 0.3 watt can be obtained at 1.68 GHz with the 2N5108 transistor. Transistor efficiency is 20 per cent at a supply voltage of 25 volts.

The basic oscillator circuit shown in Fig. 243 is useful over the range of 1 to 2 GHz with only slight modifications in the length of the transmission line $L_1$. For example, an increase of line length to 0.80 inch optimizes the circuit for operation at 1.5 GHz. Output power of 400

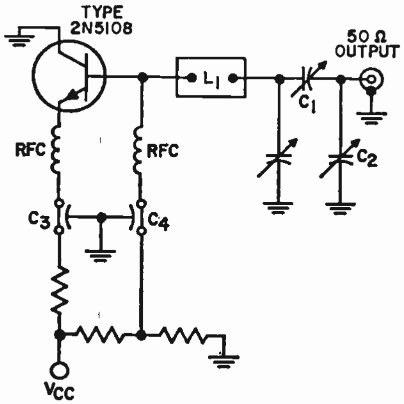



*Fig. 243—1.68-GHz fundamental-frequency oscillation using a 2N5108 transistor.*

milliwatts (with a 24-volt supply) can be expected at this frequency. In another interesting modification of the 0.80-inch line, operation is optimized at 1.25 GHz when capacitor $C_2$ is moved to the dotted position. This modification results in an improved output transformation network which can develop better than 800 milliwatts of output power at 1.25 GHz with the 24-volt supply.

S-Band Oscillators—Although the 2N5470 coaxial transistor is designed for stable operation in the common-base amplifier mode at 2.3 GHz, it can also deliver a power output of 0.3 watt at 2.3 GHz as an oscillator. In this device, the very low values of the parasitic elements are used to simplify circuit requirements; for example, lumped-constant, S-band circuits can be designed around this unit. However, because of the low feedback capacitances of the unit, external feedback loops are needed for sustained oscillation at S-band frequencies.

Fig. 244 shows a simple lumped-constant circuit using the 2N5470 transistor. The circuit is tunable over the range of 1.8 to 2.3 GHz. At 2 GHz with a 24-volt supply, the power output of this circuit is typically 0.3 watt; the efficiency is in the order of 16 per cent. The collector is grounded and power output is taken from the base circuit. All leads in the circuit must be kept as short as possible for highest frequency response. Capacitor $C_1$ forms a part of the feedback loop of the circuit, which is basically a Hartley arrangement because $L_1$ and the parastic inductances of $C_1$ make up a tapped inductor in the feedback loop. Capacitor $C_6$ is used for tuning while capacitor $C_5$ is used for maintaining output match with tuning.

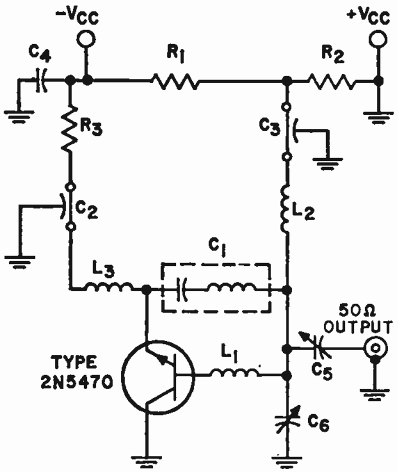



*Fig. 244—A 2-GHz lumped-constant oscillator using a 2N5470 transistor.*

Fig. 245 shows another oscillator circuit, a Colpitts type, in which the 2N5470 transistor can be used over the range of 1.8 to 2.2 GHz. The base of the transistor is directly grounded to the ground plane on the strip-line board; collector heat is conducted to this board through a beryllium oxide insulating washer. Feedback is provided by the phase-resonant loop composed of $L_4$ and $C_1$. The output line makes use of standard microstrip-line techniques: $L_2$ provides the reactance needed to tune out the output capacitance; $L_1$, a quarter-wave transformer, transforms the real collector load impedance to about 50 ohms. This circuit can also produce about 0.3 watt output at 2 GHz with a 24-volt supply.

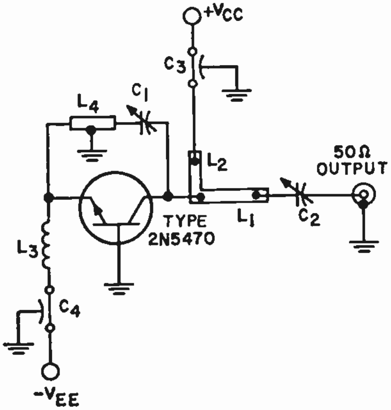



*Fig. 245—2-GHz microstrip-line oscillator using a 2N5470 transistor.*

## Transistor Frequency-Multiplier Circuits

Because the output-current waveform of power transistors can be made to contain both fundamental and harmonic frequency components, power output can be obtained at a desired harmonic frequency by use of a special type of output circuit coupled to the collector of the transistor. Transistors can be connected in either the common-base or the common-emitter configuration for frequency multiplication.

The design of transistor frequency-multiplier circuits consists of selection of a suitable transistor and design of filtering and matching networks for optimum circuit performance. The transistor must be capable of power and gain at the fundamental frequency and capable of converting power from the fundamental to a harmonic frequency. At a given input power level, the output power at a desired harmonic frequency is equal to the product of the power gain of the transistor at the drive frequency and the conversion efficiency of the frequency-multiplier circuit. Conversion gain can be obtained only when the power gain of the transistor at the fundamental frequency is larger than the conversion loss of the circuit.

Various types of instabilities can occur in transistor frequency-multiplier circuits, including low-frequency resonances, parametric oscillations, hysteresis, and high-frequency resonances. Low-frequency resonances occur because the gain of the transistor is very high at low frequency compared to that at the operating frequency. "Hysteresis" refers to discontinuous mode jumps in output power when the input power or frequency is increased or decreased. A tuned circuit used in the output coupling network has a different resonant frequency under strong drive than under weaker driving conditions. It has been found experimentally that hysteresis effect can be minimized, and sometimes eliminated, by use of the common-emitter configuration.

Perhaps the most troublesome instability in transistor frequency-multiplier circuits is high-frequency resonance. Such instability shows up in the form of oscillations at a frequency very close to the output frequency when the input drive power is removed. This effect suggests that the transistor under this condition behaves as a locked oscillator at the fundamental frequency. Common-emitter circuits have been found to be less critical for high-frequency oscillations than common-base circuits. High-frequency resonance is also strongly related to the input drive frequency, and can be eliminated if the input frequency is kept below a certain value. The input frequency at which stable operation can be obtained depends on the method used to ground the emitter of the transistor, and can be increased by use of the shortest possible path from the emitter to ground.

Varactor diodes are also used to provide frequency multiplication. Fig. 102 and associated text given previously in the section on **Other Solid-State Diodes** define the requirements for this type of application.

**400-To-800-MHz Doubler**—Fig. 246 shows the complete circuit diagram of a 400-to-800-MHz doubler that uses the 2N4012 transistor. This circuit uses lumped-element input and idler circuits and a coaxial-cavity output circuit. The transistor is placed inside the cavity with its emitter properly grounded to the chassis. A pi section ($C_1$, $C_2$, $L_1$, $L_2$, and $C_3$) is used in the input to match the impedances, at 400 MHz, of the driving source and the base-emitter junction of the transistor. $L_2$ and $C_3$ provide the necessary ground return for the nonlinear capacitance of the transistor. $L_3$ and $C_4$ form the idler loop for the collector at 400 MHz. The output circuit consists of an open-ended 1¼-inch-square coaxial cavity. A lumped capacitance $C_5$ is added in series with a ¼-inch hollow-center conductor of the cavity near the open end to provide adjustment for the electrical length. Power output at 800 MHz is obtained by direct coupling from a point near the shorted end of the cavity.

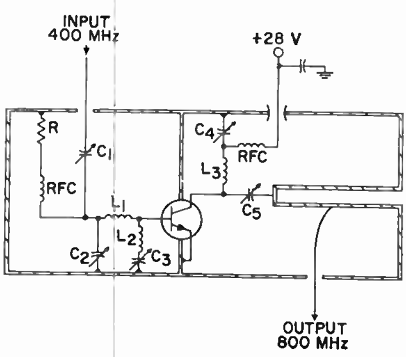



*Fig. 246—400-to-800-MHz common-emitter transistor frequency multiplier.*

Fig. 247 shows the power output at 800 MHz as a function of the power input at 400 MHz for the doubler circuit, which uses a typical 2N4012 operated at a collector supply voltage of 28 volts. The curve is nearly linear at a power output level between 0.9 and 2.7 watts. The power output is 3.3 watts at 800 MHz for an input drive of 1 watt at 400 MHz, and rises to 3.9 watts as the input drive increases to 1.7 watts.

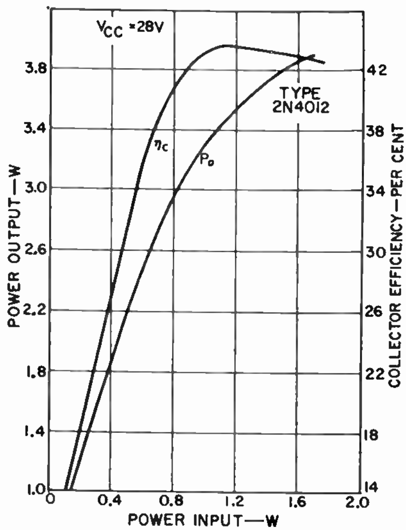



*Fig. 247—Output power and collector efficiency as a function of input power for the 400-to-800-MHz frequency doubler.*

The collector efficiency, which is defined as the ratio of the rf power output to the dc power input at a supply voltage of 28 volts, is also shown in Fig. 247. The efficiency is 43 per cent measured at an input power of 1 watt. The 3-dB bandwidth of this circuit measured at power output of 3.3 watts is 2.5 per cent. The fundamental-frequency component measured at a power-output level of 3.3 watts is 22 dB down from the output carrier. Higher attenuations of spurious components can be achieved if more filtering sections are used.

The variation of power output with collector supply voltage at an input drive level of 1 watt is shown in Fig. 248. This curve is obtained with the circuit tuned at 28 volts. The curves of Figs. 247 and 248 indicate that the transistor amplifier-multiplier circuit is capable of amplitude modulation.

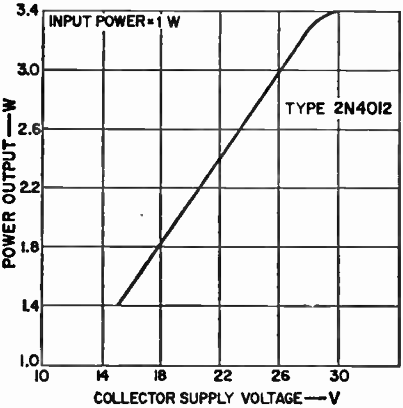



*Fig. 248—Power output as a function of supply voltage for the 400-to-800-MHz frequency doubler.*

**367-To-1100-MHz Tripler**—The 367-to-1100-MHz tripler shown in Fig. 249 is essentially the same as the doubler shown in Fig. 246 except that an additional idler loop, ($L_4$, $C_6$) is added in shunt with the collector of the transistor. This idler loop is resonant with the transistor junction capacitance at the second harmonic frequency (734 MHz) of the input drive.

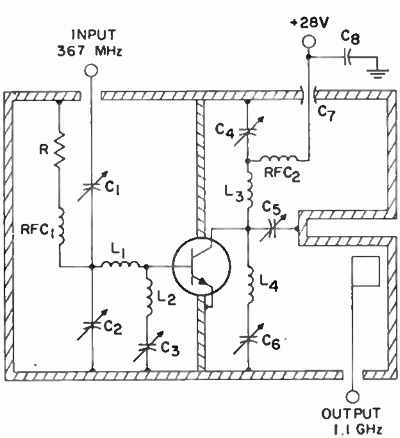



*Fig. 249—367-MHz-to-1.1-GHz common-emitter transistor frequency tripler.*

Fig. 250 shows the power output of the tripler at 1.1 GHz as a function of the power input at 367 MHz. This circuit also uses a typical 2N4012 transistor operated at a collector supply voltage of 28 volts. The solid-line curve shows the power output obtained when the circuit is retuned at each power-input level. The dashed-line curve shows the power output obtained with the circuit tuned at the 2.9-watt output level. A power output of 2.9 watts at 1.1 GHz is obtained with drive of 1 watt at 367 MHz. The 3-dB bandwidth measured at this power level is 2.3 per cent. The spurious-frequency components measured at the output are as follows: −22 dB at 340 MHz, −30 dB at 680 MHz, and −35 dB at 1360 MHz.

The variation of power output with collector supply voltage at an input drive level of 1 watt is shown in Fig. 251. The variation of collector efficiency is also shown. These curves were obtained with the circuit tuned at 28 volts.

A 367-MHz amplifier that used the same circuit configuration and components as those of the tripler circuit shown in Fig. 249 was constructed to compare the performance between amplifier and tripler. The conversion efficiency for a large number of tripler units was then measured. The conversion efficiency of the tripler is defined as the 1.1GHz power obtained from the tripler divided by the 367-MHz power obtained from the amplifier at the same power-input level (1 watt). The efficiency varies between 60 to 75 per cent, and has an average value of 65 per cent; this performance is comparable to that of a good varactor multiplier in this frequency range.

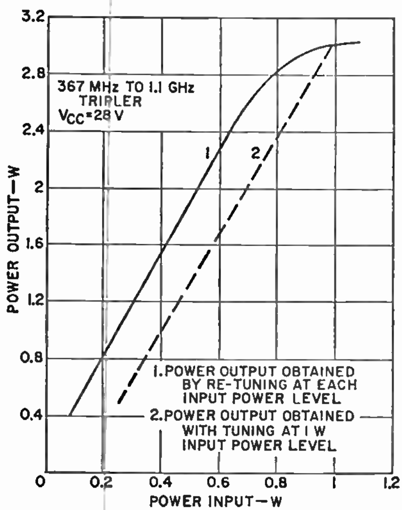



*Fig. 250—Power output as a function of power input for the 367-MHz-to-1.1-GHz frequency tripler.*

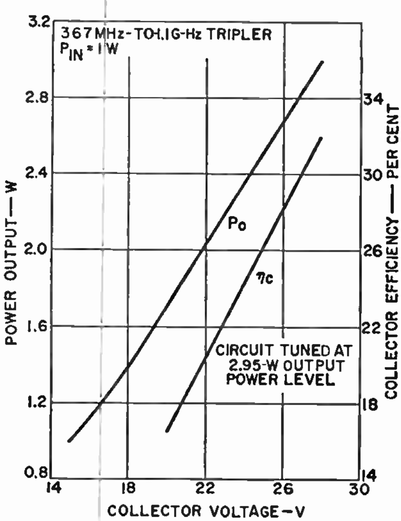



*Fig. 251—Power output as a function of collector supply voltage for the 367-MHz-to-1.1-GHz frequency tripler.*

A similar tripler circuit that uses a selected 2N3866 and that is operated from 500 MHz to 1.5 GHz can deliver a power output of 0.5 watt at 1.5 GHz with an input drive of 0.25 watt at 500 MHz.

**150-To-450-MHz Tripler Circuit**—Fig. 252 illustrates the use of the 2N4012 transistor in a 150-to-450-MHz frequency tripler. The input coupling network is designed to match the driving generator to the base-to-emitter circuit of the transistor. The network formed by $C_2$ and $L_2$ provides a ground return for harmonic output current at 450 MHz. The idler network in the collector circuit ($L_3$, $L_4$, and $C_4$) is designed to circulate fundamental and second-harmonic components of current through the voltage-variable collector-to-base capacitance, $C_{bc}$.

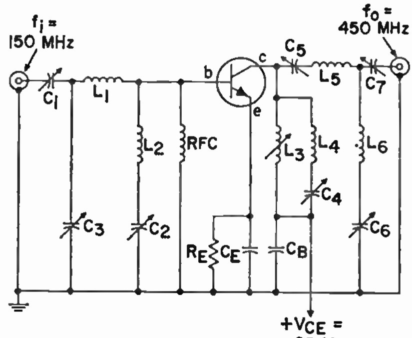



*Fig. 252—150-to-450-MHz common-emitter transistor frequency tripler.*

The network formed by $C_5$, $C_6$, $C_7$, $L_5$, and $L_6$ provides the required collector loading for 450-MHz power output. Fig. 253 shows the 450-MHz power output of the tripler as a function of the 150-MHz power input. For driving power of one watt, power output of 2.8 watts is obtained at 450 MHz. The rejection of fundamental, second, and fourth harmonics was measured as 30 dB below the 2.8-watt, 450-MHz level. The variation of power output with supply voltage is shown in Fig. 254.

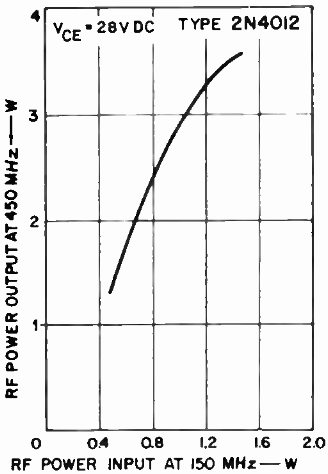



*Fig. 253—Power output as a function of power input for the 150-to-450-MHz frequency tripler.*

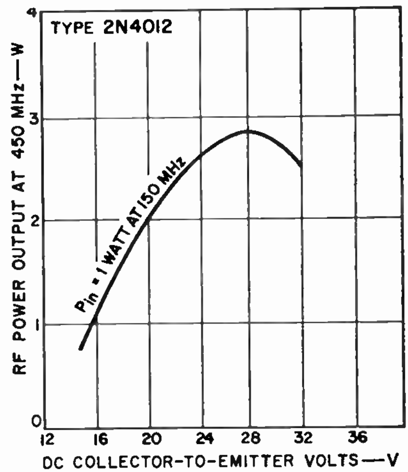



*Fig. 254—Power output as a function of collector supply voltage for the 150-to-450-MHz frequency tripler.*

# TV Deflection

For reproduction of a transmitted picture in a television receiver, the face of a cathode-ray tube is scanned with an electron beam while the intensity of the beam is varied to control the emitted light at the phosphor screen. The scanning is synchronized with a scanned image at the TV transmitter, and the black-through-white picture areas of the scanned image are converted into an electrical signal that controls the intensity of the electron beam in the picture tube at the receiver.

## SCANNING FUNDAMENTALS

The scanning procedure used in the United States employs horizontal linear scanning in an odd-line interlaced pattern. The standard scanning pattern for television systems includes a total of 525 horizontal scanning lines in a rectangular frame having an aspect ratio of 4 to 3. The frames are repeated at a rate of 30 per second, with two fields interlaced in each frame. The first field in each frame consists of all odd-number scanning lines, and the second field in each frame consists of all even-number scanning lines. The field repetition rate is thus 60 per second, and the vertical scanning rate is 60 Hz. (For color systems, the vertical scanning rate is 59.94 Hz.)

The geometry of the standard odd-line interlaced scanning pattern is illustrated in Fig. 255. The scanning beam starts at the upper left corner of the frame at point A, and sweeps across the frame with uniform velocity to cover all the picture elements in one horizontal line. At the end of each trace, the beam is rapidly returned to the left side of the frame, as shown by the dashed line, to begin the next horizontal line. The horizontal lines slope downward in the direction of scanning because the vertical deflecting signal simultaneously produces a vertical scanning motion, which is very slow compared with the horizontal scanning speed. The slope of the horizontal line trace from left to right is greater than the slope of the retrace from right to left because the shorter time of the retrace does not allow as much time for vertical deflection of the beam. Thus, the beam is continuously and slowly deflected downward as it scans

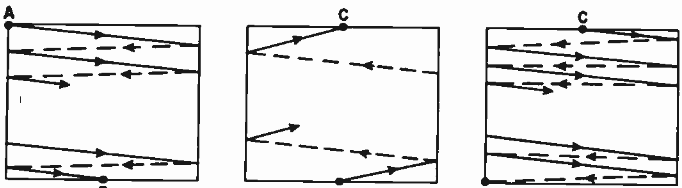



*Fig. 255—The odd-line interlaced scanning procedure.*

the horizontal lines, and its position is successively lower as the horizontal scanning proceeds.

At the bottom of the field, the vertical retrace begins, and the beam is brought back to the top of the frame to begin the second or even-number field. The vertical "flyback" time is very fast compared to the trace, but is slow compared to the horizontal scanning speed; therefore, some horizontal lines are produced during the vertical flyback.

All odd-number fields begin at point A in Fig. 255 and are the same All even-number fields begin at point C and are the same. Because the beginning of the even-field scanning at C is on the same horizontal level as A, with a separation of one-half line, and the slope of all lines is the same, the even-number lines in the even fields fall exactly between the odd-number lines in the odd field.

## SYNC

In addition to picture information, the composite video signal from the video detector of a television receiver contains timing pulses to assure that the picture is produced on the faceplate of the picture tube at the right instant and in the right location. These pulses, which are called sync pulses, control the horizontal and vertical scanning generators of the receiver.

Fig. 256 shows a portion of the detected video signal. When the picture is bright, the amplitude of the signal is low. Successively deeper grays are represented by higher amplitudes until, at the "blanking level" shown in the diagram, the amplitude represents a complete absence of light. This "black level" is held constant at a value equal to 75 per cent of the maximum amplitude of the signal during transmission. The remaining 25 per cent of the signal amplitude is used for synchronization information. Portions of the signal in this region (above the black level) cannot produce light.

In the transmission of a television picture, the camera becomes inactive at the conclusion of each horizontal line and no picture information is transmitted while the scanning beam is retracing to the beginning of the next line. The scanning beam of the receiver is maintained at the black level during this retrace interval by means of the blanking pulse shown in Fig. 256. Immediately after the beginning of the blanking period, the signal amplitude rises further above the black level to provide a horizontal-synchronization pulse that initiates the action of the horizontal scanning generator. When the bottom line of the picture is reached, a similar vertical-synchronization pulse initiates the action of the vertical scanning generator to move the scanning spot back to the top of the pattern.

The sync pulses in the composite video signal are separated from the picture information in a sync-separator stage, as shown in Figs. 257 and 258. This stage is biased sufficiently beyond cutoff so that current flows and an output signal is produced only at the peak positive swing of the input signal. In the

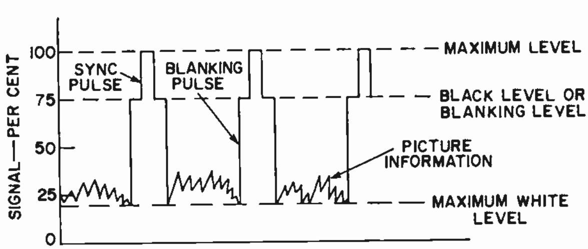



*Fig. 256—Detected video signal.*

diode circuit of Fig. 257, negative bias for the diode is developed by R and C as a result of the flow of diode current on the positive extreme of signal input. The bias automatically adjusts itself so

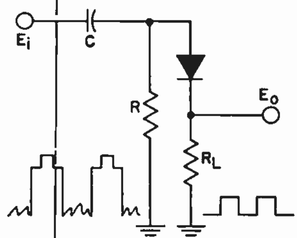



*Fig. 257—Diode sync-separator circuit.*

that the peak positive swing of the input signal drives the anode of the diode positive and allows the flow of current only for the sync pulse. In the circuit shown in Fig. 258, the base-emitter junction of the transistor functions in the same manner as the diode in Fig. 257, but in addition the pulses are amplified.

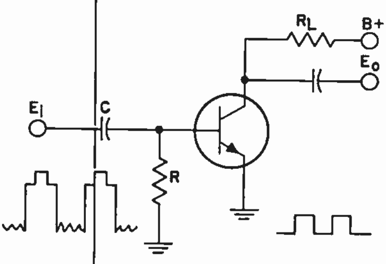



*Fig. 258—Transistor sync-separator circuit.*

After the synchronizing signals are separated from the composite video signal, it is necessary to filter out the horizontal and vertical sync signals so that each can be applied to its respective deflection generator. This filtering is accomplished by RC circuits designed to filter out all but the desired synchronizing signals. Although the horizontal, vertical, and equalizing pulses are all rectangular pulses of the same amplitude, they differ in frequency and pulse width, as shown in Fig. 259. The horizontal sync pulses have a repetition rate of 15,750 per second (one for each horizontal line) and a pulse width of 5.1 microseconds. (For color system, the repetition rate of the horizontal sync pulses is 15,734 per second.) The equalizing pulses have a width approximately half the horizontal pulse width, and a repetition rate of 31,500 per second; they occur at half-line intervals, with six pulses immediately preceding and six following the vertical synchronizing pulse. The vertical pulse is repeated at a rate of 60 per second (one for each field), and has a width of approximately 190 microseconds. The serrations in the vertical pulse occur at half-line intervals, dividing the complete pulse into six individual pulses that provide horizontal synchronization during the vertical retrace. (Although the picture is blanked out during the vertical retrace time, it is necessary to keep the horizontal scanning generator synchronized.)

All the pulses described above are produced at the transmitter by the synchronizing-pulse generator; their waveshapes and spacings are held within very close tolerances to provide the required synchronization of receiver and transmitter scanning.

The horizontal sync signals are separated from the total sync in a differentiating circuit that has a short time constant compared to the width of the horizontal pulses. When the total sync signal is applied to the differentiating circuit shown in Fig. 260, the capacitor charges completely very soon after the leading edge of each pulse, and remains charged for a period of time equal to practically the entire pulse width. When the applied voltage is removed at the time corresponding to the trailing edge of each pulse, the capacitor discharges completely within a very short time. As a result, a positive peak of voltage is obtained for each leading edge and a negative peak for the trailing edge of every pulse. One polarity is produced by the charging current for the leading edge of the applied pulse, and the

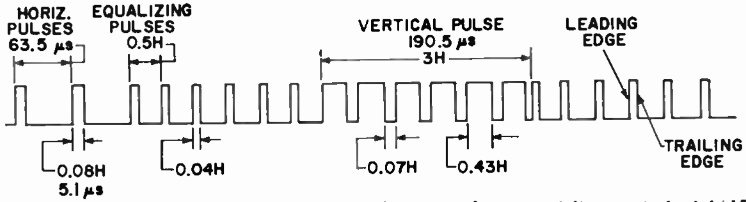



*Fig. 259—Waveform of TV synchronizing pulses (H = horizontal line period of 1/15,750 seconds, or 63.5 μs).*

opposite polarity is obtained from the discharge current corresponding to the trailing edge of the pulse.

As mentioned above, the serrations in the vertical pulse are inserted to provide the differentiated output needed to synchronize the horizontal scanning generator during the time of vertical synchronization. During the vertical blanking period, many more voltage peaks are available than are necessary for horizontal synchronization (only one pulse is used for each horizontal line period). The check marks above the differentiated output in Fig. 260 indicate the voltage peaks used to synchronize the horizontal deflection generator for one field. Because the sync system is made sensitive only to positive pulses occurring at approximately the right horizontal timing, the negative sync pulses and alternate differentiated positive pulses produced by the equalizing pulses and the serrated vertical information have no effect on horizontal timing. It can be seen that although the total sync signal (including vertical synchronizing information) is applied to the circuit of Fig. 260, only horizontal synchronization information appears at the output.

The vertical sync signal is separated from the total sync in an integrating circuit which has a time constant that is long compared with the duration of the 5-microsecond horizontal pulses, but short compared with the 190-microsecond vertical pulse width. Fig. 261 shows the general circuit configuration used, together with the input and output signals for both odd and even fields. The period between horizontal pulses, when no voltage is applied to the RC circuit, is so much longer than the horizontal pulse width that the capacitor has time to discharge almost down to zero. When the vertical pulse is applied, however, the integrated voltage across the capacitor builds

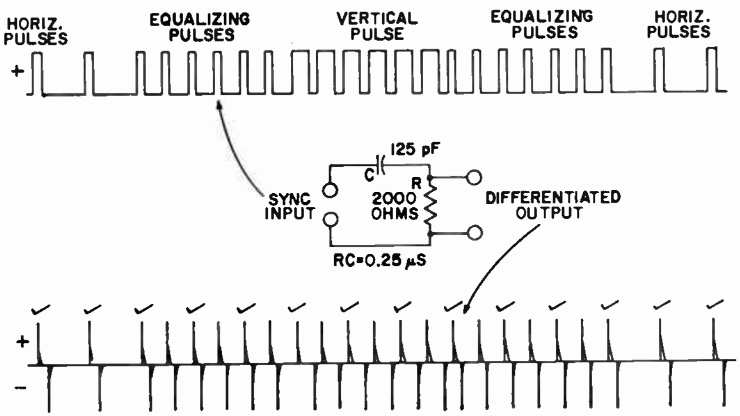



*Fig. 260—Separation of the horizontal sync signals from the total sync by a differentiating circuit.*

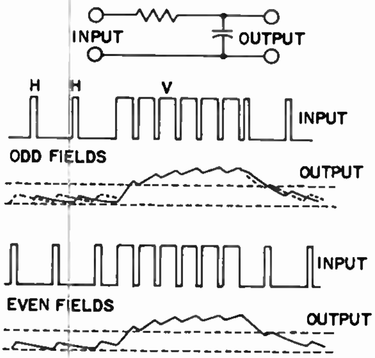



*Fig. 261—Separation of vertical sync signals from the total sync for odd and even fields with no equalizing pulses. (Dashed line indicates triggering level for vertical scanning generator.)*

up to the value required for triggering the vertical scanning generator. This integrated voltage across the capacitor reaches its maximum amplitude at the end of the vertical pulse, and then declines practically to zero, producing a pulse of the triangular wave shape shown for the complete vertical synchronizing pulse. Although the total sync signal (including horizontal information) is applied to the circuit of Fig. 258, therefore, only vertical synchronization information appears at the output.

The vertical synchronizing pulses are repeated in the total sync signal at the field frequency of 60 per second (59.94 per second in color systems). Therefore, the integrated output voltage across the capacitor of the RC circuit of Fig. 261 can be coupled to the vertical scanning generator to provide vertical synchronization. The six equalizing pulses immediately preceding and following the vertical pulse improve the accuracy of the vertical synchronization for better interlacing. The equalizing pulses that precede the vertical pulses make the average value of applied voltage more nearly the same for even and odd fields, so that the integrated voltage across the capacitor adjusts to practically equal values for the two fields before the vertical pulse begins. The equalizing pulses that follow the vertical pulse minimize any difference in the trailing edge of the vertical synchronizing signal for even and odd fields.

## VERTICAL DEFLECTION

The vertical-deflection circuit in a television receiver is essentially a class A audio amplifier with a complex load line, severe low-frequency requirements (much lower than 60 Hz), and a need for controlled linearity. The equivalent low-frequency response for a 10-per-cent deviation from linearity is 1 Hz. A simple circuit configuration is shown in Fig. 262.

The required performance can be obtained in a vertical-deflection circuit in any of three ways. The amplifier may be designed to provide a flat response down to 1 Hz. This design, however, requires an extremely large output transformer and immense capacitors. Another arrangement is to design the amplifier for fairly good low-frequency response and predistort the generated signal.

The third method is to provide extra gain so that feedback techniques can be used to provide linearity. If loop feedback of 20 or 30 dB is used, transistor gain variations and nonlinearities become fairly insignificant. The feedback automatically provides the necessary "predistortion" to correct low-frequency limitations. In addition, the coupling of miscellaneous signals (such as power-supply hum or horizontal-deflection signals) in the amplifying loop is suppressed.

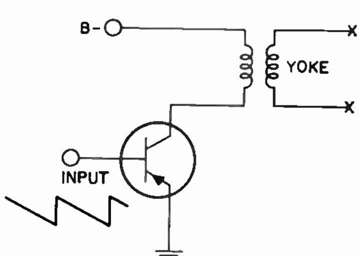



*Fig. 262—Simple vertical-deflection circuit.*

Fig. 263 shows a vertical-deflection system that employs bipolar and MOS transistors. A positive pulse fed back from the output circuit triggers the oscillator $Q_1$. The high input impedance of the MOS transistor $Q_2$, used as a predriver, permits the use of relatively large resistors and small capacitors in the gate-No.1 circuit. Negative sync is injected at gate No. 2. Only 4 to 5 volts of sync at the integrator input provides exceptionally good interlace.

The thermal compensating stage, $Q_5$, provides thermal tracking during warmup and also prevents thermal runaway. The peak current of the output stage, $Q_4$, is monitored by connection of the base of $Q_5$ to the emitter side of the emitter resistor of $Q_4$. The output voltage developed at the collector of $Q_5$ is proportional to the peak current of the vertical output stage and is fed back to gate No.1 of the predriver $Q_2$ by means of the bias-linearity control. If some condition exists which causes the peak current of the output stage to increase, the thermal-compensating transistor $Q_5$ conducts more heavily and causes a reduction in the average voltage at its collector. This decreasing voltage changes the bias of the predriver $Q_2$. Because the predriver, driver, and output stages are all direct-coupled, the changes in the peak current of the output stage are coupled back to the base of the output stage in such a polarity as to adjust the dc operating conditions of the output stage to compensate for any change in peak current.

There are two linearity potentiometers in the circuit. The first is a bias potentiometer which sets the bias on the predriver and, in turn, on the output unit so that the output unit commences scan from cutoff. The second potentiometer is located in the integrating circuit, which shapes a sawtooth waveform taken from the output and feeds it back to gate No.1 of the predriver to provide the required parabolic correction for good linearity.

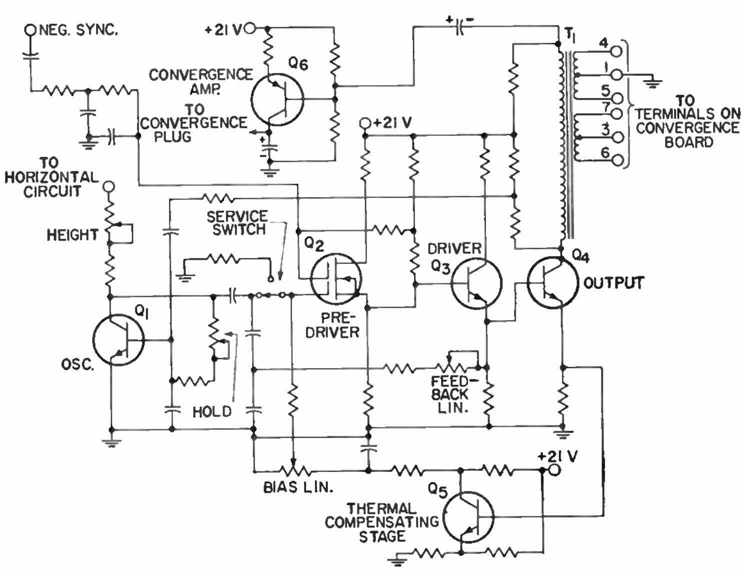



*Fig. 263—Vertical-deflection ciruit for color TV receiver.*

The parabolic sawtooth voltage required for convergence is obtained from the collector of the output transistor $Q_4$. This sawtooth voltage is coupled to the base of the convergence amplifier $Q_6$ and then applied to the convergence board.

For vertical blanking, the negative retrace pulse from the secondary of the vertical output transformer is amplified and inverted by a blanking transistor, and is then applied to the cathodes of the picture tube.

## HORIZONTAL DEFLECTION

In the horizontal-deflection stages of a television receiver, a current that varies linearly with time and has a sufficient peak-to-peak amplitude must be passed through the horizontal-deflection-yoke winding to develop a magnetic field adequate to deflect the electron beam of the television picture tube. After the beam is deflected completely across the face of the picture tube, it must be returned very quickly to its starting point. (As explained previously, the beam is extinguished during this retrace by the blanking pulse incorporated in the composite video signal, or in some cases by additional external blanking derived from the horizontal-deflection system.)

### Basic Circuit Requirements

The simplest form of a deflection circuit is shown in Fig. 264(a). In this circuit, the yoke impedance L is assumed to be a perfect inductor. When the switch is closed, the yoke current starts from zero and increases linearly. At any time t, the current i is equal to $Et/L$, where E is the applied voltage. When the switch is opened at a later time $t_1$, the current instantly drops from a value of $Et_1/L$ to zero.

Although the basic circuit shown in Fig. 264(a) crudely approaches the requirements for deflection, it presents some obvious problems and limitations. The voltage across the switch becomes extremely high, theoretically approaching infinity. In addition, if very little of the total time is spent at zero current, the circuit would require a tremendous

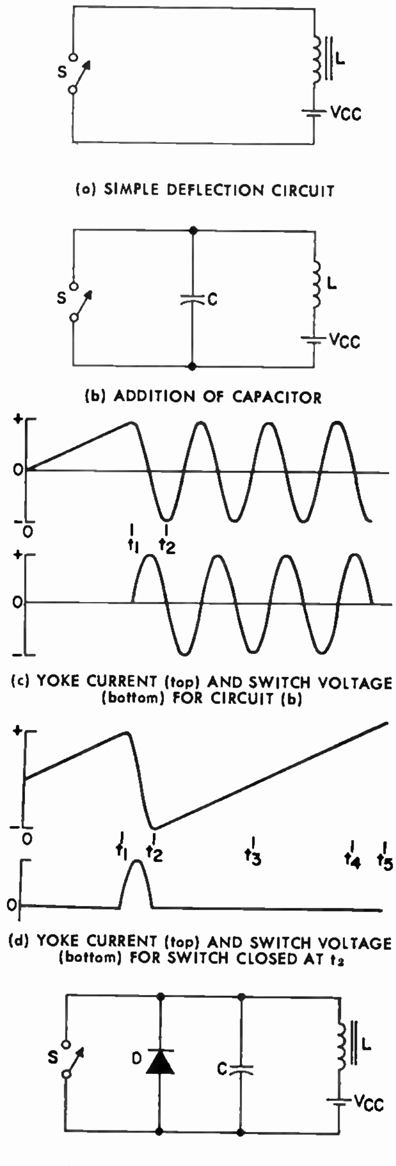



*Fig. 264—Development of horizontal-deflection circuit.*

amount of dc power. Furthermore, the operation of the switch would be rather critical with regard to both its opening and its closing. Finally, because the deflection field would be phased in only one direction, the beam would have to be centered at the extreme left of the screen for zero yoke current.

If a capacitor is placed across the switch, as shown in Fig. 272(b), the yoke current still increases linearly when the switch is closed at time $t = 0$. However, when the switch is opened at time $t = t_1$, a tuned circuit is formed by the parallel combination of L and C. The resulting yoke currents and switch voltages are then as shown in Fig. 264(c). The current is at a maximum when the voltage equals zero, and the voltage is at a maximum when the current equals zero. If it is assumed that there are no losses, the ringing frequency $f_{osc}$ is equal to $1/(2\pi\sqrt{LC})$.

If the switch is closed again at any time the capacitor voltage is not equal to zero, an infinite switch current flows as a result of the capacitive discharge. However, if the switch is closed at the precise moment $t_2$ that the capacitor voltage equals zero, the capacitor current effortlessly transfers to the switch, and a new transient condition results. Fig. 264(d) shows the yoke-current and switch-voltage waveforms for this new condition.

If the switch is again opened at $t_4$, closed at $t_5$, and so on, the desired sweep results, the peak switch voltage is finite, and the average supply current is zero. The deflection system is then lossless and efficient and, because the average yoke current is zero, beam decentering is avoided. The only fault of the circuit of Fig. 264(b) is the critical timing of the switch, particularly at time $t = t_2$. However, if the switch is shunted by a damper diode, as shown in Fig. 264(e), the diode acts as a closed switch as soon as the capacitor voltage reverses slightly. The switch may then be closed at any time between $t_2$ and $t_3$.

## Transistor Horizontal-Deflection Circuits

In horizontal-deflection circuits, the switch can be a transistor, as shown in Fig. 265. Although the transistor is forward-biased prior to $t_3$ (shown in Fig. 264), it is not an effective switch for the reverse collector current; therefore, the damper diode carries most of this current. High voltage is generated by use of the step-up transformer $T_1$ in parallel with the yoke. This step-up transformer is designed so that its leakage inductance, distributed capacitance, and output stray capacitance complement the yoke inductance and retrace tuning

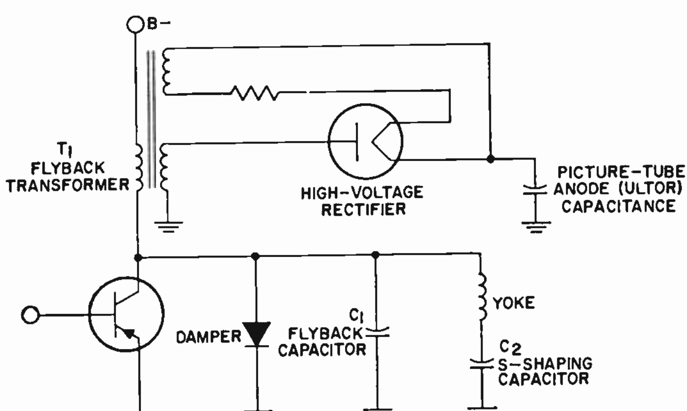



*Fig. 265—Simple transistor horizontal-deflection circuit.*

capacitance in such a manner that the peak voltage across the primary winding is reduced and the peak voltage across the secondary winding is increased, as compared to the values that would be obtained in a perfect transformer. This technique, which is referred to as "third-harmonic tuning", yields a voltage ratio of secondary-to-primary peak voltage of approximately 1.7 times the value expected in a perfect transformer.

To provide linearity correction for wide-angle television picture tubes, it is necessary to retard the sweep rate at the beginning and end of scan. Therefore, a suitable capacitor $C_2$ is placed in series with the yoke, as shown in Fig. 265, so that the direct current required to replenish circuit losses is fed through the flyback-transformer primary. A parabolic waveform is then developed across $C_2$ (called the S-shaping capacitor) so that the trace voltage across the yoke is less at the ends of the sweep than in the middle of the sweep. (This capacitor actually provides a series resonant circuit tuned to approximately 5 kHz so that an S-shaped current portion of a sine wave results.) It is desirable to place the S-shaping capacitor and the yoke between the collector and the emitter of the transistor so that the yoke current does not have to flow through the power supply.

The highest anticipated peak voltage across the transistor in Fig. 265 is a function of the dc voltage obtained at high ac line voltage and at the lowest horizontal-oscillator frequency. (At these conditions, of course, the receiver is out of sync.) The tolerance on the inductors and capacitors alters the trace time only slightly and usually may be ignored if a 10-per-cent tolerance is used for the tuning capacitor.

Fig. 266 shows a schematic of a transistor horizontal-deflection circuit for a color TV receiver. The horizontal output transistor, $Q_4$, is a high-voltage silicon transistor.

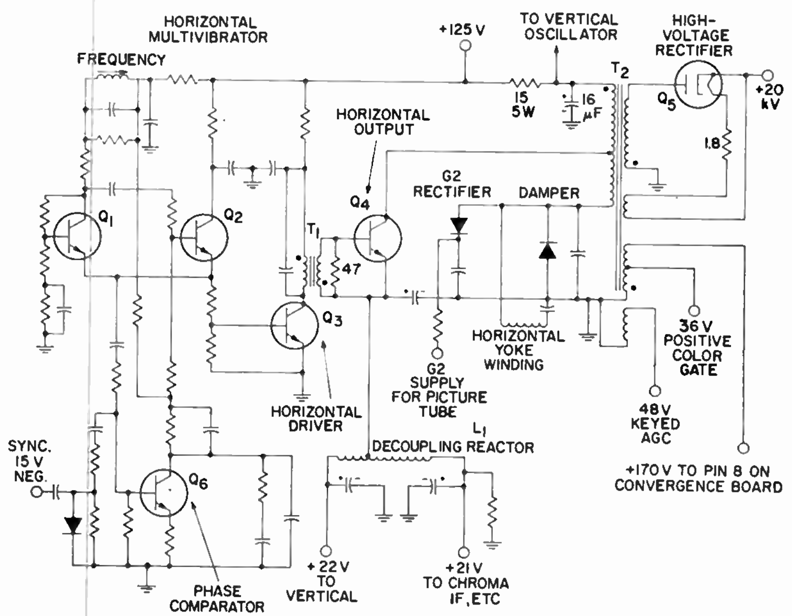



*Fig. 266—Horizontal-deflection circuit and high-voltage and low-voltage power supplies.*

The normal collector-emitter pulse voltage across $Q_4$ includes an ample safety factor that allows for any increased pulse that may result from out-of-sync operation, line surges, and other abnormal conditions.

A unique feature of the horizontal-deflection circuit is the low-voltage supply of approximately 23 volts that is derived from it. This features makes it possible to eliminate the power transformer in the power supply. The low-voltage power is used to operate all but the high-voltage receiver stages, such as the video-output stage, the audio-output stage, and the horizontal oscillator and driver. The vertical oscillator is supplied from the same point which supplies the horizontal output in such a way that the actual voltage is a function of beam current; this connection compensates for the tendency for picture height to change with brightness settings.

The transistor deflection circuit achieves commercially acceptable high-voltage regulation without the use of the high-voltage shunt regulator used with tube-type deflection circuits. With a flyback transformer of normal design and a low-voltage power supply with about 3-per-cent regulation, high-voltage regulation from zero beam to full load of 750 microamperes is about 3 kilovolts and is accompanied by a considerable increase in picture width. Improvement of this behavior with brightness changes is achieved by utilizing the accompanying changes of direct current to the deflection circuit in two ways. First, the air gap of the transformer is reduced to permit core saturation to decrease the system inductance as the high-voltage load is increased. When this method is used, regulation is improved to about half that of the normal transformers with no circuit instabilities, but picture-width change is still greater than desired. Second, series resistance is added to the B supply to decrease power input at full load and thereby reduce the change in picture width (at some sacrifice in high-voltage regulation). The net result of both changes is a regulation of about 2.8 kilovolts for the high voltage, with very little variation in picture size.

A secondary benefit of the inherently good regulation of the transistor deflection system is a reduction in the size of the flyback transformer. The size reduction is accomplished by a reduction in the area of the "window" in the flyback core. A reduction in the size of the high-voltage cage required to maintain adequate isolation of the high-voltage winding from ground is possible because of the smaller flyback transformer.

The transformer-coupled driver stage takes advantage of the high-voltage capability and switching speed of the horizontal driver transistor which is designed primarily for video-output use. A sine-wave stabilized multivibrator type of horizontal oscillator is used. This type of oscillator is especially useful in experimental work with deflection systems because it permits on-time and off-time periods to be easily varied.

The afc phase detector operates on the principle of pulse-width variation of combined sync and reference pulses. In the circuit shown in Fig. 266, timing information is related to the leading edges of the sync pulses, and the retrace process is initiated prior to the leading edge of the sync pulse; performance of the circuit is very satisfactory.

## SCR Horizontal-Deflection Circuit

A highly reliable horizontal-deflection system that uses silicon controlled rectifiers (SCR's) has been developed for use in color television receivers. This system, shown in Fig. 267, illustrates a new approach to horizontal-circuit design that represents a complete departure from the approaches currently used in commercial television receivers. The switching action required to generate the scan current in the horizontal-yoke windings and the high-voltage pulse used to derive the dc operating voltages for the picture tube is controlled by two SCR's that are used in conjunction with associated fast-recovery diodes to form bipolar switches.

The SCR's used to control the trace current and to provide the commutating action to initiate trace-retrace switching exhibit high voltage- and current-handling capabilities together with the excellent switching characteristics required for reliable operation in deflection-system applications. The switching diodes, (trace and commutating diodes), provide fast recovery times, high reverse-voltage blocking capabilities, and low turn-on voltage drops. These features and the fact

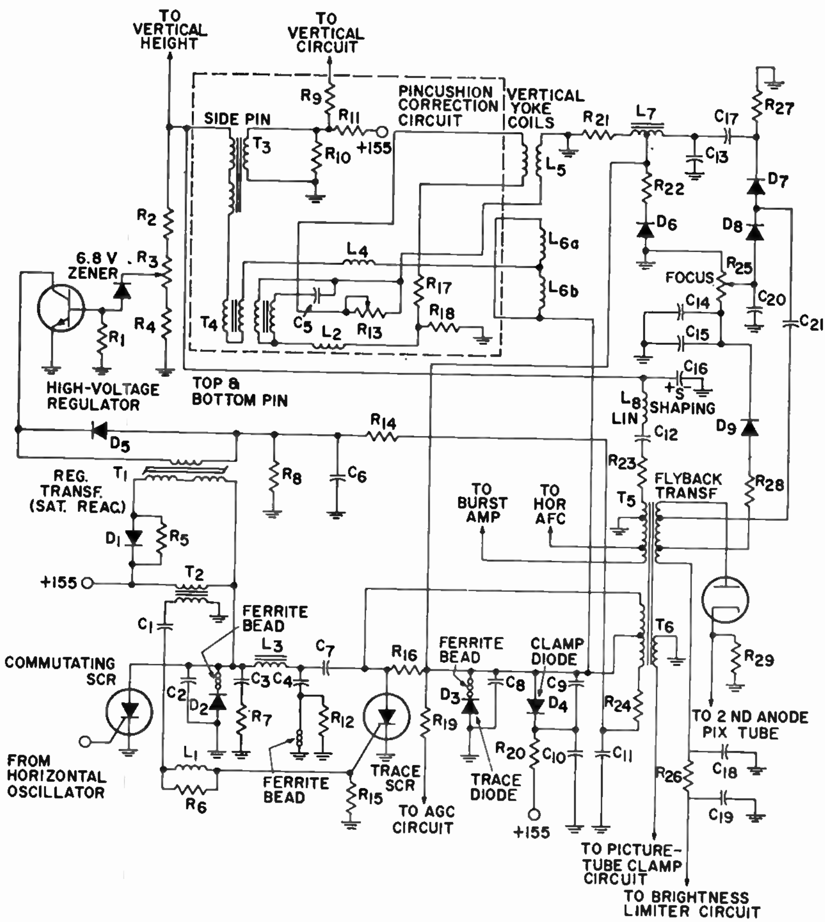



*Fig. 267—SCR horizontal-deflection circuit.*

that, with the exception of one noncritical triggering pulse, all control voltages, timing, and control polarities are supplied by passive elements within the system (rather than by external drive sources) contribute substantially to the excellent reliability of the SCR deflection system.

Fig. 267 shows the circuit configuration of the complete horizontal-deflection system. The system operates directly from a conventional, unregulated dc power supply of +155 volts, and provides full-screen deflection at angles up to 90 degrees at full beam current. The current and voltage waveforms required for horizontal deflection and for generation of the high voltage are derived essentially from LC resonant circuits. As a result, fast and abrupt switching transients which would impose strains on the solid-state device are advoided.

A regulator stage is included in the SCR horizontal-deflection circuit to maintain the scan and the high voltage within acceptable limits with variations in the ac line voltage or picture-tube beam current. The system also contains circuits that provide full protection against the effects of arcs in the picture tube or the high-voltage rectifier, and linearity and pincushion correction circuits.

The SCR horizontal-deflection system employs two bidirectional switches, each of which consists of an SCR and a diode in an inverse parallel connection. Fig. 268 shows a simplified schematic of the basic deflection circuit. $SCR_T$ and diode $D_T$ are used to control the current in the yoke winding $L_y$ during the trace interval; $SCR_C$ and diode $D_C$ provide the commutating action required for retrace.

At the beginning of the trace interval, the trace-switch diode conducts the yoke current established during previous circuit action. The trace-switch diode conducts a linearly decreasing current until the yoke current reaches zero to produce the first half of the scan current. Before the zero-yoke-current point is reached, the trace-switch SCR is made ready to conduct by application of a positive pulse to its gate electrode. When the yoke current crosses the zero point from negative to positive, the current transfers from the trace-switch diode to the trace-switch SCR. Capacitor $C_y$ then begins to discharge through the trace-switch SCR to supply current to yoke winding $L_y$ during the second half of the trace interval. The voltage across capacitor $C_y$ remains essentially constant throughout the trace-retrace cycle. This constant voltage results in a linearly rising current through the yoke winding to complete the trace period.

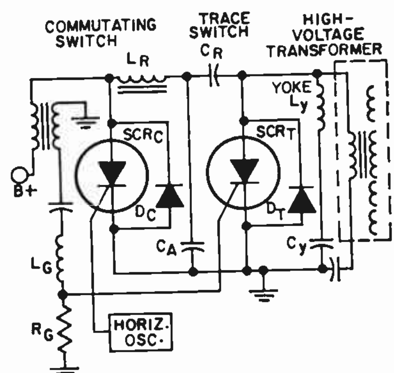



*Fig. 268—Basic circuit for generation of the deflection-current waveform in the horizontal-yoke winding.*

Just prior to the end of trace, the commutating-switch SCR is gated on by the horizontal oscillator. Capacitor $C_R$ then discharges a pulse of current through inductor $L_R$ and the trace and commutating SCR's. This current pulse, referred to as the commutating pulse, increases until it exceeds the yoke current and thereby causes the trace diode $D_T$ to turn on. The conduction of diode $D_T$ reverse-biases the trace SCR for sufficient time to allow it to turn off. When the commutating pulse declines to a value less than the yoke current, diode $D_T$ opens, and the energy in the yoke winding produces a current that charges the retrace capacitors $C_R$ and $C_A$ during the first half of retrace. This current then rings back into the yoke winding during the second half of retrace. The circuit for the ringing oscillation during the second half of retrace is completed through the commutating-switch diode and allows sufficient time for the commutating-switch SCR to turn off. When the yoke current reaches its peak negative value, the trace-switch diode begins to conduct to start the trace interval.

During the time the commutating switch is closed, the input inductor $L_{CC}$ is connected across the B+ supply, and energy is stored in this inductor. This stored energy charges the retrace capacitors $C_R$ and $C_A$ to replenish the energy loss in the circuit.

Fig. 269 shows the current and voltage waveforms applied to the trace and commutating switches as a result of the circuit actions described in the preceding paragraphs.

The SCR horizontal-deflection system offers a number of distinct advantages over the conventional types of systems currently used in commercial television receivers. The following list outlines some of the more significant circuit features of the SCR deflection system and points out the advantage derived from each of them:

1. Critical voltage and current waveforms, and timing cycles are determined by passive components in response to the action of two SCR-diode switches. The stability of the system, therefore, is determined primarily by the passive components. When the passive components are properly adjusted, the system exhibits highly predictable performance characteristics and exceptional operational dependability.

2. The only input drive signal required for the SCR deflection system is a low-power pulse which has no stringent accuracy specification in relation to either amplitude or time duration. The deflection system, therefore, can be driven directly from a pulse developed by the horizontal oscillator.

3. This deflection system is unique in that, although it operates from

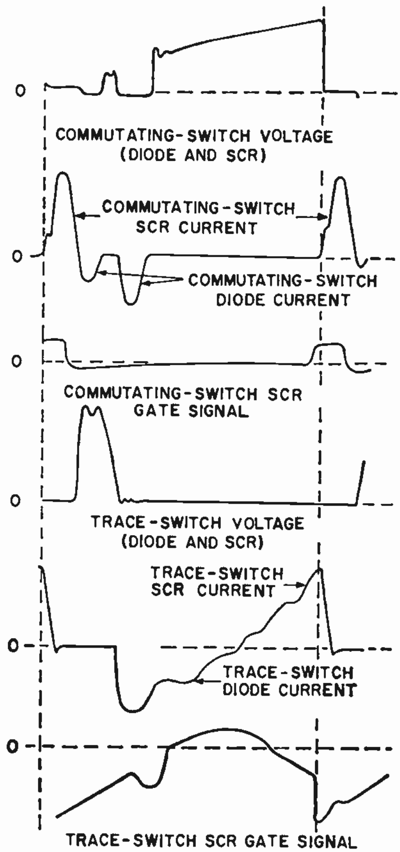



*Fig. 269—Voltage and current waveforms applied to the switching SCR's and diodes in the horizontal-deflection system.*

a conventional B+ supply of +155 volts, the flyback pulse is less than 500 volts. This level of voltage stress is substantially less than that in conventional line-operated systems, and this factor contributes to improved reliability of the switching devices.

4. Regulation in the SCR deflection system is accomplished by control of the energy stored by a reactive element. This technique

avoids the use of resistive-load regulating elements required by many other types of systems and, therefore, makes possible higher over-all system efficiency and reduces input-power requirements.

5. All switching occurs at the zero current level through the reverse recovery of high-voltage p-n junctions in the deflection diodes. The diode junctions are not limited in volt-ampere switching capabilities for either normal or abnormal conditions in the circuit.

# Power Switching and Control

TRANSISTORS have already established themselves in switching applications in radar, television, telemetering, pulse code communications, and computing equipment. More recently, triacs, diacs, and SCR's have been used in these applications and in arc-lamp ballasting circuits, automobile ignition systems, and heat, light, and motor controls. This section describes the circuits used in these applications and discusses special consideration required for their operation.

## NONSINUSOIDAL OSCILLATORS

Oscillator circuits which produce nonsinusoidal output waveforms use a regenerative circuit in conjunction with resistance-capacitance (RC) or resistance-inductance (RL) components to produce a switching action. The charge and discharge times of the reactive elements (which are directly proportional to R x C or L/R) are used to produce sawtooth, square, or pulse output waveforms.

The switching action in a nonsinusoidal oscillator occurs when an externally applied signal causes an instantaneous change in the operating state of the circuit; when this instantaneous change occurs the circuit is said to be triggered. Triggered circuits may be astable, monostable, or bistable.

Astable triggered circuits have no stable state; they operate in the active linear region and produce relaxation-type oscillations. A **monostable** circuit has one stable state in either of the stable regions (cutoff or saturation); an external pulse "triggers" the transistor to the other stable region, but the circuit then switches back to its original stable state after a period of time determined by the time constants of the circuit elements. A **bistable (flip-flop)** circuit has a stable state in each of the two stable regions. The transistor is triggered from one stable state to the other by an external pulse, and a second trigger pulse is required to switch the circuit back to its original stable state.

The multivibrator circuit shown in Fig. 270 is an example of a monostable circuit. The bias network holds transistor $Q_2$ in saturation and transistor $Q_1$ at cutoff during the quiescent or steady-state period. When an input signal is applied through the coupling capacitor $C_1$, however, transistor $Q_1$ begins to conduct. The decreasing collector voltage of $Q_1$ (coupled to the base of $Q_2$ through capacitor $C_2$) causes the base current

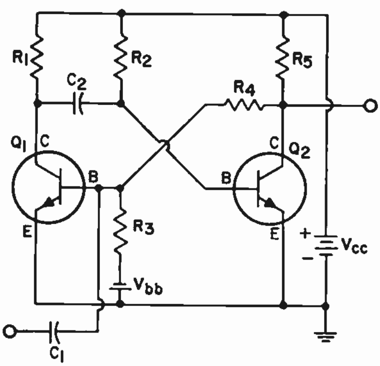



*Fig. 270—Monostable multivibrator.*

and collector current of $Q_2$ to decrease. The increasing collector voltage of $Q_2$ (coupled to the base of $Q_1$ through resistor $R_4$) then increases the forward base current of $Q_1$. This regeneration rapidly drives transistor $Q_1$ into saturation and transistor $Q_2$ into cutoff. The base of transistor $Q_2$ at this point is at a negative potential almost equal to the magnitude of the battery voltage $V_{cc}$.

Capacitor $C_2$ then discharges through resistor $R_2$ and the low saturation resistance of transistor $Q_1$. As the base potential of $Q_2$ becomes slightly positive, transistor $Q_2$ again conducts. The decreasing collector potential of $Q_2$ is coupled to the base of $Q_1$ and transistor $Q_1$ is driven into cutoff, while transistor $Q_2$ becomes saturated. This stable condition is maintained until another pulse triggers the circuit. The duration of the output pulse is primarily determined by the time constant of capacitor $C_2$ and resistor $R_2$ during discharge. In other words, the oscillating frequency of the multivibrator is determined by the values of resistance and capacitance in the circuit.

The Eccles-Jordan type multivibrator circuit shown in Fig. 279 is an example of a bistable circuit. The resistive and bias values of this circuit are chosen so that the initial application of dc power causes one transistor to be cut off and the other to be driven into saturation. Because of the feedback arrangement, each transistor is held in its original state by the condition of the other. The application of a positive trigger pulse to the base of the OFF transistor or a negative pulse to the base of the ON transistor switches the conducting state of the circuit. The new condition is then maintained until a second pulse triggers the circuit back to the original condition.

In Fig. 271, two separate inputs are shown. A trigger pulse at input A will change the state of the circuit. An input of the same polarity at input B or an input of opposite polarity at input A will then return the circuit to its original state. (Collector triggering can be accomplished in a similar manner.) The capacitors $C_3$ and $C_4$ are used to speed up the regenerative switching action. The output of the circuit is a unit step voltage when one trigger is applied, or a square wave when continuous pulsing of the input is used.

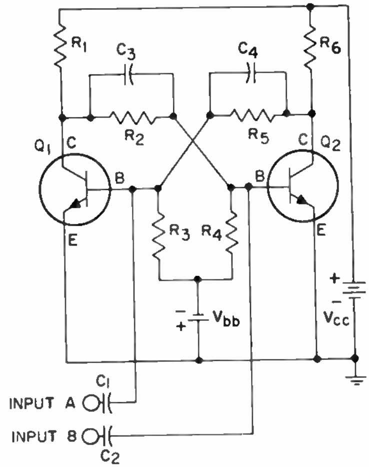


*Fig. 271—Eccles-Jordan type bistable multivibrator.*

A blocking oscillator is a form of nonsinusoidal oscillator which conducts for a short period of time and is cut off (blocked) for a much longer period. A basic circuit for this type of oscillator is shown in Fig. 272.

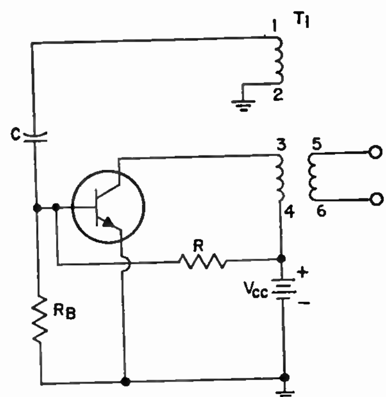


*Fig. 272—Basic circuit of blocking oscillator.*

Regenerative feedback through the tickler-coil winding 1-2 of transformer $T_1$ and capacitor C causes current through the transistor to rise rapidly until saturation is reached. The transistor is then cut off until C discharges through resistor R. The output waveform is a pulse, the width of which is primarily determined by winding 1-2. The time between pulses (resting or blocking time) is determined by the time constant of capacitor C and resistor R.

## SWITCHING REGULATORS

Fig. 273 shows the basic configuration of a switching type of transistor voltage regulator. In this circuit, the pass transistor is connected in series with the load and is pulse-duration modulated by the signal supplied from the pulse generator or multivibrator. The ON time of the multivibrator is controlled by a dc comparison between a reference voltage and the output. The pulsed output from the series transistor is integrated by the low-pass filter. When the transistor is conducting, current is delivered to the load from the input source. In the OFF condition, the diode conducts and the energy stored in the reactive elements supplies current to the load. If the output voltage tends to decrease below the reference voltage, the duration of the ON-time pulse increases. The pass transistor then conducts for a longer period of time so that the output voltage increases to the desired level. If the output voltage tends to rise above the reference voltage, the duration of the ON-time pulse decreases. The shorter conduction period of the pass transistor then results in a compensating decrease in output voltage.

When a step-down regulator is required (e.g., 100 volts down to 28 volts), the efficiency of a switching regulator is considerably higher than that of a conventional series regulator. If very precise regulation is required, the switching regulator can be used as a pre-regulator followed by a conventional regulator circuit; this configuration optimizes the advantages of both types of regulators. Over-all efficiency for such a combination circuit is typically about 80 to 85 per cent, as compared to values of 25 to 30 per cent for a conventional series-type step-down regulator. In addition, total power dissipation is reduced from several hundreds of watts to less than 50 watts.

Fig. 274 shows a switching regulator included in the design of a mercury-arc-lamp ballasting system. DC potential is applied to the $V_{IN}$ terminals so that the transistor switch $Q_1$ (part of the switching regulator) is slightly forward-biased by a small current through $R_8$ (approximately 3 milliamperes). Through positive feedback, $Q_1$ is immediately saturated by $L_2$, which also powers the control circuit. Cur-

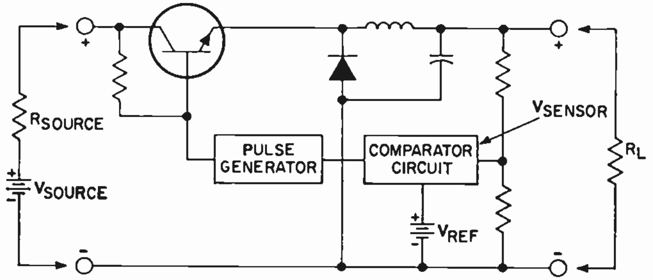



*Fig. 273—Basic diagram of switching regulator.*

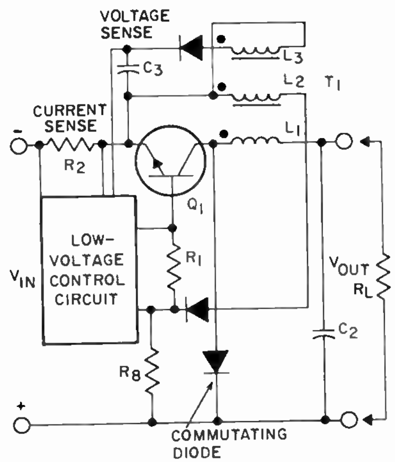



*Fig. 274—Switching-regulator design for solid-state mercury-arc-lamp ballasting.*

rent rises at a linear rate until the voltage across $R_2$ causes the control circuit to shunt the base-emitter junction of $Q_1$. $Q_1$ is shut off and held off by $L_2$ until the current through $L_1$ is zero. The inductive kickback voltage is clamped by the communtating diode and, therefore, is the same as the output voltage on $C_2$. $L_3$ charges $C_3$ to a voltage proportional to $V_{OUT}$. During the next cycle, the control circuit samples a combination of the voltage on $C_3$ and the current in $R_2$. The output waveshapes for the circuit are shown in Fig. 275; performance data are shown in Fig. 276.

The unique feature of this circuit is that only the high-current switching element $Q_1$ must meet the breakdown-voltage requirement imposed by the high input voltage; with this one exception, all of the control-circuit transistors are of the low-voltage, low-dissipation type. The circuit is able to withstand operation under short-circuit conditions.

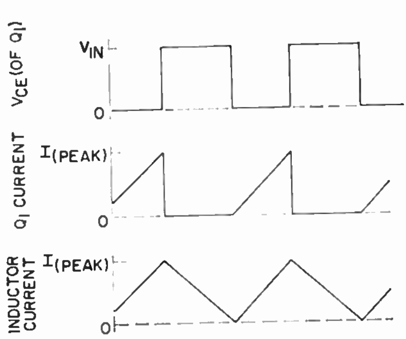



*Fig. 275—Output waveshapes for circuit of Fig. 274.*

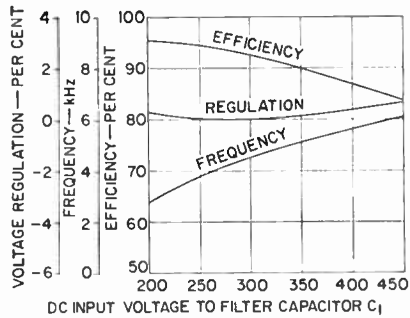



*Fig. 276—Performance curves for circuit of Fig. 274.*

A 175-watt switching-regulator ballast circuit utilizing the approach just described is shown in Fig. 277. For three-phase operation, no $C_1$ filter element is necessary provided that the dc input voltage to the switching regulator never drops below 200 volts. An input voltage drop below this level would extinguish the bulb.

Switching-regulator techniques are also utilized in motor-control systems. A servo motor control is shown in Fig. 278.

Switching-mode servo controls afford an efficient means for amplification of directional information. As an alternative to the use of cascaded linear stages to drive a class B push-pull output stage, this switching mode of control allows the active elements of the amplifier to operate in either saturation or cutoff. Because a relatively small length of time is spent in the active region of the devices, where power dissipation is high, the average power dissipation is lower. The efficiency of the over-all system, therefore, is higher. Switching servos are used in stable platforms for guidance and

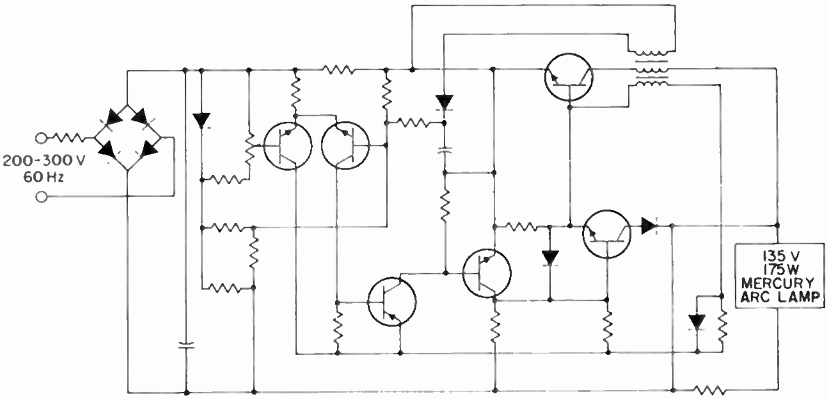



*Fig. 277—175-watt switching-regulator ballast.*

navigational systems, control of memory access devices in computer and data-processing systems, and other applications in which efficiency is a prime factor.

An ever-expanding application for switching systems is in the ac motor-control field. Sometimes this application is necessary because the standby power is dc. More generally, however, high-speed inverters or switching circuits are used because the higher-frequency motors are more efficient and weigh less than their lower-frequency counterparts.

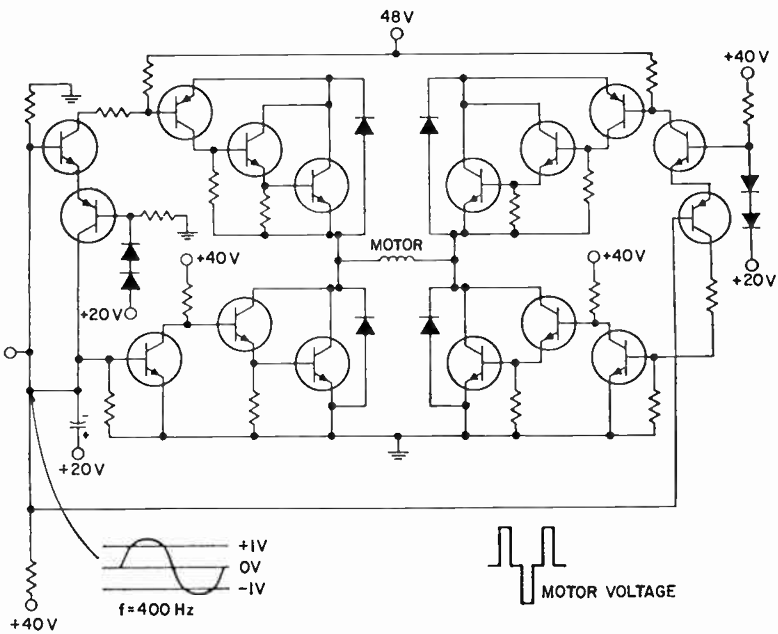



*Fig. 278—Pulse-width-modulated servo-motor-driven output stage.*

## CONVERTERS AND INVERTERS

In many applications, the aptimum value of voltage is not available from the primary power source. In such instances, dc-to-dc converters or dc-to-ac inverters may be used, with or without regulation, to provide the optimum voltage for a given circuit design.

An inverter is a power-conversion device used to transform dc power to ac power. If the ac output is rectified and filtered to provide dc again, the over-all circuit is referred to as a converter. The purpose of the converter is then to change the magnitude of the available dc voltage.

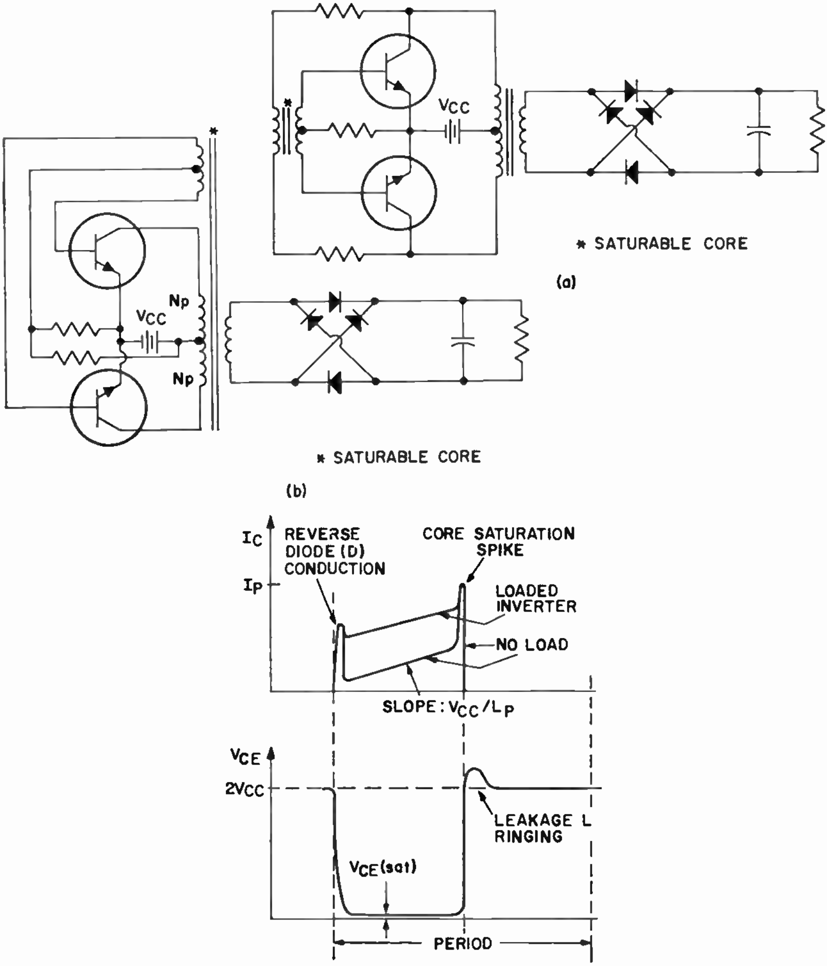



*Fig. 279—Simple converter circuits that may be ussed to replace vibrator-type converters in automobile radios: (a) converter circuit that uses separate output and feedback transformers; (b) converter circuit in which the feedback windings are included on the output transformer; (c) typical voltage and current waveforms.*

## Transistor Converters and Inverters

Fig. 279 shows two simple converter circuits which can be used in place of the conventional vibrator-type converter in automobile radios. The switching drive to the two transistors is supplied by a separate, small, saturable transformer in the circuit of Fig. 279(a), and by an additional center-tapped drive winding on a single saturable transformer in Fig. 279(b). The characteristic hysteresis loop of the auto-transformer used in the circuit of Fig. 279(b) is shown in Fig. 280. Transformer parameters such as frequency, number of turns,

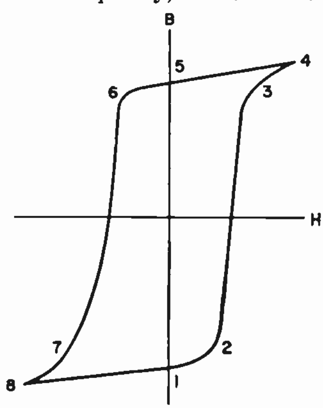



*Fig. 280—Characteristic hysteresis loop of auto-transformer used in circuit of Fig. 279(b)*

and size and type of core material are determined by the operating requirements for the circuit. Once the transformer has been established, a change in supply voltage results in a change in the operating frequency.

Switching is accomplished as a result of the saturation of the transformer. When the slope of the hysteresis loop shown in Fig. 288 is small, the magnetizing inductance is small and the magnetizing current increases rapidly. This situation exists as the loop is traversed in a counter-clockwise manner from point 1 to point 2. From point 2 to point 3, the magnetizing current increases very slowly because the magnetizing inductance is high. At point 3, the core is in saturation, and the magnetizing current again increases rapidly. As the current continues to increase (between points 3 and 4), the ON transistor comes out of saturation. When point 4 has been reached, the voltages across the primary windings of the transformer have dropped to zero, and the battery voltage is applied across the collector-to-emitter terminals of each transistor. The magnetizing current then begins to decay, and voltages of opposite polarity are induced across the transformer. At point 5, the magnetizing current has been reduced to zero, the second transistor is in saturation, and the first transistor has twice the battery voltage across its emitter-to-collector junction. This sequence of events is repeated during each half-cycle of the operation of the circuit, except for a reversal of polarity.

The approximate load line of the converter circuit of Fig. 279(b) is shown in Fig. 281. Many of the important transistor ratings can be

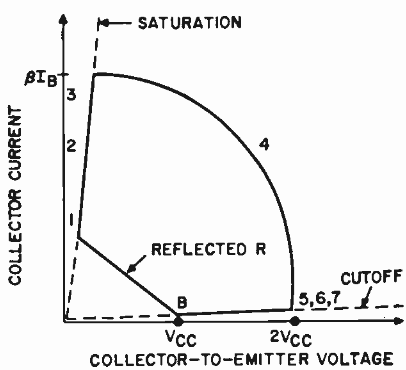



*Fig. 281—Approximate load line for converter circuit shown in Fig. 287(b).*

determined from this curve. For example, the collector-to-emitter sustaining voltage under reverse-bias conditions, $V_{CEV}(sus)$, is given by

$$V_{CEV}(sus) \geq 2V_{CC} + \Delta V_{CC}$$

where $V_{CC}$ is the collector-supply

voltage and $\triangle V_{CC}$ is the magnitude of the supply variations or "spikes." The second-breakdown voltage limit $E_{S/B}$ for the transistor is given by

$$E_{S/B} \geq \frac{1}{2}(\beta I_B)^2 L l$$

where $\beta$ is the common-emitter forward-current transfer ratio, $I_B$ is the base current, and $L_l$ is the total series inductance of the transformer and the load reflected to the input. As mentioned previously, the collector-to-emitter saturation voltage $V_{CE}(sat)$ of the transistor should be low.

Fig. 282 shows the basic circuit configuration for a ringing-choke dc-to-dc converter. In this converter,

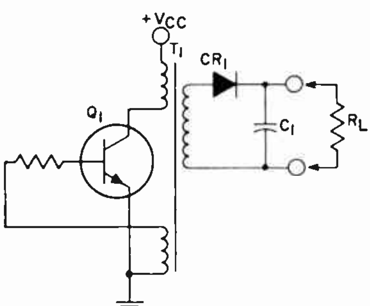



*Fig. 282—Basic circuit configuration of a ringing-choke dc-to-dc converter.*

a blocking oscillator (chopper circuit) is transformer-coupled to a half-wave-rectifier type of output circuit. The rectifier converts the pulsating oscillator output into a fixed-value dc output voltage.

When the oscillator transistor $Q_1$ conducts (as a result of either a forward bias or external drive), energy is transferred to the collector inductance presented by the primary winding of transformer $T_1$. The voltage induced across the transformer feedback winding connected to the transistor base through resistor $R_B$ increases the conduction of $Q_1$ until the transistor is driven into saturation. The rectifier diode $CR_1$ in series with the secondary winding of transformer $T_1$ is oriented so that no power is delivered to the load circuit during this portion of the oscillator cycle.

With transistor $Q_1$ in saturation, the collector current through the primary inductance of transformer $T_1$ rises linearly with time ($-di/dt = E/L$) until the base drive supplied by the transformer feedback winding can no longer maintain $Q_1$ in saturation. As the current through $Q_1$ decreases from the saturation level, the voltage induced into the feedpack winding decreases, and transistor $Q_1$ is rapidly driven beyond cutoff. The energy stored in the collector inductance (primary of transformer $T_1$) is relased by the collapsing magnetic field and coupled by the secondary winding of transformer $T_1$, through rectifier diode $CR_1$, to the load resistance $R_L$ and filter capacitor $C_1$. The filter capacitor stores the energy it receives from the collector inductance. When no current is supplied to the load circuit from the oscillator (i.e., during conduction of transistor $Q_1$), capacitor $C_1$ supplies current to the load resistance $R_L$ to maintain the output voltage at a relatively constant value. The switching action of rectifier diode $CR_1$ prevents any decrease of the energy stored by capacitor $C_1$ because of the negative pulse coupled from the oscillator during the periods that transistor $Q_1$ conducts.

The operating efficiency of the ringing-choke converter is low, and the circuit, therefore, is used primarily in low-power applications. In addition, because power is delivered to the output circuit for only a small fraction of the oscillator cycle (i.e., when $Q_1$ is not conducting), the circuit has a relatively high ripple factor which substantially increases output filtering requirements. This converter, however, provides definite advantages to the system designer in terms of design simplicity and compactness.

In a converter, the change in frequency of operation with supply voltage is not usually important because the output voltage is rectified and filtered. In an inverter circuit, however, the frequency may be very important and is generally controlled by adjustment of the supply voltage. Typically, the dc supply voltage is controlled by means of a voltage regulator inserted ahead of the converter to stabilize the input voltage and a power amplifier following the converter to isolate the converter from the effects of a varying load.

Inverters may be used to drive any equipment which requires an ac supply, such as motors, ac radios, television receivers, or fluorescent lighting. In addition, an inverter can be used to drive electromechanical transducers in ultrasonic equipment, such as ultrasonic cleaners and sonar detection devices.

Fig. 283 shows a block diagram of a typical inverter circuit. The output frequency is directly dependent on the induced voltage of the

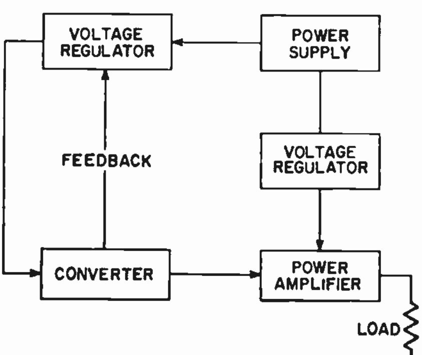



*Fig. 283—Block diagram of typical inverter circuit.*

converter transformer. The feedback shown samples this induced voltage and adjusts the output of the voltage regulator to maintain a constant induced voltage in the converter and thus a constant output frequency. If a regulated output voltage is not required, the second voltage regulator is omitted.

The push-pull switching inverter is probably the most widely used type of power-conversion circuit. For inverter applications, the circuit provides a square-wave ac output. When the inverter is used to provide dc-to-dc conversion, the square-wave voltage is usually applied to a full-wave bridge rectifier and filter.

Fig. 284 shows the configuration of the push-pull switching converter. The single saturable transformer controls circuit switching and provides the desired voltage transformation for the square-wave output delivered to the bridge rectifier. The rectifier and filter convert the square-wave voltage in a smooth, fixed-amplitude dc output voltage.

When the voltage $V_{CC}$ is applied to the converter circuit, current tends to flow through both switching transistors $Q_1$ and $Q_2$. It is very unlikely, however, that a perfect balance can be achieved between corresponding active and passive components of the two transistor sections; therefore, the initial flow of current through one of the transistors is slightly larger than that through the other transistor. If transistor $Q_1$ is assumed to conduct more heavily initially, the rise in current through its collector inductance causes a voltage to be induced in the feedback windings of transformer $T_1$ which supply the base drive to transistors $Q_1$ and $Q_2$. The base-drive voltages are in the proper polarity to increase the current through $Q_1$ and to decrease the current thruogh $Q_2$. As a result of regenerative action, the conduction of $Q_1$ is rapidly increased, and $Q_2$ is quickly driven to cutoff.

The increased current through $Q_1$ causes the core of the collector inductance to saturate. The inductance no longer impedes the rise in current, and the transistor current increases sharply into the saturation region. For this condition, the magnetic field about the collector inductance is constant, and no voltage is induced in the feedback windings of transformer $T_1$. With the cutoff base voltage removed, current is allowed to flow through transistor $Q_2$. The increase in current through the collector inductance of this transistor causes voltages to be induced in the feedback windings in the polarity that increases the current through $Q_2$ and decreases the current through $Q_1$. This effect is aided by the collapsing magnetic field about the collector inductance of $Q_1$ that results from the decrease in current through this transistor. The feedback voltages produced by this collapsing field quickly drive $Q_1$ beyond cutoff and further increase the conduction of $Q_2$ until the core of the collector inductance for this transistor saturates to initiate a new cycle of operation. The square wave of voltage produced by the switching action of transistors $Q_1$ and $Q_2$ is coupled by transformer $T_1$ to the bridge rectifier and filter, which develop a smooth, constant-amplitude dc voltage across the load resistance $R_L$. The small ripple produced by the square wave greatly simplifies filter requirements.

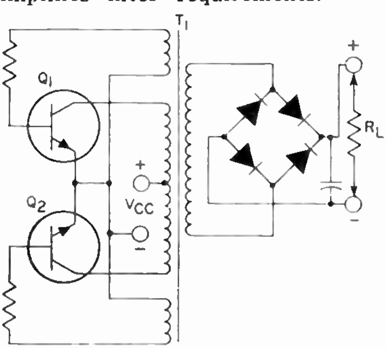


*Fig. 284—Basic circuit configuration of a single-transformer push-pull switching converter.*

Push-pull transformer-coupled converters with full-wave rectification provide power to the load continuously and are, therefore, well suited for low-impedance, high-power applications. Although not as economical as the ringing-choke design, the push-pull configuration provides higher efficiency and improved regulation.

In high-power driven inverters, it is not uncommon to use a Darlington connection to increase the current gain. However, this configuration increases the $V_{CE}$ saturation of the output and does not permit a fast turn-off. The boosted Darlington inverter shown in Fig. 285 uses two small additional transformer windings ($N_3$ and $N_4$) and eliminates both problems.

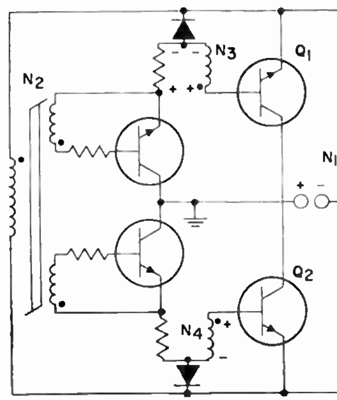


*Fig. 285—Boosted Darlington inverter with turn-off drive.*

The polarity of $N_3$ and $N_4$ is shown for $Q_1$ ON and $Q_2$ OFF. $N_3$ and $N_4$ are wound on core No. 1 which could be a motor or other magnetic structure. The voltage developed across $N_3$ allows $Q_1$ to saturate fully while the voltage across $N_4$ allows $Q_2$ to have a reverse bias applied, thus helping the device to turn off. The diodes provide a path for reverse bias when the transistor turns off and blocks voltage while the transistor is on; thus, they allow the driver transistors to control the output units.

Three-phase bridge inverters for induction motors are usually used to convert dc, 60-Hz, or 400-Hz input to a much higher frequency, possibly as high as 10 kHz. Increasing frequency reduces the motor size and increases the horsepower-to-weight ratio, desirable features in military, aviation, and portable industrial power-tool markets. Fig. 286 shows a typical three-phase bridge circuit with base driving signals and transformer primary currents.

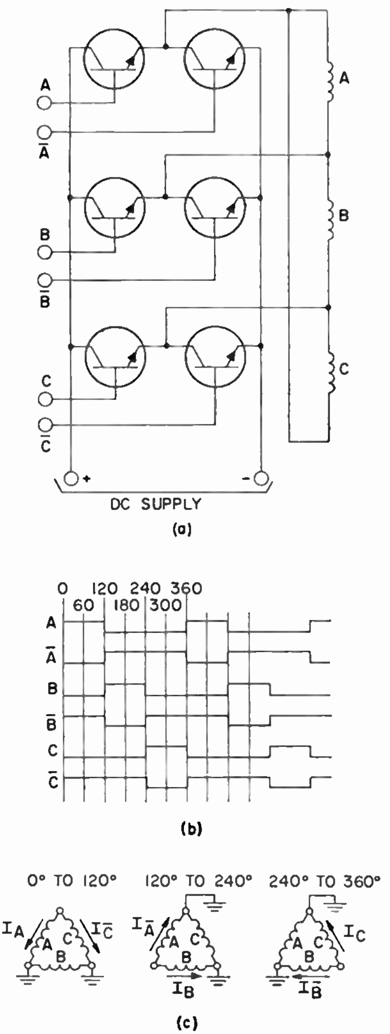



*Fig. 286—Three-phase bridge inverter: (a) circuit configuration; (b) base driving signals; (c) transformer primary current switching.*

Fig. 287 shows the schematic diagram of a two-transistor, two-transformer inverter circuit. A saturable base-drive transformer $T_2$ controls the inverter switching operation. A linearly operating output transformer $T_1$ transfers the output power to the load. The output transformer $T_1$ is not allowed to saturate; therefore, the peak collector current through the transistor is determined principally by the value of the load impedance.

Because no two transistors are perfectly matched, one of the transistors in the inverter circuit conducts more rapidly than the other when the power is turned on. This transistor, $Q_2$ for example, tends toward saturation and causes positive voltages to appear at the dotted ends of the transformers. Thus, there is an effective positive feedback that causes $Q_1$ to switch off and $Q_2$ to switch on. The voltage from the collector of $Q_1$ to the collector of $Q_2$ is then positive and equal to twice the collector supply voltage $V_{CC}$. The voltage $V_{Rfb}$ across the feedback resistor $R_{fb}$ is essentially the product of the resistance $R_{fb}$ and the base current referred to the primary of $T_2$. The voltage across $T_2$ is equal to 2 $V_{CC} - V_{Rfb}$.

At the beginning of the next half-cycle, the voltage across $R_{fb}$ increases very slowly with the slowly increasing magnetizing current through $T_2$. When $T_2$ reaches its saturation flux density, the magnetizing current increases very

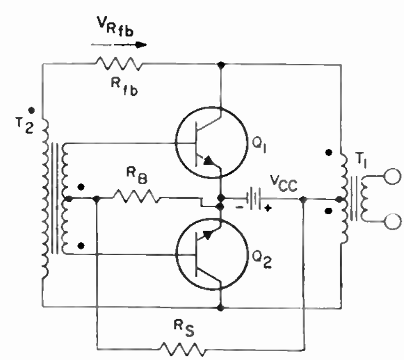



*Fig. 287—Two-transistor/two-transformer inverter.*

rapidly and causes a rapid increase in $V_{Rfb}$. As a result, the voltage across $T_2$ decerases rapidly and $Q_2$ comes out of saturation. The collector voltage of $Q_2$ then rises, and regenerative action causes $Q_1$ and $Q_2$ to reverse states. As these processes are repeated during succeeding half-cycles, oscillations are sustained.

## SCR Inverters

SCR inverters offer an efficient and economical method for conversion of direct current to alternating current. In the design of an SCR inverter, the fact that the SCR is basically a "latching" device must be considered. Anode current can be initiated at any time by application of a signal of the proper polarity to the gate. However, the gate loses control as soon as conduction begins, and current continues to flow, regardless of any gate signal which may be applied, as long as the anode remains positive. Special commutating circuitry is required to turn off the SCR at the proper time. A basic commutation circuit is shown in Fig. 288(a).

When conduction is initiated by application of a positive pulse to the gate, the voltage across the SCR decreases rapidly as current increases through it because of the voltage drop across the inductor L. The capacitor C charges through the resistor R in the polarity indicated. If the switch S is then closed, the capacitor will be connected across the SCR in such a polarity that the anode of the SCR is suddenly driven negative. Conduction of the SCR then ceases as soon as the charge stored in the device has been removed by the reverse recovery current.

The time required for the SCR to recover its forward blocking capability, as shown in Fig. 288(b), limits the maximum operating frequency of the inverter. If the SCR has not recovered its blocking capability by the time the anode swings positive, continuous conduction results, and no ac power is generated. Special fast-turn-off SCR's, which permit operation at frequencies up to 25 KHZ, are currently available.

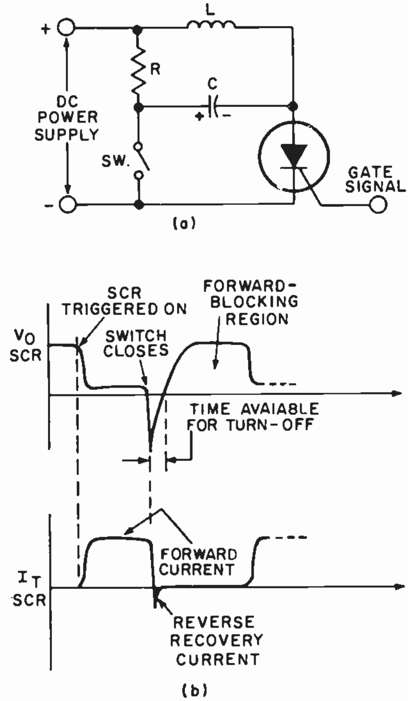



*Fig. 288—Commutation of an SCR: (a) basic commutation circuit; (b) voltage and current waveforms.*

Fig. 289(a) shows the basic configuration for an inverter circuit. An ac output can be generated by alternately closing and opening switches $S_1$ and $S_2$. A more practical method of producing an ac output is to replace switches $S_1$ and $S_2$ with SCR's, as shown in Fig. 289(b). Capacitor C is used, as previously described, to commutate $SCR_1$ and $SCR_2$ alternately.

Inverter circuits may use other methods of commutation. For example, auxiliary SCR's may be used to produce a negative commutating pulse across the inverter SCR at the proper time, or a saturable reactor may be used in series with a capacitor to produce a commutating pulse at the proper time.

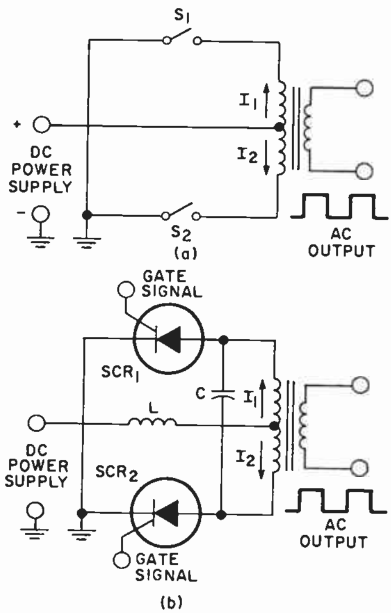



*Fig. 289—Inverter circuits: (a) basic configuration; (b) SCR inverter.*

Fig. 290 shows a typical high-frequency SCR switching inverter; Fig. 291 shows the waveshapes across the SCR and the output of the transformer. For resistive loads, this inverter is capable of delivering 500 watts of output power at an operating frequency of 8 kHz, and is provided with regulation from a no-load condition to full load. With proper output derating, this circuit can also accommodate inductive and capacitive loads. Under a capacitive load, the power dissipation of the SCR's is increased; under an inductive load, the turn-off time is decreased.

The inverter can be operated at any optional frequency up to 8 kHz provided that a suitable output transformer is used and the timing capacitors are changed in the gate-trigger-pulse generator. A change in operating frequency, however, does not require any change in the commutating components $C_1$ and $L_1$.

The operation of the SCR inverter is very similar to that of the two-transistor push-pull inverter except that external gate-trigger signals are required to initiate the SCR switching action.

Fig. 290 shows the two thyristors $SCR_1$ and $SCR_2$ connected to the output transformer $T_1$. These thyristors are alternately triggered into conduction by gate-trigger pulse generator to produce an alternating current in the primary of the power transformer. Fig. 291 shows typical operating wave forms for the SCR inverter.

The thyristors are commutated by capacitor $C_1$, which is connected between the anodes of $SCR_1$ and $SCR_2$. The flow of current through the circuit can be traced more easily if it is assumed that initially $SCR_1$ is conducting and $SCR_2$ is cut off and that the common cathode connection of the SCR's is the reference point. For this condition, the voltage at the anode of $SCR_2$ is twice the voltage of the dc power supply, i.e., $2E_{oo}$. The load current flows from the dc power supply through one-half the primary winding of transformer $T_1$, inductor $L_2$, $SCR_1$, and inductor $L_1$. When the firing current is applied to the gate of $SCR_2$, this SCR turns on and conducts.

During the "ON" period of $SCR_2$, the capacitor $C_1$ begins to discharge through $L_3$, $SCR_2$, $SCR_1$, and $L_2$. Inductors $L_2$ and $L_3$ function to limit the rate of rise of the discharge current di/dt so that the associated stresses are maintained within the capability of the device during the turn-on of the SCR. The effect of this control is to decrease the turn-on dissipation, which becomes a significant portion of the total device dissipation at high repetition rates.

The discharge current through $SCR_1$ flows in a reverse direction, and after the carriers are swept out (and recombined) the $SCR_1$ switch opens (i.e., $SCR_1$ switches to the "OFF" state). At this time, the voltage across the capacitor $C_1$, which

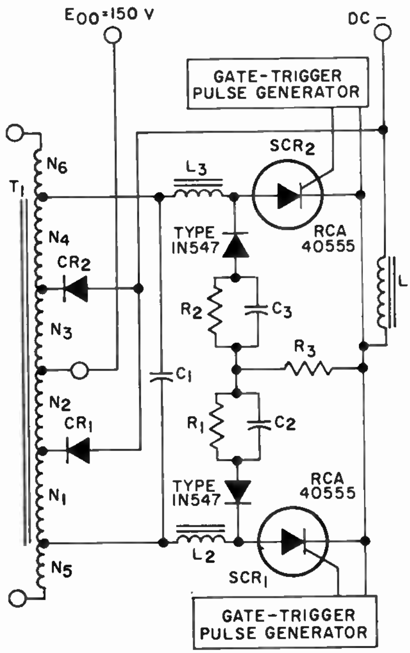



*Fig. 290—High-frequency SCR push-pull switching inverter.*

is approximately equal to $-2E_{oo}$, appears across $SCR_1$ as reverse voltage. This voltage remains long enough to allow the device to recover for forward blocking. Simultaneously during this interval, the conducting $SCR_2$ establishes another discharge path for capacitor $C_1$ through transformer $T_1$ and inductors $L_1$ and $L_3$. The role of inductor $L_1$ is to control the rate of discharge of the capacitor to allow sufficient time for turn-off.

After capacitor $C_1$ is discharged from $-2E_{oo}$ to zero, it starts to charge in the opposite direction to $+2E_{oo}$. When $C_1$ is charged to $+2E_{oo}$, because of the phase shift between voltage and current, the flux in the inductor $L_1$ at that time is a maximum. This reactive energy stored in the inductor is normally transferred to the capacitor and causes an "overvoltage" or "overcharge," which in this particular case is undesirable. Voltages on the capacitor higher than $2E_{oo}$ produce a negative voltage at the anode of $SCR_2$ with respect to the negative terminal of the dc power supply.

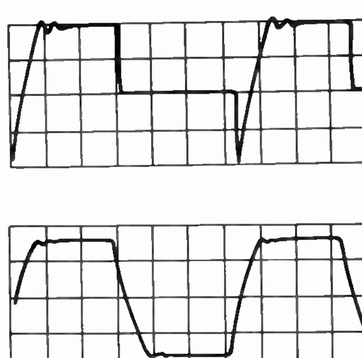


*Fig. 291—Typical operating waveforms for SCR inverter shown in Fig. 290.*

This condition is prevented by use of a clamping diode $CR_2$ connected to an extra tap on the transformer oriented close to the anode of $SCR_2$. As a result, the amount of "overcharge" of the capacitor is considerably reduced. The energy stored in inductor $L_1$ causes current to flow through diode $CR_2$, the $N_4$ transformer winding, inductor $L_3$, and $SCR_2$. Transformer windings $N_4$ and $N_3$ act as an autotransformer through which the energy stored in the inductor is fed back to the power supply.

When the firing current is applied to the gate of $SCR_1$, this device conducts and the process described above is repeated.

Each time the SCR's turn off to interrupt the reverse recovery current, a certain amount of energy remains in the inductor. This energy is transferred to the device capacitance, which is relatively small, and thus a high-voltage transient is generated. This high-voltage transient may exceed the rating of the device, produce undesirable stresses, and increase the switching dissipation. A transient-suppressor network consisting of two 1N547 diodes, resistors $R_1$, $R_2$, and $R_3$, and capacitors $C_2$ and $C_3$ prevents this transient voltage from exceeding the maximum rating of the SCR's.

## Pulse-Width-Modulated Converters

A technique referred to as pulse-width modulation can be used to maintain the output voltage of a dc-to-dc converter constant under conditions of varying input voltages and load. A block diagram of a circuit used for this type of function is shown in Fig. 292. The "on" time of the switching transistors is varied to provide varying amounts of energy to the output. The feedback

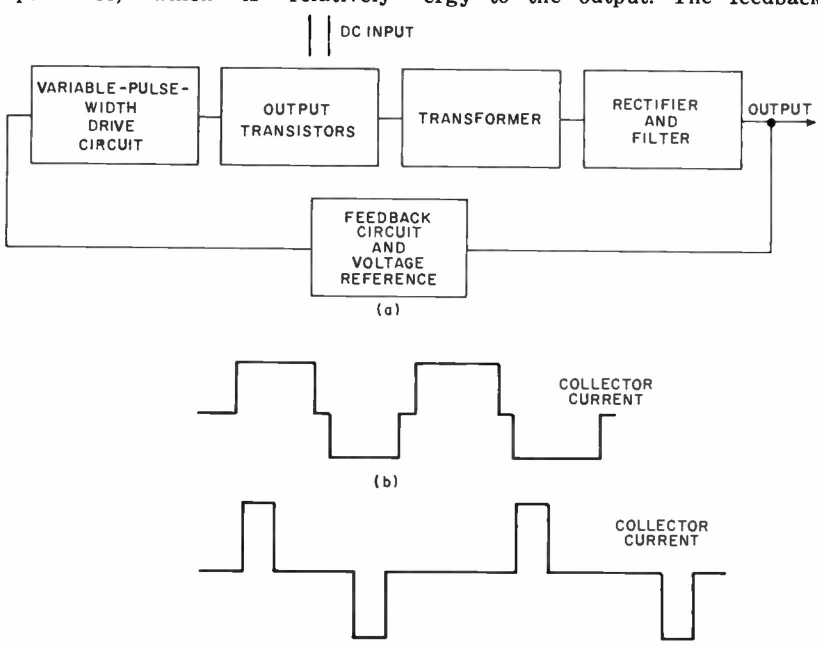



*Fig. 292—Pulse-width-modulated converter: (a) block diagram; (b) collector-current waveform when circuit is heavily loaded; (c) collector-current waveform when circuit is lightly loaded.*

circuit adjusts the pulse width to maintain a fixed-voltage output current. Waveforms are shown for a lightly loaded and a heavily loaded case.

## AUTOMOBILE IGNITION SYSTEM

Fig. 293 shows a simple ignition system that uses an n-p-n transistor; performance curves for the circuit

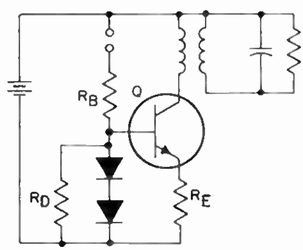



*Fig. 293—Solid-state automobile ignition system.*

are shown in Fig. 294. The advantages of this circuit include less maintenance of points and spark plugs, better performance at high engine speeds, and easier engine starting.

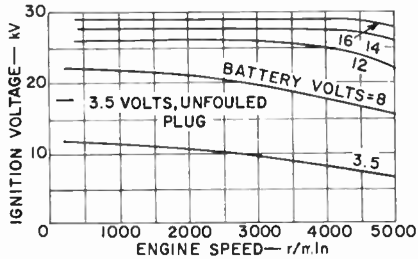



*Fig. 294—Ignition voltage as a function of engine speed.*

## PULSE MODULATORS

Silicon controlled rectifiers are often used in pulse circuits in which the ratio of peak to average current is large. Typical applications include radar pulse modulators, inverters, and switching regulators. The limiting parameter in such applications often is the time required for forward current to spread over the whole area of the junction. Losses in the SCR are high, and are concentrated in a small region until the entire junction area is in conduction. This concentraton produces undesirable high temperatures.

A typical SCR pulse modulator circuit is shown in Fig. 295; basic waveforms for the circuit are shown in Fig. 296. The capacitors of the energy-storage network are charged by the dc supply. The SCR

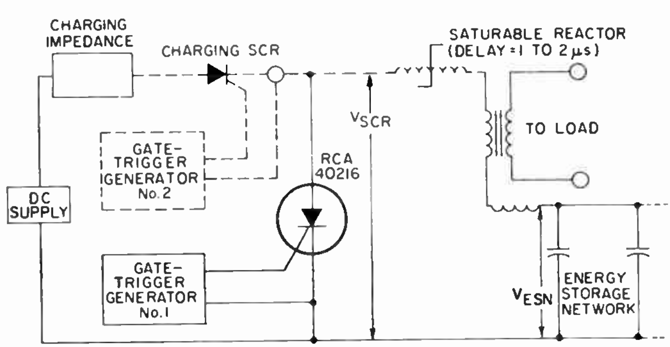



*Fig. 295—Basic pulse modulator circuit.*

is triggered by pulses from the gate-trigger generator No.1, and the energy-storage network discharges through an inductance and the load (transformer). Fig. 296 shows that the discharge of the storage network is oscillatory; the half-sine-wave shape is characteristic of a single LC-section energy-storage network.

For turn-off, the load is "mismatched" to the discharge-circuit impedance so that a negative voltage is developed on the capacitor at the end of the pulse.

As an example, the rise-time portion of turn-on is defined as the time interval between the 10-per-cent and 90-per-cent points on the current wave shape when the SCR is triggered on in a circuit that has rated forward voltage and sufficient

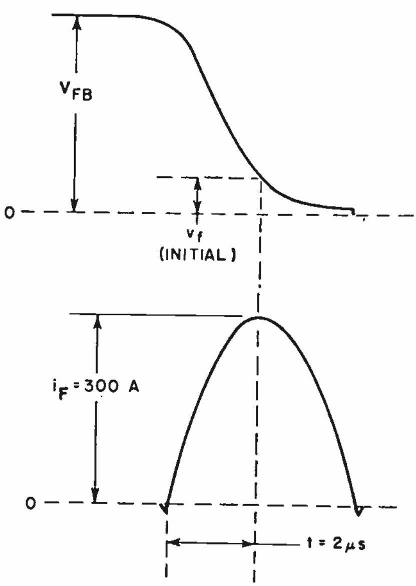



*Fig. 296—Turn-on requirements for a pulse-modulator SCR.*

resistance to limit the current to rated values. For a 600-volt device, the end of the turn-on interval occurs when the forward voltage drop across the SCR is 60 volts. This value contrasts with the steady-state forward voltage of only 1 or 2 volts under such conditions. An interval many times greater than the turn-on time may be required before the forward voltage drop reduces to the steady-state level.

## AC Power Controls

Thyristors have been widely accepted in power-control applications in industrial systems where high-performance requirements justify the economics of the application. Historically, in the commercial high-volume market, economic considerations have precluded the use of the thyristor. However, with the development of several families of thyristors by RCA designed specifically for mass-production economy and rated for 120- and 240-volt line operation, the use of these devices in controls for many types of small electric motors, incandescent lighting, and electric heating elements has been made economically feasible. The controls can be designed to provide good performance, maximum efficiency, and high reliability in compact packaging arrangements.

### Basic Requirements

The simplest form of half-wave power control is shown in Fig. 297. This circuit provides a simple, non-regulating half-wave power control that begins at the 90-degree conduction (peak-voltage) point and

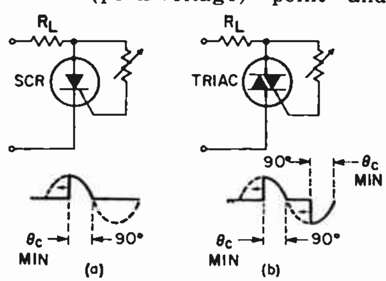



*Fig. 297—Degree of control over conduction angles when ac resistive network is used to trigger (a) SCR's and (b) triacs.*

may be adjusted to within a few degrees of full conduction (180-degree half-cycle).

The half-wave proportional control shown in Fig. 298 is a non-regulating circuit whose function depends upon an RC delay network for gate phase-lag control. This circuit is better than simple resistance firing circuits because the phase-shifting characteristics of the RC network permit the firing of the SCR beyond the peak of the impressed voltage, resulting in small conduction angles. On the positive half-cycle of the applied voltage, capacitor C is charged through the network $R_a$ and $R_b$. When the voltage across capacitor C exceeds the gate-firing voltage of the SCR, the SCR is turned on; during the remaining portion of the half-cycle, ac power is applied to the load.

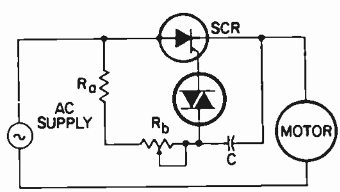



*Fig. 298—SCR half-wave proportional power control circuit.*

The delay in firing the SCR depends upon the time-constant network ($R_a$, $R_b$, C) which produces a gate-firing voltage that is shifted in phase with respect to the supply voltage. The amount of phase shift is adjusted by $R_b$. With maximum resistance in the circuit, the RC time constant is longest. This condition results in a large phase shift with a correspondingly small conduction angle. With minimum resistance, the phase shift is small, and essentially the full line voltage is applied to the load.

The control circuit uses the breakdown voltage of a diac as a threshold setting for firing the SCR. The diac is specifically designed for handling the high-current pulses required to trigger SCR's. When the voltage across capacitor C reaches the breakdown voltage of the diac, it fires and C discharges through the diac to its maintaining voltage. At this point, the diac again reverts to its high-impedance state. The discharge of the capacitor from breakdown to maintaining voltage of the diac provides a current pulse of sufficient magnitude to fire the SCR. Once the SCR has fired, the voltage across the phase-shift network reduces to the forward voltage drop of the SCR for the remainder of the half-cycle.

Two SCR's are usually required to provide full-wave power control. Because of the bidirectional switching characteristics of triacs, however, only one of these devices is needed to provide the same type of control. Fig. 299 shows three full-wave power controls that employ thyristors.

In circuits of this type, a rapidly rising off-state voltage can occur across the thyristor when the device changes from a conducting state to a blocking state (commutates). The influence of this dv/dt stress on the operation of the power-control element is described below. Consideration is given only to those circuit applications that utilize a triac as the main power-control element.

The dv/dt stress in a circuit with a resistive load (such as those just described) can be illustrated by consideration of a circuit with a 6-ampere load that has a power factor close to unity. The load resistance in this circuit is 20 ohms for a source voltage of 120 volts. If the total circuit inductance is assumed to be 500 microhenries and the total triac and stray capacitance is 500 picofarads, the circuit factor for the conducting state is 0.99996, lagging. Thus, the load current lags the line voltage by the small phase delay of approximately 25 microseconds. At the time that the triac commutates current, the line voltage is 1.6 volts. At this time, a transient damped oscillation occurs as a result of the interaction of the triac junction capacitance and the circuit inductance. For the circuit parameter values given (R = 20 ohms, L = 500 microhenries, and C = 500 picofarads), the frequency of oscillation is $3.2 \times 10^6$ Hz. Calculation of the maximum dv/dt stress across the triac yields a value of 1.97 volts per microsecond. The voltage at the time of commutation is then 1.6 volts, and the maximum commutating dv/dt becomes 3.15 volts per microsecond.

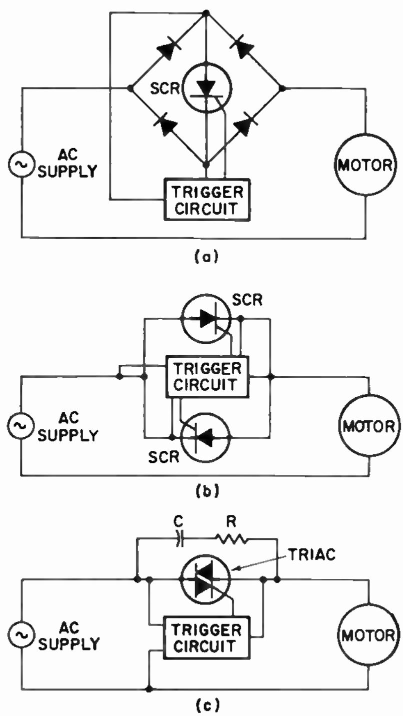



*Fig. 299—Full-wave thyristor motor control circuits using (a) bridge rectifier and a single SCR; (b) inverse parallel SCR's; (c) a triac.*

Thus, it can be seen that a definite dv/dt stress is imposed on the triac even when the load is primarily resistive. Because all resistive circuit configurations have some small inductance associated with them, a commutating dv/dt stress is produced in all resistive circuits. Fig. 300 shows a commutating dv/dt waveshape for a resistive load of 6 amperes in a 120-volt triac control circuit.

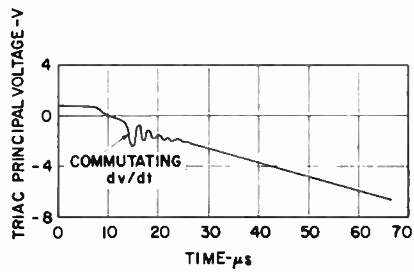



*Fig. 300—Triac principal voltage during commutation of a resistive load.*

The use of triacs for full-wave ac power control results in either fixed or adjustable power to the load. Fixed load power is achieved by use of the triac as a static on-off switch which applies effectively all of the available line voltage to the load, or by use of the triac in a fixed-phase firing mode which applies only the desired portion of the line voltage to the load. The latter method of operation is but one point of an infinite number of available points which can be attained by variable-phase firing operation.

Fig. 301 shows the current and voltage waveshapes produced when a triac is used to control ac power to a highly inductive load for on-off triac operation; Fig. 302 illustrates the waveshapes for phase-control operation. Because the load is highly inductive ($\omega L >> R$), the load current lags the line voltage by some phase angle $\theta$. When the current through the triac (i.e., the load current) goes to zero (commutates), the triac turns off. In static control operation, the triac is immediately turned on by continuous application, or re-application, of the gate triggering signal; thus, this signal causes the triac to continue conducting for the desired number of successive half-cycles.

As shown in Fig. 301, at time $t_1$, the gate is opened and the triac continues to conduct for the remainder of that half-cycle of load current. At the end of the half-cycle, commutation occurs and the triac is subjected to an off-state blocking voltage which has a polarity opposite to the conducted current and a magnitude equal to the value of line voltage at that instant. Because the triac goes from a conducting state to a blocking state in a very short period of time, the rate of rise of off-state voltage is very rapid. This rapidly rising off-state voltage produces a dv/dt across the main power terminals of the triac and can result in the triac going into conduction if the triac is incapable of withstanding the dv/dt.

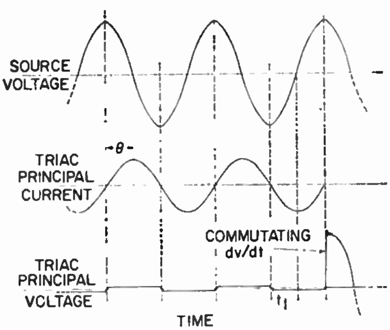



*Fig. 301—Principal voltage and current for static-switch triac operation with an inductive load.*

Fig. 302 shows the waveshapes produced for phase-control operation with an inductive load. The oscillations which are present on the peaks of the voltage waveform are the result of interaction of the circuit inductance and capacitance. For this type of operation, the stress caused by the commutating dv/dt is produced each time the current crosses the zero-axis and, therefore, occurs at a frequency equal to twice the line-voltage frequency. If the triac is incapable of sustaining the dv/dt which is produced, it goes

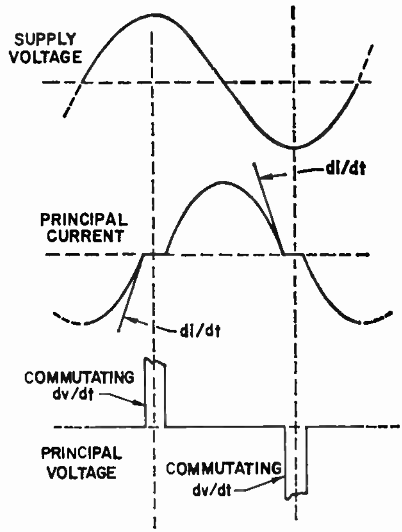



*Fig. 302—Principal voltage and current for phase-control triac operation with an inductive load.*

into a conducting state and remains in continuous conduction, supplying current to the load. This malfunction is illustrated in Fig. 303.

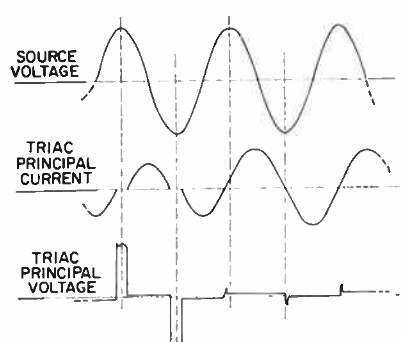
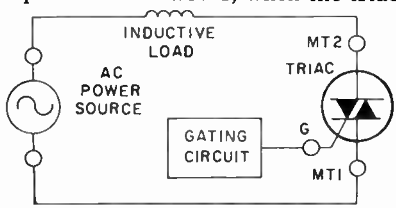
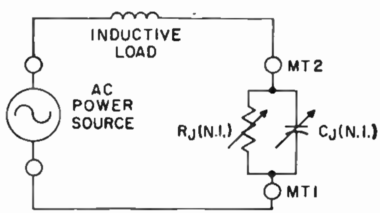



*Fig. 303—Principal voltage and current showing malfunction of triac as a result of commutating dv/dt produced by an inductive load.*

Fig. 304(a) shows the circuit diagram of a series connection of voltage source, triac, and load. An equivalent circuit for this series connection is shown in Fig. 304(b). When the triac is in conduction, the triac junction capacitance is shunted by a low-value, nonlinear resistance which minimizes the effect of triac capacitance. However, when the triac




(a)




(b)

*Fig. 304—(a) Series-circuit connection of triac, inductive load, and ac power source; and (b) equivalent circuit.*

goes out of conduction, the resistive component becomes very large and the equivalent triac shunting capacitance becomes significant. Because the circuit is basically a series RLC circuit, the voltage waveshape and the rate of rise of voltage across the triac at commutation are determined by the magnitude of source voltage and the circuit inductance, capacitance, and resistance. Thus the rising off-state voltage across the triac can be an overdamped, critically damped, or underdamped oscillation.

The increased complexity of aircraft control systems, and the need for greater reliability than electromechanical switching can offer, has led to the use of solid-state power switching in aircraft. Because 400-Hz power is used almost universally in aircraft systems, triacs employed for power switching and control in such systems must have a substantially higher commutating dv/dt capability than are those employed similarly in 60-Hz systems. (The increase in commutating dv/dt stresses on triacs with increases in frequency was explained previously in the section on Thyristors.) RCA offers an extensive line of triacs rated for 400-Hz applications.

Areas of application for 400-Hz triacs on aircraft include:

1. Heater controls for food-warming ovens and for windshield defrosters.
2. Lighting controls for instrument panels and cabin illumination.
3. Motor controls.
4. Solenoid controls.
5. Power supply switches

Fig. 305 shows a low-current triac in use in a simple, common, proportional-control application; the circuit consists of a single RC time constant and a threshold device. The trigger diac is used as a threshold device to remove the dependence of the trigger circuit on

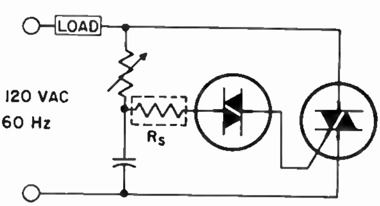



*Fig. 305—Simple control circuit using a single time constant.*

variations in gate trigger characteristics. The circuit can provide sufficient control for many applications, such as heaters and motor-speed and switching controls. Because of its simplicity, the circuit can be packaged in confined areas where space is at a premium. Electrically, it displays a hysteresis effect and initially turns on for resistive loads with a conduction angle which may be too large; however, it provides maximum power output at the full "on" position of the control potentiometer.

The hysteresis effect produced by a single-time-constant circuit can be reduced by addition of a resistor ($R_S$) in series with the trigger diac, as shown by the dotted lines in Fig. 305. The series resistor reduces the capacitor discharge time and thus provides reduced time lag because of the diac turn-on-characteristics.

The circuit shown in Fig. 306 uses a double-time-constant control to improve on the performance of the single-time-constant control circuit. This circuit minimizes the hysteresis effect and allows the triac to turn on at small conduction angles. The circuit has the advantages of low hysteresis, bidirectional operation at

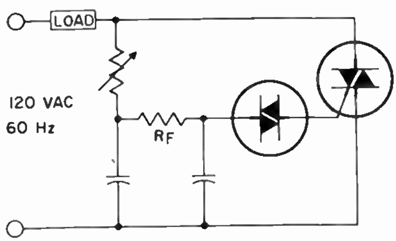



*Fig. 306—Control circuit using a double time constant.*

small conduction angles, and continuous control up to the maximum conduction angle. In addition, the fixed resistor $R_f$ can be replaced by a trimmer potentiometer for minimum control at low conduction angles.

The circuit shown in Fig. 307 uses a neon bulb as a threshold device rather than the solid-state diac. This circuit has the advantages of low hysteresis, bidirectional operation at small conduction angles, and

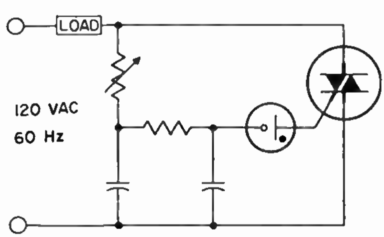



*Fig. 307—Control circuit using a neon-bulb threshold device.*

continuous control up to the maximum conduction angle. Because the neon-bulb threshold voltage is higher than that of a solid-stage diac, however, full 360-degree control may not be achieved.

Fig. 308 shows a circuit in which an SCR controls the triggering and operation of a triac in an integral-cycle control circuit which is radio-frequency-interference free. A basic SCR gate-trigger or gate-control

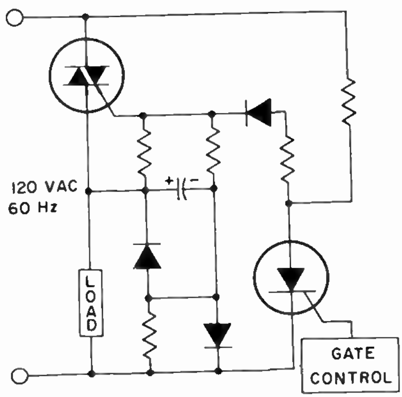



*Fig. 308—Integral-cycle control circuit.*

circuit can be represented by a voltage source and a series resistance, as shown in Fig. 309. The series resistance should include both the ex-

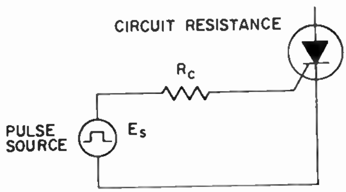



*Fig. 309—Equivalent gate trigger circuit.*

ternal circuit resistance and the internal generator resistance. With this type of equivalent circuit, the conventional load-line approach to gate trigger-circuit design can be used. With pulse-type triggering, it is assumed initially that the time required to trigger all SCR's of the same type is known, and that the maximum allowable gate trigger pulse widths for specific peak gate power inputs are to be determined. The magnitude of gate trigger current required to turn on an SCR of a given type can be determined from the turn-on characteristics shown in the section on Thyristors.

The triac in Fig. 308 is not triggered as long as the SCR is on. When the SCR is turned off by removal of the gate signal and application of a negative anode potential, the triac is triggered on at the beginning of the next half-cycle. When the triac conducts, the capacitor charges up to the peak supply voltage and retains its charge to trigger the triac on in the next half-cycle. When the triac conducts in the reverse direction, the negative charge on the capacitor is held to a low value so that it does not trigger the triac when the supply voltage reverses. If the SCR is still off, the triac repeats its conduction angle. If the SCR is conducting, the triac does not trigger on, but remains off until the SCR is again turned off. This circuit provides the unique function of integral-cycle switching, i.e., once the triac is triggered on, it completes one full cycle before turning off. This type of switching eliminates dc components present with half-wave control. The circuit also provides synchronous switching, i.e., the triac turns on at the beginning of the cycle and does not generate RFI.

## Light Dimmers

A simple, inexpensive light-dimmer circuit can be constructed with a diac, a triac, and an RC charge-control network. It is important to remember that a triac in this type of circuit dissipates power at the rate of about one watt per ampere. Therefore, some means of removing heat must be provided to keep the device within its safe operating-temperature range. On a small light-control circuit such as one built into a lamp socket, the lead-in wire serves as an effective heat sink. Attachment of the triac case directly to one of the lead-in wires provides sufficient heat dissipation for operating currents up to 2 amperes (rms). On wall-mounted controls operating up to 6 amperes, the combination of faceplate and wallbox serves as an effective heat sink. For higher-power controls, however, the ordinary faceplate and wallbox do not provide sufficient heat-sink area. In this case, additional area may be obtained by use of a finned face plate that has a cover plate which stands out from the wall so air can circulate freely over the fins.

On wall-mounted controls, it is also important that the triac be electrically isolated from the face plate, but at the same time be in good thermal contact with it. Although the thermal conductivity of most electrical insulators is relatively low when compared with metals, a low-thermal-resistance, electrically isolated bond of triac to faceplate can be obtained if the thickness of the insulator is minimized and the area for heat transfer through the insulator is maximized. Suitable insulating materials are fiberglass tape, ceramic sheet, mica, and polyimide film. Fig. 310 shows two

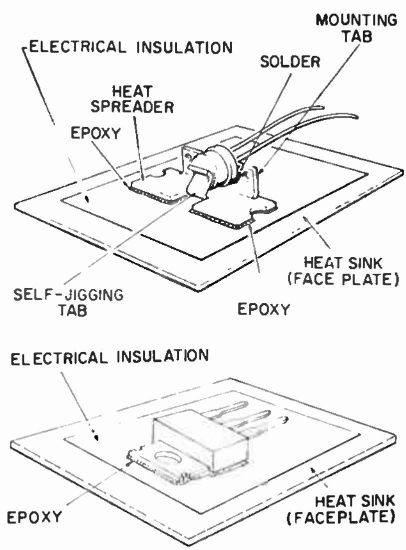



*Fig. 310—Examples of isolated mounting of triacs.*

examples of isolated mounting for triacs in a TO-5 package and the new plastic package. Electrical insulating tape is first placed over the inside of the faceplate. The triac is then mounted to the insulated faceplate by use of epoxy-resin cement.

Because the light output of an incandescent lamp depends upon the voltage impressed upon the lamp filament, changes in the lamp voltage vary the brightness of the lamp. When ac source voltages are used, a triac can be used in series with an incandescent lamp to vary the voltage to the lamp by changing its conduction angle; i.e., the portion of each half-cycle of ac line voltage in which the triac conducts to provide voltage to the lamp filament. The triac, therefore, is very attractive as a switching element in light-dimming applications.

To switch incandescent-lamp loads reliably, a triac must be able to withstand the inrush current of the lamp load. The inrush current is a result of the difference between the cold and hot resistance of the tungsten filament. The cold resistance of the tungsten filament is much lower than the hot resistance. The resulting inrush current is approximately 12 times the normal operating current of the lamp.

The simplest circuit that can be used for light-dimming applications is shown in Fig. 311. This circuit uses a diac in series with the gate of a triac to minimize the variations in

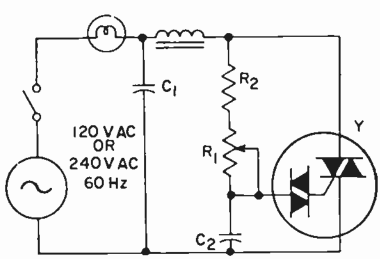



*Fig. 311—Single-time-constant light-dimmer circuit.*

gate trigger characteristics. In applications where space is at a premium, the RCA-40431 or RCA-40432, which combines the functions of both triac and diac, may be used. Changes in the resistance in series with the capacitor change the conduction angle of the triac. Because of its simplicity, this circuit can be packaged in confined areas where space is at a premium.

The capacitor in the circuit of Fig. 311 is charged through the control potentiometer and the series resistance. The series resistance is used to protect the potentiometer by limiting the capacitor charging current when the control potentiometer is at its minimum resistance setting. This resistor may be eliminated if the potentiometer can withstand the peak charging current until the triac turns on. The diac conducts when the voltage on the capacitor reaches its breakover voltage. The capacitor then discharges through the diac to produce a current pulse of sufficient amplitude and width to trigger the triac. Because the triac can be triggered with either polarity of gate signal, the same operation occurs on the opposite half-cycle of the applied voltage. The triac, therefore, is triggered and conducts on each half-cycle of the input supply voltage.

The interaction of the RC network and the trigger diode results in a hysteresis effect when the triac is initially triggered at small conduction angles. The hysteresis effect is characterized by a difference in the control potentiometer setting when the triac is first triggered and when the circuit turns off. Fig. 312 shows the interaction between the RC network and the diac to produce the hysteresis effect. The capacitor voltage and the ac line voltage are shown as solid lines. As the resistance in the circuit is decreased from its maximum value, the capacitor voltage reaches a value which fires the diac. This point is designated A on the capacitor-voltage waveshape. When the diac fires, the capacitor discharges and triggers the triac at an initial conduction angle $\theta_1$. During the forming of the gate trigger pulse, the capacitor voltage drops suddenly. The charge on the capacitor is smaller than when the diac did not conduct. As a result of the different voltage conditions on the capacitor, the breakover voltage of the diac is reached earlier in the next half-cycle. This point is labeled B on the capacitor-voltage waveform. The conduction angle $\theta_2$ corresponding to point B is greater than $\theta_1$. All succeeding conduction angles are equal to $\theta_2$ in magnitude. When the circuit resistance is increased by a change

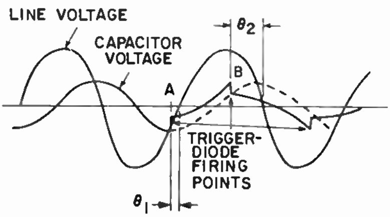



*Fig. 312—Waveforms showing interaction of control network and trigger diode.*

in the potentiometer setting, the triac is still triggered, but at a smaller conduction angle. Eventually, the resistance in series with the capacitance becomes so great that the voltage on the capacitor does not reach the breakover voltage of the diac. The circuit then turns off and does not turn on until the circuit resistance is again reduced to allow the diac to be fired. The hysteresis effect makes the voltage load appear much greater than would normally be expected when the circuit is initially turned on.

The double-time-constant circuit in Fig. 313 improves on the performance of the single-time-constant control circuit. This circuit uses an additional RC network to extend the phase angle so that the triac can be triggered at small conduction angles. The additional RC network also minimizes the hysteresis effect. Fig. 314 shows the voltage waveforms for the ac supply and the trigger capacitor of the circuit of Fig. 313. Because of the voltage drop across $R_3$, the input capacitor $C_2$ charges to a higher voltage than the trigger capacitor $C_3$. When the voltage on $C_3$ reaches the breakover voltage of the diac, it conducts and causes the capacitor to discharge and produce the gate-current pulse to trigger the triac. After the diac turns off, the charge on $C_3$ is partially restored by the charge from the input capacitor $C_2$. The partial restoration of charge on $C_3$ results in better circuit performance with a minimum of hysteresis.

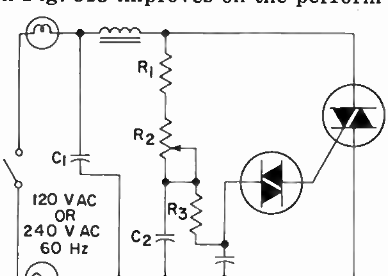



*Fig. 313—Double-time-constant light-dimmer circuit.*

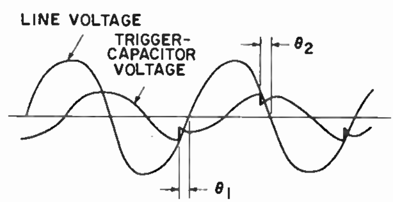



*Fig. 314—Voltage waveforms of double-time-constant control circuit.*

Fig. 315 shows a lamp-dimmer circuit in which the use of an RCA-CA3059 integrated-circuit zero-voltage switch in conjunction with a 400-Hz triac results in minimum RFI. (The CA3059 is described briefly in the section on Heater Controls. A detailed description of this integrated circuit is given in the manual on RCA Linear Integrated Circuits, Technical Series IC-42, in RCA Application Notes ICAN-4158 and ICAN-6268, or in the Technical Bulletin on the CA3059, File No. 397.

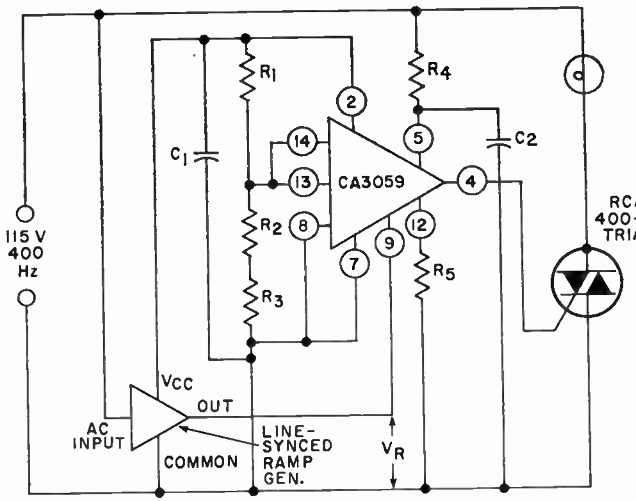



*Fig. 315—Circuit diagram for 400-Hz zero-voltage-switched lamp dimmer.*

Lamp dimming is a simple triac application that demonstrates an advantage of 400-Hz power over 60 Hz. Fig. 316 shows the adjustment

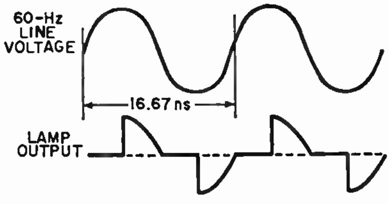



*Fig. 316—Waveforms for 60-Hz phase-controlled lamp dimmer.*

of lamp intensity by phase control of the 60-Hz line voltage. Because RFI is generated by the step functions of power each half cycle, extensive filtering is required. Fig. 317 shows a means of controlling power to the lamp by the zero-voltage-switching technique. Use of 400-Hz power makes possible the elimination of complete or half cycles within a period (typically 17.5 milliseconds) without noticeable flicker. Fourteen different levels of lamp intensity can be obtained in this manner. In the circuit shown in Fig. 315, a line-synced ramp is set up with the desired period and applied to terminal

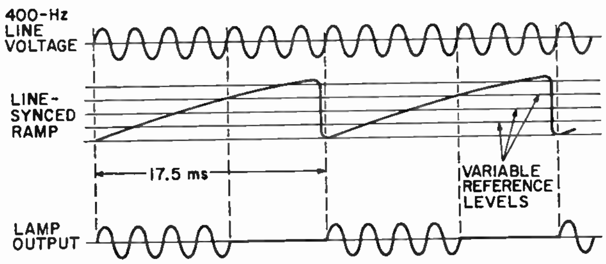



*Fig. 317—Waveforms for 400-Hz zero-voltage-switched lamp dimmer.*

No. 9 of the differential amplifier within the CA3059. The other side of the differential amplifier (terminal No. 13) uses a variable reference level, set by the potentiometer $R_2$. A change of the potentiometer setting changes the lamp intensity.

In 400-Hz applications, it may be necessary to widen and shift the CA3059 output pulse (which is typically 12 microseconds wide and centered on zero voltage crossing) to assure that sufficient latching current is available. The resistor $R_5$ (terminal No. 12 to common) and the capacitor $C_2$ (terminal No. 5 to common) are used for this adjustment.

## Heat Controls

There are three general categories of solid-state control circuits for electric heating elements: on-off control, phase control, and proportional control using integral-cycle synchronous switching. Phase-control circuits such as those used for light dimming are very effective and efficient for electric heat control except for the problem of radio-frequency interference (RFI). In higher-power applications, the RFI is of such magnitude that suppression circuits to minimize the interference become quite bulky and expensive.

On-off controls have only two levels of power input to the load. The heating coils are either energized to full power or are at zero power. Because of thermal time constants, on-off controls produce a cyclic action which alternates between thermal overshoots and undershoots with poor resolution.

This disadvantage is overcome and RFI is minimized by use of the concept of integral-cycle proportional control with synchronous switching. In this system, a time base is selected, and the on-time of the triac is varied within the time base. The ratio of the on-to-off time of the triac within this time interval depends upon the power required to the heating elements to maintain the desired temperature. Fig. 318 shows the on-off ratio of the triac. Within the time period, the on-time varies by an integral number of cycles from full ON to a single cycle of input voltage.

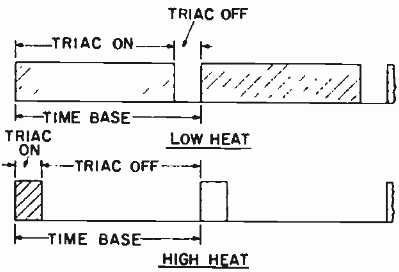



*Fig. 318—Triac duty cycle.*

One method of achieving integral-cycle proportional control is to use a fixed-frequency sawtooth generator signal which is summed with a dc control signal. The sawtooth generator establishes the period or time base of the system. The dc control signal is obtained from the output of the temperature-sensing network. The principle is illustrated in Fig. 319. As the sawtooth voltage increases, a level is reached which turns on power to the heating elements. As the temperature at the sensor changes, the dc level shifts accordingly and changes the length of time that the power is applied to the heating elements within the established time.

When the demand for heat is high, the dc control signal is high and high power is supplied continuously

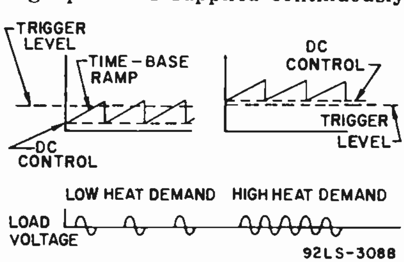
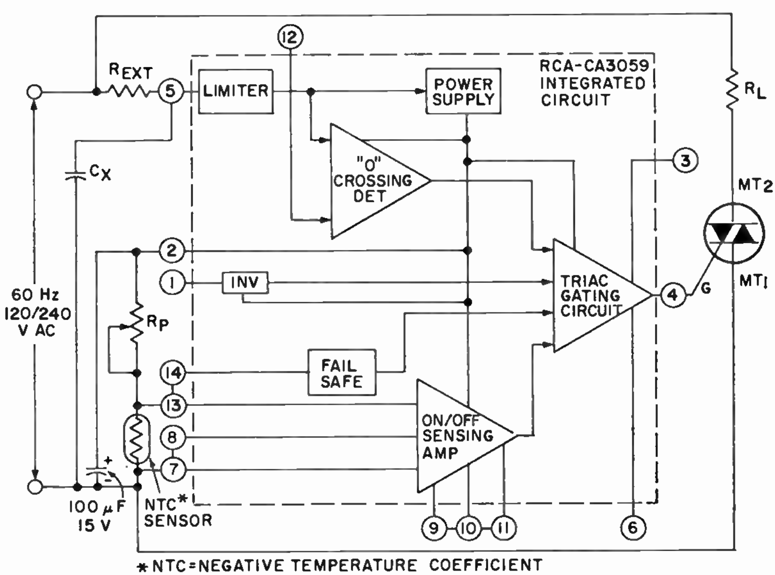



*Fig. 319—Proportional-controller waveshapes.*

to the heating elements. When the demand for heat is completely satisfied, the dc control signal is low and low power is supplied to the heating elements. Usually a system using this principle operates continuously somewhere between full ON and full OFF to satisfy the demand for heat.

The RCA-CA3059 integrated-circuit zero-voltage switch is intended primarily as a trigger circuit for the control of thyristors and is particularly suited for use in thyristor temperature-control applications. This multistage circuit employs a diode limiter, a threshold detector, a differential amplifier, and a Darlington output driver to provide the basic switching action. The dc supply voltage for these stages is supplied by an internal zener-diode-regulated power supply that has sufficient current capability to drive external circuit elements, such as transistors and other integrated circuits. The trigger pulse developed by this circuit can be applied directly to the gate of an SCR or a triac. A built-in fail-safe circuit inhibits the application of these pulses to the thyristor gate circuit in the event that the external sensor for the integrated-circuit switch should be inadvertently opened or shorted. The CA3059 may be employed as either an on-off type of controller or a proportional controller, depending upon the degree of temperature regulation required.

Fig. 320 shows a functional block diagram of the CA3059 integrated-circuit zero-voltage switch. Any triac that is driven directly from the output terminal of this circuit should be characterized for operation in the I(+) or III(+) triggering modes, i.e., with positive gate current (current flows into the gate for




**Note: Detailed descriptive information and the complete circuit diagram for the CA3059 are given in the RCA Linear Integrated Circuits Manual, Technical Series IC-42, or in RCA Application Notes ICAN-4158 and ICAN-6268 and the RCA Technical Bulletin on the CA3059, File No. 397.**

*Fig. 320—Functional block diagram of the integrated-circuit zero-voltage switch.*

both polarities of the applied ac voltage). The circuit operates directly from a 60-Hz ac line voltage of 120 or 240 volts.

The limiter stage of the CA3059 clips the incoming ac line voltage to approximately plus and minus 8 volts. This signal is then applied to the zero-voltage-crossing detector, which generates an output pulse during each passage of the line voltage through zero. The limiter output is also applied to a rectifying diode and an external capacitor that comprise the dc power supply. The power supply provides approximately 6 volts as the dc supply to the other stages of the CA3059. The on/off sensing amplifier is basically a differential comparator. The triac gating circuit contains a driver for direct triac triggering. The gating circuit is enabled when all the inputs are at a high voltage, i.e., the line voltage must be approximately zero volts, the sensing-amplifier output must be "high," the external voltage to terminal 1 must be a logical "1," and the output of the fail-safe circuit must be "high."

Fig. 321 shows the position and width of the pulses supplied to the gate of a thyristor with respect to the incoming ac line voltage. The CA3059 can supply sufficient gate voltage and current to trigger most RCA thyristors at ambient temperatures of 25°C. However, under worst-case conditions (i.e., at ambient-temperature extremes and maximum trigger requirements), selection of the higher-current thyristors may be necessary for particular applications.

As shown in Fig. 320, when terminal 13 is connected to terminal 14, the fail-safe circuit of the CA3059 is operable. If the sensor should then be accidentally opened or shorted, power is removed from the load (i.e., the triac is turned off). The internal fail-safe circuit functions properly, however, only when the ratio of the sensor impedance at 25°C, if a thermistor is the sensor, to the impedance of the potentiometer $R_p$ is less than 4 to 1.

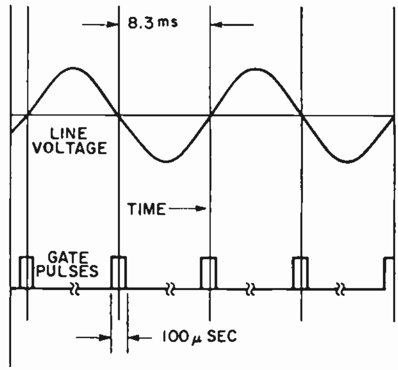



*Fig. 321—Timing relationship between the output pulses of the CA3059 and the ac line voltage.*

**On-Off Temperature Controller**—Fig. 322 shows a triac and a CA3059 used in an on-off temperature-controller configuration. The triac is turned on at zero voltage whenever the voltage $V_s$ exceeds the reference voltage $V_r$. The transfer characteristic of this system, shown in Fig. 323, indicates significant thermal overshoots and undershoots, a well-known characteristic of such a system. The differential or hysteresis of this system, however, can be further increased, if desired, by the addition of positive feedback.

**Proportional Temperature Controller**—For precise temperature-control applications, the proportional-control technique with synchronous switching is employed. The transfer curve for this type of controller is shown in Fig. 324. In this case, the duty cycle of the power supplied to the load is varied with the demand for heat required and the thermal time constant (inertia) of the system. For example, when the temperature setting is increased in an "on-off" type of controller, full power (100 per cent duty cycle) is supplied to the system. This effect results in significant temperature excursions because there is no anticipatory circuit to reduce the power gradually before the actual set temperature is

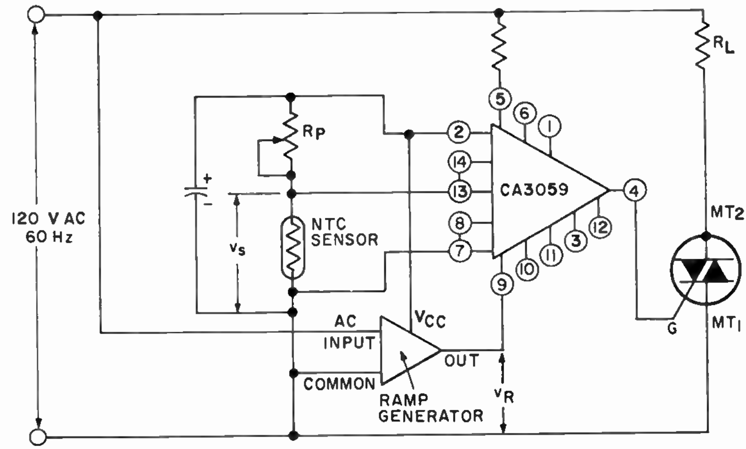



*Fig. 322—CA3059 on-off temperature controller.*

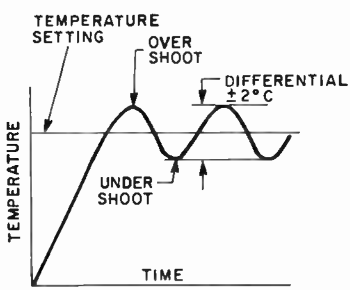



*Fig. 323—Transfer characteristics of an on-off temperature-control system.*

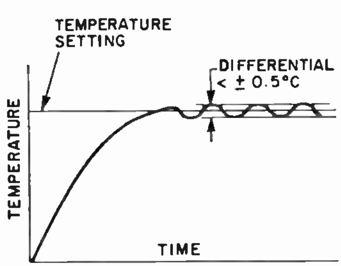



*Fig. 324—Transfer characteristics of a proportional temperature-control system.*

achieved. However, in a proportional control technique, less power is supplied to the load (reduced duty cycle) as the error signal is reduced (sensed temperature approaches the set temperature).

Before such a system is implemented, a time base is chosen so that the on-time of the triac is varied within this time base. The ratio of the on-to-off time of the triac within this time interval depends on the thermal time constant of the system and the selected temperature setting. Fig. 325 illustrates the principle of proportional control. For this operation, power is supplied to the load until the ramp voltage reaches a value greater than the dc control signal supplied to the opposite side of the differential amplifier. The triac then remains off for the remainder of the time-base period. As a result, power is "proportioned" to the load in a direct relation to the heat demanded by the system.

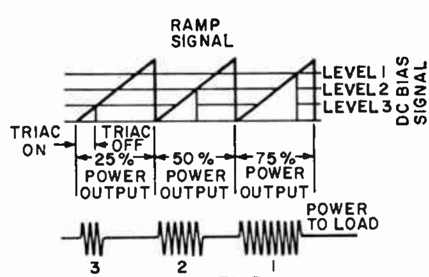



*Fig. 325—Principles of proportional control.*

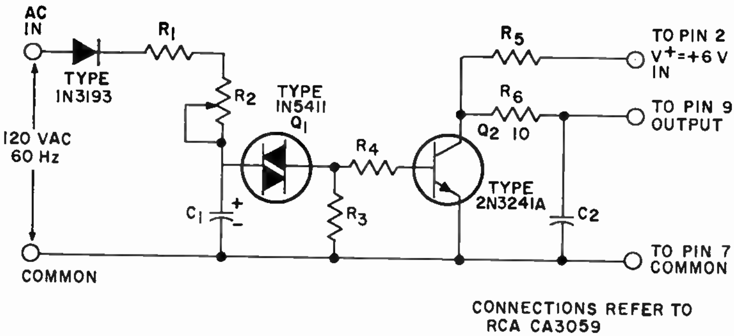



*Fig. 326—Ramp generator.*

For this application, a simple ramp generator can be realized with a minimum number of active and passive components. Exceptional ramp linearity is not necessary for proportional operation because of the nonlinearity of the thermal system and the closed-loop type of control. In the circuit shown in Fig. 326, ramp voltage is generated when the capacitor $C_2$ charges through resistors $R_4$ and $R_5$. The time base of the ramp is determined by resistors $R_1$ and $R_2$, capacitor $C_1$, and the breakover voltage of the 1N5411 diac. When the voltage across $C_1$ reaches approximately 32 volts, the diac switches and turns on the 2N3241A transistor. The capacitor $C_2$ then discharges through the collector-to-emitter junction of the transistor. This discharge time is the retrace or flyback time of the ramp. The circuit shown can generate ramp times ranging from 0.3 to 2.0 seconds through adjustment of $R_2$. For precise temperature regulations, the time base of the ramp should be shorter than the thermal time constant of the system, but long with respect to the period of the 60-Hz line voltage. Fig. 327 shows a triac and a CA3059 connected for the proportional mode.

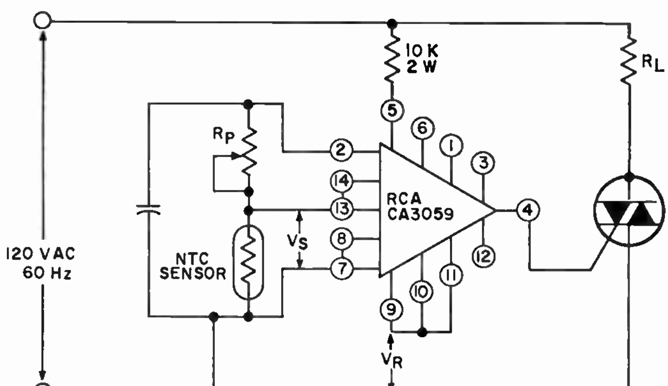


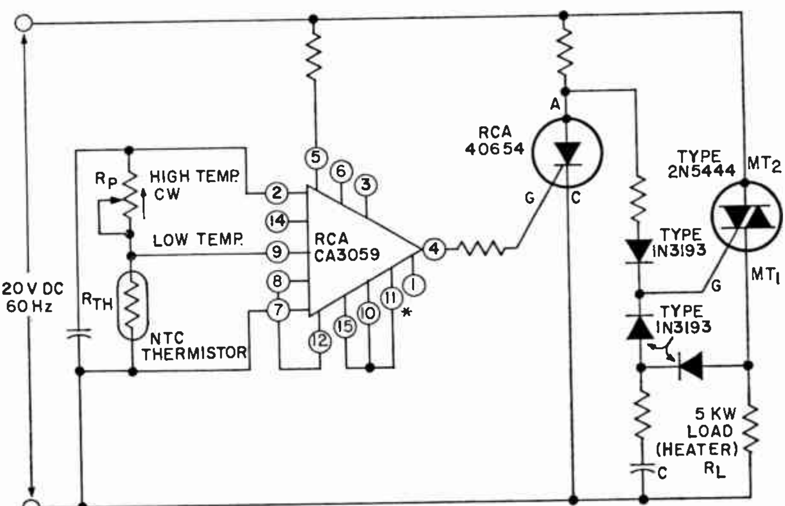

*Fig. 327—CA3059 proportional temperature controller.*

Integral-Cycle Temperature Controller (No half-cycling)—If a temperature controller which is completely devoid of half-cycling and hysteresis is required, then the circuit shown in Fig. 328 may be used This type of circuit is essential for applications in which half-cycling and the resultant dc component could cause overheating of a power transformer on the utility lines.

In the circuit shown in Fig. 327, the sensor is connected between terminals 7 and 9 of the CA3059. This arrangement is required because of the phase reversal introduced by the SCR. With this configuration, terminal 12 is connected to terminal 7 for operation of the CA3059 in the dc mode (however, the load is switched at zero voltage). Because the position of the sensor has been changed for this configuration, the internal fail-safe circuit cannot be used (terminals 13 and 14 are not connected).

In the integral-cycle controller, when the temperature being controlled is low, the resistance of the thermistor is high and an output signal at terminal 4 of zero volts is obtained. The SCR, therefore, is turned off. The triac is then triggered directly from the line on positive cycles of the ac voltage. When the triac is triggered and supplies power to the load $R_L$, capacitor C is charged to the peak of the input voltage. When the ac line swings negative, capacitor C discharges through the triac gate to trigger the triac on the negative half-cycle. The diode-resistor-capacitor "slaving network" triggers the triac on negative half-cycles of the ac input voltage after it is triggered on the positive half-cycle to provide only integral cycles of ac power to the load.

When the temperature being controlled reaches the desired value, as determined by the thermistor, then a positive voltage level appears at terminal 4 of the CA3059. The SCR then starts to conduct at the beginning of the positive input cycle to shunt the trigger current away




* FOR PROPORTIONAL OPERATION OPEN TERMINALS 10, 11, AND 13, AND CONNECT POSITIVE RAMP VOLTAGE TO TERMINAL 13

*Fig. 328—CA3059 integral-cycle temperature controller in which half-cycling effect is eliminated.*

from the gate of the triac. The triac is then turned off. The cycle repeats when the SCR is again turned by a reversal of the polarity of the applied voltage.

The circuit shown in Fig. 329 is similar to the configuration in Fig. 328 except that the fail-safe circuit incorporated in the CA3059 can be used. In this latter circuit, the NTC sensor is connected between terminals 7 and 13, and a transistor inverts the signal output at terminal 4 to nullify the phase reversal introduced by the SCR. The internal power supply of the CA3059 supplies bias current to the transistor.

The circuit shown in Fig. 329 can readily be converted to a true proportional integral-cycle temperature controller simply by connection of a positive-going ramp voltage to terminal 9 (with terminals 10 and 11 open).

## Motor Controls

Triacs and SCR's can be used very effectively to apply power to motors and perform switching, or any other desired operating condition that can be obtained by a switching action. Because most motors are line-operated, the triac can be used as a direct replacement for electromechanical switches. A very simple triac static switch for control of ac motors is shown in Fig. 330. The low-current switch controlling the gate trigger current can be any type of transducer, such as a pressure switch, a thermal switch, a photocell, or a magnetic reed relay. This simple type of circuit allows the motor to be switched directly from the transducer switch

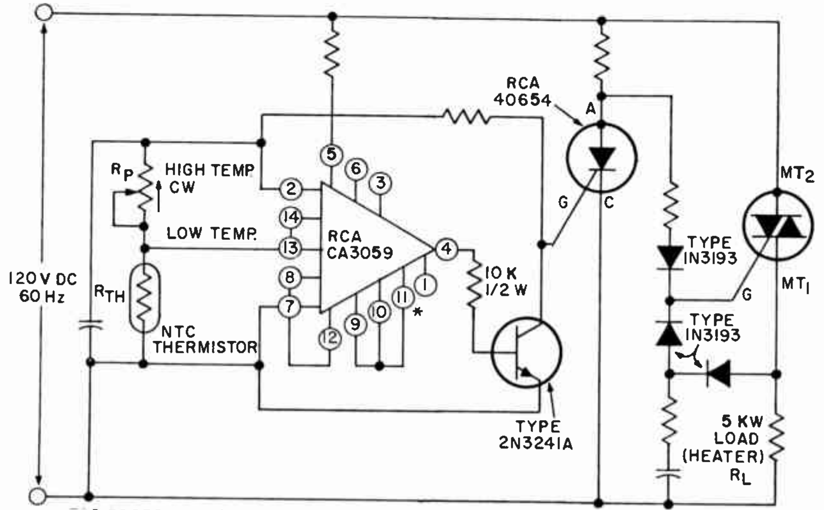



*Fig. 329—CA3059 integral-cycle temperature controller that features fail-safe operation and no half-cycling effect.*

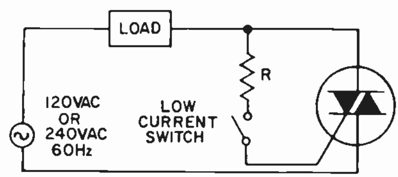



*Fig. 330—Simple triac static switch.*

without any intermediate power switch or relay.

Triacs can also be used to change the operating characteristics of motors to obtain many different speed and torque curves.

For dc control, the circuit of Fig. 331 can be used. By use of the dc triggering modes, the triac can be directly triggered from transistor

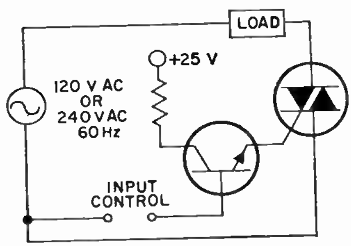



*Fig. 331—AC triac switch control from dc input.*

circuits by either a pulse or continuous signal. A transistor series-switching regulator approach can also be used to control the armature current of a dc motor, as shown in Fig. 332. Usually the transistor is full on or full off and the duration of the pulse (or the duty cycle) determines the motor speed. Its typical high-power application is in the drive motors of electric vehicles or submarines.

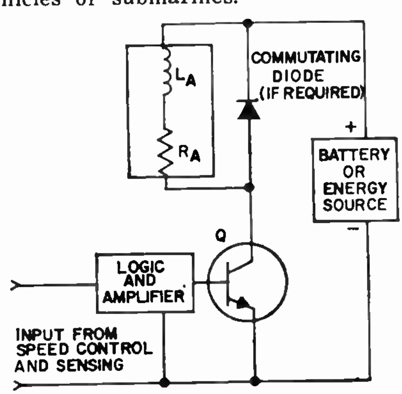



*Fig. 332—DC motor armature control.*

Many fractional-horsepower motors are series-wound "universal" motors, so named because of their ability to operate directly from either ac or dc power sources. Fig. 333 is a schematic of this type of motor operated from an ac supply. Because most domestic applications today require 60-Hz power, universal motors are usually designed to have optimum performance characteristics at this frequency. Most universal motors run faster at a given dc voltage than at the same 60-Hz ac voltage.

The field winding of a universal motor, whether distributed or lumped (salient pole), is in series with the armature and external circuit, as shown in Fig. 333. The current

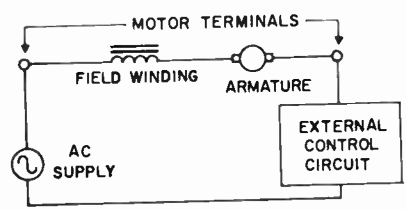



*Fig. 333—Series-wound universal motor.*

through the field winding produces a magnetic field which cuts across the armature conductors. The action of this field in opposition to the field set up by the armature current subjects the individual conductors to a lateral thrust which results in armature rotation.

AC operation of a universal motor is possible because of the nature of its electrical connections. As the ac source voltage reverses every half-cycle, the magnetic field produced by the field winding reverses its direction simultaneously. Because the armature windings are in series with the field windings through the brushes and commutating segments, the current through the armature winding also reverses. Because both the magnetic field and armature current are reversed, the direction of the lateral thrust on the armature windings remains constant. Typical performance characteristic curves for a universal motor are shown in Fig. 334.

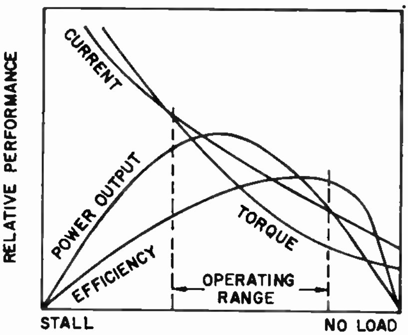



*Fig. 334—Typical performance curves for a universal motor.*

One of the simplest and most efficient means of varying the impressed voltage to a load on an ac power system is by control of the conduction angle of a thyristor placed in series with the load. Typical curves showing the variation of motor speed with conduction angle for both half-wave and full-wave impressed motor voltages are illustrated in Fig. 335.

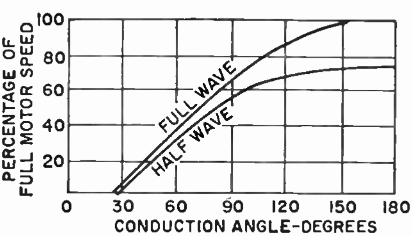



*Fig. 335—Typical performance curves for a universal motor with phase-angle control.*

Half-Wave Control—There are many good circuits available for half-wave control of universal motors. The circuits are divided into two classes: regulating and nonregulating. Regulation in this instance implies load sensing and compensation of the system to prevent changes in motor speed.

The half-wave proportional control circuit shown in Fig. 336 is a non-regulating circuit that depends upon an RC delay network for gate phase-lag control. This circuit is better than simple resistance firing circuits because the phase-shifting characteristics of the RC network permit the firing of the SCR beyond the peak of the impressed voltage, resulting in small conduction angles and very slow speed.

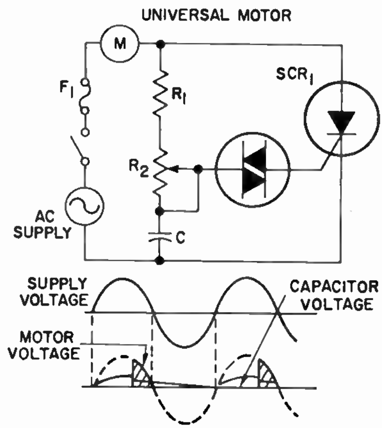



*Fig. 336—Half-wave motor control with no regulation.*

Fig. 337 shows a fundamental circuit of direct-coupled SCR control with voltage feedback. This circuit is highly effective for speed control of universal motors. The circuit makes use of the counter emf induced in the rotating armature because of the residual magnetism in the motor on the half-cycle when the SCR is blocking.

The counter emf is a function of speed and, therefore, can be used as an indication of speed changes as mechanical load varies. The gate-firing circuit is a resistance network consisting of $R_1$ and $R_2$. During the positive half-cycle of the source voltage, a fraction of the voltage is developed at the center-tap of the potentiometer and is compared with the counter emf developed in the rotating armature of the motor. When the bias developed at the gate of the SCR from the potentiometer exceeds the counter emf of the motor, the SCR fires. AC power is then applied to the motor for the

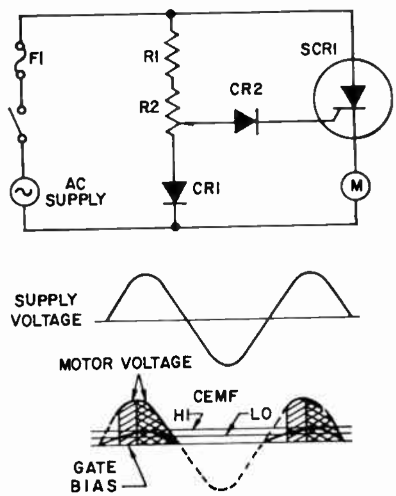



*Fig. 337—Half-wave motor control with regulation.*

remaining portion of the positive half-cycle. Speed control is accomplished by adjustment of potentiometer $R_1$. If the SCR is fired early in the cycle, the motor operates at high speed because essentially the full rated line voltage is applied to the motor. If the SCR is fired later in the cycle, the average value of voltage applied to the motor is reduced, and a corresponding reduction in motor speed occurs. On the negative half-cycle, the SCR blocks voltage to the motor. The voltage applied to the gate of the SCR is a sine wave because it is derived from the sine-wave line voltage. The minimum conduction angle occurs at the peak of the sine wave and is restricted to 90 degrees. Increasing conduction angles occur when the gate bias to the SCR is increased to allow firing at voltage values which are less than the peak value.

At no load and low speed, skip cycling operation occurs. This type of operation results in erratic motor speeds. Because no counter EMF is induced in the armature when the motor is standing still, the SCR will fire at low bias-potentiometer settings and causes the motor to accelerate to a point at which the counter emf induced in the rotating armature exceeds the gate firing bias of the SCR and prevents the SCR from firing. The SCR is not able to fire again until the speed of the motor has reduced, as a result of friction losses, to a value at which the induced voltage in the rotating armature is less than the gate bias. At this time the SCR fires again. Because the motor deceleration occurs over a number of cycles, there is no voltage applied to the motor; hence, the term skip-cycling.

When a load is applied to the motor, the motor speed decreases and thus reduces the counter emf induced in the rotating armature. With a reduced counter emf, the SCR fires earlier in the cycle and provides increased motor torque to the load. Fig. 337 also shows variations of conduction angle with changes in counter emf. The counter emf appears as a constant voltage at the motor terminals when the SCR is blocking.

**Half-Wave Motor Control Limitations**—If a universal motor is operated at low speed under a heavy mechanical load, it may stall and cause heavy current flow through the SCR. For this reason, low-speed heavy-load conditions should be allowed to exist for only a few seconds to prevent possible circuit damage. In any case, fuse ratings should be carefully determined and observed.

Nameplate data for some universal motors are given in developed horsepower to the load. This mechanical designation can be converted into its electrical current equivalent through the following procedure.

Internal motor losses are taken into consideration by assigning a figure of merit. This figure, 0.5, represents motor operation at 50-percent efficiency, and indicates that the power input to the motor is twice the power delivered to the load. With this figure of merit and the input voltage $V_{ac}$, the rms input current to the motor can be calculated as follows:

$$\text{rms current} = \frac{\text{mechanical horsepower} \times 746}{0.5\ V_{ac}}$$

For an input voltage of 120 volts, the rms input current becomes

rms current = horsepower × 12.4

For an input voltage of 240 volts, the rms input current becomes

rms current = horsepower × 6.2

The motor-control circuits described above should not be used with universal motors that have calculated rms current exceeding the values given. The circuits will accommodate universal motors with ratings up to ¾ horsepower at 120 volts input and up to 1½ horsepower at 240 volts input.

**Full-Wave Universal and Induction Motor Controls**—Fig. 338 shows a single-time-constant full-wave triac circuit which can be used as a satisfactory proportional speed control for universal motors and with certain types of induction motors, such as shaded pole or permanent split-capacitor motors when the load is fixed. No regulation is provided with this circuit. This type of circuit is best suited to applications which require speed control in the medium to full-power range. It is specifically useful in applications such as fans or blower-motor controls, where a small change in motor speed produces a large change in air velocity. Caution must be exercised if this type of circuit is used with induction motors because the motor may stall suddenly if the speed of the motor is reduced below the drop-out speed for the specific operating condition determined by the conduction angle of the triac. Because the single-time-constant circuit cannot provide speed control of an induction motor load from maximum power to full OFF, but only down to some fraction of the full-power speed, the effects of hysteresis described previously are not present. Speed ratios as high as 3:1 can be obtained from the single-time-constant circuit used with certain types of induction motors. Care must be taken to avoid continuous low-speed operation of induction motors in which sleeve bearings are used as improper lubrication will result.

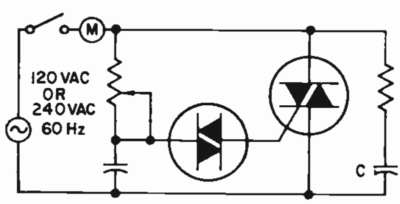



*Fig. 338—Induction motor control.*

Because motors are basically inductive loads and because the triac turns off when the current reduces to zero, the phase difference between the applied voltage and the device current causes the triac to turn off when the source voltage is at a value other than zero. When the triac turns off, the instantaneous value of input voltage is applied directly to the main terminals of the triac. This commutating voltage may have a rate of rise which can retrigger the triac. The commutating dv/dt can be limited to the capability of the triac by use of an RC network across the device, as shown in Fig. 338. The current and voltage waveshapes for the circuit are shown in Fig. 339 to illustrate the principle of commutating dv/dt.

In applications in which the hysteresis effect can be tolerated or which require speed control primarily in the medium to full-power range, a single-time-constant circuit such as that shown in Fig. 338 for induction motors can also be used for universal motors. However, it is usually desirable to extend the range of speed control from full-power ON to very low conduction angles. The double-time-constant circuit shown in Fig. 340 provides the delay necessary to trigger the triac at very low conduction angles with a minimum of hysteresis, and also provides practically full power

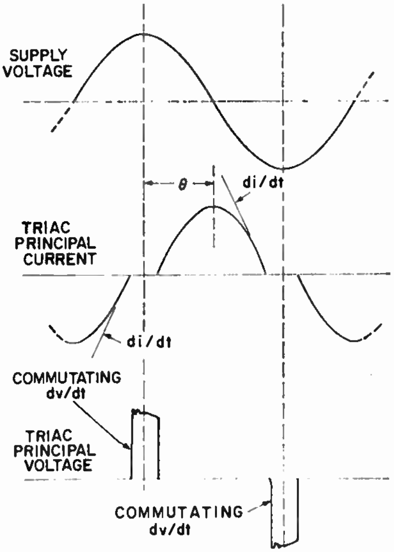



*Fig. 339—Waveshapes of commutating dv/dt characteristics.*

to the load at the minimum-resistance position of the control potentiometer. When this type of control circuit is used, an infinite range of motor speeds can be obtained from very low to full-power speeds.

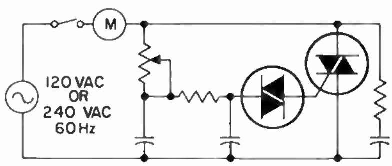



*Fig. 340—Double-time-constant motor control.*

Reversing Motor Control—In many industrial applications, it is necessary to reverse the direction of a motor, either manually or by means of an auxiliary circuit. Fig. 341 shows a circuit which uses two triacs to provide this type of reversing motor control for a split-phase capacitance motor. The reversing switch can be either a manual switch or an electronic switch used with some type of sensor to reverse the direction of the motor. A resistance is added in series with the capacitor to limit capacitor discharge current to a safe value whenever both triacs are conducting simultaneously. If triac No.1 is turned on while triac No.2 is on, a loop current resulting from capacitor discharge will occur and may damage the triacs.

The circuit operates as follows: when triac No.1 is in the off state, motor direction is controlled by triac No.2; when triac No.2 reverts to the off state and triac No.1 turns on, the motor direction is reversed.

The triac motor-reversing circuit can be extended to electronic garage-door systems which use the principle for garage-door direction

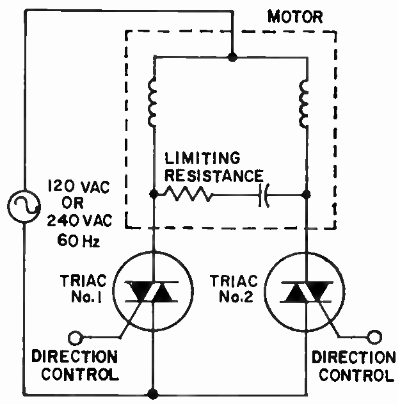



*Fig. 341—Reversing motor control.*

control. The system contains a transmitter and a receiver and provides remote control of door opening and closing. The block diagram in Fig. 342 shows the functions required for a complete solid-state system. When the garage door is closed, the gate drive to the DOWN triac is disabled by the lower-limit closure and the gate drive to the UP triac is inactive because of the state of the flip-flop. If the transmitter is momentarily keyed, the receiver activates the time-delay monostable multivibrator so that it then changes the flip-flop state and provides continuous gate drive to the UP triac. The door then continues to travel in the UP direction until the upper-limit switch closure disables gate drive to the UP triac. A second keying of the transmitter provides the DOWN triac with gate drive and causes the door to travel in the DOWN direction until the gate drive is disabled by the lower limit closure. The time in which the monostable multivibrator is active should override normal transmitter keying for the purpose of eliminating erroneous firing. A feature of this system is that, during travel, transmitter keying provides motor reversing independent of the upper- or lower-limit closures. Additional features, such as obstacle clearance, manual control, or time delay for overhead garage lights can be included very economically.

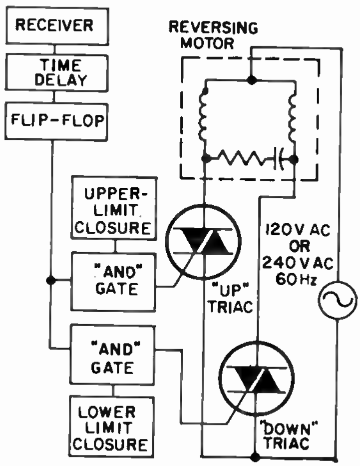



*Fig. 342—Block diagram for remote-control solid-state garage-door system.*

# DC Power Supplies

DC power supplies convert the output of a prime source, such as a generator, to a form useful to the circuit to be powered. The supply of power usually requires rectification to change ac to dc, filtering to smooth out the ac ripple in the output of the rectifier circuit, and regulation to assure a constant output from the power supply in spite of variations in the input voltage and output load.

## RECTIFICATION

The most suitable type of rectifier circuit for a particular application depends on the dc voltage and current requirements, the amount of rectifier "ripple" (undesired fluctuation in the dc output caused by an ac component) that can be tolerated in the circuit, and the type of ac power available. Figs. 343 through 349 show seven basic rectifier configurations. These illustrations include the output-voltage waveforms for the various circuits and the current waveforms for each individual rectifier in the circuits. Filtering of the output of the rectifier circuits is discussed later in this section. Ideally, the voltage waveform should be as flat as possible (i.e., approaching almost pure dc). A flat curve indicates a peak-to-average voltage ratio of one.

The single-phase half-wave circuit shown in Fig. 343 delivers only one pulse of current for each cycle of ac input voltage. As shown by the current waveform, the single rectifier conducts the entire current flow. This type of circuit contains a very high percentage of output ripple.

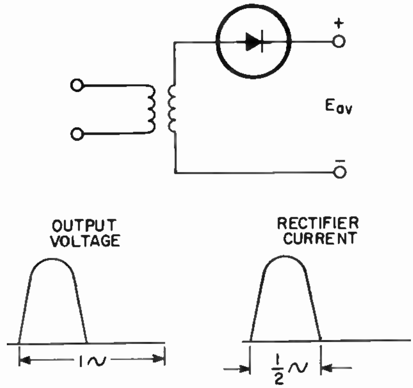



*Fig. 343—Single-phase half-wave circuit.*

Fig. 344 shows a single-phase full-wave circuit that operates from a

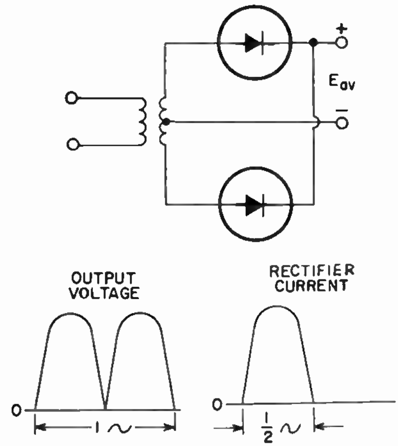



*Fig. 344—Single-phase full-wave circuit with center-tapped power transformer.*

center-tapped high-voltage transformer winding. This circuit has a lower peak-to-average voltage ratio than the circuit of Fig. 343 and about 65 per cent less ripple. Only 50 per cent of the total current flows through each rectifier. This type of circuit is widely used in television receivers and large audio amplifiers.

The single-phase full-wave bridge circuit shown in Fig. 345 uses four

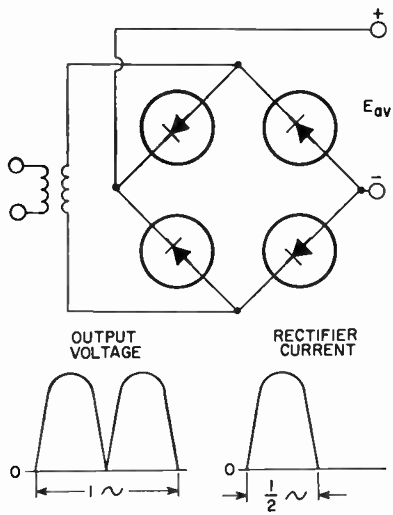



*Fig. 345—Single-phase full-wave circuit without center-tapped power transformer (i.e., bridge-rectifier circuit).*

rectifiers, and does not require the use of a transformer center-tap. It can be used to supply twice as much output voltage as the circuit of Fig. 344 for the same transformer voltage, or to expose the individual rectifiers to only half as much peak reverse voltage for the same output voltage. Only 50 per cent of the total current flows through each rectifier. This type of circuit is popular in amateur transmitter use.

The three-phase circuits shown in Figs. 346 through 349 are usually found in heavy industrial equipment such as high-power transmitters. The **three-phase Y half-wave circuit** shown in Fig. 346 uses three rectifiers. This circuit has considerably less ripple than the circuits discussed above. In addition, only one-third of the total output current flows through each rectifier.

Fig. 347 shows a **three-phase full-wave bridge circuit** which uses six rectifiers. This circuit delivers twice as much voltage output as the circuit of Fig. 346 for the same transformer conditions. In addition, this circuit, as well as those shown in Figs. 348 and 349, has an extremely small percentage of ripple.

In the **six-phase "star" circuit** shown in Fig. 348, which also uses six rectifiers, the least amount of the total output current (one-sixth) flows through each output rectifier. The **three-phase double-Y and interphase transformer circuit** shown in

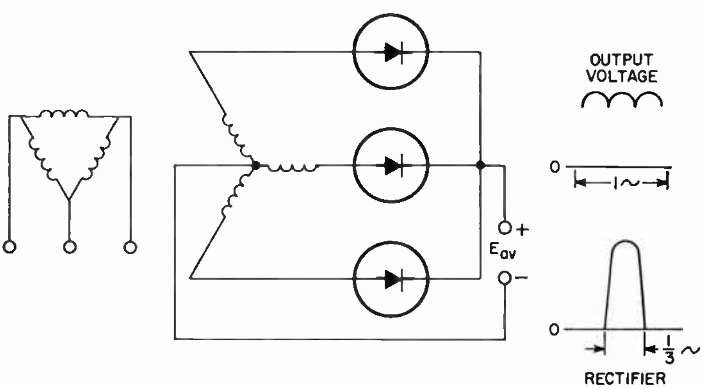



*Fig. 346—Three-phase "Y" half-wave circuit.*

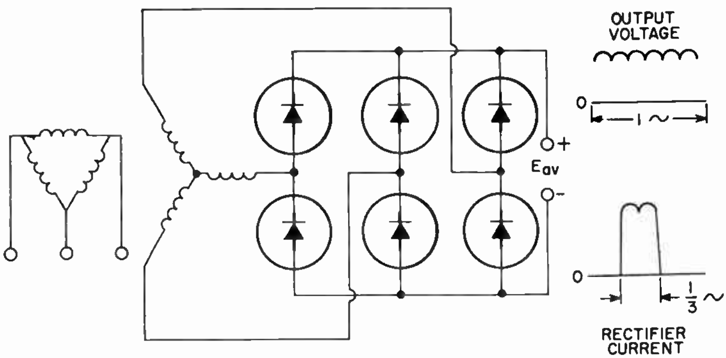



*Fig. 347—Three-phase "Y" full-wave circuit.*

Fig. 349 uses six half-wave rectifiers in parallel. This arrangement delivers six current pulses per cycle and twice as much output current as the circuit shown in Fig. 346.

Table IV lists voltage and current ratios for the circuits shown in Figs. 343 through 349 for resistive or inductive loads. These ratios apply for sinusoidal ac input voltages. It is generally recommended that inductive loads rather than resistive loads be used for filtering of rectifier current, except for the circuit of Fig. 343. Current ratios given for inductive loads apply only when a filter choke is used between the output of the rectifier and any capacitor in the filter circuit. Values shown do not take into consideration voltage drops

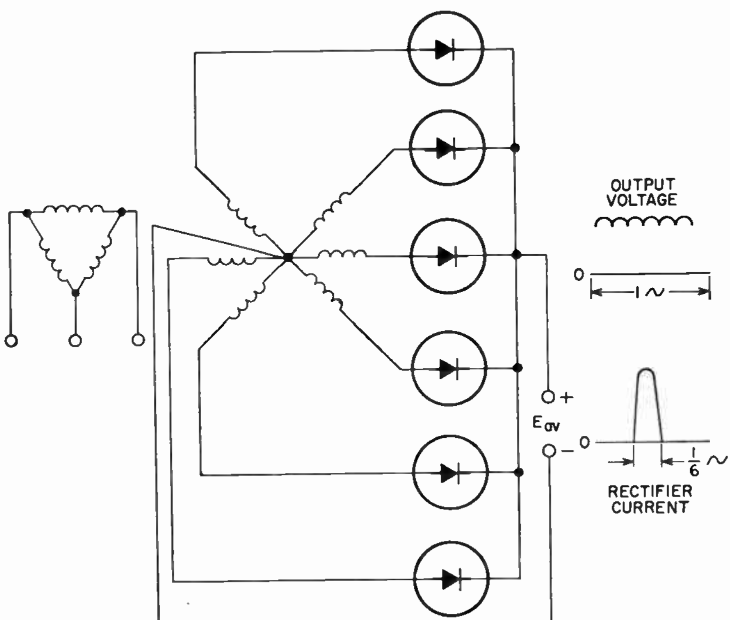



*Fig. 348—Six-phase "star" circuit.*

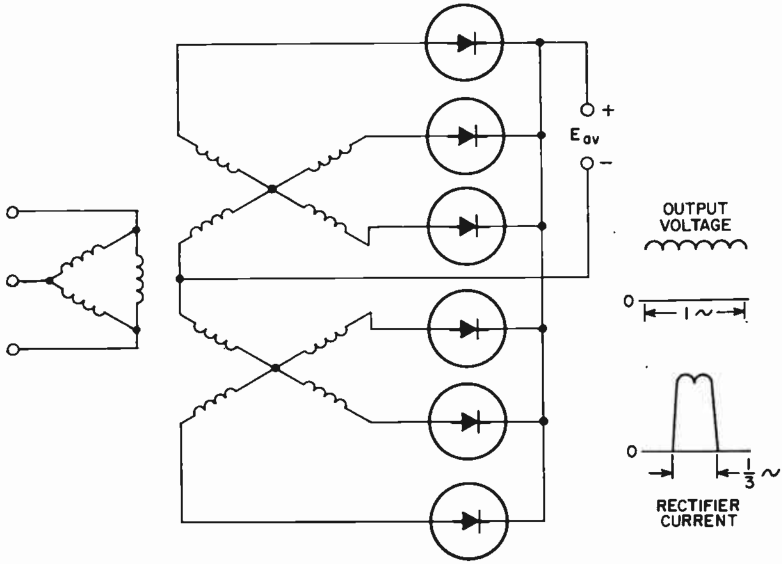



*Fig. 349—Three-phase "double-Y" and interphase-transformer circuit.*

which occur in the power transformer, the silicon rectifiers, or the filter components under load conditions. When a particular rectifier type has been selected for use in a specific circuit, Table IV can be used to determine the parameters and characteristics of the circuit.

In Table IV, all ratios are shown as functions of either the average output voltage $E_{av}$ or the average dc output current $I_{av}$, both of which are expressed as unity for each circuit. In practical applications, the magnitudes of these average values will, of course, vary for the different circuit configurations.

## FILTERING

Filter circuits are used to smooth out the ac ripple in the output of a rectifier circuit. Filters consist of two basic types, inductive "choke" input and capacitive input. Combinations and variations of these types are often used; some typical filter circuits are shown in Fig. 350.

The simplest of these filtering circuits is the capacitive input type. This type of filtering is most often used in low-current circuits in which a fairly large amount of ripple can be tolerated. Such circuits are usually single-phase, half-wave or full-wave. In this type of filter, the capacitor charges up to approximately the peak of the input voltage on each half-cycle that a rectifier conducts. The current into the load is then supplied from the capacitor rather than from the power supply until the point in the next half-cycle when the input voltage again equals the voltage across the capacitor. A rectifier circuit that uses a smoothing capacitor and the voltages involved are shown in Fig. 351. The input and output voltage wavefors for this circuit are shown in Fig. 352.

Higher average dc output voltages and currents can be obtained from this type of circuit by the use of larger capacitors. A larger capacitor also tends to reduce the ripple. However, care must be taken that the capacitor is not so large that excessive peak and rms currents cause overheating of the rectifier.

The next simplest filter is the inductive input filter. This filter performs the same function as a capacitive input filter in that it smooths

**Table IV—Voltage and Current Ratios for Rectifier Circuits Shown in Figs. 343 Through 349. Fig. 343 Uses a Resistive Load, and Figs. 344 Through 349 an Inductive Load**

| CIRCUIT RATIOS | Fig. 343 | Fig. 344 | Fig. 345 | Fig. 346 | Fig. 347 | Fig. 348 | Fig. 349 |
|---|---|---|---|---|---|---|---|
| Output Voltage: | | | | | | | |
| Average ........... | $E_{av}$ | $E_{av}$ | $E_{av}$ | $E_{av}$ | $E_{av}$ | $E_{av}$ | $E_{av}$ |
| Peak (x $E_{av}$) ...... | 3.14 | 1.57 | 1.57 | 1.21 | 1.05 | 1.05 | 1.05 |
| RMS (x $E_{av}$) ...... | 1.57 | 1.11 | 1.11 | 1.02 | 1.00 | 1.00 | 1.00 |
| Ripple (%) ....... | 121 | 48 | 48 | 18.3 | 4.3 | 4.3 | 4.3 |
| Input Voltage (RMS): | | | | | | | |
| Phase (x $E_{av}$) ...... | 2.22 | 1.11* | 1.11 | 0.855• | 0.428• | 0.74• | 0.855• |
| Line-to-Line (x $E_{av}$) | 2.22 | 2.22 | 1.11 | 1.48 | 0.74 | 1.48† | 1.71‡ |
| Average Output (Load) Current ............ | $I_{av}$ | $I_{av}$ | $I_{av}$ | $I_{av}$ | $I_{av}$ | $I_{av}$ | $I_{av}$ |
| RECTIFIER CELL RATIOS | | | | | | | |
| Forward Current: | | | | | | | |
| Average (x $I_{av}$) .... | 1.00 | 0.5 | 0.5 | 0.333 | 0.333 | 0.167 | 0.167 |
| RMS (x $I_{av}$): | | | | | | | |
| resistive load .... | 1.57 | 0.785 | 0.785 | 0.587 | 0.579 | 0.409 | 0.293 |
| inductive load .... | — | 0.707 | 0.707 | 0.578 | 0.578 | 0.408 | 0.289 |
| Peak (x $I_{av}$): | | | | | | | |
| resistive load .... | 3.14 | 1.57 | 1.57 | 1.21 | 1.05 | 1.05 | 0.525 |
| inductive load .... | — | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.500 |
| Ratio peak to average: | | | | | | | |
| resistive load .... | 3.14 | 3.14 | 3.14 | 3.63 | 3.15 | 6.30 | 3.15 |
| inductive load .... | — | 2.00 | 2.00 | 3.00 | 3.00 | 6.00 | 3.00 |
| Peak Reverse Voltage: | | | | | | | |
| x $E_{av}$ ............. | 3.14 | 3.14 | 1.57 | 2.09 | 1.05 | 2.42 | 2.09 |
| x $E_{rms}$ ............ | 1.41 | 2.82 | 1.41 | 2.45 | 2.45 | 2.83 | 2.45 |

* to center tap  • to neutral  † maximum value  ‡ maximum value, no load

the load current by storing energy during one part of the cycle and releasing it to the load during another part of the cycle. However, the inductor acts in a different way by extending the time during which current is drawn from a rectifier. When a smoothing inductor is used

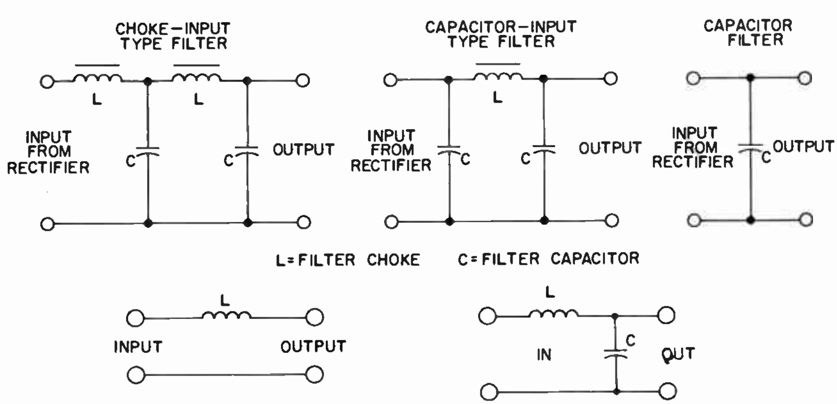



*Fig. 350—Typical filter circuits.*

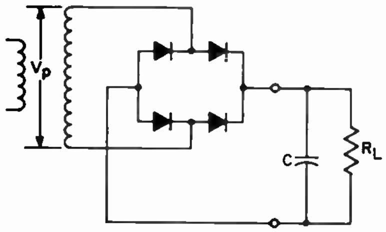



*Fig. 351—Bridge-rectifier circuit with capacitor input filter.*

in series with a full-wave rectifier circuit, the conduction period of each rectifier may be extended so that conduction does not stop in one rectifier until the other rectifier starts conducting. As a rèsult of this spreading action, any increase in inductance to reduce ripple results in a decrease in the average output voltage and current.

The smoothing capabilities of capacitors and inductors can be combined as shown in the other filters of Fig. 350 to take advantage of the best feature of each. Filters which provide maximum output and minimum ripple and use reasonably small components can thus be designed.

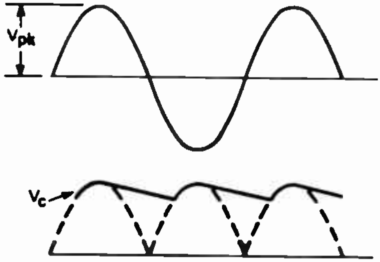



*Fig. 352—Input (top) and output (bottom) voltage waveforms for bridge rectifier shown in Fig. 351.*

## REGULATORS

In the operation of a regulator circuit, the difference between a reference input (e.g., the supply voltage) and some portion of the output voltage (e.g., a feedback signal) is used to supply an actuating error signal to the control elements. The amplified error signal is applied in a manner that tends to reduce this difference to zero. Regulators are designed to provide a constant output voltage very nearly equal to the desired value in the presence of varying input voltage and output load.

In series regulator circuits such as that shown in Fig. 353, direct-coupled

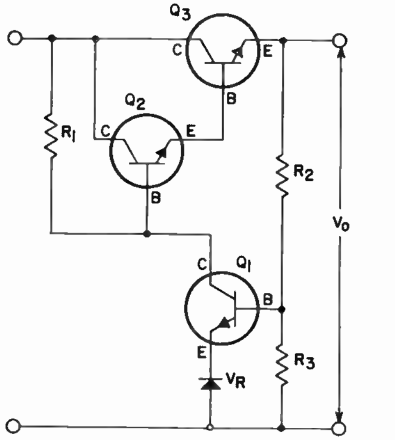
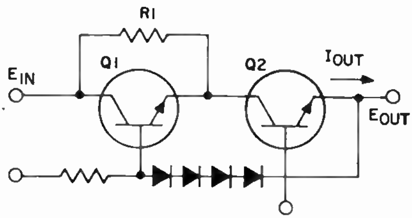



*Fig. 353—Typical series regulator circuit.*

amplifiers are used to amplify an error or difference signal obtained from a comparison between a portion of the output voltage and a reference source. The reference-voltage source $V_R$ is placed in the emitter circuit of the amplifier transistor $Q_1$ so that the error or difference signal between $V_R$ and some portion of the output voltage $V_o$ is developed and amplified. The amplified error signal forms the input to the regulating element consisting of transistors $Q_2$ and $Q_3$.

In many situations, a device for a high-voltage power supply is available with sufficient voltage capability but insufficient current dissipation or second-breakdown capability. The series-regulator circuit shown in Fig. 354 solves this problem by reducing the dissipation and current requirements in the high-voltage device $Q_1$.



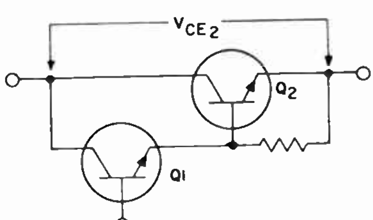

$$P_{Q1\,max} = P_{Q2\,max} = \frac{E_{max}\,I_{max}}{4}$$

$$R_1 = \frac{E_{IN\,(max)}}{I_{OUT\,(max)}}$$

*Fig. 354—Series-regulator circuit using series matching.*

In the circuit of Fig. 354, the maximum power dissipated in $Q_1$ or $Q_2$ is approximately one-fourth of the power that would be dissipated in a conventional series-pass stage. The balance of the power is dissipated in resistor $R_1$.

In many high-current applications including series regulators, a Darlington configuration is utilized to improve the current gain, as shown in Fig. 355. A serious limitation of this method, however, is the high power dissipated in the pass element because this device cannot reach saturation.




$$h_{FE\,(TOTAL)} = h_{FE_1} + h_{FE_2} + h_{FE_1} h_{FE_2}$$

$$V_{CE_2} = V_{CE_1} + V_{BE_2}$$

*Fig. 355—Darlington configuration.*

A typical automobile voltage-regulator circuit for an auto with a 12-volt system is shown in Fig. 356. Transistor $Q_2$ presents a variable resistance in series with the field. If the battery is fully charged and the electrical loading is small (e.g., only from the ignition circuit), the 10-volt zener diode breaks down, turning $Q_1$ on and $Q_2$ off (i.e., high resistance). The consequent reduction in field current reduces the armature voltage $E_A$ so that the

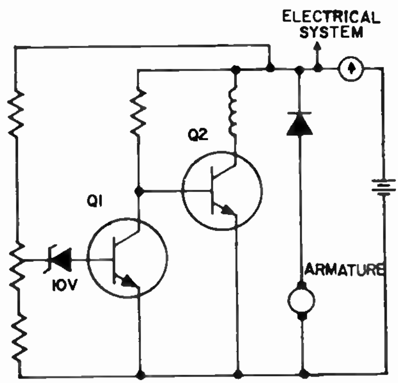



*Fig. 356—Typical automobile voltage-regulator circuit.*

battery supplies the load current. If the battery requires charging, or if the electrical load is heavy, then the lower terminal voltage is not sufficient to break down the zener. For this condition, $Q_1$ is off and $Q_2$ is on full (i.e., driven into saturation). As a result, field current is high, the armature voltage is high, and the alternator supplies current to the load and also charges the battery. Under normal operation, the transistor may be fully on, fully off, or somewhere in between (i.e., on but in the active region rather than in saturation). The actual transistor operating conditions depend on battery condition and electrical load.

**Shunt regulator circuits** are not as efficient as series regulator circuits for most applications, but they have the advantage of greater simplicity. In the shunt voltage regulator circuit shown in Fig. 357, the current through the shunt element consisting of transistors $Q_1$ and $Q_2$ varies with changes in the load current or the input voltage. This current variation is reflected across the resistance $R_1$ in series with the load so that the output voltage $V_0$ is maintained nearly constant.

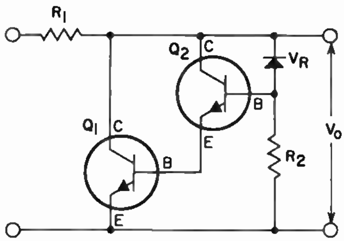



*Fig. 357—Typical shunt-regulator circuit.*

A third type of regulator, the switching regulator, was discussed previously in the section on Power Switching and Control. This type of voltage regulator is recommended for dc power-supply applications that require high efficiency, but only moderate regulation and noise immunity.

## SCR Regulated Power Supply

Fig. 358 shows the circuit configuration for a regulated dc power supply that uses an SCR as a series pass element. This type of circuit is designed to provide approximately 125 volts, regulated to ±3 per cent for both line and load. Ripple is less than 0.5 per cent rms.

The power supply is basically a half-wave phase-controlled rectifier. The capacitor $C_1$ between the cathode and gate of the SCR charges up during half of each cycle and is discharged by the firing of the SCR. The firing angle of the SCR is advanced or retarded by the charging current flowing into the capacitor $C_1$. Some of the current which would normally charge this capacitor is shunted by the collector of the control transistor $Q_1$. As the current in the control transistor increases, current is shunted around the capacitor, through the ballast lamp $I_1$, so that the capacitor charging time is increased. As a result, the firing angle of the SCR is retarded, and a lower output voltage results.

The controlling voltage on the control transistor is derived from both the dc output and from the line voltage in such a manner as to provide load and line regulation respectively. The voltage-dependent

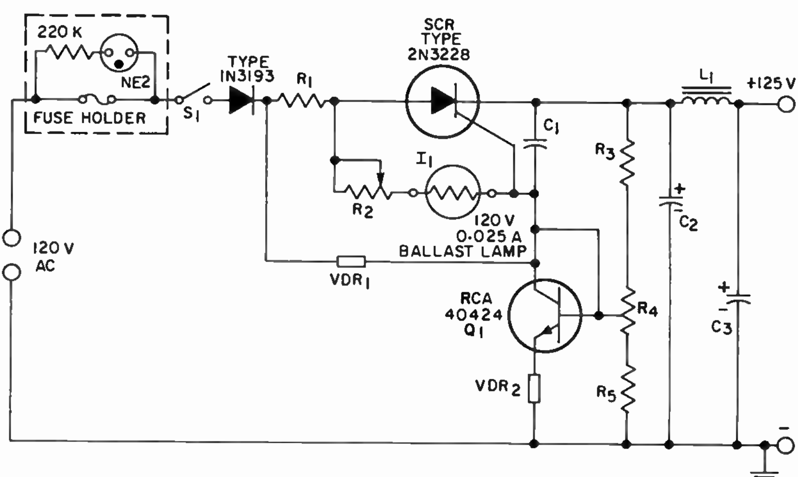



*Fig. 358—SCR regulated power supply.*

resistor ($VDR_2$) in the base circuit of the control transistor decreases resistance for an increase in line voltage and thus increases base current (and collector current) as line voltage is increased. In addition, the lamp $I_1$ exhibits an increase in resistance with increasing line voltage, and, thus, tends to retard the firing angle of the SCR. Changes in dc output voltage that result from variations in load current are fed back to the base of the control transistor by a voltage divider at the input to the filter in the proper polarity to adjust collector current in a direction to compensate for changes in dc output voltage.

# Testing and Mounting

This section covers the testing and installation suggestions which are generally applicable to all types of solid-state devices. Careful observance of these suggestions will help experimenters and technicians to obtain the best results from solid-state devices and circuits.

## TESTING

The ability to determine the condition of solid-state devices is an important requisite for servicemen, experimenters, and others who are required to operate and maintain electrical equipment that employs such devices. Although thorough, comprehensive evaluations of solid-state devices are hindered by the limited amount of commercially available test equipment, simple techniques and circuits can be readily devised to provide go/no-go type of indications or to measure significant characteristics of the devices. The following paragraphs outline various test methods, indicate some of the available test equipment, and describe simple test circuits that may be constructed for use in the test and evaluation of different types of solid-state devices.

### Bipolar Transistors

Fig. 359 shows a go/no-go test circuit for bipolar transistors. The connections shown are for an n-p-n transistor. When the base resistor is connected to the negative terminal of the battery, the lamp should go out. For p-n-p transistors, the same results should be obtained with the battery polarities reversed.

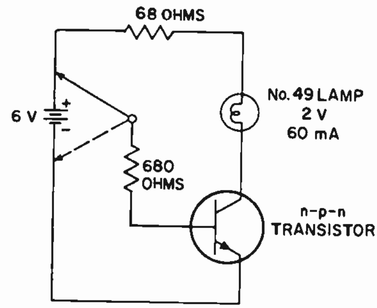



*Fig. 359—"Go/no-go" test circuit for bipolar transistors.*

A quick check of bipolar transistors can also be made prior to their installation in a circuit by resistance measurement with a conventional ohmmeter. The resistance between any two electrodes should be very high (more than 10,000 ohms) in one direction and considerably lower in the other direction (100 ohms or less between emitter and base or collector and base; about 1000 ohms between emitter and collector). It is very important to limit the voltage applied by the ohmmeter in such tests (particularly between emitter and base) so that the breakdown voltages of the transistor will not be exceeded; otherwise, the transistor may be damaged by excessive currents.

In addition to the test to determine open or shorted elements described above, any comprehensive evaluation of bipolar transistors must include measurements of the two most important transistor characteristics, beta and leakage. Commercial transistor testers are available to perform these measurements. Because there is no efficient substitute way to evaluate these characteristics, a transistor tester is a worthwhile instrument for use in the servicing of equipments that employ bipolar transistors.

The beta, or common-emitter forward-current transfer ratio ($h_{fe}$), of a bipolar transistor expresses the gain characteristics of the device. This characteristic can be determined by use of ac or dc test voltages.

Collector-to-base leakage ($I_{CBO}$), measured with the emitter open, is the critical leakage of both germanium and silicon transistors. However, these two basic transistor types can display wide differences in their leakage values and in levels of acceptability.

A transistor tester should measure leakage directly in milliamperes or microamperes.

**Transistor Tester Requirements**—The value of a transistor tester depends on its design and how it is used. For accurate measurements of a wide range of transistor types, the tester must incorporate several specific design features. The more important considerations are as follows:

1. The capability to measure beta at the collector-current level best suited to the transistor type or its application. This capability should extend to the handling of devices ranging from small-signal rf transistors that have nominal collector currents of a few milliamperes to high-power types that have ratings up to one ampere.

2. The facility to provide beta readings with an accuracy of ±5% both in and out of circuit. (It should be remembered, however, that beta is directly affected by the collector current.)

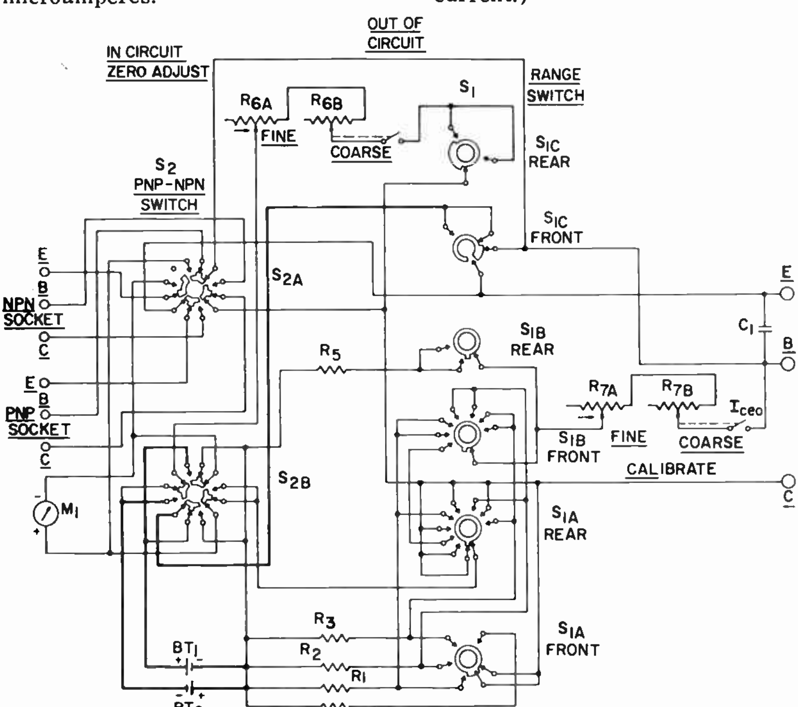



*Fig. 360—Circuit diagram for RCA WT-501A transistor tester.*

3. An adjustment which permits leakage currents to be "bucked out" before the beta measurement is made; otherwise, the beta reading may be upset by the leakage current. In the case of high-leakage germanium power transistors, the resultant beta reading may be significantly inaccurate. This rule applies to both in-circuit and out-of-circuit tests.

4. Means for calibrating the beta test for each transistor tested.

5. A facility for reading leakage current directly in values as low as one microampere.

The considerations listed above define the primary requirements of a good transistor tester. Other features are desirable, of course, to make the tester completely reliable and easy to use.

**Transistor Tester**—All of the necessary and desirable features have been included in the RCA WT-501A Transistor Tester, a measurement instrument that combines service speed and simplicity with laboratory-measurement qualities. Fig. 360 shows the overall schematic and Fig. 361 shows a photograph of the WT-501A transistor tester. This tester is designed to measure transistor collector-to-base leakage ($I_{CBO}$), collector-to-emitter leakage ($I_{CEO}$), and dc beta. Collector current ($I_C$) is continuously adjustable up to 1 ampere in four ranges. The WT-501A can also be used for in-circuit beta tests of a transistor.

A 100-microampere meter movement is used in the measuring circuits for the various test functions. Precision resistors are used to assure accurate test results.

An N-P-N/P-N-P switch provides the proper bias polarity to the transistor. Two dual potentiometers provide coarse and fine adjustment of collector current (CAL) and in-circuit zero.

The instrument has two internal 1.5-volt "D"-size batteries. One battery is used in n-p-n tests and the other is used in p-n-p tests. The batteries are also used during in-circuit tests to provide voltage in reverse polarity to cancel the effect of circuit leakage.

*Fig. 361—RCA WT-501A transistor tester.*

**Beta-measuring circuit:** A simplified diagram of the dc-beta test circuit is shown in Fig. 362. Resistors $R_b$ and $R_c$ serve both to establish

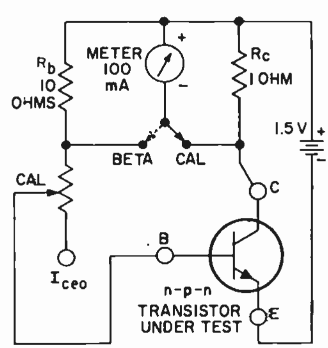



*Fig. 362—Simplified beta-measuring circuit for 0-to-100-milliampere range.*

the collector current, and to shunt the meter to the required sensitivity. Values for $R_b$ and $R_c$ are as follows:

| Range | $R_b$ | $R_c$ |
|---|---|---|
| 1 mA | 1000 ohms | 110 ohms |
| 10 mA | 110 ohms | 10 ohms |
| 100 mA | 10 ohms | 1 ohm |
| 1 A | 1 ohm | 0.1 ohm |

When the range switch is set to the CAL function, the meter is in the collector circuit. Collector current is determined by the value of the collector resistor for the particular range, and by the setting of the CAL control.

In the BETA function, the meter is switched to the base circuit. DC beta is defined as the ratio of the steady-state collector current to the base current. Because the collector current is established at a known value by the CAL adjustment, the base-current meter reading can be interpreted in terms of dc beta for the transistor.

**$I_{CBO}$ measuring circuit:** $I_{CBO}$ is the current flow, or leakage, from the collector to the base with the emitter open. As shown in Fig. 363 1.5 volts is applied to the collector and base of the transistor, and the meter is connected in the collector circuit. Collector-to-base leakage is indicated directly in microamperes.

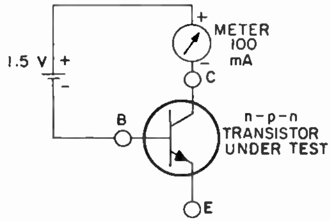



*Fig. 363—Simplified $I_{CBO}$ test circuit.*

**$I_{CEO}$ measuring circuit:** $I_{CEO}$ represents the leakage from collector to emitter, with the base open. Fig. 364 shows a simplified diagram of the $I_{CEO}$ test circuit. A voltage of 1.5 volts is applied to the transistor, and the meter is connected in the collector circuit. The resistor shunting the meter reduces the meter sensitivity to 10 milliamperes.

Measurement of $I_{CEO}$ is normally made on the CAL position of the 1-milliampere range. If $I_{CEO}$ exceeds 1 milliampere, however, the range switch can be set to the 10-milliampere or 100-milliampere range as necessary. Collector-to-emitter leakage is indicated in milliamperes, depending on the current range that is used.

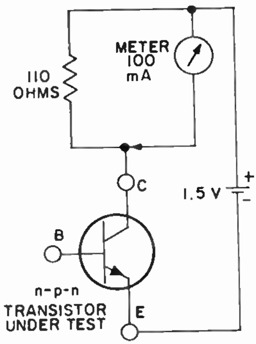



*Fig. 364—Simplified $I_{CEO}$ test circuit for 1-milliampere range.*

**In-circuit beta test:** The test circuit used to measure in-circuit current gain is similar to that used for out-of-circuit beta measurement. As shown in Fig. 365, the IN-CIRCUIT ZERO ADJUST control applies a voltage of reverse polarity

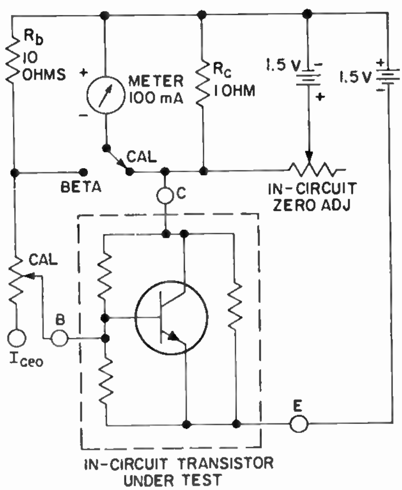



*Fig. 365—Simplified in-circuit beta test circuit for 0-to-100-milliampere range.*

to the collector metering circuit. This voltage compensates for the collector-to-emitter leakage through the components in the circuit under test, and permits the meter to be set to zero.

The CAL adjustment and the metering circuit are the same as for out-of-circuit measurement.

The resistance of the measuring circuit is low in value so that no significant loading effect occurs from the circuit being tested.

## MOS Transistors

In the servicing of electrical equipment that employs MOS transistors, it is readily determined that the test techniques required to measure the characteristics of these devices are not the same as those used for bipolar transistors. An entirely new set of techniques, aimed specifically at the unique properties of MOS transistors, is required. Simple go/no-go types of test circuits, however, may still be used for detection of open or shorted devices.

The test circuit shown in Fig. 366 can be used to test n-channel depletion or p-channel enhancement MOS transistors for opens or shorts. The substrate and source of the device being tested should be connected to terminal No. 1, the gate should be connected to terminal 2, and the drain should be connected to terminal No. 3. If the MOS transistor is a dual-gate type, the gates are tested separately. For n-channel depletion types, if the lamp lights when the switch is open and does not light when the switch is closed, the transistor is good. If the lamp lights with the switch in either position, the transistor is shorted. If the lamp remains off with the switch in either position, the transistor is open. For p-channel enhancement types, the reverse indications are obtained.

In the section of this Manual on MOS Field-Effect Transistors, the susceptibility of these devices to

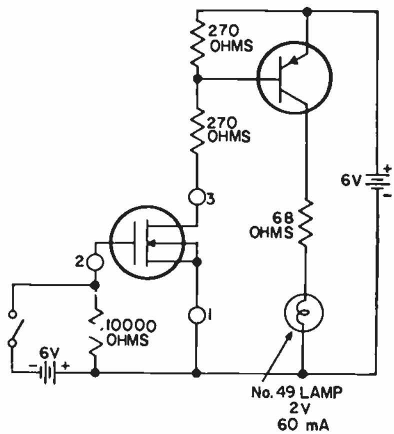



*Fig. 366—"Go/no-go" test circuit for MOS transistors.*

possible damage from the discharge of electrostatic charges was pointed out. Integral gate-protection systems used in certain types of dual-gate devices are very effective in guarding against the effects of electrostatic charges. The following special precautions, however, are necessary in handling MOS-transistors which do not contain integral-gate protection systems:

1. Prior to assembly into a circuit, all leads should be kept shorted together by either (a) use of metal shorting springs attached to the device by the vendor, as shown in Fig. 367, or (b) use of conductive foam such as "ECCOSORB LS26" or equivalent. (ECCOSORB is a Trade Mark of Emerson & Cuming, Inc.). Note: Polystyrene insulating "SNOW" can acquire high static charges and should not be used.
2. When devices are removed by hand from their carriers, the hand being used should be at ground potential. Personnel handling MOS transistors during testing should ground themselves, preferably at the hand or wrist.
3. Tips of soldering irons should be grounded.

4. Devices should never be inserted into or removed from circuits with power on.

*Fig. 367—Illustration shows shorting spring for RCA MOS field-effect transistors that do not contain the integral gate protection. (Spring should not be removed until after the device is soldered into circuit.)*

## Silicon Rectifiers

In general, silicon rectifiers and most other types of solid-state diodes can be adequately tested by resistance measurements with a conventional ohmmeter (For procedures used in the testing of tunnel diodes, refer to RCA Tunnel Diodes, Technical Manual TD-30.) Resistance measurements are taken in both the forward and reverse directions. The ratio of the "reverse" resistance reading to the "forward" resistance reading should be greater than 10 to 1. For the forward-direction measurement, it is important to assure that the forward-voltage rating of the rectifier is greater than the voltage applied by the ohmmeter (the battery voltage of a conventional ohmmeter is 1.5 volts); otherwise, the rectifier may be damaged by excessive current. The front-to-back ratio of rectifiers can also be checked at various current levels with the RCA WT-501A Transistor Tester described in the paragraph on testing of Bipolar Transistors.

There are a number of easily constructed go/no-go types of test circuits that may be used to detect open or shorted rectifiers. Several of these test circuits are shown in the following paragraphs.

Fig. 368 shows a simple "go/no-go" test circuit for silicon rectifiers operating at 120 volts. With the connection shown, the lamp operates at half-power. When the switch is closed, the lamp should brighten if the diode under test is good. If there is no change in brightness when the switch is closed, the lamp was burning at full power with the switch open; in this case, the diode is shorted. If the lamp is out with the switch open but lights when the switch is closed, the diode is open.

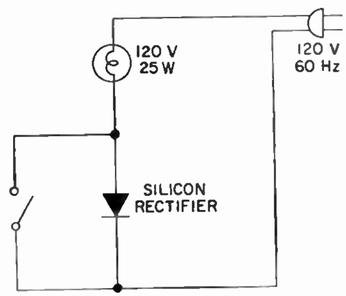



*Fig. 368—"Go/no-go" test circuit for high-voltage silicon rectifiers.*

Fig. 369 shows a "go/no-go" tester for all silicon rectifiers in this Manual that operate at low voltages

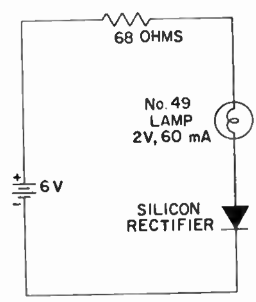



*Fig. 369—"Go/no-go" test circuit for low-voltage silicon rectifiers excluding types 134A and 1N270.*

except the 1N34A and 1N270. The test circuit for these two types is shown in Fig. 370.

With a diode connected as shown in Fig. 369 and with the polarity of the battery as shown, the lamp should light; when the polarity of the battery is reversed, the lamp should not light. If the lamp lights regardless of the polarity of the battery, the diode is shorted; if the lamp does not light with either polarity, the diode is open.

When the anode of a 1N34A or 1N270 diode is connected to terminal No. 1 in Fig. 370, the lamp should light if the diode is good; when the anode is connected to terminal No. 3 the light should go off. If the light remains lit regardless of the connection, the diode is shorted; if the light is off regardless of the connection, the diode is open.

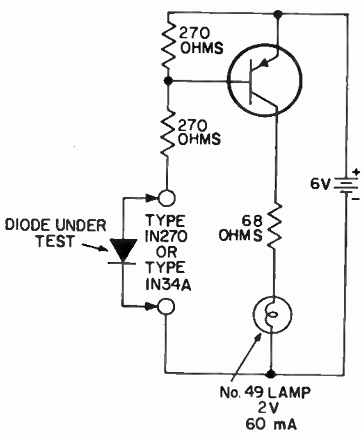



*Fig. 370—"Go/no-go" test circuit for silicon rectifier types 1N34A and 1N270.*

## SCR's and Triacs

Similar test procedures and circuits may be used for testing SCR's and triacs. The triac, however, should be tested for operation in all four operating modes. For convenience of illustration, the test circuits described show only SCR's. Triacs tested in these circuits should be connected in one direction and then reversed for each test. In addition, the triacs should be tested for both negative and positive gate signals for each direction in which they are connected.

Fig. 371 shows a go/no-go type of test circuit that can be used to test thyristors that operate directly from the line voltage. When the

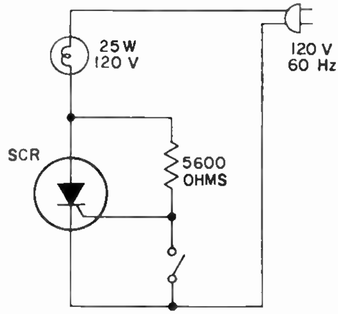



*Fig. 371—Simple test circuit for SCR's.*

switch is closed, a current of approximately 20 milliamperes flows through the 25-watt lamp, the 5600-ohm resistor, and the switch; this amount of current is not enough to light the lamp. When the switch is opened, the light should brighten to approximately half maximum brightness. Under these conditions, the SCR should be triggered into operation (shunting the 5600-ohm resistor) on each positive half-cycle of input by the 20-milliampere current flowing in the gate-cathode circuit. If the lamp lights to full brightness, the SCR is shorted. If the lamp does not brighten regardless of the position of the switch, the SCR is open.

Fig. 372 shows a simple, inexpensive test circuit that may be used to evaluate the OFF-state voltage capabilities of thyristors,

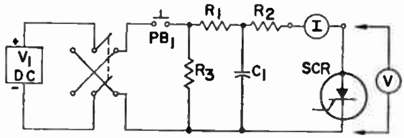



*Fig. 372—Test circuit used to determine dc forward- and reverse-voltage-blocking capabilities and leakage current of thyristors.*

and for reverse-blocking (SCR's) and leakage tests. Resistor $R_1$ and capacitor $C_1$ are included in the test circuit to limit the rate of rise of applied voltage to the thyristor under test. Resistor $R_2$ limits the discharge of capacitor $C_1$ through the thyristor in the event that the thyristor is turned on during the test. Resistor $R_3$ provides a discharge path for capacitor $C_1$.

Fig. 373 shows a simple test circuit that may be used to determine the holding and latching currents of thyristors. For the holding-current tests, the value of potentiometer $R_1$ is adjusted to approximately 50 ohms, and the spring-loaded push-button switch $PB_1$ is momentarily depressed to turn on the thyristor. The value of $R_1$ is

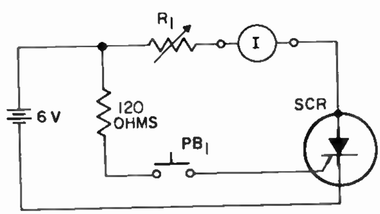



*Fig. 373—Test circuit used to determine holding and latching currents of thyristors.*

then gradually increased to the point at which the thyristor turns off.

For the latching-current test, the value of potentiometer $R_1$ is initially adjusted so that the main-terminal current is less than the holding level. The value of $R_1$ is then decreased, as push-button switch $PB_1$ is alternately depressed and released, until the thyristor latches on.

Fig. 374(a) shows a simple test circuit that may be used to determine the dv/dt capability of a thyristor. The curves in Fig. 374(b) define the critical values for linear and exponential rates of increase in reapplied forward OFF-state voltage for an SCR. The critical value for the exponential rate of rise of forward voltage is the rating given

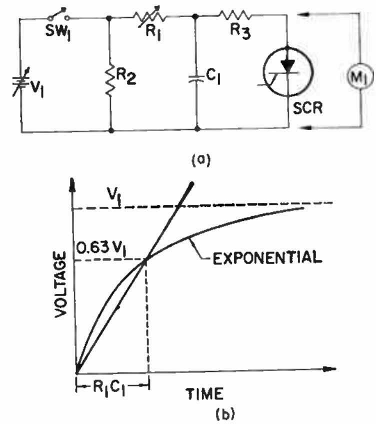



*Fig. 374—Test circuit and waveforms used to determine dv/dt capability of a thyristor.*

in the manufacturer's test specifications. This rating is determined from the following equation:

$$\frac{dv}{dt} = \frac{\text{rated value of thyristor voltage } (V_{BO})}{\text{RC time constant}} \times 0.632$$

Fig. 375 shows a simple test circuit used to determine turn-on times of thyristors. The value of resistor $R_1$ is chosen so that the rated value

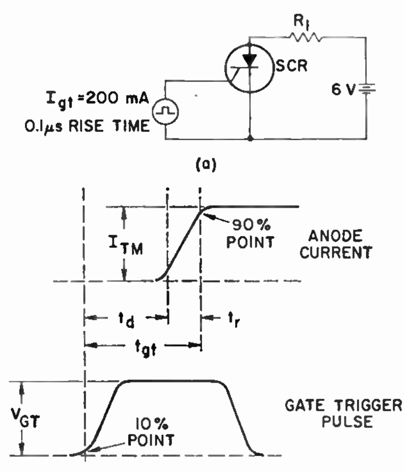



*Fig. 375—Test circuit and waveforms used to determine turn-on time of thyristors.*

of current flows through the thyristor. Turn-on time is specified by the thyristor manufacturer at the rated blocking voltage. It is defined (for resistive loads) as the time interval between 10 per cent of the gate voltage and the period required for the current to rise to 90 per cent of its maximum value.

Fig. 376 shows a simple test circuit used to measure turn-off time. The circuit subjects the thyristor to current and voltage waveforms similar to those encountered in most typical applications. In the circuit diagram, $SCR_1$ is the device under test. Initially, both SCR's are in the OFF-state; push-button switch $SW_1$ is momentarily closed to start the test. This action turns on $SCR_1$ and load current flows through this SCR and resistor $R_2$. Capacitor $C_1$ charges through resistor $R_3$ to the voltage developed across $R_2$. If the second push-button switch $SW_2$ is then closed, $SCR_2$ is turned on.

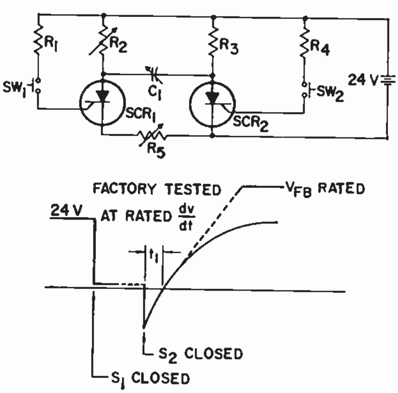



*Fig. 376—Test circuit and voltage waveforms used to determine turn-off times of thyristors.*

$SCR_1$ is then reverse-biased by the voltage across capacitor $C_1$. The discharge of this capacitor causes a short pulse of reverse current to flow through $SCR_1$ until this device recovers its reverse-blocking capability. At some time $t_1$, the anode-to-cathode voltage of $SCR_1$ passes through zero and starts to build up in a forward direction at a rate dependent upon the time constant of $C_1$ and $R_2$. The peak value of the reverse current during the recovery period can be controlled by adjustment of potentiometer $R_5$. If the turn-off time of $SCR_1$ is less than the time $t_1$, the device will turn off. The turn-off interval $t_1$ can be measured by observation of the anode-to-cathode voltage of $SCR_1$ with a high-speed oscilloscope. A typical waveform is shown in Fig. 376.

The gate voltage and current required to switch a thyristor to its low-impedance state at maximum rated forward anode current can be determined from the circuit shown in Fig. 377. The value of

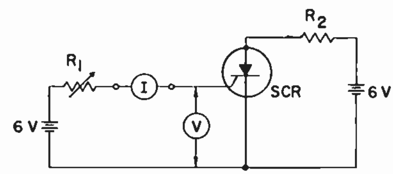



*Fig. 377—Test circuit used to determine gate-trigger-pulse requirements of thyristors.*

resistor $R_2$ is chosen so that maximum anode current, as specified in the manufacturer's current rating, flows when the device latches into its low-impedance state. The value of resistor $R_1$ is gradually decreased until the device under test is switched from its high-impedance state to its low-impedance state. The values of gate current and gate voltage immediately prior to switching are the gate voltage and current required to trigger the thyristor.

## HEAT-SINK REQUIREMENTS

All solid-state devices are temperature-sensitive, some to a greater degree than others. As a result, the device temperature or power dissipation must be kept below the maximum specified rating either by limiting the input power requirements to maintain a limited power dissipation or by providing some external means of removing the excess heat generated during normal operation. Generally, low-power semiconductor devices have sufficient mass and heat-dissipation area to conduct away the detrimental heat energy formed at their semiconductor junctions. For higher-power devices, such as power transistors, thyristors, and silicon rectifiers, however, a heat sink must be used.

Under steady-state conditions, the maximum dissipation capability of a solid-state device that has a heat sink attached depends on the sum of (a) the series thermal resistances from the semiconductor junction to the ambient, (b) the maximum junction temperature, and (c) the ambient temepration at which the device is operated. The total thermal resistance of the device from junction to ambient $\theta_{J-A}$ can be expressed as follows:

$$\theta_{J-A} = \theta_{J-C} + \theta_{C-S} + \theta_{S-A}$$

where $\theta_{J-C}$ is the thermal resistance from the semiconductor junction to the case of the device, $\theta_{C-S}$ is the thermal resistance between the device case and the surface of the heat sink, and $\theta_{S-A}$ is the thermal resistance of the heat sink (from its surface to the ambient air).

The maximum dissipation capability of a solid-state device $P_D(max)$ with a heat sink attached is given by

$$P_D(max) = \frac{T_J(max) - T(amb)}{\theta_{J-C} + \theta_{C-S} + \theta_{S-A}}$$

where $T_J(max)$ is the maximum junction temperature obtained from the manufacturer's data and T(amb) is the ambient temperature.

Discrete heat sinks are sold commercially in various size, shapes, colors, and materials. It is also common practice to use the chassis of the unit as a heat sink. In any case, the heat-dissipation capability of the heat sink is based on its thermal resistance $\theta_{S-A}$. The thermal-resistance value of the heat sink should be small enough to obtain a power-dissipation capability, as expressed in the above equation, that exceeds the power-dissipation rating of the semiconductor device. For high-power devices, the interface thermal resistance $\theta_{C-S}$ between the semiconductor case and the surface of the heat sink can be maintained at a low value (1 to 2°C per watt) by use of epoxy glue or silicone grease.

Fig. 378 shows a useful nomograph for obtaining the physical dimensions of a heat sink as a function of its thermal resistance. The data in this nomograph pertain to a heat sink that cools by convection and radiation and that is of natural bright finish of copper or aluminum. The heat-sink area is selected from the left-hand column and a line is drawn horizontally from this point. The value of thermal resistance $\theta_{S-A}$ is read directly from the graph, depending on the type and thickness of the heat-sink material and the mounting position of the heat sink, either horizontal or vertical, with respect to the mounting board.

## TRANSISTOR MOUNTING

The collector, base, and emitter terminals of transistors can be connected to associated circuit elements by means of sockets, clips, or solder connections to the leads or pins. If connections are soldered close to the lead or pin seals, care must be taken to conduct excessive heat away from the seals, otherwise the heat of the soldering operation may crack the glass seals and damage the transistor. When dip soldering is employed in the assembly of printed circuits using transistors, the temperature of the solder should be limited to about 225 to 250°C for a maximum immersion period of 10 seconds. Furthermore, the leads

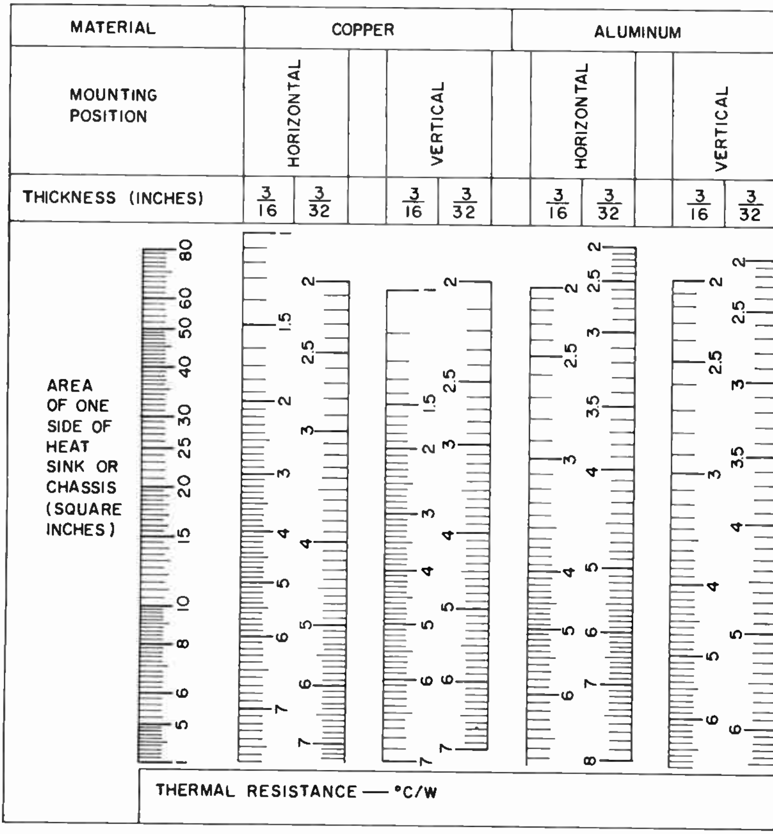


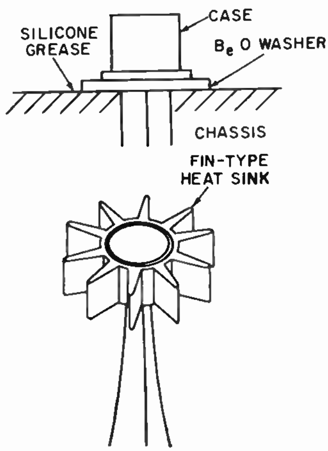

*Fig. 378—Thermal resistance as a function of heat-sink dimensions (Nomograph reprinted from ELECTRONIC DESIGN, Aug. 16, 1961).*

should not be dip-soldered too close to the transistor case. Under no circumstances should the mounting flange of a transistor be soldered to a heat sink because the heat of the soldering operation may permanently damage the transistor.

## Metal-Package Types

In some transistors, the collector electrode is connected internally to the metal case to improve heat-dissipation capabilities. More efficient cooling of the collector junction in these transistors can be accomplished by connection of the case to a heat sink. Direct connection of the case to a metal surface is practical only when a grounded-collector circuit is used. For other configurations, the collector is electrically isolated from the chassis or heat sink by means of an insulator that has good thermal conductivity. Suggested mounting arrangement for RCA transistors supplied in hermetically sealed metal packages are shown in detail in the section on Mounting Hardware.

For small general-purpose transistors, such as the 2N2102, which use a JEDEC TO-5 package, a good thermal method of isolating the collector from a metal chassis or printed circuit board is by means of a beryllium oxide washer. The use of a zinc-oxide-filled silicone compound between the washer and the chassis, together with a moderate amount of pressure from the top of the transistor, helps to improve thermal dissipation. An alternate method is the use of a fin-type heat sink. Fig. 379 illustrates both types of mounting. Fin-type heat sinks are especially suitable when transistors are mounted in Teflon sockets which




(a)

*Fig. 379—Suggested mounting arrangements for transistors in JEDEC TO-5 package.*

provide no thermal conduction to the chassis or printed circuit board.

For power transistors which use a JEDEC TO-3 package, such as the 2N3055, it is recommended that a 0.002-inch mica insulator or an anodized aluminum insulator having high thermal conductivity be used between the transistor base and the heat sink or chassis. The insulator should extend beyond the mounting clamp, as shown in Fig. 380. It should be drilled or punched to provide both the two mounting holes and the clerance holes for the emitter and base pins. Burrs should be removed from both the insulator and the holes in the chassis so that the insulating layer will not be destroyed during mounting. It is also recommended that an insulating washer be used between the mounting screws and the chassis, as shown in Fig. 380, to prevent a short circuit between them.

For large power transistors, such as the 2N2876, which use a double-ended stud package, connection to the chassis or heat sink should be made at the flat surface of the transistor perpendicular to the threaded stud. A large mating surface should be provided to avoid hot spots and high thermal drop. The hole for the stud should be only as large as necessary for clearance, and should contain no burrs or ridges on its perimeter. As mentioned above, the use of a silicon grease between the heat sink and the transistor improves thermal contact. The transistor can be screwed directly into the heat sink or can be fastened by means of a nut. In either case, care must be taken to avoid the application of too much torque lest the transistor semiconductor junction be damaged. Although the studs are made of relatively soft copper to provide high thermal conductivity, the threads should not be relied upon to provide a mating surface. The actual heat transfer must take place on the

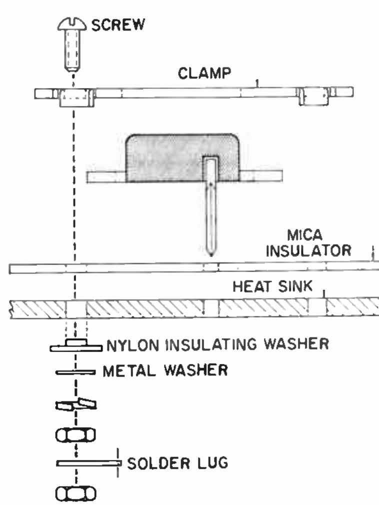



*Fig. 380—Suggested mounting arrangement for transistors in JEDEC TO-3 package.*

underside of the hexagonal part of the package.

The use of an external resistance in the emitter or collector circuit of a transistor is an effective deterrent to damage which might be caused by thermal runaway. The minimum value of this resistance for low-level stages may be obtained from the following equation:

$$R_{min} = \frac{E^2}{4\left(P_0 + \frac{25}{\theta_{J\text{-}A}}\right)}$$

where E is the dc collector supply voltage in volts, $P_0$ is the product of the collector-to-emitter voltage and the collector current at the desired operating point in watts, and $\theta_{J\text{-}A}$ is the thermal resistance of the transistor and heat sink in degrees centigrade per watt ($\theta_{J\text{-}C} + \theta_{C\text{-}S} + \theta_{S\text{-}A}$).

## Plastic-Package Types

RCA transistors are also available in two basic types of molded-silicone-plastic packages, which are supplied in a wide range of power-dissipation ratings and a variety of package configurations to assure flexibility of application. These types include the RCA Versawatt packages for medium-power applications and the RCA high-power plastic packages. Each basic type offers several different package options, and the user can select the configuration best suited to his particular application.

Fig. 381 shows the options currently available for RCA Versawatt packages. The JEDEC Type TO-220AB in-line-lead version, shown in Fig. 381(a), represents the basic style. This package features leads that can be formed to meet a variety of specific mounting requirements. Fig. 381(b) shows a modification of the basic type that allows a Versawatt package to be mounted on a printed-circuit board with a 0.100-inch grid spacing and a minimum lead spacing of 0.200 inch. Fig. 381(c) shows a JEDEC Type TO-220AA version of the Versawatt package. The dimensions of this type of transistor package are such that it can replace the JEDEC TO-66 transistor package in a commercial socket or printed-circuit board without retooling. The TO-220AA Versawatt package is also supplied with an integral heat sink.

The RCA molded-plastic high-power packages are also supplied in several configurations, as shown

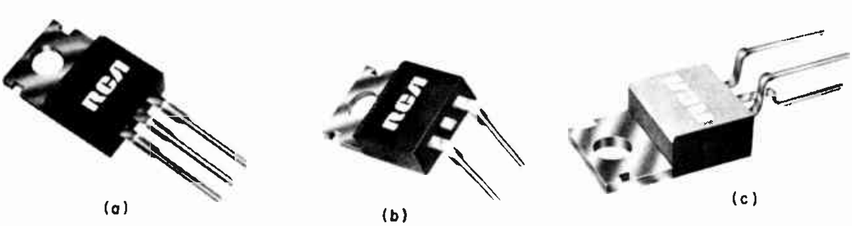
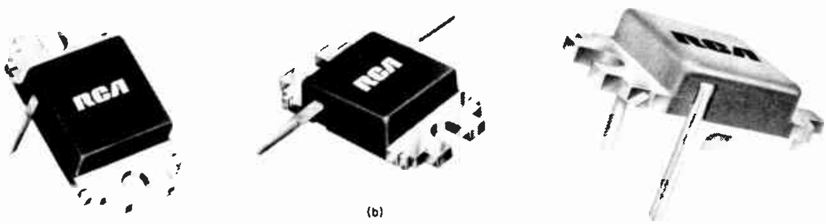



*Fig. 381—RCA Versawatt transistor packages: (a) JEDEC No. TO-220AB in-line-lead version; (b) configuration designed for mounting on printed-circuit boards; (c) JEDEC No. TO-220AA version, which may be used as a replacement for JEDEC No. TO-66 metal packages.*



(a) (b) (c)

*Fig. 382—RCA high-power plastic transistor packages: (a) JEDEC No. TO-219AB version, which represents the basic configuration; (b) JEDEC No. TO-219AA version, which may be used as a replacement for JEDEC TO-3 metal packages; (c) configuration designed for mounting on printed-circuit boards.*

in Fig. 382. The JEDEC Type TO-219AB, shown in Fig. 382(a), is the basic high-power plastic package. Fig. 382(b) shows a JEDEC Type TO-219AA version of the high-power plastic package. With the addition of an NR193B top clamp, the TO-219AA package can be used as a direct replacement for the hermetically sealed JEDEC TO-3 package. The RCA high-power plastic package is also available with an attached header-case lead, as shown in Fig. 382(c). This three-lead package is designed for mounting on a printed-circuit board.

Recommended mounting arrangements and suggested hardware for the Versawatt transistors are shown in the section on **Mounting Hardware.** The rectangular washer (NR231A) used in the mounting of these devices is designed to minimize distortion of the mounting flange when the transistor is fastened to a heat sink. Excessive distortion of the flange could cause damage to the transistor. The washer is particularly important when the size of the mounting hole exceeds 0.140 inch (6-32 clearance). Larger holes are needed to accommodate insulating bushings; however, the holes should not be larger than necessary to provide hardware clearance and, in any case, should not exceed a diameter of 0.250 inch. Flange distortion is also possible if excessive torque is used during mounting. A maximum torque of 8 inch-pounds is specified. Care should be exercised to assure that the tool used to drive the mounting screw never comes in contact with the plastic body during the driving operation. Such contact can result in damage to the plastic body and internal device connections. An excellent method of avoiding this problem is to use a spacer or combination spacer-isolating bushing which raises the screw head or nut above the top surface of the plastic body. The material used for such a spacer or spacer-isolating bushing should, of course, be carefully selected to avoid "cold flow" and consequent reduction in mounting force. Suggested materials for these bushings are diallphthalate, fiberglass-filled nylon, or fiberglass-filled polycarbonate. Unfilled nylon should be avoided.

Modification of the flange can also result in flange distortion and should not be attempted. The transistor should not be soldered to the heat sink by use of lead-tin solder because the heat required with this type of solder will cause the junction temperature of the transistor to become excessive.

The TO-220AA plastic transistor can be mounted in commercially available TO-66 sockets, such as UID Electronics Corp. Socket No. PTS-4 or equivalent. For testing purposes, the TO-220AB in-line package can be mounted in a Jetron Socket No. CD74-104 or equivalent.

The recommended hardware and mounting arrangements for RCA high-power molded-plastic transistors are also shown in the section on Mounting Hardware. These types can be mounted directly in a socket such as the Industrial Hardware Corporation No. LST-1702-1 (or equivalent) or they can be mounted in a standard TO-3 socket with the NR193B clamp. The precautions given for the Versawatt packages should also be followed in the mounting of the high-power molded-plastic packages.

The maximum allowable power dissipation in a solid-state device is limited by its junction temperature. An important factor to assure that the junction temperature remains below the specified maximum value is the ability of the associated thermal circuit to conduct heat away from the device.

When a solid-state device is operated in free air, without a heat sink, the steady-state thermal circuit is defined by the junction-to-free-air thermal resistance given in the published data on the device. Thermal considerations require that there be a free flow of air around the device and that the power dissipation be maintained below that which would cause the junction temperature to rise above the maximum rating. When the device is mounted on a heat sink, however, care must be taken to assure that all portions of the thermal circuit are considered.

Operation of the transistor with heat-sink temperatures of 100°C or greater results in some shrinkage of the insulating bushing normally used to mount power transistors. The degradation of contact thermal resistance is usually less than 25 per cent if a good thermal compound is used. (A more detailed discussion of thermal resistance can be found in the RCA Power Circuits Manual, Technical Series SP-51.)

During the mounting of RCA molded-plastic solid-state power devices, the following special precautions should be taken to assure efficient heat transfer from case to heat sink:

1. Mounting torque should be between 4 and 8 inch-pounds.
2. The mounting holes should be kept as small as possible.
3. Holes should be drilled or punched clean with no burrs or ridges, and chamfered to a maximum radius of 0.010 inch.
4. The mounting surface should be flat within 0.002 inch/inch.
5. Thermal grease (Dow Corning 340 or equivalent) should always be used (on both sides of the insulating washer if one is employed).
6. Thin insulating washers should be used (thickness of factory-supplied mica washers ranges from 2 to 4 mils).
7. A lock washer or torque washer should be used, together with materials that have sufficient creep strength to prevent degradation of heat-sink efficiency during life.

A wide variety of solvents is available for degreasing and flux removal. The usual practice is to submerge components in a solvent bath for a specified time. From a reliability standpoint, however, it is extremely important that the solvent, together with other chemicals in the solder-cleaning system (such as flux and solder covers), not adversely affect the life of the component. This consideration applies to all nonhermetic and molded-plastic components.

It is, of course, impractical to evaluate the effect on long-term transistor life of all cleaning solvents, which are marketed under a variety of brand names with numerous additives. Chlorinated solvents, gasoline, and other hydrocarbons cause the inner encapsulant to swell and damage the transistor. Alcohols are acceptable solvents and are recommended for flux removal whenever possible. Several examples of suitable alcohols are listed below:

1. methanol
2. ethanol
3. isopropanol
4. blends of the above

When considerations such as solvent flammability are of concern, selected Freon-alcohol blends are usable when exposure is limited. Solvents such as those listed below should be safe when used for normal flux removal operations, but care should be taken to assure their suitability in the cleaning procedure:

1. Freon TE
2. Freon TE-35
3. Freon TP-35 (Freon PC)

These solvents may be used for a maximum of 4 hours at 25°C or for a maximum of 1 hour at 50°C.

Care must also be used in the selection of fluxes in the soldering of leads. Rosin or activated-rosin fluxes are recommended; organic fluxes are not.

## THYRISTOR MOUNTING

For most efficient heat sinks, intimate contact should exist between the heat sink and at least one-half of the package base. The thyristor package can be mounted on the heat sink mechanically, with glue or epoxy adhesive, or by soldering. The JEDEC TO-48, TO-66, and stud-mounted packages are mounted mechanically. In these cases, silicone grease should be used between the device and the heat sink to eliminate surface voids, prevent insulation build-up due to oxidation, and help conduct heat across the interface. Although glue or epoxy adhesive provides good bonding, a significant amount of resistance may exist at the interface. To minimize this interface resistance, an adhesive material with low thermal resistance, such as Hysol* Epoxy Patch Material No. 6C or Wakefield* Delta Bond No. 152, or their equivalent, should be used.

Fig. 383 shows the special press-fit package used for some SCR's and triacs. Press-fit mounting depends upon an interference fit between the


*Fig. 383—Press-fit package.*

thyristor case and the heat sink. As the thyristor is forced into the heat-sink hole, metal from the heat sink flows into the knurl voids of the thyristor case. The resulting close contact between the heat sink and thyristor case assures low thermal resistances.

A recommended mounting method, shown in Fig. 384, shows press-fit knurl and heat-sink hole dimensions. If these dimensions are maintained, a "worst-case" condition of 0.0085 inch interference fit will allow press-fit insertion below the maximum allowable insertion force of 800 pounds. A slight chamfer in the heat-sink hole will help center and guide the press-fit package properly into the heat sink. The insertion tool should be a hollow shaft having an inner diameter of 0.380 ± 0.010 inch and an outer diameter of 0.500 inch. These dimensions provide sufficient clearance for the leads and assure that no direct force is applied to the glass seal of the thyristor.

* Products of Hyson Corporation, Olean, New York, and Wakefield Engineering, Inc., Wakefield, Massachusetts, respectively.

The press-fit package is not restricted to a single mounting arrangement; direct soldering and the use of epoxy adhesives have been successfully employed. The press-fit case is tin-plated to facilitate direct soldering to the heat sink. A 60-40 solder should be used, and heat should only be applied long enough to allow the solder to flow freely.

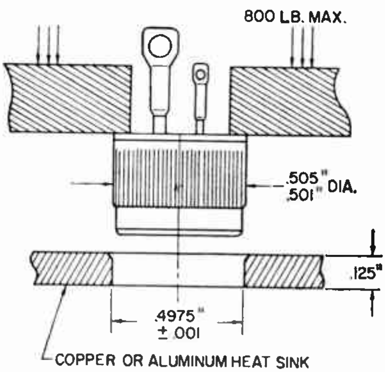



*Fig. 384—Suggested mounting arrangement for press-fit types.*

For the JEDEC TO-5, TO-8, and low-profile packages, shown in Fig. 385, soldering of the thyristor to the heat sink is preferable because it is most efficient. Not only is the bond permanent, but the thermal resistance $\theta_{C-S}$ from the thyristor case to the heat sink is easily kept below 1°C per watt under normal soldering conditions. Oven or hot-plate batch-soldering techniques are recommended because of their low cost. The use of a self-jigging arrangement of the thyristor and the heat sink and a 60-40 solder preform is recommended. If each unit is soldered individually with a flame or electric soldering iron, the heat source should be held on the heat sink and the solder on the unit. Heat should be applied only long enough to permit solder to flow freely. Because RCA thyristors are tin-plated, maximum solder wetting is easily obtainable without thyristor overheating.

The special high-conductivity leads on the two-lead TO-5 package permit operation of the thyristor at current levels that would be considered excessive for an ordinary TO-5 package. The special leads can be bent into almost any configuration to fit any monting requirement; however, they are not intended to

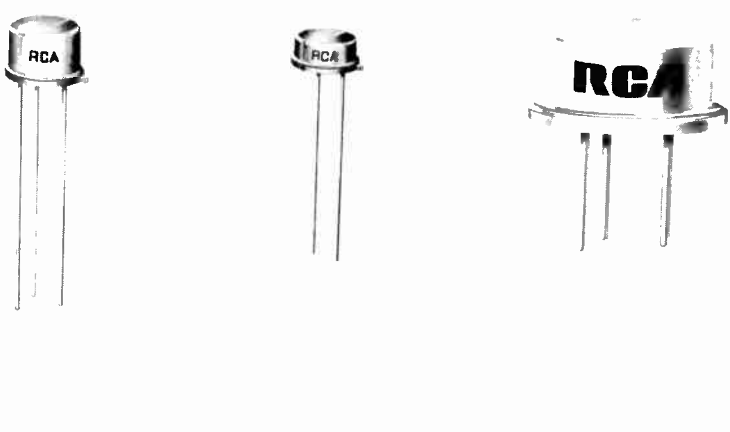



*Fig. 385—JEDEC TO-5, TO-8, and low-profile packages.*

take repeated bending and unbending. In particular, repeated bending at the glass should be avoided. The leads are not especially brittle at this point, but the glass has a sharp edge which produces an excessively small radius of curvature in a bend made at the glass. Repeated bending with a small radius of curvature at a fixed point will cause fatigue and breakage in almost any material. For this reason, right-angle bends should be made at least 0.020 inch from the glass. This practice will avoid sharp bends and maintain sufficient electrlical isolation between lead connections and header. A safe bend can be assured if the lead is gripped with pliers close to the glass seal and then bent the requisite amount with the fingers, as shown in Fig. 386. When the leads of a number of devices are to

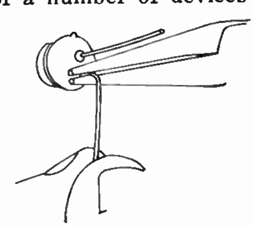


*Fig. 386—Method of bending leads on thyristor package.*

be bent into a particular configuration, it may be advantageous to use a lead-bending fixture to assure that all leads are bent to the same shape and in the correct place the first time, so that there is no need for repeated bending.

RCA thyristors are also available in plastic packages. The information given previously on the mounting and handling of plastic-package transistors is, in general, applicable to plastic-package thyristors as well.

## Typical Heat-Sink Configurations

Fig. 387 shows some typical heat-sink configurations that can be used with RCA thyristors in a TO-5 package. The thermal-resistance $\theta_{S-A}$ for each of the easily fabricated sinks is given, together with approximate dimensions. The thyristors in the illustrations are soldered to the heat sink; if epoxy is used, an additional thermal resistance $\theta_{C-S}$ of 1 to 2°C per watt must be added to the thermal-resistance values shown. The junction-to-case thermal-resistance value for the particular thyristor being used should be added to the values shown to obtain the over-all junction-to-air thermal resistance of each configuration. In the designs

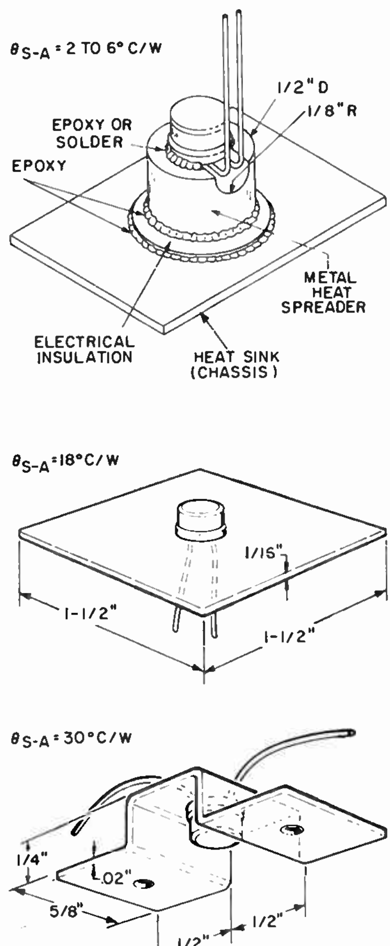



*Fig. 387—Typical heat-sink configurations for use with TO-5 package.*

shown, electrical insulation of the heat sink from the chassis or equipment housing may be required.

## Chassis-Mounted Heat Sinks

In many applications, it is desirable and practical to use the chassis or equipment housing as the heat sink. In such cases, the thyristor must be electrically insulated from the heat sink, but must still permit heat generated by the device to be efficiently transferred to the chassis or housing. This heat transfer can be achieved by use of the heat-spreader mounting method. In this method, the thyristor is attached to a metal bracket (heat spreader) which is attached to, but electrically insulated from, the chassis. The heat-sink configurations shown in Fig. 387 can serve as heat spreaders, as well as the special clip shown in Fig. 388. (Triacs soldered to this heat spreader are available from RCA as type numbers 40638 and 40639; SCR's on this spreader are available as type numbers 40656 and 40657.)

Electrical insulation may consist of material such as alumina ceramic, polyimide film or tape, fiberglass tape, or epoxy. The metal bracket itself has a low thermal resistance, and spreads the heat out over a larger area than could the thyristor case alone. The larger area in contact with the electrical insulation allows heat to transfer from bracket to chassis through the insulation with relatively low thermal resistance. Typical heat sinks, such as those shown in Fig. 387, provide a much lower thermal resistance when used as heat spreaders than when used as heat sinks.

Heat-spreader dimensions can be varied over a wide range to suit particular applications. For example, area or diameter can be increased, or shape changed, as long as the heat-transfer area in contact with the electrical insulation is sufficient. An area of 0.2 square inch or more is usually desirable. The exact thermal resistance of any heat spreader depends on the heat-transfer area, type of metal used, type of insulation used, and whether the thyristor is fastened to the heat

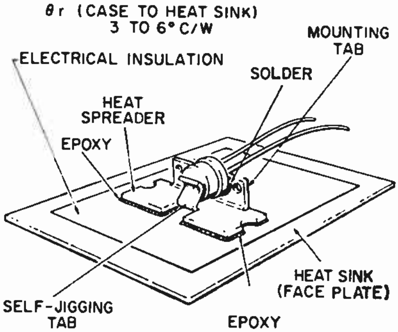



*Fig. 388—Self-jigging heat spreader.*

spreader with solder or epoxy. Soldered construction yields a thermal resistance about 1°C per watt less than that obtained with epoxy. Alumina or polyimide insulation provides a thermal resistance about 1 to 2°C per watt less than that obtained with thermosetting fiberglass-tape insulation. The heat spreader can be made of any material with suitable thermal conductivity, such as copper, brass, or aluminum. Solderable plating for aluminum is commercially available.

## RECTIFIER MOUNTING

The maximum forward-current ratings for RCA silicon rectifiers apply specifically for operation in free air (natural convection cooling). The average (dc) forward-current and the peak recurrent forward-current capabilities of these rectifiers are substantially higher than those shown in the maximum ratings when the rectifiers are attached to heat sinks.

Rectifiers used for low-power applications normally do not require an external heat sink to dissipate the heat generated at their p-n junctions. Most rectifiers in this category are packaged in the same

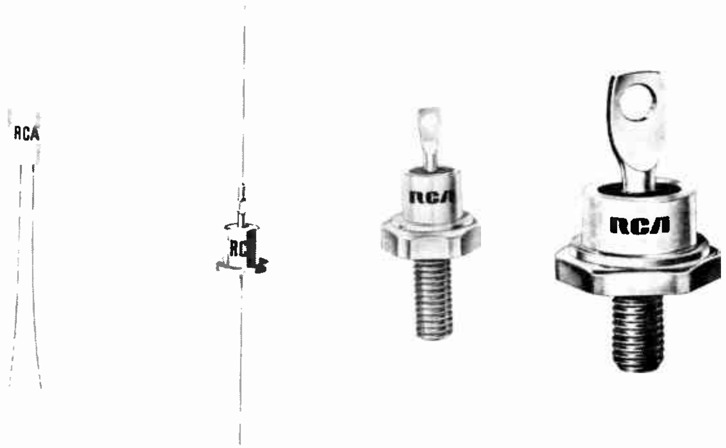



*Fig. 389—Various package designs for RCA silicon rectifiers.*

small case used for the JEDEC TO-1 package. For medium-current (1- to 2-ampere) high-voltage applications, the rectifier is packaged in a flange-case, axial-leal JEDEC DO-1 case. For higher-current applications, the DO-4 and DO-5 packages are used. These package configurations are shown in Fig. 389.

Fig. 390 shows two suggested methods for attaching the flange-case, axial-lead package to a heat sink. The flange of the rectifier may also be soldered directly to the heat sink, provided the flange temperature during soldering does not exceed 253°C for a miximum period of 10 seconds. Permanent damage to the rectifier may result if these limits are exceeded.

The flexible leads of some RCA rectifiers are usually soldered to the circuit elements. It is desirable in all installations to provide some slack or an expansion elbow in each lead to prevent excessive tension on the leads. Manual soldering should be performed carefully and quickly to avoid damage to the recfier by excessive heating. To minimize heating the rectifier junction during manual soldering, it is desirable to grip the flexible lead being soldered between the case and the soldering point with a pair of pliers.

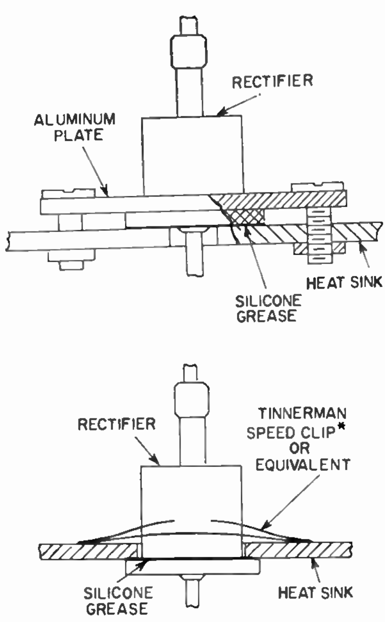



*Fig. 390—Suggested methods for attaching rectifier types 1N2858A through 1N2864A to heat sink.*

When dip soldering is used in the assembly of printed circuits, the temperature of the solder should not exceed 255°C for a maximum immersion period of 10 seconds. The leads should not be dip-soldered beyond points, "A" and "B" indicated in Fig. 391.

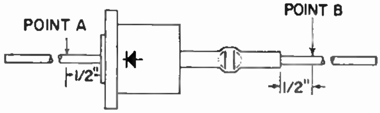



*Fig. 391—Diagram showing areas beyond which dip-soldering should not extend.*

Fig. 392 shows the suggested mounting of the higher-current-type DO-4 and DO-5 packages. Mounting components of the type shown are furnished with each rectifier. With these mounting components, the increase in thermal resistance $\theta_{C-S}$ from the rectifier case to the heat-sink surface is approximately 3°C per watt.

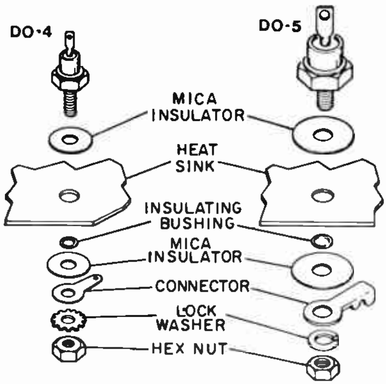



*Fig. 392—Suggested mounting arrangements for DO-4 and DO-5 packages.*

# RCA SK-Series Solid-State Replacement Devices

THE RCA "top-of-the-line" SK-series entertainment and industrial solid-state devices are a group of high-quality types specifically intended for replacement purposes in line-operated and battery-operated electronic equipment. Each transistor, rectifier, or integrated circuit included in the SK-series is designed to provide outstanding performance in a specific application or type of service and can be used to replace a broad variety of solid-state devices used in that application or type of service in original equipment.

SK devices are precisely engineered, manufactured, and tested specifically for use as replacements. Each device has electrical characteristics comparable with, or superior to, those of the devices that it replaces. In some instances, the case of an SK device may be slightly taller or thicker than that of the original device or may have a slightly different shape. These slight mechanical differences will not affect the performance of the equipment in which the replacement is made and normally will not prevent or complicate the installation of the SK device. In most cases, therefore, the recommended SK replacement device can be installed without changes in mechanical mounting arrangements, circuit wiring, or operating conditions. Dimensional outlines for the SK devices are shown in the Outlines Section of this Manual.

Fig. 393 shows the terminal diagrams for the SK devices, and Table V provides an index to the specific diagram for each type.

Because RCA SK devices are intended specifically for replacement purposes, RCA does not publish detailed technical data sheets on them, and no descriptive data on these types are included in the Technical Data Sections of this Manual. However, for the benefit of hobbyists, experimenters, and others who may require some information on the performance capability of these devices, performance data that define safe areas of operation are given in Table VI for entertainment types and in Table VII for industrial types. Operation beyond the limits specified may result in damage to the device.

For more detailed information on the use and capabilities of RCA SK solid-state devices, the reader should refer to the SK-Series Top of the Line Replacement Guide, RCA Publication No. SPG 202K. This Guide lists in numerical-alphabetical sequence more than 17,000 solid-state devices widely used in electronic equipment and the recommended SK replacement device for each type. The Guide also provides detailed instructions and precautionary measures that should be followed to assure successful use of SK types for replacement of original-equipment devices.

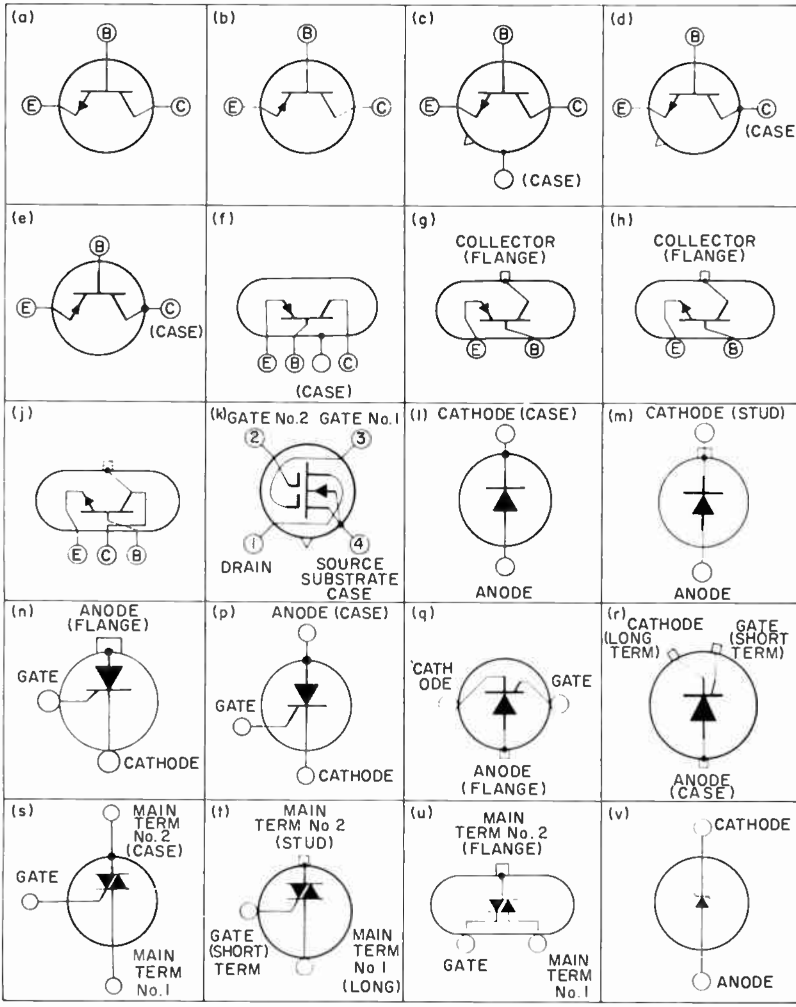



*Fig. 393—Terminal diagrams for RCA SK solid-state replacement devices. (Table V provides a type-number index to these diagrams.)*

## Table V—Type-Number Index to Terminal Diagrams of SK Devices Shown in Fig. 393

| Type | Terminal Diagram | Type | Terminal Diagram | Type | Terminal Diagram |
|---|---|---|---|---|---|
| SK3003 | (b) | SK3029 | (h) | SK3055 | (v) |
| SK3004 | (b) | SK3030 | (l) | SK3056 | (v) |
| SK3005 | (b) | SK3031 | (l) | SK3057 | (v) |
| SK3006 | (f) | SK3032 | (l) | SK3058 | (v) |
| SK3007 | (f) | SK3033 | (l) | SK3059 | (v) |
| SK3008 | (f) | SK3034 | (g) | SK3060 | (v) |
| SK3009 | (g) | SK3035 | (g) | SK3061 | (v) |
| SK3010 | (a) | SK3036 | (h) | SK3062 | (v) |
| SK3011 | (a) | SK3037 | (h) | SK3063 | (v) |
| SK3012 | (g) | SK3038 | (d) | SK3064 | (v) |
| SK3013 | (g) | SK3039 | (c) | SK3500 | (m) |
| SK3014 | (g) | SK3040 | (d) | SK3501 | (m) |
| SK3015 | (g) | SK3041 | (j) | SK3502 | (q) |
| SK3016 | (l) | SK3042 | (n) | SK3503 | (p) |
| SK3017A | (l) | SK3043 | (l) | SK3504 | (r) |
| SK3018 | (c) | SK3044 | (d) | SK3505 | (r) |
| SK3019 | (c) | SK3045 | (d) | SK3506 | (s) |
| SK3020 | (d) | SK3046 | (d) | SK3507 | (u) |
| SK3021 | (h) | SK3047 | (d) | SK3508 | (t) |
| SK3022 | * | SK3048 | (d) | SK3509 | (t) |
| SK3023 | * | SK3049 | (d) | SK3510 | (h) |
| SK3024 | (d) | SK3050 | (k) | SK3511 | (h) |
| SK3025 | (e) | SK3051 | (l) | SK3512 | (d) |
| SK3026 | (h) | SK3052 | (g) | SK3513 | (e) |
| SK3027 | (h) | SK3053 | (e) | | |
| SK3028 | (h) | SK3054 | (j) | | |

* Terminal diagrams are not shown for integrated-circuit types.

## Table VI—Performance Data for RCA SK-Series Entertainment Replacement Types

| RCA Type | Applications | LIMIT CONDITIONS | | | | | CHARACTERISTICS | | Device Outline* |
|---|---|---|---|---|---|---|---|---|---|
| | | $P_T$ W | $I_C$ A | $V_{CBO}$ V | $V_{CEO}$ V | $V_{EBO}$ V | $h_{FE}$ | $f_T$ MHz | |
| **NPN Transistor Types** | | | | | | | | | |
| SK3010 Germanium | Class A Voltage Amplifier and Driver Stages for Portable Receivers. Supply Voltages up to 15 volts | 0.1 | 0.1 | 25 | 25 | 12 | 120 | 2 | A |
| SK3011 Germanium | RF-Amplifier, Converter, and IF-Amplifier Stages for AM Broadcast-Band Receivers. Supply Voltages up to 18 volts | 0.12 | 0.2 | 25 | 15 | 20 | 20 Min. | 3 Min. | E |

* Refer to Outlines Section

## Table VI—Performance Data for RCA SK-Series Entertainment Replacement Types (cont'd)

| RCA Type | Applications | LIMIT CONDITIONS | | | | | CHARACTERISTICS | | Device Outline* |
|---|---|---|---|---|---|---|---|---|---|
| | | $P_T$ W | $I_C$ A | $V_{CBO}$ V | $V_{CEO}$ V | $V_{EBO}$ V | $h_{FE}$ | $f_T$ MHz | |
| **NPN Transistor Types (cont'd)** | | | | | | | | | |
| **SK3018 Silicon** | RF-Amplifier, Mixer, Oscillator, and IF-Amplifier Stages for VHF-TV and FM Receivers. Supply Voltages up to 25 volts | 0.18 | 0.05 | 45 | 45 | 4.5 | 130 | 120 | G |
| **SK3019 Silicon** | Oscillator Stages in UHF-TV Tuners only. Supply Voltages up to 25 volts | 0.18 | 0.05 | 45 | 45 | 4.5 | 130 | 1200 | G |
| **SK3020 Silicon** | Low-Level Driver and AF-Output Stages in Auto Radios, Hi-Fi and Communications Equipment. Supply Voltages up to 25 volts | 0.5 | 0.3 | 30 | 25 | 7.5 | 175 | 175 | H |
| **SK3021 Silicon** | AF-Power Output Stages of Line-Operated Radios, Phonographs and TV Receivers. Supply Voltage of 120 volts will provide a Power Output of 1 watt | 35 | 2 | 500 | 300 | 6 | 105 | 20 | J |
| **SK3024 Silicon** | AF-Output and Driver Stages of Hi-Fi and Communications Equipment, Supply Voltages up to 80 volts. NPN Complement of the SK3025 | 5 | 1 | 120 | 90 | 7 | 100 | 150 | E |
| **SK3026 Silicon** | Class A and B Audio Power Amplifier Stages of Hi-Fi and Communications Equipment. Supply Voltages of 40 volts will provide Power Outputs of 5-watts, Class A, and 15-watts Class B, (Push-Pull Operation) For Matched Pair use SK3028 | 29 | 4 | 70 | 60 | 7 | 70 | 1 | J |

* Refer to Outlines Section

## Table VI—Performance Data for RCA SK-Series Entertainment Replacement Types (cont'd)

| RCA Type | Applications | LIMIT CONDITIONS $P_T$ W | $I_C$ A | $V_{CBO}$ V | $V_{CEO}$ V | $V_{EBO}$ V | CHARACTERISTICS $h_{FE}$ | $f_T$ MHz | Device Outline* |
|---|---|---|---|---|---|---|---|---|---|
| **NPN Transistor Types (cont'd)** | | | | | | | | | |
| **SK3027 Silicon** | Class B push-Pull Audio Power Amplifier Stages for Hi-Fi and Communications Equipment. Supply Voltages of 80 volts will provide a power output of 40-watts (Push-Pull Operation) For Matched Pair use SK3029 | 115 | 15 | 90 | 80 | 7 | 60 | 1 | D |
| **SK3028 Silicon** | Matched Pair of SK3026 Transistors | For Data See SK3026 | | | | | | | |
| **SK3029 Silicon** | Matched Pair of SK3027 Transistors | For Data See SK3027 | | | | | | | |
| **SK3036 Silicon** | Class B Push-Pull Audio Power Amplifier Stages for Hi-Fi and Communications Equipment. Supply Voltages of 80 volts will Provide a Power Output of 100-watts rms with a 4-ohm load, (Push-Pull Operation). For Matched Pair use SK3037 | 150 | 30 | 90 | 80 | 5 | 100 | 1.5 | D |
| **SK3037 Silicon** | Matched Pair of SK3036 Transistors | For Data See SK3036 | | | | | | | |
| **SK3038 Silicon** | Small-Signal, Low-Noise AF-Preamplifier Stages For Hi-Fi and Communications Equipment. Supply Voltages up to 18 volts | 0.3 | 0.3 | 30 | 25 | 7.5 | 175 | 175 | H |
| **SK3039 Silicon** | RF-Amplifier, Mixer, and Converter Stages for UHF-TV Receivers. Supply Voltages up to 15 volts | 0.3 | 0.04 | 20 | 12 | 2.5 | 60 | 1200 | K |
| **SK3040 Silicon** | Video Output Stages of Black and White TV-Receivers. Supply Voltages up to 140 volts | 1 | 0.05 | 120 | 120 | 5 | 50 | 100 | L |
| **SK3041 Silicon** | AF-Power Output Stages for Auto Receivers. Supply Voltages up to 18 volts | 50 | 7 | 35 | 35 | 5 | 100 | 2 | M |

* Refer to Outlines Section

## Table VI—Performance Data for RCA SK-Series Entertainment Replacement Types (cont'd)

| RCA Type | Applications | LIMIT CONDITIONS $P_T$ W | $I_C$ A | $V_{CBO}$ V | $V_{CEO}$ V | $V_{EBO}$ V | CHARACTERISTICS $h_{FE}$ | $f_T$ MHz | Device Outline* |
|---|---|---|---|---|---|---|---|---|---|
| **NPN Transistor Types (cont'd)** | | | | | | | | | |
| SK3044 Silicon | Gated AGC, Color Amplifiers, and High-Voltage Regulator Circuits in Color TV Receivers. Supply Voltages up to 275 volts | 10 | 1.0 | 300 | 300 | 7 | 80 | 15 | E |
| SK3045 Silicon | Video Output, AF-Output, and High Voltage Regulator Circuits in Color TV-Receivers. Supply Voltages up to 275 volts | 10 | 1.0 | 300 | 300 | 6 | 80 | 15 | S |
| SK3046 Silicon | RF-Oscillator Stages for Citizens Band Transmitters. Supply Voltages up to 12 volts | 0.5 | 0.25 | 60 | 30 | 2 | 50 | 300 | E |
| SK3047 Silicon | RF-Driver Stages for Citizens Band Transmitters. Supply Voltages up to 12 volts | 2 | 0.25 | 60 | 30 | 2 | 50 | 300 | E |
| SK3048 Silicon | RF-Output Stages for Citizens Band Transmitters. Supply Voltages up to 12 volts | 5 | 1.5 | 60 | 30 | 2.5 | 60 | 200 | E |
| SK3049 Silicon | RF-Output Stages for Citizens Band Transmitters. Higher Power Version of SK3048. | 10 | 1.5 | 60 | 30 | 2.5 | 60 | 200 | S |
| SK3054 Silicon | AF-Drivers and Output Stages for Hi-Fi and Communications Equipment. Supply Voltages up to 50 volts | 50 | 7 | 90 | 70 | 5 | 70 | 2 | M |
| **PNP Transistor Types** | | | | | | | | | |
| SK3003 Germanium | AF-Output, Driver and Low-Level Amplifier Stages for Portable Receivers. Supply Voltages up to 9 volts | 0.15 | —0.07 | —20 | —18 | —2.5 | 90 | 1 | A |
| SK3004 Germanium | AF-Output, Driver and Low-Level Amplifier Stages for Portable Receivers. Supply Voltages up to 15 volts | 0.165 | —0.1 | —35 | —25 | —12 | 90 | 1 | A |

* Refer to Outlines Section

## Table VI—Performance Data for RCA SK-Series Entertainment Replacement Types (cont'd)

| RCA Type | Applications | LIMIT CONDITIONS | | | | | CHARACTERISTICS | | Device Outline* |
|---|---|---|---|---|---|---|---|---|---|
| | | $P_T$ W | $I_C$ A | $V_{CBO}$ V | $V_{CEO}$ V | $V_{EBO}$ V | $h_{FE}$ | $f_T$ MHz | |
| **PNP Transistor Types (cont'd)** | | | | | | | | | |
| **SK3005 Germanium** | RF-Amplifier, Converter, and IF-Amplifier Stages for AM-Broadcast Band Receivers. Supply Voltages up to 12 volts | 0.2 | —0.005 | —40 | —35 | —25 | 165 | 1 | A |
| **SK3006 Germanium** | RF-Amplifier, Converter, and IF-Amplifier Stages for FM-Broadcast Band Receivers. Supply Voltages up to 15 volts | 0.08 | —0.01 | —30 | —15 | —0.5 | 100 | 118 | B |
| **SK3007 Germanium** | RF-Amplifier, Converter, and IF-Amplifier Stages for All-Wave Receivers. Supply Voltages up to 15 volts | 0.08 | —0.01 | —24 | —15 | —0.5 | 120 | 30 | C |
| **SK3008 Germanium** | RF-Amplifier, Converter, and IF-Amplifier Stages for AM-Broadcast Band Auto Radios and Portable Receivers. Supply Voltages up to 15 volts | 0.08 | —0.01 | —34 | —15 | —0.5 | 150 | 1 | A |
| **SK3009 Germanium** | AF-Output Stages of Auto Radios, Hi-Fi Amplifier Equipment and Communications Equipment. Supply Voltages of 14.5 volts will Provide a Power Output of 5 watts in Class A Service. For Matched Pair Use SK3013 | 30 | —10 | —60 | —50 | —10 | 90 | 0.45 | D |
| **SK3012 Germanium** | AF-Power Output Stages for Auto Receivers. Supply Voltages up to 18 volts. Typical Power Output of 5 watts in Class A Service | 150 | —15 | —50 | —30 | —20 | 50 | 0.1 | F |
| **SK3013 Germanium** | Matched Pair of SK3009 Transistors | For Data See SK3009 | | | | | | | |

* Refer to Outlines Section

## Table VI—Performance Data for RCA SK-Series Entertainment Replacement Types (cont'd)

| RCA Type | Applications | LIMIT CONDITIONS | | | | | CHARACTERISTICS | | Device Outline* |
|---|---|---|---|---|---|---|---|---|---|
| | | $P_T$ W | $I_C$ A | $V_{CBO}$ V | $V_{CEO}$ V | $V_{EBO}$ V | $h_{FE}$ | $f_T$ MHz | |
| **PNP Transistor Types (cont'd)** | | | | | | | | | |
| **SK3014 Germanium** | AF-Output Stages for Auto-Radios, Hi-Fi Amplifier Equipment and Communications Equipment. Supply Voltage of 16.5 volts will Provide a Power Output of 5 watts in Class A Service. For Matched Pair Use SK3015 | 12.5 | —5 | —75 | —50 | —1.5 | 150 | 4 | D |
| **SK3015 Germanium** | Matched Pair of SK3014 Transistors | For Data See SK3014 | | | | | | | |
| **SK3025 Silicon** | AF-Drivers and Output Stages for Hi-Fi and Communications Equipment. Supply Voltages up to 80 volts. PNP Complement of the SK3024. | 7 | —1 | —90 | —90 | —7 | 100 | 100 | E |
| **SK3034 Germanium** | Vertical Output and Horizontal Driver Stages for TV-Receivers. Supply Voltages up to 36 volts | 10 | —10 | —200 | — | —2 | 35 | 2.5 | D |
| **SK3035 Germanium** | Horizontal Output Stages for TV-Receivers using Picture Tubes with Deflection Angles up to 114°, Ultor Voltage Ratings to 18 kV. Supply Voltages up to 36 volts. | 5 | —10 | —320 | — | —2 | 25 | 2.5 | D |
| **SK3052 Germanium** | AF-Output Stages of Auto Radios, Hi-Fi Amplifier Equipment and Communications Equipment. Supply Voltages up to 18 volts | 6 | —2 | —60 | —60 | —12 | 110 | 0.45 | J |
| **SK3053 Silicon** | AF-Drivers and Output Stages for Hi-Fi and Communications Equipment. Supply Voltages up to 100 volts. | 10 | —1 | —200 | —200 | —4 | 90 | 15 | E |

* Refer to Outlines Section

## Table VI—Performance Data for RCA SK-Series Entertainment Replacement Types (cont'd)

### N-Channel Dual-Insulated-Gate MOS Depletion Transistor Type

| RCA Type | Applications | LIMIT CONDITIONS $P_T$ W | $I_D$ mA | $V_{DS}$ V | $V_{G1S}$ V | $V_{G2S}$ V | CHARACTERISTICS gfs umho | $I_{DS}$ mA | Device Outline* |
|---|---|---|---|---|---|---|---|---|---|
| SK3050 Silicon | RF-Amplifier Stages for VHF TV-Receivers. Supply Voltages up to 15 volts | 0.33 | 50 | —0.2 to +20 | —6 to +3 | —6 to +4 | 12,000 | 15 | K |

### Silicon Controlled Rectifier Type, Operating Temperature Range ($T_C$): —40 to +100°C

| RCA Type | Applications | LIMIT CONDITIONS $V_{DROM}$ V | On-State Current $I_{TSM}$ A | $I_T$ A | di/dt A/μs | $V_{GT}$ V | $I_{GT}$ mA | $t_{off}$ μs | Device Outline* |
|---|---|---|---|---|---|---|---|---|---|
| SK3042 Silicon | Trace and Commutating Circuits for Horizontal Deflection Stages in TV Receivers. Supply Voltages up to 129 VAC. | 550 | 80 | 5 | 200 | 4 | 30 | 2.5 | J |

### Silicon Rectifier Types

| RCA Type | Applications | LIMIT CONDITIONS PRV V | $V_{RM}$ V | $I_F$ A | $I_{FM}$ A | $t_{rr}$ μs | $V_{FM}$ V | Device Outline* |
|---|---|---|---|---|---|---|---|---|
| SK3016 Non-insulated Case | | 500 | — | 1 | — | — | — | 0 |
| SK3017A Insulated Case | | 600 | — | 1 | — | — | — | P |
| SK3030 Insulated Case | Color and Black-and-White TV Receivers, Radio Receivers, Hi-Fi Amplifier Equipment, Phonographs, and other Entertainment-Type Electronic Equipment. | 200 | — | 1 | — | — | — | P |
| SK3031 Insulated Case | | 400 | — | 1 | — | — | — | P |
| SK3032 Insulated Case | | 800 | — | 1 | — | — | — | P |
| SK3033 Non-insulated Case | | 1000 | — | 1 | — | — | — | 0 |
| SK3043 Non-insulated Case | Trace, Commutating and Clamp Diode for Horizontal Deflection Circuits in TV Receivers | 550 | 700 | 1 | 70 | 1.1 | 1.3 | P |

* Refer to Outlines Section

## Table VI—Performance Data for RCA SK-Series Entertainment Replacement Types (cont'd)

### Silicon Rectifier Types (cont'd)

| RCA Type | Applications | LIMIT CONDITIONS PRV V | $V_{RM}$ V | $I_F$ A | $I_{FM}$ A | $t_{rr}$ $\mu s$ | $V_{FM}$ V | Device Outline* |
|---|---|---|---|---|---|---|---|---|
| SK3051 Insulated Case | Color and Black-and-White TV Receivers, Radio Receivers, Hi-Fi Amplifier Equipment, Phonographs, and other Entertainment-Type Electronic Equipment. | 1000 | — | 3 | — | — | — | T |

### Zener Voltage Regulator Types

| RCA Type | Applications | $P_D$ W | $V_Z$ (±10%) V | $I_Z$(Typical) mA | Device Outline* |
|---|---|---|---|---|---|
| SK3055 Insulated Case | Color and Black-and-White TV Receivers, Radio Receivers, Hi-Fi Amplifier Equipment, Phonographs, and other Entertainment-Type Electronic Equipment. | 1 | 3.6 | 69 | AA |
| SK3056 Insulated Case | | 1 | 5.1 | 49 | AA |
| SK3057 Insulated Case | | 1 | 5.6 | 45 | AA |
| SK3058 Insulated Case | | 1 | 6.2 | 41 | AA |
| SK3059 Insulated Case | | 1 | 7.5 | 34 | AA |
| SK3060 Insulated Case | | 1 | 9.1 | 28 | AA |
| SK3061 Insulated Case | | 1 | 10 | 25 | AA |
| SK3062 Insulated Case | | 1 | 12 | 21 | AA |
| SK3063 Insulated Case | | 1 | 15 | 17 | AA |
| SK3064 Insulated Case | | 1 | 27 | 9.5 | AA |

* Refer to Outlines Section

## Table VI—Performance Data for RCA SK-Series Entertainment Replacement Types (cont'd)

**Integrated Circuits, Linear Types**

| RCA Type | Applications | CHARACTERISTICS $P_T$ mW | CHARACTERISTICS $V_i$(Lim) μV | CHARACTERISTICS A dB | Test Conditions $V_{CC}$ V | Test Conditions f MHz | Device Outline* |
|---|---|---|---|---|---|---|---|
| SK3022 Silicon 10-Leads | Sound IF-Amplifier Stages for TV-Receivers | 190 | 300 | 67 | 7.5 | 4.5 | N |
| SK3023 Silicon 10-Formed Leads | Sound IF-Amplifier Stages for TV-Receivers | 190 | 300 | 67 | 7.5 | 4.5 | R |

## Table VII—Performance Data for RCA SK-Series Industrial Replacement Types

**Rectifier Types, Maximum Operating Temperature ($T_C$) = 200°C**

| RCA Type | MAXIMUM CONDITIONS PRV Repetitive V | PRV Transient V | $I_F$ Average A | $I_F$ Surge A | $I_R$ μA | $V_F$ (full-cycle) V | Device Outline* |
|---|---|---|---|---|---|---|---|
| SK3500 | 600 | 700 | 12 | 250 | 5 | 0.55 | U |
| S3501 | 600 | 700 | 40 | 850 | 5 | 0.65 | V |

**Thyristor Types**

| RCA Type | MAXIMUM CONDITIONS $V_{FBOM}$ V | $I_F$ RMS A | $I_F$ Surge A | $I_{GT}$ mA | $V_{GT}$ V | $i_{HOO}$ mA | dv/dt V/μs | $P_G$ W | $I_{DROM}$ μA | Device Outline* |
|---|---|---|---|---|---|---|---|---|---|---|
| **SCR Types, Maximum Operating Temperature ($T_C$) = 100°C** | | | | | | | | | | |
| SK3502 | 600 | 5 | 80 | 15 | 2 | 20 | 10 | 6 | 500 | J |
| SK3503 | 600 | 7 | 80 | 15 | 2 | 20 | 10 | 7.5 | 500 | X |
| SK3504 | 600 | 20 | 200 | 15 | 2 | 20 | 10 | 23 | 500 | Y |
| SK3505 | 600 | 35 | 350 | 40 | 2 | 70 | 10 | 38 | 500 | Y |
| **Triac Types, Maximum Operating Temperature ($T_C$) = 100°C** | | | | | | | | | | |
| SK3506 | 400 | 2.5 | 25 | 10 | 2.2 | 15 | 10 | 4 | 400 | Z |
| SK3507 | 400 | 15 | 100 | 80 | 2.5 | 60 | 10 | 22 | 500 | W |
| SK3508 | 400 | 15 | 100 | 80 | 2.5 | 75 | 30 | 22 | 500 | Y |
| SK3509‡ | 400 | 40 | 300 | 80 | 2.5 | 60 | 20 | 50 | 500 | Y |

‡ Maximum Operating Temperature ($T_C$) = 110°C.

* Refer to Outlines Section

## Table VII—Performance Data for RCA SK-Series Industrial Replacement Types (cont'd)

**Silicon Transistor Types, Maximum Operating Temperature ($T_C$) = 200°C**

| | | LIMIT CONDITIONS | | | | | CHARACTERISTICS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RCA Type | Polarity | PT at $T_C$ = 25°C W | $I_C$ A | $V_{CBO}$ V | $V_{CEO}$ V | $V_{EBO}$ V | $I_{CEO}$ mA or $I_{CBO}$▲ µA | $V_{CE}$(sat) V | $h_{FE}$ | $I_C$ A | $f_T$ MHz | Device Outline* |
| SK3510 | NPN | 115 | 15 | 100 | 60 | 7 | 0.7 | 1.1 | 45 | 4 | 0.9 | D |
| SK3511 | NPN | 150 | 20 | 100 | 60 | 7 | 10 | 1.4 | 40 | 4 | 1 | D |
| SK3512 | NPN | 10 | 2 | 100 | 75 | 7 | 0.5▲ | 0.5 | 90 | 0.4 | 70 | E |
| SK3513 | PNP | 10 | —2 | —100 | —75 | —7 | —0.5▲ | —0.7 | 70 | —0.4 | 70 | E |

‡ Maximum Operating Temperature ($T_C$) = 110°C
* Refer to Outlines Section

# Symbols

Although semiconductor-device symbols have not yet been standardized throughout the industry, many symbols have become fairly well established by common usage. The symbols used in this Manual are listed and defined in this section.

## GENERAL SEMICONDUCTOR SYMBOLS

| | |
|---|---|
| df | duty factor |
| $\eta$ (eta) | efficiency |
| NF | noise figure |
| T | temperature |
| $T_A$ | ambient temperature |
| $T_C$ | case temperature |
| $T_J$ | junction temperature |
| $T_{MF}$ | mounting-flange temperature |
| $T_S$ | soldering temperature |
| $T_{STG}$ | storage temperature |
| $\Theta$ | thermal resistance |
| $\Theta_{J-A}$ | thermal resistance, junction-to-ambient |
| $\Theta_{J-C}$ | thermal resistance, junction-to-case |
| $\Theta_{J-HS}$ | thermal resistance, junction-to-heat sink |
| $\Theta_{J-MF}$ | thermal resistance, junction-to-mounting-flange |
| t | time |
| $t_d$ | delay time |
| $t_d + t_r$ | turn-on time |
| $t_f$ | fall time |
| $t_p$ | pulse time |
| $t_r$ | rise time |
| $t_s$ | storage time |
| $t_s + t_f$ | turn-off time |
| $\tau$ (tau) | time constant |
| $\tau_S$ | saturation stored-charge time constant |

## TRANSISTOR SYMBOLS

| | |
|---|---|
| $C_{b'c}$ | collector-to-base feedback capacitance |
| $C_c$ | collector-to-case capacitance |
| $C_{cb}$ | collector-to-base feedback capacitance |
| $C_{ibo}$ | input capacitance, open circuit (common base) |
| $C_{ieo}$ | input capacitance, open circuit (common emitter) |
| CM | cross modulation |
| $C_{obo}$ | output capacitance, open circuit (common base) |
| $C_{oeo}$ | output capacitance, open circuit (common emitter) |
| $E_{S/b}$ | second-breakdown energy |
| $f_c$ | cutoff frequency |
| $f_{hfb}$ | small-signal forward-current transfer-ratio cutoff frequency, short-circuit (common base) |
| $f_{hfe}$ | small-signal forward-current transfer-ratio cutoff frequency, short-circuit (common emitter) |
| $f_T$ | gain-bandwidth product (frequency at which small-signal forward-current transfer ratio, common emitter, extrapolates to unity) |
| $g_{me}$ | small-signal transconductance (common emitter) |
| $G_{PB}$ | large-signal average power gain (common base) |
| $G_{pb}$ | small-signal average power gain (common base) |

| | |
|---|---|
| $G_{PE}$ | large-signal average power gain (common emitter) |
| $G_{pe}$ | small-signal average power gain (common emitter) |
| $h_{FB}$ | static forward-current transfer ratio (common base) |
| $h_{fb}$ | small-signal forward-current transfer ratio, short circuit (common base) |
| $h_{FE}$ | static forward-current transfer ratio (common emitter) |
| $h_{fe}$ | small-signal forward-current transfer ratio, short circuit (common emitter) |
| $h_{ib}$ | small-signal input impedance, short circuit (common base) |
| $h_{IE}$ | static input resistance (common emitter) |
| $h_{ie}$ | small-signal input impedance, short circuit (common emitter) |
| $h_{ob}$ | small-signal output impedance, open circuit (common base) |
| $h_{oe}$ | small-signal output impedance, open circuit (common emitter) |
| $h_{rb}$ | small-signal reverse-voltage transfer ratio, open circuit (common base) |
| $h_{re}$ | small-signal reverse-voltage transfer ratio, open circuit (common emitter) |
| $I_B$ | base current |
| $I_{B1}$ | turn-on current |
| $I_{B2}$ | turn-off current |
| $I_C$ | collector current |
| $i_C$ | collector current, instantaneous value |
| $I_{CB}$ | collector-cutoff current |
| $I_{CBO}$ | collector-cutoff current, emitter open |
| $I_{CEO}$ | collector-cutoff current, base open |
| $I_{CER}$ | collector-cutoff current, specified resistance between base and emitter |
| $I_{CES}$ | collector-cutoff current, base short-circuited to emitter |
| $I_{CEV}$ | collector-cutoff current, specified voltage between base and emitter |
| $I_{CEX}$ | collector-cutoff current, specified circuit between base and emitter |
| $I_{CS}$ | switching current (at minimum $h_{FE}$ per specification) |
| $I_E$ | emitter current |
| $I_{EBO}$ | emitter-cutoff current, collector open |
| $I_{S/b}$ | second-breakdown collector current |
| MAG | maximum available amplifier gain |
| $MAG_c$ | maximum available conversion gain |
| MUG | maximum usable amplifier gain |
| $P_{BE}$ | total dc or average power input to base (common emitter) |
| $p_{BE}$ | total instantaneous power input to base (common emitter) |
| $P_{CB}$ | total dc or average power input to collector (common base) |
| $p_{CB}$ | total instantaneous power input to collector (common base) |
| $P_{CE}$ | total dc or average power input to collector (common emitter) |
| $p_{CE}$ | total instantaneous power input to collector (common emitter) |
| $P_{EB}$ | total dc or average power input to emitter (common base) |
| $p_{EB}$ | total instantaneous power input to emitter (common base) |
| $P_{IB}$ | large-signal input power (common base) |
| $P_{ib}$ | small-signal input power (common base) |
| $P_{IE}$ | large-signal input power (common emitter) |
| $P_{ie}$ | small-signal input power (common emitter) |

| | |
|---|---|
| $P_{OB}$ | large-signal output power (common base) |
| $P_{ob}$ | small-signal output power (common base) |
| $P_{OE}$ | large-signal output power (common emitter) |
| $P_{oe}$ | small-signal output power (common emitter) |
| $P_T$ | total nonreactive power input to all terminals |
| $Q_s$ | stored base charge |
| $r_{bb'}$ | intrinsic base spreading resistance |
| $r_{b'}C_c$ | collector - to - base time constant |
| $r_{CE}(sat)$ | collector-to-emitter saturation resistance |
| $Re(h_{ie})$ | real part of small-signal input impedance, short circuit (common emitter) |
| $R_G$ | generator resistance |
| $R_{ie}$ | input resistance (common emitter) |
| $R_L$ | load resistance |
| $R_{oe}$ | output resistance (common emitter) |
| $R_S$ | source resistance |
| $\tau$ (thermal) | thermal time constant |
| $V_{BB}$ | base-supply voltage |
| $V_{BC}$ | base-to-collector voltage |
| $V_{BE}$ | base-to-emitter voltage |
| $V_{BE}(sat)$ | base-to-emitter saturation voltage |
| $V_{(BR)CBO}$ | collector-to-base breakdown voltage, emitter open |
| $V_{(BR)CEO}$ | collector - to - emitter breakdown voltage, base open |
| $V_{(BR)CER}$ | collector - to - emitter breakdown voltage, specified resistance between base and emitter |
| $V_{(BR)CES}$ | collector - to - emitter breakdown voltage, base short-circuited to emitter |
| $V_{(BR)CEV}$ | collector - to - emitter breakdown voltage, specified voltage between base and emitter |
| $V_{(BR)EBO}$ | emitter-to-base breakdown voltage, collector open |
| $V_{CB}$ | collector-to-base voltage |
| $V_{CB}(fl)$ | dc open-circuit voltage between collector and base (floating potential), emitter biased with respect to base |
| $V_{CE}(fl)$ | dc open-circuit voltage between collector and emitter (floating potential), base biased with respect to emitter |
| $V_{CBO}$ | collector-to-base voltage (emitter open) |
| $V_{CBV}$ | collector-to-base voltage, specified voltage between emitter and base |
| $V_{CC}$ | collector-supply voltage |
| $V_{CE}$ | collector-to-emitter voltage |
| $V_{CEO}$ | collector-to-emitter voltage, base open |
| $V_{CER}$ | collector-to-emitter voltage, specified resistance between base and emitter |
| $V_{CES}$ | collector-to-emitter voltage, base short-circuited to emitter |
| $V_{CEV}$ | collector-to-emitter voltage, specified voltage between base and emitter |
| $V_{CE}(sat)$ | collector-to-emitter saturation voltage |
| $V_{EB}$ | emitter-to-base voltage |
| $V_{EB}(fl)$ | dc open-circuit voltage between emitter and base (floating potential), collector biased with respect to base |
| $V_{EBO}$ | emitter-to-base voltage, collector open |
| $V_{EE}$ | emitter-supply voltage |
| $V_{RT}$ | reach-through voltage |
| VG | voltage gain |
| $1/Y_{22(real)}$ | real part of short-circuit output impedance |
| $Y_{fe}$ | forward transconductance |
| $Y_{ie}$ | input admittance |
| $Y_{oe}$ | output admittance |
| $Y_{re}$ | reverse transconductance |

## MOS FIELD-EFFECT TRANSISTOR SYMBOLS

| | |
|---|---|
| A | voltage amplification ($= Y_{fs}/Y_{os} + Y_L$) |
| $B_{os}$ | $= c_{ds}$ |

| | |
|---|---|
| $c_c$ | intrinsic channel capacitance |
| $c_{ds}$ | drain-to-source capacitance (includes approximately 1-pF drain-to-case and interlead capacitance) |
| $c_{gd}$ | gate-to-drain capacitance (includes 0.1-pF interlead capacitance) |
| $c_{gs}$ | gate-to-source interlead and case capacitance |
| $C_{iss}$ | small-signal input capacitance, short circuit |
| $C_{oss}$ | small-signal output capacitance, short circuit |
| $C_{rss}$ | small-signal reverse transfer capacitance, short circuit |
| $e_n$ | equivalent input noise voltage |
| $g_c$ | forward conversion conductance |
| $g_{fs}$ | forward transconductance |
| $g_{fs}(c)$ | forward conversion transductance |
| $g_{fs}(off)$ | cutoff forward transconductance |
| $g_{is}$ | input conductance |
| $g_{os}$ | output conductance |
| $G_{ps}$ | power gain |
| $G_{ps(c)}$ | conversion power gain |
| $I_D$ | dc drain current |
| $I_{DS}(OFF)$ | drain-to-source OFF current |
| $I_{DSS}$ | zero-bias drain current |
| $I_{G1SS}$ | gate No. 1 leakage current |
| $I_{G2SS}$ | gate No. 2 leakage current |
| $I_{GSS}$ | gate leakage current |
| NF | spot noise figure (generator resistance $R_G$ = 1 megohm) |
| $r_c$ | effective gate series resistance |
| $r_d$ | active channel resistance |
| $r_d'$ | unmodulated channel resistance |
| $r_{DS}(ON)$ | drain-to-source ON resistance |
| $R_{DS}(off)$ | drain-to-source cutoff resistance |
| $r_{gd}$ | gate-to-drain leakage resistance |
| $r_{gs}$ | gate-to-source leakage resistance |
| $r_{iss}$ | input resistance |
| $r_{oss}$ | output resistance |
| $V_{DB}$ | drain-to-substrate voltage |
| $V_{DG}$ | drain-to-gate voltage |
| $V_{DG1}$ | drain-to-gate No. 1 voltage |
| $V_{DG2}$ | drain-to-gate No. 2 voltage |
| $V_{DS}$ | drain-to-source voltage |
| $V_{G1S}$ | gate No. 1-to-source voltage |
| $V_{G1S}(off)$ | gate N.o 1-to-source cutoff voltage |
| $V_{G2S}$ | gate No. 2-to-source voltage |
| $V_{G2S}(off)$ | gate No. 2-to-source cutoff voltage |
| $V_{GB}$ | dc gate-to-substrate voltage |
| $v_{GB}$ | peak gate-to-substrate voltage |
| $V_{GS}$ | dc gate-to-source voltage |
| $v_{GS}$ | peak gate-to-source voltage |
| $V_{GS}(OFF)$ | gate-to-source cutoff voltage |
| $V_o$ | offset voltage |
| $Y_{fs}$ | forward transadmittance $\approx g_{fs}$ |
| $Y_{os}$ | output admittance $= g_{os} + jB_{os}$, $B_{os} = \omega c_{ds}$ |
| $Y_L$ | load admittance $= g_L + jB_L$ |
| $\angle\theta$ | phase angle of forward transadmittance |

## SCR SYMBOLS

| | |
|---|---|
| Critical dv/dt | critical rate of applied forward voltage |
| di/dt | rate of change of on-state current |
| $I_{DOM}$ | peak off-state current (open gate) |
| $I_{GT}$ | average trigger current |
| $i_{HO}$ | instantaneous holding current |
| $I_{RRDM}$ | repetitive peak reverse current (open gate) |
| $i_T$ | instantaneous on-state current |
| $I_{T(AV)}$ | average on-state current |
| $I_{T(RMS)}$ | rms on-state current |

$I_{TSM}$ surge (non-reptitive) on-state current
$[I_{TS(RMS)}]^2t$ rms surge (non-repetitive) on-state current
$P_{G(AV)}$ average on-state or off-state gate power dissipation
$P_{GM}$ peak on-state or off-state gate power dissipation
$R_L$ load resistance
$t_{gt}$ gate controlled turn-on time
$t_q$ circuit commutated turn-off time
$V_{DROM}$ repetitive peak off-state voltage (open gate)
$V_{DSOM}$ non-repetitive peak forward voltage (open gate)
$v_{F(BO)O}$ instantaneous forward breakover voltage (open gate)
$V_{GT}$ average trigger voltage
$V_{RROM}$ repetitive peak reverse voltage (open gate)
$V_{RSOM}$ non-repetitive peak reverse voltage (open gate)
$v_T$ instantaneous on-state voltage

## TRIAC SYMBOLS

Commutating dv/dt critical rate of applied commutating voltage
Critical dv/dt critical rate-of-rise of off-state voltage
di/dt rate of change of forward current
$I_{DROM}$ peak off-state current
$I_{GT}$ dc gate-trigger current
$I_{GTM}$ peak gate-trigger current
$I_{HO}$ dc holding current
$i_T$ instantaneous on-state current
$I_{T(RMS)}$ rms on-state current
$I_{TSM}$ peak surge (non-repetitive) on-state current
$P_{G(AV)}$ average gate power dissipation
$P_{GM}$ peak gate power dissipation
$R_L$ load resistance
$t_{gt}$ gate-controlled turn-on time
$v_D$ instantaneous off-state voltage
$V_{DROM}$ repetitive peak off-state voltage
$V_{DSOM}$ non-repetitive peak forward voltage
$V_{GT}$ dc gate-trigger voltage
$V_{RROM}$ repetitive peak reverse voltage
$V_{RSOM}$ non-repetitive peak reverse voltage
$v_T$ instantaneous on-state voltage
$V_{TM}$ maximum on-state voltage

## RECTIFIER SYMBOLS

$C_j$ junction capacitance
$C_S$ shunt capacitance
$I_F$ forward current, dc
$i_F$ forward current, instantaneous total
$I_{F(AV)}$ average forward current
$i_{FM}$(rep) peak recurrent forward current
$I_{FM}$ peak forward current
$i_{FM}$(surge) peak surge forward current
$I_{FRM}$ repetitive peak forward current
$I_{F(RMS)}$ forward current, total rms value
$I_{FSM}$ peak surge forward current
$I_R$ reverse current, dc
$i_R$ reverse current, instantaneous value
$I_{R(AV)}$ average reverse current
$I_{RM}$ peak reverse current
$I_{R(RMS)}$ reverse current, total rms value
$V_F$ forward voltage
$v_F$ forward voltage, instantaneous total
$V_{F(AV)}$ average forward voltage
$V_{FM}$ maximum dc forward voltage drop
$V_{F(RMS)}$ forward voltage, total rms value
$V_{(BR)R}$ reverse breakdown voltage
$V_M$(block) maximum dc blocking voltage
$V_R$ reverse voltage
$v_R$ reverse voltage, instantaneous total
$v_{RM}$ peak reverse voltage
$v_{RM}$ (non-rep) non-repetitive (transient) peak reverse voltage
$v_{RM}$(rep) repetitive peak reverse voltage

| | |
|---|---|
| $V_{RMS}$ | rms supply voltage |
| $V_{RRM}$ | repetitive peak reverse voltage |
| $V_{RSM}$ | peak reverse voltage, non-repetitive |
| $V_{RWM}$ | peak reverse voltage, working |

## RCA MILITARY-SPECIFICATION TYPES

| TYPE | MIL-S-19500/ |
|---|---|
| **Transistors** | |
| JAN-2N384 | 27 |
| JAN-2N388 | 65 |
| JAN-398 | 174 |
| JAN-2N398A | 174 |
| JAN-2N404 | 20 |
| JAN-2N404A | 20 |
| JAN-2N918 | 301 |
| JAN-2N1183 | 143 |
| JAN-2N1183A | 143 |
| JAN-2N1183B | 143 |
| JAN-2N1184 | 143 |
| JAN-2N1184A | 143 |
| JAN-2N1184B | 143 |
| JAN-2N1224 | 189 |
| JAN-2N1225 | 189 |
| JAN-2N1302 | 126 |
| JAN-2N1303 | 126 |
| JAN-2N1304 | 126 |
| JAN-2N1305 | 126 |
| JAN-2N1306 | 126 |
| JAN-2N1307 | 126 |
| JAN-2N1308 | 126 |
| JAN-2N1309 | 126 |
| JAN-2N1479 | 207 |
| JAN-2N1480 | 207 |
| JAN-2N1481 | 207 |
| JAN-2N1482 | 207 |
| JAN-2N1483 | 180 |
| JAN-TX2N1483 | 180 |
| JAN-2N1484 | 180 |
| JAN-TX2N1484 | 180 |
| JAN-2N1485 | 180 |
| JAN-TX2N1485 | 180 |
| JAN-2N1486 | 180 |
| JAN-TX2N1486 | 180 |
| JAN-2N1487 | 208 |
| JAN-2N1488 | 208 |
| JAN-2N1489 | 208 |
| JAN-2N1490 | 208 |
| JAN-2N1493 | 247 |
| JAN-2N2015 | 248 |
| JAN-2N2016 | 248 |
| JAN-2N2857 | 343 |
| JAN-TX2N2857 | 343 |
| JAN-2N3375 | 341 |
| JAN-TX2N3375 | 341 |
| JAN-2N3439 | 368 |
| JAN-2N3440 | 368 |
| JAN-2N3441 | 369 |
| JAN-2N3442 | 370 |
| JAN-2N3553 | 341 |
| JAN-TX2N3553 | 341 |
| JAN-2N4440 | 341 |
| JAN-TX2N4440 | 341 |

Copies of specification sheets may be obtained by directing requests to Department of the Navy, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pa. 19120

# Selection Charts

The accompanying charts classify RCA semiconductor devices by function, by material, and by performance level. These charts are particularly useful for an initial selection of suitable devices for a specific application. More complete data on these devices, given in the Technical Data section, should then be consulted to determine the most suitable type. Data charts for rectifiers, other semiconductor diodes, and photoconductive devices are given at the end of the Technical Data section.

## TRANSISTORS

### Audio-Frequency Applications—Linear Operations

#### SMALL SIGNAL—CLASS A

**Silicon n-p-n**

*Dissipations up to 5 W*

| | | |
|---|---|---|
| 2N697 | 2N2895 | 40231 |
| 2N699 | 2N2896 | 40232 |
| 2N718A | 2N2897 | 40233 |
| 2N720A | 2N3053 | 40234 |
| 2N1613 | 2N3241A | 40397 |
| 2N1711 | 2N3242A | 40398 |
| 2N1893 | 2N4074 | 40399 |
| 2N2102 | 2N5183 | 40400 |
| 2N2270 | 40084 | 40458 |
| 2N2405 | | |

**Germanium p-n-p**

*Dissipations up to 165 mW*

| | | |
|---|---|---|
| 2N109 | 2N591 | 40329 |
| 2N217 | 2N1613 | 40359 |
| 2N405 | 2N1614 | 40395 |
| 2N406 | 2N2953 | 40490 |

#### POWER—CLASS A, AB, B

**Silicon n-p-n**

*Dissipations up to 5 W*

| | | |
|---|---|---|
| 2N697 | 2N1482‡ | 2N2102 |
| 2N699 | 2N1613 | 2N2270 |
| 2N1479‡ | 2N1700‡ | 2N2405 |
| 2N1480‡ | 2N1711 | 2N2895 |
| 2N1481‡ | 2N1893 | 2N2896 |

*Dissipations up to 5 W (cont'd)*

| | | |
|---|---|---|
| 2N2897 | 40321 | 40398 |
| 2N3053 | 40323 | 40399 |
| 2N3241A | 40326 | 40400 |
| 2N3242A | 40327 | 40407 |
| 2N4074 | 40354 | 40408 |
| 40084 | 40355 | 40539 |
| 40309 | 40360 | 40611 |
| 40311 | 40361 | 40616 |
| 40314 | 40366• | 40625 |
| 40315 | 40367• | 40628 |
| 40317 | 40385• | 40635 |
| 40320 | 40397 | |

*Dissipations above 5 W to 29 W*

| | | |
|---|---|---|
| 2N1483‡ | 2N5786† | 40349V1*‡ |
| 2N1484‡ | 40250‡ | 40349V2‡ |
| 2N1485‡ | 40250V1 | 40368• |
| 2N1486‡ | 40310 | 40372* |
| 2N1701‡ | 40312 | 40373* |
| 2N3054‡ | 40316 | 40374* |
| 2N3439 | 40324 | 40375* |
| 2N3440 | 40346 | 40389* |
| 2N3441‡ | 40347‡ | 40390* |
| 2N4063 | 40347V1*‡ | 40392 |
| 2N4064 | 40347V2‡ | 40409* |
| 2N5320 | 40348‡ | 40412 |
| 2N5321 | 40348V1*‡ | 40544 |
| 2N5784† | 40348V2‡ | 40594 |
| 2N5785† | 40349‡ | |

* For printed-circuit-board applications.
‡ Hometaxial base type.
• High-reliability type.

*Dissipations above 29 W to 100 W*

| | | |
|---|---|---|
| 2N1487‡ | 2N5240‡ | 40328 |
| 2N1488‡ | 2N5293*‡ | 40364 |
| 2N1489‡ | 2N5294‡ | 40369‡● |
| 2N1490‡ | 2N5295*‡ | 40513*‡ |
| 2N1702‡ | 2N5296‡ | 40514‡ |
| 2N3263 | 2N5297*‡ | 40542‡ |
| 2N3264 | 2N5298‡ | 40543‡ |
| 2N3583 | 2N5490*‡ | 40613 |
| 2N3584 | 2N5491‡ | 40618 |
| 2N3585 | 2N5492*‡ | 40621 |
| 2N3878 | 2N5493‡ | 40622 |
| 2N3879 | 2N5494*‡ | 40624 |
| 2N4240 | 2N5495‡ | 40627 |
| 2N4347‡ | 2N5496*‡ | 40629 |
| 2N5034‡ | 2N5497‡ | 40630 |
| 2N5035*‡ | 40313 | 40631 |
| 2N5036‡ | 40318 | 40632 |
| 2N5037*‡ | 40322 | 40633 |
| 2N5239‡ | | |

*Dissipation above 100 W to 150 W*

| | | |
|---|---|---|
| 2N2015 | 2N3772‡ | 2N5579‡ |
| 2N2016 | 2N3773‡ | 2N5580‡ |
| 2N2338‡ | 2N4348‡ | 40251‡ |
| 2N3055‡ | 2N5575‡ | 40325 |
| 2N3265 | 2N5576‡ | 40363 |
| 2N3266 | 2N5577‡ | 40411‡ |
| 2N3442‡ | 2N5578‡ | 40636 |
| 2N3771‡ | | |

**Silicon p-n-p**

*Dissipation to 10 W*

| | | |
|---|---|---|
| 2N4036 | 2N5322 | 40410 |
| 2N4037 | 40319 | 40537 |
| 2N4314 | 40362 | 40538 |
| 2N5323 | 40391* | 40595 |
| 2N5415 | 40394* | 40634 |
| 2N5416 | 40406 | |

**Germanium n-p-n**

*Dissipation to 300 mW*

| | | |
|---|---|---|
| 2N647 | 2N649 | 40396 |

**Germanium p-n-p**

*Dissipation to 30 W*

| | | |
|---|---|---|
| 2N176 | 2N1183A | 2N1906 |
| 2N351 | 2N1183B | 2N2147 |
| 2N376 | 2N1184 | 2N2148 |
| 2N407 | 2N1184A | 2N2869/ |
| 2N408 | 2N1184B | 2N301 |
| 2N1183 | 2N1905 | |

*Dissipation to 30 W (cont'd)*

| | | |
|---|---|---|
| 2N2870/ 2N301A | 40051 | 40462 |
| | 40254 | 40612 |
| 40022 | 40396 | 40623 |
| 40050 | 40421 | 40626 |

**HIGH-VOLTAGE**

**Germanium p-n-p**

| | | |
|---|---|---|
| 2N3730 | 2N3732 | 40439 |
| 2N3731 | 2N4346 | 40440 |

**Silicon n-p-n**

| | | |
|---|---|---|
| 2N2016 | 2N3773 | 2N5240‡ |
| 2N2102 | 2N3878 | 40346 |
| 2N2405 | 2N3879 | 40349‡ |
| 2N3263 | 2N4063 | 40349V1*‡ |
| 2N3264 | 2N4064 | 40349V2‡ |
| 2N3265 | 2N4068 | 40354 |
| 2N3266 | 2N4069 | 40355 |
| 2N3439 | 2N4240 | 40366● |
| 2N3440 | 2N4347‡ | 40373* |
| 2N3441‡ | 2N4348‡ | 40374* |
| 2N3442‡ | 2N4390 | 40375* |
| 2N3583 | 2N5184 | 40385● |
| 2N3584 | 2N5185 | 40390* |
| 2N3585 | 2N5239‡ | |

## Radio-Frequency Applications—Linear and Class C Operation

**SMALL SIGNAL**

**MOS FET Silicon N-Channel-Single Gate**

| | | |
|---|---|---|
| 3N128 | 3N143 | 40467A |
| 3N139 | 3N152 | 40468A |
| 3N142 | 3N154 | 40559A |

**MOS FET Silicon N-Channel-Dual Gate**

| | | |
|---|---|---|
| 3N140 | 40600 | 40603 |
| 3N141 | 40601 | 40604 |
| 3N159 | 40602 | |

**MOS FET Silicon N-Channel Protected Dual Gate**

| | | |
|---|---|---|
| 3N187 | 40819 | 40822 |
| 3N200 | 40820 | 40823 |
| 40673 | 40821 | |

* For printed-circuit-board applications.
‡ Hometaxial base type.
● High-reliability type.

**Silicon n-p-n**

*$f_T$ to 700 MHz (Typ.)*

| | | |
|---|---|---|
| 2N2102 | 2N2897 | 2N5189• |
| 2N2270 | 2N3053 | 40084 |
| 2N2405 | 2N5181 | 40354 |
| 2N2895 | 2N5182 | 40355 |
| 2N2896 | 2N5188• | 40637 |

*$f_T$ to 1200 MHz (Min.)*

| | | |
|---|---|---|
| 2N917 | 2N4935 | 40242 |
| 2N918 | 2N4936 | 40243 |
| 2N2708 | 2N5109 | 40244 |
| 2N2857 | 2N5179 | 40245 |
| 2N3478 | 2N5180 | 40246 |
| 2N3600 | 40235 | 40294• |
| 2N3839 | 40236 | 40295• |
| 2N3932 | 40237 | 40405 |
| 2N3933 | 40238 | 40413 |
| 2N4259 | 40239 | 40414 |
| 2N4934 | 40240 | 40519 |

**Germanium p-n-p**

*$f_T$ to 132 MHz (Typ.)*

| | | |
|---|---|---|
| 2N370 | 2N1180 | 2N1637 |
| 2N372 | 2N1524 | 2N1638 |
| 2N410 | 2N1525 | 2N1639 |
| 2N412 | 2N1526 | 40487 |
| 2N1177 | 2N1527 | 40488 |
| 2N1178 | 2N1631 | 40489 |
| 2N1179 | 2N1632 | |

### POWER

**Silicon n-p-n**

| | | |
|---|---|---|
| 2N1491 | 2N5102 | 40281 |
| 2N1492 | 2N5108 | 40282 |
| 2N1493 | 2N5470 | 40290 |
| 2N2631 | 2N5913 | 40291 |
| 2N2876 | 2N5914 | 40292 |
| 2N3118 | 2N5915 | 40305• |
| 2N3229 | 2N5916 | 40306• |
| 2N3375 | 2N5917 | 40307• |
| 2N3553 | 2N5918 | 40340 |
| 2N3632 | 2N5919 | 40341 |
| 2N3733 | 2N5921 | 40405 |
| 2N3866 | 2N5992 | 40446 |
| 2N4012 | 2N5993 | 40577• |
| 2N4427 | 2N5994 | 40578• |
| 2N4440 | 2N5995 | 40581 |
| 2N4932 | 2N5996 | 40582 |
| 2N4933 | 40080 | 40608 |
| 2N5016 | 40081 | 40665 |
| 2N5070 | 40082 | 40666 |
| 2N5071 | 40279• | 40675 |
| 2N5090 | 40280 | |

## SWITCHING AND PULSE APPLICATIONS
## Computer and Power

### COMPUTER—LOW LEVEL, MEDIUM-SPEED LOGIC SWITCHING

**Silicon n-p-n**

*$f_T$ to 175 MHz (Min.)*

| | | |
|---|---|---|
| 2N697 | 2N2896 | 2N3879 |
| 2N699 | 2N2897 | 2N5183 |
| 2N718A | 2N3053 | 2N5202 |
| 2N720A | 2N3241A | 2N5320 |
| 2N1613 | 2N3242A | 2N5321 |
| 2N1711 | 2N3262 | 40084 |
| 2N1893 | 2N3263 | 40375* |
| 2N2102 | 2N3264 | 40389* |
| 2N2270 | 2N3265 | 40392 |
| 2N2405 | 2N3266 | 40458 |
| 2N2895 | 2N3878 | 40459 |

**Silicon p-n-p**

*$f_T$ to 60 MHz (Min.)*

| | | |
|---|---|---|
| 2N4036 | 2N5322 | 40391* |
| 2N4037 | 2N5323 | 40394* |
| 2N4314 | | |

### HIGH-SPEED LOGIC SWITCHING

**Silicon n-p-n**

*$f_T$ to 600 MHz (Min.)*

| | | |
|---|---|---|
| 2N706 | 2N2369A | 2N3261 |
| 2N706A | 2N2475 | 2N5186 |
| 2N709 | 2N3119 | 2N5187 |
| 2N834 | | |

### HIGH-VOLTAGE SWITCHING

**Silicon p-n-p**

*$f_T$ to 600 MHz (Min.)*

| | | |
|---|---|---|
| 2N2476 | 2N3512 | 2N5189• |
| 2N2477 | 2N5188• | 2N5262 |
| 2N3261 | | |

**Germanium p-n-p**

| | | |
|---|---|---|
| 2N398 | 2N398A | 2N398B |

### LOW- AND MEDIUM-SPEED SWITCHING

**Germanium p-n-p**

*$f_T$ to 50 MHz (Min.)*

| | | |
|---|---|---|
| 2N404 | 2N1301 | 2N1307 |
| 2N404A | 2N1303 | 2N1309 |
| 2N414 | 2N1305 | 2N1683 |
| 2N1300 | | |

* For printed-circuit-board applications.
• High-reliability type.

**Germanium n-p-n**

*$f_T$ to 15 MHz (Min.)*

| | | |
|---|---|---|
| 2N388 | 2N1302 | 2N1308 |
| 2N388A | 2N1304 | 2N1605 |
| 2N585 | 2N1306 | 2N1605A |

## CHOPPER AND MULTIPLEX SERVICE

**MOS FET Silicon N-Channel-Single Gate**

| | |
|---|---|
| 3N138 | 3N153 |

### POWER—LOW SPEED SWITCHING

**Silicon n-p-n**

*Dissipations to 8.75 W*

| | | |
|---|---|---|
| 2N697 | 2N3053 | 40349‡ |
| 2N699 | 2N3262 | 40349V1*‡ |
| 2N718A | 40250V1* | 40360 |
| 2N720A | 40309 | 40361 |
| 2N1479‡ | 40311 | 40366• |
| 2N1480‡ | 40314 | 40367• |
| 2N1481‡ | 40315 | 40372* |
| 2N1482‡ | 40317 | 40374* |
| 2N1613 | 40320 | 40375* |
| 2N1700‡ | 40321 | 40385 |
| 2N1711 | 40323 | 40389* |
| 2N1893 | 40326 | 40390* |
| 2N2102 | 40327 | 40392 |
| 2N2270 | 40346V1* | 40407 |
| 2N2405 | 40347* | 40408 |
| 2N2895 | 40347V1*‡ | 40409* |
| 2N2896 | 40348‡ | 40412V1* |
| 2N2897 | 40348V1*‡ | |

*Dissipations above 8.75 W to 50 W*

| | | |
|---|---|---|
| 2N1483‡ | 2N5293*‡ | 40312 |
| 2N1484‡ | 2N5294‡ | 40313 |
| 2N1485‡ | 2N5295*‡ | 40316 |
| 2N1486‡ | 2N5296‡ | 40318 |
| 2N1701‡ | 2N5297*‡ | 40322 |
| 2N3054‡ | 2N5298‡ | 40324 |
| 2N3439 | 2N5490*‡ | 40328 |
| 2N3440 | 2N5491‡ | 40346 |
| 2N3441‡ | 2N5492*‡ | 40346V2 |
| 2N3583 | 2N5493‡ | 40347V2‡ |
| 2N3584 | 2N5494*‡ | 40348V2‡ |
| 2N3585 | 2N5495‡ | 40349V2‡ |
| 2N3878 | 2N5496*‡ | 40364 |
| 2N3879 | 2N5497‡ | 40368• |
| 2N4063 | 40250‡ | 40412 |
| 2N4064 | 40310 | 40412V2 |
| 2N4240 | | |

*Dissipations above 50 W to 150 W*

| | | |
|---|---|---|
| 2N1487‡ | 2N3771‡ | 2N5577‡ |
| 2N1488‡ | 2N3772‡ | 2N5578‡ |
| 2N1489‡ | 2N3773‡ | 2N5579‡ |
| 2N1490‡ | 2N4347‡ | 2N5580‡ |
| 2N1702‡ | 2N4348‡ | 2N6032 |
| 2N2015 | 2N5034‡ | 2N6033 |
| 2N2016 | 2N5035*‡ | 40251‡ |
| 2N2338‡ | 2N5036‡ | 40325 |
| 2N3055‡ | 2N5037*‡ | 40363 |
| 2N3263 | 2N5038 | 40369‡• |
| 2N3264 | 2N5039‡ | 40411‡ |
| 2N3265 | 2N5240‡ | 40513*‡ |
| 2N3266 | 2N5575‡ | 40514‡ |
| 2N3442‡ | 2N5576‡ | |

**Silicon p-n-p**

*Dissipations to 7 W*

| | | |
|---|---|---|
| 40319 | 40391* | 40406 |
| 40362 | 40394* | 40410* |

**Germanium p-n-p**

*Dissipation to 30 W*

| | | |
|---|---|---|
| 2N1905 | 2N1183A | 2N1184A |
| 2N1906 | 2N1183B | 2N1184B |
| 2N1183 | 2N1184 | |

### HIGH-VOLTAGE SWITCHING

**Silicon n-p-n**

*Collector-to-Emitter Voltage to 350 V (max.)*

| | | |
|---|---|---|
| 2N3439 | 2N4347‡ | 40346V2 |
| 2N3440 | 2N4348‡ | 40349‡ |
| 2N3441‡ | 2N4390 | 40349V1*‡ |
| 2N3442‡ | 2N5239‡ | 40349V2‡ |
| 2N3583 | 2N5240‡ | 40354 |
| 2N3584 | 2N5804 | 40373* |
| 2N3585 | 2N5805 | 40374* |
| 2N3773 | 2N5838 | 40385• |
| 2N4063 | 2N5839 | 40390* |
| 2N4064 | 2N5840 | 40412 |
| 2N4068 | 40346 | 40412V1* |
| 2N4069 | 40346V1* | 40412V2 |
| 2N4240 | | |

**Silicon p-n-p**

*Collector-to-Emitter Sustaining Voltage to —300 V (max.)*

| | |
|---|---|
| 2N5415 | 2N5416 |

* For printed-circuit-board applications.
‡ Hometaxial base type.
• High-reliability type.

# THYRISTORS

## TRIACS

*Low-Voltage Operation 50 & 60 Hz*

| | | |
|---|---|---|
| 2N5754 | 40534 | 40696 |
| 40525 | 40684 | 40766 |
| 40528 | 40693 | 40767 |
| 40531 | | |

*120-V Line Operation 50 & 60 Hz*

| | | |
|---|---|---|
| 2N5441 | 40535 | 40711 |
| 2N5567 | 40575 | 40713 |
| 2N5569 | 40638 | 40715 |
| 2N5571 | 40660 | 40717 |
| 2N5573 | 40662 | 40719 |
| 2N5755 | 40668 | 40721 |
| 40429 | 40685 | 40725 |
| 40431 | 40688 | 40727 |
| 40485 | 40691 | 40729 |
| 40502 | 40694 | 40731 |
| 40509 | 40697 | 40733 |
| 40511 | 40699 | 40761 |
| 40526 | 40702 | 40799 |
| 40529 | 40705 | 40802 |
| 40532 | 40707 | 40805 |

*240-V Line Operation 50 & 60 Hz*

| | | |
|---|---|---|
| 2N5442 | 40576 | 40712 |
| 2N5445 | 40639 | 40714 |
| 2N5568 | 40661 | 40716 |
| 2N5570 | 40663 | 40718 |
| 2N5572 | 40664 | 40720 |
| 2N5574 | 40667 | 40722 |
| 2N5756 | 40669 | 40723 |
| 40430 | 40686 | 40724 |
| 40432 | 40689 | 40726 |
| 40486 | 40692 | 40728 |
| 40503 | 40695 | 40730 |
| 40510 | 40698 | 40732 |
| 40512 | 40700 | 40734 |
| 40527 | 40703 | 40762 |
| 40530 | 40706 | 40800 |
| 40533 | 40708 | 40803 |
| 40536 | | |

*High-Voltage Operation 50 & 60 Hz*

| | | |
|---|---|---|
| 2N5443 | 40690 | 40796 |
| 2N5446 | 40701 | 40797 |
| 2N5757 | 40704 | 40798 |
| 40611 | 40709 | 40801 |
| 40672 | 40710 | 40804 |
| 40687 | 40795 | 40807 |

*400 Hz Service $V_{DROM}$ = 200 V*

| | | |
|---|---|---|
| 40769 | 40775 | 40781 |
| 40771 | 40777 | 40783 |
| 40773 | 40779 | 40785 |

*400 Hz Service $V_{DROM}$ = 400 V*

| | | |
|---|---|---|
| 40770 | 40776 | 40782 |
| 40772 | 40778 | 40784 |
| 40774 | 40780 | 40786 |

## SILICON CONTROLLED RECTIFIERS

*Low-Voltage Operation 50 & 60 Hz*

| | | |
|---|---|---|
| 2N681 | 2N1845A | 40741 |
| 2N682 | 2N3650 | 40745 |
| 2N683 | 2N3668 | 40749 |
| 2N684 | 2N3870 | 40753 |
| 2N1842A | 2N3897 | 40757 |
| 2N1843A | 40680 | 40810 |
| 2N1844A | 40737 | |

*120-V Line Operation 50 & 60 Hz*

| | | |
|---|---|---|
| 2N685 | 40378 | 40738 |
| 2N1846A | 40504 | 40742 |
| 2N3228 | 40507 | 40746 |
| 2N3528 | 40553 | 40750 |
| 2N3651 | 40654 | 40754 |
| 2N3669 | 40656 | 40758 |
| 2N3871 | 40658 | 40811 |
| 2N3897 | 40681 | |

*240-V Line Operation 50 & 60 Hz*

| | | |
|---|---|---|
| 2N688 | 40379 | 40739 |
| 2N1849A | 40505 | 40743 |
| 2N3525 | 40508 | 40747 |
| 2N3529 | 40554 | 40751 |
| 2N3653 | 40655 | 40755 |
| 2N3670 | 40657 | 40759 |
| 2N3872 | 40659 | 40812 |
| 2N3898 | 40682 | |

*High-Voltage Operation 50 & 60 Hz*

| | | |
|---|---|---|
| 2N686 | 2N4101 | 40735 |
| 2N687 | 2N4102 | 40740 |
| 2N689 | 2N4103 | 40744 |
| 2N690 | 40216 | 40748 |
| 2N1847A | 40506 | 40752 |
| 2N1848A | 40555 | 40756 |
| 2N1850A | 40640 | 40760 |
| 2N3652 | 40641 | 40813 |
| 2N3873 | 40683 | |

# RECTIFIERS

## SILICON RECTIFIERS—LOW POWER

*$I_{F(AV)}$ to 2A*

| | | |
|---|---|---|
| 1N440B | 1N2859A | 1N3755 |
| 1N441B | 1N2860A | 1N3756 |
| 1N442B | 1N2861A | 1N5211 |
| 1N443B | 1N2862A | 1N5212 |
| 1N444B | 1N2863A | 1N5213 |
| 1N445B | 1N2864A | 1N5214 |
| 1N536 | 1N3193 | 1N5215 |
| 1N537 | 1N3194 | 1N5216 |
| 1N538 | 1N3195 | 1N5217 |
| 1N539 | 1N3196 | 1N5218 |
| 1N540 | 1N3253 | 40265 |
| 1N547 | 1N3254 | 40266 |
| 1N1095 | 1N3255 | 40267 |
| 1N1763A | 1N3256 | 40642 |
| 1N1764A | 1N3563 | 40643 |
| 1N2858A | 1N3754 | 40644 |

## SILICON RECTIFIERS—HIGH POWER

*$I_{F(AV)}$ 12 A to 40 A*

| | | |
|---|---|---|
| 1N248C | 1N1203A | 40109 |
| 1N249C | 1N1204A | 40110 |
| 1N250C | 1N1205A | 40111 |
| 1N1183A | 1N1206A | 40112 |
| 1N1184A | 1N1341B | 40113 |
| 1N1186A | 1N1342B | 40114 |
| 1N1187A | 1N1344B | 40115 |
| 1N1188A | 1N1345B | 40208 |
| 1N1189A | 1N1346B | 40209 |
| 1N1190A | 1N1347B | 40210 |
| 1N1195A | 1N1348B | 40211 |
| 1N1196A | 1N1612 | 40212 |
| 1N1197A | 1N1613 | 40213 |
| 1N1198A | 1N1614 | 40214 |
| 1N1199A | 1N1615 | |
| 1N1200A | 1N1616 | |
| 1N1202A | 40108 | |

## HIGH-VOLTAGE RECTIFIER ASSEMBLIES

| | | |
|---|---|---|
| CR101 | CR301 | CR323 |
| CR102 | CR302 | CR324 |
| CR103 | CR303 | CR325 |
| CR104 | CR304 | CR331 |
| CR105 | CR305 | CR332 |
| CR106 | CR306 | CR333 |
| CR107 | CR307 | CR334 |
| CR108 | CR311 | CR335 |
| CR109 | CR312 | CR341 |
| CR110 | CR313 | CR342 |
| CR201 | CR314 | CR343 |
| CR203 | CR315 | CR344 |
| CR204 | CR316 | CR351 |
| CR206 | CR317 | CR352 |
| CR208 | CR321 | CR353 |
| CR210 | CR322 | CR354 |
| CR212 | | |

## BRIDGE RECTIFIERS

**Single-phase, full-wave**

| | | |
|---|---|---|
| CR401 | CR404 | CR407 |
| CR402 | CR405 | CR408 |
| CR403 | CR406 | CR409 |

**Three-phase, full-wave**

| | | |
|---|---|---|
| CR501 | CR503 | CR505 |
| CR502 | CR504 | CR506 |

## DIACS

### FOR TRIGGERING TRIACS

1N5411 40583

# DIODES

## DAMPER DIODES

1N4785 40442

## COMPENSATING DIODES

1N2326 40428

# Interpretation of Data

THE technical data for RCA solid-state devices included in the following sections are grouped according to product types. Ratings, characteristics, typical operation values, and characteristic curves for all current RCA signal bipolar transistors, low- and medium-frequency power transistors, rf power transistors, MOS field-effect transistors, thyristors, and certain special diodes are presented in display format. Ratings and characteristics data for RCA silicon rectifiers are presented in easy-to-read quick-reference charts to facilitate comparison and selection of individual types. Tabular data are also provided on discontinued RCA transistors and thyristors for use in the selection of suitable replacement types. Unless otherwise specified, the voltages and currents indicated in these data are dc values, and values are obtained at an ambient temperature of 25°C.

Ratings are established for solid-state devices to help equipment designers use the performance and service capabilities of each type to the best advantage. The ratings are based on careful study and extensive testing; they indicate limits within which the specified characteristic must be maintained to assure satisfactory performance. The maximum ratings given for the solid-state devices listed in this Manual are based on the **Absolute Maximum System.** This system has been defined by the Joint Electron Device Engineering Council (JEDEC) and standardized by the National Electrical Manufacturers Association (NEMA) and the Electronic Industries Association (EIA).

**Absolute-maximum ratings** are limiting values of operating and environmental conditions which should not be exceeded by any device of a specified type under any condition of operation. Effective use of these ratings requires close control of supply-voltage variations, component variations, equipment-control adjustment, load variations, signal variations, and environmental conditions.

Voltage and current ratings for solid-state devices, in general, are self-explanatory; a brief explanation of some ratings, however, will aid in the understanding and interpretation of device data.

**Voltage ratings** are established with reference to a specified electrode (e.g., collector-to-emitter voltage) and indicate the maximum potential that can be placed across the two specified electrodes before crystal breakdown occurs. These ratings are specified for particular conditions (e.g., with the third electrode open, or with specific bias voltages or external resistances for transistors).

**Transistor dissipation** is the power dissipated in the form of heat by the device. It is the difference between the input power supplied to the device and the power delivered to the load. Because of the sensitivity of semiconductor materials to variations in thermal conditions, maximum dissipation ratings are usually given for specific temperature conditions.

In many cases, dissipation ratings for solid-state devices are specified for ambient, case, or mounting-flange temperatures up to 25°C and must be reduced linearly for operation of the devices at higher temperatures. (A typical derating curve for bipolar transistors and instructions for use of this curve to determine maximum permissible dissipation values for particular temperatures above 25°C are shown on page 300.)

Solid-state devices require close control of thermal variations not only during operation, but also during storage. For this reason, the maximum ratings for such devices usually include a maximum permissible storage temperature, as well as a maximum operating temperature.

Characteristics of solid-state devices are discussed in detail in the sections that provide the basic descriptions of these devices. Such data should be interpreted in accordance with the definitions given in those sections. Characteristic curves represent the characteristics of an average device. Individual solid-state devices, like any manufactured product, may have characteristics that range above or below the values given in the characteristic curves. Although some curves are extended beyond the maximum rating of the device, this extension has been made only for convenience in calculation; no solid-state device should be operated outside of its maximum ratings.

The technical data for RCA solid-state devices are presented in seven major sections. These major sections are listed below, and a location marker is shown in the margin opposite each section heading. Similar markers are shown on the right-hand pages in each technical-data section in the same location as the respective markers on this page.

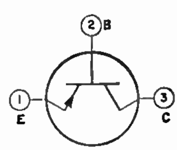
# Technical Data for Small-Signal Bipolar Transistors

THIS section contains detailed technical data for all current RCA small-signal bipolar transistors. These data are presented in three major functional groupings to identify types used most frequently in audio-frequency, radio-frequency, and switching applications. Within each grouping, the transistors are listed in order of ascending power-dissipation ratings.

In selection of devices for use in new electronic equipment, a prospective user should refer to the appropriate section of the Selection Guide included earlier in the Manual. For the reader who requires data on specific types, a complete numerical-alphabetical-numerical index to all current RCA solid-state devices is provided immediately following the Circuits Section in the back of the Manual.

## *Audio-Frequency Types*

### 2N591 0.085W




Ge p-n-p alloy-junction type used in large-signal af driver applications in class A stages of automobile radio receivers. JEDEC TO-1, Outline No.1.

#### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −32 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | −32 | V |
| Collector Current | $I_C$ | −40 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 55°C | $P_T$ | 85 | mW |
| $T_C$ up to 55°C | $P_T$ | 200 | mW |
| $T_A$ or $T_C$ above 55°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Ambient) | $T_A$(opr) | 71 | °C |
| Storage | $T_{STG}$ | −65 to 85 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

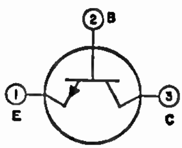
#### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-Cutoff Current ($V_{CB}$ = −10 V, $I_E$ = 0) | $I_{CBO}$ | −7 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −1 V, $I_C$ = 0) | $I_{EBO}$ | −20 max | μA |

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = −0.05 mA, $I_B$ = 0) | $V_{(BR)CBO}$ | −32 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = −0.3 mA, $I_B$ = 0) | $V_{(BR)CEX}$ | −32 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.05 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | −12 min | V |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −12 V, $I_C$ = −2 V, f = 1 kHz) | $h_{fe}$ | 40 to 120 | |
| Thermal Resistance: | | | |
| Junction-to-Ambient | $\theta_{J-A}$ | 353 max | °C/W |
| Junction-to-Case | $\theta_{J-C}$ | 150 max | °C/W |

## 0.1W 2N647




Ge **n-p-n** alloy-junction type used in large-signal af-amplifier applications in battery-operated portable radio receivers and phonograhs. N-P-N construction permits complementary push-pull operation with a matching p-n-p type, such as the 2N217. JEDEC TO-1, Outline No.1.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 25 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 25 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 12 | V |
| Collector Current | $I_C$ | 100 | mA |
| Emitter Current | $I_E$ | −100 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 100 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Ambient) | $T_A$(opr) | −65 to 71 | °C |
| Storage | $T_{STG}$ | −65 to 85 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

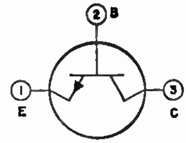
### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.05 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 25 min | V |
| Collector-to-Emitter Breakdown Voltage ($V_{ER}$ = 5 V, $I_C$ = 0.014 mA) | $V_{(BR)CEV}$ | 25 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.014 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 12 min | V |
| Collector-Cutoff Current ($V_{CB}$ = 25 V, $I_E$ = 0) | $I_{CBO}$ | 14 max | µA |
| Emitter-Cutoff Current ($V_{EB}$ = 12 V, $I_C$ = 0) | $I_{EBO}$ | 14 max | µA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 1 V, $I_C$ = 50 mA) | $h_{FE}$ | 50 to 150 | |
| Gain Bandwidth Product ($V_{CE}$ = 6 V, $I_C$ = 2 mA) | $f_T$ | 2 | MHz |
| Intrinsic Base-Spreading Resistance ($V_{CE}$ = 6 V, $I_C$ = 2 mA) | $r_{bb}'$ | 350 max | Ω |

### TYPICAL OPERATION IN CLASS B COMPLEMENTARY-SYMMETRY CIRCUIT

| | | | |
|---|---|---|---|
| DC Collector-Supply Voltage | $V_{CC}$ | 6 | V |
| DC Collector-to-Emitter Voltage for driver stage | $V_{CE}$ | 2.3 | V |
| Zero-Signal DC Base-to-Emitter Voltage for output stage | $V_{BE}$ | 0.14 | V |
| Peak Collector Current for each transistor in output stage | $i_c$(peak) | 70 | mA |
| Zero-Signal DC Collector Current for each transistor (driver and output stage) | $I_C$ | 1.5 | mA |
| Signal Frequency | | 1 | kHz |
| Input Resistance | $R_S$ | 1100 | Ω |
| Load Resistance | $R_L$ | 45 | Ω |
| Power Gain | | 54 | dB |
| Total Harmonic Distortion | | 10 | % |
| Power Output (input = 20 mV) | $P_{OE}$ | 100 | mW |

# 2N649 0.1W




Ge **n-p-n** alloy-junction type used in large-signal af-amplifier applications in battery-operated portable radio receivers and phonographs. N-P-N construction permits complementary push-pull operation with a matching p-n-p type, such as the 2N408. JEDEC TO-1, Outline No.1.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 20 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 18 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2.5 | V |
| Collector Current | $I_C$ | 100 | mA |
| Emitter Current | $I_E$ | −100 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 100 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Ambient) | $T_A$(opr) | −65 to 71 | °C |
| Storage | $T_{STG}$ | −65 to 85 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

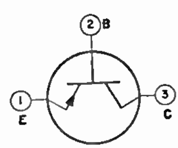
## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.05 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 20 min | V |
| Collector-to-Emitter Breakdown Voltage ($V_{EB}$ = 2 V, $I_C$ = 0.05 mA) | $V_{(BR)CEV}$ | 18 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.014 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 2.5 min | V |
| Collector-Cutoff Current ($V_{CB}$ = 12 V, $I_E$ = 0) | $I_{CBO}$ | 14 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 2.5 V, $I_C$ = 0) | $I_{EBO}$ | 14 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 1 V, $I_C$ = 50 mA) | $h_{FE}$ | 50 to 150 | |
| Gain-Bandwidth Product ($V_{CE}$ = 6 V, $I_C$ = 2 mA) | $f_T$ | 2 | MHz |
| Intrinsic Base-Spreading Resistance ($V_{CE}$ = 6 V, $I_C$ = 2 mA) | $r_{bb}$ | 350 max | Ω |

## TYPICAL OPERATION IN CLASS B COMPLEMENTARY-SYMMETRY CIRCUIT

| | | | |
|---|---|---|---|
| DC Collector Supply Voltage | $V_{CC}$ | 6 | V |
| DC Collector-to-Emitter Voltage for driver stage | $V_{CE}$ | 2.3 | V |
| Zero-Signal DC Base-to-Emitter Voltage for output stage | $V_{BE}$ | 0.14 | V |
| Peak Collector Current for each transistor in output stage | $i_C$(peak) | 70 | mA |
| Zero-Signal DC Collector Current for each transistor (driver and output stage) | $I_C$ | 1.5 | mA |
| Signal Frequency | | 1 | kHz |
| Input Resistance | $R_S$ | 1100 | Ω |
| Load Resistance | $R_L$ | 45 | Ω |
| Power Gain | | 54 | dB |
| Total Harmonic Distortion ($P_{oe}$ = 100 mW) | | 10 max | % |
| Power Output (input = 20 mV) | $P_{OE}$ | 100 | mW |

# 2N2614 0.12W



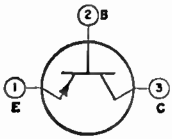

Ge **p-n-p** alloy-junction type used in small-signal and low-power audio frequency applications. JEDEC TO-1, Outline No.1.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −40 | V |
| Collector-to-Emitter Voltage ($R_{BE}$ = 10 kΩ) | $V_{CER}$ | −35 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −25 | V |
| Collector Current | $I_C$ | −50 | mA |
| Emitter Current | $I_E$ | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 55°C | $P_T$ | 120 | mW |
| $T_C$ up to 55°C | $P_T$ | 300 | mW |
| $T_A$ or $T_C$ above 55°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 100 | °C |
| Storage | $T_{STG}$ | −65 to 100 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = −0.05 mA, $V_{BE}$ = 2 V) | $V_{(BR)CBV}$ | −40 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = −1 mA, $R_{BE}$ = 10 kΩ) | $V_{(BR)CER}$ | −35 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −0.05 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | −25 min | V |
| Collector-Cutoff Current ($V_{CB}$ = −20 V, $I_E$ = 0) | $I_{CBO}$ | −5 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −20 V, $I_C$ = 0) | $I_{EBO}$ | −7.5 max | μA |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −6 V, $I_C$ = −1 mA, f = 1 kHz) | $h_{fe}$ | 100 to 250 | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CE}$ = −6 V, $I_C$ = −1 mA) | $f_{hfe}$ | 4 min | MHz |
| Collector-to-Base Feedback Capacitance ($V_{CE}$ = −6 V, $I_C$ = −1 mA) | $c_{b'c}$ | 12 max | pF |
| Intrinsic Base-Spreading Resistance ($V_{CE}$ = −6 V, $I_C$ = −1 mA, f = 20 MHz) | $r_{bb'}$ | 300 | Ω |




0.12W

# 2N2953

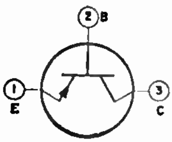
Ge p-n-p alloy-junction type used in af-driver amplifier applications in consumer and industrial equipment. JEDEC TO-1, Outline No.1.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −30 | V |
| Collector-to-Emitter Voltage ($R_{BE}$ = 10 kΩ) | $V_{CER}$ | −25 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 25 | V |
| Collector Current | $I_C$ | −0.15 | A |
| Emitter Current | $I_E$ | 0.15 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 55°C | $P_T$ | 120 | mW |
| $T_C$ up to 55°C (in an infinite heat sink) | $P_T$ | 300 | mW |
| $T_C$ up to 55°C (with practical heat sink, θ = 50°C/W) | $P_T$ | 225 | mW |
| $T_A$ or $T_C$ (with practical heat sink) above 55°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 100 | °C |
| Storage | $T_{STG}$ | −65 to 100 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = −0.05 A, $V_{EB}$ = −2 V) | $V_{(BR)CBV}$ | −30 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = −1 mA, $R_{BE}$ = 10 kΩ) | $V_{(BR)CER}$ | −25 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −0.05 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | −25 min | V |
| Collector-Cutoff Current ($V_{CB}$ = −20 V, $I_E$ = 0) | $I_{CBO}$ | −5 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −20 V, $I_C$ = 0) | $I_{EBO}$ | −7.5 max | μA |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −10 V, $I_C$ = −10 mA, f = 1 kHz) | $h_{fe}$ | 200 min | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CE}$ = −12 V, $I_C$ = −1 mA) | $f_{hfb}$ | 10 | MHz |
| Intrinsic Base-Spreading Resistance ($V_{CE}$ = −10 V, $I_C$ = −10 mA, f = 20 MHz) | $r_{bb'}$ | 300 | Ω |
| Collector-to-Base Feedback Capacitance ($V_{CE}$ = −12 V, $I_C$ = −1 mA) | $c_{b'c}$ | 6.5 | pF |




0.12W

# 40329

Ge p-n-p alloy type for low-level, intermediate-level, and class A driver stages in consumer and industrial af-amplifier equipment such as preamplifiers, tone-control stages, and phonograph amplifiers using crystal pickups. JEDEC TO-1, Outline No.1.

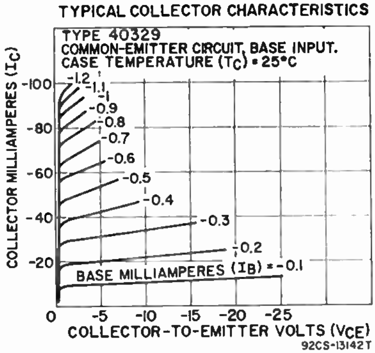
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −25 | V |
| Collector-to-Emitter Voltage ($R_{BE}$ ≦ 4700 Ω) | $V_{CER}$ | −25 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −2.5 | V |
| Collector Current | $I_C$ | −100 | mA |
| Emitter Current | $I_E$ | 100 | mA |
| Base Current | $I_B$ | −20 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 55°C (With infinite heat sink) | $P_T$ | 375 | mW |
| $T_A$ up to 55°C (With practical heat sink, θ = 50°C/W) | $P_T$ | 265 | mW |
| $T_A$ up to 55°C (Without heat sink) | $P_T$ | 125 | mW |
| $T_A$ with and without heat sink above 55°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 100 | °C |
| Storage | $T_{STG}$ | −65 to 100 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

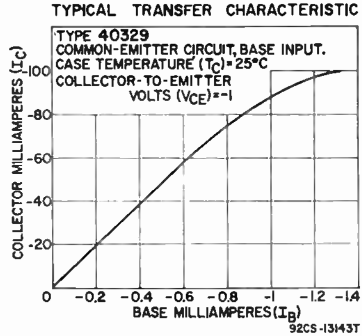
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = −0.05 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | −25 min | V |
| Collector-to-Emitter Breakdown Voltage ($R_{BE}$ = 4700 Ω, $I_C$ = −1 mA) | $V_{(BR)CER}$ | −25 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −0.05 mA) | $V_{(BR)EBO}$ | −2.5 min | V |
| Collector-Cutoff Current ($V_{CB}$ = −12 V, $I_E$ = 0) | $I_{CBO}$ | −14 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −2 V, $I_C$ = 0) | $I_{EBO}$ | −14 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −1 V, $I_C$ = −25 mA) | $h_{FE}$ | 50 to 200 | |
| Small-Signal Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = −10 V, $I_C$ = −10 mA, f = 1 kHz | $h_{fe}$ | 75 to 300 | |
| $V_{CE}$ = − V, $I_C$ = −1 mA, f = 1 kHz | $h_{fe}$ | 50 to 200 | |
| Small-Signal Forward-Current Transfer Ratio Cutoff Frequency ($V_{CB}$ = −6 V, $I_C$ = 1 mA) | $f_{hfb}$ | 1.5 | MHz |
| Output Capacitance ($V_{CB}$ = −6 V, f = 1 kHz) | $C_{obo}$ | 35 | pF |
| Small-Signal Input Impedance ($V_{CE}$ = −10 V, $I_C$ = −10 mA, f = 1 kHz) | $h_{ie}$ | 400 | Ω |
| Small-Signal Output Admittance ($V_{CE}$ = −10 V, $I_C$ = −10 mA, f = 1 kHz) | $h_{oe}$ | 175 | μmhos |
| Small-Signal Reverse Voltage-Transfer Ratio ($V_{CE}$ = −10 V, $I_C$ = −10 mA, f = 1 kHz) | $h_{re}$ | 300 x $10^{-6}$ | |
| Equivalent RMS Noise Input Current ($V_{CE}$ = −6 V, $I_C$ = −0.5 mA, f = 20 Hz to 20 kHz) | | 0.02 max | μA |
| Intrinsic Base-Spreading Resistance ($V_{CE}$ = −6 V, $I_C$ = −1 mA, f = 20 MHz) | $r_{bb'}$ | 100 | Ω |

TYPICAL COLLECTOR CHARACTERISTICS

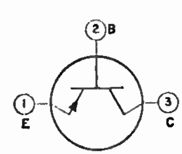



TYPICAL TRANSFER CHARACTERISTIC




# 40359

**0.12W**



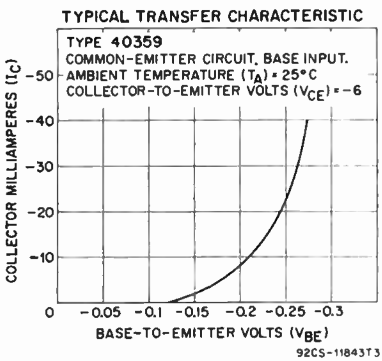

Ge p-n-p alloy-junction type used in af-amplifier applications in consumer product and industrial equipment. JEDEC TO-1, Outline No.1.

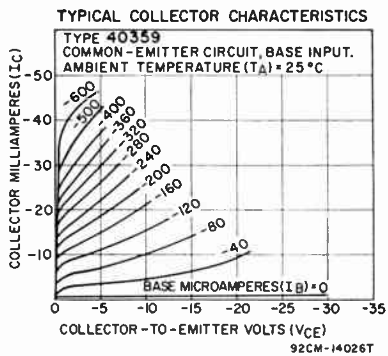
## MAXIMUM RATINGS

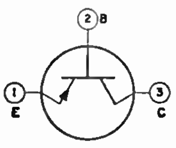
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −20 | V |
| Collector-to-Emitter Voltage ($R_{BE}$ ≤ 10000 Ω) | $V_{CER}$ | −18 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −2.5 | V |
| Collector Current | $I_C$ | −50 | mA |
| Emitter Current | $I_E$ | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 55°C | $P_T$ | 120 | mW |
| $T_A$ above 55°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating | $T_A$ | −65 to 100 | °C |
| Storage | $T_{STG}$ | −65 to 100 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($R_{BE}$ = 10 kΩ, $I_C$ = −1 mA) | $V_{(BR)CER}$ | −18 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −0.05 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 2.5 min | V |
| Collector-Cutoff Current ($V_{CB}$ = −15 V, $I_E$ = 0) | $I_{CBO}$ | −12 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 2.5 V, $I_C$ = 0) | $I_{EBO}$ | −12 max | μA |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −6 V, $I_C$ = −1 mA, f = 1 kHz) | $h_{fe}$ | 40 to 165 | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CE}$ = −6 V, $I_C$ = −1 mA) | $f_{hfb}$ | 10 | MHz |
| Intrinsic Base-Spreading Resistance ($V_{CE}$ = −6 V, $I_C$ = −1 mA, f = 100 MHz) | $r_{bb}'$ | 200 | Ω |




**0.12W** **40395**

Ge p-n-p alloy-junction type used in high-gain low-level audio stages. JEDEC TO-1, Outline No.1.

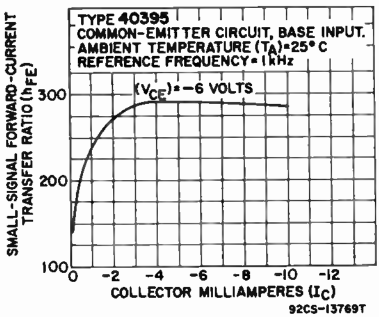
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −20 | V |
| Collector-to-Emitter Voltage ($R_{BE}$ ≦ 4.7 kΩ) | $V_{CER}$ | −18 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −20 | V |
| Collector Current | $I_C$ | −50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 55°C | $P_T$ | 120 | mW |
| $T_A$ above 55°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 100 | °C |
| Storage | $T_{STG}$ | −65 to 100 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($I_C = -1$ mA, $I_B = 0$, $R_{BE} = 10$ kΩ) | $V_{(BR)CER}$ | −18 min | V |
| Collector-Cutoff Current ($V_{CB} = -20$ V, $I_E = 0$) | $I_{CBO}$ | −12 max | µA |
| Emitter-Cutoff Current ($V_{EB} = 20$ V, $I_C = 0$) | $I_{EBO}$ | −12 max | µA |
| Noise Current ($V_{CE} = -6$ V, $I_C = -1$ mA, f = 0.05 to 15 kHz) | | 10 max | nA |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE} = -6$ V, $I_C = -1$ mA) | $h_{fe}$ | 170 min | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CB} = -6$ V, $I_C = -1$ mA) | $f_{hfb}$ | 10 | MHz |

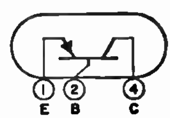
TYPICAL SMALL-SIGNAL FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTIC




# 2N405

**0.15W**

Ge p-n-p alloy-junction type used in low-power class A af-amplifier applications in battery-operated portable radio-receivers. JEDEC TO-40, Outline No.16.




### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −20 | V |
| Collector Current | $I_C$ | −35 | mA |
| Emitter Current | $I_E$ | 35 | mA |
| Transistor Dissipation: $T_A = 25$°C | $P_T$ | 150 | mW |
| Temperature Range: Operating (Ambient) | $T_A$ (opr) | −65 to 71 | °C |

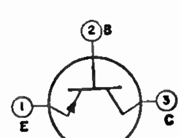
### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-Cutoff Current | $I_{CBO}$ | −14 max | µA |
| Static Forward-Current Transfer Ratio ($V_{CB} = -6$ V, $I_E = 1$ mA) | $h_{FE}$ | 35 min | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CB} = -6$ V, $I_C = -1$ mA) | $f_{hfb}$ | 650 | kHz |
| Output Capacitance | $C_{obo}$ | 40 | pF |
| Power Gain | $G_{pe}$ | 43 | dB |

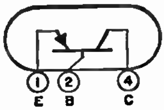
# 2N406

**0.15W**

Ge p-n-p alloy-junction type used in low-power class A af-amplifier applications in battery-operated portable radio receivers. JEDEC TO-1, Outline No.1. This type is electrically identical with type 2N405.



## 0.15W 2N407




Ge p-n-p alloy-junction type used in class A amplifiers and class B push-pull output stages of battery-operated radio receivers and af amplifiers. JEDEC TO-40, Outline No.16.

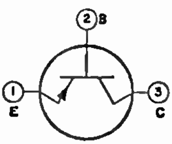
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | –20 | V |
| Collector Current | $I_C$ | –70 | mA |
| Emitter Current | $I_E$ | 70 | mA |
| Transistor Dissipation: | | | |
| $T_A$ = 25°C | $P_T$ | 150 | mW |
| Temperature Range: | | | |
| Operating (Ambient) | $T_A$(opr) | –65 to 71 | °C |

### CHARACTERISTICS

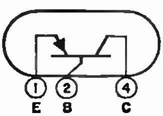
| | | | |
|---|---|---|---|
| Collector-Cutoff Current ($V_{CB}$ = –12 V, $I_E$ = 0) | $I_{CBO}$ | –14 max | µA |
| Emitter-Cutoff Current ($V_{EB}$ = –2.5 V, $I_C$ = 0) | $I_{EBO}$ | –14 max | µA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = –1 V, $I_C$ = –50 mA) | $h_{FE}$ | 65 | |
| Power Gain (f = 0.001 MHz) | $G_{pe}$ | 33 | dB |
| Total Harmonic Distortion ($P_{oe}$ = 0.16 W) | THD | 10 max | % |

## 0.15W 2N408




Ge p-n-p alloy-junction type used in class A amplifiers and class B push-pull output stages of battery-operated radio receivers and af amplifiers. JEDEC TO-1, Outline No.1. This type is electrically identical with type 2N407.

## 0.165W 2N109




Ge p-n-p alloy-junction type used in low-power, small-signal and large-signal audio applications in consumer-product equipment. JEDEC TO-40, Outline No.16.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | –35 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | –25 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | –12 | V |
| Collector Current | $I_C$ | –150 | mA |
| Transistor Dissipation: | | | |
| $T_A$ = 25°C | $P_T$ | 165 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | –65 to 71 | °C |
| Storage | $T_{STG}$ | –65 to 85 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

### CHARACTERISTICS

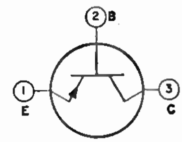
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = –50 µA, $I_E$ = 0) | $V_{(BR)CBO}$ | –35 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = –1 mA, $I_B$ = 0) | $V_{(BR)CEO}$ | –25 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = –7 µA, $I_C$ = 0) | $V_{(BR)EBO}$ | –12 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = –50 mA, $I_B$ = –5 mA) | $V_{CE}$ (sat) | –0.15 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = –1 V, $I_C$ = –50 mA) | $V_{BE}$ | 0.2 to 0.4 | V |
| Collector-Cutoff Current ($V_{CB}$ = –30 V, $I_E$ = 0) | $I_{CBO}$ | –14 max | µA |
| Emitter-Cutoff Current ($V_{EB}$ = –12 V, $I_C$ = 0) | $I_{EBO}$ | –7 max | µA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = –1 V, $I_C$ = –50 mA) | $h_{FE}$ | 75 min | |
| Power Gain▲ (f = 0.001 MHz) | $G_{pe}$ | 33 | dB |

### CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Total Harmonic Distortion▲ ($P_{oe}$ = 0.16 W) | THD | 10 max | % |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −6 V, $I_E$ = −1 mA, f = 1 kHz) | $h_{fe}$ | 50 to 150 | |
| Small-Signal Input Impedance ($V_{CE}$ = −6 V, $I_E$ = −1 mA, f = 1 kHz) | $h_{ie}$ | 1000 to 4000 | Ω |
| Output Capacitance ($V_{CB}$ = −6 V, $I_C$ = −1 mA, f = 0.5 MHz) | $C_{obo}$ | 20 to 60 | pF |

▲ This characteristic does not apply to type 2N217.

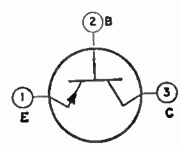
## 2N217 0.165W



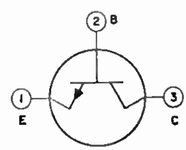
Ge p-n-p alloy-junction type used in low-power, small-signal and large-signal audio applications in consumer-product equipment. JEDEC TO-1, Outline No.1. This type is electrically identical with type 2N109 except for the following items:

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-Cutoff Current ($V_{CB}$ = −30 V, $I_E$ = 0) | $I_{CBO}$ | −7 | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −1 V, $I_C$ = −50 mA) | $h_{FE}$ | 65 to 120 | |



## 40396 0.3W (Matched Pair)



Ge p-n-p and Ge n-p-n types, in separate packages, with matched characteristics for use in complementary symmetry af output-amplifier stages. JEDEC TO-1, Outline No.1.

### MAXIMUM RATINGS

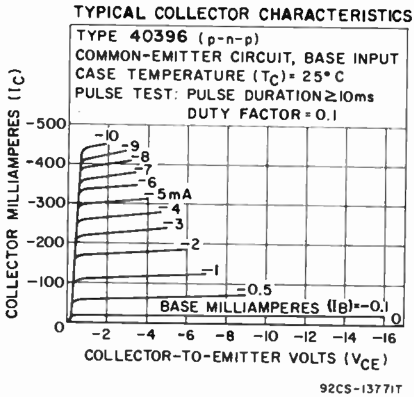
| | | p-n-p | n-p-n | |
|---|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −18 | 18 | V |
| Collector-to-Emitter Voltage ($R_{BE}$ ≦ 4.7 kΩ) | $V_{CER}$ | −18 | 18 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −2.5 | 2.5 | V |
| | | p-n-p | n-p-n | |
| Collector Current | $I_C$ | −500 | 500 | mA |
| Transistor Dissipation: | | | | |
| $T_C$ up to 55°C | $P_T$ | 300 | 300 | mW |
| $T_C$ above 55°C | $P_T$ | See curve page 300 | | |
| Temperature Range: | | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 85 | | °C |
| Storage | $T_{STG}$ | −65 to 85 | | °C |
| Lead-Soldering Temperature | $T_L$ | 255 | 255 | °C |

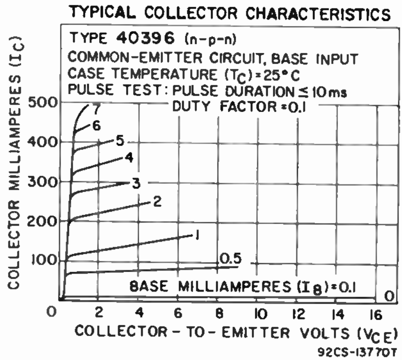
### CHARACTERISTICS

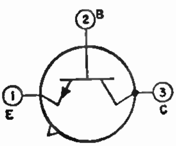
| | | p-n-p | n-p-n | |
|---|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage: | | | | |
| $I_C$ = −1 mA, $R_{BE}$ = 4.7 kΩ | $V_{(BR)CER}$ | −18 min | | V |
| $I_C$ = 1 mA, $R_{BE}$ = 4.7 kΩ | $V_{(BR)CER}$ | | 18 min | V |
| Collector-to-Emitter Saturation Voltage: | | | | |
| $I_C$ = −250 mA, $I_B$ = −25 mA | $V_{CE}$(sat) | −0.5 max | | V |
| $I_C$ = 250 mA, $I_B$ = 25 mA | $V_{CE}$(sat) | | 0.5 max | V |
| Collector-Cutoff Current: | | | | |
| $V_{CB}$ = −12 V, $I_E$ = 0 | $I_{CBO}$ | −14 max | | μA |
| $V_{CB}$ = 12 V, $I_E$ = 0 | $I_{CBO}$ | | 14 max | μA |
| Emitter-Cutoff Current: | | | | |
| $V_{EB}$ = −2.5 V, $I_C$ = 0 | $I_{EBO}$ | −14 max | | μA |
| $V_{EB}$ = 2.5 V, $I_C$ = 0 | $I_{EBO}$ | | 14 max | μA |

## CHARACTERISTICS (cont'd)

| | | | | |
|---|---|---|---|---|
| Static Forward-Current Transfer Ratio: | | | | |
| $V_{CE}$ = −1 V, $I_C$ = −50 mA | $h_{FE}$ | 50 min | 50 min | |
| $V_{CE}$ = 1 V, $I_C$ = 50 mA | $h_{FE}$ | | | |
| $V_{CE}$ = −1 V, $I_C$ = −250 mA | $h_{FE}$ | 30 min | | |
| $V_{CE}$ = 1 V, $I_C$ = 250 mA | $h_{FE}$ | | 30 min | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency: | | | | |
| $V_{CE}$ = −6 V, $I_C$ = −1 mA | $f_{hfb}$ | 1.5 | | MHz |
| $V_{CE}$ = 6 V, $I_C$ = 1 mA | $f_{hfb}$ | | 2 | MHz |




## 0.5W 2N3241A

Si n-p-n epitaxial planar type used in high-voltage, high-current audio and video amplifier and switching service in commercial, industrial, and computer equipment. JEDEC TO-104, Outline No.32.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 30 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1 V | $V_{CEV}$ | 25 | V |
| Base open | $V_{CEO}$ | 25 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7.5 | V |
| Collector Current | $I_C$ | Limited by dissipation | |
| Transistor Dissipation: | | | |
| $T_C$ up to 75°C | $P_T$ | 2 | W |
| $T_C$ above 75°C | $P_T$ | See curve page 300 | |
| $T_A$ up to 25°C | $P_T$ | 0.5 | W |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$ (opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

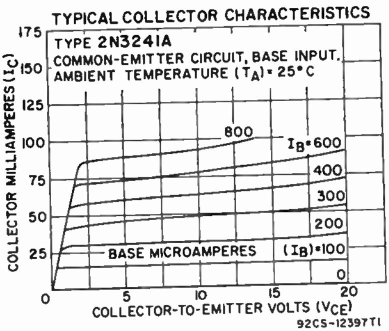
## CHARACTERISTICS

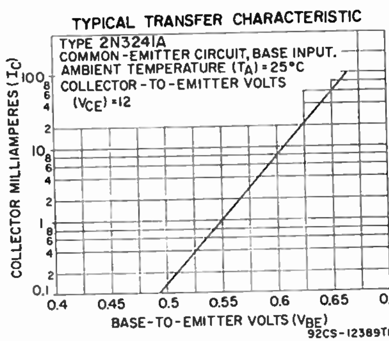
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.05 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 30 min | V |
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_C$ = 10 mA, $I_B$ = 0 | $V_{(BR)CBO}$ | 25 min | V |
| $V_{BE}$ = −1 V, $I_C$ = 0.01 mA | $V_{(BR)CEV}$ | 25 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.05 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 7.5 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 200 mA, $I_B$ = 10 mA) | $V_{CE}$(sat) | 0.22 typ; 0.25 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 200 mA, $I_B$ = 10 mA) | $V_{BE}$(sat) | 0.88 typ; 1.25 max | V |

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 25 V, $I_E$ = 0 | $I_{CBO}$ | 100 max | nA |
| $V_{CB}$ = 25 V, $I_E$ = 0, $T_A$ = 150°C | $I_{CBO}$ | 10 max | µA |
| Emitter-Cutoff Current ($V_{BE}$ = 2.5 V, $I_C$ = 0) | $I_{EBO}$ | 100 max | nA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 10 mA) | $h_{FE}$ | 100 to 200 | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{fe}$ | 100 to 250 | |
| Magnitude of Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 12 V, $I_C$ = 1 mA, f = 100 MHz) | $\|h_{fe}\|$ | 0.5 min; 1 typ | |
| Gain-Bandwidth Product ($V_{CE}$ = 10 V, $I_C$ = 10 mA, f = 50 MHz) | $f_T$ | 175 | MHz |
| Collector-to-Base Feedback Capacitance* ($V_{CB}$ = 6 V, $I_E$ = 0, f = 1 MHz) | $C_{cb}$ | 20 max | pF |
| Intrinsic Base-Spreading Resistance ($V_{CE}$ = 6 V, $I_C$ = 1 mA, f = 100 MHz) | $r_{bb'}$ | 20 | Ω |
| Noise Figure: | | | |
| $V_{CE}$ = 6 V, $I_C$ = 0.1 mA, f = 10 kHz, $R_G$ = 1000 Ω, circuit bandwidth = 1 Hz | NF | 2.5 | dB |
| $V_{CE}$ = 6 V, $I_C$ = 0.5 mA, f = 1 kHz, $R_G$ = 1000 Ω, circuit bandwidth = 1 Hz | NF | 8 typ; 10 max | dB |
| Small-Signal Input Impedance ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{ie}$ | 200 to 1000 | Ω |
| Small-Signal Output Admittance ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{oe}$ | 30 to 350 | µmhos |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 50 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 300 max | °C/W |

* Emitter terminal guarded.

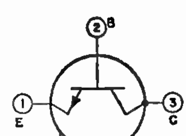



# 2N3242A

**0.5W**

Si n-p-n epitaxial planar type used in high-voltage, high-current audio and video amplifier and switching service in commercial, industrial, and computer equipment. JEDEC TO-104, Outline No.32. For collector-characteristics and transfer-characteristics curves, refer to type 2N3241A.



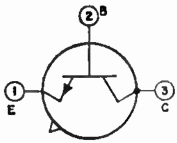

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 40 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1 V | $V_{CEV}$ | 40 | V |
| Base open | $V_{CEO}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 8 | V |
| Collector Current | $I_C$ | Limited by dissipation | |
| Transistor Dissipation: | | | |
| $T_C$ up to 75°C | $P_T$ | 2 | W |
| $T_C$ above 75°C | $P_T$ | See curve page 300 | |
| $T_A$ up to 25°C | $P_T$ | 0.5 | W |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 40 min | V |
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_C$ = 10 mA, $I_B$ = 0 | $V_{(BR)CEO}$ | 40 min | V |
| $V_{BE}$ = –1 V, $I_C$ = 0.01 mA | $V_{(BR)CEV}$ | 40 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.05 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 8 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 300 mA, $I_B$ = 15 mA) | $V_{CE}$(sat) | 0.24 typ; 0.3 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 300 mA, $I_B$ = 15 mA) | $V_{BE}$(sat) | 0.93 typ; 1.5 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 25 V, $I_E$ = 0 | $I_{CBO}$ | 10 max | nA |
| $V_{CB}$ = 25 V, $I_E$ = 0, $T_A$ = 150 °C | $I_{CBO}$ | 1 max | µA |
| Emitter-Cutoff Current ($V_{BE}$ = 2.5 V, $I_C$ = 0) | $I_{EBO}$ | 10 max | nA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 10 mA) | $h_{FE}$ | 125 to 300 | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{fe}$ | 125 to 375 | |
| Magnitude of Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 6 V, $I_C$ = 1 mA, f = 100 MHz) | $\|h_{fe}\|$ | 0.5 min; 1 typ | |
| Gain-Bandwidth Product ($V_{CE}$ = 10 V, $I_C$ = 10 mA, f = 50 MHz) | $f_t$ | 175 | MHz |
| Collector-to-Base Feedback Capacitance* ($V_{CB}$ = 6 V, $I_E$ = 0, f = 1 MHz) | $C_{cb}$ | 20 max | pF |
| Intrinsic Base-Spreading Resistance ($V_{CE}$ = 6 V, $I_C$ = 1 mA, f = 100 MHz) | $r_{bb'}$ | 20 | Ω |
| Noise Figure: | | | |
| $V_{CE}$ = 6 V, $I_C$ = 0.1 mA, f = 10 kHz, $R_G$ = 1000 Ω, circuit bandwidth = 1 Hz | NF | 2 | dB |
| $V_{CE}$ = 6 V, $I_C$ = 0.5 mA, f = 1 kHz, $R_G$ = 1000 Ω, circuit bandwidth = 1 Hz | NF | 4 typ; 6 max | dB |
| Small-Signal Input Impedance ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{ie}$ | 250 to 1500 | Ω |
| Small-Signal Output Admittance ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{oe}$ | 30 to 350 | µmhos |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 50 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 300 max | °C/W |

* Emitter terminal guarded.




## 0.5W 2N4074

Si n-p-n epitaxial planar type used in high-voltage, high-current audio and video amplifier service in commercal and industrial equipment. JEDEC TO-104, Outline No.32.

## MAXIMUM RATINGS

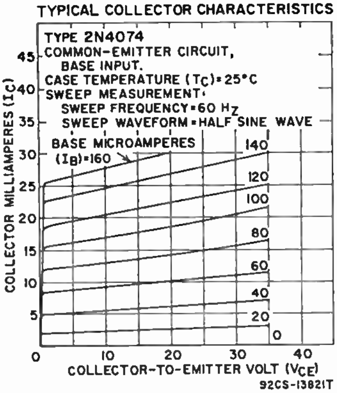
| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = –1 V | $V_{CEV}$ | 40 | V |
| Base open | $V_{CEO}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 8 | V |
| Collector Current | $I_C$ | 300 | mA |
| Emitter Current | $I_E$ | –300 | mA |
| Transistor Dissipation: | | | |
| $T_C$ up to 75°C | $P_T$ | 2 | W |
| $T_C$ above 75°C | $P_T$ | See curve page 300 | |
| $T_A$ up to 25°C | $P_T$ | 0.5 | W |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | –65 to 175 | °C |
| Storage | $T_{STG}$ | –65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

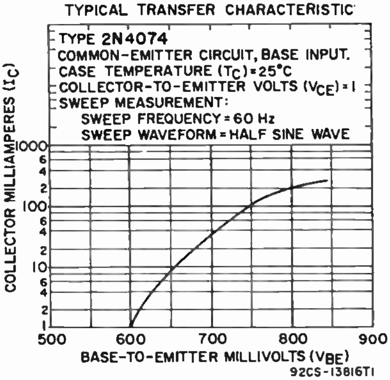
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 10 mA, $I_B$ = 0) | $V_{(BR)CEO}$ | 40 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.05 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 8 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 300 mA, $I_B$ = 15 mA) | $V_{CE}$(sat) | 0.22 typ; 0.3 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 300 mA, $I_B$ = 15 mA) | $V_{BE}$(sat) | 1 typ; 1.5 max | V |

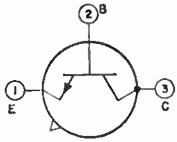
## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 25 V, $I_E$ = 0 | $I_{CBO}$ | 10 max | nA |
| $V_{CB}$ = 25 V, $I_E$ = 0, $T_C$ = 85°C | $I_{CBO}$ | 1 max | µA |
| $V_{CE}$ = 40 V, $V_{BE}$ = 1 V | $I_{CEV}$ | 10 max | µA |
| Emitter-Cutoff Current ($V_{BE}$ = −2.5 V, $I_C$ = 0) | $I_{EBO}$ | 10 max | nA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 6 V, $I_C$ = 0.5 mA | $h_{FE}$ | 35 min; 75 typ | |
| $V_{CE}$ = 10 V, $I_C$ = 10 mA | $h_{FE}$ | 75 to 300 | |
| $V_{CE}$ = 1 V, $I_C$ = 100 mA | $h_{FE}$ | 50 min; 140 typ | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{fe}$ | 75 min; 175 typ | |
| Gain-Bandwidth Product ($V_{CE}$ = 6 V, $I_C$ = 1 mA, f = 100 MHz) | $f_T$ | 50 min; 80 typ | MHz |
| Intrinsic Base-Spreading Resistance ($V_{CE}$ = 6 V, $I_C$ = 1 mA, f = 100 MHz) | $r_{bb'}$ | 20 typ; 40 max | Ω |
| Output Capacitance ($V_{CB}$ = 6 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 12 typ; 20 max | pF |
| Small-Signal Input Impedance ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{ie}$ | 600 | Ω |
| Small-Signal Output Admittance ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{oe}$ | 75 | µmhos |
| Small-Signal Reverse-Voltage Transfer Ratio ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{re}$ | 125 x $10^{-6}$ | |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 50 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 300 max | °C/W |




# 2N4390 0.5W




Si **n-p-n** type used for direct "on-off" control of high-voltage, low-power devices such as numerical display tubes and relays, and for other control applications in industrial equipment. JEDEC TO-104, Outline No.32.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 120 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 6 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 120 | V |
| Collector Current | $I_C$ | Limited by dissipation | |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 500 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating ($T_A$) and Storage ($T_{STG}$) | | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

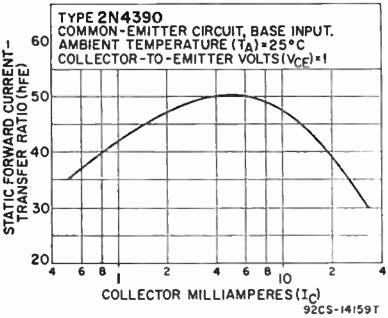
## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 120 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 1 mA, $I_B$ = 0) | $V_{(BR)CEO}$ | 120 min | V |

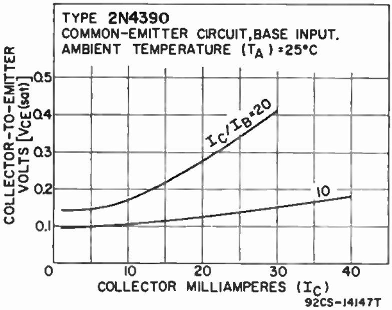
## CHARACTERISTICS (cont'd)

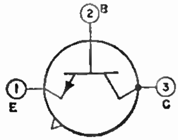
| | | | |
|---|---|---|---|
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 6 min | V |
| Collector-to-Emitter Saturation Voltage: | | | |
| $I_C$ = 20 mA, $I_B$ = 2 mA | $V_{CE}$(sat) | 0.3 max | V |
| $I_C$ = 2 mA, $I_B$ = 0.2 mA | $V_{CE}$(sat) | 0.2 max | V |
| Base-to-Emitter Voltage: | | | |
| $I_C$ = 20 mA, $I_B$ = 2 mA | $V_{BE}$ | 0.85 max | V |
| $I_C$ = 2 mA, $I_B$ = 0.2 mA | $V_{BE}$ | 0.75 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 70 V, $V_{EB}$ = 1 V) | $I_{CEV}$ | 1 max | μA |
| Base-Cutoff Current ($V_{CE}$ = 70 V, $V_{EB}$ = 1 V) | $I_{BEV}$ | 1 max | μA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 1 V, $I_C$ = 2 mA | $h_{FE}$ | 20 min | |
| $V_{CE}$ = 1 V, $I_C$ = 20 mA | $h_{FE}$ | 20 min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 20 mA, f = 4 MHz) | $h_{fe}$ | 12.5 min | |
| Feedback Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0, f = 1 MHz) | $C_{cb}$ | 6 max | pF |
| Input Capacitance ($V_{EB}$ = 0.5 V, $I_E$ = 0, f = 1 MHz) | $C_{ibo}$ | 40 max | pF |
| Delay Time ($V_{CC}$ = 3.4 V, $V_{BE}$(off) = 1.5 V, $I_{B1}$ = 2 mA, $I_{CS}$ = 20 mA) | $t_d$ | 150 max | ns |
| Rise Time ($V_{CC}$ = 3.4 V, $V_{BE}$(off) = 1.5 V, $I_{B1}$ = 2 mA, $I_{CS}$ = 20 mA) | $t_r$ | 500 max | ns |
| Storage Time ($V_{CC}$ = 3.4 V, $I_{B1}$ = 2 mA, $I_{CS}$ = 20 mA, $I_{B2}$ = −2 mA) | $t_s$ | 800 max | ns |
| Fall Time ($V_{CC}$ = 3.4 V, $I_{B1}$ = 2 mA, $I_{CS}$ = 20 mA, $I_{B2}$ = −2 mA) | $t_f$ | 500 max | ns |

TYPICAL DC FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTICS




TYPICAL COLLECTOR CHARACTERISTICS




**0.5W**

# 2N5183

Si n-p-n double-diffused epitaxial planar type used for general-purpose applications in amplifier and computer equipment. JEDEC TO-104, Outline No.32.

## MAXIMUM RATINGS

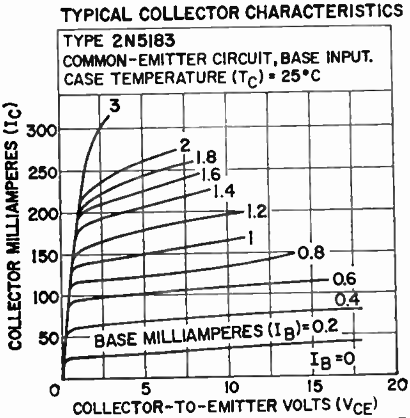
| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage | $V_{CEO}$ | 18 | V |
| Collector-to-Base Voltage | $V_{CBO}$ | 18 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.5 | W |
| $T_A$ above 25°C | $P_T$ | Derate at 3.3 | mW/°C |
| $T_C$ up to 75°C | $P_T$ | 2 | W |
| $T_C$ above 75°C | $P_T$ | Derate at 20 | mW/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

## CHARACTERISTICS

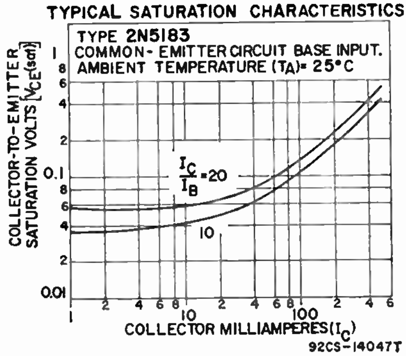
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA) | $V_{(BR)CBO}$ | 18 min | V |
| Emitter-to-Base Breakdown Votlage ($I_E$ = 0.05 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 7 min | V |
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 10 mA, $I_B$ = 0) | $V_{CEO}$(sus) | 18 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 300 mA, $I_B$ = 15 mA) | $V_{CE}$(sat) | 0.35 typ; 0.5 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 300 mA, $I_B$ = 15 mA) | $V_{BE}$(sat) | 0.05 typ; 1.5 max | V |
| Collector-Cutoff Current ($V_{CB}$ = 12 V, $I_E$ = 0) | $I_{CBO}$ | 500 max | nA |
| Emitter-Cutoff Current ($V_{EB}$ = 2.5 V, $I_C$ = 0) | $I_{EBO}$ | 500 max | nA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CB}$ = 10 V, $I_C$ = 10 mA | $h_{FE}$ | 75 to 400 | |
| $V_{CB}$ = 10 V, $I_C$ = 150 mA | $h_{FE}$ | 120 | |
| $V_{CB}$ = 1 V, $I_C$ = 300 mA | $h_{FE}$ | 40 min; 75 typ | |
| Magnitude of Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $\|h_{fe}\|$ | 70 min; 175 typ | |
| Small-Signal Input Impedance ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{ie}$ | 600 | Ω |
| Small-Signal Output Admittance ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{oe}$ | 75 | mmho |
| Small-Signal Reverse-Voltage Transfer Ratio ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{re}$ | $125 \times 10^{-6}$ | |
| Collector-to-Base Feedback Capacitance* ($V_{CB}$ = 6 V, $I_E$ = 0, f = 1 MHz) | $C_{cb}$ | 20 max | pF |
| Gain-Bandwidth Product ($V_{CE}$ = 1 V, $I_C$ = 50 MHz, f = 50 MHz) | $f_T$ | 125 min; 200 typ | MHz |
| Intrinsic Base-Spreading Resistance ($V_{CE}$ = 6 V, $I_C$ = 1 mA, f = 100 MHz) | $r_{bb'}$ | 20 | Ω |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 50 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 300 max | °C/W |

* Three-terminal measurement: Lead No. 1 (emitter) connected to guard terminal.

TYPICAL COLLECTOR CHARACTERISTICS



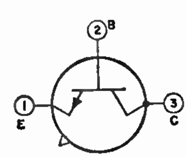

TYPICAL SATURATION CHARACTERISTICS




# 2N5184

**0.5W**

Si **n-p-n** type used in video-output-amplifier applications in black-and-white television receivers, and control applications in industrial equipment. JEDEC TO-104, Outline No.32.

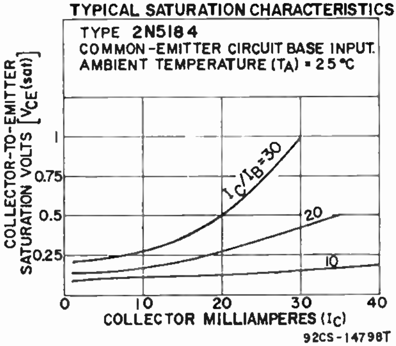


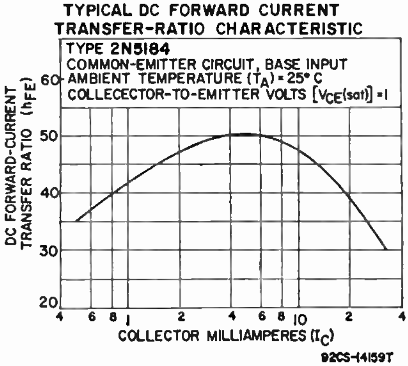
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage | $V_{CEO}$ | 120 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.5 | W |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

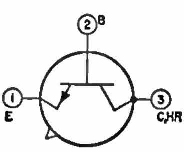
## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 1 mA, $I_B$ = 0) | $V_{(BR)CEO}$ | 120 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −10 μA, $I_C$ = 0) | $V_{(BR)EBO}$ | 5 min; 7 typ | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 30 mA, $I_B$ = 1 mA) | $V_{CE}$(sat) | 1 typ; 5 max | V |
| Collector-Cutoff Current ($V_{CB}$ = 120 V, $I_E$ = 0) | $I_{CBO}$ | 100 max | nA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 50 mA) | $h_{FE}$ | 10 min; 55 max | |
| Collector-to-Base Feedback Capacitance ($V_{CE}$ = 10 V, $I_C$ = 30 mA, f = 1 MHz) | $C_{cb}$ | 2.8 typ; 3.5 max | pF |
| Gain-Bandwidth Product: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 45 mA | $f_T$ | 30 min; 100 typ | MHz |
| $V_{CE}$ = 120 V, $I_C$ = 2 mA | $f_T$ | 50 min; 100 typ | MHz |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 45 typ; 60 max | °C/W |



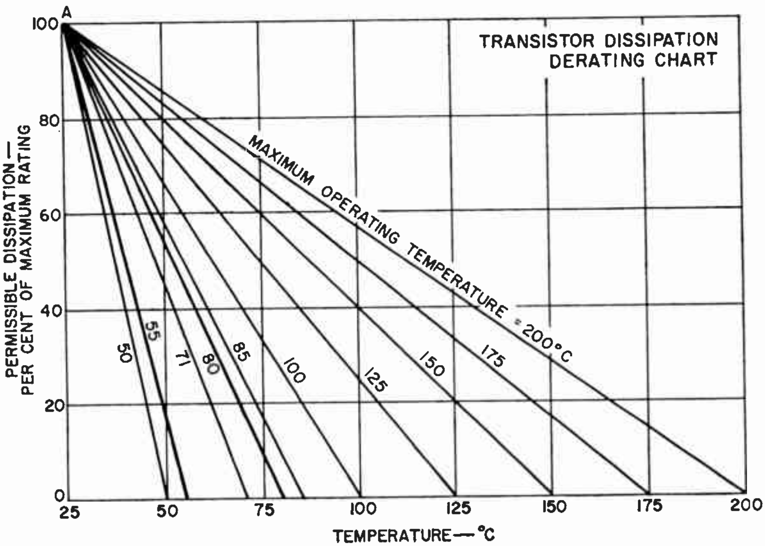

## 0.5W 2N5185




Si n-p-n type used in video-output-amplifier applications in black-and-white television receivers, and control applications in industrial equipment. JEDEC TO-104 (with radiator), Outline No.33. This type is identical with type 2N5184 except for the following item:

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |




For many transistors, the maximum value of dissipation is specified for ambient, case, or mounting-flange temperatures up to 25°C, and must be reduced linearly for higher temperatures. For such types, the chart above can be used to determine maximum permissible dissipation values at particular temperature conditions above 25°C. (This chart cannot be assumed to apply to types other than those for which it is specified in the data section.) The curves show the permissible percentage of the maximum dissipation ratings as a function of ambient or case temperature. Individual curves are plotted for maximum operating temperatures of 50, 55, 71, 80, 85, 100, 125, 150, 175, and 200°C. If the maximum operating temperature of a transistor is some other value, a new curve can be drawn from point A in the figure to the desired temperature value on the abscissa.

To use the chart, it is necessary to know the maximum dissipation rating and the maximum operating temperature for a given transistor. The calculation involves only two steps:

1. A vertical line is drawn at the desired operating temperature value on the abscissa to intersect the curve representing the maximum operating temperature for the transistor.

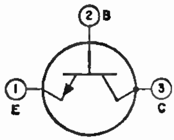
2. A horizontal line drawn from this intersection point to the ordinate establishes the permissible percentage of the maximum dissipation at the given temperature.

The following example illustrates the calculation of the maximum permissible dissipation for transistor type 2N1487 at a case temperature of 100°C. This type has a maximum dissipation rating of 75 watts at a case temperature of 25°C, and a maximum permissible case-temperature rating of 200°C.

1. A perpendicular line is drawn from the 100-degree point on the abscissa to the 200-degree curve.

2. Projection of this point to the ordinate shows a percentage of 57.5.

Therefore, the maximum permissible dissipation for the 2N1487 at a case temperature of 100°C is 0.575 times 75, or approximately 43 watts.




## 0.5W 40231

Si **n-p-n planar** type used in low-to-intermediate-signal-level af amplifier circuits, such as preamplifiers, "voltage amplifiers", and driver stages in consumer and industrial equipment. JEDEC TO-104, Outline No.32.

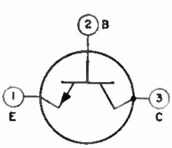
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 18 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 18 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 100 | mA |
| Emitter Current | $I_E$ | −100 | mA |
| Base Current | $I_B$ | 25 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.5 | W |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| $T_C$ up to 125°C | $P_T$ | 1 | W |
| $T_C$ above 125°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 50 μA, $I_E$ = 0) | $V_{(BR)CBO}$ | 18 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 10 mA, $I_B$ = 0) | $V_{(BR)CEO}$ | 18 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 50 μA, $I_C$ = 0) | $V_{(BR)EBO}$ | 5 min | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 12 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | 0.5 max | μA |
| $V_{CB}$ = 12 V, $I_E$ = 0, $T_A$ = 85°C | $I_{CBO}$ | 10 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 2.5 V, $I_C$ = 0) | $I_{EBO}$ | 0.5 max | μA |
| Small-Signal Forward-Current Transfer Ratio ($I_C$ = 2 mA, $V_{CE}$ = 10 V, f = 1 kHz) | $h_{fe}$ | 55 to 180 | |
| Gain-Bandwidth Product ($V_{CE}$ = 6 V, $I_C$ = 1 mA) | $f_T$ | 60 | MHz |
| Intrinsic Base-Spreading Resistance ($V_{CE}$ = 6 V, $I_C$ = 1 mA, f = 100 MHz) | $r_{bb'}$ | 20 | Ω |
| Output Capacitance ($V_{CB}$ = 6 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 22 | pF |
| Noise Figure ($R_G$ = 1000 Ω, $V_{CE}$ = 6 V, $I_C$ = 0.1 mA, circuit bandwidth = 1 Hz, f = 10 kHz) | NF | 2.8 | dB |
| Thermal Resistance, Junction-to-Case ($T_J$ = 175°C) | $\Theta_{J-C}$ | 50 max | °C/W |
| Thermal Resistance, Junction-to-Ambient ($T_J$ = 175°C) | $\Theta_{J-A}$ | 300 max | °C/W |

## 0.5W 40232

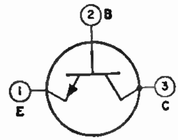



Si **n-p-n planar** type used in low-to-intermediate-signal-level af amplifier circuits, such as preamplifiers, "voltage amplifiers", and driver stages in consumer and industrial equipment. JEDEC TO-104, Outline No.32. This type is identical with type 40231 except for the following item:

### CHARACTERISTICS

| | | |
|---|---|---|
| Small-Signal Forward-Current Transfer Ratio ($I_C$ = 2 mA, $V_{CE}$ = 10 V, f = 1 kHz) | $h_{fe}$ | 90 to 300 |

# 40233 0.5W

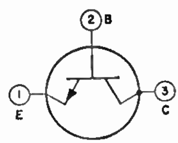



Si n-p-n planar type used in low-to-intermediate-signal-level af amplifier circuits, such as preamplifiers, "voltage amplifiers", and driver stages in consumer and industrial equipment. JEDEC TO-104, Outline No.32. This type is identical with type 40231 except for the following items:

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-Cutoff Current ($V_{CB}$ = 12 V, $I_E$ = 0, $T_A$ = 25°C) | $I_{CBO}$ | 0.25 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 2.5 V, $I_C$ = 0) | $I_{EBO}$ | 0.25 max | μA |
| Small-Signal Forward-Current Transfer Ratio ($I_C$ = 2 mA, $V_{CE}$ = 10 V, f = 1 kHz) | $h_{fe}$ | 90 to 300 | |
| Noise Figure: | | | |
| $R_G$ = 1000 Ω, $V_{CE}$ = 6 V, $I_C$ = 0.1 mA, circuit bandwidth = 1 Hz, f = 10 kHz | NF | 2 | dB |
| $R_G$ = 1000 Ω, $V_{CE}$ = 6 V, $I_C$ = 0.5 mA, circuit bandwidth = 1 Hz, f = 1 kHz | NF | 6 max | dB |

# 40234 0.5W




Si n-p-n planar type used in low-to-intermediate-signal-level af amplifier circuits, such as preamplifiers, "voltage amplifiers", and driver stages in consumer and industrial equipment. JEDEC TO-104, Outline No.32. This type is identical with type 40231 except for the following items:

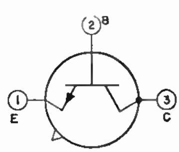
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_A$ up to 55°C | $P_T$ | 0.4 | W |
| $T_A$ above 55°C | $P_T$ | See curve page 300 | |
| $T_A$ up to 125°C | $P_T$ | 1 | W |
| $T_C$ above 125°C | $P_T$ | See curve page 300 | |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage ($I_C$ = 50 mA, $I_B$ = 5 mA) | $V_{CE}$(sat) | 0.2 | V |
| Small-Signal Forward-Current Transfer Ratio ($I_C$ = 2 mA, $V_{CE}$ = 10 V, f = 1 kHz) | $h_{fe}$ | 35 to 180 | |

# 40397 0.5W



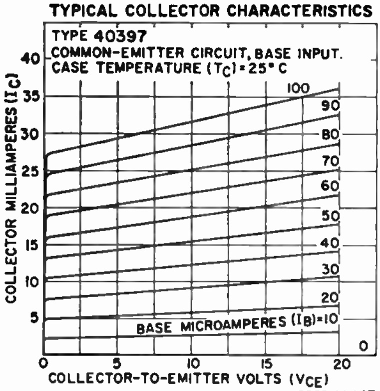

Si n-p-n epitaxial planar type used in high-voltage, high-current audio and video amplifier service in commercial and industrial equipment. JEDEC TO-104, Outline No.32.

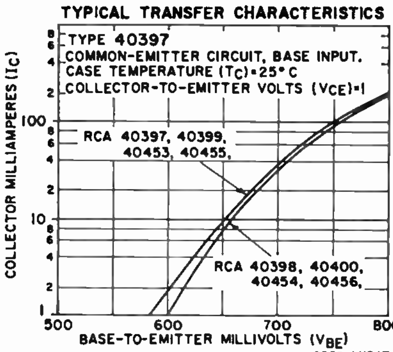
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage: | | | |
| Base open | $V_{CEO}$ | 25 | V |
| $V_{BE}$ = −1 V | $V_{CEV}$ | 25 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7.5 | V |
| Collector Current | $I_C$ | 200 | mA |
| Emitter Current | $I_E$ | −200 | mA |
| Base Current | $I_B$ | 25 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.5 | W |
| $T_C$ up to 75°C | $P_T$ | 2 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

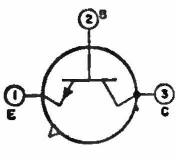
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 10 mA, $I_B$ = 0) | $V_{(BR)CEO}$ | 25 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.05 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 7.5 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 200 mA, $I_B$ = 10 mA) | $V_{CE}$(sat) | 0.15 typ; 0.25 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 200 mA, $I_B$ = 10 mA) | $V_{BE}$(sat) | 0.8 typ; 1.3 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 25 V, $I_E$ = 0 | $I_{CBO}$ | 100 max | nA |
| $V_{CB}$ = 25 V, $I_E$ = 0, $T_C$ = 85°C | $I_{CBO}$ | 5 max | μA |
| $V_{CE}$ = 25 V, $V_{BE}$ = −1 V | $I_{CEV}$ | 10 max | μA |
| Emitter-Cutoff Current ($V_{BE}$ = −2.5 V, $I_C$ = 0) | $I_{EBO}$ | 100 max | nA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 6 V, $I_C$ = 0.5 mA | $h_{FE}$ | 20 min; 175 typ | |
| $V_{CE}$ = 10 V, $I_C$ = 10 mA | $h_{FE}$ | 165 to 600 | |
| $V_{CE}$ = 1 V, $I_C$ = 100 mA | $h_{FE}$ | 100 min; 245 typ | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{fe}$ | 165 min; 375 typ | |
| Gain-Bandwidth Product ($V_{CE}$ = 6 V, $I_C$ = 1 mA, f = 100 MHz) | $f_T$ | 50 min; 80 typ | MHz |
| Intrinsic Base-Spreading Resistance ($V_{CE}$ = 6 V, $I_C$ = 1 mA, f = 100 MHz) | $r_{bb'}$ | 20 typ; 40 max | Ω |
| Output Capacitance ($V_{CB}$ = 6 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 12 typ; 20 max | pF |
| Small-Signal Input Impedance ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{ie}$ | 1200 | Ω |
| Small-Signal Output Admittance ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{oe}$ | 120 | μmhos |
| Small-Signal Reverse-Voltage Transfer Ratio ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{re}$ | $250 \times 10^{-6}$ | |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 50 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 300 max | °C/W |



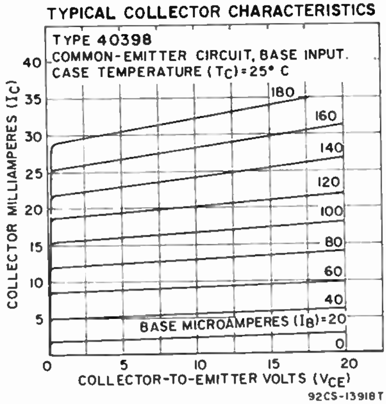

## 0.5W 40398

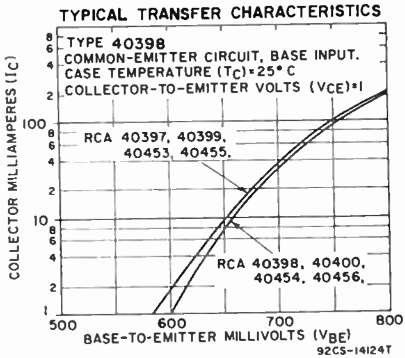



Si n-p-n epitaxial planar type used in high-voltage, high-current audio and video amplifier service in commercial and industrial equipment. JEDEC TO-104, Outline No.32. This type is identical with type 40397 except for the following items:

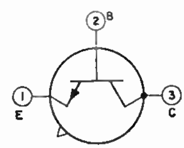
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 6 V, $I_C$ = 0.5 mA | $h_{FE}$ | 20 min; 75 typ | |
| $V_{CE}$ = 10 V, $I_C$ = 10 mA | $h_{FE}$ | 75 to 300 | |
| $V_{CE}$ = 1 V, $I_C$ = 100 mA | $h_{FE}$ | 50 min; 140 typ | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{fe}$ | 75 min; 200 typ | |
| Small-Signal Input Impedance ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{ie}$ | 600 | Ω |
| Small-Signal Output Admittance ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{oe}$ | 75 | μmhos |
| Small-Signal Reverse-Voltage Transfer Ratio ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{re}$ | $125 \times 10^{-6}$ | |




# 40399 0.5W




Si n-p-n epitaxial planar type used in high-voltage, high-current audio and video amplifier service in commercial and industrial equipment. JEDEC TO-104, Outline No.32.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage: | | | |
| Base open | $V_{CEO}$ | 18 | V |
| $V_{BE}$ = −1 V | $V_{CEV}$ | 18 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 200 | mA |
| Emitter Current | $I_E$ | −200 | mA |
| Base Current | $I_B$ | 25 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.5 | W |
| $T_C$ up to 75°C | $P_T$ | 2 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

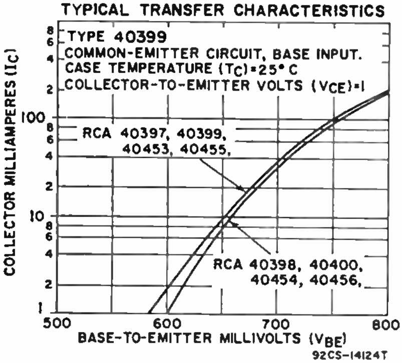
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 10 mA, $I_B$ = 0) | $V_{(BR)CEO}$ | 18 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.05 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 7 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 100 mA, $I_B$ = 5 mA) | $V_{CE}$(sat) | 0.1 typ; 0.2 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 100 mA, $I_B$ = 5 mA) | $V_{BE}$(sat) | 0.75 typ; 1.3 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 12 V, $I_E$ = 0 | $I_{CBO}$ | 500 max | nA |
| $V_{CB}$ = 12 V, $I_E$ = 0, $T_C$ = 85°C | $I_{CBO}$ | 10 max | μA |

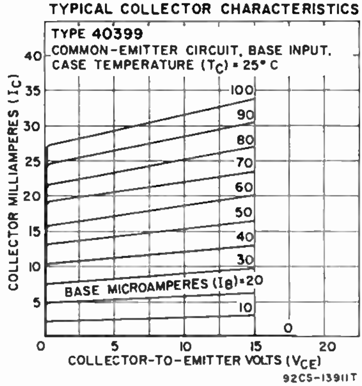
## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Emitter-Cutoff Current ($V_{BE}$ = −2.5 V, $I_C$ = 0) | $I_{EBO}$ | 500 max | nA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 6 V, $I_C$ = 0.5 mA | $h_{FE}$ | 175 | |
| $V_{CE}$ = 10 V, $I_C$ = 10 mA | $h_{FE}$ | 165 to 600 | |
| $V_{CE}$ = 1 V, $I_C$ = 100 mA | $h_{FE}$ | 100 min; 245 typ | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{fe}$ | 165 min; 375 typ | |
| Gain-Bandwidth Product ($V_{CE}$ = 6V, $I_C$ = 1 mA, f = 100 MHz) | $f_T$ | 50 typ; 80 max | MHz |
| Intrinsic Base-Spreading Resistance ($V_{CE}$ = 6 V, $I_C$ = 1 mA, f = 100 MHz) | $r_{bb'}$ | 20 typ; 40 max | Ω |
| Output Capacitance ($V_{CB}$ = 6 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 12 typ; 20 max | pF |
| Small-Signal Input Impedance ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{ie}$ | 1200 | Ω |
| Small-Signal Output Admittance ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{oe}$ | 120 | μmhos |
| Small-Signal Reverse-Voltage Transfer Ratio ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{re}$ | 250 x $10^{-6}$ | |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 50 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 300 max | °C/W |

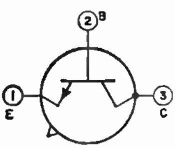
TYPICAL TRANSFER CHARACTERISTICS




TYPICAL COLLECTOR CHARACTERISTICS

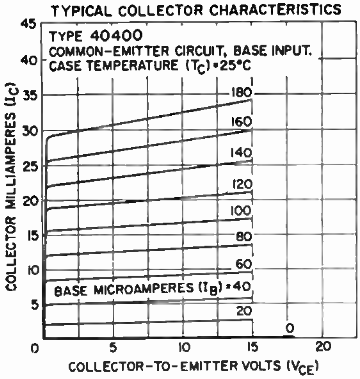



## 0.5W 40400

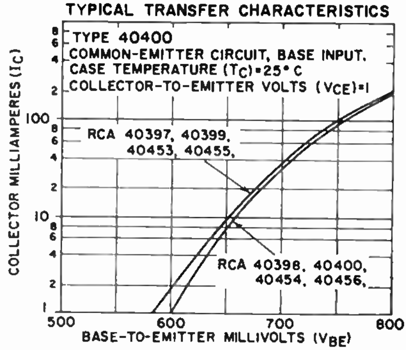



Si n-p-n epitaxial planar type used in high-voltage, high-current audio and video amplifier service in commercial and industrial equipment. JEDEC TO-104, Outline No.32. This type is identical with type 40399 except for the following items:

TYPICAL COLLECTOR CHARACTERISTICS




TYPICAL TRANSFER CHARACTERISTICS

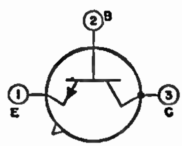


## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 6 V, $I_C$ = 0.5 mA | $h_{FE}$ | 75 | |
| $V_{CE}$ = 10 V, $I_C$ = 10 mA | $h_{FE}$ | 75 to 300 | |
| $V_{CE}$ = 1 V, $I_C$ = 100 mA | $h_{FE}$ | 50 min; 140 typ | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{fe}$ | 75 min; 200 typ | |
| Small-Signal Input Impedance ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{ie}$ | 600 | Ω |
| Small-Signal Output Admittance ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f= 1 kHz) | $h_{oe}$ | 75 | µmhos |
| Small-Signal Reverse-Voltage Transfer Ratio ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{re}$ | $125 \times 10^{-6}$ | |

# 40458 0.5W

Si n-p-n double-diffused epitaxial planar type used in high-peak-current audio and video amplifier applications in commercial and industrial equipment and high-current switching and driver service in computer equipment. JEDEC TO-104, Outline No.32.



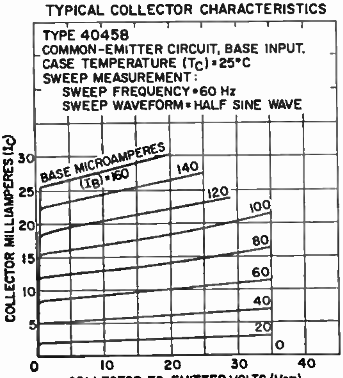

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 60 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 8 | V |
| Collector Current | $I_C$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.5 | W |
| $T_A$ above 25°C | $P_T$ | Derate linearly 3.3 | mW/°C |
| $T_C$ up to 75°C | $P_T$ | 2 | W |
| $T_C$ above 75°C | $P_T$ | Derate linearly 20 | mW/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

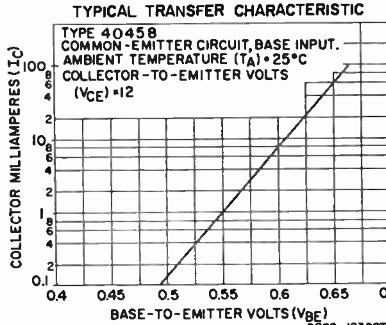
## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 60 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.05 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 8 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 100 mA, $I_B$ = 0, $t_p$ = 300 µs, df = 0.018%) | $V_{(BR)CEO}$(sus) | 40 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 300 mA, $I_B$ = 15 mA) | $V_{CE}$(sat) | 0.24 typ; 0.3 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 300 mA, $I_B$ = 15 mA) | $V_{BE}$(sat) | 0.93 typ; 1.5 max | V |

TYPICAL COLLECTOR CHARACTERISTICS




TYPICAL TRANSFER CHARACTERISTIC

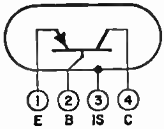


## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 25 V, $I_E$ = 0 | $I_{CBO}$ | 10 max | nA |
| $V_{CB}$ = 25 V, $I_E$ = 0, $T_A$ = 85°C | $I_{CBO}$ | 1 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 2.5 V, $I_C$ = 0) | $I_{EBO}$ | 10 max | nA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 10 mA | $h_{FE}$ | 100 to 300 | |
| $V_{CE}$ = 10 V, $I_C$ = 150 mA | $h_{FE}$ | 150 | |
| $V_{CE}$ = 1 V, $I_C$ = 300 mA | $h_{FE}$ | 50 min; 75 typ | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{fe}$ | 75 min; 175 typ | |
| Gain-Bandwidth Product ($V_{CE}$ = 1 V, $I_C$ = 50 mA, f = 50 MHz) | $f_T$ | 150 min; 200 typ | MHz |
| Feedback Capacitance* ($V_{CB}$ = 6 V, $I_E$ = 0, f = 1 MHz) | $C_{cb}$ | 20 max | pF |
| Small-Signal Input Impedance ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{ie}$ | 600 | Ω |
| Small-Signal Output Impedance ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{oe}$ | 75 | mmhos |
| Small-Signal Reverse-Voltage Transfer Ratio ($V_{CE}$ = 12 V, $I_C$ = 10 mA, f = 1 kHz) | $h_{re}$ | $125 \times 10^{-6}$ | |
| Intrinsic Base-Spreading Resistance ($V_{CE}$ = 6 V, $I_C$ = 1 mA, f = 100 MHz) | $r_{bb'}$ | 20 | Ω |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 50 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 300 max | °C/W |

* Three-terminal measurement with lead No. 1 (emitter) guarded.

# *Radio-Frequency Types*




## 0.08W 2N370

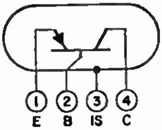
Ge p-n-p alloy-junction drift-field type used in rf-amplifier service in AM broadcast-band portable radio receivers and short-wave receivers. JEDEC TO-7, Outline No.9.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | –24 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | –0.5 | V |
| Collector Current | $I_C$ | –10 | mA |
| Transistor Dissipation: $T_A$ = 25°C | $P_T$ | 80 | mW |
| Temperature Range: Operating (Ambient) | $T_A$(opr) | –65 to 71 | °C |

### CHARACTERISTICS

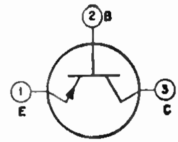
| | | | |
|---|---|---|---|
| Collector-Cutoff Current | $I_{CBO}$ | –20 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = –12 V, $I_C$ = –1 mA) | $h_{FE}$ | 60 min | |
| Gain-Bandwidth Product | $f_T$ | 30 | MHz |
| Output Capacitance* | $C_{obo}$ | 1.7 | pF |
| Power Gain* (f = 1.5 MHz) | $G_{pe}$ | 31 | dB |




## 0.08W 2N372

Ge p-n-p alloy-junction drift-field type for use as an rf mixer in AM broadcast-band portable radio receivers and short-wave receivers. JEDEC TO-7, Outline No.9. This type is identical with type 2N370.

# 2N410 0.08W




Ge p-n-p alloy-junction type used in 455-kHz if-amplifier service in battery-operated portable radio receivers and automobile radio receivers. JEDEC TO-1, Outline No.1.

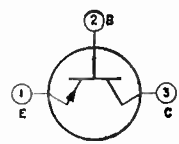
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −13 | V |
| Collector Current | $I_C$ | −15 | mA |
| Transistor Dissipation: $T_A$ = 25°C | $P_T$ | 80 | mW |
| Temperature Range: Operating (Ambient) | $T_A$(opr) | −65 to 71 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = −10 μA, $I_E$ = 0) | $V_{(BR)CBO}$ | −13 min | V |
| Collector-Cutoff Current ($V_{CB}$ = −13 V, $I_E$ = 0) | $I_{CBO}$ | −10 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −9 V, $I_C$ = −1 mA) | $h_{FE}$ | 48 | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency | $f_{hfb}$ | 6.7 | MHz |
| Output Capacitance | $C_{obo}$ | 9.5 | pF |
| Power Gain (f = 0.455 MHz) | $G_{pe}$ | 38.8 | dB |

# 2N412 0.08W




Ge p-n-p alloy-junction type used in converter and mixer-oscillator applications in battery-operated portable radio receivers. JEDEC TO-1, Outline No.1.

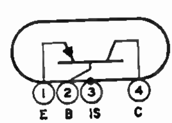
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −13 | V |
| Collector Current | $I_C$ | −15 | mA |
| Transistor Dissipation: $T_A$ = 25°C | $P_T$ | 80 | mW |
| Temperature Range: Operating (Ambient) | $T_A$(opr) | −65 to 71 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = −10 μA, $I_E$ = 0) | $V_{(BR)CBO}$ | −13 min | V |
| Collector-Cutoff Current ($V_{CB}$ = −13 V, $I_E$ = 0) | $I_{CBO}$ | −10 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −9 V, $I_C$ = −0.6 mA) | $h_{FE}$ | 75 | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CB}$ = −9 V, $I_E$ = 0.6 mA) | $f_{hfb}$ | 10 | MHz |
| Oscillator Injection Voltage (f = 1 MHz) | | 100 | mV |
| Output Capacitance | $C_{obo}$ | 9.5 | pF |
| Power Gain (f = 1 MHz) | $G_{pe}$ | 32 | dB |

# 2N1177 0.08W




Ge p-n-p alloy-junction drift-field type used in radio-frequency amplifier applications in FM and AM/FM radio receivers. JEDEC TO-45, Outline No.18.

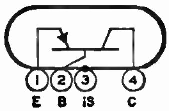
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −30 | V |
| Collector Current | $I_C$ | −10 | mA |
| Transistor Dissipation: $T_A$ = 25°C | $P_T$ | 80 | mW |
| Temperature Range: Operating (Ambient) | $T_A$(opr) | −65 to 71 | °C |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($V_{BE}$ = 0.5 V, $I_C$ = −50 μA) | $V_{(BR)CBO}$ | −30 min | V |
| Collector-Cutoff Current ($V_{CB}$ = −12 V, $I_E$ = 0) | $I_{CBO}$ | −12 max | μA |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −12 V, $I_C$ = −1 mA, f = 1 kHz) | $h_{fe}$ | 100 min | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency | $f_{hfb}$ | 140 | MHz |
| Output Capacitance | $C_{obo}$ | 2 | pF |
| Power Gain (f = 100 MHz) | $G_{pe}$ | 14 | dB |

## 0.08W 2N1178

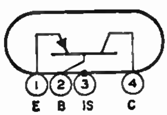



Ge p-n-p alloy-junction drift-field type used in radio-frequency oscillator applications in FM and AM/FM radio receivers. JEDEC TO-45, Outline No.18. This type is identical with type 2N1177 except for the following item:

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −12 V, $I_C$ = −1 mA, f = 1 kHz) | $h_{fe}$ | 40 min | |

## 0.08W 2N1179

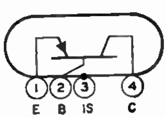



Ge p-n-p alloy-junction drift-field type used in radio-frequency mixer applications in FM and AM/FM radio receivers. JEDEC TO-45, Outline No.18. This type is identical with type 2N1177 except for the following items:

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −12 V, $I_C$ = −1 mA, f = 1 kHz) | $h_{fe}$ | 80 min | |
| Oscillator Injection Voltage (f = 100 MHz) | | 125 max | mV |
| Power Gain (f = 100 MHz) | $G_{pe}$ | 17 | dB |

## 0.08W 2N1180

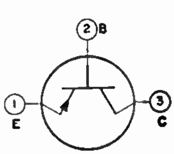



Ge p-n-p alloy-junction drift-field type used in intermediate-frequency amplifier applications in FM and AM/FM radio receivers. JEDEC TO-45, Outline No.18. This type is identical with type 2N1177 except for the following items:

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −12 V, $I_C$ = −1 mA, f = 1 kHz) | $h_{fe}$ | 80 min | |
| Small-Signal Forward-Current Transfer Ratio Cutoff Frequency ($V_{CB}$ = −12 V, $I_C$ = −1 mA) | $f_{hfb}$ | 100 | MHz |
| Power Gain (f = 10.7 MHz) | $G_{pe}$ | 35 | dB |

## 0.08W 2N1524



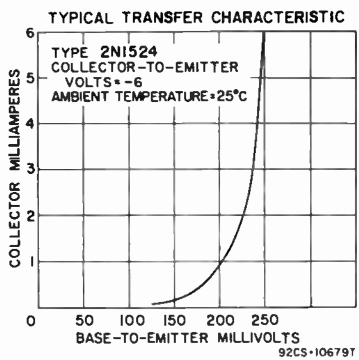

Ge p-n-p drift-field type used in 455-kHz if-amplifier service in battery-operated portable radio receivers and automobile radio receivers operating from either a 6-volt or a 12-volt supply. JEDEC TO-1, Outline No.1.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −24 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −0.5 | V |
| Collector Current | $I_C$ | −10 | mA |
| Emitter Current | $I_E$ | 10 | mA |
| Transistor Dissipation: | | | |
| $T_A$ = 25°C | $P_T$ | 80 | mW |
| $T_A$ = 55°C | $P_T$ | 50 | mW |
| $T_A$ = 71°C | $P_T$ | 35 | mW |
| Temperature Range: | | | |
| Operating (Ambient) | $T_A$(opr) | −65 to 71 | °C |
| Storage | $T_{STG}$ | −65 to 85 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

## CHARACTERISTICS

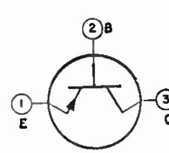
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($V_{EB}$ = −0.5 V, $I_C$ = −50 μA) | $V_{(BR)CBV}$ | −24 min | V |
| Collector-Cutoff Current ($V_{CB}$ = −12 V, $I_E$ = 0) | $I_{CBO}$ | −16 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −0.5 V, $I_C$ = 0) | $I_{EBO}$ | −16 max | μA |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −12 V, $I_E$ = −1 mA, f = 1 kHz) | $h_{fe}$ | 60 | |
| Collector-to-Base Feedback Capacitance ($V_{CE}$ = −8.5 V, $I_E$ = 1 mA) | $C_{cb}$ | 2.1 | pF |
| Maximum Available Amplifier Gain▲ ($V_{CE}$ = −8.5 V, $I_E$ = 1 mA, f = 455 kHz) | MAG* | 52.4 | dB |
| Maximum Usable Amplifier Gain, Unneutralized▲ ($V_{CE}$ = −8.5 V, $I_E$ = 1 mA, f = 455 kHz) | MUG | 30 | dB |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 0.4 | °C/mW |




▲ This characteristic does not apply to type 2N1526.
* Measured in a single-tuned unilateralized circuit matched to the generator and load impedances for maximum transfer of power (transformer insertion losses not included).

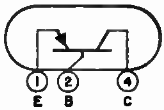
# 2N1526 0.08W

Ge p-n-p drift-field type used in mixer and oscillator applications in battery-operated portable radio receivers and automobile radio receivers operating from either a 6-volt or a 12-volt supply. JEDEC TO-1, Outline No.1. This type is identical with type 2N1524 except for the following items:




## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −12 V, $I_E$ = 1 mA, f = 1 kHz) | $h_{fe}$ | 130 | |
| Maximum Available Conversion Power Gain ($V_{CE}$ = −8 V, $I_E$ = 0.65 mA, f = 1.5 MHz) | $MAG_C$ | 46.1 | dB |
| Maximum Usable Conversion Power Gain ($V_{CE}$ = −8 V, $I_E$ = 0.65 mA, f = 1.5 MHz) | $MUG_C$ | 34.5 | dB |
| Base-to-Emitter Oscillator-Injection Voltage ($V_{CE}$ = −8 V, $I_E$ = 0.65 mA) | | 100 | mV(rms) |




## 0.08W 2N1631

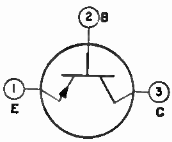
Ge p-n-p drift-field type used in rf-amplifier applications in battery-operated AM radio receivers. JEDEC TO-40, Outline No.16.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −34 | V |
| Collector Current | $I_C$ | −10 | mA |
| Transistor Dissipation: | | | |
| $T_A$ = 25°C | $P_T$ | 80 | mW |
| Temperature Range: | | | |
| Operating (Ambient) | $T_A$(opr) | −65 to 71 | °C |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = −50 μA, $I_E$ = 0) | $V_{(BR)CBO}$ | −34 min | V |
| Collector-Cutoff Current ($V_{CB}$ = −12 V, $I_E$ = 0) | $I_{CBO}$ | −16 max | μA |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −12 V, $I_C$ = −1 mA, f = 1 kHz) | $h_{fe}$ | 80 min | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CB}$ = −12 V, $I_E$ = 1 mA) | $f_{hfb}$ | 45 | MHz |
| Output Capacitance | $C_{obo}$ | 2 | pF |
| Power Gain (f = 1.5 MHz) | $G_{pe}$ | 47.7 | dB |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 0.4 max | °C/W |




## 0.08W 2N1632

Ge p-n-p drift-field type used in rf-amplifier applications in battery-operated AM radio receivers. JEDEC TO-1, Outline No.1.

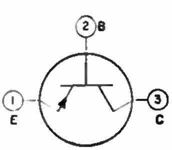
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −34 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −0.5 | V |
| Collector Current | $I_C$ | −10 | mA |
| Emitter Current | $I_E$ | 10 | mA |
| Transistor Dissipation: | | | |
| $T_A$ = 25°C | $P_T$ | 80 | mW |
| $T_A$ = 55°C | $P_T$ | 50 | mW |
| $T_A$ = 71°C | $P_T$ | 35 | mW |
| Temperature Range: | | | |
| Operating (Ambient) | $T_A$(opr) | −65 to 71 | °C |
| Storage | $T_{STG}$ | −65 to 85 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = −0.05 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | −34 min | V |
| Collector-Cutoff Current ($V_{CB}$ = −12 V, $I_E$ = 0) | $I_{CBO}$ | −16 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −0.5 V, $I_C$ = 0.05 mA) | $I_{EBO}$ | −16 max | μA |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −12V, $I_E$ = 1 mA, f = 1 kHz) | $h_{fe}$ | 40 to 170 | |
| Collector-to-Base Feedback Capacitance ($V_{CE}$ = −8.5 V, $I_E$ = 1 mA) | $C_{cb}$ | 2.1 | pF |
| Maximum Available Amplifier Gain* ($V_{CE}$ = −8.5 V, $I_E$ = 1 mA, f = 1 kHz) | MAG | 44.3 | dB |
| Maximum Usable Amplifier Gain, Unneutralized ($V_{CE}$ = −8.5 V, $I_E$ = 1 mA, f = 1.5 kHz) | MUG | 25.5 | dB |

* Measured in a single-tuned unilateralized circuit matched to the generator and load impedances for maximum transfer of power (transformer insertion losses not included).




## 0.08W 2N1637

Ge p-n-p drift-field type used in rf-amplifier applications in AM automobile radio receivers. JEDEC TO-1, Outline No.1.

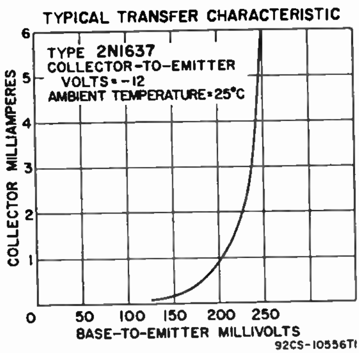
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −34 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −1.5 | V |
| Collector Current | $I_C$ | −10 | mA |
| Emitter Current | $I_E$ | 10 | mA |
| Transistor Dissipation: | | | |
| $T_A$ = 25°C | $P_T$ | 80 | mW |
| $T_A$ = 55°C | $P_T$ | 50 | mW |
| $T_A$ = 71°C | $P_T$ | 35 | mW |
| Temperature Range: | | | |
| Operating (Ambient) | $T_A$(opr) | −65 to 71 | °C |
| Storage | $T_{STG}$ | −65 to 85 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

## CHARACTERISTICS

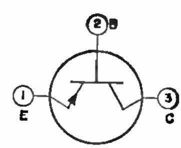
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = −50 μA, $I_E$ = 0) | $V_{(BR)CBO}$ | −34 min | V |
| Collector-Cutoff Current ($V_{CB}$ = −12 V, $I_E$ = 0) | $I_{CBO}$ | −12 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −1.5 V, $I_C$ = 0) | $I_{EBO}$ | −15 max | μA |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −12 V, $I_C$ = −1 mA, f = 1 kHz) | $h_{fe}$ | 80 | |
| Collector-to-Base Feedback Capacitance ($V_{CB}$ = −12 V, $I_C$ = −1 mA) | $C_{cb}$ | 2 | pF |
| Maximum Available Amplifier Gain* ($V_{CE}$ = −11 V, $I_E$ = 1 mA, f = 1.5 MHz) | MAG | 47.7 | dB |
| Maximum Usable Amplifier Gain, Unneutralized ($V_{CE}$ = −11 V, $I_E$ = 1 mA, f = 1.5 MHz) | MUG | 25.6 | dB |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 0.4 max | °C/mW |

* Measured in a single-tuned unilateralized circuit matched to the generator and load impedances for maximum transfer of power (transformer insertion losses not included).




# 2N1638

**0.08W**



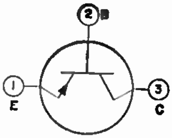

Ge p-n-p drift-field type used in if-amplifier applications in AM automobile radio receivers. JEDEC TO-1, Outline No.1. This type is identical with type 2N1637 except for the following items:

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-Cutoff Current ($V_{CB}$ = −12 V, $I_C$ = 0) | $I_{CBO}$ | −12 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −0.5 V, $I_C$ = 0) | $I_{EBO}$ | −12 max | μA |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −12 V, $I_C$ = −1 mA, f = 1 kHz) | $h_{fe}$ | 75 | |
| Maximum Available Amplifier Gain▲* ($V_{CE}$ = −11 V, $I_E$ = 2 mA, f = 262.5 kHz) | MAG | 61.5 | dB |
| Maximum Usable Amplifier Gain, Unneutralized▲ ($V_{CE}$ = −11 V, $I_E$ = 2 mA, f = 262.5 kHz) | MUG | 36.6 | dB |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 0.4 max | °C/mW |

▲ This characteristic does not apply to type 2N1639.

* Measured in a single-tuned unilateralized circuit matched to the generator and load impedances for maximum transfer of power (transformer insertion losses not included).

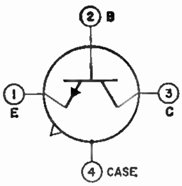



## 0.08W 2N1639

Ge **p-n-p drift-field** type used in converter, mixer, and oscillator applications in AM automobile radio receivers. JEDEC TO-1, Outline No.1. This type is identical with type 2N1637 except for the following items:

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −12 V, $I_C$ = −1 mA, f = 1 kHz) | $h_{fe}$ | 75 | |
| Maximum Usable Conversion Power Gain ($V_{CE}$ = −11 V, $I_E$ = 0.25 mA, f = 1.5 MHz) | MUGc | 37 | dB |
| Base-to-Emitter Oscillator-Injection Voltage (RMS) ($V_{CE}$ = −11 V, $I_E$ = 0.25 mA) | | 100 | mV(rms) |




## 0.175W 2N4259

Si **n-p-n epitaxial planar** type used in vhf and uhf applications in industrial and military equipment. JEDEC TO-104, Outline No.31. See **Mounting Hardware** for desired mounting arrangement.

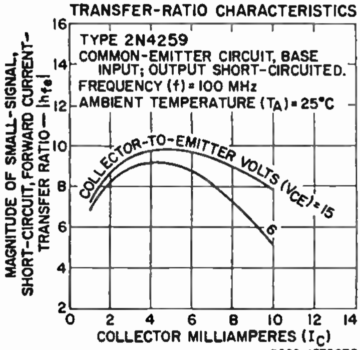
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 40 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 30 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2.5 | V |
| Collector Current | $I_C$ | Limited by dissipation | |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 175 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

### CHARACTERISTICS

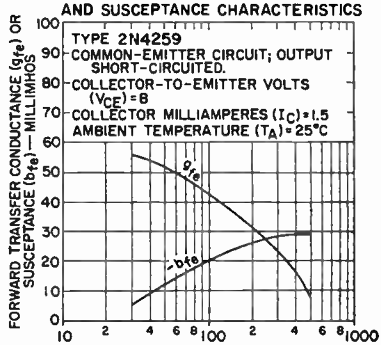
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.001 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 40 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 1 mA) | $V_{(BR)CEO}$ | 30 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.001 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 2.5 min | V |
| Collector-Cutoff Current ($V_{CB}$ = 15 V, $I_E$ = 0) | $I_{CBO}$ | 0.01 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 8 V, $I_C$ = 2 mA) | $h_{FE}$ | 60 to 250 | |
| Small-Signal Forward-Current Transfer Ratio:▲ | | | |
| $V_{CE}$ = 8 V, $I_C$ = 2 mA, f = 0.001 MHz | $h_{fe}$ | 70 to 280 | |
| $V_{CE}$ = 8 V, $I_C$ = 2 mA, f = 100 MHz | $h_{fe}$ | 7.5 to 16 | |

TYPICAL SMALL-SIGNAL FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTICS




92CS-12756T2

TYPICAL FORWARD TRANSFER CONDUCTANCE AND SUSCEPTANCE CHARACTERISTICS

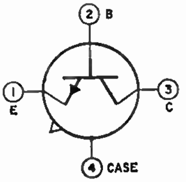



92CS-13973T

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-to-Base Feedback Capacitance* ($V_{CB}$ = 8 V, $I_E$ = 0, f = 0.1 to 1 MHz) | $C_{cb}$ | 0.35 typ; 0.55 max | pF |
| Collector-to-Base Time Constant▲ ($V_{CB}$ = 8 V, $I_E$ = 2 mA, f = 31.9 MHz) | $r_b'C_c$ | 1 to 8 | ps |
| Small-Signal Power Gain▲ ($V_{CE}$ = 8 V, $I_C$ = 1.5 mA, f = 450 MHz) | $G_{pe}$ | 11.5 to 16.5 | dB |
| Noise Figure▲ ($V_{CE}$ = 8 V, $I_C$ = 1.5 mA, $R_G$ and $R_L$ = 50 Ω, f = 450 MHz) | NF | 5 max | dB |

▲ Lead 4 (case) grounded.
* Three-terminal capacitance measurement with lead No. 1 (emitter) and lead No. 4 (case) connected to guard terminal.




# 2N5180 0.18W

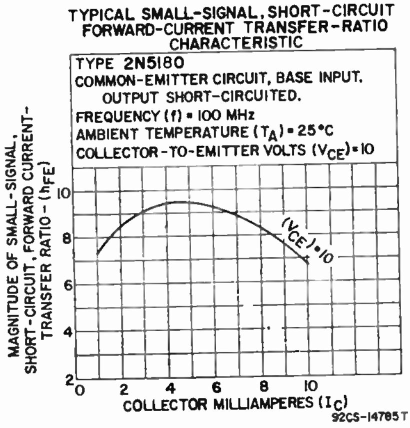
Si n-p-n epitaxial planar type used as a general-purpose amplifier at vhf frequencies. JEDEC TO-72, Outline No.28.

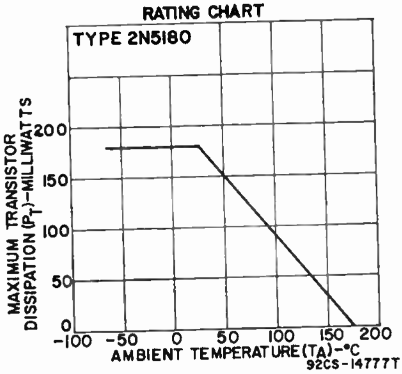
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 30 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 15 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2 | V |
| Collector Current | $I_C$ | Limited by dissipation | |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 180 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.001 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 30 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 0.001 mA) | $V_{(BR)CEO}$ | 15 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −0.001 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 2 min | V |
| Collector-Cutoff Current ($V_{CB}$ = 1 V, $I_E$ = 0) | $I_{CBO}$ | 0.025 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 8 V, $I_C$ = 2 mA) | $h_{FE}$ | 20 to 200 | |

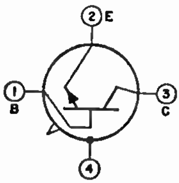


## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Magnitude of Small-Signal Forward-Current Transfer Ratio* ($V_{CE}$ = 8 V, $I_C$ = 2 mA, f = 100 MHz) | $\lvert h_{fe}\rvert$ | 6.5 to 16 | |
| Collector-to-Base Feedback Capacitance‡ ($V_{CB}$ = 8 V, $I_E$ = 0, f = 0.1 to 1 MHz) | $C_{cb}$ | 1 max | pF |
| Maximum Usable Amplifier Gain, Neutralized* ($V_{CE}$ = 8 V, $I_C$ = 2 mA, f = 200 MHz) | MUG | 12 to 19 | dB |
| Noise Figure*: | | | |
| $V_{CE}$ = 8 V, $I_C$ = 2 mA, f = 200 MHz | NF | 4.5 max | dB |
| $V_{CE}$ = 8 V, $I_C$ = 1 mA, $R_S$ = 400 Ω f = 60 MHz | NF | 2.5 | dB |

* Fourth lead (case) grounded.
‡ Three-terminal measurement of the collector-to-base capacitance: Lead No. 1 (emitter and lead No. 4 (case) connected to guard terminal.




## 0.18W 2N5181

Si n-p-n type used in rf and if amplifier circuits at frequencies up to 250 MHz. The terminal arrangement permits shielding between input and output terminals for superior high-frequency performance and greater circuit stability, particularly on printed-circuit boards. JEDEC TO-104, Outline No.31.

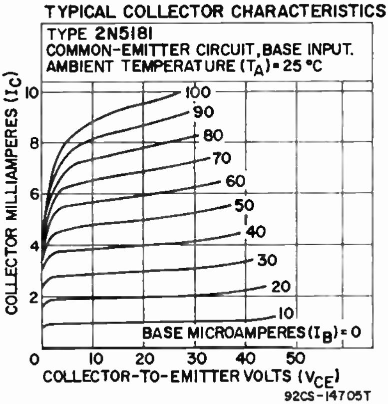
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 45 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 3 | V |
| Collector Current | $I_C$ | 50 | mW |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 180 | mA |
| $T_A$ above 25°C | $P_T$ | Derate at 1.2 | mW/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

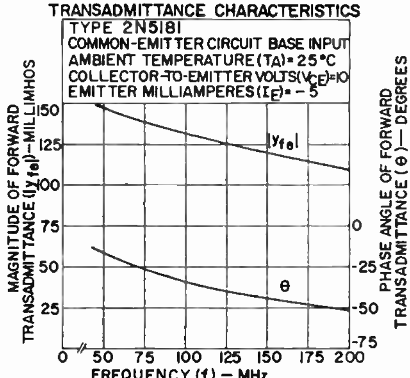
## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 1 V, $I_E$ = 0 | $I_{CBO}$ | 0.02 max | μA |
| $V_{CB}$ = 45 V, $I_E$ = 0 | $I_{CBO}$ | 1 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 3 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 6 V, $I_E$ = −1 mA) | $h_{FE}$ | 27 to 275 | |
| Gain Bandwidth Product ($V_{CE}$ = 6 V, $I_E$ = −2 mA, f = 100 MHz) | $f_T$ | 700 | MHz |
| Collector-to-Base Feedback Capacitance ($V_{CE}$ = 10 V, $I_E$ = −3 mA, f = 0.1 to 1 MHz) | $C_{cb}$ | 0.22 typ; 0.34 max | pF |

TYPICAL COLLECTOR CHARACTERISTICS



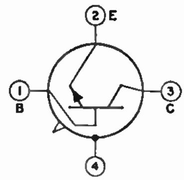

TYPICAL FORWARD TRANSADMITTANCE CHARACTERISTICS



## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Maximum Available Amplifier Gain ($V_{CE}$ = 10 V, $I_E$ = −2 mA, f = 200 MHz) | MAG | 29.9 | dB |
| Maximum Usable Amplifier Gain, Unneutralized ($V_{CE}$ = 10 V, $I_E$ = −2 mA, f = 200 MHz) | MUG | 20.4 | dB |
| Maximum Usable Amplifier Gain, Neutralized ($V_{CE}$ = 10 V, $I_E$ = −2 mA, f = 200 MHz) | MUG | 24.2 | dB |

# 2N5182 0.18W




Si **n-p-n** type used in rf and if amplifier circuits at frequencies up to 250 MHz. The terminal arrangement permits shielding between input and output terminals for superior high-frequency performance and greater circuit stability, particularly on printed-circuit boards. JEDEC TO-104, **Outline** No.31. Type 2N5182 is identical to type 2N5181 except for the following items:

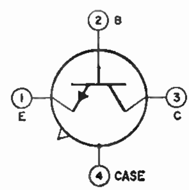
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector Current | $I_C$ | 4 | mA |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 1 V, $I_E$ = 0 | $I_{CBO}$ | 0.03 max | μA |
| $V_{CB}$ = 35 V, $I_E$ = 0 | $I_{CBO}$ | 1 | μA |
| Maximum Available Amplifier Gain ($V_{CE}$ = 10 V, $I_E$ = −2 mA, f = 200 MHz) | MAG | 29.5 | dB |

# 40235 0.18W




Si **n-p-n** type used as rf amplifier in television tuners covering channels 2 through 13. JEDEC TO-104, **Outline** No.31.

## MAXIMUM RATINGS

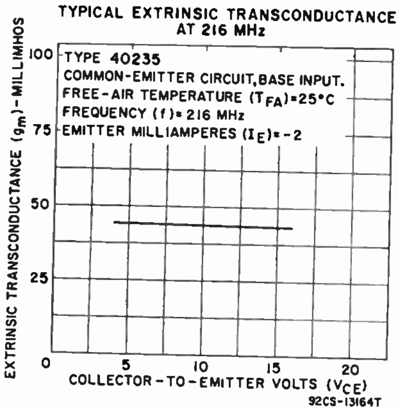
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage: | | | |
| $V_{EB}$ = 1 V | $V_{CBO}$ | 45 | V |
| Emitter open | $V_{CBO}$ | 45 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4.5 | V |
| Collector Current | $I_C$ | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 180 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating ($T_A$) and Storage ($T_{STG}$) | | −65 to 175 | °C |
| Lead Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

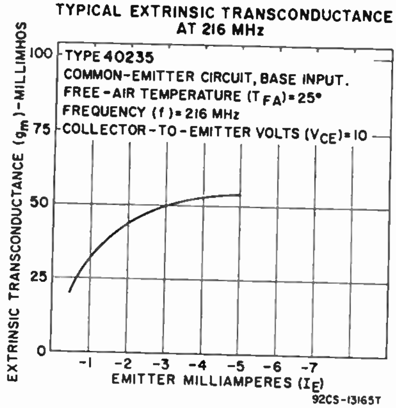
## CHARACTERISTICS

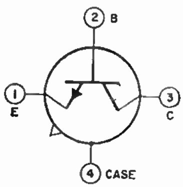
| | | | |
|---|---|---|---|
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 1 V, $I_E$ = 0 | $I_{CBO}$ | 0.02 max | μA |
| $V_{CB}$ = 35 V, $I_E$ = 0 | $I_{CBO}$ | 1 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 4.5 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 6 V, $I_E$ = −1 mA) | $h_{FE}$ | 40 to 170 | |
| Gain-Bandwidth Product ($V_{CE}$ = 6 V, $I_E$ = −2 mA, f = 100 MHz) | $f_T$ | 1000 | MHz |
| Collector-to-Base Feedback Capacitance ($V_{CE}$ = 10 V, $I_E$ = −2 mA, f = 216 MHz) | $C_{cb}$ | 0.65 max | pF |
| Input Resistance ($V_{CE}$ = 10 V, $I_E$ = −2 mA, f = 216 MHz) | $R_{ie}$ | 190 | Ω |
| Output Resistance ($V_{CE}$ = 10 V, $I_E$ = −2 mA, f = 216 MHz) | $R_{oe}$ | 8.9 | kΩ |

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Extrinsic Transconductance ($V_{CE}$ = 10 V, $I_E$ = −2 mA, f = 216 MHz) | $g_m$ | 43.7 | mmhos |
| Noise Figure ($V_{CE}$ = 10 V, $I_E$ = −2 mA, $R_G$ and $R_L$ = 50 Ω, f = 216 MHz) | NF | 3.3 | dB |
| Maximum Available Amplifier Gain ($V_{CE}$ = 10 V, $I_E$ = −2 mA, f = 216 MHz) | MAG | 29.1 | dB |
| Maximum Usable Amplifier Gain, Neutralized ($V_{CE}$ = 10 V, $I_E$ = −2 mA, $R_G$ and $R_L$ = 50 Ω, f = 216 MHz) | MUG | 18.1 | dB |



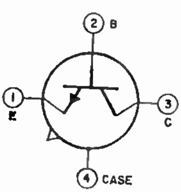




## 0.18W 40236

Si n-p-n type used as rf mixer in television tuners covering channels 2 through 13. JEDEC TO -104, Outline No.31. The maximum ratings for this type are identical with type 40235.

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 1 V, $I_E$ = 0 | $I_{CBO}$ | 0.02 max | μA |
| $V_{CB}$ = 35 V, $I_E$ = 0 | $I_{CBO}$ | 1 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 1 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 6 V, $I_E$ = −1 mA) | $h_{FE}$ | 40 to 275 | |
| Gain-Bandwidth Product ($V_{CE}$ = 6 V, $I_E$ = −1 mA, f = 100 MHz) | $f_T$ | 1000 | MHz |
| Collector-to-Base Feedback Capacitance ($V_{CE}$ = 12 V, $I_E$ = 1.5 mA, f = 216 MHz) | $C_{cb}$ | 0.65 max | pF |
| Input Resistance ($V_{CE}$ = 12 V, $I_E$ = −1.5 mA, f = 216 MHz) | $R_{ie}$ | 230 | Ω |
| Output Resistance ($V_{CE}$ = 12 V, $I_E$ = −1.5 mA, f = 45 MHz) | $R_{oe}$ | 65 | kΩ |
| Maximum Available Conversion Gain ($V_{CE}$ = 12 V, $I_E$ = −1.5 mA, f = 216 to 45 MHz) | $MAG_c$ | 19 | dB |

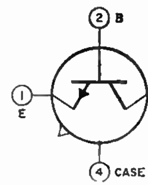



## 0.18W 40237

Si n-p-n type used as rf local oscillator in television tuners covering channels 2 through 13. JEDEC TO-104, Outline No.31. The maximum ratings for this type are identical with type 40235.

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 1 V, $I_E$ = 0 | $I_{CBO}$ | 0.02 max | µA |
| $V_{CB}$ = 35 V, $I_E$ = 0 | $I_{CBO}$ | 1 max | µA |
| Emitter-Cutoff Current ($V_{EB}$ = 1 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | µA |
| Collector-to-Base Feedback Capacitance ($V_{CE}$ = 12 V, $I_E$ = 1.5 mA, f = 216 MHz) | $C_{cb}$ | 0.8 max | pF |
| Output Capacitance ($V_{CB}$ = 12 V, $I_C$ = −2.5 mA, f = 257 MHz) | $C_{obo}$ | 0.6 max | pF |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 6 V, $I_E$ = −1 mA) | $h_{FE}$ | 27 to 275 | |
| Gain-Bandwidth Product ($V_{CE}$ = 6 V, $I_E$ = −1 mA, f = 100 MHz) | $f_T$ | 1000 | MHz |




# 40238 0.18W

Si n-p-n type used as 45-MHz if amplifier in television receivers. JEDEC TO-104, Outline No.31.

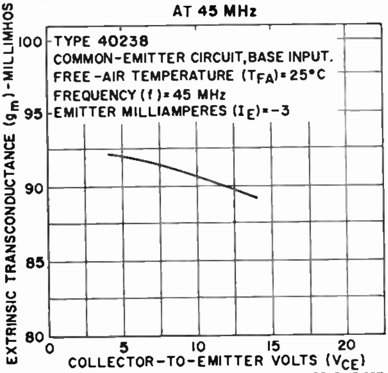
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage: | | | |
| $V_{BE}$ = −1 V | $V_{CBV}$ | 45 | V |
| Emitter open | $V_{CBO}$ | 45 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4.5 | V |
| Collector Current | $I_C$ | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 180 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating ($T_A$) and Storage ($T_{STG}$) | | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

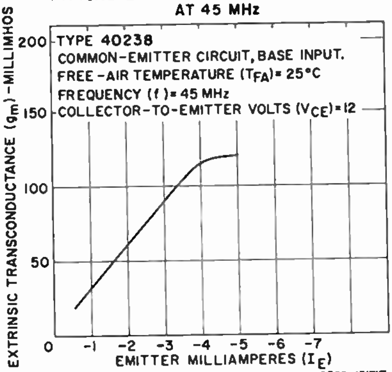
## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 1 V, $I_E$ = 0 | $I_{CBO}$ | 0.02 max | µA |
| $V_{CB}$ = 35 V, $I_E$ = 0 | $I_{CBO}$ | 1 max | µA |
| Emitter-Cutoff Current ($V_{EB}$ = 1 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | µA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 6 V, $I_E$ = −1 mA) | $h_{FE}$ | 40 to 170 | |
| Gain-Bandwidth Product ($V_{CE}$ = 6 V, $I_E$ = −2 mA, f = 100 MHz) | $f_T$ | 800 | MHz |
| Collector-to-Base Feedback Capacitance ($V_{CE}$ = 12 V, $I_E$ = −3 mA, f = 216 MHz) | $C_{cb}$ | 0.65 max | pF |
| Input Resistance ($V_{CE}$ = 12 V, $I_E$ = −3 mA, f = 45 MHz) | $R_{ie}$ | 480 | Ω |

TYPICAL EXTRINSIC TRANSCONDUCTANCE AT 45 MHz

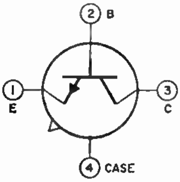



TYPICAL EXTRINSIC TRANSCONDUCTANCE AT 45 MHz



## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Output Resistance ($V_{CE}$ = 12 V, $I_E$ = −3 mA, f = 45 MHz) | $R_{oe}$ | 35 | kΩ |
| Extrinsic Transconductance ($V_{CE}$ = 12 V, $I_E$ = −3 mA, f = 45 MHz) | $g_m$ | 90 | mmhos |
| Maximum Available Amplifier Gain For 1, 2, or 3 Stages ($V_{CE}$ = 12 V, $I_E$ = −3 mA, f = 45 MHz) | MAG | 45.3 | dB |
| Maximum Usable Amplifier Gain, Unneutralized ($V_{CE}$ = 12 V, $I_E$ = −3 mA, f = 45 MHz): | | | |
| For 1 stage | MUG | 22.9 | dB |
| For 2 stages | MUG | 20.7 | dB |
| For 3 stages | MUG | 19 | dB |
| Maximum Usable Amplifier Gain, Neutralized ($V_{CE}$ = 12 V, $I_E$ = −3 mA, f = 45 MHz): | | | |
| For 1 stage | MUG | 28 | dB |
| For 2 stages | MUG | 25.8 | dB |
| For 3 stages | MUG | 24.1 | dB |

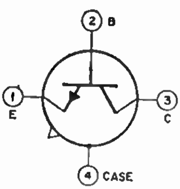



## 0.18W 40239

Si n-p-n type used as 45-MHz if amplifier in television receivers. JEDEC TO-104, Outline No.31. This type is identical with type 40238 except for the following item:

### CHARACTERISTICS

| | | |
|---|---|---|
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 6 V, $I_E$ = −1 mA) | $h_{FE}$ | 27 to 100 |

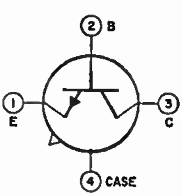



## 0.18W 40240

Si n-p-n type used as 45-MHz if amplifier in television receivers. JEDEC TO-104, Outline No.31. This type is identical uith type 40238 except for the following item:

### CHARACTERISTICS

| | | |
|---|---|---|
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 6 V, $I_E$ = −1 mA) | $h_{FE}$ | 27 to 275 |




## 0.18W 40242

Si n-p-n planar type used in rf-amplifier applications in conjunction with types 40243 (mixer), 40244 (rf oscillator), and 40245 and 40246 (if amplifiers) to make up a "front-end" and if complement for FM and AM/FM receivers. JEDEC TO-104, Outline No.31.

### MAXIMUM RATINGS

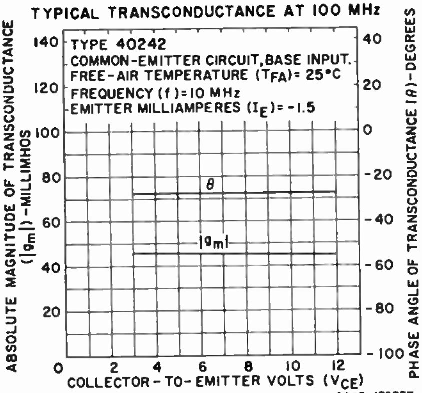
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage: | | | |
| Emitter open | $V_{CBO}$ | 45 | V |
| $V_{EB}$ = −1 V | $V_{CEO}$ | 45 | V |
| Collector-to-Emitter Voltage | $V_{CBV}$ | 45 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4.5 | V |
| Collector Current | $I_C$ | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 180 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating ($T_A$) and Storage ($T_{STG}$) | | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

## CHARACTERISTICS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage: $I_C$ = 0.001 mA, $I_E$ = 0 | $V_{(BR)CBO}$ | 45 min | V |
| $V_{EB}$ = −1 V, $I_C$ = 0.001 mA | $V_{(BR)CBV}$ | 45 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_E$ = 0.5 mA, $I_B$ = 0) | $V_{(BR)CEO}$ | 45 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −0.001 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4.5 min | V |
| Collector-Cutoff Current ($V_{CE}$ = 1 V, $I_E$ = 0) | $I_{CBO}$ | 0.02 max | μA |
| Emitter-Cutoff Current ($V_{CE}$ = 1.5 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 6 V, $I_E$ = −1 mA) | $h_{FE}$ | 40 to 170 | |
| Extrinsic Transconductance ($V_{CE}$ = 7.5 V, $I_E$ = −1.5 mA, f = 100 MHz) | $g_m$ | 45 | mmhos |
| Maximum Available Amplifier Gain* ($V_{CE}$ = 7.5 V, $I_E$ = −1.5 mA, f = 100 MHz) | MAG | 38.3 | dB |
| Maximum Usable Amplifier Gain*: Neutralized—$V_{CE}$ = 7.5 V, $I_E$ = −1.5 mA, f = 100 MHz | MUG | 21.5 | dB |
| Unneutralized—$V_{CC}$ = 15 V, f = 100 MHz | MUG | 16.4 | dB |
| Input Capacitance ($V_{CE}$ = 7.5 V, $I_E$ = −1.5 mA, f = 100 MHz) | $C_{ie}$ | 5.2 | pF |
| Feedback Capacitance ($V_{CE}$ = 8 V, $I_E$ = 0, f = 1 MHz) | $C_{cb}$ | 0.65 max | pF |
| Input Resistance ($V_{CE}$ = 7.5 V, $I_E$ = −1.5 mA, f = 100 MHz) | $R_{ie}$ | 450 | Ω |
| Output Resistance ($V_{CE}$ = 7.5 V, $I_E$ = −1.5 mA, f = 100 MHz) | $R_{oe}$ | 30 | kΩ |
| Output Capacitance ($V_{CE}$ = 7.5 V, $I_E$ = −1.5 mA, f = 100 MHz) | $C_{oe}$ | 1.35 | pF |
| Noise Figure* ($V_{CC}$ = 15 V, $R_G$ = 50 Ω, f = 100 MHz) | NF | 2.5 | dB |

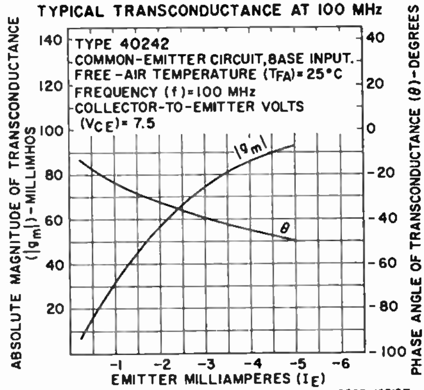
* This characteristic applies only to type 40242.

TYPICAL TRANSCONDUCTANCE AT 100 MHz



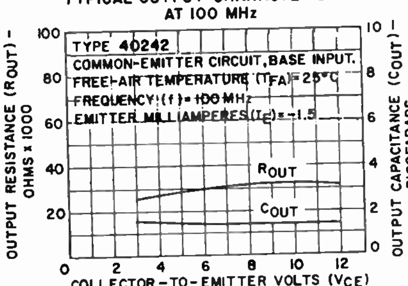

92CS-12927T

TYPICAL TRANSCONDUCTANCE AT 100 MHz



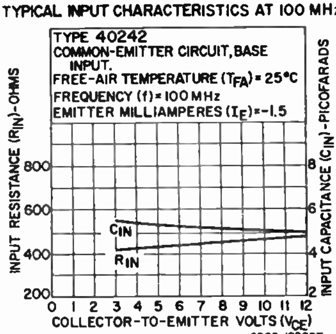

92CS-12919T

TYPICAL OUTPUT CHARACTERISTICS AT 100 MHz

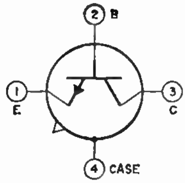



92CS-12928T

TYPICAL INPUT CHARACTERISTICS AT 100 MHz




92CS-12920T

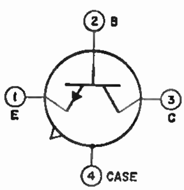



## 0.18W 40243

Si n-p-n planar type used in mixer applications in conjunction with types 40242 (rf amplifier), 40244 (rf oscillator), and 40245 and 40246 (if amplifiers) to make up a "front-end" and if complement for FM and AM/FM receivers. JEDEC TO-104, Outline No.31. This type is identical with type 40242 except for the following items:

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Emitter-Cutoff Current ($V_{EB}$ = 3 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 6 V, $I_E$ = −1 mA) | $h_{FE}$ | 40 to 170 | |
| Extrinsic Transconductance ($V_{CE}$ = 7.5 V, $I_E$ = −1 mA, f = 100 MHz) | $g_m$ | 32 | mmhos |
| Maximum Available Conversion Gain ($V_{CE}$ = 7.5 V, $I_E$ = −1 mA, f = 10.7 to 100 MHz) | $MAG_c$ | 37.64 | dB |
| Input Capacitance ($V_{CE}$ = 7.5 V, $I_E$ = −1 mA, f = 100 MHz) | $C_{ie}$ | 4.5 | pF |
| Input Resistance ($V_{CE}$ = 7.5 V, $I_E$ = −1 mA, f = 100 MHz) | $R_{ie}$ | 650 | Ω |
| Output Resistance ($V_{CE}$ = 7.5 V, $I_E$ = −1 mA, f = 100 MHz) | $R_{oe}$ | 30 | kΩ |
| Output Capacitance ($V_{CE}$ = 7.5 V, $I_E$ = −1 mA, f = 100 MHz) | $C_{oe}$ | 1.35 | pF |




## 0.18W 40244

Si n-p-n planar type used in rf-oscillator applications in conjunction with types 40242 (rf amplifier), 40243 (mixer), and 40245 and 40246 (if amplifiers) to make up a "front-end" and if complement for FM and AM/FM receivers. JEDEC TO-104, Outline No.31.

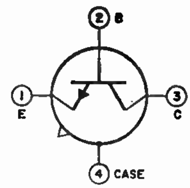
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage: | | | |
| Emitter open | $V_{CBO}$ | 45 | V |
| $V_{EB}$ = −1 V | $V_{CBV}$ | 45 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 45 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4.5 | V |
| Collector Current | $I_C$ | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 180 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating ($T_A$) and Storage ($T_{STG}$) | | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage: | | | |
| $I_C$ = 0.001 mA, $I_E$ = 0 | $V_{(BR)CBO}$ | 45 min | V |
| $V_{BE}$ = −1 V, $I_C$ = 0.001 mA | $V_{(BR)CBV}$ | 45 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −0.001 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 3 min | V |
| Collector-Cutoff Current ($V_{CB}$ = 1 V, $I_E$ = 0) | $I_{CBO}$ | 0.02 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 3 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 6 V, $I_E$ = −1 mA) | $h_{FE}$ | 27 to 170 | |
| Oscillator Output Voltage, Common Base Circuit ($V_{CC}$ = 6 V, $R_L$ = 50 Ω, f = 120 MHz) | $V_{ob}$ | 55 | mV |
| Feedback Capacitance ($V_{CB}$ = 8 V, $I_E$ = 0, f = 1 MHz) | $C_{cb}$ | 0.8 max | pF |

# 40245 0.18W




Si n-p-n planar type used in if-amplifier applications in conjunction with types 40242 (rf amplifier), 40243 (mixer), 40244 (rf oscillator), and 40246 (if amplifier) to make up a "front-end" and if complement for FM and AM/FM receivers. JEDEC TO-104, Outline No.31.

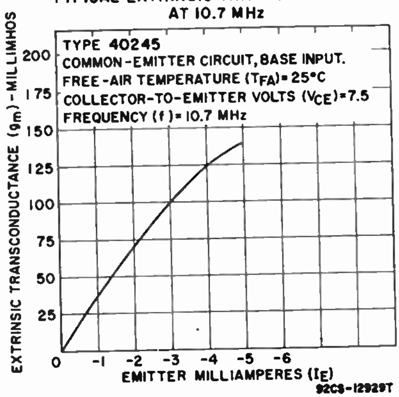
## MAXIMUM RATINGS

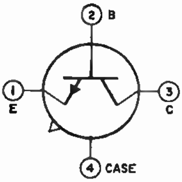
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage: | | | |
| Emitter open | $V_{CBO}$ | 45 | V |
| $V_{EB}$ = −1 V | $V_{CBV}$ | 45 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 45 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4.5 | V |
| Collector Current | $I_C$ | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 180 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating ($T_A$) and Storage ($T_{STG}$) | | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage: | | | |
| $I_C$ = 0.001 mA, $I_E$ = 0 | $V_{(BR)CBO}$ | 45 min | V |
| $V_{BE}$ = −1 V, $I_C$ = 0.001 mA | $V_{(BR)CBV}$ | 45 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −0.001 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 3 min | V |
| Collector-Cutoff Current ($V_{CB}$ = 1 V, $I_E$ = 0) | $I_{CBO}$ | 0.02 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 3 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 6 V, $I_E$ = −1 mA) | $h_{FE}$ | 70 to 275 | |
| Feedback Capacitance ($V_{CE}$ = 8 V, $I_E$ = 0, f = 1 MHz) | $C_{cb}$ | 0.65 max | pF |
| Extrinsic Transconductance ($V_{CE}$ = 7.5 V, $I_E$ = −2 mA, f = 10.7 MHz) | $g_m$ | 70 | mmhos |
| Maximum Available Amplifier Gain ($V_{CE}$ = 7.5 V, $I_E$ = −2 mA, f = 10.7 MHz) | MAG | 51.4 | dB |
| Maximum Usable Amplifier Gain: | | | |
| Neutralized—$V_{CC}$ = 12 V, f = 10.7 MHz | MUG | 33.2 | dB |
| Unneutralized—$V_{CE}$ = 7.5 V, $I_E$ = −2 mA, f = 10.7 MHz | MUG | 28.1 | dB |
| Input Capacitance ($V_{CE}$ = 7.5 V, $I_E$ = −2 mA, f = 10.7 MHz) | $C_{ie}$ | 8.2 | pF |
| Input Resistance ($V_{CE}$ = 7.5 V, $I_E$ = −2 mA, f = 10.7 MHz) | $R_{ie}$ | 1500 | Ω |
| Output Resistance ($V_{CE}$ = 7.5 V, $I_E$ = −2 mA, f = 10.7 MHz) | $R_{oe}$ | 80 | kΩ |
| Output Capacitance ($V_{CE}$ = 7.5 V, $I_E$ = −2 mA, f = 10.7 MHz) | $C_{oe}$ | 1.5 | pF |

TYPICAL EXTRINSIC TRANSCONDUCTANCE AT 10.7 MHz



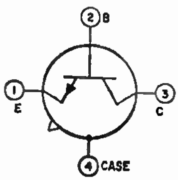



## 0.18W 40246

Si n-p-n planar type used in if-amplifier applications in conjunction with types 40242 (rf amplifier), 40243 (mixer), 40244 (if oscillator), and 40245 (if amplifier) to make up a "front-end" and if complement for FM and AM/FM receivers. JEDEC TO-104, Outline No.31. This type is identical with type 40245 except for the following items:

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 6 V, $I_E$ = −1 mA) | $h_{FE}$ | 27 to 90 | |
| Maximum Available Amplifier Gain ($V_{CE}$ = 7.5 V, $I_E$ = −2 mA, f = 10.7 MHz) | MAG | 51.2 | dB |
| Input Resistance ($V_{CE}$ = 7.5 V, $I_E$ = −2 mA, f = 10.7 MHz) | $R_{ie}$ | 1200 | Ω |
| Output Resistance ($V_{CE}$ = 7.5 V, $I_E$ = −2 mA, f = 10.7 MHz) | $R_{oe}$ | 90 | kΩ |




## 0.2W 2N918

Si n-p-n epitaxial planar type used in low-noise amplifier, oscillator, and converter applications at vhf frequencies. JEDEC TO-72, Outline No.28. This type is identical with type 2N3600 except for the following items:

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector Current | $I_C$ | 50 | mA |

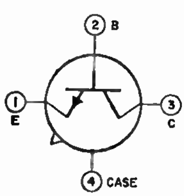
### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Small-Signal Forward-Current Transfer Ratio* (f = 100 MHz, $V_{CE}$ = 10 V, $I_C$ = 4 mA) | $h_{fe}$ | 6 min | |
| Input Capacitance (f = 0.1 to 1 MHz, $V_{EB}$ = 0.5 V, $I_C$ = 0) | $C_{ibo}$ | 2 max | pF |
| Output Capacitance:■ $V_{CB}$ = 10 V, $I_E$ = 0, f = 0.1 to 1 MHz | $C_{obo}$ | 1.7 max | pF |
| $V_{CB}$ = 0, $I_E$ = 0, f = 0.1 to 1 MHz | $C_{obo}$ | 3 max | pF |
| Collector-to-Base Time Constant* (f = 40 MHz, $V_{CB}$ = 6 V, $I_C$ = 2 mA) | $r_b'C_c$ | 15 | ps |
| Small-Signal Power Gain:* Unneutralized Amplifier Circuit ($V_{CE}$ = 10 V, $I_C$ = 5 mA, f = 200 MHz) | $G_{pe}$ | 13 | dB |
| Neutralized Amplifier Circuit ($V_{CE}$ = 12 V, $I_C$ = 6 mA, f = 200 MHz) | $G_{pe}$ | 15 min<br>18 typ | dB<br>dB |
| Power Output, Oscillator Circuit† ($V_{CB}$ = 10 V, $I_E$ = 12 mA, f = 500 MHz) | $P_{oe}$ | 30 min | mW |
| Noise Figure* ($V_{CE}$ = 6 V, $I_C$ = 1 mA, $R_G$ = 400 Ω, f = 60 MHz) | NF | 6 max | dB |

* Fourth lead (case) grounded.

■ Three-terminal measurement of the collector-to-base capacitance with the case and emitter leads connected to the guard terminal.

† Fourth lead (case) floating.




## 0.2W 2N3478

Si n-p-n epitaxial planar type for vhf-uhf applications at frequencies up to 470 MHz in industrial and commercial equipment. JEDEC TO-104, Outline No.31.

## MAXIMUM RATINGS

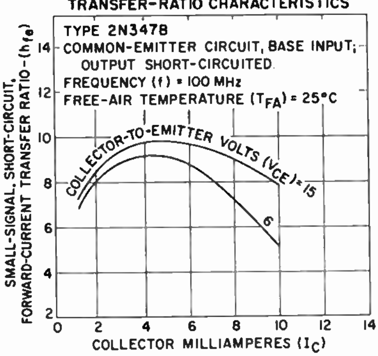
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 30 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 15 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2 | V |
| Collector Current | $I_C$ | Limited by power dissipation | |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 200 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

## CHARACTERISTICS

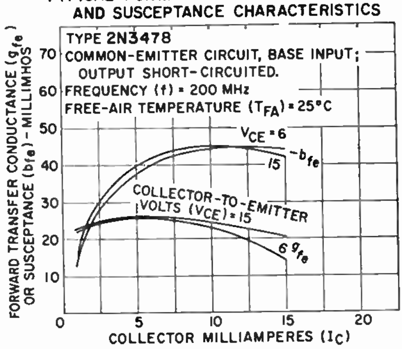
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.001 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 30 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 0.001 mA, $I_B$ = 0) | $V_{(BR)CEO}$ | 15 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.001 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 2 min | V |
| Collector-Cutoff Current ($V_{CB}$ = 1 V, $I_E$ = 0) | $I_{CBO}$ | 0.02 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 8 V, $I_C$ = 2 mA) | $h_{FE}$ | 25 to 150 | |
| Small-Signal Forward-Current Transfer Ratio* ($V_{CE}$ = 8 V, $I_C$ = 2 mA, f = 100 MHz) | $h_{fe}$ | 7.5 to 16 | |
| Collector-to-Base Feedback Capacitance ($V_{CB}$ = 8 V, $I_E$ = 0, f = 0.1 to 1 MHz) | $C_{cb}$ | 0.7 max | pF |
| Small-Signal Power Gain: | | | |
| Unneutralized Amplifier Circuit* $V_{CE}$ = 8 V, $I_C$ = 2 mA, f = 200 MHz | $G_{pe}$ | 11.5 to 17 | dB |
| Neutralized Amplifier Circuit $R_S$ = 50 Ω, $I_C$ = 1.5 mA, $V_{CE}$ = 6 V, f = 470 MHz | $G_{pe}$ | 12 | dB |
| Noise Figure* | | | |
| UHF—$R_S$ = 50 Ω, $V_{CE}$ = 6 V, $I_C$ = 1.5 mA, f = 470 MHz | NF | 5 | dB |
| VHF—$V_{CE}$ = 8 V, $I_C$ = 2 mA, f = 200 MHz | NF | 4.5 max | dB |

* Lead 4 (case) grounded.

TYPICAL SMALL-SIGNAL FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTICS

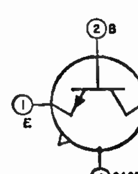



TYPICAL FORWARD TRANSFER CONDUCTANCE AND SUSCEPTANCE CHARACTERISTICS




# 2N3600

**0.2W**




Si n-p-n epitaxial planar type used in low-noise amplifier, oscillator, and converter applications at vhf frequencies in military, communications, and industrial equipment. JEDEC TO-72, Outline No.28.

## MAXIMUM RATINGS

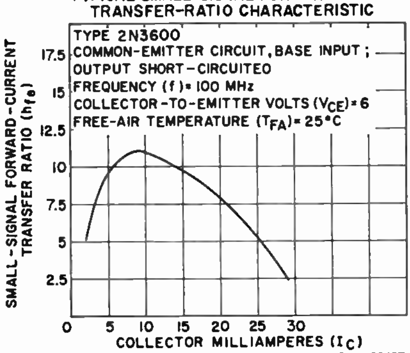
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 30 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 15 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 3 | V |
| Collector Current | $I_C$ | Limited by power dissipation | |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 200 | mW |
| $T_C$ up to 25°C (with heat sink) | $P_T$ | 300 | mW |
| $T_A$ or $T_C$ (with heat sink) above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (60 s max) | $T_L$ | 300 | °C |

## CHARACTERISTICS

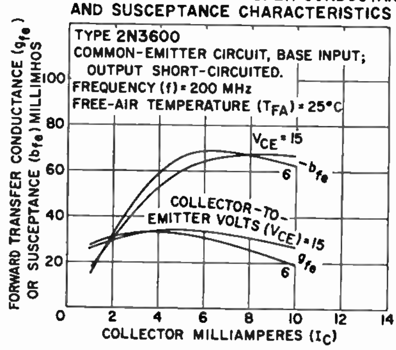
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.001 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 30 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.01 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 3 min | V |
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 3 mA, $I_B$ = 0) | $V_{(BR)CEO}$(sus) | 15 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 10 mA, $I_B$ = 1 mA) | $V_{CE}$(sat) | 0.4 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 10 mA, $I_B$ = 1 mA) | $V_{BE}$(sat) | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | 0.01 max | µA |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_A$ = 150°C | $I_{CBO}$ | 1 max | µA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 1 V, $I_C$ = 3 mA) | $h_{FE}$ | 20 to 150▲ | |
| Small-Signal Forward-Current Transfer Ratio:* | | | |
| $V_{CE}$ = 6 V, $I_C$ = 5 mA, f = 100 MHz | $h_{fe}$ | 8.5 to 15▲ | |
| $V_{CE}$ = 6 V, $I_C$ = 2 mA, f = 1 kHz | $h_{fe}$ | 40 to 200▲ | |
| Input Capacitance† ($V_{EB}$ = 0.5 V, $I_C$ = 0, f = 0.1 to 1 MHz) | $C_{ibo}$ | 1.4 | pF |
| Output Capacitance† ($V_{CB}$ = 10 V, $I_E$ = 0, f = 0.1 to 1 MHz) | $C_{obo}$ | 1.7 max | pF |
| Collector-to-Base Feedback Capacitance■ ($V_{CB}$ = 10 V, $I_E$ = 0, f = 0.1 to 1 MHz) | $C_{cb}$ | 1 max▲ | pF |
| Collector-to-Base Time Constant* ($V_{CB}$ = 6 V, $I_C$ = 5 mA, f = 31.9 MHz) | $r_b'C_c$ | 4 to 15 | ps |
| Small-Signal Power Gain, Amplifier Circuit, Neutralized* ($V_{CE}$ = 6 V, $I_C$ = 5 mA, f = 200 MHz) | $G_{pe}$ | 17 to 24▲ | dB |
| Power Output, Oscillator Circuit† ($V_{CB}$ = 10 V, $I_E$ = 12 mA, f = 500 MHz) | $P_{oe}$ | 20 min | mW |
| Noise Figure:* | | | |
| $V_{CE}$ = 6 V, $I_C$ = 1.5 mA, f = 200 MHz | NF | 4.5 max▲ | dB |
| $V_{CE}$ = 6 V, $I_C$ = 1 mA, f = 60 MHz | NF | 3 | dB |

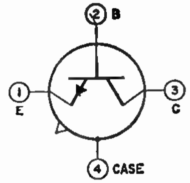
* Lead 4 (case) grounded.
† Lead 4 (case) floating.
▲ This value does not apply to type 2N918.
■ Three-terminal measurement of the collector-to-base capacitance with the case and emitter leads connected to the guard terminal.

TYPICAL SMALL-SIGNAL FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTIC




TYPICAL FORWARD TRANSFER CONDUCTANCE AND SUSCEPTANCE CHARACTERISTICS






# 2N3932

**0.2W**

Si n-p-n epitaxial planar type for general purpose vhf-uhf applications in rf amplifiers. JEDEC TO-104, Outline No.31.

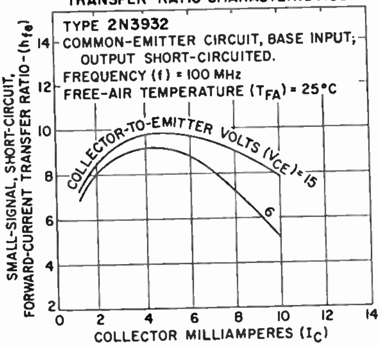
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 30 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 20 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2.5 | V |
| Collector Current | $I_C$ | Limited by power dissipation | |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 200 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

## CHARACTERISTICS

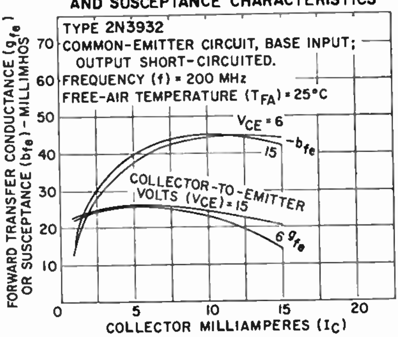
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.001 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 30 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 1 mA, $I_B$ = 0) | $V_{(BR)CEO}$ | 20 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.001 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 2.5 min | V |
| Collector-Cutoff Current ($V_{CB}$ = 15 V, $I_E$ = 0) | $I_{CBO}$ | 0.01 max | μA |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 8 V, $I_C$ = 2 mA, f = 100 MHz, lead No. 4 grounded) | $h_{fe}$ | 7.5 to 16 | |
| Gain-Bandwidth Product | $f_T$ | 750 min | MHz |
| Collector-to-Base Time Constant ($V_{CB}$ = 8 V, $I_E$ = 2 mA, f = 31.9 MHz) | $r_b'C_c$ | 1 to 8 | ps |
| Collector-to-Base Feedback Capacitance ($V_{CB}$ = 8 V, $I_E$ = 0, f = 0.1 to 1 MHz, lead Nos. 1 and 4 connected to guard terminal) | $C_{cb}$ | 0.55 max | pF |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 8 V, $I_C$ = 2 mA) | $h_{FE}$ | 40 to 150 | |
| Small-Signal Power Gain, Unneutralized Amplifier ($V_{CB}$ = 8 V, $I_C$ = 2 mA, f = 200 MHz, lead No. 4 grounded) | $G_{pe}$ | 11.5 to 17 | dB |
| Noise Figure: | | | |
| $V_{CE}$ = 8 V, $I_C$ = 2 mA, Rs = 200 Ω, f = 200 MHz | NF | 4.5 max | dB |
| $V_{CE}$ = 6 V, $I_C$ = 1.5 mA, Rs = 200 Ω, f = 450 MHz | NF | 5 | dB |

TYPICAL SMALL-SIGNAL FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTICS

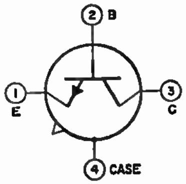



92CS-12756T1

TYPICAL FORWARD TRANSFER CONDUCTANCE AND SUSCEPTANCE CHARACTERISTICS




92CS-12759T




## 0.2W 2N3933

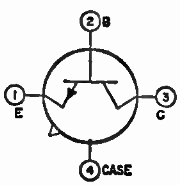
Si n-p-n epitaxial planar type for general purpose vhf and uhf applications in rf amplifiers. JEDEC TO-104, Outline No.31. This type is identical with type 2N3932 except for the following items:

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 40 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 30 | V |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.001 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 40 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 1 mA, $I_B$ = 0) | $V_{(BR)CEO}$ | 30 min | V |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 8 V, $I_C$ = 2 mA) | $h_{FE}$ | 60 to 200 | |
| Small-Signal Power Gain, Unneutralized Amplifier ($V_{CB}$ = 8 V, $I_C$ = 2 mA, f = 200 MHz, lead No. 4 grounded) | $G_{pe}$ | 14 to 18 | |
| Collector-to-Base Time Constant ($V_{CB}$ = 8 V, $I_E$ = 2 mA, f = 31.9 MHz) | $r_{b'}C_c$ | 1 to 6 | ps |
| Noise Figure ($V_{CE}$ = 8 V, $I_C$ = 2 mA, $R_S$ = 200 Ω, f = 200 MHz) | NF | 4 max | dB |




## 0.3W 2N917

Si n-p-n epitaxial planar type used in low-noise amplifier, oscillator, and converter applications at vhf frequencies. JEDEC TO-72, Outline No.28.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 30 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 15 | C |
| Emitter-to-Base Voltage | $V_{EBO}$ | 3 | V |
| Collector Current | $I_C$ | Limited by power dissipation | |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 200 | mW |
| $T_C$ up to 25°C | $P_T$ | 300 | mW |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$ | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (60 s max) | $T_L$ | 300 | °C |

### CHARACTERISTICS

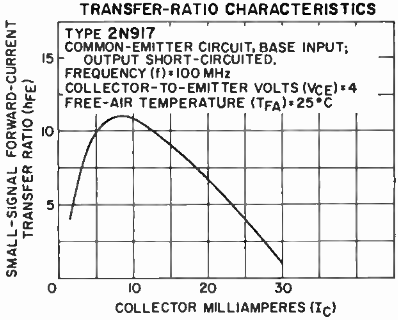
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.001 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 30 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.01 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 3 min | V |
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 3 mA, $I_B$ = 0, $t_p$ = 300 μs, df = 1%) | $V_{CEO}$(sus) | 15 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 3 mA, $I_B$ = 0.15 mA) | $V_{CE}$(sat) | 0.5 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 3 mA, $I_B$ = 0.15 mA) | $V_{BE}$(sat) | 0.87 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | 0.001 max | μA |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_A$ = 150°C | $I_{CBO}$ | 0.1 max | |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 1 V, $I_C$ = 3 mA) | $h_{FE}$ | 20 to 200 | μA |

### CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Small-Signal Forward-Current Transfer Ratio* ($V_{CE}$ = 10 V, $I_C$ = 4 mA, f = 100 MHz) | $h_{fe}$ | 5 min | |
| Input Capacitance† ($V_{EB}$ = 0.5 V, $I_C$ = 0, f = 0.1 to 1 MHz) | $C_{ibo}$ | 1.6 max | pF |
| Output Capacitance† ($V_{CB}$ = 10 V, $I_E$ = 0, f = 0.1 to 1 MHz) | $C_{obo}$ | 1.7 max | pF |
| Collector-to-Base Time Constant* ($V_{CB}$ = 10 V, $I_C$ = 4 mA, f = 40 MHz) | $r_b'C_c$ | 75 max | ps |
| Small-Signal Power Gain, Unneutralized Amplifier Circuit* ($V_{CE}$ = 10 V, $I_C$ = 5 mA, f = 200 MHz) | $G_{pe}$ | 9 min | dB |
| Power Output in Oscillator Circuit† ($V_{CB}$ = 15 V, $I_C$ = 8 mA, f = 500 MHz) | $P_{oe}$ | 10 min | mW |
| Noise Figure† ($V_{CE}$ = 6 V, Ic = 1 mA, $R_G$ = 400 Ω, f = 60 MHz) | NF | 6 max | dB |

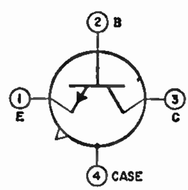
* Fourth lead (case) grounded.
† Fourth lead (case) floating.

TYPICAL SMALL-SIGNAL FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTICS




92CS-12846T

## 2N2708 0.3W




Si n-p-n double-diffused epitaxial planar type used in rf amplifiers, mixers, and oscillator circuits for vhf and uhf applications (200 to 500 MHz). JEDEC TO-72, Outline No.28.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 35 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 20 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 3 | V |
| Collector Current | $I_C$ | Limited by power dissipation | |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.2 | W |
| $T_C$ up to 25°C | $P_T$ | 0.3 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

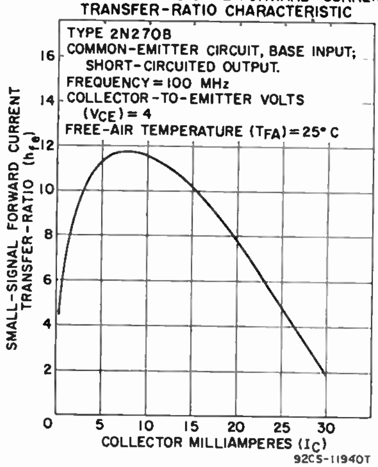
### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 1 μA, $I_E$ = 0) | $V_{(BR)CBO}$ | 35 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 3 mA, $I_B$ = 0, $t_p$ = 300 μs, df = 1%) | $V_{(BR)CEO}$(sus) | 20 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 10 μA, $I_C$ = 0) | $V_{(BR)EBO}$ | 3 min | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | 0.01 max | μA |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_A$ = 150°C | $I_{CBO}$ | 1 max | μA |

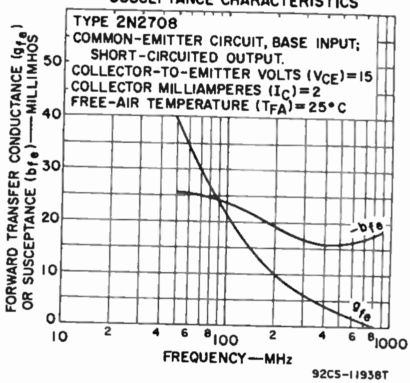
## CHARACTERISTICS (cont'd)

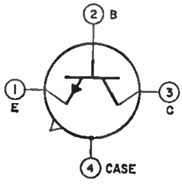
| | | | |
|---|---|---|---|
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 2 V, $I_C$ = 2 mA) | $h_{FE}$ | 30 to 200 | |
| Small-Signal Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 15 V, $I_C$ = 2 mA, f = 1 kHz | $h_{fe}$ | 30 to 180 | |
| $V_{CE}$ = 15 V, $I_C$ = 2 mA, f = 100 MHz | $h_{fe}$ | 7 to 12 | |
| Input Capacitance ($V_{EB}$ = 0.5 V, $I_C$ = 0, f = 0.14 MHz) | $C_{ibo}$ | 1.4 | pF |
| Output Capacitance ($V_{CB}$ = 15 V, $I_E$ = 0, f = 0.14 MHz) | $C_{obo}$ | 1.5 max | pF |
| Collector-to-Base Time Constant ($V_{CB}$ = 1.5 V, $I_C$ = 2 mA, f = 31.9 MHz) | $r_b'C_c$ | 9 to 33 | ps |
| Small-Signal Common-Emitter Power Gain: | | | |
| (In neutralized amplifier) $V_{CE}$ = 15 V, $I_C$ = 2 mA, f = 200 MHz | $G_{pe}$ | 15 to 22 | dB |
| (In unneutralized amplifier) $V_{CE}$ = 15 V, $I_C$ = 2 mA, f = 200 MHz | $G_{pe}$ | 12 | dB |
| Small-Signal Transconductance ($V_{CE}$ = 15 V, $I_C$ = 2 mA, f = 200 MHz) | $g_{me}$ | 25 | mmhos |
| Noise Figure: | | | |
| $V_{CE}$ = 15 V, $I_C$ = 2 mA, $R_S$ = 50 Ω, f = 200 MHz | NF | 7.5 max | dB |
| $V_{CE}$ = 6 V, $I_C$ = 1 mA, $R_S$ = 400 Ω, f = 60 MHz | NF | 3.5 | dB |

TYPICAL SMALL-SIGNAL FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTIC




TYPICAL SMALL-SIGNAL FORWARD TRANSFER CONDUCTANCE AND SUSCEPTANCE CHARACTERISTICS




## 0.3W 2N2857

Si n-p-n **double-diffused epitaxial** planar type used in low-noise amplifier, oscillator, and converter applications at frequencies up to 500 MHz in a common-emitter circuit, and up to 1200 MHz in a common-base circuit. JEDEC TO-72, Outline No.28.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 30 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 15 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2.5 | V |
| Collector Current | $I_C$ | 40 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 200 | mW |
| $T_C$ up to 25°C | $P_T$ | 300 | mW |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

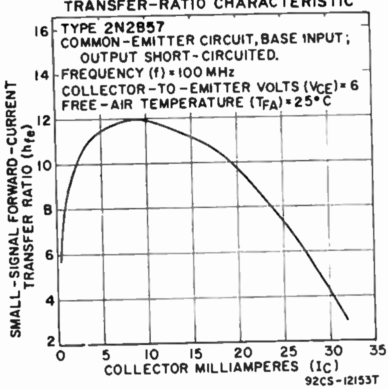
## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.001 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 30 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 3 mA, $I_B$ = 0) | $V_{(BR)CEO}$ | 15 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.01 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 2.5 min | V |
| Collector-Cutoff Current ($V_{CB}$ = 15 V, $I_E$ = 0) | $I_{CBO}$ | 0.01 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 1 V, $I_C$ = 3 mA) | $h_{FE}$ | 30 to 150 | |
| Small-Signal Forward-Current Transfer Ratio:† | | | |
| $V_{CB}$ = 6 V, $I_C$ = 5 mA, f = 100 MHz | $h_{fe}$ | 10 to 19 | |
| $V_{CE}$ = 6 V, $I_C$ = 2 mA, f = 1 kHz | $h_{fe}$ | 50 to 220 | |
| Collector-to-Base Feedback Capacitance■ ($V_{CB}$ = 10 V, $I_E$ = 0, f = 0.1 to 1 MHz) | $C_{cb}$ | 1 max | pF |
| Input Capacitance* ($V_{EB}$ = 0.5 V, $I_C$ = 0, f = 0.1 to 1 MHz) | $C_{ibo}$ | 1.4 | pF |
| Output Capacitance: | | | |
| $V_{CB}$ = 10 V, $I_E$ = 0, f = 0.14 MHz | $C_{obo}$ | 1.3† max | pF |
| $V_{CB}$ = 10 V, $I_E$ = 0, f = 0.14 MHz | $C_{obo}$ | 1.8* max | pF |
| Collector-to-Base Time Constant† ($V_{CB}$ = 6 V, $I_C$ = 2, f = 31.9 MHz) | $r_b'C_c$ | 4 to 15 | ps |
| Small-Signal Power Gain, Neutralized Amplifier† ($V_{CE}$ = 6 V, $I_C$ = 1.5 mA, f = 450 MHz) | $G_{pe}$ | 12.5 to 19 | dB |
| Power Output, Oscillator Circuit* ($V_{CB}$ = 10 V, $I_E$ = −12 mA, f = 500 MHz) | $P_{oe}$ | 30 min | mW |
| Noise Figure:† | | | |
| $V_{CE}$ = 6 V, $I_C$ = 1.5 mA, $R_G$ = 50 Ω, f = 450 MHz | NF | 4.5 max | dB |
| $V_{CE}$ = 6 V, $I_C$ = 1 mA, $R_G$ = 400 Ω, f = 60 MHz | NF | 2.2 | dB |

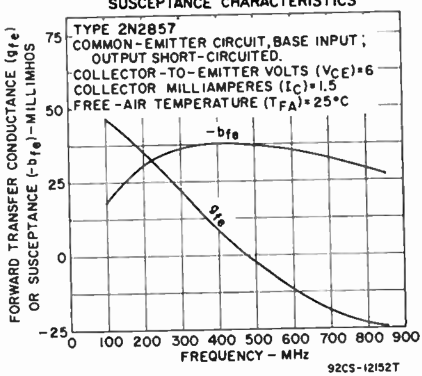
* Fourth lead (case) not connected †Fourth lead (case) grounded

■ Three-terminal measurement: Lead No. 1 (emitter) and lead No. 4 (case) connected to guard terminal.

TYPICAL SMALL-SIGNAL FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTIC

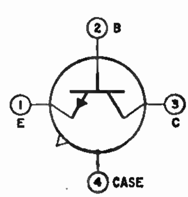



TYPICAL SMALL-SIGNAL FORWARD TRANSFER CONDUCTANCE AND SUSCEPTANCE CHARACTERISTICS




# 2N3839

**0.3W**




Si n-p-n **double-diffused epitaxial planar** type used in low-noise amplifier, oscillator, and converter applications at frequencies up to 500 MHz in a common-emitter circuit and 1200 MHz in a common-base circuit. JEDEC TO-72, Outline No.28. For maximum ratings, refer to type 2N2857.

## CHARACTERISTICS

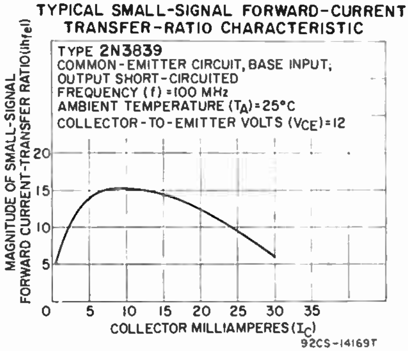
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.001 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 30 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 3 mA, $I_B$ = 0) | $V_{(BR)CEO}$ | 15 min | V |

## CHARACTERISTICS (cont'd)

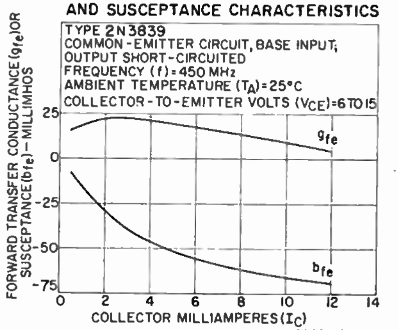
| | | | |
|---|---|---|---|
| Emitter-to-Base Breakdown Voltage ($I_E$ = −0.01 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 2.5 min | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 15 V, $I_E$ = 0 | $I_{CBO}$ | 10 max | μA |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_A$ = 150°C | $I_{CBO}$ | 1 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 1 V, $I_C$ = 3 mA) | $h_{FE}$ | 30 to 150 | |
| Small-Signal Forward-Current Transfer Ratio*: | | | |
| $V_{CE}$ = 6 V, $I_C$ = 2 mA, f = 0.001 MHz | $h_{fe}$ | 50 to 220 | |
| $V_{CE}$ = 6 V, $I_C$ = 5 mA, f = 100 MHz | $h_{fe}$ | 10 to 20 | |
| Feedback Capacitance• ($V_{CB}$ = 10 V, $I_E$ = 0, f = 0.1 to 1 MHz) | $C_{cb}$ | 0.6 typ; 1 max | pF |
| Input Capacitance ($V_{EB}$ = 0.5 V, $I_C$ = 0, f = 0.1 to 1 MHz) | $C_{ibo}$ | 1.4 | pF |
| Collector-to-Base Time Constant▪ ($V_{CB}$ = 6 V, $I_E$ = −2 mA, f = 31.9 MHz) | $r_{b'}C_c$ | 1 to 15 | ps |
| Small-Signal Power Gain▪ ($V_{CE}$ = 6 V, $I_C$ = 1.5 mA, f = 450 MHz) | $G_{pe}$ | 12.5 to 19 | dB |
| Power Output* ($V_{CB}$ = 10 V, $I_E$ = −12 mA, f ≥ 500 MHz) | $P_{oe}$ | 30 min | mW |
| Noise Figure▪: | | | |
| UHF Measured ($V_{CE}$ = 6 V, $I_C$ = 1.5 mA, f = 450 MHz, $R_G$ = 50 Ω) | NF | 3.9 max | dB |
| UHF Device ($V_{CE}$ = 6 V, $I_C$ = 1.5 mA, f = 450 MHz, $R_G$ = 50 Ω) | NF | 3.4 max | dB |
| VHF Measured ($V_{CE}$ = 6 V, $I_C$ = 1 mA, f = 60 MHz, $R_G$ = 400 Ω) | NF | 2 | dB |

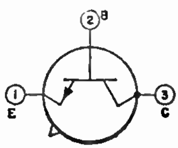
* Lead No. 4 (case) not connected.
• Three-terminal measurement with emitter and case connected to guard terminal.
▪ Lead No. 4 (case) grounded.

TYPICAL SMALL-SIGNAL FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTIC




TYPICAL FORWARD TRANSFER CONDUCTANCE AND SUSCEPTANCE CHARACTERISTICS




0.3W

# 2N5186

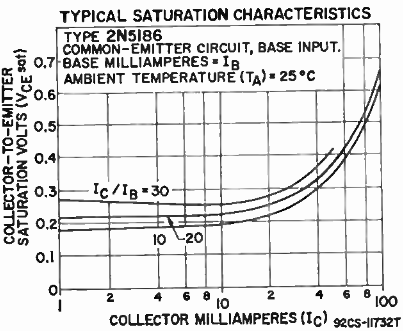
Si n-p-n epitaxial planar type used for switching applications in data-processing equipment and other critical military and industrial equipment. JEDEC TO-52, Outline No.21.

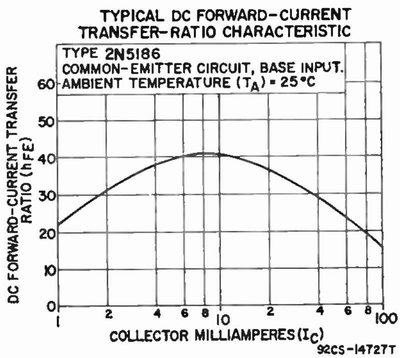
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 10 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 3 | V |
| Collector Current | $I_C$ | 300 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 300 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| $T_C$ up to 100°C | $P_T$ | 500 | mW |
| $T_C$ above 100°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$ (opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

## CHARACTERISTICS

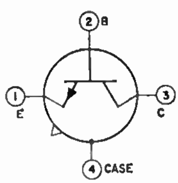
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.01 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 10 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −0.01 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 3 min | V |
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 10 mA, $I_B$ = 0) | $V_{CEO}$(sus) | 6 min; 10 typ | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 10 mA, $I_B$ = 1 mA) | $V_{CE}$(sat) | 0.3 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 10 mA, $I_B$ = 1 mA) | $V_{BE}$(sat) | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 5 V, $I_E$ = 0 | $I_{CBO}$ | 0.002 typ; 0.05 max | μA |
| $V_{CB}$ = 5 V, $I_E$ = 0, $T_A$ = 150°C | $I_{CBO}$ | 0.9 typ; 5 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 1 V, $I_C$ = 10 mA) | $h_{FE}$ | 25 min | |
| Magnitude of Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 10 mA, f = 100 MHz) | $\|h_{fe}\|$ | 4 min; 6 typ | |
| Output Capacitance ($V_{CB}$ = 5 V, $I_E$ = 0, f = 0.140 MHz) | $C_{obo}$ | 3 max | pF |
| Input Capacitance ($V_{EB}$ = 0.5 V, $I_C$ = 0, f = 0.140 MHz) | $C_{ibo}$ | 3 max | pF |
| Storage Time ($I_C$ = 5 mA, $I_{B1}$ = $-I_{B2}$ = 5 mA) | $t_s$ | 10 max | ns |
| Turn-On Time ($I_C$ = 10 mA, $I_{B1}$ = $-I_{B2}$ = 1 mA) | $t_d + t_r$ | 25 max | ns |
| Turn-Off Time ($I_C$ = 10 mA, $I_{B1}$ = $-I_{B2}$ = 1 mA) | $t_s + t_f$ | 25 max | ns |



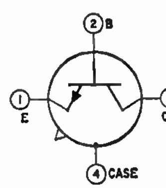

## 40294 0.3W

Si **n-p-n double-diffused epitaxial planar** type used in uhf amplifier, mixer, and oscillator applications. This type is electrically and mechanically identical with type 2N2857, but is specially controlled, processed, and tested for critical aerospace and military applications. JEDEC TO-72, Outline No.28.



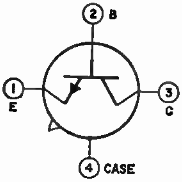

## 40295 0.3W

Si **n-p-n double-diffused epitaxial planar** type used in uhf amplifier, mixer, and oscillator applications. This type is specially controlled, processed, and tested for critical aerospace and military applications. JEDEC TO-72, Outline No.28. This type is identical to type 2N2708 except for the following item:



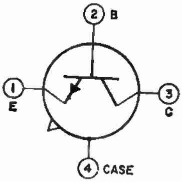

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector Current | $I_C$ | 40 | mA |



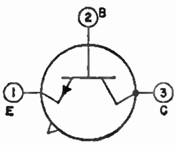

## 0.3W 40413

Si **n-p-n double-diffused epitaxial planar** type used in rf amplifier and mixer applications up to 200 MHz, and in oscillator applications up to 500 MHz. JEDEC TO-72, **Outline** No.28. This type is electrically and mechanically similar to type 2N2708, but each shipment of type 40413 is accompanied by a certified summary of electrical and environmental tests. For typical characteristics curves, refer to type 2N2857.




## 0.3W 40414

Si **n-p-n double-diffused epitaxial planar** type used in low-noise amplifier, oscillator, and converter applications at frequencies up to 500 MHz in a common-emitter circuit and 1200 MHz in a common-base circuit. JEDEC TO-72, **Outline** No.28. This type is electrically and mechanically similar to type 2N2857, but each shipment of type 40414 is accompanied by a certified summary of electrical and environmental tests. For typical characteristics curves, refer to type 2N2857.




## 0.5W 2N4068

Si **n-p-n** type used in wide-band-amplifier and relay-driver applications in critical industrial equipment such as video amplifiers, television cameras, camera chains, monitors, oscilloscopes, and neon-indicator drivers. JEDEC TO-104, **Outline** No.32.

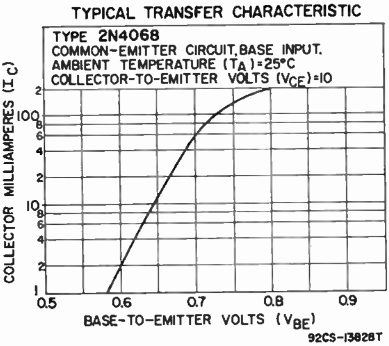
### MAXIMUM RATINGS

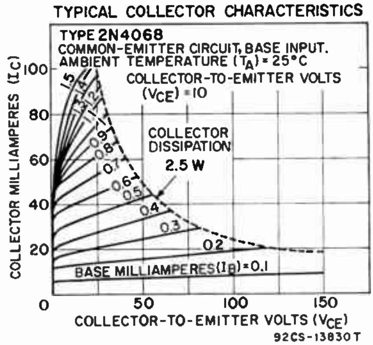
| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage | $V_{CEO}$ | 150 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector-Current | $I_C$ | 200 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.5 | W |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

### CHARACTERISTICS

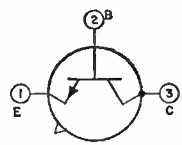
| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 1 mA, $I_B$ = 0) | $V_{(BR)CEO}$ | 150 min; 180 typ | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −10 μA, $I_C$ = 0) | $V_{(BR)EBO}$ | 5 min; 7 typ | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 30 mA, $I_B$ = 1 mA) | $V_{CE}$(sat) | 1 typ; 3 max. | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 30 mA, $I_B$ = 1 mA) | $V_{BE}$(sat) | 0.68 | V |
| Collector-Cutoff Current ($V_{CB}$ = 120 V, $I_E$ = 0) | $I_{CBO}$ | 5 typ; 50 max | nA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 30 mA) | $h_{FE}$ | 30 min; 70 typ | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 30 mA, f = 1 kHz) | $h_{fe}$ | 80 | |
| Gain-Bandwidth Product: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 30 mA, f = 100 MHz | $f_T$ | 50 min; 100 typ | MHz |
| $V_{CE}$ = 140 V, $I_C$ = 2 mA, f = 100 MHz | $f_T$ | 50 min; 100 typ | MHz |
| Output Capacitance* ($V_{CE}$ = 10 V, $I_C$ = 0, f = 1 MHz) | $C_{obo}$ | 2.8 typ; 3.5 max | pF |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 45 typ; 60 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 300 max | °C/W |

* Three-terminal measurement with lead No. 1 (emitter) and lead No. 3 (case) connected to guard terminal.




# 40354 0.5W



Si **n-p-n** type used in video-output amplifier stages of black-and-white television receivers. JEDEC TO-104, **Outline** No.32.

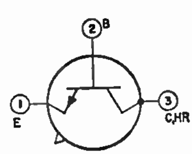
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage | $V_{CEO}$ | 150 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.5 | W |
| $T_A$ above 25°C | $P_T$ | See curve page | 300 |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 1 mA, $I_B$ = 0) | $V_{(BR)CEO}$ | 150 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −10 μA, $I_C$ = 0) | $V_{(BR)EBO}$ | 5 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 30 mA, $I_B$ = 1 mA) | $V_{CE}$(sat) | 5 max | V |
| Collector-Cutoff Current ($V_{CB}$ = 120 V, $I_E$ = 0) | $I_{CBO}$ | 100 max | V |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 10 mA) | $h_{FE}$ | 55 | |
| Collector-to-Base Feedback Capacitance ($V_{CE}$ = 10 V, $I_C$ = 30 mA) | $C_{cb}$ | 3.5 max | pF |
| Gain-Bandwidth Product: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 30 mA | $f_T$ | 50 min | MHz |
| $V_{CE}$ = 140 V, $I_C$ = 2 mA | $f_T$ | 50 min | MHz |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 60 max | °C/W |

# 2N4069 1W



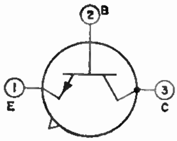
Si **n-p-n** type used in wide-band-amplifier and relay-driver applications in critical industrial equipment such as video amplifiers, television cameras, camera chains, monitors, oscilloscopes, and neon-indicator drivers. JEDEC TO-104 (with heat radiator), **Outline** No.33. This type is electrically identical with type 2N4068 except for the following items:

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 150 max | °C/W |




# 1W 2N5187

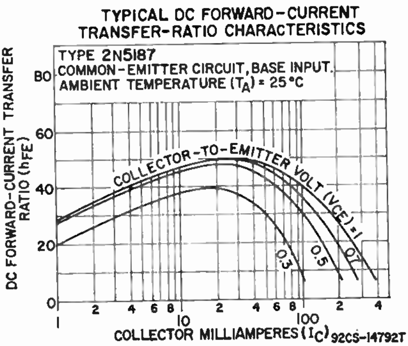
Si n-p-n epitaxial planar type used for switching applications in data-processing equipment and other critical applications in military and industrial equipment. JEDEC TO-52, Outline No.21.

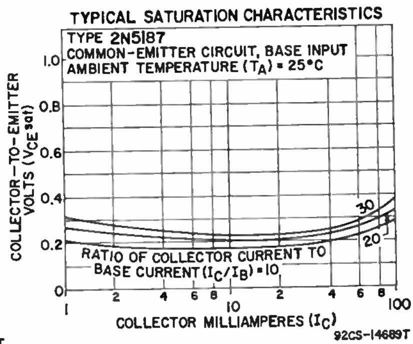
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 25 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 10 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 500 | mA |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ above 25°C | $P_T$ | Derate at 5.72 | mW/°C |
| $T_A$ up to 25°C | $P_T$ | 0.3 | W |
| $T_A$ above 25°C | $P_T$ | Derate at 1.71 | mW/°C |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

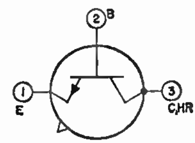
## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.01 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 25 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 10 mA, $I_B$ = 0, $t_P \leq 100$ µs, df $\leq$ 0.02) | $V_{(BR)CEO}$ | 10 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −0.01 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 5 min | V |
| Collector-to-Emitter Saturation Voltage: | | | |
| $I_C$ = 100 mA, $I_B$ = 10 mA, $t_P \leq 100$ µs, df $\leq$ 0.02 | $V_{CE}$(sat) | 0.3 typ; 0.5 max | V |
| $I_C$ = 10 mA, $I_B$ = 1 mA | $V_{CE}$(sat) | 0.2 typ; 0.25 max | V |
| Base-to-Emitter Saturation Voltage: | | | |
| $I_C$ = 100 mA, $I_B$ = 10 mA, $t_P \leq 100$ µs, df $\leq$ 0.02 | $V_{BE}$(sat) | 0.98 typ; 1.2 max | V |
| $I_C$ = 10 mA, $I_B$ = 1 mA | $V_{BE}$(sat) | 0.8 typ; 0.85 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 20 V, $V_{EB}$ = 0) | $I_{CBO}$ | 450 max | nA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 1 V, $I_C$ = 10 mA | $h_{FE}$ | 30 min | |
| $V_{CE}$ = 0.4 V, $I_C$ = 30 mA | $h_{FE}$ | 25 min | |
| Magnitude of Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 10 mA, f = 100 MHz) | $\lvert h_{fe} \rvert$ | 4 min; 6 typ | |
| Output Capacitance ($V_{CB}$ = 5 V, $I_E$ = 0, f = 0.140 MHz) | $C_{obo}$ | 2.8 typ; 3.5 max | pF |
| Input Capacitance ($V_{EB}$ = 0.5 V, $I_C$ = 0, f = 0.140 MHz) | $C_{ibo}$ | 3 typ; 4 max | pF |
| Delay Time ($V_{CC}$ = 6 V, $V_{BE}$(off) = −4 V, $I_{B1}$ = 10 mA, $I_{CS}$ = 100 mA, $I_{B2}$ = −10 mA) | $t_d$ | 6 typ; 8 max | ns |
| Rise Time ($V_{CC}$ = 6 V, $V_{BE}$ (off) = −4 V, $I_{B1}$ = 10 mA, $I_{CS}$ = 100 mA, $I_{B2}$ = −10 mA) | $t_r$ | 6 typ; 10 max | ns |
| Storage Time: | | | |
| $V_{CC}$ = 6 V, $I_{B1}$ = 10 V, $I_{CS}$ = 100 mA, $I_{B2}$ = −10 mA | $t_s$ | 9 typ; 13 max | ns |
| $V_{CC}$ = 10 V, $I_{B1}$ = 10 mA, $I_{CS}$ = 10 mA, $I_{B2}$ = − 10 mA | $t_s$ | 9 typ; 13 max | ns |
| Fall Time ($V_{CC}$ = 6 V, $I_{B1}$ = 10 mA, $I_{CS}$ = 100 mA, $I_B$ = −10 mA) | $t_f$ | 5 typ; 8 max | ns |




## 40355 1W

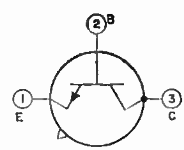



Si n-p-n type used in video-output amplifier stages of black-and-white television receivers. JEDEC TO-104 (with heat radiator), Outline No.33. This type is identical with type 40354 except for the following item:

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |

## 40405 1W




Si n-p-n epitaxial planar type used in class C rf power amplifiers, drivers, and frequency multipliers at frequencies to 400 MHz in battery-operated communications equipment. JEDEC TO-52, Outline No.21.

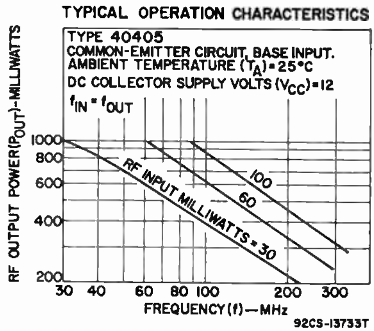
### MAXIMUM RATINGS

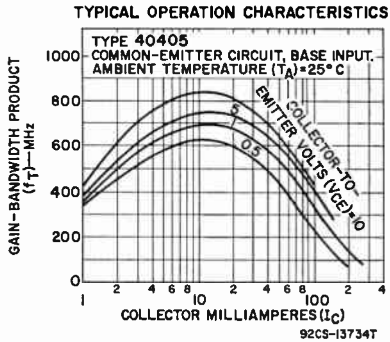
| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage: | | | |
| Base open | $V_{CEO}$ | 16 | V |
| $V_{BE} = 0$ | $V_{CES}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 6 | V |
| Collector Current | $I_C$ | 0.5 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.3 | W |
| $T_C$ up to 25°C | $P_T$ | 1 | W |
| $T_A$ and $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating ($T_A$-$T_C$) | | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 300 | °C |

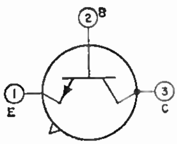
### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_C = 10$ mA, $I_B = 0$, $t_p = 100$ μs, df = 2% | $V_{(BR)CEO}$ | 16 min | V |
| $I_C = 5$ mA, $R_{BE} = 0$ | $V_{(BR)CES}$ | 40 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E = 0.01$ mA, $I_C = 0$) | $V_{(BR)EBO}$ | 6 min | V |
| Collector-Cutoff Current ($V_{CE} = 15$ V, $R_{BE} = 0$) | $I_{CES}$ | 0.4 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE} = 1$ V, $I_C = 100$ mA) | $h_{FE}$ | 20 min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE} = 1$ V, $I_C = 100$ mA, f = 100 MHz) | $h_{fe}$ | 3 min | |
| Gain Bandwidth Product ($I_C = 100$ mA, $V_{CE} = 1$ V) | $f_T$ | 300 min | MHz |
| Output Capacitance ($V_{CB} = 5$ V, $I_E = 0$, f = 0.1 to 1 MHz) | $C_{obo}$ | 3.5 max | pF |
| RF Power Output, Frequency-Doubler ($V_{CC} = 15$ V, $P_{ie} = 30$ mW, f(in) = 86 MHz, f(out) = 172 MHz | $P_{oe}$ | 200* min | mW |

* For conditions given, minimum efficiency = 35 per cent.




## 1W 40519

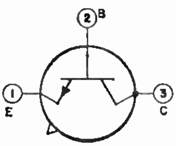
Si n-p-n epitaxial planar type used for class C rf-amplifier, driver, and frequency-multiplier service in battery-operated communications equipment. JEDEC TO-52, Outline No.21.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage: | | | |
| $R_{BE}$ = 0 | $V_{CES}$ | 40 | V |
| Base open | $V_{CEO}$ | 16 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 500 | mA |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| $T_A$ up to 25°C | $P_T$ | 0.3 | W |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_C$ = 10 mA, $I_B$ = 0, tp = 100 μs, df ≤ 0.02 | $V_{(BR)CEO}$ | 16 min | V |
| $I_C$ = 5 mA, $V_{BE}$ = 0 | $V_{(BR)CES}$ | 40 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −0.01 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 5 min | V |
| Collector-Cutoff Current ($V_{CB}$ = 20 V, $V_{BE}$ = 0, $I_E$ = 0) | $I_{CBO}$ | 25 max | nA |
| Static Forward-Current Transfer Ratio ($I_C$ = 50 mA, $V_{CE}$ = 1 V) | $h_{FE}$ | 20 min | |
| Magnitude of Small-Signal Forward-Current Transfer Ratio ($I_C$ = 50 mA, $V_{CE}$ = 1 V, f = 100 MHz) | $\|h_{fe}\|$ | 3 min | |
| Output Capacitance ($V_{CB}$ = 5 V, $I_E$ = 0, f = 0.1 to 1 MHz) | $C_{obo}$ | 3.5 max | pF |
| Power Output, Frequency Doubler ($P_{ie}$ = 15 mW, f(in) = 86 MHz, f(out) = 172 MHz) | $P_{oe}$ | 70 min | mW |
| Efficiency, Frequency Doubler (f(in) = 86 MHz, f(out) = 172 MHz) | $\eta$ | 20 min | % |




## 1W 40637

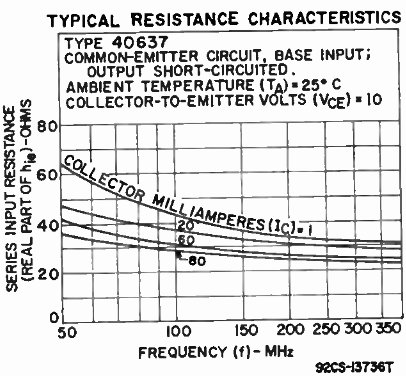
Si n-p-n epitaxial planar type used for frequency multiplier service to 175 MHz for low-level stages in mobile, marine and sonobouy vhf transmitters. JEDEC TO-52, Outline No.21.

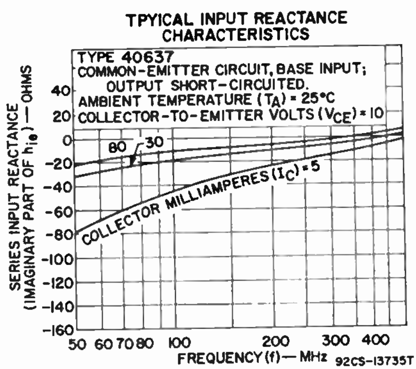
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage | $V_{CES}$ | 30 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 100 | mA |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| $T_A$ up to 25°C | $P_T$ | 0.3 | W |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 0.01 mA, $V_{BE}$ = 0) | $V_{(BR)CES}$ | 30 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −0.01 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 5 min | V |
| Collector-to-Emitter Saturation Voltage ($I_B$ = 1 mA, $I_C$ = 10 mA) | $V_{CE}$(sat) | 0.6 max | V |
| Magnitude of Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 1 V, $I_C$ = 50 mA, f = 100 MHz) | $\|h_{fe}\|$ | 3 | |
| Collector-to-Base Capacitance ($V_{CB}$ = 12 V, $I_E$ = 0, f = 0.1 to 1 MHz) | $C_{obo}$ | 3 | pF |
| Power Output, Frequency Doubler ($P_{ie}$ = 37 mW, $f_{in}$ = 78 MHz, $f_{out}$ = 156 MHz) | $P_{oe}$ | 100 min | mW |
| Efficiency, Frequency Doubler ($f_{in}$ = 78 MHz, $f_{out}$ = 156 MHz) | n | 18 min | % |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 0.15 max | °C/mW |

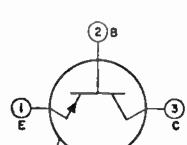



# *Switching Types*

## 2N398 0.5W
## 2N398A 0.15W
## 2N398B 0.25W

Ge p-n-p alloy-junction types used for direct "on-off" control of high-voltage, low-power devices such as neon indicators, relays, incandescent-lamp indicators, indicator counters of electronic computers, and similar applications in critical industrial and military equipment. Designed to meet MIL specifications, including mechanical, environmental, and life tests. JEDEC TO-5, Outline No.5.

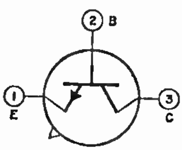


## MAXIMUM RATINGS

| | | 2N398 | 2N398A | 2N398B | |
|---|---|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −105 | −105 | −105 | V |
| Collector-to-Emitter ($R_{BE}$ = 0) | $V_{CES}$ | −105 | −105 | −105 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −50 | −50 | −75 | V |
| Collector Current | $I_C$ | −100 | −200 | −200 | mA |
| Emitter Current | $I_E$ | 100 | 200 | 200 | mA |
| Transistor Dissipation: | | | | | |
| $T_A$ up to 25°C | $P_T$ | 50 | 150 | 250 | mW |
| $T_A$ above 25°C | $P_T$ | | See curve page 300 | | |
| Temperature Range: | | | | | |
| Operating (Ambient) | $T_A$(opr) | −65 to 55 | −65 to 100 | | °C |
| Storage | $T_{STG}$ | −65 to 85 | −65 to 100 | | °C |
| Lead-Soldering Temperature: | | | | | |
| 10 seconds max | $T_L$ | 230 | — | 250 | °C |
| 3 seconds max | $T_L$ | — | 250 | — | °C |

## CHARACTERISTICS

| | | 2N398 | 2N398A | 2N398B | |
|---|---|---|---|---|---|
| Collector-to-Base Breakdown Voltage: | | | | | |
| $I_C$ = −0.025 mA, $I_E$ = 0 | $V_{(BR)CBO}$ | — | — | −105 min | V |
| $I_C$ = −0.05 mA, $I_E$ = 0 | $V_{(BR)CBO}$ | −105 | −105 | — min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −0.05 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | −50 | −50 | −75 min | V |
| Collector-to-Emitter Reach-Through Voltage | $V_{RT}$ | −105 | −105 | −105 min | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = −5 mA, $I_B$ = −0.25 mA) | $V_{BE}$(sat) | −0.4 | −0.4 | −0.3 max | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = −5 mA, $I_B$ = −0.25 mA) | $V_{CE}$(sat) | −0.35 | −0.35 | −0.25 max | V |
| Collector-Cutoff Current: | | | | | |
| $V_{CE}$ = −105 V, $R_{BE}$ = 0, $T_A$ = 25°C | $I_{CES}$ | −600 | −600 | −300 max | μA |
| $V_{CE}$ = −55 V, $R_{BE}$ = 10 kΩ, $T_A$ = 25°C | $I_{CER}$ | — | — | −300 max | μA |
| $V_{CB}$ = −2.5 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | −14 | −14 | −6 max | μA |
| $V_{CB}$ = −105 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | −50 | −50 | −25 max | μA |
| $V_{CB}$ = −105 V, $I_E$ = 0, $T_A$ = 71°C | $I_{CBO}$ | — | — | −300 max | μA |
| Emitter-Cutoff Current: | | | | | |
| $V_{EB}$ = −2.5 V, $I_C$ = 0 | $I_{EBO}$ | — | — | −6 max | μA |
| $V_{EB}$ = −50 V, $I_C$ = 0 | $I_{EBO}$ | −50 | −50 | — max | μA |
| $V_{EB}$ = −75 V, $I_C$ = 0 | $I_{EBO}$ | — | — | −50 max | μA |
| Static Forward-Current Transfer Ratio: | | | | | |
| $V_{CE}$ = −0.25 V, $I_C$ = −5 mA | $h_{FE}$ | — | — | 20 min | |
| $V_{CE}$ = −0.35 V, $I_C$ = −5 mA | $h_{FE}$ | 20 | 20 | — min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −6 V, $I_C$ = −1 mA, f = 1 kHz) | $h_{fe}$ | – | 20 | 40 min | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CB}$ = −6 V, $I_E$ = 1 mA) | $f_{hfb}$ | – | – | 1 max | MHz |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | – | 0.5 | 0.3 max | °C/W |




# 0.12W 2N585

Ge n-p-n alloy-junction type used in switching applications in data-processing equipment. JEDEC TO-5, Outline No.5.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 25 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1 V | $V_{CEV}$ | 24 | V |
| Base open | $V_{CEO}$ | 15 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 20 | V |
| Collector Current | $I_C$ | 200 | mA |
| Emitter Current | $I_E$ | −200 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 120 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Ambient) | $T_A$(opr) | 71 | °C |
| Storage | $T_{STG}$ | −65 to 85 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

## CHARACTERISTICS

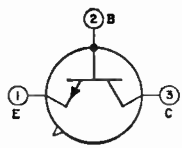
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 25 μA, $I_E$ = 0) | $V_{(BR)CBO}$ | 25 min | V |

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 600 μA, $I_B$ = 0) | $V_{(BR)CEO}$ | 15 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −25 μA, $I_C$ = 0) | $V_{(BR)EBO}$ | 20 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 20 mA, $I_B$ = 1 mA) | $V_{CE}$(sat) | 0.2 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 20 mA, $I_B$ = 1 mA) | $V_{BE}$(sat) | 0.45 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 0.25 V, $I_E$ = 0 | $I_{CBO}$ | 6 max | μA |
| $V_{CB}$ = 12 V, $I_E$ = 0 | $I_{CBO}$ | 8 max | μA |
| Emitter-Cutoff Current ($V_{BE}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 0.2 V, $I_C$ = 20 mA) | $h_{FE}$ | 20 min | |
| Small-Signal Forward-Current Transfer Ratio Cutoff Frequency ($V_{CB}$ = 6 V, $I_E$ = −1 mA) | $f_{hfb}$ | 3 min | MHz |
| Output Capacitance ($V_{CB}$ = 6 V, $I_E$ = 0) | $C_{obo}$ | 25 max | pF |
| Stored Base Charge ($I_C$ = 20 mA, $I_B$ = 2 mA) | $Q_S$ | 3000 max | pC |

# 2N388
# 2N388A

**0.15W**



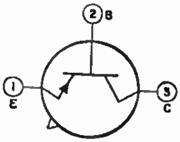

Ge n-p-n alloy-junction types used in switching applications in data-processing equipment. JEDEC TO-5, Outline No.5.

## MAXIMUM RATINGS

| | | *2N388* | *2N388A* | |
|---|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 25 | 40 | V |
| Collector-to-Emitter Voltage: | | | | |
| $V_{BE}$ = −0.5 V | $V_{CEV}$ | — | 40 | V |
| $R_{BE}$ = 10000 Ω | $V_{CER}$ | 20 | 20 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 15 | 15 | V |
| Collector Current | $I_C$ | 200 | 200 | mA |
| Transistor Dissipation: | | | | |
| $T_A$ up to 25°C | $P_T$ | 150 | 150 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | | |
| Temperature Range: | | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 100 | | °C |
| Storage | $T_{STG}$ | −65 to 100 | | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 235 | 235 | °C |

## CHARACTERISTICS

| | | *2N388* | *2N388A* | |
|---|---|---|---|---|
| Base-to-Emitter Voltage: | | | | |
| $I_B$ = 10 mA, $I_C$ = 200 mA | $V_{BE}$ | 1.5 | 1.5 max | V |
| $I_B$ = 4 mA, $I_C$ = 100 mA | $V_{BE}$ | 0.8 | 0.8 max | V |
| Collector-Cutoff Current: | | | | |
| $V_{CE}$ = 20 V, $R_{BE}$ = 10000 Ω | $I_{CER}$ | 50 | 50 max | μA |
| $V_{CE}$ = 40 V, $V_{BE}$ = −0.5 V | $I_{CEV}$ | — | 50 max | μA |
| $V_{CB}$ = 40 V, $I_E$ = 0 | $I_{CBO}$ | — | 40 max | μA |
| $V_{CB}$ = 25 V, $I_E$ = 0 | $I_{CBO}$ | 10 | 10 max | μA |
| $V_{CB}$ = 1 V, $I_E$ = 0 | $I_{CBO}$ | 5 | 5 max | μA |
| Emitter-Cutoff Current: | | | | |
| $V_{EB}$ = 15 V, $I_C$ = 0 | $I_{EBO}$ | 10 | 10 max | μA |
| $V_{EB}$ = 1 V, $I_C$ = 0 | $I_{EBO}$ | 5 | 5 max | μA |
| Static Forward-Current Transfer Ratio: | | | | |
| $V_{CE}$ = 0.75 V, $I_C$ = 200 mA | $h_{FE}$ | 30 | 30 min | |
| $V_{CE}$ = 0.5 V, $I_C$ = 30 mA | $h_{FE}$ | 60 to 180 | | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CB}$ = 6 V, $I_C$ = 1 mA) | $f_{hfb}$ | 5 | 5 min | MHz |
| Output Capacitance ($V_{CB}$ = 6 V, $I_C$ = 1 mA) | $C_{obo}$ | 20 | 20 max | pF |
| Turn-On Time ($V_{CC}$ = 20 V, $I_{B1}$ = 10 mA, $I_{B2}$ = −10 mA, $I_C$ = 0.2 A, $R_C$ = 100 Ω) | $t_d + t_r$ | 1 | 1 max | μs |
| Storage Time ($V_{CC}$ = 20 V, $I_{B1}$ = 10 mA, $I_{B2}$ = −10 mA, $I_C$ = 0.2 A, $R_C$ = 100 Ω) | $t_s$ | 0.7 | 0.7 max | μs |
| Fall Time ($V_{CC}$ = 20 V, $I_{B1}$ = 10 mA, $I_{B2}$ = −10 mA, $I_C$ = 0.2 A, $R_C$ = 100 Ω) | $t_f$ | 0.7 | 0.7 max | μs |




0.15W

# 2N404
# 2N404A

Ge p-n-p alloy-junction types used in switching applications in data-processing equipment. JEDEC TO-5, Outline No.5.

## MAXIMUM RATINGS

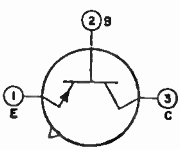
| | | *2N404* | *2N404A* | |
|---|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −25 | −40 | V |
| Collector-to-Emitter Voltage ($V_{BE}$ = 1 V) | $V_{CEV}$ | −24 | −35 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −12 | −25 | V |
| Collector Current | $I_C$ | −100 | −150 | mA |
| Emitter Current | $I_E$ | 100 | 150 | mA |
| Transistor Dissipation:● | | | | |
| $T_A$ up to 25°C | $P_T$ | 150 | 150 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | | |
| Temperature Range: | | | | |
| Operating (Ambient) | $T_A$(opr) | −65 to 85 | −65 to 100 | °C |
| Storage | $T_{STG}$ | −65 to 100 | −65 to 100 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | 255 | °C |

## CHARACTERISTICS

| | | | | |
|---|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = −0.02 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | −25 | −40 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −0.02 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | −12 | −25 min | V |
| Base-to-Emitter Saturation Voltage: | | | | |
| $I_C$ = −12 mA, $I_B$ = −0.4 mA | $V_{BE}$(sat) | −0.35 | −0.35 max | V |
| $I_C$ = −24 mA, $I_B$ = −1 mA | $V_{BE}$(sat) | −0.4 | −0.4 max | V |
| Collector-to-Emitter Saturation Voltage: | | | | |
| $I_C$ = −12 mA, $I_B$ = −0.4 mA | $V_{CE}$(sat) | −0.15 | −0.15 max | V |
| $I_C$ = −24 mA, $I_B$ = −1 mA | $V_{CE}$(sat) | −0.2 | −0.2 max | V |
| Collector-Cutoff Current: | | | | |
| $V_{CB}$ = −12 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | −5 | −5 max | μA |
| $V_{CB}$ = −12 V, $I_E$ = 0, $T_A$ = 80°C | $I_{CBO}$ | −90* | −90 max | μA |
| Static Forward-Current Transfer Ratio: | | | | |
| $V_{CE}$ = −0.2 V, $I_C$ = −24 mA | $h_{FE}$ | 24 | 24 min | |
| $V_{CE}$ = −0.15 V, $I_C$ = −12 mA | $h_{FE}$ | 30 | 30 min | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CB}$ = −6 V, $I_C$ = −1 mA) | $f_{hfb}$ | 4 | 4 min | MHz |
| Output Capacitance: | | | | |
| $V_{CB}$ = −6 V, $I_C$ = 0 | $C_{obo}$ | 20 | — max | pF |
| $V_{CB}$ = −6 V, $I_E$ = 1 mA, f = 2 MHz | $C_{obo}$ | — | 20 max | pF |
| Stored Base Charge ($I_C$ = −10 mA, $I_B$ = −1 mA) | $Q_S$ | 1400 | 1400 max | pC |

● For higher dissipation values in switching applications, see RCA Application Note AN-181.

* This value does not apply to type 2N581.




0.15W

# 2N414

Ge p-n-p alloy-junction type used in switching applications in data-processing equipment. JEDEC TO-5, Outline No.5.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −30 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = 1 V | $V_{CEV}$ | −20 | V |
| Base open | $V_{CEO}$ | −15 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −20 | mA |
| Peak Collector Current | $i_C$ | −400 | mA |
| Collector Current | $I_C$ | −200 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 150 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| $T_A$ = 55°C | $P_T$ | 75 | mW |

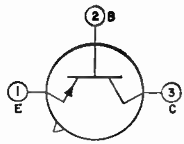
## MAXIMUM RATINGS (cont'd)

| | | | |
|---|---|---|---|
| Ambient-Temperature Range: | | | |
| Operating ($T_A$) and Storage ($T_{STG}$) | | −65 to 85 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 240 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-Cutoff Current ($V_{CB}$ = −12 V, $I_E$ = 0) | $I_{CBO}$ | −5 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −12 V, $I_C$ = 0) | $I_{EBO}$ | −5 max | μA |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −6 V, $I_E$ = 1 mA, f = 1 kHz) | $h_{fe}$ | 80 | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CB}$ = −6 V, $I_E$ = 1 mA) | $f_{hfb}$ | 8 | MHz |
| Output Capacitance ($V_{CB}$ = −6 V, $I_C$ = −1 mA) | $C_{obo}$ | 11 | pF |
| Small-Signal Short-Circuit Input Impedance ($V_{CB}$ = −6 V, $I_E$ = 1 mA, f = 1 kHz) | $h_{ib}$ | 30 | Ω |
| Small-Signal Open-Circuit Reverse-Voltage Transfer Ratio ($V_{CB}$ = −6 V, $I_E$ = 0, f = 1 kHz) | $h_{rb}$ | 0.5 x $10^{-4}$ | |
| Noise Figure ($V_{CE}$ = −6 V, $I_E$ = 1 mA, f = 1.5 MHz) | NF | 6 | dB |
| Power Gain ($V_{CE}$ = −6 V, $I_E$ = 1 mA, f = 1.5 MHz) | $G_{pe}$ | 16 | dB |

# 2N1300 0.15W




Ge p-n-p diffused-junction type used in computer applications in commercial and military data-processing equipment. JEDEC TO-5, Outline No.5.

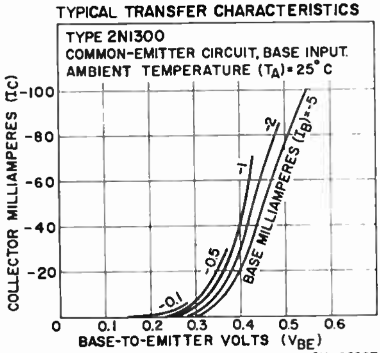
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −13 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | −12 | V |
| Emitter-to-Base Voltage* | $V_{EBO}$ | −1 | V |
| Collector Current | $I_C$ | −100 | mA |
| Emitter Current | $I_E$ | 100 | mA |
| Transistor Dissipation: | | | |
| $T_A$ = 25°C | $P_T$ | 150 | mW |
| $T_A$ = 55°C | $P_T$ | 75 | mW |
| $T_A$ = 71°C | $P_T$ | 35 | mW |
| Ambient-Temperature Range: | | | |
| Operating ($T_A$) and Storage ($T_{STG}$) | | −65 to 85 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 225 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = −0.02 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | −13 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | −1 min | V |
| Collector-to-Emitter Breakdown Voltage | $V_{(BR)CERL}$ | −12 | V |
| Base-to-Emitter Voltage ($I_C$ = −10 mA, $I_B$ = −0.33 mA) | $V_{BE}$ | −0.4 max | V |

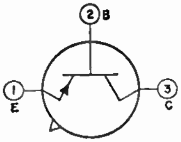
TYPICAL TRANSFER CHARACTERISTICS



## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-Cutoff Current ($V_{CB}$ = −6 V, $I_E$ = 0) | $I_{CBO}$ | −3 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −0.3 V, $I_C$ = −10 mA) | $h_{FE}$ | 30 min | |
| Gain-Bandwidth Product ($V_{CE}$ = −3 V, $I_C$ = −10 mA) | $f_T$ | 25 min | MHz |
| Output Capacitance ($V_{CB}$ = −6 V, $I_E$ = 0) | $C_{obo}$ | 12 max | pF |
| Thermal Time Constant | $\tau$(thermal) | 10 | ms |
| Total Stored Charge ($I_C$ = −10 mA, $I_B$ = −1 mA) | $Q_S$ | 400 max | pC |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 400 max | °C/W |

* This rating may be exceeded and the emitter-to-base junction operated in the breakdown condition provided the emitter dissipation is limited to 30 milliwatts at 25°C. For ambient temperatures above 25°C, the dissipation must be reduced by 0.5 milliwatts per °C.




## 0.15W 2N1301

Ge p-n-p diffused-junction type used in computer applications in data-processing equipment. JEDEC TO-5, Outline No.5. This type is identical with type 2N1300 except for the following items:

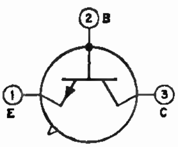
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Emitter-to-Base Voltage* | $V_{EBO}$ | −4 | V |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | −4 min | V |
| Base-to-Emitter Voltage ($I_C$ = −40 mA, $I_B$ = −1 mA) | $V_{BE}$ | −0.6 max | V |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = −0.3 V, $I_C$ = −10 mA | $h_{FE}$ | 30 min | |
| $V_{CE}$ = −0.5 V, $I_C$ = −40 mA | $h_{FE}$ | 40 min | |
| Gain-Bandwidth Product ($V_{CE}$ = −3 V, $I_C$ = −10 mA) | $f_T$ | 35 min | MHz |
| Total Stored Charge: | | | |
| $I_C$ = −10 mA, $I_B$ = −1 mA | $Q_S$ | 325 max | pC |
| $I_C$ = −40 mA, $I_B$ = −2 mA | $Q_S$ | 800 max | pC |

* This rating may be exceeded and the emitter-to-base junction operated in the breakdown condition provided the emitter dissipation is limited to 30 millivolts at 25°C. For ambient temperatures above 25°C, reduce the dissipation by 0.5 millivolts per °C.




## 0.15W 2N1302

Ge n-p-n alloy-junction type used in medium-speed switching applicatons in commercial and military data-processing equipment. The n-p-n construction permits complementary operation with a matching p-n-p type, such as the 2N1303. JEDEC TO-5, Outline No.5.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 25 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 25 | V |
| Collector Current | $I_C$ | 0.3 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 150 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 85 | °C |
| Storage | $T_{STG}$ | −65 to 100 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

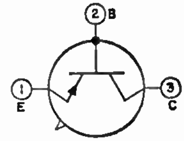
### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage ($I_B$ = 0.5 mA, $I_C$ = 10 mA) | $V_{CE}$(sat) | 0.2 max | V |
| Base-to-Emitter Voltage ($I_B$ = 0.5 mA, $I_C$ = 10 mA) | $V_{BE}$ | 0.15 to 0.4 | V |
| Collector-to-Emitter Reach-Through Voltage | $V_{RT}$ | 25 min | V |
| Collector-Cutoff Current ($V_{CB}$ = 25 V, $I_E$ = 0) | $I_{CBO}$ | 6 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 25 V, $I_C$ = 0) | $I_{EBO}$ | 6 max | μA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 1 V, $I_C$ = 10 mA | $h_{FE}$ | 20 min | |
| $V_{CE}$ = 0.35 V, $I_C$ = 200 mA | $h_{FE}$ | 10 min | |

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CB}$ = 5 V, $I_E$ = −1 mA) | $f_{hfb}$ | 3 min | MHz |
| Output Capacitance ($V_{CB}$ = 5 V, $I_E$ = 0) | $C_{obo}$ | 20 max | pF |

# 2N1303 0.15W




Ge **p-n-p** alloy-junction type used in medium-speed switching applications in data-processing equipment. The 2N1303 is the p-n-p complement of the n-p-n type 2N1302. JEDEC TO-5, Outline No.5.

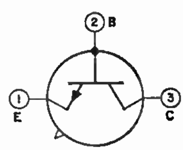
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −30 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −25 | V |
| Collector Current | $I_C$ | −0.3 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 150 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 85 | °C |
| Storage | $T_{STG}$ | −65 to 100 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage ($I_B$ = −0.5 mA, $I_C$ = −10 mA) | $V_{CE}$(sat) | −0.2 max | V |
| Base-to-Emitter Voltage ($I_B$ = −0.5 mA, $I_C$ = −10 mA) | $V_{BE}$ | −0.15 to −0.4 | V |
| Collector-to-Emitter Reach-Through Voltage | $V_{RT}$ | −25 min | V |
| Collector-Cutoff Current ($V_{CB}$ = −25 V, $I_E$ = 0) | $I_{CBO}$ | −6 max | µA |
| Emitter-Cutoff Current ($V_{EB}$ = −25 V, $I_C$ = 0) | $I_{EBO}$ | −6 max | µA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = −1 V, $I_C$ = −10 mA | $h_{FE}$ | 20 min | |
| $V_{CE}$ = −0.35 V, $I_C$ = −200 mA | $h_{FE}$ | 10 min | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CB}$ = −5 V, $I_E$ = 1 mA) | $f_{hfb}$ | 3 min | MHz |
| Output Capacitance ($V_{CB}$ = −5 V, $I_E$ = 0) | $C_{obo}$ | 20 max | pF |

# 2N1304 0.15W

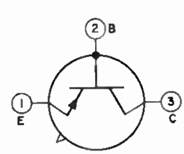



Ge **n-p-n** alloy-junction type used in medium-speed switching applications in data-processing equipment. The n-p-n construction permits complementary operation with a matching p-n-p type, such as the 2N1305. JEDEC TO-5, Outline No.5. This type is identical with type 2N1302 except for the following items:

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage ($I_B$ = 0.25 mA, $I_C$ = 10 mA) | $V_{CE}$(sat) | 0.2 max | V |
| Base-to-Emitter Voltage ($I_B$ = 0.5 mA, $I_C$ = 10 mA) | $V_{BE}$ | 0.15 to 0.35 | V |
| Collector-to-Emitter Reach-Through Voltage | $V_{RT}$ | 20 min | V |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 1 V, $I_C$ = 10 mA | $h_{FE}$ | 40 to 200 | |
| $V_{CE}$ = 0.35 V, $I_C$ = 200 mA | $h_{FE}$ | 15 min | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CB}$ = 5 V, $I_E$ = −1 mA) | $f_{hfb}$ | 5 min | MHz |

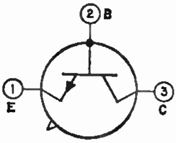
# 2N1305 0.15W




Ge **p-n-p** alloy-junction type used in medium-speed switching applications in data-processing equipment. The 2N1305 is the p-n-p complement of the n-p-n type 2N1304. JEDEC TO-5, Outline No.5. This type is identical with type 2N1303 except for the following items:

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage ($I_B$ = −25 mA, $I_C$ = −10 mA) | $V_{CE}$(sat) | −0.2 max | V |
| Base-to-Emitter Voltage ($I_B$ = −0.5 mA, $I_C$ = −10 mA) | $V_{BE}$ | −0.15 to −0.35 | V |
| Collector-to-Emitter Reach-Through Voltage | $V_{RT}$ | −20 min | V |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = −1 V, $I_C$ = −10 mA | $h_{FE}$ | 40 to 200 | |
| $V_{CE}$ = −0.35 V, $I_C$ = −200 mA | $h_{FE}$ | 15 min | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CB}$ = −5 V, $I_E$ = 1 mA) | $f_{hfb}$ | 5 min | MHz |

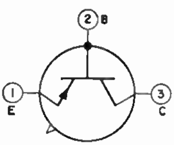



# 0.15W 2N1306

Ge n-p-n alloy-junction type used in medium-speed switching applications in data processing equipment. The 2N1306 is the n-p-n complement of the p-n-p type 2N1307. JEDEC TO-5, Outline No.5. This type is identical with type 2N1302 except for the following items:

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage ($I_B$ = 0.17 mA, $I_C$ = 10 mA) | $V_{CE}$(sat) | 0.2 max | V |
| Base-to-Emitter Voltage ($I_B$ = 0.5 mA, $I_C$ = 10 mA) | $V_{BE}$ | 0.15 to 0.35 | V |
| Collector-to-Emitter Reach-Through Voltage | $V_{RT}$ | 15 min | V |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 1 V, $I_C$ = 10 mA | $h_{FE}$ | 60 to 300 | |
| $V_{CE}$ = 0.35 V, $I_C$ = 200 mA | $h_{FE}$ | 20 min | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CB}$ = 5 V, $I_E$ = −1 mA) | $f_{hfb}$ | 10 min | MHz |

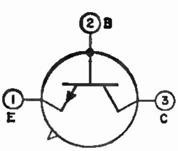



# 0.15W 2N1307

Ge p-n-p alloy-junction type used in medium-speed switching applications in data-processing equipment. The 2N1307 is the p-n-p complement of the n-p-n type 2N1306. JEDEC TO-5, Outline No.5. This type is identical with type 2N1303 except for the following items:

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage ($I_B$ = −0.17 mA, $I_C$ = −10 mA) | $V_{CE}$(sat) | −0 2 max | V |
| Base-to-Emitter Voltage ($I_B$ = −0.5 mA, $I_C$ = −10 mA) | $V_{BE}$ | −0.15 to −0.35 | V |
| Collector-to-Emitter Reach-Through Voltage | $V_{RT}$ | −15 min | V |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = −1 V, $I_C$ = −10 mA | $h_{FE}$ | 60 to 300 | |
| $V_{CE}$ = −0.35 V, $I_C$ = −200 mA | $h_{FE}$ | 20 min | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CB}$ = −5 V, $I_E$ = 1 mA) | $f_{hfb}$ | 10 min | MHz |




# 0.15W 2N1308

Ge n-p-n alloy-junction type used in medium-speed switching applications in data processing equipment. The 2N1308 is the n-p-n complement of the p-n-p type 2N1309. JEDEC TO-5, Outline No.5. This type is identical with type 2N1302 except for the following items:

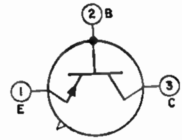
## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage ($I_B$ = 0.13 mA, $I_C$ = 10 mA) | $V_{CE}$(sat) | 0.2 max | V |
| Base-to-Emitter Voltage ($I_B$ = 0.5 mA, $I_C$ = 10 mA) | $V_{BE}$ | 0.15 to 0.35 | V |
| Collector-to-Emitter Reach-Through Voltage | $V_{RT}$ | 15 min | V |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 1 V, $I_C$ = 10 mA | $h_{FE}$ | 80 min | |
| $V_{CE}$ = 0.35 V, $I_C$ = 200 mA | $h_{FE}$ | 20 min | |

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CB}$ = 5 V, $I_E$ = −1 mA) | $f_{hfb}$ | 15 | MHz |

# 2N1309 0.15W

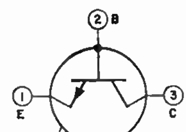



Ge **p-n-p** alloy-junction type used in medium-speed switching applicatons in data-processing equipment. The 2N1309 is the p-n-p complement of the n-p-n type 2N1308. JEDEC TO-5, Outline No.5. This type is identical with type 2N1303 except for the following items:

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage ($I_B$ = −0.13 mA, $I_C$ = −10 mA) | $V_{CE}$(sat) | −0.2 max | V |
| Base-to-Emitter Voltage ($I_B$ = −0.5 mA, $I_C$ = −10 mA) | $V_{BE}$ | −0.15 to −0.35 | V |
| Collector-to-Emitter Reach-Through Voltage | $V_{RT}$ | −15 min | V |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = −1 V, $I_C$ = −10 mA | $h_{FE}$ | 80 min | |
| $V_{CE}$ = −0.35 V, $I_C$ = −200 mA | $h_{FE}$ | 20 min | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CB}$ = −5 V, $I_E$ = 1 mA) | $f_{hfb}$ | 15 min | MHz |

# 2N1605 0.15W
# 2N1605A 0.2W




Ge **n-p-n** alloy-junction types used in medium-speed switching applications in data-processing equipment.

The n-p-n construction permits complementary operation with a matching p-n-p type such as the 2N404. JEDEC TO-5, Outline No.5.

## MAXIMUM RATINGS

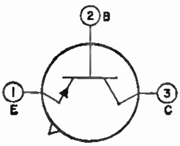
| | | *2N1605* | *2N1605A* | |
|---|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 25 | 40 | V |
| Collector-to-Emitter Voltage ($V_{BE}$ = −1 V) | $V_{CEV}$ | 24 | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 12 | 12 | V |
| Collector Current | $I_C$ | 100 | 100 | mA |
| Emitter Current | $I_E$ | −100 | −100 | mA |
| Transistor Dissipation: | | | | |
| $T_A$ up to 25°C | $P_T$ | 150 | 200 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | | |
| Temperature Range: | | | | |
| Operating (Junction) | $T_J$(opr) | 100 | 100 | °C |
| Storage | $T_{STG}$ | −65 to 100 | | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 235 | 235 | °C |

## CHARACTERISTICS

| | | | | |
|---|---|---|---|---|
| Collector-to-Base Breakdown Voltage: | | | | |
| $I_C$ = 0.02 mA, $I_E$ = 0 | $V_{(BR)CBO}$ | 25 | — min | V |
| $I_C$ = 0.01 mA, $I_E$ = 0 | $V_{(BR)CBO}$ | — | 40 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.02 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 12 | 12 min | V |
| Collector-to-Emitter Saturation Voltage: | | | | |
| $I_C$ = 12 mA, $I_B$ = 0.4 mA | $V_{CE}$(sat) | 0.15 | 0.15 max | V |
| $I_C$ = 24 mA, $I_B$ = 1 mA | $V_{CE}$(sat) | 0.2 | 0.2 max | V |
| Base-to-Emitter Voltage: | | | | |
| $I_C$ = 12 mA, $I_B$ = 0.4 mA | $V_{BE}$ | 0.35 | 0.35 max | V |
| $I_C$ = 24 mA, $I_B$ = 1 mA | $V_{BE}$ | 0.4 | 0.4 max | V |
| Emitter Floating Potential (11-MΩ min voltmeter between emitter and base): | | | | |
| $V_{CB}$ = 24 V | $V_{EB}$(fl) | 1 | — max | V |
| $V_{CB}$ = 40 V | $V_{EB}$(fl) | — | 1 max | V |
| Collector-Cutoff Current: | | | | |
| $V_{CB}$ = 12 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | 5 | — max | μA |
| $V_{CB}$ = 12 V, $I_E$ = 0, $T_A$ = 80°C | $I_{CBO}$ | 125 | 125 max | μA |
| $V_{CB}$ = 40 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | — | 10 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 2.5 V, $I_C$ = 0) | $I_{EBO}$ | 2.5 | 2.5 max | μA |

## CHARACTERISTICS (cont'd)

| | | | | |
|---|---|---|---|---|
| Static Forward-Current Transfer Ratio: | | | | |
| $V_{CE}$ = 0.15 V, $I_C$ = 12 mA | $h_{FE}$ | 30 | 30 min | |
| $V_{CE}$ = 0.2 V, $I_C$ = 24 mA | $h_{FE}$ | 24 | 24 min | |
| $V_{CE}$ = 0.25 V, $I_C$ = 20 mA | $h_{FE}$ | 40 | 40 min | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CB}$ = 6 V, $I_E$ = 1 mA) | $f_{hfb}$ | 4 | 4 min | MHz |
| Total Stored Charge ($V_{CC}$ = 5.25 V, $I_C$ = 10 mA, $I_B$ = 1 mA) | $Q_S$ | 1400 | 1400 max | pC |
| Output Capacitance ($V_{CB}$ = 6 V, $I_E$ = 1 mA, f = 2 MHz) | $C_{obo}$ | 20 | 20 max | pF |




0.15W

# 2N1683

Ge p-n-p diffused-junction type used in computer applications in data-processing equipment. JEDEC TO-5, Outline No.5. This type is identical with type 2N1300 except for the following items:

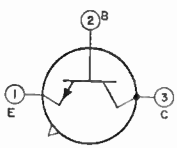
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Emitter-to-Base Voltage* | $V_{EBO}$ | −4 | V |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Emitter-to-Base Breakdown Voltage ($I_E$ = −0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | −4 min | V |
| Base-to-Emitter Voltage ($I_C$ = −40 mA, $I_B$ = −1 mA) | $V_{BE}$ | −0.6 max | V |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = −0.3 V, $I_C$ = −10 mA | $h_{FE}$ | 50 min; 75 typ | |
| $V_{CE}$ = −0.5 V, $I_C$ = −40 mA | $h_{FE}$ | 50 min; 85 typ | |
| Gain-Bandwidth Product ($V_{CE}$ = −3 V, $I_C$ = −10 mA) | $f_T$ | 50 min | MHz |
| Total Stored Charge: | | | |
| $I_C$ = −10 mA, $I_B$ = −0.4 mA | $Q_S$ | 160 max | pC |
| $I_C$ = −40 mA, $I_B$ = −1.6 mA | $Q_S$ | 410 max | pC |

* This rating may be exceeded and the emitter-to-base junction operated in the breakdown condition provided the emitter dissipation is limited to 30 milliwatts at 25°C. For ambient temperatures above 25°C, reduce the dissipation by 0.5 milliwatts per °C.




0.3W

# 2N706
# 2N706A

Si n-p-n epitaxial planar types used in high-speed switching applications in data-processing equipment. JEDEC TO-18, Outline No.12.

## MAXIMUM RATINGS

| | | *2N706* | *2N706A* | |
|---|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 25 | 25 | V |
| Collector-to-Emitter Voltage ($R_{BE}$ = 10 Ω) | $V_{CER}$ | 20 | 20 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 3 | 5 | V |
| Collector Current | $I_C$ | — | 50 | A |
| Transistor Dissipation: | | | | |
| $T_A$ up to 25°C | $P_T$ | 0.3 | 0.3 | W |
| $T_C$ (with heat sink) up to 25°C | $P_T$ | 1 | 1 | W |
| $T_A$ or $T_C$ (with heat sink) above 25°C | $P_T$ | See curve page 300 | | |
| Temperature Range: | | | | |
| Operating (Junction) | $T_J$(opr) | 175 | 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | | °C |

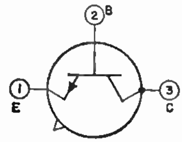
## CHARACTERISTICS

| | | | | |
|---|---|---|---|---|
| Collector-to-Emitter Saturation Voltage: | | | | |
| ($I_C$ = 10 mA, $I_B$ = 1 mA) | $V_{CE}$(sat) | 0.6 | 0.6 max | V |
| Base-to-Emitter Saturation Voltage: | | | | |
| ($I_C$ = 10 mA, $I_B$ = 1 mA) | $V_{BE}$(sat) | 0.9 | 0.9 max | V |
| Collector-Cutoff Current: | | | | |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | 0.5 | 0.5 max | μA |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_A$ = 150°C | $I_{CBO}$ | 30 | 30 max | μA |
| Static Forward-Current Transfer Ratio: | | | | |
| $V_{CE}$ = 1 V, $I_C$ = 10 mA | $h_{FE}$ | — | 20 to 60 | |
| $V_{CE}$ = 1 V, $I_C$ = 10 mA, tp ≦ 12 ms, df ≦ 2% | $h_{FE}$ | 20 | — min | |

### CHARACTERISTICS (cont'd)

| | | | | |
|---|---|---|---|---|
| Small-Signal Forward-Current Transfer Ratio: | | | | |
| $V_{CB}$ = 15 V, $I_C$ = 10 mA, f = 100 MHz | $h_{fe}$ | 2 | — min | |
| $V_{CE}$ = 10 V, $I_C$ = 10 mA, f = 100 MHz | $h_{fe}$ | — | 2 min | |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0) | $C_{obo}$ | 6 | — max | pF |
| Turn-On Time ($V_{CC}$ = 3 V, $I_C$ = 10 mA, $I_{B1}$ = 3 mA, $I_{B2}$ = −1 mA, $R_L$ = 270 Ω) | $t_d + t_r$ | — | 40 max | ns |
| Turn-Off Time ($V_{CC}$ = 3 V, $I_C$ = 10 mA, $I_{B1}$ = 3 mA, $I_{B2}$ = −1 mA, $R_L$ = 270 Ω) | $t_s + t_f$ | — | 75 max | ns |
| Storage Time ($V_{CC}$ = 10 V, $I_{B1}$ = 10 mA, $I_{B2}$ = −10 mA, $R_L$ = 1000 Ω) | $t_s$ | 60 | 25 max | ns |

## 2N709 0.3W

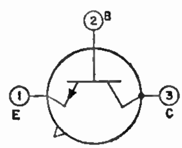



Si n-p-n epitaxial planar type used in switching applications in data-processing equipment. JEDEC TO-18, Outline No.12. This type is identical with type 2N2475 except for the following items:

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage ($I_C$ = 3 mA, $I_B$ = 0.15 mA) | $V_{CE}(sat)$ | 0.3 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 3 mA, $I_B$ = 0.15 mA) | $V_{BE}(sat)$ | 0.7 to 0.85 | V |
| Static Forward-Current Transfer Ratio: | | | |
| $I_C$ = 10 mA, $V_{CE}$ = 0.5 V, $T_A$ = 25°C | $h_{FE}$ | 20 to 120 | |
| $I_C$ = 30 mA, $V_{CE}$ = 1 V, $T_A$ = 25°C | $h_{FE}$ | 15 min | |
| $I_C$ = 10 mA, $V_{CE}$ = 0.5 V, $T_A$ = −55°C | $h_{FE}$ | 10 min | |
| Small-Signal Forward-Current Transfer Ratio ($I_C$ = 5 mA, $V_{CE}$ = 4 V, f = 100 MHz) | $h_{fe}$ | 6 min | |
| Input Capacitance ($V_{EB}$ = 0.5 V, $I_C$ = 0, f = 140 kHz) | $C_{ibo}$ | 2 max | pF |
| Output Capacitance ($V_{CB}$ = 5 V, $I_E$ = 0, f = 140 kHz) | $C_{obo}$ | 3 max | pF |
| Turn-On Time ($I_C$ = 10 mA, $I_{B1}$ = 2 mA, $I_{B2}$ = −1 mA, $V_{CC}$ = 1 V) | $t_d + t_r$ | 15 max | ns |
| Turn-Off Time ($I_C$ = 10 mA, $I_{B1}$ = 2 mA, $I_{B2}$ = −1 mA, $V_{CC}$ = 1 V) | $t_s + t_f$ | 15 max | ns |

## 2N2475 0.3W




Si n-p-n epitaxial planar type used in very-high-speed switching applications in logic circuits in military and commercial data-processing equipment. Similar to JEDEC TO-18, Outline No.12, except has minimum case height of 0.100 inch.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 15 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 6 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | Limited by power dissipation | |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.3 | W |
| $T_C$ up to 100°C | $P_T$ | 0.5 | W |
| $T_A$ above 25°C or $T_C$ above 100°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J(opr)$ | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 300 | °C |

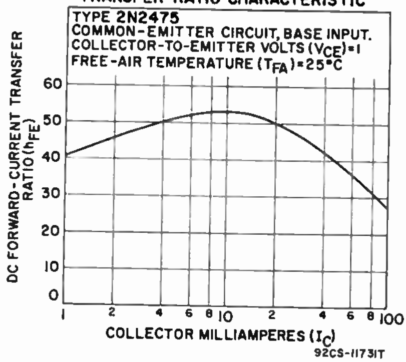
### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 10 μA, $I_E$ = 0) | $V_{(BR)CBO}$ | 15 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 10 μA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 10 mA, $I_B$ = 0, $t_p \geqq$ 300 ns, df $\leqq$ 2%) | $V_{CEO}(sus)$ | 6 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 20 mA, $I_B$ = 0.66 mA) | $V_{CE}(sat)$ | 0.4 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 20 mA, $I_B$ = 0.66 mA) | $V_{BE}(sat)$ | 0.8 to 1 | V |

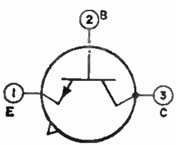
## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 5 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | 0.05 max | μA |
| $V_{CB}$ = 5 V, $I_E$ = 0, $T_A$ = 150°C | $I_{CBO}$ | 5 max | μA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 0.5 V, $I_C$ = 50 mA, $T_A$ = 25°C | $h_{FE}$ | 20 min | |
| $V_{CE}$ = 0.4 V, $I_C$ = 20 mA, $T_A$ = −55°C | $h_{FE}$ | 15 min | |
| $V_{CE}$ = 0.4 V, $I_C$ = 20 mA, $T_A$ = 25°C | $h_{FE}$ | 30 to 150 | |
| $V_{CE}$ = 0.3 V, $I_C$ = 1 mA, $T_A$ = 25°C | $h_{FE}$ | 20 min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 2 V, $I_C$ = 20 mA, f = 100 MHz) | $h_{fe}$ | 6 min | |
| Input Capacitance ($V_{EB}$ = 0.5 V, $I_C$ = 0, f = 0.14 MHz) | $C_{ibo}$ | 3 max | pF |
| Output Capacitance ($V_{CB}$ = 5 V, $I_E$ = 0, f = 0.14 MHz) | $C_{obo}$ | 2.5 max | pF |
| Storage Time ($I_C$ = 5 mA, $I_{B1}$ = 5 mA, $I_{B2}$ = 5 mA, $V_{CC}$ = 3 V) | $t_s$ | 6 max | ns |
| Turn-On Time ($I_C$ = 20 mA, $I_{B1}$ = 1 mA, $I_{B2}$ = −1 mA, $V_{CC}$ = 1.8 V) | $t_d + t_r$ | 20 max | ns |
| Turn-Off Time ($I_C$ = 20 mA, $I_{B1}$ = 1 mA, $I_{B2}$ = −1 mA, $V_{CC}$ = 1.8 V) | $t_s + t_f$ | 15 max | ns |

TYPICAL DC FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTIC




## 0.3W 2N3261




Si n-p-n epitaxial planar type used in high-speed switching applications in military and commercial data-processing equipment such as digital-logic circuits, terminated-line-driver service, and as a high-speed-memory driver. JEDEC TO-52, Outline No.21.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 40 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 15 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 6 | V |
| Collector Current | $I_C$ | 500 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.3 | W |
| $T_C$ up to 25°C | $P_T$ | 1 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating ($T_A$-$T_C$) | | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

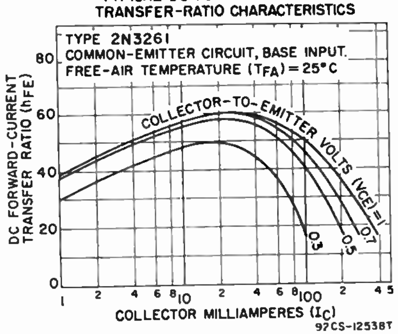
## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.01 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 40 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 10 mA, $I_B$ = 0, $t_p$ = 100 μs, df ≤ 2%) | $V_{(BR)CEO}$ | 15 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.01 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 6 min | V |

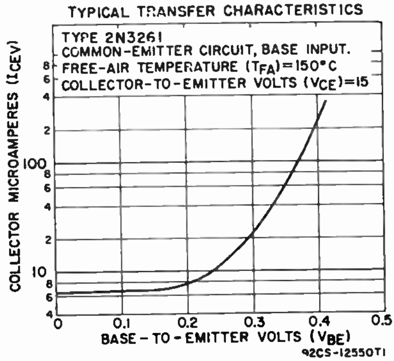
## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Base-to-Emitter Saturation Voltage ($I_C$ = 100 mA, $I_B$ = 10 mA) | $V_{BE}(sat)$ | 0.8 to 1.1 | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 100 mA, $I_B$ = 10 mA, $t_p$ = 100 µs, df ≦ 2%) | $V_{CE}(sat)$ | 0.35 max | V |
| Base-Cutoff Current ($V_{CE}$ = 15 V, $V_{BE}$ = 0) | $I_{BEV}$ | −25 max | nA |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 15 V, $V_{EB}$ = 0, $T_A$ = 15°C | $I_{CEV}$ | 25 max | nA |
| $V_{CE}$ = 15 V, $V_{EB}$ = 0, $T_A$ = 150°C | $I_{CEV}$ | 25 max | µA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 1 V, $I_C$ = 10 mA, $T_A$ = 25°C | $h_{FE}$ | 40 to 150 | |
| $V_{CE}$ = 1 V, $I_C$ = 10 mA, $T_A$ = −55°C | $h_{FE}$ | 20 min | |
| Pulsed Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 1 V, $I_C$ = 100 mA, $t_p$ = 300 µs, df ≦ 2% | $h_{FE}$(pulsed) | 30 min | |
| $V_{CE}$ = 1 V, $I_C$ = 200 mA, $t_p$ = 300 µs, df ≦ 2% | $h_{FE}$(pulsed) | 20 min | |
| Small-Signal Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 1 V, $I_C$ = 100 mA, f = 100 MHz | $h_{fe}$ | 3 min | |
| $V_{CE}$ = 10 V, $I_C$ = 10 mA, f = 100 MHz | $h_{fe}$ | 6 min | |
| Input Capacitance ($V_{EB}$ = 0.5 V, $I_C$ = 0, f = 1 MHz) | $C_{ibo}$ | 4 max | pF |
| Output Capacitance ($V_{CB}$ = 5 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 3.5 max | pF |
| Delay Time ($V_{CC}$ = 6 V, $V_{BE}(off)$ = −4 V, $I_{B_1}$ = 10 mA, $I_{CS}$ = 100 mA, $I_{B_2}$ = −10 mA) | $t_d$ | 6 max | ns |
| Rise Time ($V_{CC}$ = 6 V, $V_{BE}(off)$ = −4 V, $I_{B1}$ = 10 mA, $I_{CS}$ = 100 mA, $I_{B2}$ = −10 mA) | $t_r$ | 7 max | ns |
| Fall Time ($V_{CC}$ = 6 V, $I_{B_1}$ = 10 mA, $I_{CS}$ = 100 mA, $I_{B_2}$ = −10 mA) | $t_f$ | 6 max | ns |
| Storage Time ($V_{CC}$ = 6 V, $I_{B_1}$ = 10 mA, $I_{CS}$ = 100 mA, $I_{B_2}$ = −10 mA) | $t_s$ | 10 max | ns |

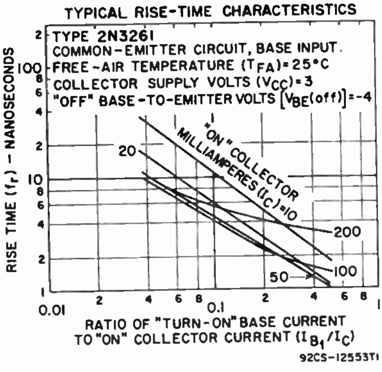
TYPICAL DC FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTICS



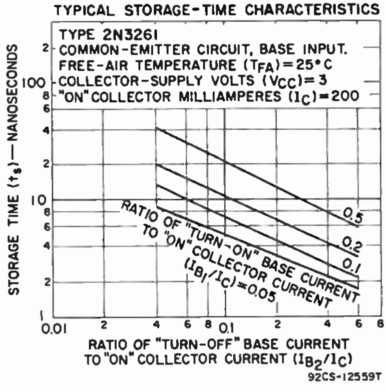

TYPICAL TRANSFER CHARACTERISTICS

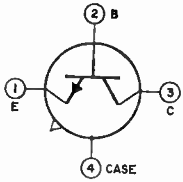



TYPICAL RISE-TIME CHARACTERISTICS




TYPICAL STORAGE-TIME CHARACTERISTICS






# 0.3W 2N5179

Si n-p-n double-diffused epitaxial planar type used in low-noise tuned-amplifier and converter applications at vhf frequencies, and as an oscillator up to 500 MHz. JEDEC TO-72, Outline No.28.

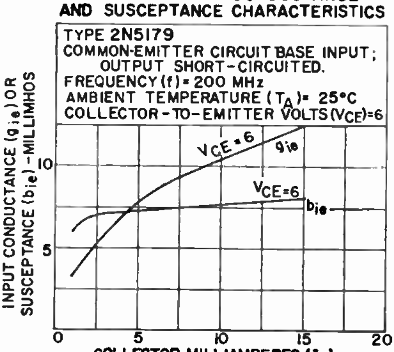
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 20 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 12 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2.5 | V |
| Collector Current | $I_C$ | 50 | mA |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 300 | mW |
| $T_C$ above 25°C | $P_T$ | Derate at 2 | mW/°C |
| $T_A$ up to 25°C | $P_T$ | 200 | mW |
| $T_A$ above 25°C | $P_T$ | Derate at 1.33 | mW/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

## CHARACTERISTICS

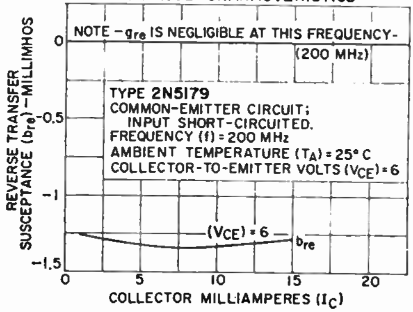
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.001 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 20 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −0.01 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 2.5 min | V |
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 3 mA, $I_B$ = 0) | $V_{CEO}$(sus) | 12 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 10 mA, $I_B$ = 1 mA) | $V_{CE}$(sat) | 0.4 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 10 mA, $I_B$ = 1 mA) | $V_{BE}$(sat) | 1 max | V |
| Collector-Cutoff Current: | | | |
| $I_C$ = 15 mA, $I_E$ = 0 | $I_{CBO}$ | 0.02 max | μA |
| $I_C$ = 15 mA, $I_E$ = 0, $T_A$ = 150°C | $I_{CBO}$ | 1 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 1 V, $I_C$ = 3 mA) | $h_{FE}$ | 25 to 250 | |
| Magnitude of Small-Signal Forward Current-Transfer Ratio•: | | | |
| $V_{CE}$ = 6 V, $I_C$ = 5 mA, f = 100 MHz | $\lvert h_{fe} \rvert$ | 9 to 20 | |
| $V_{CE}$ = 6 V, $I_C$ = 2 mA, f = 1 kHz | $\lvert h_{fe} \rvert$ | 25 to 300 | |
| Collector-to-Base Feedback Capacitance‡ ($V_{CB}$ = 10 V, $I_E$ = 0, f = 0.1 to 1 MHz) | $C_{cb}$ | 0.7 typ; 1 max | pF |
| Common-Base Input Capacitance• ($V_{EB}$ = 0.5 V, $I_C$ = 0, f = 0.1 to 1 MHz) | $C_{ibo}$ | 2 max | pF |

TYPICAL INPUT CONDUCTANCE AND SUSCEPTANCE CHARACTERISTICS




92CS-14732T

TYPICAL REVERSE TRANSFER SUSCEPTANCE CHARACTERISTICS



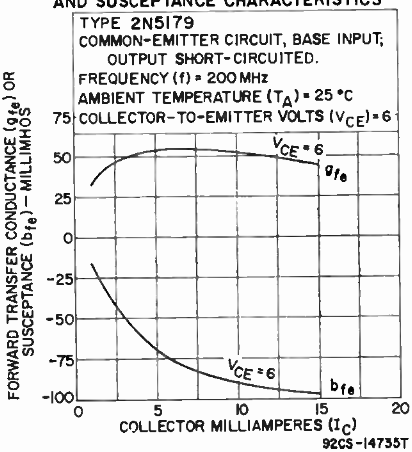

92CS-14734T

## CHARACTERISTICS (cont'd)

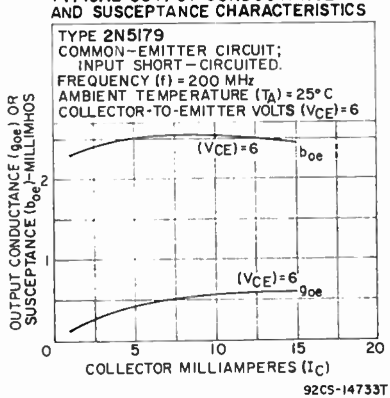
| | | | |
|---|---|---|---|
| Collector-to-Base Time Constant* ($V_{CB}$ = 6 V, $I_C$ = 2 mA, f = 31.9 MHz) | $r_b'C_c$ | 3 to 14 | ps |
| Small-Signal Power Gain, Neutralized Amplifier* ($V_{CE}$ = 12 V, $I_C$ = 5 mA, $R_G$ = 125 Ω, f = 200 MHz) | $G_{pe}$ | 15 min; 21 typ | dB |
| Power Output, Oscillator Circuit• ($V_{CB}$ = 10 V, $I_E$ = −12 mA, f > 500 MHz) | $P_o$ | 20 min | mW |
| Noise Figure* ($V_{CE}$ = 6 V, $I_C$ = 1.5 mA, f = 200 MHz) | NF | 3 typ; 4.5 max | dB |

* Lead No. 4 (case) grounded.
‡ Three-terminal measurement of the collector-to-base capacitance: Lead No. 1 (emitter) and lead No. 4 (case) connected to guard terminal.
• Lead No. 4 (case) floating.

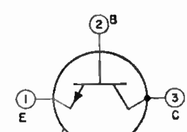
TYPICAL FORWARD TRANSFER CONDUCTANCE AND SUSCEPTANCE CHARACTERISTICS




TYPICAL OUTPUT CONDUCTANCE AND SUSCEPTANCE CHARACTERISTICS




# 2N718A 0.5W




Si n-p-n planar triple-diffused-junction type used primarily for small-signal and switching applications in data-processing equipment. JEDEC TO-18, Outline No.12.

## MAXIMUM RATINGS

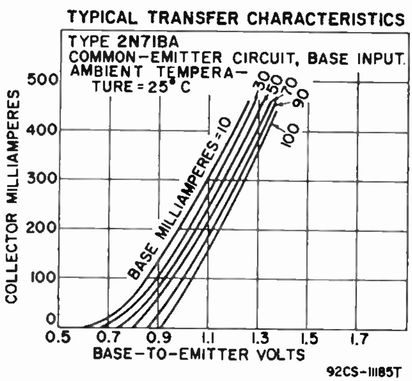
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 75 | V |
| Collector-to-Emitter Voltage: | | | |
| Base open | $V_{CEO}$ | 32 | V |
| $R_{BE}$ ≦ 10 Ω | $V_{CER}$ | 50 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.5 | W |
| $T_C$ up to 25°C | $P_T$ | 1.8 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 300 | °C |

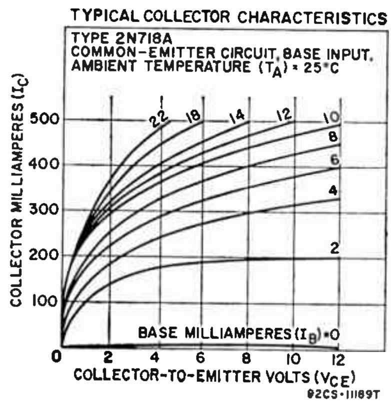
## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 75 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 7 min | V |
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $I_B$ = 0, $R_{BE}$ = 10 Ω, $t_p$ ≦ 300 μs, df ≦ 2%) | $V_{CER}$(sus) | 50 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA, $t_p$ ≦ 300 μs, df ≦ 2%) | $V_{CE}$(sat) | 1.5 max | V |

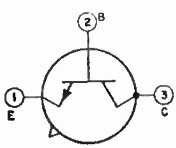
## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Base-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA, $t_p \leqq$ 300 μs, df $\leqq$ 2%) | $V_{BE}$(sat) | 1.3 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 60 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | 0.01 max | μA |
| $V_{CB}$ = 60 V, $I_E$ = 0, $T_A$ = 150°C | $I_{CBO}$ | 10 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 0.01 max | μA |
| Pulsed Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 150 mA, $t_p \leqq$ 300 μs, df $\leqq$ 2% | $h_{FE}$(pulsed) | 40 to 120 | |
| $V_{CE}$ = 10 V, $I_C$ = 10 mA, $t_p \leqq$ 300 μs, df $\leqq$ 2% | $h_{FE}$(pulsed) | 35 min | |
| $V_{CE}$ = 10 V, $I_C$ = 10 mA, $T_A$ = −55°C, $t_p \leqq$ 300 μs, df $\leqq$ 2% | $h_{FE}$(pulsed) | 20 min | |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 0.1 mA) | $h_{FE}$ | 20 min | |
| Small-Signal Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 1 mA, f = 1 kHz | $h_{fe}$ | 30 to 100 | |
| $V_{CE}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz | $h_{fe}$ | 35 to 150 | |
| $V_{CE}$ = 10 V, $I_C$ = 50 mA, f = 20 MHz | $h_{fe}$ | 3 min | |
| Input Capacitance ($V_{EB}$ = 0.5 V, $I_C$ = 0) | $C_{ibo}$ | 80 max | pF |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0) | $C_{obo}$ | 25 max | pF |
| Input Resistance: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 1 mA, f = 1 kHz | $h_{ib}$ | 24 to 34 | Ω |
| $V_{CE}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz | $h_{ib}$ | 4 to 8 | Ω |
| Voltage-Feedback Ratio: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 1 mA, f = 1 kHz | $h_{rb}$ | $3 \times 10^{-4}$ max | |
| $V_{CE}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz | $h_{rb}$ | $3 \times 10^{-4}$ max | |
| Output Conductance: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 1 mA, f = 1 kHz | $h_{ob}$ | 0.5 max | μmhos |
| $V_{CE}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz | $h_{ob}$ | 1 max | μmhos |
| Noise Figure ($V_{CE}$ = 10 V, $I_C$ = 0.3 mA, f = 1 kHz) | NF | 12 max | dB |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 97 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 350 max | °C/W |




## 0.5W 2N720A




Si n-p-n planar triple-diffused-junction type used primarily in small-signal and switching applications in data-processing equipment. JEDEC TO-18, Outline No.12. For collector and transfer curves, refer to type 2N718A.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 120 | V |
| Collector-to-Emitter Voltage: | | | |
| $R_{BE} \leqq$ 10 Ω | $V_{CER}$ | 100 | V |
| Base open | $V_{CEO}$ | 80 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |

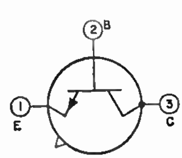
## MAXIMUM RATINGS (cont'd)

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.5 | W |
| $T_C$ up to 25°C | $P_T$ | 1.8 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 300 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 120 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 7 min | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 100 mA, $I_B$ = 0, $t_p \leqq$ 300 μs, df $\leqq$ 2% | $V_{CEO}$(sus) | 80 min | V |
| $I_C$ = 100 mA, $I_B$ = 0, $R_{BE}$ = 10 Ω, $t_p \leqq$ 300 μs, df $\leqq$ 2% | $V_{CER}$(sus) | 100 min | V |
| Collector-to-Emitter Saturation Voltage: | | | |
| $I_C$ = 150 mA, $I_B$ = 15 mA, $t_p \leqq$ 300 μs, df $\leqq$ 2% | $V_{CE}$(sat) | 5 max | V |
| $I_C$ = 50 mA, $I_B$ = 5 mA | $V_{CE}$(sat) | 1.2 max | V |
| Base-to-Emitter Saturation Voltage: | | | |
| $I_C$ = 150 mA, $I_B$ = 15 mA, $t_p \leqq$ 300 μs, df $\leqq$ 2% | $V_{BE}$(sat) | 1.3 max | V |
| $I_C$ = 50 mA, $I_B$ = 15 mA | $V_{BE}$(sat) | 0.9 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 90 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | 0.01 max | μA |
| $V_{CB}$ = 90 V, $I_E$ = 0, $T_A$ = 150°C | $I_{CBO}$ | 15 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 0.01 max | μA |
| Pulsed Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 150 mA, $t_p \leqq$ 300 μs, df $\leqq$ 2% | $h_{FE}$(pulsed) | 40 to 120 | |
| $V_{CE}$ = 10 V, $I_C$ = 10 mA, $t_p \leqq$ 300 μs, df $\leqq$ 2% | $h_{FE}$(pulsed) | 35 min | |
| $V_{CE}$ = 10 V, $I_C$ = 10 mA, $T_A$ = −55°C, $t_p \leqq$ 300 μs, df $\leqq$ 2% | $h_{FE}$(pulsed) | 20 min | |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 0.1 mA) | $h_{FE}$ | 20 min | |
| Small-Signal Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 1 mA, f = 1 kHz | $h_{fe}$ | 30 to 100 | |
| $V_{CE}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz | $h_{fe}$ | 45 min | |
| $V_{CE}$ = 10 V, $I_C$ = 50 mA, f = 20 MHz | $h_{fe}$ | 2.5 min | |
| Input Capacitance ($V_{EB}$ = 0.5 V, $I_C$ = 0) | $C_{ibo}$ | 85 max | pF |
| Output Capacitance ($V_{CBO}$ = 10 V, $I_E$ = 0) | $C_{obo}$ | 15 max | pF |
| Input Resistance: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 1 mA, f = 1 kHz | $h_{ib}$ | 20 to 30 | Ω |
| $V_{CB}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz | $h_{ib}$ | 4 to 8 | Ω |
| Voltage-Feedback Ratio: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 1 mA, f = 1 kHz | $h_{rb}$ | 1.25 x $10^{-4}$ max | |
| $V_{CB}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz | $h_{rb}$ | 1.5 x $10^{-4}$ max | |
| Output Conductance: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 1 mA, f = 1 kHz | $h_{ob}$ | 0.5 max | μmhos |
| $V_{CE}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz | $h_{ob}$ | 0.5 max | μmhos |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 97 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 350 max | °C/W |

# 2N697 0.6W



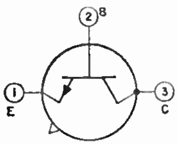

Si n-p-n planar triple-diffused-base type used in switching applications in data-processing equipment. JEDEC TO-5, Outline No.5.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 60 | V |
| Collector-to-Emitter Voltage: | | | |
| $R_{BE} \leqq$ 10 Ω | $V_{CER}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 500 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.6 | W |
| $T_C$ up to 25°C | $P_T$ | 2 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating ($T_A$ and $T_C$) | T(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 300 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 60 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 5 min | V |
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $t_p \leqq$ 12 ms, df $\leqq$ 2%, $R_{BE}$ = 10 Ω) | $V_{CER}$(sus) | 40 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA) | $V_{CE}$(sat) | 1.5 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA) | $V_{BE}$(sat) | 1.3 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | 1 max | μA |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_A$ = 150°C | $I_{CBO}$ | 100 max | μA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 150 mA, tp $\leqq$ 12 ms, df $\leqq$ 2%) | $h_{FE}$ | 40 to 120 | |
| Small-Signal Forward-Current Transfer Ratio (f = 20 MHz, $V_{CE}$ = 10 V, $I_C$ = 50 mA) | $h_{fe}$ | 2.5 min | |
| Gain-Bandwidth Product | $f_T$ | 100 | MHz |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0) | $C_{obo}$ | 35 max | pF |




# 1W 2N834

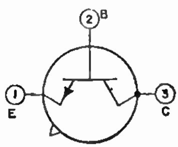
Si n-p-n epitaxial planar type used in high-speed switching applications in equipment requiring high reliablity and hgh packing densities. JEDEC TO-18, Outline No.12.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 40 | V |
| Collector-to-Emitter Voltage ($R_{BE}$ = 0) | $V_{CES}$ | 30 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 200 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.3 | W |
| $T_C$ up to 25°C | $P_T$ | 1 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 240 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 40 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 5 min | V |
| Collector-to-Emitter Saturation Voltage: | | | |
| $I_C$ = 10 mA, $I_B$ = 1 mA | $V_{CE}$(sat) | 0.25 max | V |
| $I_C$ = 50 mA, $I_B$ = 5 mA | $V_{CE}$(sat) | 0.4 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 10 mA, $I_B$ = 1 mA) | $V_{BE}$(sat) | 0.9 max | |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 20 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | 0.5 max | μA |
| $V_{CB}$ = 20 V, $I_E$ = 0, $T_A$ = 150°C | $I_{CBO}$ | 30 max | μA |
| $V_{CE}$ = 30 V, $R_{BE}$ = 0, $T_A$ = 25°C | $I_{CES}$ | 10 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 1 V, $I_C$ = 10 mA) | $h_{FE}$ | 25 min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 15 V, $I_C$ = 10 mA, f = 100 MHz) | $h_{fe}$ | 3.5 min | |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0, f = 100 kHz) | $C_{obo}$ | 4 max | pF |
| Gain-Bandwidth Product ($V_{CE}$ = 15 V, $I_C$ = 10 mA, f = 100 MHz) | $f_T$ | 350 min | MHz |
| Storage Time ($V_{CC}$ = 10 V, $I_{B1}$ = 10 mA, $I_{B2}$ = −10 mA, $I_C$ = 10 mA) | $t_s$ | 25 max | ns |
| Turn-On Time ($V_{CC}$ = 0 to 3.5 V, $I_C$ = 10 mA) | $t_d + t_r$ | 35 max | ns |
| Turn-off Time ($V_{CC}$ = 0 to 3.5 V, $I_C$ = 10 mA) | $t_s + t_f$ | 75 max | ns |




# 1.2W 2N2369A

Si n-p-n planar epitaxial type used for high-speed saturated switching in logic applications. JEDEC TO-18, Outline No.12.

## MAXIMUM RATINGS

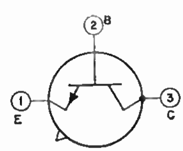
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 40 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 15 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4.5 | V |
| Collector Current | $I_C$ | 0.2 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.36 | W |
| $T_C$ up to 25°C | $P_T$ | 1.2 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (60 s max) | $T_L$ | 300 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.01 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 40 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 0.01 mA, $V_{EB}$ = 0) | $V_{(BR)CES}$ | 40 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.01 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4.5 min | V |
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 10 mA, $I_B$ = 0, $t_p$ = 300 μs, df = 2%) | $V_{CEO}$(sus) | 15 min | V |
| Collector-to-Emitter Saturation Voltage: | | | |
| $I_C$ = 10 mA, $I_B$ = 1 mA, $T_A$ = 25°C | $V_{CE}$(sat) | 0.2 max | V |
| $I_C$ = 10 mA, $I_B$ = 1 mA, $T_A$ = 125°C | $V_{CE}$(sat) | 0.3 max | V |
| $I_C$ = 30 mA, $I_B$ = 3 mA | $V_{CE}$(sat) | 0.25 max | V |
| $I_C$ = 100 mA, $I_B$ = 10 mA, $T_A$ = 25°C | $V_{CE}$(sat) | 0.5 max | V |
| Base-to-Emitter Saturation Voltage: | | | |
| $I_C$ = 10 mA, $I_B$ = 1 mA, $T_A$ = 25°C | $V_{BE}$(sat) | 0.7 to 0.85 | V |
| $I_C$ = 10 mA, $I_B$ = 1 mA, $T_A$ = 125°C | $V_{BE}$(sat) | 0.59 min | V |
| $I_C$ = 10 mA, $I_B$ = 1 mA, $T_A$ = −55°C | $V_{BE}$(sat) | 1.02 max | V |
| $I_C$ = 30 mA, $I_B$ = 3 mA | $V_{BE}$(sat) | 1.15 max | V |
| $I_C$ = 100 mA, $I_B$ = 10 mA, $T_A$ = 25°C | $V_{BE}$(sat) | 1.6 max | V |
| Collector-Cutoff Current ($V_{CB}$ = 20 V, $I_E$ = 0, $T_A$ = 150°C) | $I_{CBO}$ | 30 max | μA |
| Collector-Cutoff Current ($V_{CE}$ = 20 V, $V_{EB}$ = 0) | $I_{CES}$ | 0.4 max | μA |
| Pulsed Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 1 V, $I_C$ = 10 mA, $T_A$ = 25°C, $t_p$ = 300 μs, df = 2% | $h_{FE}$(pulsed) | 120 max | |
| $V_{CE}$ = 0.35 V, $I_C$ = 10 mA, $t_p$ = 300 μs, df = 2% | $h_{FE}$(pulsed) | 40 min | |
| $V_{CE}$ = 0.4 V, $I_C$ = 30 mA, $t_p$ = 300 μs, df = 2% | $h_{FE}$(pulsed) | 30 min | |
| $V_{CE}$ = 0.35 V, $I_C$ = 10 mA, $T_A$ = −55°C, $t_p$ = 300 μs, df = 2% | $h_{FE}$(pulsed) | 20 min | |
| $V_{CE}$ = 1 V, $I_C$ = 100 mA, $T_A$ = 25°C, $t_p$ = 300 μs, df = 2% | $h_{FE}$(pulsed) | 20 min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 10 mA, f = 100 MHz) | $h_{fe}$ | 5 min | |
| Output Capacitance ($V_{CB}$ = 5 V, $I_E$ = 0, f = 0.14 MHz) | $C_{obo}$ | 4 max | pF |
| Storage Time ($V_{CC}$ = 10 V, $I_C$ = 10 mA, $I_{B1}$ = 10 mA, $I_{B2}$ = −10 mA) | $t_s$ | 13 max | ns |
| Turn-On Time ($V_{CC}$ = 3 V, $I_C$ = 10 mA, $I_{B1}$ = 3 mA, $V_{BE}$(off) = −3 V) | $t_d + t_r$ | 12 max | ns |
| Turn-Off Time ($V_{CC}$ = 3 V, $I_C$ = 10 mA, $I_{B1}$ = 3 mA, $I_{B2}$ = −1.5 mA) | $t_s + t_f$ | 18 max | ns |

# 2N2476

**2W**




Si n-p-n double-diffused epitaxial planar type used in core-driving and line-driving applications where high switching speeds at high current are primary design requirements. JEDEC TO-5, Outline No.5.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 60 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 20 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | Limited by power dissipation | |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.6 | W |
| $T_C$ up to 25°C | $P_T$ | 2 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |

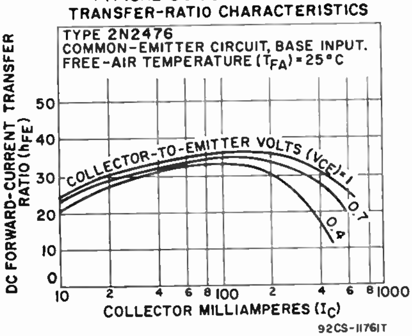
## MAXIMUM RATINGS (cont'd)

| | | | |
|---|---|---|---|
| Temperature Range: | | | |
| Operating (Junction) | $T_J$ (opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 200 | °C |

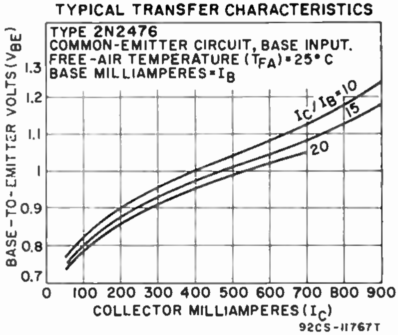
## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 10 μA, $I_E$ = 0) | $V_{(BR)CBO}$ | 60 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 50 mA, $I_B$ = 0, $t_p \leq$ 400 μs, df = 3%) | $V_{(BR)CEO}$ | 20 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 5 min | V |
| Collector-to-Emitter Saturation Voltage | | | |
| $I_C$ = 150 mA, $I_B$ = 7.5 mA | $V_{CE}$(sat) | 0.4 max | V |
| $I_C$ = 500 mA, $I_B$ = 50 mA | $V_{CE}$(sat) | 0.75 max | V |
| Base-to-Emitter Voltage ($I_C$ = 150 mA, $I_B$ = 7.5 mA) | $V_{BE}$ | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | 0.2 max | μA |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_A$ = 150°C | $I_{CBO}$ | 200 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 100 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 0.4 V, $I_C$ = 150 mA) | $h_{FE}$ | 20 min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 50 mA, f = 100 MHz) | $h_{fe}$ | 2.5 min | |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0, f = 0.14 MHz) | $C_{obo}$ | 10 max | pF |
| Storage Time ($V_{CC}$ = 6.4 V, $R_C$ = 40 Ω, $I_{B1}$ = 15 mA, $I_{B2}$ = −15 mA, $I_C$ = 150 mA) | $t_s$ | 25 max | ns |
| Turn-On Time ($V_{CC}$ = 6.4 V, $I_{B1}$ = 15 mA, $I_{B2}$ = −15 mA, $I_C$ = 150 mA) | $t_d + t_r$ | 25 max | ns |
| Turn-Off Time ($V_{CC}$ = 6.4 V, $I_{B1}$ = 15 mA, $I_{B2}$ = −15 mA, $I_C$ = 150 mA) | $t_s + t_f$ | 45 max | ns |

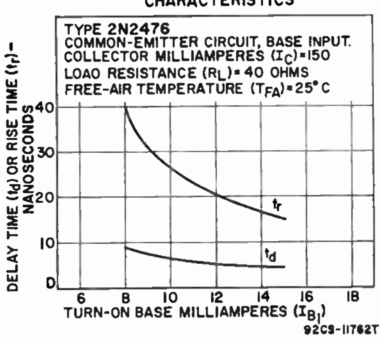
TYPICAL DC FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTICS



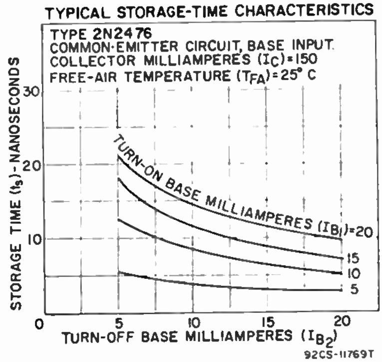

TYPICAL TRANSFER CHARACTERISTICS




TYPICAL DELAY-TIME AND RISE-TIME CHARACTERISTICS

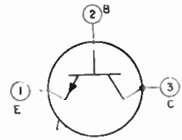



TYPICAL STORAGE-TIME CHARACTERISTICS



# 2N2477

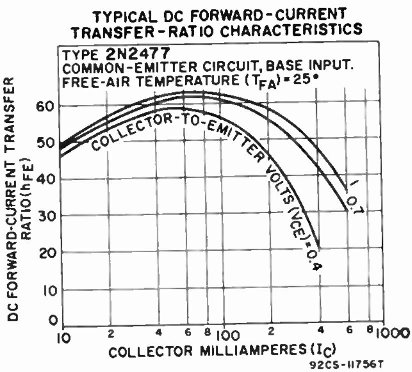
**2W**

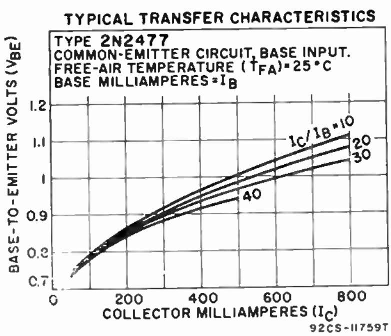



Si n-p-n double-diffused epitaxial planar type used in core-driving and line-driving applications where high switching speeds at high current are primary design requirements. JEDEC TO-5, Outline No.5. This type is identical with type 2N2476 except for its switching characteristics and the following items:

## CHARACTERISTICS

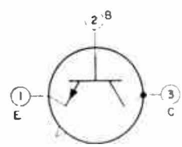
| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage: | | | |
| $I_C$ = 150 mA, $I_B$ = 3.75 mA | $V_{CE}$(sat) | 0.4 max | V |
| $I_C$ = 500 mA, $I_B$ = 50 mA | $V_{CE}$(sat) | 0.65 max | V |
| Base-to-Emitter Voltage ($I_C$ = 150 mA, $I_B$ = 3.75 mA) | $V_{BE}$ | 0.95 max | V |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 0.4 V, $I_C$ = 150 mA) | $h_{FE}$ | 40 min | |




# 2N3512

**4W**




Si n-p-n double-diffused epitaxial planar type used for core-driver and line-driver service in high-performance computers and in other critical applications requiring considerable output power. JEDEC TO-5, Outline No.5.

## MAXIMUM RATINGS

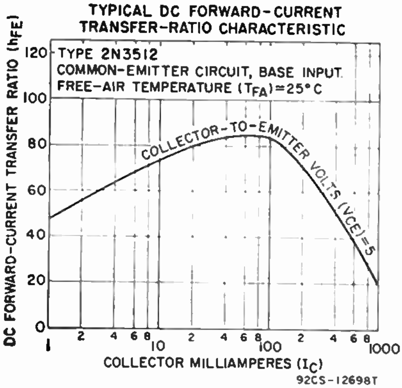
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 60 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 35 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | Limited by power dissipation | |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.8 | W |
| $T_C$ up to 25°C (with heat sink) | $P_T$ | 4 | W |
| $T_A$ or $T_C$ (with heat sink) above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

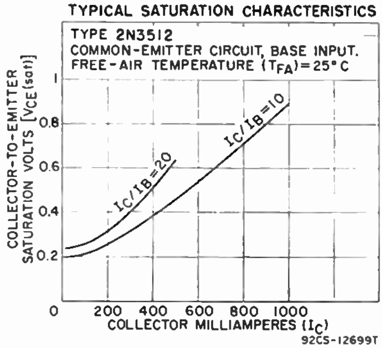
## CHARACTERISTICS

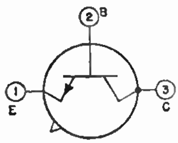
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.01 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 60 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 50 mA, $I_B$ = 0) | $V_{(BR)CEO}$ | 35 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 5 min | V |

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage: | | | |
| $I_C$ = 150 mA, $I_B$ = 7.5 mA | $V_{CE}$(sat) | 0.4 max | V |
| $I_C$ = 500 mA, $I_B$ = 50 mA, $t_p$ = 400 μs, df ≤ 3% | $V_{CE}$(sat) (pulsed) | 1 max | V |
| Base-to-Emitter Voltage ($I_C$ = 150 mA, $I_B$ = 7.5 mA) | $V_{BE}$ | 1 max | V |
| Base-Cutoff Current ($V_{CE}$ = 30 V, $V_{BE}$ = −0.3 V) | $I_{BEV}$ | 0.5 max | μA |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 30 V, $V_{BE}$ = −0.3 V, $T_A$ = 25°C | $I_{CEV}$ | 0.5 max | μA |
| $V_{CE}$ = 30 V, $V_{BE}$ = −0.3 V, $T_A$ = 100°C | $I_{CEV}$ | 100 max | μA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE}$ = 1 V, $I_C$ = 0.5 A, $t_p$ = 400 μs, df ≤ 3%) | $h_{FE}$(pulsed) | 10 min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 50 mA, f = 100 MHz) | $h_{fe}$ | 2.5 min | |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0, f = 0.14 MHz) | $C_{obo}$ | 10 max | pF |
| Storage Time ($V_{CC}$ = 6.4 V, $V_{BB}$ = 15.9 V, $I_C$ = 150 mA, $I_B$ = 15 mA) | $t_s$ | 30 max | ns |
| Turn-On Time ($V_{CC}$ = 6.4 V, $I_C$ = 150 mA, $I_{B_1}$ = 15 mA, $I_{B_2}$ = −15 mA) | $t_d + t_r$ | 30 max | ns |
| Turn-Off Time ($V_{CC}$ = 6.4 V, $V_{BB}$ = 15.9 V, $I_C$ = 150 mA, $I_{B_2}$ = −15 mA, $I_{B_1}$ = 15 mA) | $t_s + t_f$ | 45 max | ns |




# 4W 2N5188

Si n-p-n double-diffused epitaxial planar type used for core-driver and line-driver service in data-processing equipment and other critical applications in military and industrial equipment. JEDEC TO-39, Outline No.15.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 60 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 25 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | Limited by dissipation | |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 4 | W |
| $T_C$ above 25°C | $P_T$ | Derate at 22.8 | mW/°C |
| $T_A$ up to 25°C | $P_T$ | 0.8 | W |
| $T_A$ above 25°C | $P_T$ | Derate at 4.6 | mW/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

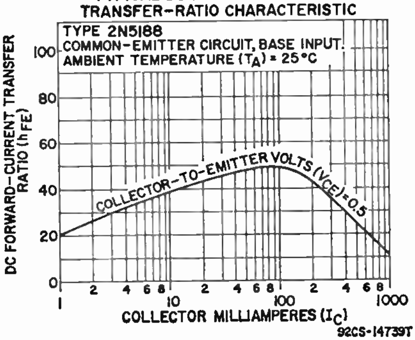
## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 30 mA, $I_E$ = 0) | $V_{(BR)CEO}$ | 25 min | V |

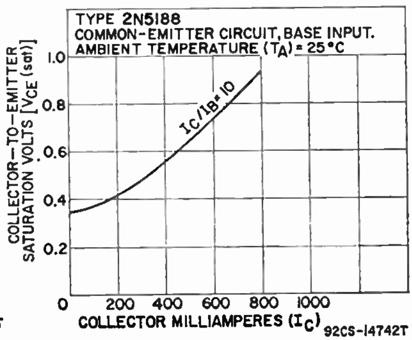
## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.01 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 60 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −0.01 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 5 min | V |
| Collector-to-Emitter Saturation Voltage: | | | |
| $I_C$ = 150 mA, $I_B$ = 7.5 mA | $V_{CE}$(sat) | 0.5 max | V |
| $I_C$ = 500 mA, $I_B$ = 50 mA, $t_P$ < 400 μs, df < 0.03 | $V_{CE}$(sat) | 1 max | V |
| Base-to-Emitter Voltage: | | | |
| $I_C$ = 150 mA, $I_B$ = 7.5 mA | $V_{BE}$ | 1.1 max | V |
| $I_C$ = 500 mA, $I_B$ = 50 mA, $t_P$ < 400 μs, df < 0.03 | $V_{BE}$ | 1.5 max | V |
| Collector-Cutoff Current ($V_{CB}$ = 30 V, $I_E$ = 0) | $I_{CBO}$ | 0.5 max | μA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 1 V, $I_C$ = 500 mA, $t_P$ < 400 μs, df < 0.03 | $h_{FE}$(pulsed) | 20 min | |
| $V_{CE}$ = 0.5 V, $I_C$ = 150 mA | $h_{FE}$ | 25 min | |
| Magnitude of Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 50 mA, f = 100 MHz) | $\lvert h_{fe}\rvert$ | 2.5 min | |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0, f = 140 kHz) | $C_{obo}$ | 8 typ; 10 max | pF |
| Storage Time ($V_{CC}$ = 6.4 V, $I_C$ = 150 mA, $I_{B1}$ = $I_{B2}$ = 15 mA | $t_s$ | 35 max | ns |
| Turn-On Time ($V_{CC}$ = 6.4 V, $I_C$ = 150 mA, $I_{B1}$ = $I_{B2}$ = 15 mA | $t_d + t_r$ | 35 max | ns |
| Turn-Off Time ($V_{CC}$ = 6.4 V, $I_C$ = 150 mA, $I_{B1}$ = $I_{B2}$ = 15 mA | $t_s + t_f$ | 50 max | ns |

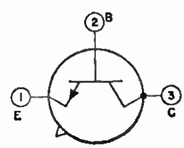
TYPICAL DC FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTIC




TYPICAL SATURATION CHARACTERISTIC




# 2N5189 5W




Si n-p-n double-diffused epitaxial planar type used for core-driver and line-driver service in data-processing equipment and other critical applications in military and industrial equipment. Outline No.58.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 60 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 35 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | Limited by dissipation | |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_C$ above 25°C | $P_T$ | Derate at 28.5 | mW/°C |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_A$ above 25°C | $P_T$ | Derate at 5.7 | mW/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

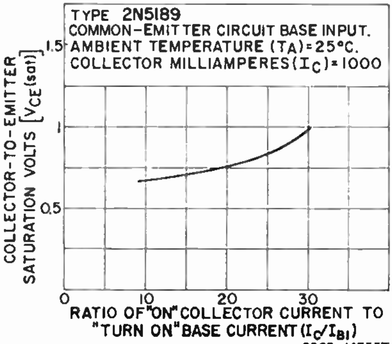
## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA) | $V_{(BR)CBO}$ | 60 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 10 mA) | $V_{(BR)CEO}$ | 35 min | V |

## CHARACTERISTICS (cont'd)

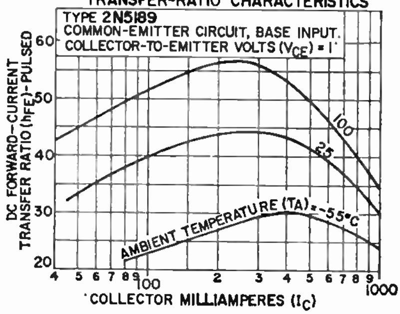
| | | | |
|---|---|---|---|
| Emitter-to-Base Breakdown Voltage ($I_E = -0.1$ mA) | $V_{(BR)EBO}$ | 5 max | V |
| Collector-to-Emitter Saturation Voltage ($I_C = 1000$ mA, $I_B = 100$ mA) | $V_{CE}$(sat) | 1 max | V |
| Base-to-Emitter Saturation Voltage ($I_C = 1000$ mA, $I_B = 100$ mA) | $V_{BE}$(sat) | 1.5 max | V |
| Collector-Cutoff Current ($V_{CE} = 30$ V) | $I_{CBO}$ | 0.5 max | μA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE} = 1$ V, $I_C = 100$ mA | $h_{FE}$ | 30 max | |
| $V_{CE} = 1$ V, $I_C = 500$ mA | $h_{FE}$ | 35 max | |
| $V_{CE} = 1$ V, $I_C = 500$ mA, $t_P \leq 400$ μs, df $\leq 0.03$ | $h_{FE}$(pulsed) | 15 max | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE} = 10$ V, $I_C = 50$ mA, f = 100 MHz) | $h_{fe}$ | 2.5 min | |
| Output Capacitance ($V_{CB} = 10$ V, $I_E = 0$, f = 0.1 MHz) | $C_{obo}$ | 12 max | pF |
| Turn-On Time ($I_C = 1000$ mA, $I_{B1} = 100$ mA) | $t_d + t_r$ | 40 max | ns |
| Turn-Off Time ($I_C = 1000$ mA, $I_{B1} = 100$ mA, $I_{B2} = -100$ mA) | $t_s + t_f$ | 70 maxsu | |

TYPICAL SATURATION CHARACTERISTIC

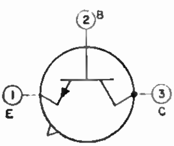



92CS-14755T

TYPICAL DC FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTICS




92CS-14748T




## 5W 2N5262

Si n-p-n epitaxial planar type used for high-speed, high-voltage, high-current switching applications for memory driver service in data-processing equipment and other critical industrial applications. Outline No.58.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 75 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 50 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 2 | A |
| Peak Collector Current | $i_C$ | 3 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_C$ above 25°C | $P_T$ | Derate at 28.5 | mW/°C |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_A$ above 25°C | $P_T$ | Derate at 5.7 | mW/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

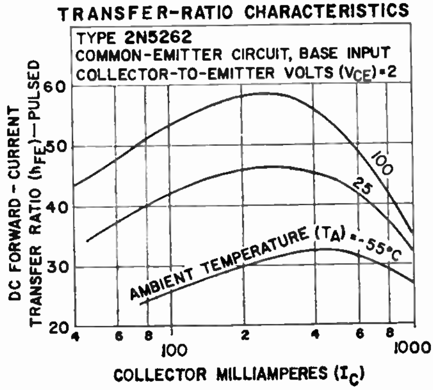
## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C = 0.1$ mA) | $V_{(BR)CBO}$ | 75 min; 110 typ | V |
| Collector-to-Emitter Breakdown Voltage ($I_C = 10$ mA) | $V_{(BR)CEO}$ | 50 min; 56 typ | V |
| Emitter-to-Base Breakdown Voltage ($I_E = -0.1$ mA) | $V_{(BR)EBO}$ | 5 min; 8 typ | V |
| Collector-to-Emitter Saturation Voltage ($I_C = 1000$ mA, $I_B = 100$ mA) | $V_{CE}$(sat) | 0.5 typ; 0.8 max | V |

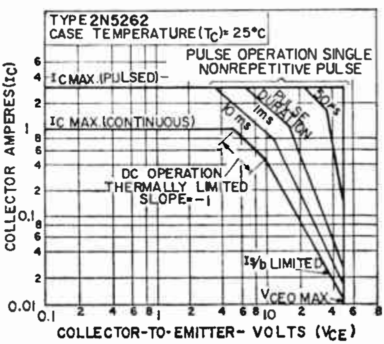
## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Base-to-Emitter Saturation Voltage ($I_C$ = 1000 mA, $I_B$ = 100 mA) | $V_{BE}$(sat) | 1 typ; 1.4 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 60 V | $I_{CES}$ | 10 max | $\mu$A |
| $V_{CE}$ = 30 V | $I_{CES}$ | 0.4 typ; 1 max | $\mu$A |
| $V_{CE}$ = 30 V, $T_A$ = 100°C | $I_{CES}$ | 100 max | $\mu$A |
| Static Forward Current Transfer Ratio: | | | |
| $V_{CE}$ = 1 V, $I_C$ = 100 mA | $h_{FE}$ | 35 min; 55 typ | |
| $V_{CE}$ = 1 V, $I_C$ = 500 mA | $h_{FE}$ | 40 min; 65 typ | |
| $V_{CE}$ = 1 V, $I_C$ = 1000 mA, $t_P \leq$ 400 $\mu$s, df $\leq$ 0.03 | $h_{FE}$(pulsed) | 25 min; 45 typ | |
| Small-Signal Forward Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 50 mA, f = 100 MHz) | $h_{fe}$ | 2.5 min; 3.5 typ | |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0, f = 0.1 to 1 MHz) | $C_{obo}$ | 9 typ; 12 max | pF |
| Turn-On Time ($I_C$ = 1000 mA, $I_{B1}$ = 100 mA) | $t_d + t_r$ | 18 min; 30 max | ns |
| Turn-Off Time ($I_C$ = 1000 mA, $I_{B1}$ = 100 mA, $I_{B2}$ = −100 mA) | $t_s + t_f$ | 35 typ; 60 max | ns |

TYPICAL DC FORWARD CURRENT TRANSFER-RATIO CHARACTERISTICS




MAXIMUM OPERATING AREAS



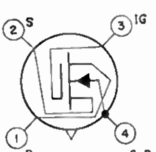
# Technical Data for MOS Field-Effect Transistors

THIS section contains detailed technical data for all current RCA MOS field-effect transistors. The data for MOS transistors are grouped separately for single gate, dual-gate, and dual-gate-protected types. Within each grouping, the transistors are listed according to the numerical-alphabetical-numerical sequence of type designations.

In selection of devices for use in new electronic equipment, a prospective user should refer to the appropriate section of the Selection Guide included earlier in the Manual.

## *Single Gate Types*

bottom view,




### FIELD-EFFECT TRANSISTOR 3N128

Si insulated-gate field-effect (MOS) n-channel depletion type used in vhf amplifier service in military and industrial applications at frequencies up to 250 MHz. JEDEC TO-72, Outline No.28.

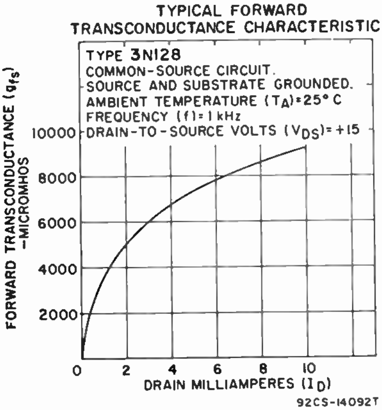
#### MAXIMUM RATINGS

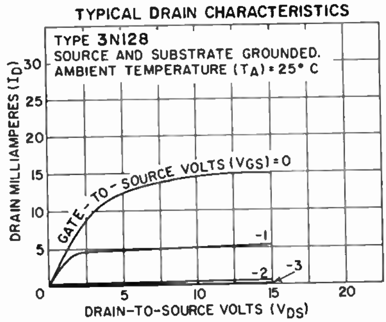
| | | | |
|---|---|---|---|
| Drain-to-Source Voltage | $V_{DS}$ | 20 | V |
| Gate-to-Source Voltage: | | | |
| Continuous (dc) | $V_{GS}$ | −8 to 1 | V |
| Peak (ac) | $v_{GS}$ | ±15 | V |
| Drain Current ($t_p \leq$ 20 ms, df $\leq$ 0.15) | $I_D$(pulsed) | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 330 | mW |
| $T_A$ above 25°C | $P_T$ | Derate at 2.2 | mW/°C |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

### CHARACTERISTICS

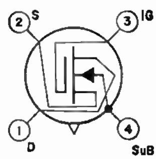
| | | | |
|---|---|---|---|
| Gate Leakage Current: | | | |
| $V_{GS} = -8$ V, $V_{DS} = 0$ | $I_{GSS}$ | 0.1 typ; 50 max | pA |
| $V_{GS} = -8$ V, $V_{DS} = 0$, $T_A = 125°C$ | $I_{GSS}$ | 5 max | nA |
| Zero-Bias Drain Current ($V_{DS} = 15$ V, $V_{GS} = 0$) | $I_{DSS}$ | 5 to 25 | mA |
| Drain-to-Source Cutoff Current ($V_{DS} = 20$ V, $V_{GS} = -8$ V) | $I_D(off)$ | 50 max | µA |
| Small-Signal Input Capacitance ($V_{DS} = 15$ V, $I_D = 5$ mA, f = 0.1 to 1 MHz) | $C_{iss}$ | 5.5 typ; 7 max | pF |
| Small-Signal Reverse Transfer Capacitance‡ ($V_{DS} = 15$ V, $I_D = 5$ mA, f = 0.1 to 1 MHz) | $C_{rss}$ | 0.16 typ; 0.28 max | pF |
| Drain-to-Source Channel Resistance ($V_{DS} = 0$, $V_{GS} = 0$, f = 1 kHz) | $r_{DS}(on)$ | 200 | Ω |
| Gate-to-Source Cutoff Voltage ($V_{DS} = 15$ V, $I_D = 50$ µA) | $V_{GS}(off)$ | −3 to −8 | V |
| Forward Transconductance $V_{DS} = 15$ V, $I_D = 5$ mA, f = 1 kH z | $g_{fs}$ | 5000 to 12000 | µmhos |
| Maximum Available Power Gain ($V_{DS} = 15$ V, $I_D = 5$ mA, f = 200 MHz) | MAG | 21▲ | dB |
| Insertion Power Gain, Neutralized ($V_{DS} = 15$ V, $I_D = 5$ mA, f = 200 MHz) | $G_{PS}$ | 13.5 min; 16 typ▲ | dB |
| Noise Figure ($V_{DS} = 15$ V, $I_D = 5$ mA, f = 200 MHz) | NF | 3.5 typ; 5 max▲ | dB |

‡ Three terminal measurement with source returned to guard terminal.
▲ This characteristic does not apply to type 3N143.




## 3N138 FIELD-EFFECT TRANSISTOR




Si insulated-gate field-effect (MOS) n-channel depletion type used in critical chopper applications and multiplex service up to 60 MHz. The terminal arrangement permits shielding between input and output terminals for superior high-frequency performance and greater circuit stability, particularly on printed-circuit boards. JEDEC TO-72, Outline No.28.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Drain-to-Source Voltage | $V_{DS}$ | 35 | V |
| Drain-to-Substrate Voltage | $V_{DB}$ | −0.3 to 35 | V |
| Source-to-Substrate Voltage | $V_{SB}$ | −0.3 to 35 | V |
| Gate-to-Source Voltage: | | | |
| Continuous | $V_{GS}$ | ±10 | V |
| Peak | $v_{GS}$ | ±14 | V |

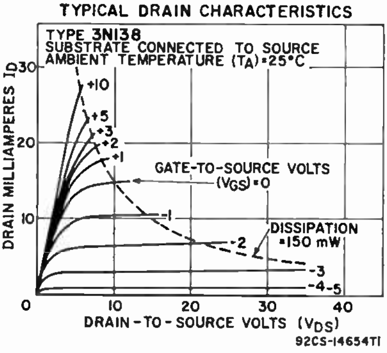
## MAXIMUM RATINGS (cont'd)

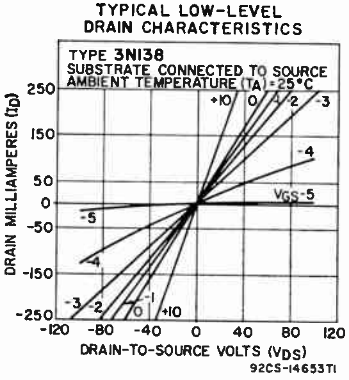
| | | | |
|---|---|---|---|
| Peak Voltage, Gate-to-All Other Terminals, $V_{GS}$, $V_{GD}$, $V_{GB}$, non-repetitive | | ±45 | V |
| Drain Current ($t_P \leq$ 20 ms, df $\leq$ 0.10) | $I_D$ | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 330 | mW |
| $T_A$ above 25°C | $P_T$ | Derate at 2.2 | mW/°C |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

## CHARACTERISTICS

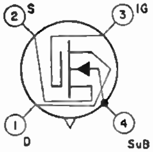
| | | | |
|---|---|---|---|
| Gate-Leakage Current: | | | |
| $V_{GS}$ = ±10 V, $V_{DS}$ = 0 | $I_{GSS}$ | 0.1 typ; 10 max | pA |
| $V_{GS}$ = ±10 V, $V_{DS}$ = 0, $T_A$ = 125°C | $I_{GSS}$ | 20 typ; 200 max | pA |
| Drain-to-Source "ON" Resistance: | | | |
| $V_{GS}$ = 0, $V_{DS}$ = 0, f = 1 kHz | $r_{DS}$(on) | 240 typ; 300 max | Ω |
| $V_{GS}$ = 10 V, $V_{DS}$ = 0, f = 1 kHz | $r_{DS}$(on) | 135 | Ω |
| $V_{GS}$ = 0, $V_{DS}$ = 0, f = 1 kHz, $T_A$ = 125°C | $r_{DS}$(on) | 350 | Ω |
| Drain-to-Source "OFF" Resistance ($V_{GS}$ = −10 V, $V_{DS}$ = 1 V) | $R_{DS}$(off) | $2 \times 10^{9}$ min; $10^{11}$ typ | Ω |
| Drain-to-Source Cutoff Current: | | | |
| $V_{GS}$ = −10 V, $V_{DS}$ = 1 V | $I_D$(off) | 0.01 typ; 0.5 max | nA |
| $V_{GS}$ = −10 V, $V_{DS}$ = 1 V, $T_A$ = 125°C | $I_D$(off) | 0.01 typ; 0.5 max | μA |
| Small-Signal, Reverse Transfer Capacitance ($V_{GS}$ = −10 V, $V_{DS}$ = 0, f = 1 MHz) | $C_{rss}$ | 0.2 typ; 0.25 max | pF |
| Small-Signal Input Capacitance ($V_{GS}$ = −10 V, $V_{DS}$ = 0, f = 1 MHz) | $C_{iss}$ | 3 typ; 5 max | pF |
| Zero-Gate Bias Forward Transconductance ($V_{GS}$ = 0, $V_{DS}$ = 12 V) | $g_{fs}$ | 6000 | μmhos |
| Offset Voltage ($V_{GS}$ = ±10 V, $V_{DS}$ = 0) | $V_O$ | 0‡ | V |

‡ In measurements of offset voltage, thermocouple effects and contact potentials in the measurement setup may cause erroneous readings of 1 microvolt or more. These errors may be minimized by the use of solder having a low thermal e.m.f., such as Leeds & Northrup No. 107-1.0.1, or equivalent.




## FIELD-EFFECT TRANSISTOR 3N139




Si insulated-gate field-effect (MOS) n-channel depletion type used in audio, video, and rf amplifier applications. The terminal arrangement permits shielding between input and output terminals for superior high-frequency performance and greater circuit stability, particularly on printed-circuit boards. JEDEC TO-72, Outline No.28.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Drain-to-Source Voltage | $V_{DS}$ | 35 | V |
| Drain-to-Substrate Voltage | $V_{DB}$ | −0.3 to 35 | V |

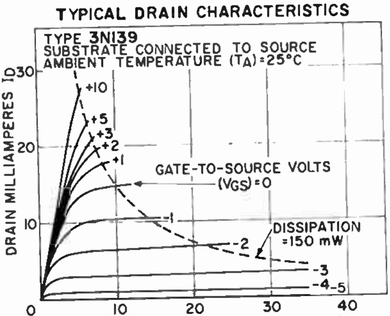
## MAXIMUM RATINGS (cont'd)

| | | | |
|---|---|---|---|
| Source-to-Substrate Voltage | $V_{SB}$ | −0.3 to 35 | V |
| Gate-to-Source Voltage: | | | |
| Continuous | $V_{GS}$ | ±10 | V |
| Peak | $v_{GS}$ | ±14 | V |
| Peak Voltage, Gate-to-All Other Terminals; $V_{GS}$, $V_{GD}$, $V_{GB}$, non-repetitive | | ±42 | V |
| Drain Current ($t_p \leq$ 20 ms, df $\leq$ 0.10) | $I_D$(pulsed) | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 330 | mW |
| $T_A$ above 25°C | $P_T$ | Derate at 2.2 | mW/°C |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

## CHARACTERISTICS

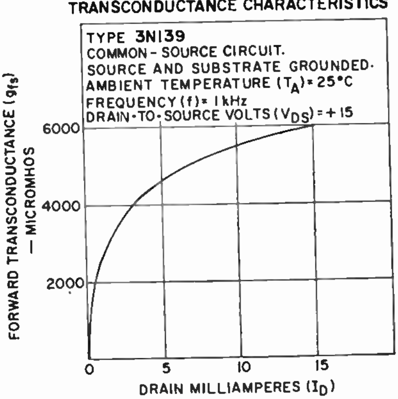
| | | | |
|---|---|---|---|
| Gate Leakage Current: | | | |
| $V_{GS}$ = ±10 V, $V_{DS}$ = 0 | $I_{GSS}$ | 0.1 typ; 1 max | nA |
| $V_{GS}$ = ±10 V, $V_{DS}$ = 0, $T_A$ = 125°C | $I_{GSS}$ | 4 max | nA |
| Forward Transconductance: | | | |
| $V_{DS}$ = 15 V, $R_S$ = 0, f = 1 kHz | $g_{fs}$ | 3000 min; 6000 typ | μmhos |
| $V_{DD}$ = 15 V, $R_S$ = 360 Ω, f = 1 kHz | $g_{fs}$ | 3000 to 7500 | μmhos |
| $V_{DD}$ = 15 V, $R_S$ = 360 Ω, f = 1 kHz, $T_A$ = 125°C | $g_{fs}$ | 3300 | μmhos |
| Zero-Bias Drain Current ($V_{DS}$ = 15 V, $R_S$ = 0, $t_p$ = 300 μs, df $\leq$ 0.10) | $I_{DSS}$(pulsed) | 5 to 25 | mA |
| Drain Current: | | | |
| $V_{DD}$ = 15 V, $R_S$ = 360 Ω | $I_D$ | 3 to 7 | mA |
| $V_{DD}$ = 15 V, $R_S$ = 360 Ω, $T_A$ = 125°C | $I_D$ | 3.3 | mA |
| Output Resistance: | | | |
| $V_{DS}$ = 15 V, $R_S$ = 0, f = 1 kHz | $r_d$ | 5 | kΩ |
| $V_{DD}$ = 15 V, $R_S$ = 360 Ω, f = 1 kHz | $r_d$ | 20 | kΩ |
| $V_{DD}$ = 15 V, $R_S$ = 360 Ω, f = 1 kHz, $T_A$ = 125°C | $r_d$ | 23 | kΩ |
| Drain-to-Source Cutoff Current: | | | |
| $V_{DS}$ = 15 V, $V_{GS}$ = −6 V | $I_{DS}$(off) | 1 typ; 50 max | μA |
| $V_{DS}$ = 15 V, $V_{GS}$ = −6 V, $T_A$ = 125°C | $I_{DS}$(off) | 2 | μA |
| $V_{DS}$ = 35 V, $V_{GS}$ = −6 V | $I_{DS}$(off) | 75 max | μA |
| Equivalent Input Noise Voltage: | | | |
| $V_{DS}$ = 15 V, $R_S$ = 0, $R_g$ = 0, f = 1 kHz | $e_n$ | 0.06 | μV/√Hz |
| $V_{DD}$ = 15 V, $R_S$ = 360 Ω, $R_g$ = 0, f = 1 kHz | $e_n$ | 0.06 | μV/√Hz |
| Audio Spot Noise Figure‡ ($V_{DD}$ = 15 V, $R_S$ = 360 Ω, $R_g$ = 1 MΩ, f = 1 kHz) | NF | 0.86 | dB |
| Small-Signal Input Capacitance: | | | |
| $V_{DS}$ = 15 V, $R_S$ = 0, f = 1 MHz | $C_{iss}$ | 3.3 | pF |
| $V_{DD}$ = 15 V, $R_S$ = 360 Ω, f = 1 MHz | $C_{iss}$ | 3 typ; 7 max | pF |
| Small-Signal Reverse Transfer Capacitance: | | | |
| $V_{DS}$ = 15 V, $R_S$ = 0, f = 1 MHz | $C_{rss}$ | 0.2 | pF |
| $V_{DD}$ = 15 V, $R_S$ = 360 Ω, f = 1 MHz | $C_{rss}$ | 0.19 typ; 0.30 max | pF |
| Power Gain ($V_{DD}$ = 15 V, $R_S$ = 360 Ω, f = 200 MHz) | $G_{ps}$ | 15 min; 17 typ | dB |
| Noise Figure ($V_{DD}$ = 15 V, $R_S$ = 360 Ω, f = 200 MHz) | NF | 4 typ; 6 max | dB |

TYPICAL DRAIN CHARACTERISTICS




92CS-14678T

TYPICAL FORWARD TRANSCONDUCTANCE CHARACTERISTICS

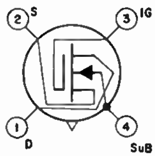



92CS-14680T

‡ Noise Figure $= 10 \log_{10} \left[ 1 + \frac{e_n^2}{4\ KT\ BW\ R_g} \right]$

where: $K = 1.38 \times 10^{-23}$, $T$ = Temperature in °Kelvin, $BW$ = Bandwidth in Hz, $R_g$ = Generator Resistance

## FIELD-EFFECT TRANSISTOR 3N142




Si insulated-gate field-effect (MOS) n-channel depletion type used in rf-amplifier applications in FM receivers covering the 88-to-108-MHz band, and in general amplifier applications at frequencies up to 175 MHz. JEDEC TO-72, Outline No.28. For typical drain characteristics curve, refer to type 3N128.

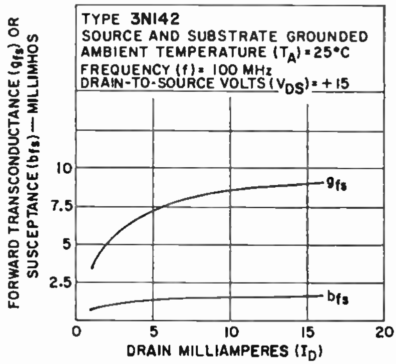
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Drain-to-Source Voltage | $V_{DS}$ | 20 | V |
| Gate-to-Source Voltage: | | | |
| Continuous | $V_{GS}$ | 1 to −8 | V |
| Peak | $V_{GS}$ | ±15 | V |
| Drain-to-Gate Voltage | $V_{DG}$ | 20 | V |
| Drain Current ($t_P$ = 20 ms, df ≤ 0.1) | $I_D$(pulsed) | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 330 | mW |
| $T_A$ above 25°C | $P_T$ | Derate at 2.2 | mW/°C |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature | $T_L$ | 265 | °C |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Drain-to-Source Cutoff Current ($V_{DS}$ = 20 V, $V_{GS}$ = −8 V) | $I_D$(off) | 50 | μA |
| Zero-Bias Drain Current ($V_{DS}$ = 15 V, $V_{GS}$ = 0) | $I_{DSS}$ | 5 to 25 | mA |
| Gate Leakage Current: | | | |
| $V_{GS}$ = −8 V, $V_{DS}$ = 0 | $I_{GSS}$ | 1 max | nA |
| $V_{GS}$ = −8 V, $V_{DS}$ = 0, $T_A$ = 125°C | $I_{GSS}$ | 200 max | nA |
| Gate-to-Source Cutoff Voltage ($V_{DS}$ = 15 V, $I_D$ = 50 μA) | $V_{GS}$(off) | −0.5 to −8 | V |
| Small-Signal Reverse Transfer Capacitance, Drain to Gate ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 1 MHz) | $C_{rss}$ | 0.16 typ; 0.28 max | pF |
| Input Capacitance ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 1 MHz) | $C_{iss}$ | 5.5 typ; 7 max | pF |

TYPICAL FORWARD TRANSCONDUCTANCE CHARACTERISTICS

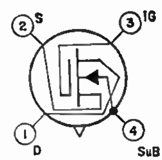



92CS-14154T1

### CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Forward Transconductance ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 1 kHz) | $g_{fs}$ | 5000 min; 7500 typ | µmho |
| Maximum Available Power Gain ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 100 MHz) | MAG | 26 | dB |
| Maximum Usable Power Gain, Unneutralized ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 100 MHz) | MUG | 17 | dB |
| Maximum Usable Power Gain, Neutralized ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 100 MHz) | MUG | 16 min | dB |
| Noise Figure ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 100 MHz) | NF | 2.5 typ; 4 max | dB |

## 3N143 FIELD-EFFECT TRANSISTOR

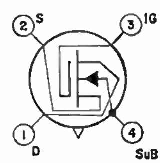



Si insulated-gate field-effect (MOS) n-channel depletion type used in vhf mixer and oscillator applications in military and industrial applications. JEDEC TO-72, Outline No.28. This type is identical with type 3N128 except for the following items:

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Gate Leakage Current: | | | |
| $V_{GS}$ = −8 V, $V_{DS}$ = 0 | $I_{GSS}$ | 0.1 typ; 1000 max | pA |
| $V_{GS}$ = −8 V, $V_{DS}$ = 0, $T_A$ = 125°C | $I_{GSS}$ | 200 max | nA |
| Zero-Bias Drain Current ($V_{DS}$ = 15 V, $V_{GS}$ = 0) | $I_{DSS}$ | 5 to 30 | mA |
| Conversion Power Gain ($V_{DS}$ = 15 V, $I_D$ = 1 mA, $f_{in}$ = 200 MHz, $f_{out}$ = 30 MHz) | $G_{PS(c)}$ | 10 min; 13.5 typ | dB |

## 3N152 FIELD-EFFECT TRANSISTOR




Si insulated-gate field-effect (MOS) n-channel depletion type used in low-noise rf applications in military and industrial vhf communications equipment up to 250 MHz. JEDEC TO-72, Outline No.28. For typical forward transconductance curve, refer to type 3N128.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Drain-to-Source Voltage | $V_{DS}$ | 20 | V |
| Gate-to-Source Voltage: | | | |
| Continuous (dc) | $V_{GS}$ | −8 to 1 | V |
| Peak (ac) | $v_{GS}$ | ±15 | V |
| Drain Current ($t_P$ ≤ 20 ms, df ≤ 0.15) | $I_D$(pulsed) | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 330 | mW |
| $T_A$ above 25°C | $P_T$ | Derate at 2.67 | mW/°C |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

### CHARACTERISTICS

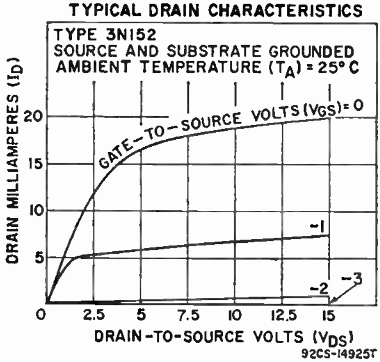
| | | | |
|---|---|---|---|
| Drain-to-Source Cutoff Current ($V_{DS}$ = 20 V, $V_{GS}$ = −8 V) | $I_D$(off) | 50 max | µA |
| Gate Leakage Current: | | | |
| $V_{DS}$ = 0, $V_{GS}$ = −8 V | $I_{GSS}$ | 0.0001 to 1 | nA |
| $V_{DS}$ = 0, $V_{GS}$ = −8 V, $T_A$ = 125°C | $I_{GSS}$ | 200 max | nA |
| Zero-Bias Drain Current ($V_{DS}$ = 15 V, $V_{GS}$ = 0) | $I_{DSS}$ | 5 to 30 | mA |
| Drain-to-Source Channel Resistance ($V_{DS}$ = 0, $V_{GS}$ = 0, f = 1 kHz) | $r_{DS}$(on) | 200 | Ω |
| Maximum Available Power Gain ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 200 MHz) | MAG | 21 | dB |
| Insertion Power Gain, Neutralized ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 200 MHz) | $G_{PS}$ | 14.5 min; 16 typ | dB |
| Small-Signal Input Capacitance ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 0.1 to 1 MHz) | $C_{iss}$ | 5.5 typ; 7 max | pF |
| Small-Signal Reverse Transfer Capacitance‡ ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 0.1 to 1 MHz) | $C_{rss}$ | 0.16 typ; 0.28 max | pF |
| Forward Transconductance ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 1 kHz) | $g_{fs}$ | 5000 to 12000 | µmhos |

## CHARACTERISTICS (cont'd)

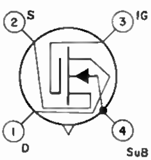
| | | | |
|---|---|---|---|
| Input Admittance ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 200 MHz) | $Y_{is}$ | 0.4 + j 7.3 | mmho |
| Output Admittance ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 200 MHz) | $Y_{os}$ | 0.28 + j 1.8 | mmho |
| Noise Figure ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 200 MHz) | NF | 2.5 typ; 3.5 min | dB |

‡ Three-terminal measurement with source returned to guard terminal.

TYPICAL DRAIN CHARACTERISTICS




## FIELD-EFFECT TRANSISTOR 3N153




Si dual-insulated gate field-effect (MOS) n-channel depletion type used in critical chopper and multiplex applications up to 60 MHz. The terminal arrangement permits shielding between input and output terminals for superior high-frequency performance and greater circuit stability, particularly on printed-circuit boards. JEDEC TC-72, Outline No.28.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Drain-to-Source Voltage | $V_{DS}$ | 20 | V |
| Drain-to-Substrate Voltage | $V_{DB}$ | −0.3 to 20 | V |
| Source-to-Substrate Voltage | $V_{SB}$ | −0.3 to 20 | V |
| DC Gate-to-Source Voltage | $V_{GS}$ | −8 to 6 | V |
| Peak Gate-to-Source Voltage | $v_{GS}$ | ±14 | V |
| Drain Current | $I_D$ | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 330 | mW |
| $T_A$ above 25°C | $P_T$ | Derate linearly at 2.2 | mW/°C |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

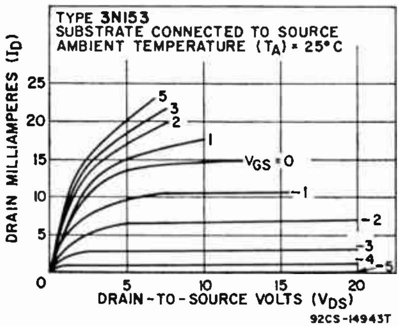
## CHARACTERISTICS

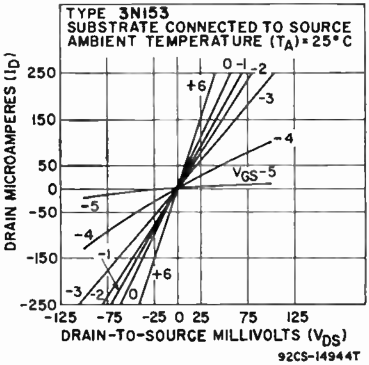
| | | | |
|---|---|---|---|
| Drain-to-Source Cutoff Current: | | | |
| $V_{GS}$ = −8 V, $V_{DS}$ = 1 V | $I_D$(off) | 0.1 typ; 1 max | nA |
| $V_{GS}$ = −8 V, $V_{DS}$ = 1 V, $T_A$ = 125°C | $I_D$(off) | 0.1 typ; 1 max | μA |
| Gate-Leakage Current: | | | |
| $V_{GS}$ = −8 to 6 V, $V_{DS}$ = 0 | $I_{GSS}$ | 0.1 typ; 50 max | pA |
| $V_{GS}$ = −8 to 6 V, $V_{DS}$ = 0, $T_A$ = 125°C | $I_{GSS}$ | 1 max | nA |
| Static Drain-to-Source "ON" Resistance ($V_{GS}$ = 0, $V_{DS}$ = 0) | $r_{DS}$(on) | 200 typ; 300 max | Ω |
| Drain-to-Source "OFF" Resistance ($V_{GS}$ = −8 V, $V_{DS}$ = 1 V) | $R_{DS}$(off) | $10^9$ min; $10^{10}$ typ | Ω |
| Small-Signal Reverse Transfer Capacitance: | | | |
| $V_{GS}$ = −8 V, $V_{DS}$ = 0, f = 1 MHz | $C_{rss}$ | 0.34 typ; 0.5 max | pF |
| $V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 1 MHz | $C_{rss}$ | 0.12 typ; 0.2 max | pF |

## CHARACTERISTICS (cont'd)

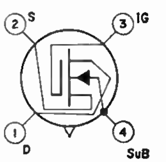
| | | | |
|---|---|---|---|
| Small-Signal Input Capacitance ($V_{GS}$ = −8 V, $V_{DS}$ = 0, f = 1 MHz) | $C_{iss}$ | 6 typ; 8 max | pF |
| Small-Signal, Drain-to-Source Capacitance ($V_{GS}$ = −8 V, $V_{DS}$ = 0, f = 1 MHz) | $C_{ds}$ | 3 max | μmhos |
| Zero-Gate-Bias Forward Transconductance ($V_{GS}$ = 0, $V_{DS}$ = 15 V) | $g_{fs}$ | 10000 | pF |
| Offset Voltage ($V_{GS}$ = −8 to 6 V, $V_{DS}$ = 0) | $V_O$ | 0‡ | V |

‡ In measurements of Offset Voltage, thermocouple effects and contact potentials in the measurement setup may cause erroneous readings of 1 microvolt or more. These errors may be minimized by the use of solder having a low thermal e.m.f., such as Leeds & Northrup No. 107-1.0.1., or equivalent.




# 3N154 FIELD-EFFECT TRANSISTOR




Si insulated-gate field-effect (MOS) n-channel depletion type used in vhf amplifier service in military and industrial applications up to 250 MHz. JEDEC TO-72, Outline No.28. For typical drain characteristics and typical forward transconductance curves, refer to type 3N128.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Drain-to-Source Voltage | $V_{DS}$ | 20 | V |
| Gate-to-Source Voltage: | | | |
| Continuous (dc) | $V_{GS}$ | −8 to 1 | V |
| Peak (ac) | $v_{GS}$ | ±15 | V |
| Drain-to-Gate Voltage | $V_{DG}$ | 20 | V |
| Drain Current ($t_P$ ≤ 20 ms, df ≤ 0.15) | $I_D$(pulsed) | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 330 | mW |
| $T_A$ above 25°C | $P_T$ | Derate at 2.2 | mW/°C |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

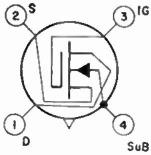
## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Gate-to-Source Cutoff Voltage ($V_{DS}$ = 15 V, $I_D$ = 50 μA) | $V_{GS}$(off) | −0.5 to −8 | V |
| Drain-to-Source Cutoff Current ($V_{DS}$ = 20 V, $V_{GS}$ = −8 V) | $I_D$(off) | 50 max | μA |
| Zero-Bias Drain Current ($V_{DS}$ = 15 V, $V_{GS}$ = 0) | $I_{DSS}$ | 10 to 25 | mA |
| Gate Leakage Current: | | | |
| $V_{GS}$ = −8 V, $V_{DS}$ = 0 | $I_{GSS}$ | 0.0001 typ; 0.05 max | nA |
| $V_{GS}$ = −8 V, $V_{DS}$ = 0, $T_A$ = 125°C | $I_{GSS}$ | 5 max | nA |
| $V_{GS}$ = 1 V, $V_{DS}$ = 0 | $I_{GSS}$ | 0.0001 typ; 0.05 max | nA |
| $V_{GS}$ = 1 V, $V_{DS}$ = 0, $T_A$ = 125°C | $I_{GSS}$ | 5 max | nA |

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Forward Transadmittance ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 200 MHz) | $Y_{fs}$ | 7 − j 2 | mmho |
| Forward Transconductance ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 1 kHz) | $g_{fs}$ | 5000 to 12000 | μmho |
| Small-Signal Input Capacitance ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 0.1 to 1 MHz) | $C_{iss}$ | 5.5 typ; 7 max | pF |
| Small-Signal Reverse Transfer Capacitance‡ ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 0.1 to 1 MHz) | $C_{rss}$ | 0.03 to 0.2 | pF |
| Drain-to-Source Channel Resistance ($V_{DS}$ = 0, $V_{GS}$ = 0, f = 1 kHz) | $r_{DS}(on)$ | 200 | Ω |
| Input Conductance ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 200 MHz) | $Y_{is}$ | 0.4 + j 7.3 | mmho |
| Output Conductance ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 200 MHz) | $Y_{os}$ | 0.28 + j 1.8 | mmho |
| Maximum Available Power Gain ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 200 MHz) | MAG | 21 | dB |
| Insertion Power Gain, Neutralized ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 200 MHz) | $G_{PS}$ | 13.5 min; 16 typ | dB |
| Noise Figure ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 200 MHz) | NF | 3.5 typ; 5 max | dB |

‡ Three-terminal measurement with source returned to guard terminal.



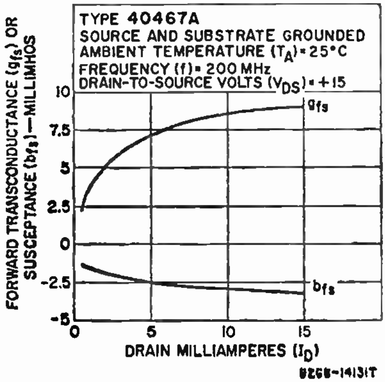

## FIELD-EFFECT TRANSISTOR 40467A

Si insulated-gate field-effect (MOS) n-channel depletion type used in vhf tuners and other vhf amplifier applications in industrial and commercial electronic equipment. JEDEC TO-72, Outline No.28.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Drain-to-Source Voltage | $V_{DS}$ | 20 | V |
| Gate-to-Source Voltage: | | | |
| Continuous (dc) | $V_{GS}$ | −8 to 1 | V |
| Peak (ac) | $v_{GS}$ | ±15 | V |
| Drain-to-Gate Voltage | $V_{DG}$ | 20 | V |
| Drain Current | $I_D$ | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 330 | mW |
| $T_A$ above 25°C | $P_T$ | Derate at 2.2 | mW/°C |
| Temperature Range: | | | |
| Operating | Topr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

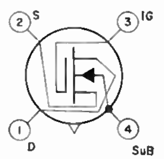
TYPICAL FORWARD TRANSCONDUCTANCE CHARACTERISTICS



## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Gate-to-Source Cutoff Voltage ($V_{DS}$ = 12 V, $I_D$ = 0.1 mA) | $V_{GS}$(off) | −5 typ; −8 max | V |
| Gate Leakage Current: $V_{GS}$ = 1 V, $V_{DS}$ = 0 | $I_{GSS}$ | 1 max | nA |
| $V_{GS}$ = −8 V, $V_{DS}$ = 0 | $I_{GSS}$ | 1 max | nA |
| Zero-Bias Drain Current ($V_{DS}$ = 15 V, $V_{GS}$ = 0) | $I_{DSS}$ | 10 to 50 | mA |
| Small-Signal, Forward Transconductance ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 1 kHz) | $g_{fs}$ | 4000 min; 7500 typ | µmho |
| Small-Signal Reverse Transfer Capacitance ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 1 MHz) | $C_{rss}$ | 0.03 to 0.28 | pF |
| Maximum Available Power Gain ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 200 MHz) | MAG | 21 | dB |
| Maximum Usable Power Gain, Unneutralized ($V_{CE}$ = 15 V, $I_D$ = 5 mA, f = 200 MHz) | MUG | 12 | dB |
| Maximum Usable Power Gain, Neutralized ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 200 MHz) | MUG | 12 min; 16 typ | dB |
| Noise Figure ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 200 MHz) | NF | 3.5 typ; 5 max | dB |

# 40468A FIELD-EFFECT TRANSISTOR




**Si insulated-gate field-effect (MOS) n-channel depletion** type used in rf-amplifier applications in FM receivers covering the 88-to-108-MHz band, and in general amplifier applications at frequencies up to 125 MHz. JEDEC TO-72, Outline No.28.

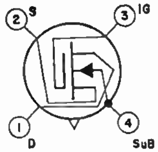
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Drain-to-Source Voltage | $V_{DS}$ | 20 | V |
| Gate-to-Source Voltage: Continuous | $V_{GS}$ | −8 to 1 | V |
| Peak | $v_{GS}$ | ±15 | V |
| Drain-to-Gate Voltage | $V_{DG}$ | 20 | V |
| Drain Current | $I_D$ | 25 | mA |
| Transistor Dissipation: $T_A$ up to 25°C | $P_T$ | 375 | mW |
| $T_A$ above 25°C | $P_T$ | Derate at 2.5 | mW/°C |
| Temperature Range: Operating | T(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Drain-to-Source Cutoff Current ($V_{DS}$ = 12 V, $V_{GS}$ = −8 V) | $I_D$(off) | 100 max | µA |
| Gate Leakage Current: $V_{GS}$ = −8 V, $V_{DS}$ = 0 | $I_{GSS}$ | 1 max | nA |
| $V_{GS}$ = 1 V, $V_{DS}$ = 0 | $I_{GSS}$ | 1 max | nA |
| Zero-Bias Drain Current ($V_{DS}$ = 15 V, $V_{GS}$ = 0) | $I_{DSS}$ | 5 to 30 | mA |
| Small-Signal Forward Transconductance ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 1 kHz) | $g_{fs}$ | 7500▲ | µmhos |
| Small-Signal Reverse-Transfer Capacitance, Drain-to-Gate ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 1 MHz) | $C_{rss}$ | 0.16 typ; 0.28 max | pF |
| Input Capacitance ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 1 MHz) | $C_{iss}$ | 5.5 | pF |
| Maximum Available Power Gain ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 100 MHz) | MAG | 26▲ | dB |
| Maximum Usable Power Gain, Unneutralized ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 100 MHz) | MUG | 14▲ | dB |
| Maximum Usable Power Gain, Neutralized ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 100 MHz) | MUG | 14 min; 17 typ▲ | dB |
| Noise Figure ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 100 MHz) | NF | 3.5 typ; 5 max▲ | dB |

▲ This characteristic does not apply to type 40559A.



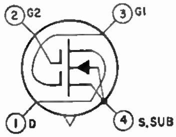

## FIELD-EFFECT TRANSISTOR 40559A

Si insulated-gate field-effect (MOS) n-channel depletion type used in mixer applications in FM receivers covering the 88-to-108-MHz band, and in general amplifier applications at frequencies up to 125 MHz. JEDEC TO-72, Outline No.28. For typical forward transconductance characteristics curves, refer to type 3N140. This type is identical with 40468A except for the following items:

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Drain-to-Source Cutoff Current ($V_{DS}$ = 12 V, $V_{GS}$ = −8 V) | $I_D$(off) | 500 max | μA |
| Small-Signal Reverse-Transfer Capacitance, Drain-to-Gate ($V_{DS}$ = 15 V, $I_D$ = 5 mA, f = 1 MHz) | $C_{rss}$ | 0.17 typ; 0.3 max | pF |
| Forward Conversion Transconductance ($V_{DS}$ = 15 V, $I_D$ = 3 mA, $V_{BS}$ = −3 V, f = 1 kHz) | $g_{fs}$(c) | 2800 | μmhos |
| Maximum Available Conversion Gain ($V_{DS}$ = 15 V, $I_D$ = 3 mA, $f_{in}$ = 100 MHz, $f_{out}$ = 10.7 MHz) | $MAG_C$ | 22 | dB |

# *Dual-Gate Types*




## FIELD-EFFECT TRANSISTOR 3N140

Si dual insulated-gate field-effect (MOS) n-channel depletion type used in rf amplifier applications at frequencies up to 300 MHz. JEDEC TO-72, Outline No.28.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Drain-to-Source Voltage | $V_{DS}$ | 0 to 20 | V |
| Gate-No.1-to-Source Voltage: | | | |
| Continuous (dc) | $V_{G1S}$ | −8 to 1 | V |
| Peak (ac) | $v_{G1S}$ | −8 to 20 | V |
| Gate-No.2-to-Source Voltage: | | | |
| Continuous (dc) | $V_{G2S}$ | −8 to (0.4 of $V_{DS}$) | V |
| Peak (ac) | $v_{G2S}$ | −8 to 20 | V |
| Drain-to-Gate-No.1 Voltage | $V_{DG1}$ | 20 | V |
| Drain-to-Gate-No.2 Voltage | $V_{DG2}$ | 20 | V |
| Drain Current | $I_D$ | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 330 | mW |
| $T_A$ above 25°C | $P_T$ | Derate linearly at 2.2 | mW/°C |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

### CHARACTERISTICS

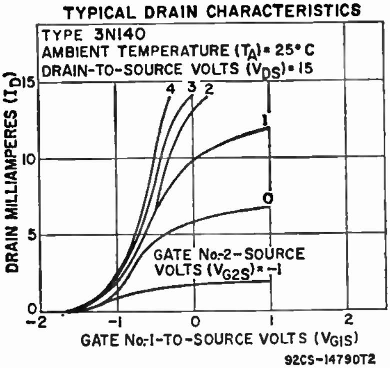
| | | | |
|---|---|---|---|
| Gate-No.1-to-Source Cutoff Voltage ($V_{DS}$ = 16 V, $V_{G2S}$ = 4 V, $I_D$ = 200 μA) | $V_{G1S}$(off) | −2 typ; −4 max | V |
| Gate-No.2-to-Source Cutoff Voltage ($V_{DS}$ = 16 V, $V_{G1S}$ = 0, $I_D$ = 200 μA) | $V_{G2S}$(off) | −2 typ; −4 max | V |
| Gate-No.1 Leakage Current: | | | |
| $V_{G1S}$ = −20 V, $V_{G2S}$ = 0, $V_{DS}$ = 0 | $I_{G1SS}$ | 1 max | nA |
| $V_{G1S}$ = 1 V, $V_{G2S}$ = 0, $V_{DS}$ = 0 | $I_{G1SS}$ | 1 max | nA |
| $V_{G1S}$ = −20 V, $V_{G2S}$ = 0, $V_{DS}$ = 0, $T_A$ = 125°C | $I_{G1SS}$ | 0.2 max | μA |
| Gate-No.2 Leakage Current: | | | |
| $V_{G2S}$ = −20 V, $V_{G1S}$ = 0, $V_{DS}$ = 0 | $I_{G2SS}$ | 1 max | nA |
| $V_{G2S}$ = 1 V, $V_{G1S}$ = 0, $V_{DS}$ = 0 | $I_{G2SS}$ | 1 max | nA |
| $V_{G2S}$ = −20 V, $V_{G1S}$ = 0, $V_{DS}$ = 0, $T_A$ = 125°C | $I_{G2SS}$ | 0.2 max | μA |
| Zero-Bias Drain Current ($V_{DD}$ = 14 V, $V_{G1S}$ = 0, $V_{G2S}$ = 4 V, $t_P \leq$ 20 ms, df $\leq$ 0.15) | $I_{DSS}$(pulsed) | 5 to 30 | mA |
| Forward Transconductance, Gate-No.1 to Drain ($V_{DD}$ = 14 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 1 kHz) | $g_{fs}$ | 6000 to 18000 | μmhos |

## CHARACTERISTICS (cont'd)

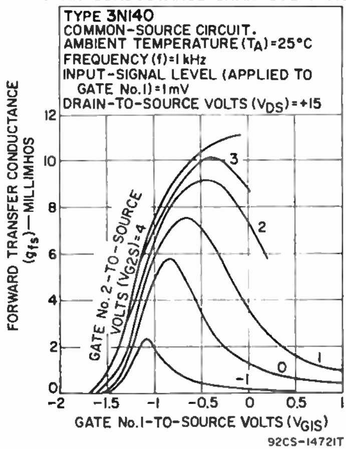
| | | | |
|---|---|---|---|
| Cutoff Forward Transconductance, Gate-No.1 to Drain ($V_{DD}$ = 14 V, $V_{G1S}$ = 0.5 V, $V_{G2S}$ = −2 V, f = 1 kHz) | $g_{fs}$(off)‡ | 100 max | μmhos |
| Small-Signal Input Capacitance• ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 1 MHz) | $C_{iss}$ | 3 to 7 | pF |
| Small-Signal Reverse Transfer Capacitance, Drain to Gate-No.1▲ ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 1 MHz) | $C_{rss}$ | 0.01 to 0.03 | pF |
| Small-Signal Output Capacitance ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 1 MHz) | $C_{oss}$ | 2.2 | pF |
| Power Gain ($V_{DD}$ = 15 V, $R_S$ = 270 Ω, $R_G$ = 50 Ω, f = 200 MHz) | $G_{ps}$‡ | 16 min; 18 typ | dB |
| Noise Figure ($V_{DD}$ = 15 V, $R_S$ = 270 Ω, $R_G$ = 50 Ω, f = 200 MHz) | NF‡ | 3.5 typ; 4.5 max | dB |

• Capacitance between gate No.1 and all other terminals.
▲ Three-terminal measurement with gate No.2 and source returned to guard terminal.
‡ This value does not apply to type 3N141.

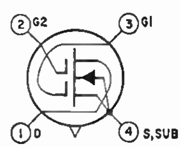
TYPICAL DRAIN CHARACTERISTICS




TYPICAL FORWARD TRANSCONDUCTANCE CHARACTERISTICS




# 3N141 FIELD-EFFECT TRANSISTOR

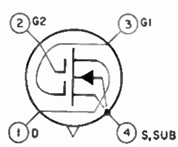



Si dual insulated-gate field-effect (MOS) n-channel depletion type used in mixer applications at frequencies up to 300 MHz. JEDEC TO-72, Outline No.28. This type is identical with type 3N140 except for the following item:

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Conversion Power Gain ($V_{DD}$ = 15 V, $R_S$ = 120 Ω, $f_{in}$ = 200 MHz, $f_{out}$ = 30 MHz, oscillator injection voltage from gate No.2 to source = 2.5 V (rms)) | $G_{ps}$(c) | 13 min; 17 typ | dB |

# 3N159 FIELD-EFFECT TRANSISTOR




Si insulated-gate field-effect (MOS) n-channel depletion type used in rf amplifier applications at frequencies up to 300 MHz. JEDEC TO-72, Outline No.28.

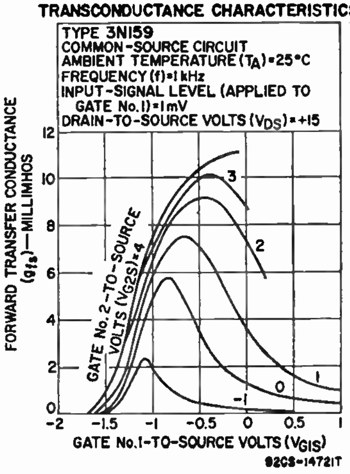
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Drain-to-Source Voltage | $V_{DS}$ | 0 to 20 | V |
| Gate-No.1-to-Source Voltage: | | | |
| Continuous (dc) | $V_{G1S}$ | −8 to 1 | V |
| Peak (ac) | $V_{G1S}$ | −8 to 20 | V |
| Gate-No.2-to-Source Voltage: | | | |
| Continuous (dc) | $V_{G2S}$ | −8 to (0.4 $V_{DS}$) | V |
| Peak (ac) | $V_{G2S}$ | −8 to 20 | V |
| Drain-to-Gate-No.1 Voltage | $V_{DG1}$ | 20 | V |
| Drain-to-Gate-No.2 Voltage | $V_{DG2}$ | 20 | V |
| Drain Current | $I_D$ | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 330 | mW |
| $T_A$ above 25°C | $P_T$ | Derate linearly at 2.2 | mW/°C |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Gate-No.1-to-Source Cutoff Voltage ($V_{DS}$ = 16 V, $V_{G2S}$ = 4 V, $I_D$ = 200 μA) | $V_{G1S}$(off) | −2 typ; −4 max | V |
| Gate-No.2-to-Source Cutoff Voltage ($V_{DS}$ = 16 V, $V_{G1S}$ = 0, $I_D$ = 200 μA) | $V_{G2S}$(off) | −2 typ; −4 max | V |
| Gate-No.1-Leakage Current: | | | |
| $V_{G1S}$ = −20 V, $V_{G2S}$ = 0, $V_{DS}$ = 0 | $I_{G1SS}$ | 1 max | nA |
| $V_{G1S}$ = 1 V, $V_{G2S}$ = 0, $V_{DS}$ = 0 | $I_{G1SS}$ | 1 max | nA |
| $V_{G1S}$ = −20 V, $V_{G2S}$ = 0, $V_{DS}$ = 0, $T_A$ = 125°C | $I_{G1SS}$ | 0.2 max | μA |
| Gate-No.2-Leakage Current: | | | |
| $V_{G2S}$ = −20 V, $V_{G1S}$ = 0, $V_{DS}$ = 0 | $I_{G2SS}$ | 1 max | nA |
| $V_{G2S}$ = 1 V, $V_{G1S}$ = 0, $V_{DS}$ = 0 | $I_{G2SS}$ | 1 max | nA |
| $V_{G2S}$ = −20 V, $V_{G1S}$ = 0, $V_{DS}$ = 0, $T_A$ = 125°C | $I_{G2SS}$ | 0.2 max | μA |
| Zero-Bias Drain Current ($V_{DD}$ = 14 V, $V_{G1S}$ = 0, $V_{G2S}$ = 4 V, $t_p$ ≤ 20 ms, df ≤ 0.15) | $I_{DSS}$(pulsed) | 5 to 30 | mA |
| Forward Transconductance, Gate-No.1 to Drain ($V_{DD}$ = 14 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 1 kHz) | $g_{fs}$ | 7000 to 18000 | μmhos |
| Cutoff Forward Transconductance, Gate-No.1 to Drain ($V_{DD}$ = 14 V, $V_{G1S}$ = −0.5 V, $V_{G2S}$ = −2 V, f = 1 kHz) | $g_{fs}$(off) | 100 max | μmhos |
| Small-Signal Input Capacitance‡ ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 1 MHz) | $C_{iss}$ | 3 to 7 | pF |
| Small-Signal Reverse Transfer Capacitance, Drain to Gate-No.1▲ ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 1 MHz) | $C_{rss}$ | 0.01 to 0.03 | pF |
| Small-Signal Output Capacitance ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 1 MHz) | $C_{oss}$ | 2.2 | pF |

TYPICAL FORWARD TRANSCONDUCTANCE CHARACTERISTICS

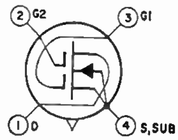


## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Maximum Usable Power Gain ($V_{DD}$ = 15 V, $R_S$ = 270 Ω, $R_G$ = 50 Ω, f = 200 MHz) | MUG | 16 to 22 | dB |
| Noise Figure ($V_{DD}$ = 15 V, $R_S$ = 270 Ω, $R_G$ = 50 Ω, f = 200 MHz) | NF | 2.5 typ; 3.5 max | dB |

‡ Capacitance between gate No.1 and all other terminals.
▲ Three-terminal measurement with gate No.2 and source returned to guard terminal.

# 40600 FIELD-EFFECT TRANSISTOR




**Si dual insulated-gate field-effect (MOS) n-channel depletion type used in rf-amplifier applications in vhf television receivers and other types of commercial equipment operating at frequencies up to approximately 250 MHz. JEDEC TO-72, Outline No.28. For typical drain characteristics and typical forward transconductance curves, refer to type 3N140.**

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Drain-to-Source Voltage | $V_{DS}$ | 0 to 20 | V |
| Gate No.1-to-Source Voltage: | | | |
| Continuous (dc) | $V_{G1S}$ | −8 to 1 | V |
| Peak (ac) | $v_{G1S}$ | −8 to 20 | V |
| Gate No.2-to-Source Voltage: | | | |
| Continuous (dc) | $V_{G2S}$ | −8 to (0.4 $V_{DS}$) | V |
| Peak (ac) | $v_{G2S}$ | −8 to 20 | V |
| Drain-to-Gate No. 1 Voltage | $V_{DG1}$ | 20 | V |
| Drain-to-Gate No. 2 Voltage | $V_{DG2}$ | 20 | V |
| Drain Current ($t_P \leq$ 20 ms, df $\leq$ 0.15) | $I_D$(pulsed) | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 330 | mW |
| $T_A$ above 25°C | $P_T$ | Derate linearly at 2.2 | mW/°C |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

## CHARACTERISTICS

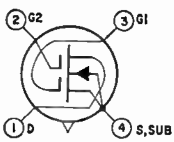
| | | | |
|---|---|---|---|
| Gate-No.1-to-Source Voltage ($V_{DS}$ = 15 V, $V_{G2S}$ = 4 V, $I_D$ = 200 μA) | $V_{G1S}$(off) | −3 | V |
| Gate-No.2-to-Source Cutoff Voltage ($V_{DS}$ = 15 V, $V_{G1S}$ = 0, $I_D$ = 200 μA) | $V_{G2S}$(off) | −3 | V |
| Gate-No.1 Leakage Current ($V_{G1S}$ = −20 V, $V_{G2S}$ = 0, $V_{DS}$ = 0) | $I_{G1SS}$ | 1 max | nA |
| Gate-No.2 Leakage Current ($V_{G2S}$ = −20 V, $V_{G1S}$ = 0, $V_{DS}$ = 0) | $I_{G2SS}$ | 1 max | nA |
| Drain Current ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $V_{G1S}$ = 0) | $I_{DSS}$ | 18 | mA |
| Forward Transconductance ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 1 kHz) | $g_{fs}$ | 10000 | μmhos |
| Small-Signal Reverse Transfer Capacitance, Drain to Gate No.1 ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 1 MHz) | $C_{rss}$ | 0.02 typ; 0.03 max | pF |
| Output Capacitance ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 200 MHz) | $C_{oss}$ | 2.2 | pF |
| Input Capacitance ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 200 MHz) | $C_{iss}$ | 5.5 | pF |
| Input Resistance ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 200 MHz) | $r_{iss}$ | 1.2 | kΩ |
| Output Resistance ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 200 MHz) | $r_{oss}$ | 2.8 | kΩ |
| Magnitude of Forward Transadmittance ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 200 MHz) | $\lvert Y_{fs} \rvert$ | 11000 | μmhos |
| Phase Angle of Forward Transadmittance ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 200 MHz) | $\angle\theta$ | −46 | degrees |
| Maximum Available Power Gain ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 200 MHz) | MAG | 20 | dB |
| Maximum Usable Power Gain, Unneutralized ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 200 MHz) | MUG | 20▲ | dB |
| Power Gain ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 200 MHz) | $G_{PS}$ | 17.5‡ | dB |

### CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Noise Figure ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 200 MHz) | NF | 5‡ max | dB |

▲ Limited by practical design considerations.
‡ This characteristic does not apply to ty 40602.

## FIELD-EFFECT TRANSISTOR 40601

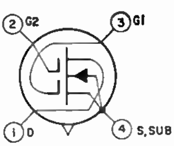



Si dual insulated-gate field-effect (MOS) n-channel depletion type used in mixer applications in vhf television receivers and other types of commercial equipment operating at frequencies up to approximately 250 MHz. JEDEC TO-72, Outline No.28. The maximum ratings for this type are identical with type 40600.

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Gate-No.1-to-Source Cutoff Voltage ($V_{DS}$ = 15 V, $V_{G2S}$ = 4 V, $I_D$ = 200 μA) | $V_{G1S}$(off) | −3 | V |
| Gate-No.2-to-Source Cutoff Voltage ($V_{DS}$ = 15 V, $V_{G2S}$ = 4 V, $I_D$ = 200 μA) | $V_{G2S}$(off) | −3 | V |
| Gate-No.1 Leakage Current ($V_{G1S}$ = −20 V, $V_{G2S}$ = 0, $V_{DS}$ = 0) | $I_{G1SS}$ | 1 max | nA |
| Gate-No.2 Leakage Current ($V_{G2S}$ = −20 V, $V_{G1S}$ = 0, $V_{DS}$ = 0) | $I_{G2SS}$ | 1 max | nA |
| Drain Current ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $V_{G1S}$ = 0) | $I_{DSS}$ | 18 | mA |
| Forward Transconductance ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 1 kHz) | $g_{fs}$ | 10000 | μmhos |
| The following test conditions apply to all remaining characteristics, unless otherwise specified: Local-oscillator injection voltage on gate No.2 = 750 mV, $V_{DS}$ = 15 V, $V_{G2S}$ = 0.6 V, $V_{G1S}$ = 0.75 V, f = 200 MHz. | | | |
| Small-Signal Reverse Transfer Capacitance, Drain-to-Gate No.1 (f = 1 MHz) | $C_{rss}$ | 0.02 typ; 0.03 max | pF |
| Output Capacitance (f = 44 MHz) | $C_{oss}$ | 2.2 | pF |
| Input Capacitance | $C_{iss}$ | 5.5 | pF |
| Input Resistance | $r_{iss}$ | 1.2 | kΩ |
| Output Resistance (f = 44 MHz) | $r_{oss}$ | 12 | kΩ |
| Magnitude of Forward Conversion Transadmittance | $\lvert Y_{fs(c)} \rvert$ | 2700 | μmhos |
| Maximum Available Conversion Gain | $MAG_C$ | 14 | dB |

## FIELD-EFFECT TRANSISTOR 40602

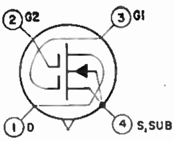



Si dual insulated-gate field-effect (MOS) n-channel depletion type used in first-if amplifier applications in vhf television receivers and other types of commercial equipment operating at frequencies up to approximately 250 MHz. JEDEC TO-72, Outline No.28. This type is identical with type 40600 except for the following items:

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Input Resistance | $r_{iss}$ | 10 | kΩ |
| Output Resistance | $r_{oss}$ | 12 | kΩ |
| Phase Angle of Forward Transadmittance | $\angle\theta$ | −11 | degrees |
| Maximum Available Power Gain | MAG | 35 | dB |
| Maximum Usable Power Gain, Unneutralized: | | | |
| For 1 stage | MUG | 28 | dB |
| For 2 stages | MUG | 26 | dB |
| For 3 stages | MUG | 24 | dB |

## FIELD-EFFECT TRANSISTOR 40603




Si dual insulated-gate field-effect (MOS) n-channel depletion type used in rf amplifier applications in FM tuners and other commercial equipment operating at frequencies up to approximately 150 MHz. JEDEC TO-72, Outline No.28. For typical forward transconductance curves, refer to type 3N140.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Drain-to-Source Voltage | $V_{DS}$ | 0 to 20 | V |
| Gate-No.1-to-Source Voltage: | | | |
| Continuous (dc) | $V_{G1S}$ | −8 to 1 | V |
| Peak (ac) | $v_{G1S}$ | −8 to 20 | V |
| Gate-No.2-to-Source Voltage: | | | |
| Continuous (dc) | $V_{G2S}$ | −8 to (0.4$V_{DS}$) | V |
| Peak (ac) | $v_{G2S}$ | −8 to 20 | V |
| Drain-to-Gate-No.1 Voltage | $V_{G1S}$ | 20 | V |
| Drain-to-Gate-No.2 Voltage | $V_{G2S}$ | 20 | V |
| Drain Current ($t_p \leq$ 20 ms, df $\leq$ 0.15) | $I_D$(pulsed) | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 330 | mW |
| $T_A$ above 25°C | $P_T$ | Derate linearly at 2.2 | mW/°C |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

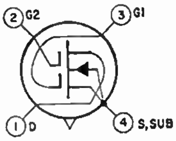
## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Gate-No.1-to-Source Cutoff Voltage ($V_{DS}$ = 15 V, $V_{G2S}$ = 4 V, $I_D$ = 200 μA) | $V_{G1S}$(off) | −3 | V |
| Gate-No.2-to-Source Cutoff Voltage ($V_{DS}$ = 15 V, $V_{G1S}$ = 0, $I_D$ = 200 μA) | $V_{G2S}$(off) | −3 | V |
| Gate-No.1 Leakage Current ($V_{G1S}$ = −20 V, $V_{G2S}$ = 0, $V_{DS}$ = 0) | $I_{G1SS}$ | 1 max | nA |
| Gate-No.2 Leakage Current ($V_{G2S}$ = −20 V, $V_{G1S}$ = 0, $V_{DS}$ = 0) | $I_{G2SS}$ | 1 max | nA |
| Zero-Bias-Voltage Drain Current ($V_{G2S}$ = 4 V, $V_{G1S}$ = 0, $V_{DS}$ = 13 V) | $I_{DSS}$ | 18 | mA |
| Small-Signal Reverse Transfer Capacitance, Drain-to-Gate-No.1 ($V_{DS}$ = 13 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 1 MHz) | $C_{rss}$ | 0.02 typ; 0.03 max | pF |
| Input Capacitance ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 1 MHz) | $C_{iss}$ | 5.5 | pF |
| Output Capacitance ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 100 MHz) | $C_{oss}$ | 21 | pF |
| Input Resistance ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 100 MHz) | $r_{iss}$ | 3.5 | kΩ |
| Output Resistance ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 100 MHz) | $r_{oss}$ | 4 | kΩ |
| Forward Transconductance ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 1 kHz) | $g_{fs}$ | 10000● | μmhos |
| Maximum Available Power Gain ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 100 MHz) | MAG | 26 | dB |
| Maximum Usable Power Gain, Unneutralized ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 100 MHz) | MUG | 25▲● | dB |
| Noise Figure ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 100 MHz) | NF | 3 typ; 4 max | dB |

▲ Limited by practical design considerations.

● This characteristic does not apply to type 40604.

# 40604 FIELD-EFFECT TRANSISTOR

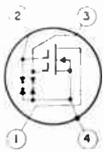



Si dual insulated-gate field-effect (MOS) n-channel depletion type used in mixer applications in FM tuners and other commercial equipment operating at frequencies up to approximately 150 MHz. JEDEC TO-72, Outline No.28. This type is identical with type 40603 except for the following items:

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Output Capacitance ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 100 MHz) | $C_{oss}$ | 2.3 | pF |
| Output Resistance ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 10.7 MHz) | $r_{oss}$ | 20 | kΩ |
| Conversion Transconductance ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 1 kHz) | $g_{fs(c)}$ | 2800 | μmhos |
| Conversion Power Gain ($V_{DS}$ = 13 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 100 MHz, $f_{out}$ = 10.7 MHz) | $MAG_c$ | 23 | dB |

# *Dual-Gate Protected Types*




## FIELD-EFFECT TRANSISTOR 3N187

Si insulated-gate field-effect (mos) n-channel depletion type with integrated gate-protection circuits for military and industrial applications up to 300 MHz. JEDEC TO-72. Outline No.28.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Drain-to-Source Voltage | $V_{DS}$ | −0.2 to 20 | V |
| Gate-No. 1-to-Source Voltage: | | | |
| Continuous (dc) | $V_{G1S}$ | −6 to 3 | V |
| Peak (ac) | $V_{G1S}$ | −6 to 6 | V |
| Gate-No. 2-to-Source Voltage: | | | |
| Continuous (dc) | $V_{G2S}$ | −6 to (0.3 $V_{DS}$) | V |
| Peak (ac) | $V_{G2S}$ | −6 to 6 | V |
| Drain-to-Gate-No. 1 Voltage | $V_{DG1}$ | 20 | |
| Drain-to-Gate-No. 2 Voltage | $V_{DG2}$ | 20 | |
| Drain Current | $I_D$ | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 330 | mW |
| $T_A$ above 25°C | $P_T$ | Derate linearly at 2.2 | mW/°C |
| Temperature Range: | | | |
| Operating | $T_J$ (opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

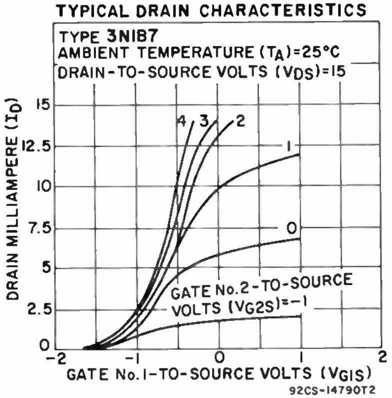
### CHARACTERISTICS

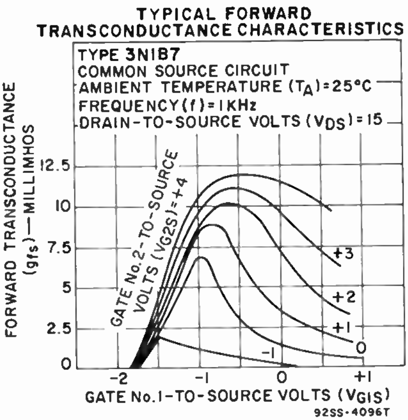
| | | | |
|---|---|---|---|
| Gate-No. 1-to-Source Cutoff Voltage ($V_{DS}$ = 15 V, $I_D$ = 50 µA, $V_{G2S}$ = 4 V) | $V_{G1S}$(off) | −0.5 to −4 | V |
| Gate-No. 2-to-Source Cutoff Voltage ($V_{DS}$ = 15 V, $I_D$ = 50 µA, $V_{G1S}$ = 0) | $V_{G2S}$(off) | −0.5 to −4 | V |
| Gate-No. 1-Terminal Forward Current: | | | |
| $V_{G1S}$ = 1 V, $V_{G2S}$ = $V_{DS}$ = 0 | $I_{G1SSF}$ | 50 max | nA |
| $V_{G1S}$ = 1 V, $V_{G2S}$ = $V_{DS}$ = 0, $T_A$ = 100°C | $I_{G1SSF}$ | 5 max | µA |
| Gate-No. 1-Terminal Reverse Current: | | | |
| $V_{G1S}$ = −6 V, $V_{G2S}$ = $V_{DS}$ = 0 | $I_{G1SSR}$ | 50 max | nA |
| $V_{G1S}$ = −6 V, $V_{G2S}$ = $V_{DS}$ = 0, $T_A$ = 100°C | $I_{G1SSR}$ | 5 max | µA |
| Gate-No. 2-Terminal Forward Current: | | | |
| $V_{G2S}$ = 6 V, $V_{G1S}$ = $V_{DS}$ = 0 | $I_{G2SSF}$ | 50 max | nA |
| $V_{G2S}$ = 6 V, $V_{G1S}$ = $V_{DS}$ = 0, $T_A$ = 100°C | $I_{G2SSF}$ | 5 max | µA |
| Gate-No. 2-Terminal Reverse Current: | | | |
| $V_{G2S}$ = −6 V, $V_{G1S}$ = $V_{DS}$ = 0 | $I_{G2SSR}$ | 50 max | nA |
| $V_{G2S}$ = −6 V, $V_{G1S}$ = $V_{DS}$ = 0, $T_A$ = 100°C | $I_{G2SSR}$ | 5 max | µA |
| Zero-Bias Drain Current ($V_{DS}$ = 15 V, $V_{G1S}$ = 0, $V_{G2S}$ = 4 V) | $I_{DS}$ | 5 to 30 | mA |
| Forward Transconductance, Gate No.1-to-Drain ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 1 kHz) | $g_{fs}$ | 7000 to 18000 | µmho |
| Small-Signal Input Capacitance● ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 1 MHz) | $C_{iss}$ | 4 to 8.5 | pF |
| Small-Signal Reverse Transfer Capacitance, Drain-to-Gate No. 1 ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 1 MHz) | $C_{rss}$ | 0.005 to 0.03 | pF |
| Small-Signal Output Capacitance ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 1 MHz) | $C_{oss}$ | 2 | pF |
| Power Gain ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 200 MHz) | $G_{PS}$ | 16 to 22 | dB |
| Maximum Available Power Gain ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 200 MHz) | MAG | 20 | dB |
| Maximum Usable Power Gain, Unneutralized ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 200 MHz) | MUG | 20 | dB |
| Noise Figure ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 200 MHz) | NF | 3.5 typ; 4.5 max | dB |
| Magnitude of Forward Transadmittance ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 200 MHz) | $\lvert Y_{fs} \rvert$ | 12000 | µmho |

## CHARACTERISTICS (cont'd)

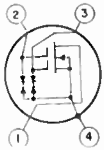
| | | | |
|---|---|---|---|
| Phase Angle of Forward Transadmittance ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 200 MHz) | $\theta$ | −35 | degrees |
| Magnitude of Reverse Transadmittance ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 200 MHz) | $\|Y_{rs}\|$ | 25 | μmho |
| Angle of Reverse Transadmittance ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 200 MHz) | $\theta_{rs}$ | −25 | degrees |
| Input Resistance ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 200 MHz) | $r_{iss}$ | 1 | kΩ |
| Output Resistance ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 200 MHz) | $r_{oss}$ | 2.8 | kΩ |
| Gate-to-Source Forward Breakdown Voltage: | | | |
| Gate No. 1 ($I_{G1SSF}$ = $I_{G2SSF}$ = 100 μA) | $V_{(BR)G1SSF}$ | 6.5 min; 10 typ | V |
| Gate No. 2 ($I_{G1SSF}$ = $I_{G2SSF}$ = 100 μA) | $V_{(BR)G2SSF}$ | 6.5 min; 10 typ | V |
| Gate-to-Source Reverse Breakdown Voltage: | | | |
| Gate No. 1 ($I_{G1SSR}$ = $I_{G2SSR}$ = −100 μA) | $V_{(BR)G1SSR}$ | −6.5 min; −10 typ | V |
| Gate No. 2 ($I_{G1SSR}$ = $I_{G2SSR}$ = −100 μA) | $V_{(BR)G2SSR}$ | −6.5 min; −10 typ | V |

● Capacitance between gate No. 1 and all other terminals.
‡ Three-terminal measurement with gate No. 2 and source returned to guard terminal.




# 3N200 FIELD-EFFECT TRANSISTOR




**Si insulated-gate field-effect (mos) n-channel depletion type with integrated gate-protection circuits for military and industrial applications up to 500 MHz. JEDEC TO-72. Outline No.28.**

## MAXIMUM RATINGS

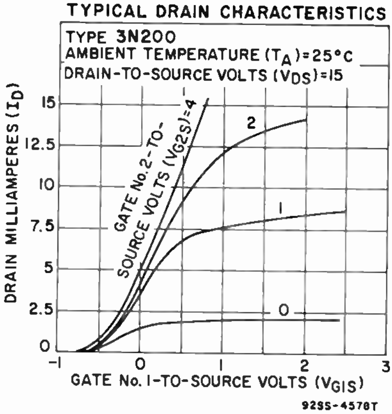
| | | | |
|---|---|---|---|
| Drain-to-Source Voltage | $V_{DS}$ | −0.2 to 20 | V |
| Gate-No. 1-to-Source Voltage: | | | |
| Continuous (dc) | $V_{G1S}$ | −6 to 3 | V |
| Peak (ac) | $V_{G1S}$ | −6 to 6 | V |
| Gate-No. 2-to-Source Voltage: | | | |
| Continuous (dc) | $V_{G2S}$ | −6 to (0.3 $V_{DS}$) | V |
| Peak (ac) | $V_{G2S}$ | −6 to 6 | V |
| Drain-to-Gate-No. 1 Voltage | $V_{DG1}$ | 20 | |
| Drain-to-Gate-No. 2 Voltage | $V_{DG2}$ | 20 | |
| Drain Current | $I_D$ | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 330 | mW |
| $T_A$ above 25°C | $P_T$ | Derate linearly at 2.2 | mW/°C |
| Temperature Range: | | | |
| Operating | $T_J$(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

## CHARACTERISTICS

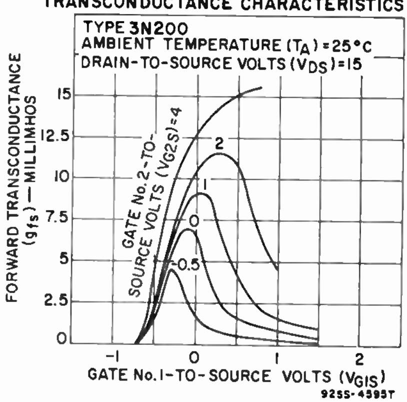
| | | | |
|---|---|---|---|
| Gate-No. 1-to-Source Cutoff Voltage ($V_{DS}$ = 15 V, $I_D$ = 50 μA, $V_{G2S}$ = 4 V) | $V_{G1S}(off)$ | −0.1 to −3 | V |
| Gate-No. 2-to-Source Cutoff Voltage ($V_{DS}$ = 15 V, $I_D$ = 50 μA, $V_{G1S}$ = 0) | $V_{G2S}(off)$ | −0.1 to −3 | V |
| Gate-No. 1-Terminal Forward Current: | | | |
| $V_{G1S}$ = 1 V, $V_{G2S}$ = $V_{DS}$ = 0 | $I_{G1SSF}$ | 50 max | ηA |
| $V_{G1S}$ = 1 V, $V_{G2S}$ = $V_{DS}$ = 0, $T_A$ = 100°C | $I_{G1SSF}$ | 5 max | μA |
| Gate-No. 1-Terminal Reverse Current: | | | |
| $V_{G1S}$ = −6 V, $V_{G2S}$ = $V_{DS}$ = 0 | $I_{G1SSR}$ | 50 max | ηA |
| $V_{G1S}$ = −6 V, $V_{G2S}$ = $V_{DS}$ = 0, $T_A$ = 100°C | $I_{G1SSR}$ | 5 max | μA |
| Gate-No. 2-Terminal Forward Current: | | | |
| $V_{G2S}$ = 6 V, $V_{G1S}$ = $V_{DS}$ = 0 | $I_{G2SSF}$ | 50 max | ηA |
| $V_{G2S}$ = 6 V, $V_{G1S}$ = $V_{DS}$ = 0, $T_A$ = 100°C | $I_{G2SSF}$ | 5 max | μA |
| Gate-No. 2-Terminal Reverse Current: | | | |
| $V_{G2S}$ = −6 V, $V_{G1S}$ = $V_{DS}$ = 0 | $I_{G2SSR}$ | 50 max | ηA |
| $V_{G2S}$ = −6 V, $V_{G1S}$ = $V_{DS}$ = 0, $T_A$ = 100°C | $I_{G2SSR}$ | 5 max | μA |
| Zero-Bias Drain Current ($V_{DS}$ = 15 V, $V_{G1S}$ = 0, $V_{G2S}$ = 4 V) | $I_{DS}$ | 0.5 to 12 | mA |
| Forward Transconductance, Gate No. 1-to-Drain ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 1 kHz) | $g_{fs}$ | 10000 to 20000 | μmho |
| Small-Signal Input Capacitance● ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 1 MHz) | $C_{iss}$ | 4 to 8.5 | pF |
| Small-Signal Reverse Transfer Capacitance, Drain-to-Gate No. 1‡ ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 1 MHz) | $C_{rss}$ | 0.005 to 0.03 | pF |
| Small-Signal Output Capacitance ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 1 MHz) | $C_{oss}$ | 2 | pF |
| Power Gain ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 400 MHz) | $G_{PS}$ | 10 min; 12.5 typ | dB |
| Noise Figure ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 400 MHz) | NF | 4.5 typ; 6 max | dB |
| Bandwidth ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 400 MHz) | BW | 28 to 38 | MHz |
| Gate-to-Source Forward Breakdown Voltage: | | | |
| Gate No. 1 ($I_{G1SSF}$ = $I_{G2SSF}$ = 100 μA, $V_{G2S}$ = $V_{DS}$ = 0) | $V_{(BR)G1SSF}$ | 6.5 to 13 | V |
| Gate No. 2 ($I_{G1SSF}$ = $I_{G2SSF}$ = 100 μA, $V_{G1S}$ = $V_{DS}$ = 0) | $V_{(BR)G2SSF}$ | 6.5 to 13 | V |
| Gate-to-Source Reverse Breakdown Voltage: | | | |
| Gate No. 1 ($I_{G1SSR}$ = $I_{G2SSR}$ = 100 μA, $V_{G2S}$ = $V_{DS}$ = 0) | $V_{(BR)G1SSR}$ | −6.5 to −13 | V |
| Gate No. 2 ($I_{G1SSR}$ = $I_{G2SSR}$ = 100 μA, $V_{G1S}$ = $V_{DS}$ = 0) | $V_{(BR)G2SSR}$ | −6.5 to −13 | V |

● Capacitance between gate No. 1 and all other terminals.
‡ Three-terminal measurement with gate No. 2 and source returned to guard terminal.

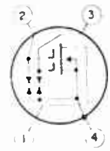
TYPICAL DRAIN CHARACTERISTICS




TYPICAL FORWARD TRANSCONDUCTANCE CHARACTERISTICS



# 40673 FIELD-EFFECT TRANSISTOR




Si dual-insulated gate field-effect (MOS) n-channel depletion type with integrated gate-protection circuits for rf-amplifier applications up to 400 MHz. JEDEC TO-72, Outline No.28.

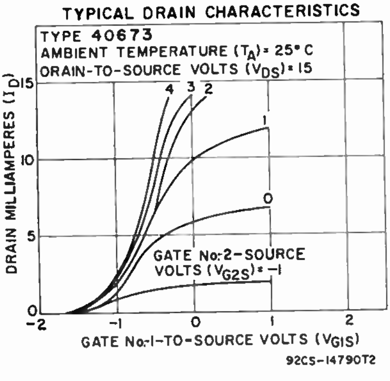
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Drain-to-Source Voltage | $V_{DS}$ | −0.2 to 20 | V |
| Gate-No. 1-to-Source Voltage: | | | |
| Continuous (dc) | $V_{G1S}$ | −6 to 1 | V |
| Peak (ac) | $V_{G1S}$ | −6 to 6 | V |
| Gate-No. 2-to-Source Voltage: | | | |
| Continuous | $V_{G2S}$ | −6 to (0.3 $V_{DS}$) | V |
| Peak (ac) | $V_{G2S}$ | −6 to 6 | V |
| Drain-to-Gate-No. 1 Voltage | $V_{DG1}$ | 20 | V |
| Drain-to-Gate-No. 2 Voltage | $V_{DG2}$ | 20 | V |
| Drain Current | $I_D$ | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 330 | mW |
| $T_A$ above 25°C | $P_T$ | Derate linearly at 2.2 mW/°C | |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

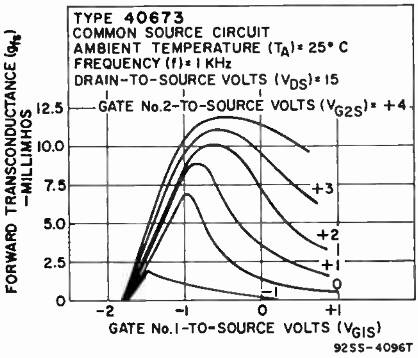
## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Gate-No. 1-to-Source Cutoff Voltage ($V_{DS}$ = 15 V, $V_{G2S}$ = 4 V, $I_D$ = 200 μA) | $V_{G1S}$(off) | −2 typ; −4 max | V |
| Gate-No. 2-to-Source Cutoff Voltage ($V_{DS}$ = 15 V, $V_{G1S}$ = 0, $I_D$ = 200 μA) | $V_{G2S}$(off) | −2 typ; −4 max | V |
| Gate-No. 1 Leakage Current ($V_{G1S}$ = 1 or −6 V, $V_{G2S}$ = 0, $V_{DS}$ = 0) | $I_{G1SS}$ | 20 max | nA |
| Gate-No. 2 Leakage Current ($V_{G2S}$ = ±6 V, $V_{G1S}$ = 0, $V_{DS}$ = 0) | $I_{G2SS}$ | 20 max | nA |
| Zero-Bias Drain Current ($V_{DS}$ = 15 V, $V_{G1S}$ = 0, $V_{G2S}$ = 4 V) | $I_{DSS}$ | 5 to 35 | mA |
| Forward Transconductance, Gate No. 1-to-Drain ($V_{DS}$ = 15 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 1 kHz) | $g_{fs}$ | 12000 | μmhos |
| Small-Signal Input Capacitance* ($V_{DS}$ = 15 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 1 MHz) | $C_{iss}$ | 6 | pF |
| Small-Signal Reverse Transfer Capacitance, Drain-to-Gate No. 1‡ ($V_{DS}$ = 15 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 1 MHz) | $C_{rss}$ | 0.01 to 0.03 | pF |
| Small-Signal Output Capacitance ($V_{DS}$ = 15 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 1 MHz) | $C_{oss}$ | 2 | pF |
| Power Gain ($V_{DS}$ = 15 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 200 MHz) | $G_{PS}$ | 14 min; 18 typ | dB |
| Maximum Available Power Gain ($V_{DS}$ = 15 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 200 MHz) | MAG | 20 | dB |

TYPICAL DRAIN CHARACTERISTICS



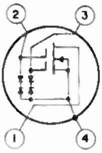

TYPICAL FORWARD TRANSCONDUCTANCE CHARACTERISTICS



## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Maximum Usable Power Gain (Unneutralized ($V_{DS}$ = 15 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 200 MHz) | MUG | 20■ | dB |
| Noise Figure ($V_{DS}$ = 15 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 200 MHz) | NF | 3.5 typ; 6 max | dB |
| Magnitude of Forward Transadmittance ($V_{DS}$ = 15 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 200 MHz) | $\|Y_{fs}\|$ | 12000 | μmho |
| Phase Angle of Forward Transadmittance ($V_{DS}$ = 15 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 200 MHz) | $\theta$ | −35 | degrees |
| Input Resistance ($V_{DS}$ = 15 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 200 MHz) | $r_{iss}$ | 1 | kΩ |
| Output Resistance ($V_{DS}$ = 15 V, $V_{G2S}$ = 4 V, $I_D$ = 10 mA, f = 200 MHz) | $r_{oss}$ | 2.8 | kΩ |
| Protective Diode Knee Voltage ($I_{DIODE(REVERSE)}$ = ±100 μA) | $V_{knee}$ | ±10 | V |

* Capacitance between gate No. 1 and all other terminals.
‡ Three-terminal measurement with gate No. 2 and all other terminals.
■ Limited only by practical design considerations.



## FIELD-EFFECT TRANSISTOR 40819

Si dual insulated-gate field-effect (mos) n-channel depletion type with integrated gate-protection circuits used in rf-amplifier applications up to 250 MHz. JEDEC TO-72. Outline No.28. For typical drain characteristics and typical forward transconductance curves, refer to type 3N187.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Drain-to-Source Voltage | $V_{DS}$ | −0.2 to 25 | V |
| Gate-No. 1 Terminal Current | $I_{G1S}$ | ±100 | μA |
| Gate-No. 2 Terminal Current | $I_{G2S}$ | ±100 | μA |
| Drain-to-Gate-No. 1 Voltage | $V_{DG1}$ | 31 | V |
| Drain-to-Gate-No. 2 Voltage | $V_{DG2}$ | 31 | V |
| Drain Current | $I_D$ | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 330 | mW |
| $T_A$ above 25°C | $P_T$ | Derate linearly 2.2 | mW/°C |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |
| Continuous Working Voltage, at $T_A$ = 25°C: | | | |
| Gate No. 1-to-Source Voltage | $V_{G1S}$ | −6 to 3 | V |
| Gate No. 2-to-Source Voltage | $V_{G2S}$ | −6 to 6 or 0.4 $V_{DS}$* | V |
| Drain-to-Gate No. 1 Voltage | $V_{DG1}$ | 25 | V |
| Drain-to-Gate No. 2 Voltage | $V_{DG2}$ | 25 | V |

* Whichever value is less.

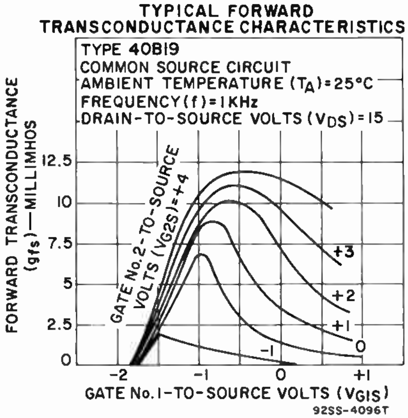
### CHARACTERISTICS

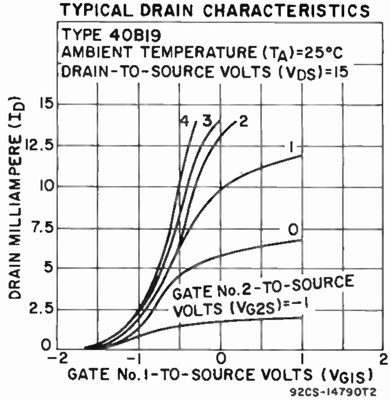
| | | | |
|---|---|---|---|
| Gate-No. 1-to-Source Cutoff Voltage ($V_{DS}$ = 15 V, $I_D$ = 200 μA, $V_{G2S}$ = 4 V) | $V_{G1S}$(off) | −2 typ; −4 max | V |
| Gate-No. 2-to-Source Cutoff Voltage $V_{DS}$ = 15 V, $I_D$ = 200 μA, $V_{G1S}$ = 0) | $V_{G2S}$(off) | −2 typ; −4 max | V |
| Gate-No. 1-Leakage Current ($V_{G1S}$ = ±6 V, $V_{DS}$ = 0, $V_{G2S}$ = 0) | $I_{G1SS}$ | 50 max | ηA |
| Gate-No. 2-Leakage Current ($V_{G2S}$ = ±6 V, $V_{DS}$ = 0, $V_{G1S}$ = 0) | $I_{G2SS}$ | 50 max | ηA |
| Zero-Bias Drain Current ($V_{DS}$ = 15 V, $V_{G2S}$ = 4 V, $V_{G1S}$ = 0) | $I_{DSS}$ | 5 to 35 | mA |
| Forward Transconductance, Gate-No. 1 to Drain ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 1 kHz) | $g_{fs}$ | 12000 | μmho |
| Small-Signal Input Capacitance‡ ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 1 MHz) | $C_{iss}$ | 6 | pF |

## CHARACTERISTICS (cont'd)

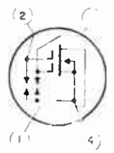
| | | | |
|---|---|---|---|
| Small-Signal Reverse Transfer Capacitance, Drain-to-Gate No. 1● ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 1 MHz) | $C_{rss}$ | 0.005 to 0.03 | pF |
| Small-Signal Output Capacitance ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 1 MHz) | $C_{oss}$ | 2 | pF |
| Power Gain ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 200 MHz) | $G_{PS}$ | 14 min; 18 typ | dB |
| Maximum Available Power Gain ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 200 MHz) | MAG | 20 | dB |
| Maximum Usable Power Gain, Unneutralized ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 200 MHz) | MUG | 20 | dB |
| Noise Figure ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 200 MHz) | NF | 3.5 typ; 6 max | dB |
| Magnitude of Forward Transadmittance ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 200 MHz) | $\|Y_{fs}\|$ | 12000 | μmho |
| Phase Angle of Forward Transadmittance ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 200 MHz) | θ | −35 | degrees |
| Input Resistance ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 200 MHz) | $r_{iss}$ | 1 | kΩ |
| Output Resistance ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 200 MHz) | $r_{oss}$ | 2.8 | kΩ |
| Protective Diode Knee Voltage ($I_{diode}$ (reverse) = ±100 μA) | $V_{knee}$ | ±10 | V |

‡ Capacitance between gate No. 1 and all other terminals.
● Three-terminal measurement with gate No. 2 and source returned to guard terminal.




## 40820 FIELD-EFFECT TRANSISTOR



Si dual insulated-gate field-effect (mos) n-channel depletion type with integrated gate-protection circuits used for rf-amplifier applications in vhf television receivers and other commercial equipment operating at frequencies up to 250 MHz. JEDEC TO-72. Outline No.28.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Drain-to-Source Voltage | $V_{DS}$ | −0.2 to 20 | V |
| Gate-No. 1 Terminal Current | $I_{G1S}$ | ±100 | μA |
| Gate-No. 2 Terminal Current | $I_{G2S}$ | ±100 | μA |

## MAXIMUM RATINGS (cont'd)

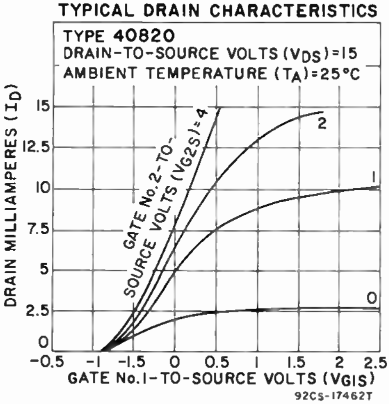
| | | | |
|---|---|---|---|
| Drain-to-Gate-No. 1 Voltage | $V_{DG1}$ | 26 | V |
| Drain-to-Gate-No. 2 Voltage | $V_{DG2}$ | 26 | V |
| Drain Current | $I_D$ | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 330 | mW |
| $T_A$ above 25°C | $P_T$ | Derate linearly 2.2 | mW/°C |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |
| Continuous Working Voltage, at $T_A$ = 25°C: | | | |
| Gate No. 1-to-Source Voltage | $V_{G1S}$ | −6 to 3 | V |
| Gate No. 2-to-Source Voltage | $V_{G2S}$ | −6 to 6 or 0.4 $V_{DS}$* | V |
| Drain-to-Gate No. 1 Voltage | $V_{DG1}$ | 20 | V |
| Drain-to-Gate No. 2 Voltage | $V_{DG2}$ | 20 | V |

* Whichever value is less.

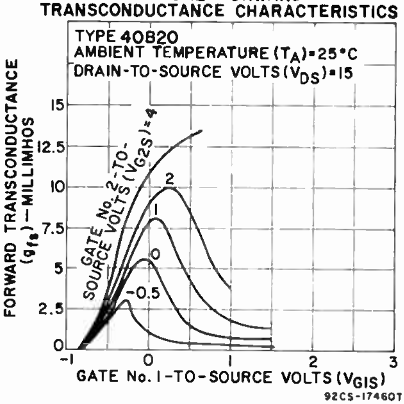
## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Gate-No. 1-to-Source Cutoff Voltage ($V_{DS}$ = 15 V, $I_D$ = 50 μA, $V_{G2S}$ = 4 V) | $V_{G1S}$(off) | −1 typ; −3 max | V |
| Gate-No. 2-to-Source Cutoff Voltage ($V_{DS}$ = 15 V, $I_D$ = 50 μA, $V_{G1S}$ = 0) | $V_{G2S}$(off) | −1 typ; −3 max | V |
| Gate-to-Source Forward Breakdown Voltage: | | | |
| Gate No. 1 ($I_{G1SSF}$ = $I_{G2SSF}$ = 100 μA, $V_{G2S}$ = $V_{DS}$ = 0) | $V_{(BR)G1SSF}$ | 9 | V |
| Gate No. 2 ($I_{G1SSF}$ = $I_{G2SSF}$ = 100 μA, $V_{G1S}$ = $V_{DS}$ = 0) | $V_{(BR)G1SSF}$ | 9 | V |
| Gate-to-Source Reverse Breakdown Voltage: | | | |
| Gate No. 1 ($I_{G1SSR}$ = $I_{G2SSR}$ = 100 μA, $V_{G2S}$ = $V_{DS}$ = 0) | $V_{(BR)G1SSR}$ | 9 | V |
| Gate No. 2 ($I_{G1SSR}$ = $I_{G2SSR}$ = 100 μA, $V_{G1S}$ = $V_{DS}$ = 0) | $V_{(BR)G1SSR}$ | 9 | V |
| Gate No. 1-Terminal Forward Current ($V_{DS}$ = $V_{G2S}$ = 0, $V_{G1S}$ = 6 V) | $I_{G1SSF}$ | 50 max | ηA |
| Gate No. 1-Terminal Reverse Current ($V_{DS}$ = $V_{G2S}$ = 0, $V_{G1S}$ = −6 V) | $I_{G1SSR}$ | 50 max | ηA |
| Gate No. 2-Terminal Forward Current ($V_{DS}$ = $V_{G1S}$ = 0, $V_{G2S}$ = 6 V) | $I_{G2SSF}$ | 50 max | ηA |
| Gate No. 2-Terminal Reverse Current ($V_{DS}$ = $V_{G1S}$ = 0, $V_{G2S}$ = −6 V) | $I_{G2SSR}$ | 50 max | ηA |

TYPICAL DRAIN CHARACTERISTICS




TYPICAL FORWARD TRANSCONDUCTANCE CHARACTERISTICS

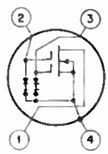


## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Zero-Bias Drain Current ($V_{DS}$ = 15 V, $V_{G1S}$ = 0, $V_{G2S}$ = 4 V) | $I_{DS}$ | 0.5 to 15 | mA |
| Forward Transconductance, Gate No. 1-to-Drain ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 1 kHz) | $g_{fs}$ | 12000 | μmho |
| Small-Signal Input Capacitance● ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 1 MHz) | $C_{iss}$ | 6 typ; 8.5 max | pF |
| Small-Signal Reverse Transfer Capacitance, Drain-to-Gate-No. 1‡ ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 1 MHz) | $C_{rss}$ | 0.005 to 0.03 | pF |
| Small-Signal Output Capacitance ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 1 MHz) | $C_{oss}$ | 2 | pF |
| Power Gain ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 200 MHz) | $G_{PS}$ | 14 min; 17 typ | dB |
| Noise Figure ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 200 MHz) | NF | 4.5 typ; 6 max | dB |

● Capacitance between gate No. 1 and all other terminals.
‡ Three-terminal measurement with gate No. 2 and source returned to guard terminal.

## 40821 FIELD-EFFECT TRANSISTOR




Si dual insulated-gate field-effect (mos) n-channel depletion type with integrated gate-protection circuits used for mixer applications in vhf television receivers and other commercial equipment operating at frequencies up to 250 MHz. JEDEC TO-72. Outline No.28. For typical drain characteristics and typical forward transconductance curves, refer to type 40820.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Drain-to-Source Voltage | $V_{DS}$ | −0.2 to 20 | V |
| Gate-No. 1 Terminal Current | $I_{G1S}$ | ±100 | μA |
| Gate-No. 2 Terminal Current | $I_{G2S}$ | ±100 | μA |
| Drain-to-Gate-No. 1 Voltage | $V_{DG1}$ | 24.5 | V |
| Drain-to-Gate-No. 2 Voltage | $V_{DG2}$ | 24.5 | V |
| Drain Current | $I_D$ | 50 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 330 | mW |
| $T_A$ above 25°C | $P_T$ | Derate linearly 2.2 | mW/°C |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |
| Continuous Working Voltage, at $T_A$ = 25°C: | | | |
| Gate No. 1-to-Source Voltage | $V_{G1S}$ | −4.5 to 3 | V |
| Gate No. 2-to-Source Voltage | $V_{G2S}$ | −4.5 to 4.5 or −4.5 to 0.4 $V_{DS}$* | V |
| Drain-to-Gate No. 1 Voltage | $V_{DG1}$ | 20 | V |
| Drain-to-Gate No. 2 Voltage | $V_{DG2}$ | 20 | V |

* Whichever value is less.

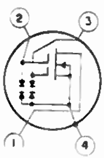
### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Gate No. 1-to-Source Cutoff Voltage ($V_{DS}$ = 15 V, $I_D$ = 50 μA, $V_{G2S}$ = 4 V) | $V_{G1S}$(off) | −1 typ; −3 max | V |
| Gate No. 2-to-Source Cutoff Voltage ($V_{DS}$ = 15 V, $I_D$ = 50 μA, $V_{G1S}$ = 0) | $V_{G2S}$(off) | −1 typ; −3 max | V |
| Gate-to-Source Forward Breakdown Voltage: | | | |
| Gate No. 1 ($I_{G1SSF}$ = $I_{G2SSF}$ = 100 μA, $V_{G2S}$ = $V_{DS}$ = 0) | $V_{(BR)G1SSF}$ | 11 | V |
| Gate No. 2 ($I_{G1SSF}$ = $I_{G2SSF}$ = 100 μA, $V_{G1S}$ = $V_{DS}$ = 0) | $V_{(BR)G1SSF}$ | 11 | V |
| Gate-to-Source Reverse Breakdown Voltage: | | | |
| Gate No. 1 ($I_{G1SSR}$ = $I_{G2SSR}$ = 100 μA, $V_{G2S}$ = $V_{DS}$ = 0) | $V_{(BR)G1SSR}$ | 11 | V |
| Gate No. 2 ($I_{G1SSR}$ = $I_{G2SSR}$ = 100 μA, $V_{G1S}$ = $V_{DS}$ = 0) | $V_{(BR)G1SSR}$ | 11 | V |

### CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Gate No. 1-Terminal Forward Current ($V_{DS} = V_{G2S} = 0$, $V_{G1S} = 4.5$ V) | $I_{G1SSF}$ | 50 max | ηA |
| Gate No. 1-Terminal Reverse Current ($V_{DS} = V_{G2S} = 0$, $V_{G1S} = -4.5$ V) | $I_{G1SSR}$ | 50 max | ηA |
| Gate No. 2-Terminal Forward Current ($V_{DS} = V_{G1S} = 0$, $V_{G2S} = 4.5$ V) | $I_{G2SSF}$ | 50 max | ηA |
| Gate No. 2-Terminal Reverse Current ($V_{DS} = V_{G1S} = 0$, $V_{G2S} = -4.5$ V) | $I_{G2SSR}$ | 50 max | ηA |
| Zero-Bias Drain Current ($V_{DS} = 15$ V, $V_{G1S} = 0$, $V_{G2S} = 4$ V) | $I_{DS}$ | 0.5 to 20 | mA |
| Forward Transconductance, Gate No. 1-to-Drain ($V_{DS} = 15$ V, $I_D = 10$ mA, $V_{G2S} = 4$ V, f = 1 kHz) | $g_{fs}$ | 12000 | μmho |
| Small-Signal Input Capacitance● ($V_{DS} = 15$ V, $I_D = 10$ mA, $V_{G2S} = 4$ V, f = 1 MHz) | $C_{iss}$ | 6 typ; 9 max | pF |
| Small-Signal Reverse Transfer Capacitance, Drain-to-Gate-No. 1‡ ($V_{DS} = 15$ V, $I_D = 10$ mA, $V_{G2S} = 4$ V, f = 1 MHz) | $C_{rss}$ | 0.005 to 0.04 | pF |
| Small-Signal, Output Capacitance ($V_{DS} = 15$ V, $I_D = 10$ mA, $V_{G2S} = 4$ V, f = 1 MHz) | $C_{oss}$ | 2 | pF |
| Conversion Gain ($V_{DS} = 15$ V, $I_D = 10$ mA, $V_{G2S} = 4$ V, f = 200/44 MHz) | $G_{PS(C)}$ | 11 min | dB |

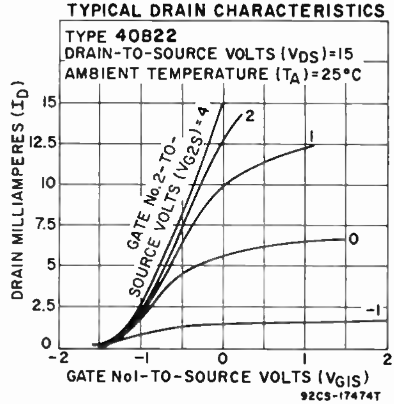
● Capacitance between gate No. 1 and all other terminals.
‡ Three-terminal measurement with gate No. 2 and source returned to guard terminal.




## FIELD-EFFECT TRANSISTOR 40822

Si dual insulated-gate field-effect (mos) n-channel depletion type with integrated gate-protection circuits used for rf-amplifier applications in vhf television receivers and other commercial equipment operating at frequencies up to 250 MHz. JEDEC TO-72. Outline No.28. This type is identical with type 40820 except for the following items. For typical forward transconductance characteristics curves, refer to type 3N187.

TYPICAL DRAIN CHARACTERISTICS



## MAXIMUM RATINGS

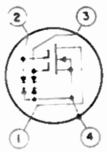
| | | | |
|---|---|---|---|
| Drain-to-Source Voltage | $V_{DS}$ | −0.2 to 18 | V |
| Drain-to-Gate No. 1 Voltage | $V_{DG1}$ | 24 | V |
| Drain-to-Gate No. 2 Voltage | $V_{DG2}$ | 24 | V |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Gate No. 1-to-Source Cutoff Voltage ($V_{DS}$ = 15 V, $I_D$ = 50 μA, $V_{G2S}$ = 4 V) | $V_{G1S}$(off) | −2 typ; −4 max | V |
| Gate No. 2-to-Source Cutoff Voltage ($V_{DS}$ = 15 V, $I_D$ = 50 μA, $V_{G1S}$ = 0) | $V_{G2S}$(off) | −2 typ; −4 max | V |
| Zero-Bias Drain Current ($V_{DS}$ = 15 V, $V_{G1S}$ = 0, $V_{G2S}$ = 4 V) | $I_{DS}$ | 5 to 30 | mA |
| Small-Signal Input Capacitance‡ ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 1 MHz) | $C_{iss}$ | 6.5 typ; 9.5 max | pF |
| Power Gain ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 200 MHz) | $G_{PS}$ | 19 min; 24 typ | dB |
| Noise Figure ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 200 MHz) | NF | 2 typ; 3.5 max | dB |

‡ Capacitance between gate No. 1 and all other terminals.

# 40823 FIELD-EFFECT TRANSISTOR




Si dual insulated-gate field-effect (mos) n-channel depletion type with integrated gate-protection circuits used for mixer applications in vhf television receivers and other commercial equipment operating at frequencies up to 250 MHz. JEDEC TO-72. Outline No.28. This type is identical with type 40821 except for the following items. For typical drain characteristics and typical forward transconductance curves, refer to type 40822.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Drain-to-Source Voltage | $V_{DS}$ | −0.2 to 18 | V |
| Drain-to-Gate No. 1 Voltage | $V_{DG1}$ | 22.5 | V |
| Drain-to-Gate No. 2 Voltage | $V_{DG2}$ | 22.5 | V |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Gate No. 1-to-Source Cutoff Voltage ($V_{DS}$ = 15 V, $I_D$ = 50 μA, $V_{G2S}$ = 4 V) | $V_{G1S}$(off) | −2 typ; −4 max | V |
| Gate No. 2-to-Source Cutoff Voltage ($V_{DS}$ = 15 V, $I_D$ = 50 μA, $V_{G1S}$ = 0) | $V_{G2S}$(off) | −2 typ; −4 max | V |
| Zero-Bias Drain Current ($V_{DS}$ = 15 V, $V_{G1S}$ = 0, $V_{G2S}$ = 4 V) | $I_{DS}$ | 5 to 35 | mA |
| Small-Signal Input Capacitance‡ ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 1 MHz) | $C_{iss}$ | 6.5 typ; 10 max | pF |
| Small-Signal Reverse Transfer Capacitance, Drain-to-Gate-No. 1● ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 1 MHz) | $C_{rss}$ | 0.005 to 0.045 | pF |
| Conversion Gain ($V_{DS}$ = 15 V, $I_D$ = 10 mA, $V_{G2S}$ = 4 V, f = 100 to 10.7 MHz) | $G_{PS(c)}$ | 14 min; 18 typ | dB |

‡ Capacitance between gate No. 1 and all other terminals.
● Three-terminal measurement with gate No. 2 and source returned to guard terminal.

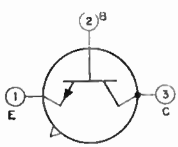
# Technical Data for Low- and Medium-Frequency Power Transistors

THIS section contains detailed technical data for all current RCA low- and medium-frequency power transistors intended for both linear and switching applications. Separate groupings of data are provided for low-voltage n-p-n (hometaxial-base) types, p-n-p power types, high voltage n-p-n types, high-speed n-p-n (switching) types, diffused-junction n-p-n types, germanium power types, and special audio silicon types. Within each group, transistors are listed in order of ascending power ratings.

In selection of devices for use in new electronic equipment, a prospective user should refer to the appropriate section of the Selection Guide included earlier in the Manual. For the reader who requires data on specific types, a complete numerical-alphabetical-numerical index to all current RCA solid-state devices is provided immediately following the Circuits Section in the back of the Manual.

## *Low-Voltage N-P-N (Hometaxial-Base) Types*

### 1.5A, 8.75W — 40347




Si n-p-n single-diffused type featuring a base comprised of a homogeneous-resistivity silicon material. This type is used in a wide variety of low- and medium-power applications where medium- and high-voltage power transistors are required, such as switching regulators, converters, inverters, relay controls, oscillators, and pulse and audio amplifiers. JEDEC TO-5, Outline No.5.

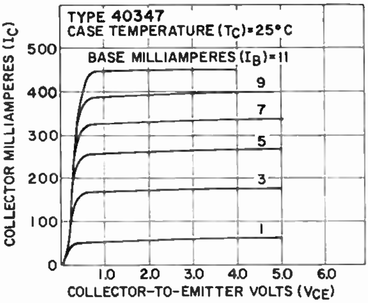
#### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 60 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE} = -1.5$ V | $V_{CEV}$ | 60 | V |
| Base open | $V_{CEO}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 1.5 | A |
| Peak Collector Current | $i_C$ | 3 | A |
| Base Current | $I_B$ | 0.5 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 8.75 | W |
| $T_A$ and $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

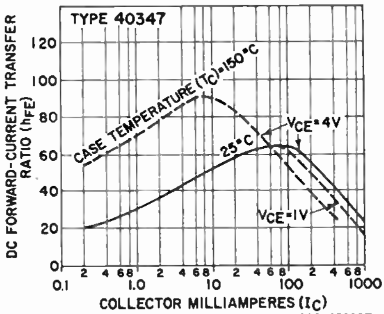
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE}$ = −1.5 V, $I_C$ = 50 mA | $V_{CEV}$(sus) | 60 min | V |
| $I_C$ = 50 mA, $I_B$ = 0 | $V_{CEO}$(sus) | 40 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 450 mA, $I_B$ = 45 mA) | $V_{CE}$(sat) | 1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 450 mA) | $V_{BE}$ | 1.5 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 30 V, $R_{BE}$ = 1 kΩ, $T_C$ = 25°C | $I_{CER}$ | 1 max | μA |
| $V_{CE}$ = 30 V, $R_{BE}$ = 1 kΩ, $T_C$ = 150°C | $I_{CER}$ | 1 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 7 V, $I_C$ = 0) | $I_{EBO}$ | 10 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 450 mA) | $h_{FE}$ | 25 to 100 | |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 20 max | °C/W |

TYPICAL COLLECTOR CHARACTERISTICS



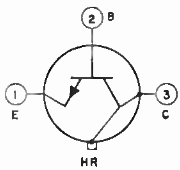

92SS-2322CT

TYPICAL DC FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTICS




92SS-2328CT

# 40347V1 1.5A, 8.75W




Si n-p-n single-diffused type featuring a base comprised of a homogeneous-resistivity silicon material. This type has an attached heat radiator for printed-circuit-board use in a wide variety of low- and medium-power applications requiring medium- and high-voltage power transistors for switching regulators, converters, inverters, relay controls, oscillators, and pulse and audio amplifiers. JEDEC TO-5 (with heat radiator), Outline No.8. This type is identical with type 40347 except for the following items:

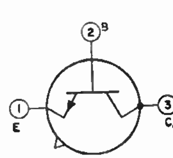
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 4.4 | W |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 40 max | °C/W |

# 40347V2 1.5A, 8.75W




Si n-p-n single-diffused type featuring a base comprised of a homogeneous-resistivity silicon material. This type is used in a wide variety of low- and medium-power applications requiring medium- and high-voltage power transistors for switching regulators, converters, inverters, relay controls, oscillators, and pulse and audio amplifiers. JEDEC TO-5 (with flange), Outline No.6. See Mounting Hardware for desired mounting arrangement. This type is identical with type 40347 except for the following items:

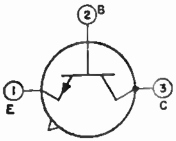
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 11.7 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 15 max | °C/W |

## 1.5A, 8.75W — 40348



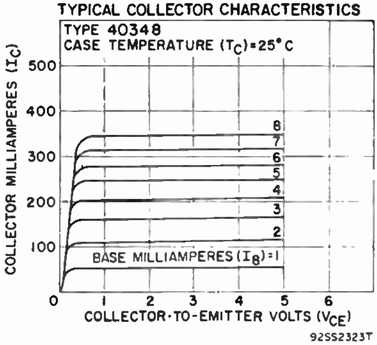

Si n-p-n single-diffused type featuring a base comprised of a homogeneous-resistivity silicon material. This type is used in a wide variety of low- and medium-power applications where medium- and high-voltage power transistors are required, such as switching regulators, converters, inverters, relay controls, oscillators, and pulse and audio amplifiers. JEDEC TO-5, Outline No.5.

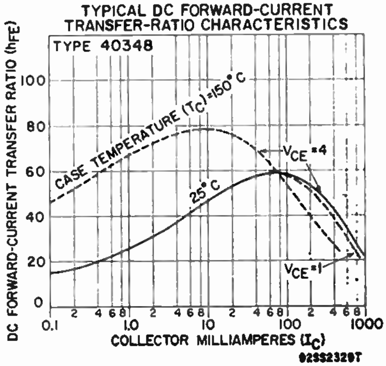
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 90 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 90 | V |
| Base open | $V_{CEO}$ | 65 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Peak Collector Current | $i_C$ | 3 | A |
| Collector Current | $I_C$ | 1.5 | A |
| Base Current | $I_B$ | 0.5 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 8.75 | W |
| $T_A$ and $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE}$ = −1.5 V, $I_C$ = 50 mA | $V_{CEV}$(sus) | 90 min | V |
| $I_C$ = 50 mA, $I_B$ = 0 | $V_{CEO}$(sus) | 65 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 300 mA, $I_B$ = 30 mA) | $V_{CE}$(sat) | 0.75 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 300 mA) | $V_{BE}$ | 1.3 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 60 V, $R_{BE}$ = 1 kΩ, $T_C$ = 25°C | $I_{CER}$ | 1 max | µA |
| $V_{CE}$ = 60 V, $R_{BE}$ = 1 kΩ, $T_C$ = 150°C | $I_{CER}$ | 1 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 7 V, $I_C$ = 0) | $I_{EBO}$ | 10 max | µA |

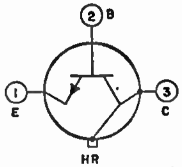


## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 4 V, $I_C$ = 300 mA | $h_{FE}$ | 30 to 100 | |
| $V_{CE}$ = 4 V, $I_C$ = 1 A | $h_{FE}$ | 10 min | |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 20 max | °C/W |

# 40348V1 1.5A, 8.75W




Si n-p-n single-diffused type featuring a base comprised of a homogeneous-resistivity silicon material. This type has an attached heat radiator for printed-ricuit-board use in a wide variety of low- and medium-power applications requiring medium- and high-voltage power transistors for switching regulators, converters, inverters, relay controls, oscillators, and pulse and audio amplifiers. JEDEC TO-5 (with heat radiator), Outline No.8. This type is identical with type 40348 except for the following items:

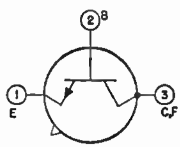
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 4.4 | W |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 40 max | °C/W |

# 40348V2 POWER TRANSISTOR




Si n-p-n single-diffused type featuring a base comprised of a homogeneous-resistivity silicon material. This type is used in a wide variety of low -and medium-power applications requiring medium- and high-voltage power transistors for switching regulators, converters, inverters, relay controls, oscillators, and pulse and audio amplifiers. JEDEC TO-5 (with flange), Outline No.6. See Mounting Hardware for desired mounting arrangement. This type is identical with type 40348 except for the following items:

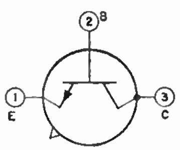
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 11.7 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |

## CHARACTERISTICS (At mounting-flange temperature = 25°C)

| | | | |
|---|---|---|---|
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 15 max | °C/W |

# 40349 1.5A, 8.75W




Si n-p-n single-diffused type featuring a base comprised of a homogeneous-resistivity silicon material. This type is used in a wide variety of low- and medium-power applications where medium- and high-voltage power transistors are required, such as switching regulators, converters, inverters, relay controls, oscillators, and pulse and audio amplifiers. JEDEC TO-5, Outline No.5.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 160 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 160 | V |
| Base open | $V_{CEO}$ | 140 | V |

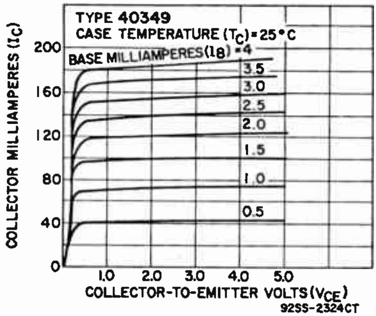
## MAXIMUM RATINGS (cont'd)

| | | | |
|---|---|---|---|
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 1.5 | A |
| Peak Collector Current | $i_C$ | 3 | A |
| Base Current | $I_B$ | 0.5 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 8.75 | W |
| $T_A$ and $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

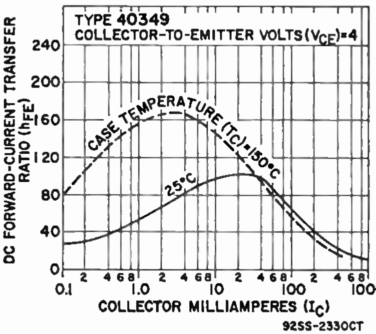
## CHARACTERISTICS (At case temperature = 25°C)

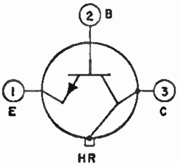
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE}$ = −1.5 V, $I_C$ = 50 mA, tp = 300 μs, df = 1.8% | $V_{CEV}$(sus) | 160 min | V |
| $I_C$ = 50 mA, $I_B$ = 0, tp = 300 μs, df = 1.8% | $V_{CEO}$(sus) | 140 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA) | $V_{CE}$(sat) | 0.5 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 150 mA) | $V_{BE}$ | 1.1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 90 V, $R_{BE}$ = 1 kΩ, $T_C$ = 25°C | $I_{CER}$ | 1 max | μA |
| $V_{CE}$ = 90 V, $R_{BE}$ = 1 kΩ, $T_C$ = 150°C | $I_{CEO}$ | 1 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 7 V, $I_C$ = 0) | $I_{EBO}$ | 10 max | μA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 4 V, $I_C$ = 150 mA | $h_{FE}$ | 25 to 100 | |
| $V_{CE}$ = 4 V, $I_C$ = 450 mA | $h_{FE}$ | 10 min | |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 20 max | °C/W |

TYPICAL COLLECTOR CHARACTERISTICS




TYPICAL DC FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTICS




## POWER TRANSISTOR 40349V1

Si n-p-n single-diffused type featuring a base comprised of a homogeneous-resistivity silicon material. This type has an attached heat radiator for printed-circuit-board use in a wide variety of low- and medium-power applications requiring medium- and high-voltage power transistors for switching regulators, converters, inverters, relay controls, oscillators, and pulse and audio amplifiers. JEDEC TO-5 (with heat radiator), Outline No.8. This type is identical with type 40439 except for the following items:

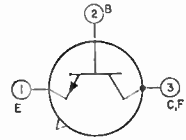
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 4.4 | W |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 40 max | °C/W |

# 40349V2 POWER TRANSISTOR




Si n-p-n single-diffused type featuring a base comprised of a homogeneous-resistivity silicon material. This type is used in a wide variety of low- and medium-power applications requiring medium- and high-voltage power transistors for switching regulators, converters, inverters, relay controls, oscillators, and pulse and audio amplifiers. JEDEC TO-5 (with flange), Outline No.6. See Mounting Hardware for desired mounting arrangement. This type is identical with type 40349 except for the following items:

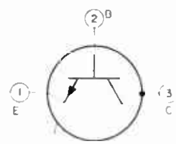
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 11.7 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 15 max | °C/W |

# 2N5784 3.5A, 10W



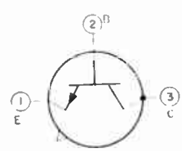

Si n-p-n type features a base comprised of a homogeneous-resistivity silicon material. This type is used for medium-power switching and complementary-symmetry audio amplifier applications. JEDEC TO-5, Outline No.5. This type and type 2N5781 form a complementary pair and is identical with type 2N5781 except for reversal of polarity signs and the following items:

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Magnitude of Small-Signal Forward-Current Transfer Ratio▲ ($V_{CE}$ = 2 V, $I_C$ = 0.1 A, f = 200 kHz) | $\lvert h_{fe}\rvert$ | 5 to 20 | |
| Turn-On Time ($V_{CC}$ = 30 V, $I_C$ = 1 A, $I_{B1}$ = 0.1 A) | $t_d + t_r$ | 5 max | μs |
| Turn-Off Tme ($V_{CC}$ = 30 V, $I_C$ = 1 A, $I_{B2}$ = 0.1 A) | $t_s + t_f$ | 15 max | μs |

▲ Measured at a frequency where $\lvert h_{fe}\rvert$ is decreasing at approximately 6 dB per octave.

# 2N5785 3.5A, 10W



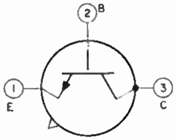

Si n-p-n type features a base comprised of a homogeneous-resistivity silicon material. This type is used for medium-power switching and complementary-symmetry audio amplifier applications. JEDEC TO-5, Outline No.5. This type and type 2N5782 form a complementary pair and is identical with type 2N5782 except for reversal of polarity signs and the following items:

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Magnitude of Small-Signal Forward-Current Transfer Ratio▲ ($V_{CE}$ = 2 V, $I_C$ = 0.1 A, f = 200 kHz) | $\lvert h_{fe}\rvert$ | 5 to 20 | |
| Turn-On Time ($V_{CC}$ = 30 V, $I_C$ = 1 A, $I_{B1}$ = 0.1 A) | $t_d + t_r$ | 5 max | μs |
| Turn-Off Time ($V_{CC}$ = 30 V, $I_C$ = 1 A, $I_{B2}$ = 0.1 A) | $t_s + t_f$ | 15 max | μs |

▲ Measured at a frequency where $\lvert h_{fe}\rvert$ is decreasing at approximately 6 dB per octave.

## 3.5A, 10W — 2N5786



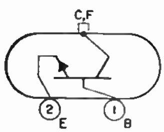

Si **n-p-n** type features a base comprised of a homogeneous-resistivity silicon material. This type is used for medium-power switching and complementary-symmetry audio amplifier applications. JEDEC TO-5, Outline No.5. This type and type 2N5783 form a complementary pair and is identical with type 2N5783 except for reversal of polarity signs and the following items:

**CHARACTERISTICS** (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Magnitude of Small-Signal Forward-Current Transfer Ratio▲ ($V_{CE}$ = 2 V, $I_C$ = 0.1 A, f = 200 kHz) | $\|h_{fe}\|$ | 5 to 20 | |
| Turn-On Time ($V_{CC}$ = 30 V, $I_C$ = 1 A, $I_{B1}$ = 0.1 A) | $t_d + t_r$ | 5 max | μs |
| Turn-Off Time ($V_{CC}$ = 30 V, $I_C$ = 1 A, $I_{B2}$ = 0.1 A) | $t_s + t_f$ | 15 max | μs |

▲ Measured at a frequency where $|h_{fe}|$ is decreasing at approximately 6 dB per octave.

## 4A, 25W — 2N3441

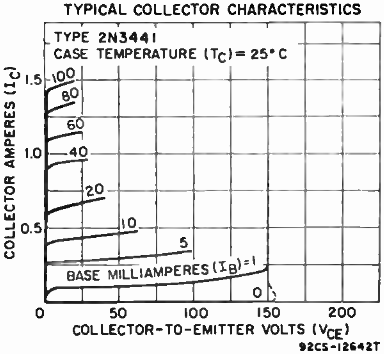



Si **n-p-n** diffused type for high-voltage applications in power-switching circuits, series- and shunt-regulator driver and output stages, and in dc-to-dc converters in military, industrial, and commercial equipment. This type features a base comprised of a homogeneous-resistivity silicon material. JEDEC TO-66, Outline No.25. See Mounting Hardware for desired mounting arrangement.

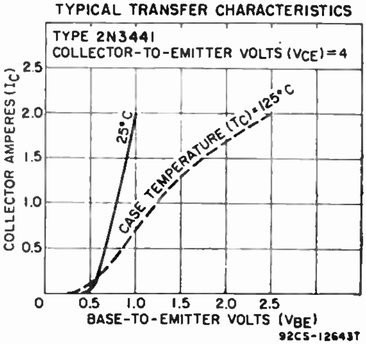
**MAXIMUM RATINGS**

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 160 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 160 | V |
| Base open (sustaining voltage) | $V_{CEO}$(sus) | 140 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 3 | A |
| Peak Collector Current | $i_C$ | 4 | A |
| Base Current | $I_B$ | 2 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 25 | W |
| $T_A$ up to 25°C | $P_T$ | 5.8 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 255 | °C |

TYPICAL COLLECTOR CHARACTERISTICS




TYPICAL TRANSFER CHARACTERISTICS



### CHARACTERISTICS (At case temperature = 25°C)

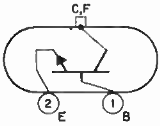
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 0.1 to 2 A, $I_B$ = 0 | $V_{CEO}(sus)$ | 140 min | V |
| $I_C$ = 0.1 to 1 A, $V_{BE}$ = −1.5 V | $V_{CEV}(sus)$ | 160 min | V |
| $I_C$ = 0.1 to 1 A, $R_{BE}$ = 100 Ω | $V_{CER}(sus)$ | 150* min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 0.5 A, $I_B$ = 50 mA) | $V_{CE}(sat)$ | 1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 0.5 A) | $V_{BE}$ | 1.7 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 140 V, $V_{BE}$ = −1.5 V, $T_C$ = 25°C | $I_{CEV}$ | 1 max | mA |
| $V_{CE}$ = 140 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C | $I_{CEV}$ | 5 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 7 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 0.5 A) | $h_{FE}$ | 20 to 80 | |
| Power Rating Test: | | | |
| $V_{CE}$ = 32.5 V, $I_C$ = 0.9 A, t = 1 s | | 29 | W |
| $V_{CE}$ = 120 V, I = 0.24 A, t = 1 s | | 29 | W |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 7● max | °C/W |

* This value does not apply to type 2N3442.
● This value does not apply to type 40373.

## 2N3054

**4A, 25W**

Si n-p-n diffused-junction type used in power-switching circuits, series- and shunt-regulator driver and output stages, and high-fidelity amplifiers in commercial and industrial equipment. JEDEC TO-66, Outline No.25. See Mounting Hardware for desired mounting arrangement.



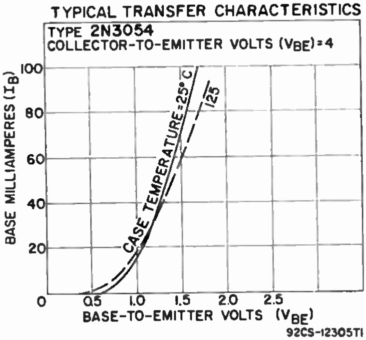

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 90 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}(sus)$ | 90 | V |
| $R_{BE}$ = 100 Ω | $V_{CER}(sus)$ | 60 | V |
| Base open | $V_{CEO}(sus)$ | 55 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 4 | A |
| Base Current | $I_B$ | 2 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 25 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating ($T_C$) and Storage ($T_{STG}$) | | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 235 | °C |

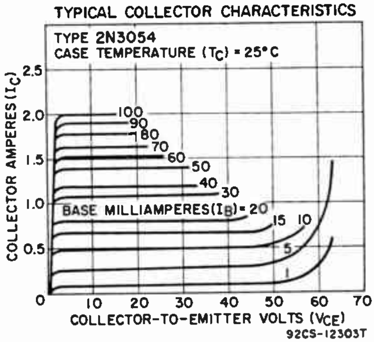
### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 100 mA, $R_{BE}$ = 100 Ω | $V_{CER}(sus)$ | 60 min | V |
| $I_C$ = 100 mA, $I_B$ = 0 | $V_{CEO}(sus)$ | 55 min | V |
| Collector-to-Emitter Saturation Voltage: | | | |
| $I_C$ = 500 mA, $I_B$ = 50 mA | $V_{CE}(sat)$ | 1 max | V |
| $I_C$ = 3 A, $I_B$ = 1 A | $V_{CE}(sat)$ | 6 max | V |

TYPICAL TRANSFER CHARACTERISTICS




TYPICAL COLLECTOR CHARACTERISTICS

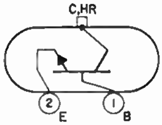


## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 500 mA) | $V_{BE}$ | 1.7 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 30 V, $I_B$ = 0 | $I_{CEO}$ | 0.5 max | mA |
| $V_{CE}$ = 90 V, $V_{BE}$ = −1.5 V | $I_{CEX}$ | 1 max | mA |
| $V_{CE}$ = 90 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C | $I_{CEX}$ | 5 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 7 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 500 mA) | $h_{FE}$ | 25 to 100 | |
| Small-Signal Forward-Current Ratio ($V_{CE}$ = 4 V, $I_C$ = 0.1 A, f = 1 kHz) | $h_{fe}$ | 25 min | |
| Gain-Bandwidth Product ($I_C$ = 0.2 A) | $f_T$ | 800 min | kHz |
| Small-Signal Forward-Current Transfer Ratio Cutoff Frequency ($V_{CE}$ = 4 V, $I_C$ = 0.1 A) | $f_{hfe}$ | 30 min | kHz |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 7• max | °C/W |

• This value applies only to type 2N3054.

## 4A, 25W 40372




Si n-p-n diffused-junction type featuring a base comprised of a homogeneous-resistivity silicon material. This type has an attached heat radiator for printed-circuit-board use in power-switching circuits, series- and shunt-regulator driver and output stages, and high-fidelity amplifiers in commercial and industrial equipment. JEDEC TO-66 (with heat radiators), Outline No.26. This type is identical with type 2N3054 except for the following items:

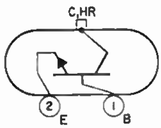
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 5.8 | W |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 30 max | °C/W |

## 4A, 25W 40373




Si n-p-n diffused type features a base comprised of a homogeneous-resistivity silicon material. This type has an attached radiator for printed-circuit-board used in high-voltage applications in power-switching circuits, series- and shunt-regulator driver and output stages, and dc-to-dc converters in military, commercial, and industrial equipment. JEDEC TO-66 (with heat radiator), Outline No.26. This type is identical with type 2N3441 except for the following items:

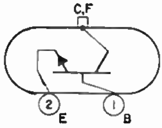
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 5.8 | W |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 30 max | °C/W |

## 4A, 29W 40250




Si n-p-n diffused-junction type used in audio and inverter circuits in 12-volt mobile radio and portable communications equipment and in a wide variety of intermediate- and high-power applications. JEDEC TO-66, Outline No.25. See Mounting Hardware for desired mounting arrangement.

## MAXIMUM RATINGS

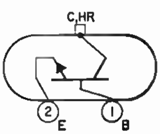
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 50 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = —1.5 V | $V_{CEV}$ | 50 | V |
| Base open | $V_{CEO}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 4 | A |
| Base Current | $I_B$ | 2 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 29* | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | —65 to 200 | °C |
| Storage | $T_{STG}$ | —65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 235 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.05 A, $I_E$ = 0) | $V_{(BR)CBO}$ | 50 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 0.05 A, $V_{BE}$ = —1.5 V) | $V_{(BR)CEV}$ | 50 min | V |
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 0.1 A) | $V_{CEO}$(sus) | 40 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.005 A, $I_C$ = 0) | $V_{(BR)EBO}$ | 5 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 1.5 A, $I_B$ = 0.15 A) | $V_{CE}$(sat) | 1.5 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 1.5 A) | $V_{BE}$ | 2.2 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 1 max | mA |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 5 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 1.5 A) | $h_{FE}$ | 25 to 100 | |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 6* max | °C/W |

* This value does not apply to type 40250V1.

# 40250V1 4A, 29W




Si **n-p-n diffused-junction** type used in audio and inverter circuits in 12-volt mobile radio and portable communications equipment and in a wide variety of intermediate- and high-power applications. This type has an attached heat radiator for mounting on printed-circuit-board applications. JEDEC TO-66 (with heat radiator), **Outline** No.26. This type is identical with type 40250 except for the following items:

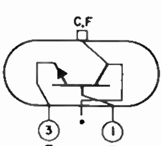
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 5.8 | W |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 30 max | °C/W |

# 2N5293 4A, 36W




Si **n-p-n** type featuring a base comprised of a homogeneous-resistivity silicon material and molded silicone plastic package with vertical leads. This type fits a standard TO-66 socket. It is used in a wide variety of medium-power switching and amplifier applications such as series and shunt regulators, and in driver and output stages of high-fidelity amplifiers. **Outline** No.52. See **Mounting Hardware** for desired mounting arrangement.

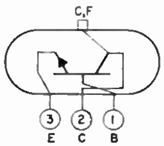
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 80 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE} = -1.5$ V | $V_{CEV}$(sus) | 80 | V |
| $R_{BE} = 100\ \Omega$ | $V_{CER}$(sus) | 75 | V |
| Base open | $V_{CEO}$(sus) | 70 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 4 | A |
| Base Current | $I_B$ | 2 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 36 | W |
| $T_A$ up to 25°C | $P_T$ | 1.8 | W |
| $T_C$ above 25°C | $P_T$ | Derate linearly at 0.288 | W/°C |
| $T_A$ above 25°C | $P_T$ | Derate linearly at 0.0144 | W/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 150 | °C |
| Storage | $T_{STG}$ | −65 to 150 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 235 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

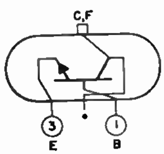
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C = 0.1$ A, $I_B = 0$, $t_P = 300\ \mu s$, df = 0.018 | $V_{CEO}$(sus) | 70 min | V |
| $I_C = 0.1$ A, $t_P = 300\ \mu s$, df = 0.018 | $V_{CER}$(sus) | 75 min | V |
| $V_{BE} = -1.5$ V, $I_C = 0.1$ A, $t_P = 300\ \mu s$, df = 0.018 | $V_{CEV}$(sus) | 80 min | V |
| Base-to-Emitter Voltage ($V_{CE} = 4$ V, $I_C = 0.5$ A, $t_P = 300\ \mu s$, df = 0.018) | $V_{BE}$ | 1.1 max | V |
| Collector-to-Emitter Saturation Voltage ($I_C = 0.5$ A, $I_B = 0.05$ A, $t_P = 300\ \mu s$, df = 0.018) | $V_{CE}$(sat) | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE} = 65$ V, $V_{BE} = -1.5$ V | $I_{CEV}$ | 0.5 max | mA |
| $V_{CE} = 65$ V, $V_{BE} = -1.5$ V, $T_C = 150$°C | $I_{CEV}$ | 3 max | mA |
| $V_{CE} = 50$ V, $R_{BE} = 100\ \Omega$ | $I_{CER}$ | 0.5 max | mA |
| $V_{CE} = 50$ V, $R_{BE} = 100\ \Omega$, $T_C = 150$°C | $I_{CER}$ | 2 max | mA |
| Emitter-Cutoff Current ($V_{EB} = 7$ V) | $I_{EBO}$ | 1 max | mA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE} = 4$ V, $I_C = 0.5$ A, $t_P = 300\ \mu s$, df = 0.018) | $h_{FE}$(pulsed) | 30 to 120 | |
| Gain-Bandwidth Product ($V_{CE} = 4$ V, $I_C = 0.2$ A) | $f_T$ | 0.8 min | MHz |
| Turn-On Time ($V_{CC} = 30$ V, $I_C = 0.5$ A, $I_{B1} = 0.05$ A) | $t_d + t_r$ | 5 max | $\mu s$ |
| Turn-Off Time ($V_{CC} = 30$ V, $I_C = 0.5$ A, $I_{B1} = -0.05$ A) | $t_s + t_f$ | 15 max | $\mu s$ |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 3.5 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 70 max | °C/W |

## 4A, 36W 2N5294




Si n-p-n type featuring a base comprised of a homogeneous-resistivity silicon material and molded silicone plastic package having horizontal leads for mounting on printed-circuit boards. It is used in a wide variety of medium-power switching and amplifier applications such as series and shunt regulators, and in driver and output stages of high-fidelity amplifiers. Outline No.53. See Mounting Hardware for desired mounting arrangement. This type is electrically identical to type 2N5293.

## 4A, 36W 2N5295




Si n-p-n type featuring a base comprised of a homogeneous-resistivity silicon material and molded silicone plastic package with vertical leads. This type fits a standard TO-66 socket. It is used in a wide variety of medium-power switching and amplifier applications such as series and shunt regulators, and in driver and output stages of high-fidelity amplifiers. Outline No.52. See Mounting Hardware for desired mounting arrangement.

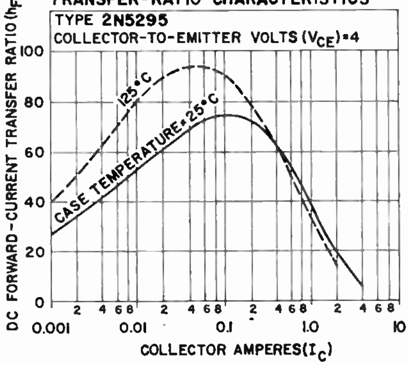
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 60 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE} = -1.5$ V | $V_{CEV}$(sus) | 60 | V |
| $R_{BE} = 100\ \Omega$ | $V_{CER}$(sus) | 50 | V |
| Base open | $V_{CEO}$(sus) | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 4 | A |
| Base Current | $I_B$ | 2 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 36 | W |
| $T_A$ up to 25°C | $P_T$ | 1.8 | W |
| $T_C$ above 25°C | $P_T$ Derate linearly at | 0.288 | W/°C |
| $T_A$ above 25°C | $P_T$ Derate linearly at | 0.0144 | W/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 150 | °C |
| Storage | $T_{STG}$ | −65 to 150 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 235 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

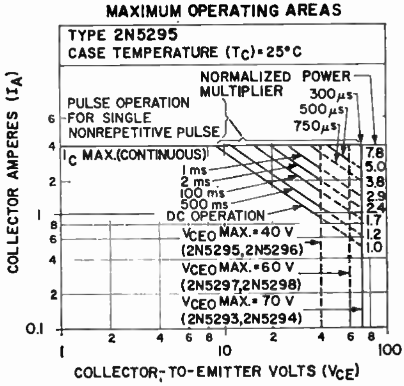
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C = 0.1$ A, $I_B = 0$, $t_P = 300\ \mu s$, df = 0.018 | $V_{CEO}$(sus) | 40 min | V |
| $I_C = 0.1$ A, $t_P = 300\ \mu s$, df = 0.018 | $V_{CER}$(sus) | 50 min | V |
| $V_{BE} = -1.5$ V, $I_C = 0.1$ A, $t_P = 300\ \mu s$, df = 0.018 | $V_{CEV}$(sus) | 60 min | V |
| Base-to-Emitter Voltage ($V_{CE} = 4$ V, $I_C = 1$ A, $t_P = 300\ \mu s$, df = 0.018) | $V_{BE}$ | 1.3 max | V |
| Collector-to-Emitter Saturation Voltage ($I_C = 1$ A, $I_B = 0.1$ A, $t_P = 300\ \mu s$, df = 0.018) | $V_{CE}$(sat) | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE} = 35$ V, $V_{BE} = -1.5$ V | $I_{CEV}$ | 2 max | mA |
| $V_{CE} = 35$ V, $V_{BE} = -1.5$ V, $T_C = 150°C$ | $I_{CEV}$ | 5 max | mA |
| Emitter-Cutoff Current ($V_{EB} = 5$ V) | $I_{EBO}$ | 1 max | mA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE} = 4$ V, $I_C = 1$ A, $t_P = 300\ \mu s$, df = 0.018) | $h_{FE}$(pulsed) | 30 to 120 | |
| Gain-Bandwidth Product ($V_{CE} = 4$ V, $I_C = 0.\ 2$A) | $f_T$ | 0.8 max | MHz |
| Turn-On Time ($V_{CC} = 30$ V, $I_C = 1$ A, $I_{B1} = 0.1$ A) | $t_d + t_r$ | 5 max | $\mu s$ |
| Turn-Off Time ($V_{CC} = 30$ V, $I_C = 1$ A, $I_{B2} = -0.1$ A) | $t_s + t_f$ | 15 max | $\mu s$ |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 3.5 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 70 max | °C/W |

TYPICAL DC FORWARD CURRENT TRANSFER-RATIO CHARACTERISTICS




92SS-3732T

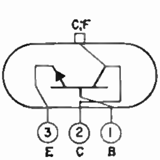
MAXIMUM OPERATING AREAS




92SS-3617T

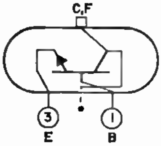
# 2N5296

**4A, 36W**




Si n-p-n type featuring a base comprised of a homogeneous-resistivity silicon material and molded silicone plastic package having horizontal leads for mounting on printed-circuit boards. It is used in a wide variety of medium-power switching and amplifier applications such as series and shunt regulators, and in driver and output stages of high-fidelity amplifiers. Outline No.53. See Mounting Hardware for desired mounting arrangement. This type is electrically identical to type 2N5295.

## 4A, 36W 2N5297




Si n-p-n type featuring a base comprised of a homogeneous-resistivity silicon material and molded silicone plastic package with vertical leads. This type fits a standard TO-66 socket. It is used in a wide variety of medium-power switching and amplifier applications such as series and shunt regulators, and in driver and output stages of high-fidelity amplifiers. Outline No.52. See Mounting Hardware for desired mounting arrangement.

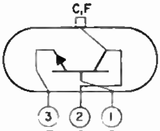
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 80 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE} = -1.5$ V | $V_{CEV}$(sus) | 80 | V |
| $R_{BE} = 100\ \Omega$ | $V_{CER}$(sus) | 70 | V |
| Base open | $V_{CEO}$(sus) | 60 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 4 | A |
| Base Current | $I_B$ | 2 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 36 | W |
| $T_A$ up to 25°C | $P_T$ | 1.8 | W |
| $T_C$ above 25°C | $P_T$ Derate linearly at | 0.228 | W/°C |
| $T_A$ above 25°C | $P_T$ Derate linearly at | 0.0144 | W/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 150 | °C |
| Storage | $T_{STG}$ | −65 to 150 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 235 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C = 0.1$ A, $I_B = 0$, $t_P = 300\ \mu s$, df = 0.018 | $V_{CEO}$(sus) | 60 min | V |
| $I_C = 0.1$ A, $t_P = 300\ \mu s$, df = 0.018 | $V_{CER}$(sus) | 70 min | V |
| $V_{BE} = -1.5$ V, $I_C = 0.1$ A, $t_P = 300\ \mu s$, df = 0.018 | $V_{CEV}$(sus) | 80 min | V |
| Base-to-Emitter Voltage ($V_{CE} = 4$ V, $I_C = 1.5$ A, $t_P = 300\ \mu s$, df = 0.018) | $V_{BE}$ | 1.5 max | V |
| Collector-to-Emitter Saturation Voltage ($I_C = 1.5$ A, $I_B = 0.15$ A, $t_P = 300\ \mu s$, df = 0.018) | $V_{CE}$(sat) | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE} = 65$ V, $V_{BE} = -1.5$ V | $I_{CEV}$ | 0.5 max | mA |
| $V_{CE} = 65$ V, $V_{BE} = -1.5$ V, $T_C = 150$°C | $I_{CEV}$ | 3 max | mA |
| $V_{CE} = 50$ V, $R_{BE} = 100\ \Omega$ | $I_{CER}$ | 0.5 max | mA |
| $V_{CE} = 50$ V, $R_{BE} = 100\ \Omega$, $T_C = 150$°C | $I_{CER}$ | 2 max | mA |
| Emitter-Cutoff Current ($V_{EB} = 5$ V) | $I_{EBO}$ | 1 max | mA |
| Pulsed-Cutoff Current Transfer Ratio ($V_{CE} = 4$ V, $I_C = 1.5$ A, $t_P = 300\ \mu s$, df = 0.018) | $h_{FE}$(pulsed) | 20 to 80 | |
| Gain-Bandwidth Product ($V_{CE} = 4$ V, $I_C = 0.2$ A) | $f_T$ | 0.8 min | MHz |
| Turn-On Time ($V_{CC} = 30$ V, $I_C = 1.5$ A, $I_{B1} = 0.15$ A) | $t_d + t_r$ | 5 max | $\mu s$ |
| Turn-Off Time ($V_{CC} = 30$ V, $I_C = 1.5$ A, $I_{B2} = -0.15$ A) | $t_s + t_f$ | 15 max | $\mu s$ |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 3.5 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 70 max | °C/W |

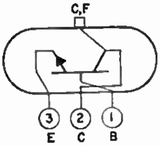
## 4A, 36W 2N5298




Si n-p-n type featuring a base comprised of a homogeneous-resistivity silicon material and molded silicone plastic package having horizontal leads for mounting on printed-circuit boards. It is used in a wide variety of medium-power switching and amplifier applications such as series and shunt regulators, and in driver and output stages of high-fidelity amplifiers. Outline No.53. See Mounting Hardware for desired mounting arrangement. This type is electrically identical to type 2N5297.

# 2N5490

**7A, 50W**




Si n-p-n type featuring a base comprised of a homogeneous-resistivity silicon material and molded silicone plastic package having horizontal leads for mounting on printed-circuit boards. It is used in a wide variety of medium-power switching and amplifier applications in military, industrial, and commercial equipment. Outline No.53. See Mounting Hardware for desired mounting arrangement.

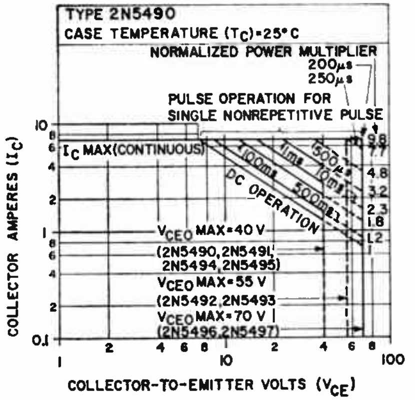
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 60 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE} = -1.5$ V | $V_{CEV}(sus)$ | 60 | V |
| $R_{BE} = 100\ \Omega$ | $V_{CER}(sus)$ | 50 | |
| Base open | $V_{CEO}(sus)$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 7 | A |
| Base Current | $I_B$ | 3 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 50 | W |
| $T_C$ above 25°C | $P_T$ Derate linearly at | 0.4 | W/°C |
| $T_A$ up to 25°C | $P_T$ | 1.8 | W |
| $T_A$ above 25°C | $P_T$ Derate linearly at | 0.0144 | W/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 150 | °C |
| Storage | $T_{STG}$ | −65 to 150 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 235 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

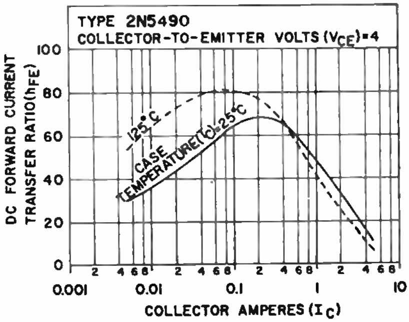
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C = 0.1$ A, $I_B = 0$, base open, $t_P = 300\ \mu s$, df = 0.018 | $V_{CEO}(sus)$ | 40 min | V |
| $I_C = 0.1$ A, $R_{BE} = 100\ \Omega$, $t_P = 300\ \mu s$, df = 0.018 | $V_{CER}(sus)$ | 50 min | V |
| $V_{BE} = -1.5$ V, $I_C = 0.1$ A, base-emitter junction reverse biased, $t_P = 300\ \mu s$, df = 0.018 | $V_{CEV}$ | 60 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C = 2$ A, $I_B = 0.2$ A, $t_P = 300\ \mu s$, df = 0.018) | $V_{CE}(sat)$ | 1 max | V |
| Base-to-Emitter Voltage ($V_{CE} = 4$ V, $I_C = 2$ A, $t_P = 300\ \mu s$, df = 0.018) | $V_{BE}$ | 1.1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE} = 40$ V, $R_{BE} = 100\ \Omega$ | $I_{CER}$ | 2 max | mA |
| $V_{CE} = 40$ V, $R_{BE} = 100\ \Omega$, $T_C = 150°C$ | $I_{CER}$ | 5 max | mA |
| Emitter-Cutoff Current ($V_{EB} = 5$ V) | $I_{EBO}$ | 1 max | mA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE} = 4$ V, $I_C = 2$ A, $t_P = 300\ \mu s$, df = 0.018) | $h_{FE}$(pulsed) | 20 to 100 | |
| Gain-Bandwidth Product ($V_{CE} = 4$ V, $I_C = 0.5$ A) | $f_T$ | 0.8 min | MHz |

MAXIMUM OPERATING AREAS




92CS-15379T

TYPICAL DC FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTICS

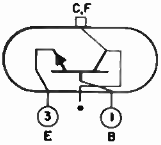



92CS-14981T

**CHARACTERISTICS (cont'd)**

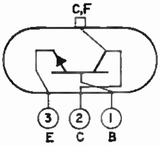
| | | | |
|---|---|---|---|
| Turn-On Time ($V_{CC}$ = 30 V, $I_C$ = 2 A, $I_B$ = 0.2 A) | $t_d + t_r$ | 5 max | μs |
| Turn-Off Time ($V_{CC}$ = 30 V, $I_C$ = 2 A, $I_B$ = 0.2 A) | $t_s + t_f$ | 15 max | μs |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 2.5 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 70 max | °C/W |

## 7A, 50W 2N5491




Si n-p-n type featuring a base comprised of a homogeneous-resistivity silicon material and molded silicone plastic package with vertical leads. This type fits a standard TO-66 socket. It is used in a wide variety of medium-power switching and amplifier applications in military, industrial, and commercial equipment. Outline No.52. See Mounting Hardware for desired mounting arrangement. This type is electrically identical to type 2N5490.

## 7A, 50W 2N5492




Si n-p-n type featuring a base comprised of a homogeneous-resistivity silicon material and molded silicone plastic package having horizontal leads for mounting on printed-circuit boards. It is used in a wide variety of medium-power switching and amplifier applications in military, industrial, and commercial equipment. Outline No.53. See Mounting Hardware for desired mounting arrangement. For maximum operating area curves, refer to type 2N5490.

**MAXIMUM RATINGS**

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 75 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$(sus) | 75 | V |
| $R_{BE}$ = 100 Ω | $V_{CER}$(sus) | 65 | V |
| Base open | $V_{CEO}$(sus) | 55 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 7 | A |
| Base Current | $I_B$ | 3 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 50 | W |
| $T_C$ above 25°C | $P_T$ | Derate linearly at 0.4 | W/°C |
| $T_A$ up to 25°C | $P_T$ | 1.8 | W |
| $T_A$ above 25°C | $P_T$ | Derate linearly at 0.0144 | W/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 150 | °C |
| Storage | $T_{STG}$ | −65 to 150 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 235 | °C |

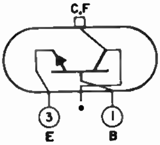
**CHARACTERISTICS (At case temperature = 25°C)**

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 0.1 A, $I_B$ = 0, base open, $t_p$ = 300 μs, df = 0.018 | $V_{CEO}$(sus) | 55 min | V |
| $I_C$ = 0.1 A, $R_{BE}$ = 100 Ω, $t_p$ = 300 μs, df = 0.018 | $V_{CER}$(sus) | 65 min | V |
| $V_{BE}$ = −1.5 V, $I_C$ = 0.1 A, base-emitter junction reverse biased, $t_p$ = 300 μs, df = 0.018 | $V_{CEV}$(sus) | 75 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 2.5 A, $I_B$ = 0.25 A, $t_p$ = 300 μs, df = 0.018) | $V_{CE}$(sat) | 1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 2.5 A, $t_p$ = 300 μs, df = 0.018) | $V_{BE}$ | 1.3 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 70 V, $V_{BE}$ = −1.5 V, base-emitter reverse biased | $I_{CEV}$ | 1 max | mA |
| $V_{CE}$ = 70 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C, base-emitter reverse biased | $I_{CEV}$ | 5 max | mA |
| $V_{CE}$ = 55 V, $R_{BE}$ = 100 Ω | $I_{CER}$ | 0.5 max | mA |
| $V_{CE}$ = 55 V, $R_{BE}$ = 100 Ω, $T_C$ = 150°C | $I_{CER}$ | 3.5 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V) | $I_{EBO}$ | 1 max | mA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 2.5 A, $t_p$ = 300 μs, df = 0.018) | $h_{FE}$(pulsed) | 20 to 100 | |
| Gain-Bandwidth Product ($V_{CE}$ = 4 V, $I_C$ = 0.5 A) | $f_T$ | 0.8 min | MHz |

**CHARACTERISTICS (cont'd)**

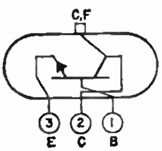
| | | | |
|---|---|---|---|
| Turn-On Time ($V_{CC}$ = 30 V, $I_C$ = 2.5 A, $I_{B1}$ = 0.25 A) | $t_d + t_r$ | 5 max | µs |
| Turn-Off Time ($V_{CC}$ = 30 V, $I_C$ = 2.5 A, $I_{B2}$ = 0.25 A) | $t_s + t_f$ | 15 max | µs |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 2.5 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 70 max | °C/W |

## 2N5493 7A, 50W




Si **n-p-n** type featuring a base comprised of a homogeneous-resistivity silicon material and molded silicone plastic package with vertical leads. This type fits a standard TO-66 socket. It is used in a wide variety of medium-power switching and amplifier applications in military, industrial, and commercial equipment. Outline No.52. See **Mounting Hardware** for desired mounting arrangement. This type is electrically identical to type 2N5492.

## 2N5494 7A, 50W

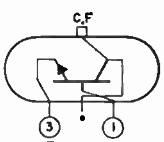



Si **n-p-n** type featuring a base comprised of a homogeneous-resistivity silicon material and molded silicone plastic package having horizontal leads for mounting on printed-circuit boards. It is used in a wide variety of medium-power switching and amplifier applications in military, industrial, and commercial equipment. Outline No.53. See **Mounting Hardware** for desired mounting arrangement. For maximum ratings and maximum operating area curves, refer to type 2N5490.

**CHARACTERISTICS (At case temperature = 25°C)**

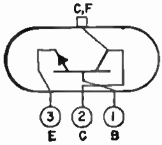
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 0.1 A, $I_B$ = 0, base open, $t_p$ = 300 µs, df = 0.018 | $V_{CEO}$(sus) | 40 min | V |
| $I_C$ = 0.1 A, $R_{BE}$ = 100 Ω, $t_p$ = 300 µs, df = 0.018 | $V_{CER}$(sus) | 50 min | V |
| $V_{BE}$ = −1.5 V, $I_C$ = 0.1 A, base-emitter junction reverse biased | $V_{CEV}$(sus) | 60 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 3 A, $I_B$ = 0.3 A, $t_p$ = 300 µs, df = 0.018) | $V_{CE}$(sat) | 1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 3A, $t_p$ = 300 µs, df = 0.018) | $V_{BE}$ | 1.5 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 55 V, $V_{BE}$ = −1.5 V | $I_{CEV}$ | 1 max | mA |
| $V_{CE}$ = 55 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C | $I_{CEV}$ | 5 max | mA |
| $V_{CE}$ = 40 V, $R_{BE}$ = 100 Ω | $I_{CER}$ | 0.5 max | mA |
| $V_{CE}$ = 40 V, $R_{BE}$ = 100 Ω, $T_C$ = 150°C | $I_{CER}$ | 3.5 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V) | $I_{EBO}$ | 1 max | mA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 3 A, $t_p$ = 300 µs, df = 0.018) | $h_{FE}$(pulsed) | 20 to 100 | |
| Gain-Bandwidth Product ($V_{CE}$ = 4 V, $I_C$ = 0.5 A) | $f_T$ | 0.8 min | MHz |
| Turn-On Time ($V_{CC}$ = 30 V, $I_C$ = 3 A, $I_{B1}$ = 0.3 A) | $t_d + t_r$ | 5 max | µs |
| Turn-Off Time ($V_{CC}$ = 30 V, $I_C$ = 3 A, $I_{B2}$ = 0.3 A) | $t_s + t_f$ | 15 max | µs |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 2.5 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 70 max | °C/W |

## 2N5495 7A, 50W




Si **n-p-n** type featuring a base comprised of a homogeneous-resistivity silicon material and molded silicone plastic package with vertical leads. This type fits a standard TO-66 socket. It is used in a wide variety of medium-power switching and amplifier applications in military, industrial, and commercial equipment. Outline No.52. See **Mounting Hardware** for desired mounting arrangement. This type is electrically identical to type 2N5494.

## 7A, 50W 2N5496




Si n-p-n type featuring a base comprised of a homogeneous-resistivity silicon material and molded silicone plastic package having horizontal leads for mounting on printed-circuit boards. It is used in a wide variety of medium-power switching and amplifier applications in military, industrial, and commercial equipment. Outline No.53. See Mounting Hardware for desired mounting arrangement. For maximum operating area curves, refer to type 2N5490.

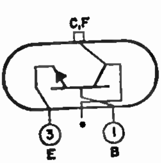
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 90 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$(sus) | 90 | V |
| $R_{BE}$ = 100 Ω | $V_{CER}$(sus) | 80 | V |
| Base open | $V_{CEO}$(sus) | 70 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Colector Current | $I_C$ | 7 | A |
| Base Current | $I_B$ | 3 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 50 | W |
| $T_C$ above 25°C | $P_T$ Derate linearly at | 0.4 | W/°C |
| $T_A$ up to 25°C | $P_T$ | 1.8 | W |
| $T_A$ above 25°C | $P_T$ Derate linearly at | 0.0144 | W/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 150 | °C |
| Storage | $T_{STG}$ | −65 to 150 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 235 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

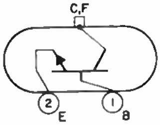
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 0.1 A, $I_B$ = 0, base open, $t_P$ = 300 μs, df = 0.018 | $V_{CEO}$(sus) | 70 min | V |
| $I_C$ = 0.1 A, $R_{BE}$ = 100 Ω, $t_P$ = 300 μs, df = 0.018 | $V_{CER}$(sus) | 80 min | V |
| $V_{BE}$ = −1.5 V, $I_C$ = 0.1 A, base-emitter junction reverse biased | $V_{CEV}$(sus) | 90 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 3.5 A, $I_B$ = 0.35 A, $t_P$ = 300 μs, df = 0.018) | $V_{CE}$(sat) | 1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 3.5 A, $t_P$ = 300 μs, df = 0.018) | $V_{BE}$ | 1.7 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 85 V, $V_{BE}$ = −1.5 V | $I_{CEV}$ | 1 max | mA |
| $V_{CE}$ = 85 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C | $I_{CEV}$ | 5 max | mA |
| $V_{CE}$ = 70 V, $R_{BE}$ = 100 Ω | $I_{CER}$ | 0.5 max | mA |
| $V_{CE}$ = 70 V, $R_{BE}$ = 100 Ω, $T_C$ = 150°C | $I_{CER}$ | 3.5 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V) | $I_{EBO}$ | 1 max | mA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 3.5 A, $t_P$ = 300 μs, df = 0.018) | $h_{FE}$(pulsed) | 20 to 100 | |
| Gain-Bandwidth Product ($V_{CE}$ = 4 V, $I_C$ = 0.5 A) | $f_T$ | 0.8 min | MHz |
| Turn-On Time ($V_{CC}$ = 30 V, $I_C$ = 3.5 A, $I_{B1}$ = 0.35 A) | $t_d + t_r$ | 5 max | μs |
| Turn-Off Time ($V_{CC}$ = 30 V, $I_C$ = 3.5 A, $I_{B2}$ = 0.35 A) | $t_s + t_f$ | 15 max | μs |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 2.5 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 70 max | °C/W |

## 7A, 50W 2N5497




Si n-p-n type featuring a base comprised of a homogeneous-resistivity silicon material and molded silicone plastic package with vertical leads. This type fits a standard TO-66 socket. It is used in a wide variety of medium-power switching and amplifier applications in military, industrial, and commercial equipment. Outline No.52. See Mounting Hardware for desired mounting arrangement. This type is electrically identical to type 2N5496.

# 2N4347 15A, 117W



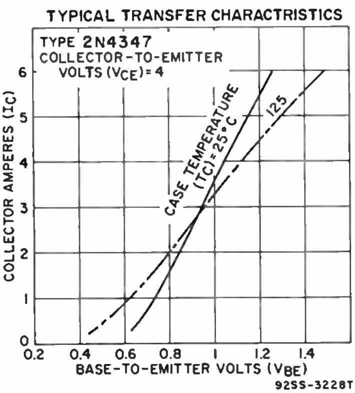

Si n-p-n type featuring a base comprised of a homogeneous-resistivity silicon material. This type is used in high-voltage applications in power-switching circuits, audio amplifiers, series and shunt regulators, drivers, and output stages, dc-to-dc converters, inverters, and solenoid (hammer)/relay driver service in military, industrial, and commercial equipment. JEDEC TO-3, Outline No.2. See Mounting Hardware for desired mounting arrangement.

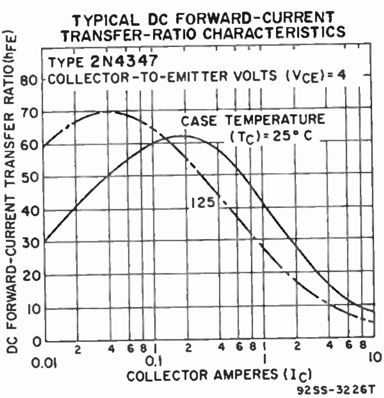
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 140 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 140 | V |
| Base open | $V_{CEO}$ | 120 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 5 | A |
| Peak Collector Current | $i_C$ | 10 | A |
| Base Current | $I_B$ | 3 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 100 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 255 | °C |

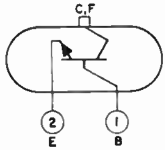
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 0.2 A to 3 A, $I_B$ = 0 | $V_{CEO}$(sus) | 120 min | V |
| $V_{BE}$ = −1.5 V, $I_C$ = 0.1 A to 1.5 A | $V_{CEV}$(sus) | 140 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 2 A, $I_B$ = 0.2 A) | $V_{CE}$(sat) | 1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 2 A) | $V_{BE}$ | 2 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 120 V, $V_{BE}$ = −1.5 V | $I_{CEV}$ | 2 max | mA |
| $V_{CE}$ = 120 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C | $I_{CEV}$ | 10 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 7 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 2 A) | $h_{FE}$ | 20 to 70 | |
| Power Rating Test ($V_{CE}$ = 67 V, $I_C$ = 1.5 A, t = 1 s) | | 100 | W |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 1.75 max | °C/W |



## 12A, 100W 2N5034



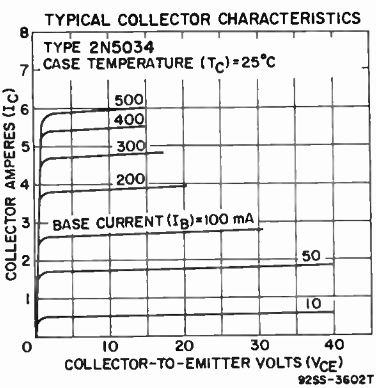

Si n-p-n type featuring a base comprised of a homogeneous-resistivity silicon material and molded silicone plastic pacgage with vertical leads. This type fits a standard TO-3 socket. It is used in a wide variety of high-power switching and amplifier applications such as series and shunt regulators, drivers, and output stages for high-fidelity amplifiers. Outline No.50. See Mounting Hardware for desired mounting arrangement.

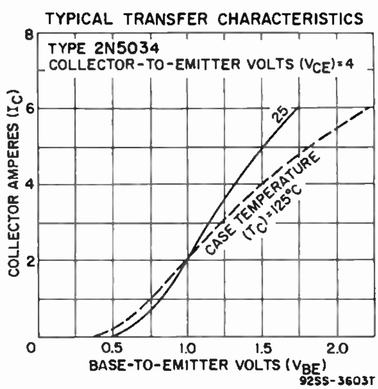
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 55 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$(sus) | 55 | V |
| $R_{BE}$ = 100 Ω | $V_{CER}$(sus) | 45 | V |
| Base open | $V_{CEO}$(sus) | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 6 | A |
| Peak Collector Current | $i_C$ | 12 | A |
| Base Current | $I_B$ | 6 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 83 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 150 | °C |
| Storage | $T_{STG}$ | −65 to 150 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 235 | °C |

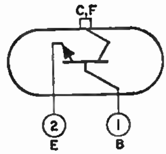
### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Emitter-to-Base Breakdown Voltage ($I_E$ = 5 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 5 min | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 0.2 A, $I_B$ = 0, $t_p$ = 300 μs, df = 1.8% | $V_{CEO}$(sus) | 40 min | V |
| $V_{BE}$ = −1.5 V, $I_C$ = 0.1 A, $t_p$ = 300 μs, df = 1.8% | $V_{CEV}$(sus) | 55 min | V |
| $R_{BE}$ = 100 Ω, $I_C$ = 0.2 A, $t_p$ = 300 μs, df = 1.8% | $V_{CER}$(sus) | 45 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 2.5 A, $t_p$ = 300 μs, df = 1.8%) | $V_{BE}$ | 1.7 max | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 2.5 A, $I_B$ = 0.25 A, $t_p$ = 300 μs, df = 1.8%) | $V_{CE}$(sat) | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 35 V, $R_{BE}$ = 100 Ω | $I_{CER}$ | 1 max | mA |
| $V_{CE}$ = 35 V, $R_{BE}$ = 100 Ω, $T_C$ = 150°C | $I_{CER}$ | 5 max | mA |
| $V_{CE}$ = 50 V, $V_{BE}$ = −1.5 V | $I_{CEV}$ | 1 max | mA |
| $V_{CE}$ = 50 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C | $I_{CEV}$ | 5 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | mA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 2.5 A, $t_p$ = 300 μs, df = 1.8%) | $h_{FE}$(pulsed) | 20 to 70 | |
| Gain-Bandwidth Product ($V_{CE}$ = 4 V, $I_C$ = 0.5 A) | $f_T$ | 0.8 to 2.8 | MHz |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 1.5 max | °C/W |



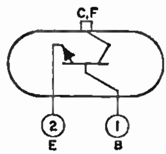



# 2N5035 12A, 100W




Si **n-p-n** type featuring a base comprised of a homogeneous-resistivity silicon material and molded silicone plastic package having horizontal leads for mounting on printed-circuit boards. It is used in a wide variety of high-power switching and amplifier applications such as series and shunt regulators, drivers, and output stages for high-fidelity amplifiers. Outline No.51. See Mounting Hardware for desired mounting arrangement. This type is electrically identical to type 2N5034.

# 2N5036 12A, 100W



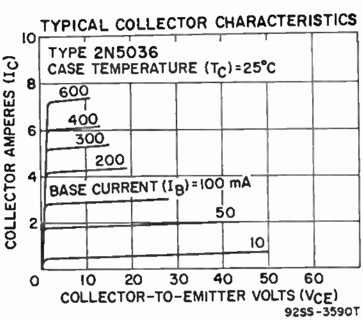

Si **n-p-n** type featuring a base comprised of a homogeneous-resistivity silicon material and molded silicone plastic package with vertical leads. This type fits a standard TO-3 socket. It is used in a wide variety of high-power switching and amplifier applications such as series and shunt regulators, drivers, and output stages for high-fidelity amplifiers. Outline No.50. See Mounting Hardware for desired mounting arrangement.

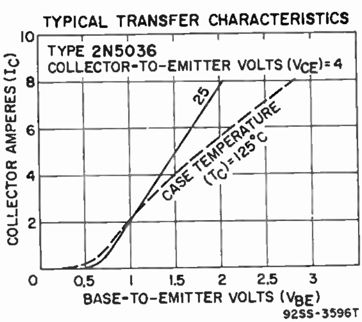
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 70 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE} = -1.5$ V | $V_{CEV}$(sus) | 70 | V |
| $R_{BE} = 100\ \Omega$ | $V_{CER}$(sus) | 60 | V |
| Base open | $V_{CEO}$(sus) | 50 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 8 | A |
| Peak Collector Current | $i_C$ | 12 | A |
| Base Current | $I_B$ | 6 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 83 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 150 | °C |
| Storage | $T_{STG}$ | −65 to 150 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 235 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Emitter-to-Base Breakdown Voltage ($I_E = 5$ mA, $I_C = 0$) | $V_{(BR)EBO}$ | 5 min | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C = 0.2$ A, $I_B = 0$, $t_p = 300\ \mu$s, df = 1.8% | $V_{CEO}$(sus) | 50 min | V |
| $V_{BE} = -1.5$ V, $I_C = 0.1$ A, $t_p = 300\ \mu$s, df = 1.8% | $V_{CEV}$(sus) | 70 min | V |
| $R_{BE} = 100\ \Omega$, $I_C = 0.2$ A, $t_p = 300\ \mu$s, df = 1.8% | $V_{CER}$(sus) | 60 min | V |
| Base-to-Emitter Voltage ($V_{CE} = 4$ V, $I_C = 3$ A, $t_p = 300\ \mu$s, df = 1.8%) | $V_{BE}$ | 1.7 max | V |

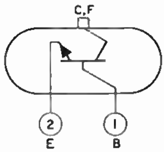


## CHARACTERISTICS (cont'd)

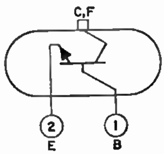
| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage ($I_C$ = 3 A, $t_p$ = 300 $\mu$s, df = 1.8%, $I_B$ = 0.3 A) | $V_{CE}$(sat) | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 50 V, $R_{BE}$ = 100 Ω | $I_{CER}$ | 1 max | mA |
| $V_{CE}$ = 50 V, $R_{BE}$ = 100 Ω, $T_C$ = 150°C | $I_{CER}$ | 5 max | mA |
| $V_{CE}$ = 65 V, $V_{BE}$ = −1.5 V | $I_{CEV}$ | 1 max | mA |
| $V_{CE}$ = 65 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C | $I_{CEV}$ | 5 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | mA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 3 A, $t_p$ = 300 $\mu$s, df = 1.8%) | $h_{FE}$(pulsed) | 20 to 70 | |
| Gain-Bandwidth Product ($V_{CE}$ = 4 V, $I_C$ = 0.5 A) | $f_T$ | 0.8 to 2.8 | MHz |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 1.5 max | °C/W |

## 12A, 100W 2N5037



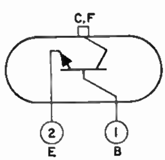

Si n-p-n type featuring a base comprised of a homogeneous-resistivity silicon material and molded silicone plastic package having horizontal leads for mounting on printed-circuit boards. It is used in a wide variety of high-power switching and amplifier applications such as series and shunt regulators, drivers, and output stages for high-fidelity amplifiers. Outline No.51. See Mounting Hardware for desired mounting arrangement. This type is electrically identical to type 2N5036.

## 12A, 100W 40513




Si n-p-n type featuring a base comprised of a homogeneous-resistivity silicon material and molded silicone plastic package having horizontal leads for mounting on printed-circuit boards. It is used in a wide variety of high-power switching and amplifier applications such as series and shunt regulators, drivers, and output stages for high-fidelity amplifiers. Outline No.51. See Mounting Hardware for desired mounting arrangement. This type is electrically identical with type 40514.

## 12A, 100W 40514




Si n-p-n type featuring a base comprised of a homogeneous-resistivity silicon material and molded silicone plastic package with vertical leads. This type fits a standard TO-3 socket. It is used in a wide variety of high-power switching and amplifier applications such as series and shunt regulators, drivers, and output stages for high-fidelity amplifiers. Outline No.50. See Mounting Hardware for desired mounting arrangement. For collector-characteristics and transfer-characteristics curves, refer to type 2N5034.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 100 Ω) | $V_{CER}$(sus) | 45 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 6 | A |
| Peak Collector Current | $i_C$ | 12 | A |
| Base Current | $I_B$ | 6 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 83 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |

## MAXIMUM RATINGS (cont'd)

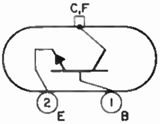
| | | | |
|---|---|---|---|
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 150 | °C |
| Storage | $T_{STG}$ | −65 to 150 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 235 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Emitter-to-Base Breakdown Voltage ($I_E$ = 5 mA) | $V_{(BR)EBO}$ | 5 min | V |
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 100 Ω, $I_C$ = 0.2 A, tp = 300 μs, df = 1.8%) | $V_{CER}$(sus) | 45 min | V |
| Base-to-Emitter Voltage ($V_{BE}$ = 4 V, $I_C$ = 2.5 A, tp = 300 μs, df = 1.8%) | $V_{BE}$ | 1.7 max | V |
| Collector-to-Emitter-to-Saturation Voltage ($I_C$ = 2.5 A, $t_p$ = 300 μs, df = 1.8%, $I_B$ = 0.25 A) | $V_{CE}$(sat) | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 20 V, $R_{BE}$ = 100 Ω | $I_{CER}$ | 2.5 max | mA |
| $V_{CE}$ = 20 V, $R_{BE}$ = 100 Ω, $T_C$ = 150°C | $I_{CER}$ | 5 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | mA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 2.5 A, tp = 300 μs, df = 1.8%) | $h_{FE}$(pulsed) | 20 to 70 | |
| Gain-Bandwidth Product ($V_{CE}$ = 4 V, $I_C$ = 0.5 A) | $f_T$ | 0.8 to 2.8 | MHz |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 1.5 max | °C/W |

# 2N3055 15A, 117W

Si **n-p-n diffused-junction** type used in power-switching circuits, series- and shunt-regulator driver and output stages, and high-fidelity amplifiers in commercial and industrial equipment. JEDEC TO-3, **Outline No.2.** See **Mounting Hardware** for desired mounting arrangement.



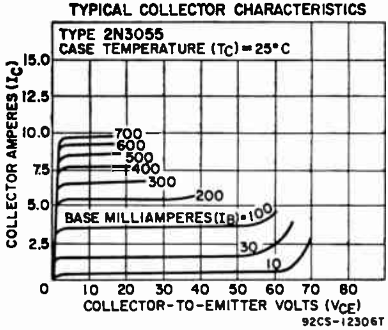

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 100 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $R_{BE}$ = 100 Ω | $V_{CER}$(sus) | 70 | V |
| Base open | $V_{CEO}$(sus) | 60 | V |
| $V_{BE}$ = −1.5 V | $V_{CEV}$(sus) | 90 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 15 | A |
| Base Current | $I_B$ | 7 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 115 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 235 | °C |

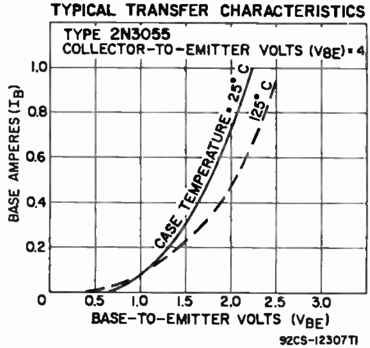
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 0.2 A, $t_p$ = 300 μs, df = 1.8% | $V_{CEO}$(sus) | 60 min | V |
| $I_C$ = 0.2 A, $t_p$ = 300 μs, df = 1.8%, $R_{BE}$ = 100 Ω | $V_{CER}$(sus) | 70 min | V |
| $I_C$ = 0.1 A, $V_{BE}$ = −1.5 V, $t_p$ = 300 μs, df = 1.8% | $V_{CEV}$(sus) | 90 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 4 A, $t_p$ = 300 μs, df = 1.8%) | $V_{BE}$ | 1.8 | V |
| Collector-to-Emitter Saturation Voltage: | | | |
| $I_C$ = 4 A, $I_B$ = 0.4 A | $V_{CE}$(sat) | 1.1 max | V |
| $I_C$ = 10 A, $I_B$ = 3.3 A | $V_{CE}$(sat) | 8 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 30 V, $I_B$ = 0 | $I_{CEO}$ | 0.7 max | mA |
| $V_{CE}$ = 100 V, $V_{BE}$ = −1.5 V | $I_{CEX}$ | 5 max | mA |
| $V_{CE}$ = 100 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C | $I_{CEX}$ | 30 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 7 V) | $I_{EBO}$ | 5 max | mA |
| Pulsed Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 4 V, $I_C$ = 10 A, $t_p$ = 300 μs, df = 1.8% | $h_{FE}$ | 5 min | |
| $V_{CE}$ = 4 V, $I_C$ = 4 A, $t_p$ = 300 μs, df = 1.8% | $h_{FE}$ | 20 to 70 | |
| Small-Signal Forward-Current Ratio ($V_{CE}$ = 4 V, $I_C$ = 1 A) | $h_{fe}$ | 15 to 120 | |
| Gain-Bandwidth Product ($I_C$ = 1 A) | $f_T$ | 800 min | kHz |
| Small-Signal Forward-Current Transfer Ratio Cutoff Frequency ($V_{CE}$ = 4 V, $I_C$ = 1 A) | $f_{hfe}$ | 10 min | kHz |
| Second-Breakdown Collector Current ($V_{CE}$ = 60 V, $I_C$ = 1.95 A) | $I_{S/b}$ | 1 min | s |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 1.5 max | °C/W |

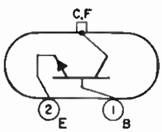
TYPICAL COLLECTOR CHARACTERISTICS




TYPICAL TRANSFER CHARACTERISTICS




## 15A, 117W 2N3442




Si n-p-n diffused type for high-voltage applications in power-switching circuits, series- and shunt-regulator driver and output stages, and in dc-to-dc converters in military, industrial, and commercial equipment. This type features a base comprised of a homogeneous-resistivity silicon material. JEDEC TO-3, Outline No.2. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N3441 except for the following items:

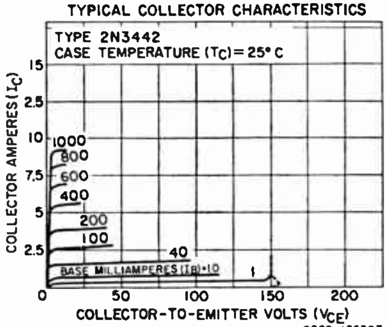
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector Current | $I_C$ | 10 | A |
| Base Current | $I_B$ | 7 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 117 | W |
| $T_C$ up to 25°C | $P_T$ | See curve page 300 | |

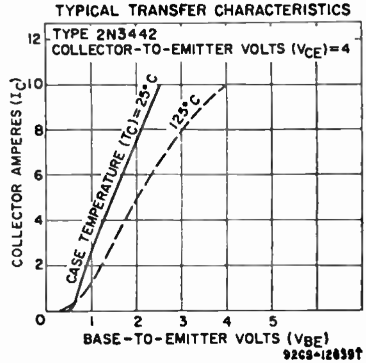
### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 0.2 to 3 A, $I_B$ = 0 | $V_{CEO}$(sus) | 140 min | V |
| $I_C$ = 0.1 to 1.5 A, $V_{BE}$ = −1.5 V | $V_{CEV}$(sus) | 160 min | V |
| Collector-to-Emitter Saturation Voltage | | | |
| ($I_C$ = 3 A, $I_B$ = 300 mA) | $V_{CE}$(sat) | 1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 3 A) | $V_{BE}$ | 1.7 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 140 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C | $I_{CEV}$ | 10 max | mA |
| $V_{CB}$ = 140 V, $I_E$ = 0 | $I_{CEV}$ | 1 | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 7 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | mA |
| Static Forward-Current Transfer Ratio | | | |
| ($V_{CE}$ = 4 V, $I_C$ = 3 A) | $h_{FE}$ | 20 to 70 | |
| Power Rating Test | | | |
| ($V_{CE}$ = 78 V, $I_C$ = 1.5 A, t = 1 s) | | 117 | W |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 1.5 max | °C/W |

TYPICAL COLLECTOR CHARACTERISTICS



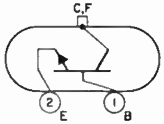

TYPICAL TRANSFER CHARACTERISTICS



# 40251

**15A, 117W**

Si n-p-n diffused-junction type used in audio and inverter circuits in 12-volt mobile radio and portable communications equipment and in a wide variety of intermediate- and high-power applications. JEDEC TO-3, Outline No.2. See Mounting Hardware for desired mounting arrangement.

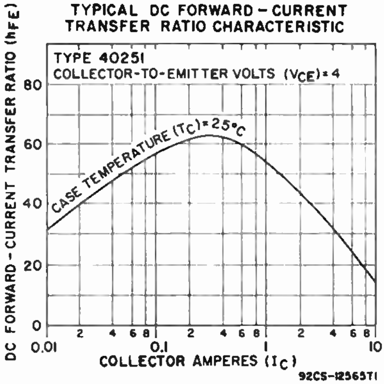


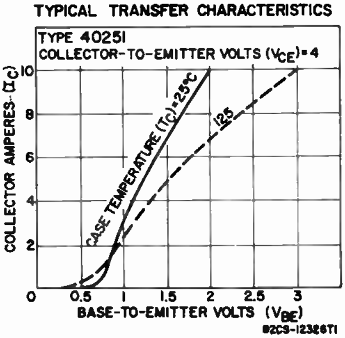

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 50 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 50 | V |
| Base open | $V_{CEO}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 15 | A |
| Base Current | $I_B$ | 7 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 117 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 235 | °C |

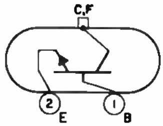
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 A, $I_E$ = 0) | $V_{(BR)CBO}$ | 50 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 0.1 A, $V_{BE}$ = −1.5 V) | $V_{(BR)CEV}$ | 50 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.01 A, $I_C$ = 0) | $V_{(BR)EBO}$ | 5 min | V |
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 0.2 A) | $V_{CEO}$(sus) | 40 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 8 A, $I_B$ = 0.8 A) | $V_{CE}$(sat) | 1.5 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 8 A) | $V_{BE}$ | 2.2 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 40 V, $V_{BE}$ = −1.5 V, $T_C$ = 25°C | $I_{CEV}$ | 2 max | mA |
| $V_{CE}$ = 40 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C | $I_{CEV}$ | 10 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 10 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 8 A) | $h_{FE}$ | 15 to 60 | |
| Power Rating Test ($V_{CE}$ = 39 V, $I_C$ = 3 mA) | | 1 | s |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 1.5 max | °C/W |



## 30A, 150W 2N4348



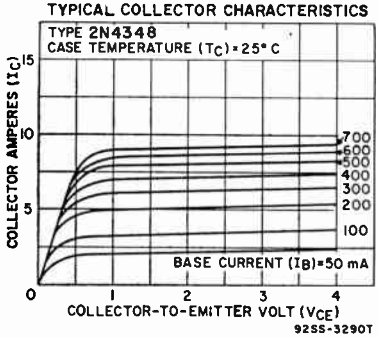

Si n-p-n type featuring a base comprised of a homogeneous-resistivity silicon material. This type is used in high-voltage applications in power-switching circuits, audio amplifiers, series and shunt regulators, drivers, and output stages, dc-to-dc converters, inverters, and solenoid (hammer)/relay driver service in military, industrial, and commercial equipment. JEDEC TO-3, Outline No.2. See Mounting Hardware for desired mounting arrangement.

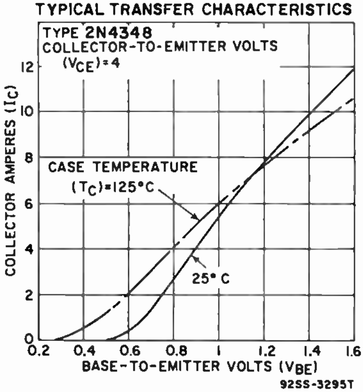
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 140 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 140 | V |
| Base open | $V_{CEO}$ | 120 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 10 | A |
| Peak Collector Current | $i_C$ | 30 | A |
| Base Current | $I_B$ | 4 | A |
| Peak Base Current | $i_B$ | 15 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 120 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 230 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

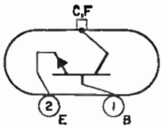
| | | | |
|---|---|---|---|
| Emitter-to-Base Breakdown Voltage ($I_E$ = 5 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 7 min | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE}$ = −1.5 V, $I_C$ = 0.1 A to 1.5 A | $V_{CEX}$(sus) | 140 min | V |
| $I_C$ = 0.2 A to 3 A, $I_B$ = 0 | $V_{CEO}$(sus) | 120 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 5 A, $I_B$ = 0.5 A) | $V_{CE}$(sat) | 1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 5 A) | $V_{BE}$ | 2 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 120 V, $V_{BE}$ = −1.5 V | $I_{CEV}$ | 2 max | mA |
| $V_{CE}$ = 120 V, $I_B$ = 0, $T_C$ = 150°C | $I_{CEV}$ | 10 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 7 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | mA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 5 A, $t_p$ = 300 μs, f = 60 Hz) | $h_{FE}$(pulsed) | 15 to 60 | |
| Power Rating Test ($V_{CE}$ = 80 V, $I_C$ = 1.5 A, t = 1 s) | | 120 | W |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 1.46 max | °C/W |



# 2N3771 30A, 150W

Si **n-p-n** type with high collector-current rating (30 A max) for intermediate- and high-power applications such as public-address amplifiers, power supplies, and low-speed switching regulators and inverters. This type features a base comprised of a homogeneous-resistivity silicon material. JEDEC TO-3, Outline No.2. See Mounting Hardware for desired mounting arrangement.



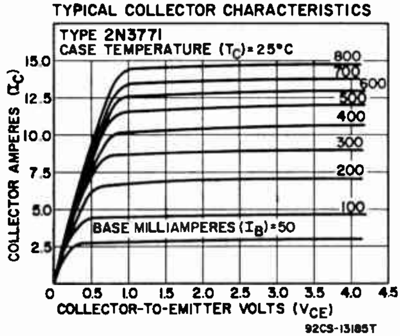

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 50 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE} = -1.5$ V, $R_{BE} = 100\ \Omega$ | $V_{CEV}$ | 50 | V |
| Base open | $V_{CEO}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 30 | A |
| Peak Collector Current | $i_C$ | 30 | V |
| Base Current | $I_B$ | 7.5 | V |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 150 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 230 | °C |

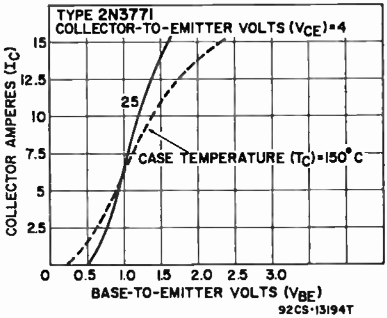
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $R_{BE} = 100\ \Omega$, $I_C = 0.2$ A | $V_{CER}$(sus) | 45 | V |
| $V_{EB} = -1.5$ V, $I_C = 0.2$ A | $V_{CEV}$(sus) | 50 | V |
| $V_{BE} = -1.5$ V, $I_C = 0.3$ A, $R_{BE} = 100\ \Omega$ | $V_{CEV}$(sus) | 50 min | V |
| $I_C = 0.2$ A, $I_B = 0$ | $V_{CEO}$(sus) | 40 min | V |
| Collector-to-Emitter Saturation Voltage ($I_B = 1.5$ A, $I_C = 15$ A, $t_p = 300\ \mu s$, $f = 60$ Hz) | $V_{CE}$(sat) | 2 max | V |
| Base-to-Emitter Voltage ($V_{CE} = 4$ V, $I_C = 15$ A, $t_P = 300\ \mu s$, $f = 60$ Hz) | $V_{BE}$ | 2.7 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB} = 50$ V, $I_E = 0$, $T_C = 25$°C | $I_{CBO}$ | 2 max | mA |
| $V_{CB} = 30$ V, $I_E = 0$, $T_C = 150$°C | $I_{CBO}$ | 10 max | mA |
| $V_{CE} = 50$ V, $V_{BE} = -1.5$ V, $T_C = 25$°C | $I_{CEV}$ | 2 max | mA |
| $V_{CE} = 30$ V, $V_{BE} = -1.5$ V, $T_C = 150$°C | $I_{CEV}$ | 10 max | mA |
| $V_{CE} = 30$ V, $I_B = 0$, $T_C = 25$°C | $I_{CEO}$ | 10 max | mA |
| Emitter-Cutoff Current ($V_{EB} = 5$ V, $I_C = 0$) | $I_{EBO}$ | 5 max | mA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE} = 4$ V, $I_C = 15$ A, $t_p = 300\ \mu s$, $f = 60$ Hz) | $h_{FE}$(pulsed) | 15 to 60 | |
| Gain-Bandwidth Product ($V_{CE} = 4$ V, $I_C = 1$ A) | $f_T$ | 800 | kHz |
| Power Rating Test ($V_{CE} = 33.5$ V, $I_C = 4.5$ A, $t = 1$ s) | | 150 | W |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 1.17 max | °C/W |

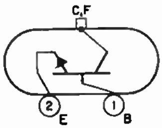
TYPICAL COLLECTOR CHARACTERISTICS




TYPICAL TRANSFER CHARACTERISTICS



## 30A, 150W 2N3772




Si n-p-n type with high collector-current rating (30 A max) for intermediate- and high-power applications such as public-address amplifiers, power supplies, and low-speed switching regulators and inverters. This type features a base comprised of a homogeneous-resistivity silicon material. JEDEC TO-3, Outline No.2. See Mounting Hardware for desired mounting arrangement.

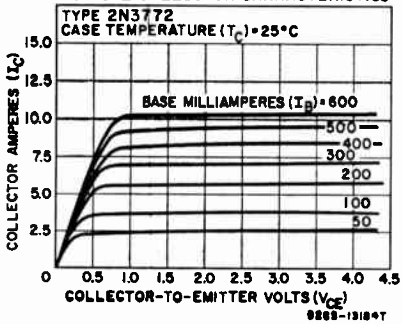
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 100 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 90 | V |
| Base open | $V_{CEO}$ | 60 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 20 | A |
| Peak Collector Current | $i_C$ | 30 | A |
| Base Current | $I_B$ | 5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 150 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 230 | °C |

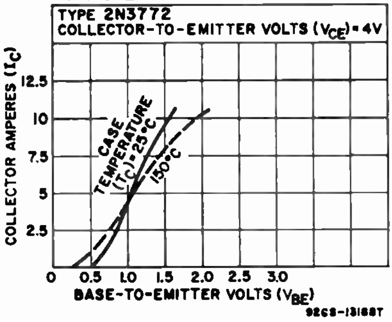
### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE}$ = −1.5 V, $I_C$ = 0.3 A, $R_{BE}$ = 100 Ω | $V_{CEV}$(sus) | 90 min | V |
| $V_{EB}$ = −1.5 V, $I_C$ = 0.2 A | $V_{CEV}$(sus) | 80 | V |
| $R_{BE}$ = 100 Ω, $I_C$ = 0.2 A | $V_{CER}$(sus) | 45 | V |
| $I_C$ = 0.2 A, $I_B$ = 0 | $V_{CEO}$(sus) | 60 min | V |
| Collector-to-Emitter Saturation Voltage ($I_B$ = 1 A, $I_C$ = 10 A, $t_p$ = 300 μs, f = 60 Hz) | $V_{CE}$(sat) | 1.4 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 10 A, $t_p$ = 300 μs, f = 60 Hz) | $V_{BE}$ | 2.2 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 100 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 5 max | mA |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 10 max | mA |
| $V_{CE}$ = 100 V, $V_{BE}$ = −1.5 V, $T_C$ = 25°C | $I_{CEV}$ | 5 max | mA |
| $V_{CE}$ = 30 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C | $I_{CEV}$ | 10 max | mA |
| $V_{CE}$ = 50 V, $I_B$ = 0, $T_C$ = 25°C | $I_{CEO}$ | 10 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 7 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | mA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 10 A, $t_p$ = 300 μs, f = 60 Hz) | $h_{FE}$(pulsed) | 15 to 60 | |
| Gain-Bandwidth Product ($V_{CE}$ = 4 V, $I_C$ = 1 A) | $f_T$ | 800 | kHz |
| Power Rating Test ($V_{CE}$ = 33.5 V, $I_C$ = 4.5 A, t = 1 s) | | 150 | W |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 1.17 max | °C/W |

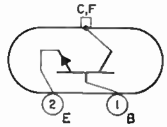
TYPICAL COLLECTOR CHARACTERISTICS




TYPICAL TRANSFER CHARACTERISTICS



# 2N3773 30A, 150W




Si **n-p-n** type with high collector-current rating (30 A max) for intermediate- and high-power applications such as public-address amplifiers, power supplies, and low-speed switching regulators and inverters. This type features a base comprised of a homogeneous-resistivity silicon material. JEDEC TO-3, Outline No.2. See Mounting Hardware for desired mounting arrangement.

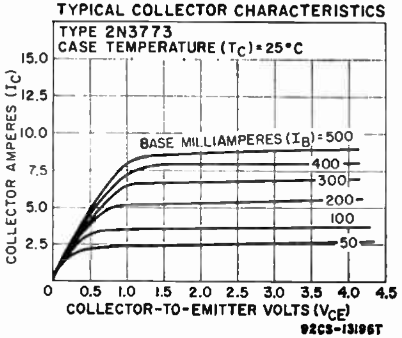
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 160 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE} = -1.5$ V | $V_{CEV}$ | 160 | V |
| Base open | $V_{CEO}$ | 140 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 16 | A |
| Peak Collector Current | $i_C$ | 30 | A |
| Base Current | $I_B$ | 4 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 150 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 230 | °C |

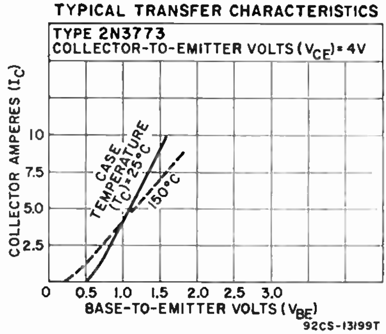
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Emitter-to-Base Breakdown Voltage ($I_E$ = 5 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 7 max | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE} = -1.5$ V, $I_C$ = 0.1 to 1.5 A | $V_{CEV}$(sus) | 160 min | V |
| $I_C$ = 0.2 to 3 A, $I_B$ = 0 | $V_{CEO}$(sus) | 140 min | V |
| Collector-to-Emitter Saturation Voltage ($I_B$ = 0.8 A, $I_C$ = 8 A, $t_p$ = 300 $\mu$s, f = 60 Hz) | $V_{CE}$(sat) | 1.4 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 8 A, $t_p$ = 300 $\mu$s, f = 60 Hz) | $V_{BE}$ | 2.2 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 140 V, $V_{BE} = -1.5$ V, $T_C$ = 25°C | $I_{CEV}$ | 2 max | mA |
| $V_{CE}$ = 140 V, $I_B$ = 0, $T_C$ = 150°C | $I_{CEV}$ | 10 max | mA |
| $V_{CE}$ = 120 V, $I_B$ = 0, $T_C$ = 25°C | $I_{CEO}$ | 2 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 7 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | mA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 8 A, $t_p$ = 300 $\mu$s, f = 60 Hz) | $h_{FE}$(pulsed) | 15 to 60 | |
| Power Rating Test ($V_{CE}$ = 100 V, $I_C$ = 1.5 A, t = 1 s) | | 150 | W |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 1.17 max | °C/W |

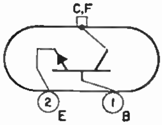
TYPICAL COLLECTOR CHARACTERISTICS




TYPICAL TRANSFER CHARACTERISTICS



## 100A, 300W 2N5578




Si n-p-n type features a base comprised of a homogeneous-resistivity silicon material. It is used in high-power linear and switching applications in military, industrial, and commercial equipment. Outline No.55. For maximum operating area curves, refer to type 2N5575.

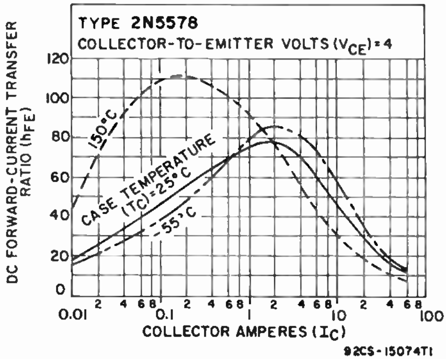
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 90 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $R_{BE}$ = 10 Ω, $V_{BE}$ = −1.5 V | $V_{CEX}$(sus) | 90 | V |
| Base open | $V_{CEO}$(sus) | 70 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 8 | V |
| Collector Current | $I_C$ | 60 | A |
| Peak Collector Current | $i_C$ | 80 | A |
| Base Current | $I_B$ | 15 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C, $V_{CE}$ up to 25 V | $P_T$ | 300 | W |
| $T_C$ up to 25°C, $V_{CE}$ above 25 V | $P_T$ | See curve page 300 | |
| $T_C$ above 25°C, $V_{CE}$ above 25 V | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 230 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 0.2 A | $V_{CEO}$(sus) | 70 min | V |
| $V_{BE}$ = −1.5 V, $I_C$ = 0.2 A, $R_{BE}$ = 10 Ω, base-emitter junction reverse biased | $V_{CEX}$(sus) | 90 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$= 40 A, $I_B$ = 4 V, $t_P$ ≤ 350 μs, df = 0.02) | $V_{CE}$(sat) | 1.5 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 40 A, $I_B$ = 4 V, $t_P$ ≤ 350 μs, df = 0.02) | $V_{BE}$(sat) | 2.5 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 40 V, $t_P$ ≤ 350 μs, df = 0.02) | $V_{BE}$ | 2.5 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 80 V, $V_{BE}$ = −1.5 V, base-emitter junction reverse biased | $I_{CEV}$ | 10 max | mA |
| $V_{CE}$ = 70 V, $R_{BE}$ = 10 Ω | $I_{CER}$ | 5 max | mA |
| $V_{CE}$ = 80 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C, base-emitter junction reverse biased | $I_{CEV}$ | 20 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 8 V) | $I_{EBO}$ | 10 max | mA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 40 A, $t_P$ ≤ 350 μs, df = 0.02) | $h_{FE}$(pulsed) | 10 to 40 | |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0) | $C_{obo}$ | 2000max | pF |
| Input Capacitance ($V_{EB}$ = 0.5 V, $I_C$ = 0) | $C_{ibo}$ | 4000 max | pF |
| Gain-Bandwidth Product ($V_{CE}$ = 4 V, $I_C$ = 10 A) | $f_T$ | 400 to 2000 | kHz |

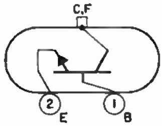
TYPICAL DC FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTICS



## CHARACTERISTICS (cont'd)

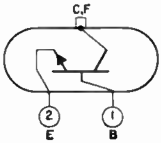
| | | | |
|---|---|---|---|
| Second-Breakdown Collector Current ($V_{CE}$ = 25 V, non-repetitive pulse = 1 s, base forward biased) | $I_{S/b}$ | 12 min | A |
| Second Breakdown Energy ($V_{BE}$ = −1.5 V, $I_C$ = 7 A, $R_{BB}$ = 10 Ω, L = 33 mH, base reverse biased) | $E_{S/b}$ | 0.8 min | J |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 0.5 max | °C/W |

# 2N5579 100A, 300W



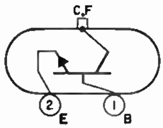

Si n-p-n type features a base comprised of a homogeneous-resistivity silicon material. It is used in high-power linear and switching applications in military, industrial, and commercial equipment. Outline No.56. This type is electrically identical to type 2N5578.

# 2N5580 100A, 300W




Si n-p-n type features a base comprised of a homogeneous-resistivity silicon material. It is used in high-power linear and switching applications in military, industrial, and commercial equipment. Outline No.57. This type is electrically identical to type 2N5578.

# 2N5575 100A, 300W

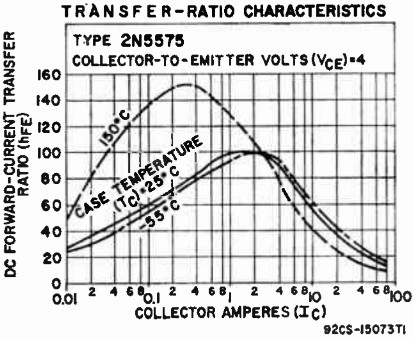



Si n-p-n type features a base comprised of a homogeneous-resistivity silicon material. It is used in high-power linear and switching applications in military, industrial, and commercial equipment. Outline No.55.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 70 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $R_{BE}$ = 10 Ω, $V_{BE}$ = −1.5 V | $V_{CEX}$(sus) | 70 | V |
| Base open | $V_{CEO}$(sus) | 50 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 8 | V |
| Collector Current | $I_C$ | 80 | A |
| Peak Collector Current | $i_C$ | 100 | A |
| Base Current | $I_B$ | 20 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C, $V_{CE}$ up to 25 V | $P_T$ | 300 | W |
| $T_C$ up to 25°C, $V_{CE}$ above 25 V | $P_T$ | See curve page 300 | |
| $T_C$ above 25°C, $V_{CE}$ above 25 V | $P_T$ | See curve page 300 | |

TYPICAL DC FORWARD CURRENT TRANSFER-RATIO CHARACTERISTICS



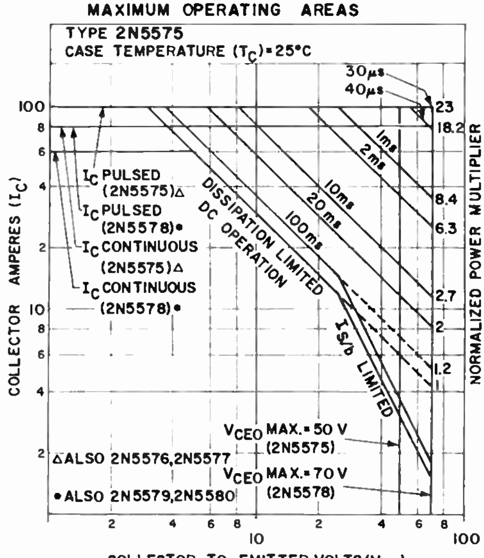
## MAXIMUM RATINGS (cont'd)

| | | | |
|---|---|---|---|
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 230 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

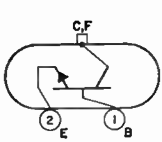
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 0.2 A | $V_{CEO}$(sus) | 50 min | V |
| $V_{BE}$ = −1.5 V, $I_C$ = 0.2 A, $R_{BE}$ = 10 Ω, base-emitter junction reverse biased | $V_{CEX}$(sus) | 70 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 60 A, $I_B$ = 6 A, $t_P$ ≤ 350 μs, df = 0.02) | $V_{CE}$(sat) | 2 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 60 A, $I_B$ = 6 A, $t_P$ ≤ 350 μs, df = 0.02) | $V_{BE}$(sat) | 3 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 60 A, $t_P$ ≤ 350 μs, df = 0.02) | $V_{BE}$ | 3 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 60 V, $V_{BE}$ = −1.5 V, base-emitter junction reverse biased | $I_{CEV}$ | 10 max | mA |
| $V_{CE}$ = 50 V, $R_{BE}$ = 10 Ω | $I_{CER}$ | 5 max | mA |
| $V_{CE}$ = 60 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C, base-emitter junction reverse biased | $I_{CEV}$ | 20 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 8 V) | $I_{EBO}$ | 10 max | mA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 60 A, $t_P$ ≤ 350 μs, df = 0.02) | $h_{FE}$(pulsed) | 10 to 40 | |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0) | $C_{obo}$ | 2000 max | pF |
| Input Capacitance ($V_{EB}$ = 0.5 V, $I_C$ = 0) | $C_{ibo}$ | 4000 max | pF |
| Gain-Bandwidth Product ($V_{CE}$ = 4 V, $I_C$ = 10 A) | $f_T$ | 400 to 2000 | kHz |
| Second-Breakdown Collector Current ($V_{CE}$ = 25 V, non-repetitive pulse = 1 s, base forward biased) | $I_{S/b}$ | 12 min | A |
| Second Breakdown Energy ($V_{BE}$ = −1.5 V, $I_C$ = 7 A, $R_{BE}$ = 10 Ω, L = 33 mH, base reverse biased) | $E_{S/b}$ | 0.8 min | J |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 0.5 max | °C/W |

MAXIMUM OPERATING AREAS



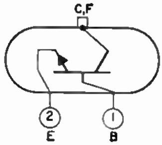

92CS-15085T1

## 100A, 300W — 2N5576




Si n-p-n type features a base comprised of a homogeneous silicon material. It is used in high-power linear and switching applications in military, industrial, and commercial equipment. Outline No.56. This type is electrically identical with type 2N5575.

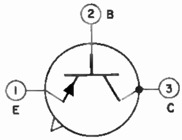
## 2N5577 100A, 300W




Si **n-p-n** type features a base comprised of a homogeneous silicon material. It is used in high-power linear and switching applications in military, industrial, and commercial equipment. Outline No.57. This type is electrically identical with type 2N5575.

# *P-N-P Power Types*

## 2N4036 −1A, 7W




Si **p-n-p** double-diffused epitaxial planar type used in a wide variety of small-signal, medium-power, and high-speed saturated switching applications in military, industrial, and commercial equipment. The p-n-p construction permits complementary operation with a matching n-p-n type such as the 2N2102. JEDEC TO-5, Outline No.5.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −90 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE}$ = 1.5 V | $V_{CEV}$(sus) | −85 | V |
| $R_{BE} \leqq 200\ \Omega$ | $V_{CER}$(sus) | −85 | V |
| Base open | $V_{CEO}$(sus) | −65 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −7 | V |
| Collector Current | $I_C$ | −1 | A |
| Base Current | $I_B$ | −0.5 | A |
| Transistor Dissipation:* | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 7 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

* See curve for maximum pulse operating areas.

### CHARACTERISTICS (At case temperature = 25°C)

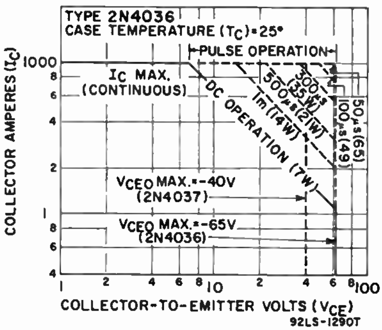
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | −90 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | −7 min | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE}$ = 1.5 V, $I_C$ = −100 mA | $V_{CEV}$(sus) | −85 min | V |
| $R_{BE} \leqq 200\ \Omega$, $I_C$ = −100 mA | $V_{CER}$(sus) | −85 min | V |
| $I_C$ = −100 mA, $I_B$ = 0 | $V_{CEO}$(sus) | −65 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = −150 mA, $I_B$ = −15 mA) | $V_{CE}$(sat) | −0.65 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = −10 V, $I_C$ = −150 mA) | $V_{BE}$ | −1.1 | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = −60 V, $I_E$ = 0 | $I_{CBO}$ | −0.02 max | μA |
| $V_{CE}$ = −30 V, $I_B$ = 0 | $I_{CEO}$ | −0.5 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −5 V, $I_C$ = 0) | $I_{EBO}$ | −0.02 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −10 V, $I_C$ = −0.1 mA) | $h_{FE}$ | 20 min | |
| Pulsed Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = −10 V, $I_C$ = −150 mA, $t_p$ = 300 μs, df $\leqq$ 2% | $h_{FE}$(pulsed) | 40 to 140 | |
| $V_{CE}$ = −10 V, $I_C$ = −500 mA, $t_p$ = 300 μs, df $\leqq$ 2% | $h_{FE}$(pulsed) | 20 min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −10 V, $I_C$ = −50 mA, f = 20 MHz) | $h_{fe}$ | 3 min | |
| Input Capacitance ($V_{EB}$ = −0.5 V, $I_C$ = 0) | $C_{ibo}$ | 90 max | pF |
| Output Capacitance ($V_{CB}$ = −10 V, $I_E$ = 0) | $C_{obo}$ | 30 max | pF |
| Saturated Switching Turn-On Time ($V_{CE}$ = −30 V, $I_C$ = −150 mA, $I_{B_1}$ = −15 mA, $V_{BB} \approx$ 4 V) | $t_d + t_r$ | 110* max | ns |

## CHARACTERISTICS (cont'd)

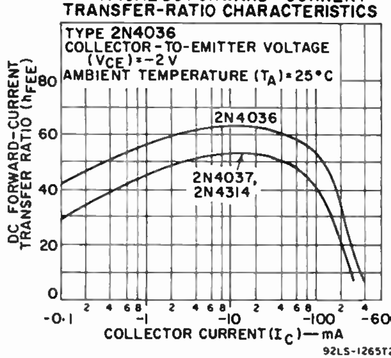
| | | | |
|---|---|---|---|
| Saturated Switching Turn-Off Time ($V_{CE}$ = −30 V, $I_C$ = −150 mA, $I_{B_2}$ = 15 mA, $V_{BB}$ ≈ 4 V) | $t_s + t_f$ | 700* max | ns |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 25 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 165 max | °C/W |

* This value does not apply to type 2N4314.

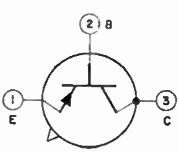
MAXIMUM OPERATING AREAS




TYPICAL DC FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTICS




## −1A, 7W 2N4037




Si p-n-p double-diffused epitaxial planar type used in a wide variety of small-signal, medium-power applications in military, industrial, and commercial equipment. The p-n-p construction permits complementary operation with a matching n-p-n type such as the 2N3053. JEDEC TO-5, Outline No.5. For maximum operating and transfer-ratio characteristics curves, refer to type 2N4036.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −60 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE}$ = 1.5 V | $V_{CEV}$(sus) | −60 | V |
| $R_{BE}$ ≦ 200 Ω | $V_{CER}$(sus) | −60 | V |
| Base open | $V_{CEO}$(sus) | −40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −7 | V |
| Collector Current | $I_C$ | −1 | A |
| Base Current | $I_B$ | −0.5 | A |
| Transistor Dissipation:* | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 7 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

* See curve for maximum pulse operating areas.

## CHARACTERISTICS (At case temperature = 25°C)

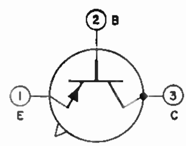
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = −0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | −60 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | −7 min | V |
| Collector-to-Emitter Sustaining Voltage: | | | V |
| $V_{BE}$ = 1.5 V, $I_C$ = −100 mA | $V_{CEV}$(sus) | −60 min | |
| $R_{BE}$ ≦ 200 Ω, $I_C$ = −100 mA | $V_{CER}$(sus) | −60 min | V |
| $I_C$ = −100 mA, $I_B$ = 0 | $V_{CEO}$(sus) | −40 min | V |

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage ($I_C$ = −150 mA, $I_B$ = −15 mA) | $V_{CE}$(sat) | −1.4 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = −60 V, $I_E$ = 0 | $I_{CBO}$ | −0.25 max | μA |
| $V_{CE}$ = −30 V, $I_B$ = 0 | $I_{CEO}$ | −5 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −5 V, $I_C$ = 0) | $I_{EBO}$ | −1 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −10 V, $I_C$ = −1 mA) | $h_{FE}$ | 15 min | |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE}$ = −10 V, $I_C$ = −150 mA, $t_p$ = 300 μs, df ≦ 2%) | $h_{FE}$(pulsed) | 50 to 250 | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −10 V, $I_C$ = −50 mA, f = 20 MHz) | $h_{fe}$ | 3 min | |
| Input Capacitance ($V_{EB}$ = −0.5 V, $I_C$ = 0) | $C_{ibo}$ | 90 max | pF |
| Output Capacitance ($V_{CB}$ = −10 V, $I_E$ = 0) | $C_{obo}$ | 30 max | pF |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 25 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 165 max | °C/W |

* This value does not apply to type 40391.

# 2N4314 −1A, 7W

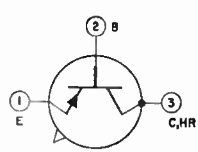



Si p-n-p double-diffused epitaxial planar type used in a wide variety of small-signal, medium-power applications in industrial and commercial applications. JEDEC TO-5, Outline No.5. This type is identical to type 2N4036 except for the following items:

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage ($I_C$ = −150 mA, $I_B$ = 15 mA) | $V_{CE}$(sat) | −1.4 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = −10 V, $I_C$ = −150 mA) | $V_{BE}$ | −1.5 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = −60 V, $I_E$ = 0 | $I_{CBO}$ | −0.25 max | μA |
| $V_{CE}$ = −30 V, $I_B$ = 0 | $I_{CEO}$ | −5 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −5 V, $I_C$ = 0) | $I_{EBO}$ | −1 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −10 V, $I_C$ = −1 mA) | $h_{FE}$ | 15 min | |
| Pulsed Forward-Current Transfer Ratio ($V_{CE}$ = −10 V, $I_C$ = −150 mA, $t_P$ = 300μs, df < 2%) | $h_{FE}$(pulsed) | 50 to 250 | |

# 40391 −1A, 7W




Si p-n-p double-diffused epitaxial planar type with an attached heat radiator for printed-circuit-board use in a wide variety of small-signal, medium-power applications in military, industrial, and commercial equipment. JEDEC TO-5 (with heat radiator), Outline No.8. This type is identical with type 2N4037 except for the following items:

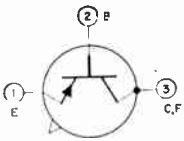
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 3.5 | W |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 50 max | °C/W |

## —1A, 7W **40394**

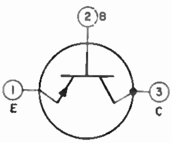



Si p-n-p double-diffused epitaxial planar type used in a wide variety of small-signal, medium-power applications in military, industrial, and commercial equipment. JEDEC TO-5 (with flange), Outline No.6. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N4037 except for the following items:

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |

## —1A, 10W **2N5415**

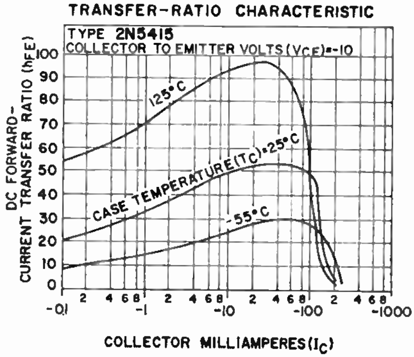



Si p-n-p triple-diffused type used for high-speed switching and linear-amplifier applications in military, industrial, and commercial equipment. P-N-P structure permits complementary operation with a matching n-p-n type such as the 2N3440. JEDEC TO-5, Outline No.5.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | —200 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | —4 | V |
| Collector Current | $I_C$ | —1 | A |
| Base Current | $I_B$ | —0.5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 10 | W |
| $T_C$ above 25°C | | See curve page 300 | |
| $T_A$ up to 50°C | $P_T$ | 1 | |
| $T_A$ above 50°C | $P_T$ | Derate linearly at 6.7 mW/°C | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | —65 to 200 | °C |
| Storage | $T_{STG}$ | —65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

TYPICAL DC FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTIC

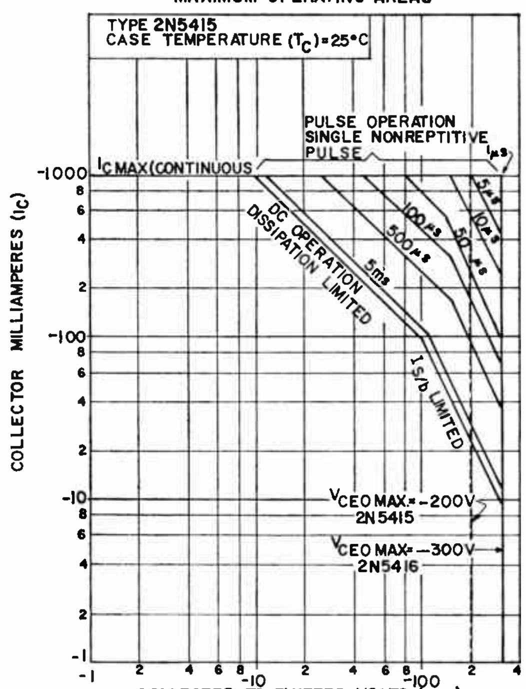



92SS-3719T1

**CHARACTERISTICS (At case temperature = 25°C)**

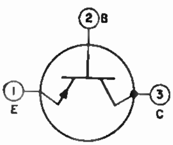
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = −50 mA, $I_B$ = 0) | $V_{CEO}$(sus) | −200 min | V |
| Base-to-Emitter Saturation Voltage ($V_{CE}$ = −10 V, $I_C$ = −50 V) | $V_{BE}$(sat) | −1.5 max | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = −50 mA, $I_B$ = 5 mA) | $V_{CE}$(sat) | −2.5 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = −150 V, $I_B$ = 0 | $I_{CEO}$ | −50 max | μA |
| $V_{CE}$ = −200 V, $V_{BE}$ = 1.5 V | $I_{CEV}$ | −50 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −4 V, $I_C$ = 0) | $I_{EBO}$ | −20 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −10 V, $I_C$ = −50 mA) | $h_{FE}$ | 30 to 150 | |
| Small-Signal, Forward-Current Transfer Ratio ($V_{CE}$ = −10 V, $I_C$ = −10 mA, f = MHz) | $h_{fe}$ | 3 min | |
| Output Capacitance ($V_{CB}$ = −10 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 15 max | pF |
| Second-Breakdown Collector Current ($V_{CE}$ = −100 V, base forward-biased) | $I_{S/b}$ | −100 min | mA |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 17.5 max | °C/W |

MAXIMUM OPERATING AREAS




## 2N5416 —1A, 10W

Si p-n-p triple-diffused type used for high-speed switching linear-amplifier applications in military, industrial, and commercial equipment. P-N-P structure permits complementary operation with a matching n-p-n type such as the 2N3439. JEDEC TO-5, Outline No.5.



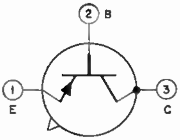
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −350 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| Base open | $V_{CEO}$(sus) | −300 | V |
| $R_{BE}$ = 50 Ω | $V_{CER}$(sus) | −350 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −6 | A |
| Collector Current | $I_C$ | −1 | A |
| Base Current | $I_B$ | −0.5 | W |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 10 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| $T_A$ up to 50°C | $P_T$ | 1 | °C |
| $T_A$ above 50°C | $P_T$ | Derate linearly at 6.7 mW/°C | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| Base open | $V_{CEO}$(sus) | −300 min | V |
| $R_{BE}$ = 50 Ω | $V_{CER}$(sus) | −350 min | V |
| Base-to-Emitter Saturation Voltage ($V_{CE}$ = 10 V, $I_C$ = 50 mA) | $V_{BE}$(sat) | −1.5 max | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = −50 mA, $I_B$ = 5 mA) | $V_{CE}$(sat) | −2 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = −250 V, $I_B$ = 0 | $I_{CEO}$ | −50 max | μA |
| $V_{CE}$ = −300 V, $V_{BE}$ = 1.5 V | $I_{CEV}$ | −50 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −6 V, $I_C$ = 0) | $I_{EBO}$ | −20 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −10 V, $I_C$ = 50 mA) | $h_{FE}$ | 30 to 120 | |
| Small-Signal, Forward-Current Transfer Ratio ($V_{CE}$ = −10 V, $I_C$ = −10 mA, f = 5 MHz) | $h_{fe}$ | 3 min | |
| Output Capacitance ($V_{CB}$ = −10 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 15 max | pF |
| Second-Breakdown Collector Current ($V_{CE}$ = −100 V, base forward-biased) | $I_{S/b}$ | −100 min | mA |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 17.5 | °C/W |

## −2A, 10W 2N5322




Si p-n-p double-diffused epitaxial-planar type used for small-signal medium-power applications in military, industrial, and commercial equipment. The p-n-p construction permits complementary operation with a matching n-p-n type such as the 2N5320. JEDEC TO-5, Outline No.5.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −100 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE}$ = 1.5 V | $V_{CEV}$(sus) | −100 | V |
| $R_{BE}$ = 100 V | $V_{CER}$(sus) | −90 | V |
| Base open | $V_{CEO}$(sus) | −75 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −7 | V |
| Collector Current | $I_C$ | −2 | A |
| Base Current | $I_B$ | −1 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 10 | W |
| $T_C$ above 25°C | $P_T$ | Derate linearly at 0.057 W/°C | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

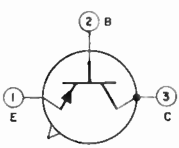
| | | | |
|---|---|---|---|
| Emitter-to-Base Breakdown Voltage ($I_E$ = −0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | −7 min | V |
| Collector-to-Emitter Breakdown Voltage ($V_{BE}$ = 1.5 V, $I_C$ = −0.1 mA, Base-emitter reversed biased) | $V_{(BR)CEV}$ | −100 min | V |

### CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C = -100$ mA, $R_{BE} = 100\ \Omega$ | $V_{CER}(sus)$ | −90 min | V |
| $I_C = -100$ mA, $I_B = 0$, base open | $V_{CEO}(sus)$ | −75 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C = -500$ mA, $I_B = -50$ mA) | $V_{CE}(sat)$ | −0.7 min | V |
| Base-to-Emitter Voltage ($V_{CE} = -4$ V, $I_C = -500$ mA) | $V_{BE}$ | −1.1 max | V |
| Collector-Cutoff Current ($V_{CB} = -80$ V, $I_E = 0$) | $I_{CBO}$ | −0.5 max | µA |
| Emitter-Cutoff Current ($V_{EB} = -5$ V, $I_C = 0$) | $I_{EBO}$ | −0.1 max | µA |
| Pulsed Static Forward-Current Transfer Ratio: | | | |
| $V_{CE} = -4$ V, $I_C = -500$ mA, $t_p \leq 300$ µs, df $\leq 0.02$ | $h_{FE}$(pulsed) | 30 to 130 | |
| $V_{CE} = -2$ V, $I_C = -1000$ mA, $t_p \leq 300$ µs, df $\leq 0.02$ | $h_{FE}$(pulsed) | 10 min | |
| Gain-Bandwidth Product ($V_{CE} = -4$ V, $I_C = -50$ mA) | $f_T$ | 50 | MHz |
| Second-Breakdown Collector Current ($V_{CE} = -35$ V, base forward-biased) | $I_{S/b}$ | −285 | mA |
| Turn-On Time ($V_{CE} = -30$ V, $I_C = -500$ mA, $I_B = -50$ mA) | $t_d + t_r$ | 100 max | ns |
| Turn-Off Time ($V_{CE} = -30$ V, $V_{BE} = -500$ mA, $I_E = -50$ mA) | $t_s + t_f$ | 1000 max | ns |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 17.5 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 150 max | °C/W |

# 2N5323 —2A, 10W

Si p-n-p double-diffused epitaxial-planar type used for small-signal medium-power applications in military, industrial, and commercial equipment. The p-n-p construction permits complementary operation with a matching n-p-n type such as the 2N5321. JEDEC TO-5, Outline No.5.




### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −75 | V |
| Collector-to-Emitter Sustaining Voltage | | | |
| $V_{BE} = 1.5$ V | $V_{CEV}(sus)$ | −75 | V |
| $R_{BE} = 100$ V | $V_{CER}(sus)$ | −65 | V |
| Base open | $V_{CEO}(sus)$ | −50 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −5 | V |
| Collector Current | $I_C$ | −2 | A |
| Base Current | | | |
| Transistor Dissipation: | $I_B$ | −1 | A |
| $T_C$ up to 25°C | $P_T$ | 10 | W |
| $T_C$ above 25°C | $P_T$ | Derate linearly at 0.057 | W/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Emitter-to-Base Breakdown Voltage ($I_E = -0.1$ mA, $I_C = 0$) | $V_{(BR)EBO}$ | −5 min | V |
| Collector-to-Emitter Breakdown Voltage ($V_{BE} = 1.5$ V, $I_C = -0.1$ mA, Base-emitter reverse biased) | $V_{(BR)CEV}$ | −75 min | V |
| Collector-to-Emitter Sustaining Voltage | | | |
| $I_C = -100$ mA, $R_{BE} = 100\ \Omega$ | $V_{CER}(sus)$ | −65 min | V |
| $I_C = -100$ mA, base open | $V_{CEO}(sus)$ | −50 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C = -500$ mA, $I_B = -50$ mA) | $V_{CE}(sat)$ | −1.2 max | V |
| Base-to-Emitter Voltage ($V_{EB} = -4$ V, $I_C = -500$ mA) | $V_{BE}$ | −1.4 max | V |
| Collector-Cutoff Current ($V_{CB} = -60$ V, $I_E = 0$) | $I_{CBO}$ | −5 max | µA |
| Emitter-Cutoff Current ($V_{EB} = -4$ V, $I_C = 0$) | $I_{EBO}$ | −0.5 max | µA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE} = -4$ V, $I_C = -500$ mA) | $h_{FE}$(pulsed) | 40 to 250 | |
| Gain-Bandwidth Product ($V_{CE} = -4$ V, $I_C = -50$ mA) | $f_T$ | 50 min | MHz |
| Second-Breakdown Collector Current ($V_{CE} = -35$ V, base forward-biased, non-repetitive pulse = 1 s) | $I_{S/b}$ | −285 min | mA |
| Turn-On Time ($V_{CE} = -30$ V, $I_C = -500$ mA, $I_B = -50$ mA) | $t_d + t_r$ | 100 max | ns |
| Turn-Off Time ($V_{CE} = -30$ V, $I_C = -500$ mA, $I_B = -50$ mA) | $t_s + t_f$ | 1000 max | ns |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 17.5 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 150 max | °C/W |

# 2N5781

**−3.5A, 10W**

Si p-n-p diffused epitaxial-base type used in medium power switching and complementary-symmetry audio amplifier applications. This type and type 2N5784 form a complementary pair. JEDEC TO-5, Outline No.5.

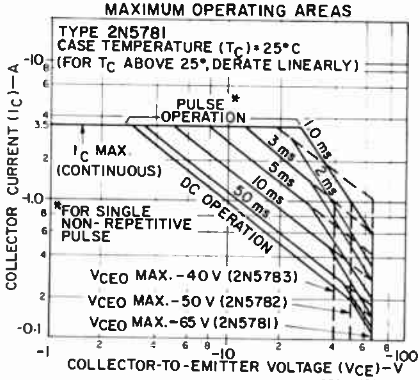
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −80 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $R_{BE}$ = 100 Ω | $V_{CER}$(sus) | −80 | V |
| Base open | $V_{CEO}$(sus) | −65 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −5 | V |
| Collector Current | $I_C$ | −3.5 | A |
| Base Current | $I_B$ | −1 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 10 | W |
| $T_C$ above 25°C | $P_T$ | Derate linearly at 0.057 | W/°C |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_A$ above 25°C | $P_T$ | Derate linearly at 0.0057 | W/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

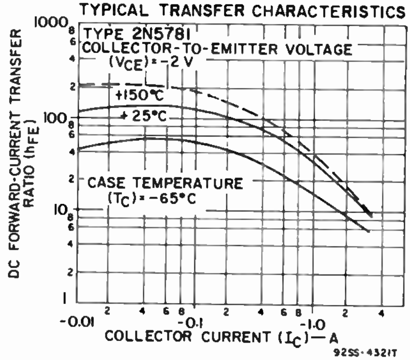
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = −0.1 A | $V_{CEO}$(sus) | −65 min | V |
| $R_{BE}$ = 100 Ω, $I_C$ = 0.1 A | $V_{CER}$(sus) | −80 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = −2 V, $I_C$ = −1 A) | $V_{BE}$ | −1.5 max | V |
| Collector-to-Emitter Saturation Voltage, Measured 0.25 in. from case†: | | | |
| $I_C$ = −1 A, $I_B$ = −0.1 A | $V_{CE}$(sat) | −0.5 max | V |
| $I_C$ = −3.2 A, $I_B$ = −0.8 A | $V_{CE}$(sat) | −2 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = −50 V | $I_{CEO}$ | −100 max | μA |
| $R_{BE}$ = 100 Ω, $V_{CE}$ = −65 V | $I_{CER}$ | −10 max | μA |
| $R_{BE}$ = 100 Ω, $V_{CE}$ = −65 V, $T_C$ = 150°C | $I_{CER}$ | −1 max | mA |
| $R_{BE}$ = 100 Ω, $V_{CE}$ = −75 V, $V_{BE}$ = −1.5 V, base-emitter junction reverse biased | $I_{CEX}$ | −10 max | μA |
| $R_{BE}$ = 100 Ω, $V_{CE}$ = −75 V, $V_{BE}$ = −1.5 V, base-emitter junction biased, $T_C$ = 150°C | $I_{CEX}$ | −1 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = −5) | $I_{EBO}$ | −10 max | μA |

MAXIMUM OPERATING AREAS




TYPICAL TRANSFER CHARACTERISTICS

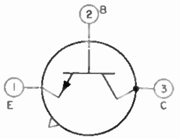


## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Pulsed Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = −2 V, $I_C$ = −1 A, $t_p$ = 300 μs, df = 0.018 | $h_{FE}$(pulsed) | 20 to 100 | |
| $V_{CE}$ = −2 V, $I_C$ = −3.2 A, $t_p$ = 300 μs, df = 0.018 | $h_{FE}$(pulsed) | 4 min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −2 V, $I_C$ = −0.1 A) | $h_{fe}$ | 25 min | |
| Magnitude of Small-Signal Forward-Current Transfer Ratio▲ ($V_{CE}$ = −2 V, $I_C$ = −0.1 A, f = 4 MHz) | $\lvert h_{fe}\rvert$ | 2 to 15 | |
| Turn-On Time ($V_{CC}$ = −30 V, $I_C$ = −1 A, $I_{B1}$ = −0.1 A) | $t_d + t_r$ | 0.5 max | μs |
| Turn-Off Time ($V_{CC}$ = −30 V, $I_C$ = −1 A, $I_{B2}$ = −0.1 A) | $t_s + t_f$ | 2.5 max | μs |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 17.5 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 175 max | °C/W |

† Lead resistance is critical in this test.
▲ Measured at a frequency where $\lvert h_{fe}\rvert$ is decreasing at approximately 6 dB per octave.

# 2N5782 −3.5A, 10W




Si p-n-p diffused epitaxial-base type used in medium power switching and complementary-symmetry audio amplifier applications. This type and type 2N5785 form a complementary pair. JEDEC TO-5, Outline No.5. For Maximum Operating Area curves, refer to type 2N5781.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collctor-to-Base Voltage | $V_{CBO}$ | −65 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $R_{BE}$ = 100 Ω | $V_{CER}$(sus) | −65 | V |
| Base open | $V_{CEO}$(sus) | −50 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −5 | V |
| Collector Current | $I_C$ | −3.5 | A |
| Base Current | $I_B$ | −1 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 10 | W |
| $T_C$ above 25°C | $P_T$ | Derate linearly at 0.057 | W/°C |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_A$ above 25°C | $P_T$ | Derate linearly at 0.0057 | W/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

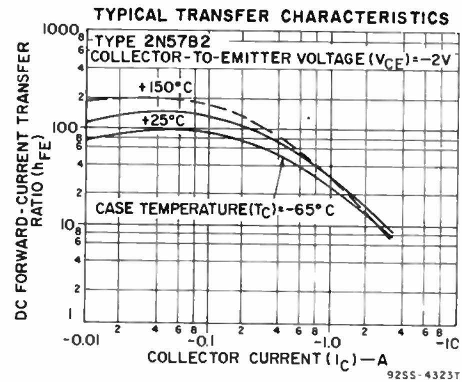
## CHARACTERISTICS (At case temperature = 25°C)

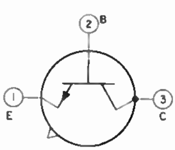
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = −0.1 A | $V_{CEO}$(sus) | −50 min | V |
| $R_{BE}$ = 100 Ω, $I_C$ = −0.1 A | $V_{CER}$(sus) | | V |
| Base-to-Emitter Voltage ($V_{CE}$ = −2 V, $I_C$ = −1.2 A) | $V_{BE}$ | −1.5 max | V |
| Collector-to-Emitter Saturation Voltage, Measured 0.25 in. from case†: | | | |
| $I_C$ = −1.2 A, $I_B$ = −0.12 A | $V_{CE}$(sat) | −0.75 max | V |
| $I_C$ = −3.2 A, $I_B$ = −0.8 A | $V_{CE}$(sat) | −2 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = −35 V | $I_{CEO}$ | −100 max | μA |
| $R_{BE}$ = 100 Ω, $V_{CE}$ = −50 V | $I_{CER}$ | −10 max | μA |
| $R_{BE}$ = 100 Ω, $V_{CE}$ = −50 V, $T_C$ = 150°C | $I_{CER}$ | −1 max | mA |
| $R_{BE}$ = 100 Ω, $V_{BE}$ = −1.5 V, $V_{CE}$ = −60 V, base-emitter junction reverse-biased | $I_{CEX}$ | −10 max | μA |
| $R_{BE}$ = 100 Ω, $V_{BE}$ = −1.5 V, $V_{CE}$ = −60 V, $T_C$ = 15°C, base-emitter junction reverse-biased | $I_{CEX}$ | −1 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = −5 V) | $I_{EBO}$ | −10 max | μA |
| Pulsed Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = −2 V, $I_C$ = −1.2 A | $h_{FE}$(pulsed) | 20 to 100 | |
| $V_{CE}$ = −2 V, $I_C$ = −3.2 A | $h_{FE}$(pulsed) | 4 min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −2 V, $I_C$ = −0.1 A) | $h_{fe}$ | 25 min | |
| Magnitude of Small-Signal Forward-Current Transfer Ratio▲ ($V_{CE}$ = −2 V, $I_C$ = −0.1 ,A f = 4 MHz) | $\lvert h_{fe}\rvert$ | 2 to 15 | |

**CHARACTERISTICS (cont'd)**

| | | | |
|---|---|---|---|
| Turn-On Time ($V_{CC}$ = −30 V, $I_C$ = −1 A, $I_{B1}$ = −0.1 A) | $t_d + t_r$ | 0.5 max | µs |
| Turn-Off Time ($V_{CC}$ = −30 V, $I_C$ = −1 A, $I_{B2}$ = −0.1 A) | $t_s + t_f$ | 2.5 max | µs |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 17.5 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 175 max | °C/W |

† Lead resistance is critical in this test.
▲ Measured at a frequency where $|h_{fe}|$ is decreasing at approximately 6 dB per octave.




## −3.5A, 10W 2N5783

Si p-n-p diffused epitaxial-base type used in medium power switching and complementary-symmetry audio amplifier applications. This type and type 2N5786 form a complementary pair. JEDEC TO-5, Outline No.5. For Maximum Operating Area curves, refer to type 2N5781.

**MAXIMUM RATINGS**

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −45 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $R_{BE}$ = 100 Ω | $V_{CER}$(sus) | −45 | V |
| Base open | $V_{CEO}$(sus) | −40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −3.5 | V |
| Collector Current | $I_C$ | −3.5 | A |
| Base Current | $I_B$ | −1 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 10 | W |
| $T_C$ above 25°C | $P_T$ | Derate linearly at 0.057 | W/°C |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_A$ above 25°C | $P_T$ | Derate linearly at 0.0057 | W/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

**CHARACTERISTICS (At case temperature = 25°C)**

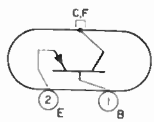
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = −0.1 A | $V_{CEO}$(sus) | −40 min | V |
| $R_{BE}$ = 100 Ω, $I_C$ = −0.1 A | $V_{CER}$(sus) | −45 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = −2 V, $I_C$ = −1.6 A) | $V_{BE}$ | −1.5 max | V |
| Collector-to-Emitter Saturation Voltage, Measured 0.25 in. from case†: | | | |
| $I_C$ = −1.6 A, $I_B$ = −0.16 A | $V_{CE}$(sat) | −1 max | V |
| $I_C$ = −3.2 A, $I_B$ = −0.8 A | $V_{CE}$(sat) | −2 max | V |

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = −25 V | $I_{CEO}$ | −100 max | μA |
| $R_{BE}$ = 100 Ω, $V_{CE}$ = −40 V | $I_{CER}$ | −10 max | μA |
| $R_{BE}$ = 100 Ω, $V_{CE}$ = −40 V, $T_C$ = 150°C | $I_{CER}$ | −1 max | mA |
| $R_{BE}$ = 100 Ω, $V_{CE}$ = −45 V, $V_{BE}$ = −1.5 V, base-emitter junction reverse-biased | $I_{CEX}$ | −10 max | μA |
| $R_{BE}$ = 100 Ω, $V_{CE}$ = −45 V, $V_{BE}$ = −1.5 V, base-emitter junction reverse-biased, $T_C$ = 150°C | $I_{CEX}$ | −1 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = −3.5 V) | $I_{EBO}$ | −10 max | μA |
| Pulsed Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = −2 V, $I_C$ = −1.6 A | $h_{FE}$(pulsed) | 20 to 100 | |
| $V_{CE}$ = −2 V, $I_C$ = −3.2 A | $h_{FE}$(pulsed) | 4 min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −2 V, $I_C$ = −0.1 A) | $h_{fe}$ | 25 min | |
| Magnitude of Small-Signal Forward-Current Transfer Ratio▲ ($V_{CE}$ = −2 V, $I_C$ = −0.1 A, f = 4 MHz) | $\|h_{fe}\|$ | 2 to 15 | |
| Turn-On Time ($V_{CC}$ = −30 V, $I_C$ = −1 A, $I_{B1}$ = −0.1 A) | $t_d + t_r$ | 0.5 max | μs |
| Turn-Off Time ($V_{CC}$ = −30 V, $I_C$ = −1 A, $I_{B2}$ = −0.1 A) | $t_s + t_f$ | 2.5 max | μs |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 17.5 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 175 max | °C/W |

† Lead resistance is critical in this test.
▲ Measured at a frequency where $|h_{fe}|$ is decreasing at approximately 6 dB per octave.

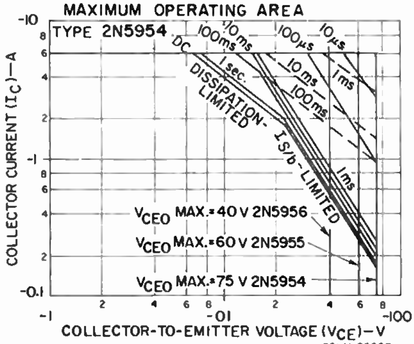
# 2N5954 −6A, 40W

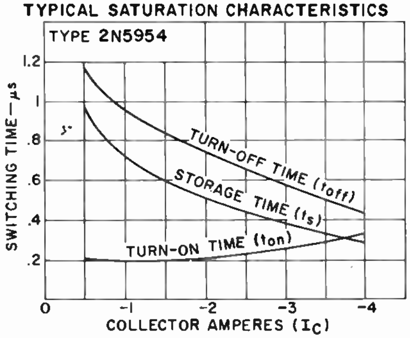



Si p-n-p multiple-epitaxial, multiple diffused type used for switching applications in military, industrial and commercial equipment. JEDEC TO-66, Outline No.25. See Mounting Hardware for desired mounting arrangement.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −85 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = 1.5 V, $R_{BE}$ = 100 Ω | $V_{CEX}$ | −85 | V |
| $R_{BE}$ = 100 Ω | $V_{CER}$ | −80 | V |
| Base open | $V_{CEO}$ | −75 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −5 | V |
| Collector Current | $I_C$ | −6 | V |
| Base Current | $I_B$ | −2 | V |



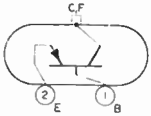
## MAXIMUM RATINGS (cont'd)

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 40 | W |
| $T_C$ above 25°C | $P_T$ | Derate linearly at 0.232 | W/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature | $T_P$ | 235 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = −0.1 A | $V_{CEO}$(sus) | −75 min | V |
| $I_C$ = −0.1 A, $R_{BE}$ = 100 Ω | $V_{CER}$(sus) | −80 min | V |
| $V_{BE}$ = 1.5 V, $I_C$ = −0.1 A, $R_{BE}$ = 100 Ω, base-emitter junction reverse biased | $V_{CEX}$(sus) | −85 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = −4 V, $I_C$ = −2 A, $t_p$ = 300 μs, df = 0.018) | $V_{BE}$ | −2 max | V |
| Collector-to-Emitter Saturation Voltage: | | | |
| $I_C$ = −2 A, $I_B$ = −0.2 A, tp = 300 μs, df = 0.018 | $V_{CE}$(sat) | −1 max | V |
| $I_C$ = −6 A, $I_B$ = −1.2 A, tp = 300 μs, df = 0.018 | $V_{CE}$(sat) | −2 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = −70 V, $R_{BE}$ = 100 Ω | $I_{CER}$ | −100 max | μA |
| $V_{CE}$ = 70 V, $R_{BE}$ = 100 Ω, $T_C$ = 150°C | $I_{CER}$ | −2 max | mA |
| $V_{CE}$ = −80 V, $V_{BE}$ = 1.5 V, $R_{BE}$ = 100 Ω, base-emitter junction reverse biased | $I_{CEX}$ | −100 max | μA |
| $V_{CB}$ = −80 V, $V_{BE}$ = 1.5 V, $R_{BE}$ = 100 Ω, base-emitter junction reverse biased, $T_C$ = 150°C | $I_{CEX}$ | −2 max | μA |
| Collector-Cutoff Current ($V_{CE}$ = −60 V) | $I_{CEO}$ | −1 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = −5 V) | $I_{EBO}$ | −0.1 max | mA |
| Pulsed Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = −4 V, $I_C$ = −2 A, $t_p$ = 300 μs, df = 0.018 | $h_{FE}$(pulsed) | 20 to 100 | |
| $V_{CE}$ = −4 V, $I_C$ = 6 A, tp = 300 μs, df = 0.018 | $h_{FE}$(pulsed) | 5 min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −4 V, $I_C$ = − 0.5 A, f = 1 kHz) | $\|h_{fe}\|$ | 25 min | |
| Gain-Bandwidth Product ($V_{CE}$ = −4 V, $I_C$ = −1 A) | $f_T$ | 5 min | MHz |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 4.3 max | °C/W |

## −6A, 40W — 2N5955




Si p-n-p multiple-epitaxial, multiple diffused type used for switching applications in military, industrial and commercial equipment. JEDEC TO-66, Outline No.25. See Mounting Hardware for desired mounting arrangement. For Maximum Operating Area and Typical Saturation Characteristics curves, refer to type 2N5954.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −70 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = 1.5 V, $R_{BE}$ = 100 Ω | $V_{CEX}$ | −70 | V |
| $R_{BE}$ = 100 Ω | $V_{CER}$ | −65 | V |
| Base open | $V_{CEO}$ | −60 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −5 | V |
| Collector Current | $I_C$ | −6 | V |
| Base Current | $I_B$ | −2 | V |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 40 | W |
| $T_C$ above 25°C | $P_T$ | Derate linearly at 0.232 | W/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature | $T_P$ | 235 | °C |

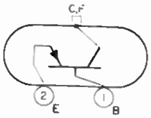
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = −0.1 A | $V_{CEO}$(sus) | −60 min | V |
| $I_C$ = −0.1 A, $R_{BE}$ = 100 Ω | $V_{CER}$(sus) | −65 min | V |

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| $V_{BE}$ = 1.5 V, $I_C$ = −0.1 A, $R_{BE}$ = 100 Ω, base-emitter junction reverse biased | $V_{CEX}$(sus) | −70 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = −4 V, $I_C$ = −2.5 A, $t_p$ = 300 μs, df = 0.018) | $V_{BE}$ | −2 max | V |
| Collector-to-Emitter Saturation Voltage: | | | |
| $I_C$ = −2.5 A, $I_B$ = −0.25 A, $t_p$ = 300 μs, df = 0.018 | $V_{CE}$(sat) | −1 max | V |
| $I_C$ = −6 A, $I_B$ = −1.2 A, $t_p$ = 300 μs, df = 0.018 | $V_{CE}$(sat) | −2 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = −55 V, $R_{BE}$ = 100 Ω | $I_{CER}$ | −100 max | μA |
| $V_{CE}$ = −55 V, $R_{BE}$ = 100 Ω, $T_C$ = 150°C | $I_{CER}$ | −2 max | mA |
| $V_{CE}$ = −65 V, $V_{BE}$ = 1.5 V, $R_{BE}$ = 100 Ω, base-emitter junction reverse biased | $I_{CEX}$ | −100 max | μA |
| $V_{CE}$ = −65 V, $V_{BE}$ = 1.5 V, $R_{BE}$ = 100 Ω, base-emitter junction reverse biased, $T_C$ = 150°C | $I_{CEX}$ | −2 max | μA |
| Collector-Cutoff Current ($V_{CE}$ = −45 V) | $I_{CEO}$ | −1 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = −5 V) | $I_{EBO}$ | −0.1 max | mA |
| Pulsed Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = −4 V, $I_C$ = −2.5 A, $t_p$ = 300 μs, df = 0.018 | $h_{FE}$(pulsed) | 20 to 100 | |
| $V_{CE}$ = −4 V, $I_C$ = 6 A, $t_p$ = 300 μs, df = 0.018 | $h_{FE}$(pulsed) | 5 min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −4 V, $I_C$ = −0.5 A, f = 1 kHz) | $\lvert h_{fe} \rvert$ | 25 min | |
| Gain-Bandwidth Product ($V_{CE}$ = −4 V, $I_C$ = −1 A) | $f_T$ | 5 min | MHz |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 4.3 max | °C/W |

# 2N5956 −6A, 40W




Si p-n-p multiple-epitaxial, multiple diffused type used for switching applications in military, industrial and commercial equipment. JEDEC TO-66, Outline No.25. See Mounting Hardware for desired mounting arrangement. For Maximum Operating Area and Typical Saturation Characteristics curves, refer to type 2N5954.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −50 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = 1.5 V, $R_{BE}$ = 100 Ω | $V_{CEX}$ | −50 | V |
| $R_{BE}$ = 100 Ω | $V_{CER}$ | −45 | V |
| Base open | $V_{CEO}$ | −40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −5 | V |
| Collector Current | $I_C$ | −6 | V |
| Base Current | $I_B$ | −2 | V |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 40 | W |
| $T_C$ above 25°C | $P_T$ | Derate linearly at 0.232 | W/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature | $T_P$ | 235 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

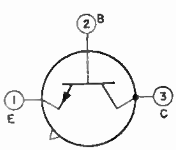
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = −0.1 A | $V_{CEO}$(sus) | −40 min | V |
| $I_C$ = −0.1 A, $R_{BE}$ = 100 Ω | $V_{CER}$(sus) | −45 min | V |
| $V_{BE}$ = 1.5 V, $I_C$ = −0.1 A, $R_{BE}$ = 100 Ω, base-emitter junction reverse biased | $V_{CEX}$(sus) | −50 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = −4 V, $I_C$ = −3 A, $t_p$ = 300 μs, df = 0.018) | $V_{BE}$ | −2 max | V |
| Collector-to-Emitter Saturation Voltage: | | | |
| $I_C$ = −3 A, $I_B$ = −0.3 A, $t_p$ = 300 μs, df = 0.018 | $V_{CE}$(sat) | −1 max | V |
| $I_C$ = −6 A, $I_B$ = −1.2 A, $t_p$ = 300 μs, df = 0.018 | $V_{CE}$(sat) | −2 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = −35 V, $R_{BE}$ = 100 Ω | $I_{CER}$ | −100 max | μA |
| $V_{CE}$ = −35 V, $R_{BE}$ = 100 Ω, $T_C$ = 150°C | $I_{CER}$ | −2 max | mA |

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| $V_{CE}$ = −45 V, $V_{BE}$ = 1.5 V, $R_{BE}$ = 100 Ω, base-emitter junction reverse biased | $I_{CEX}$ | −100 max | μA |
| $V_{CE}$ = −45 V, $V_{BE}$ = 1.5 V, $R_{BE}$ = 100 Ω, base-emitter junction reverse biased, $T_C$ = 150°C | $I_{CEX}$ | −2 max | μA |
| Collector-Cutoff Current ($V_{CE}$ = −25 V) | $I_{CEO}$ | −1 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = −5 V) | $I_{EBO}$ | −0.1 max | mA |
| Pulsed Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = −4 V, $I_C$ = −3 A, $t_p$ = 300 μs, df = 0.018 | $h_{FE}$(pulsed) | 20 to 100 | |
| $V_{CE}$ = −4 V, $I_C$ = 6 A, $t_p$ = 300 μs, df = 0.018 | $h_{FE}$(pulsed) | 5 min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −4 V, $I_C$ = −0.5 A, f = 1 kHz) | $\lvert h_{fe} \rvert$ | 25 min | |
| Gain-Bandwidth Product ($V_{CE}$ = −4 V, $I_C$ = −1 A) | $f_T$ | 5 min | MHz |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 4.3 max | °C/W |

# *High-Voltage N-P-N Power Types*

## 1A, 10W 2N3439

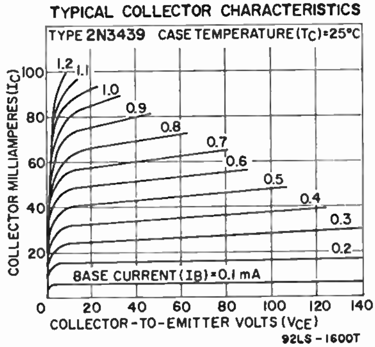



Si **n-p-n** triple-diffused type used in high-speed-switching and linear-amplifier applications, such as high-voltage differential and operational amplifiers, high-voltage inverters, and series regulators for industrial and military applications. JEDEC TO-5, Outline No.5.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 450 | V |
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | 350 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 1 | A |
| Base Current | $I_B$ | 0.5 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 50°C | $P_T$ | 1● | W |
| $T_C$ up to 25°C | $P_T$ | 10 | W |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

TYPICAL COLLECTOR CHARACTERISTICS

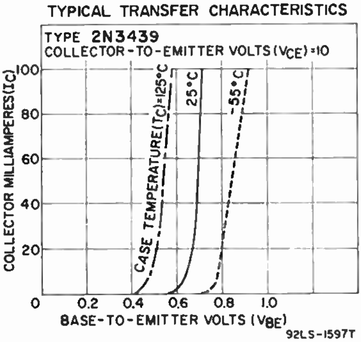


## CHARACTERISTICS (At case temperature = 25°C)

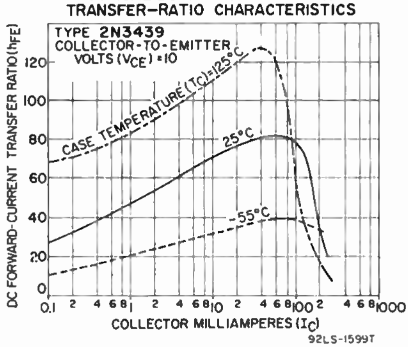
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 50 mA, $I_B$ = 0) | $V_{CEO}(sus)$ | 350 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 50 mA, $I_B$ = 4 mA) | $V_{CE}(sat)$ | 0.5 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 50 mA, $I_B$ = 4 mA) | $V_{BE}(sat)$ | 1.3 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 300 V, $I_B$ = 0 | $I_{CEO}$ | 20 max | µA |
| $V_{CE}$ = 450 V, $V_{BE}$ = −1.5 V | $I_{CEV}$ | 500 max | µA |
| Emitter-Cutoff Current ($V_{EB}$ = 6 V, $I_C$ = 0) | $I_{EBO}$ | 20 max | µA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 20 mA | $h_{FE}$ | 40 to 160 | |
| $V_{CE}$ = 10 V, $I_C$ = 2 mA | $h_{FE}$ | 30* min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 10 mA, f = 5 MHz) | $h_{fe}$ | 3 min | |
| Second-Breakdown Current, Safe Operating Region ($V_{CE}$ = 200 V) | $I_{S/b}$ | 50 min | mA |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 10 max | pF |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 17.5 max | °C/W |

* This value does not apply to type 2N3440.
● This value does not apply to types 2N4063 and 2N4064.

TYPICAL TRANSFER CHARACTERISTICS



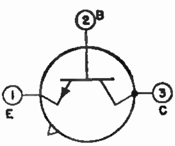

TYPICAL DC FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTICS




# 2N3440

**1A, 10W**

Si n-p-n triple-diffused type used in high-speed-switching and linear-amplifier applications such as high-voltage differential and operational amplifiers, high-voltage inverters, and series regulators for industrial and military applications. JEDEC TO-5, Outline No.5. This type is identical with type 2N3439 except for the following items:



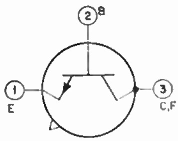

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 300 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 300 | V |
| Base open (sustaining voltage) | $V_{CEO}(sus)$ | 250 | V |

## CHARACTERISTICS (At case temperature = 25°C)

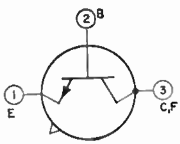
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 50 mA, $I_B$ = 0) | $V_{CEO}(sus)$ | 250 | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 200 V, $I_B$ = 0 | $I_{CEO}$ | 50 max | µA |
| $V_{CE}$ = 300 V, $V_{BE}$ = −1.5 V | $I_{CEV}$ | 500 max | µA |

## 1A, 10W — 2N4063



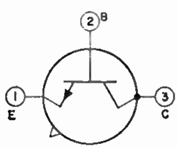

Si n-p-n triple-diffused type used in high-speed-switching and linear-amplifier applications, such as high-voltage differential and operational amplifiers, high-voltage inverters, and series regulators for industrial and military applications. JEDEC TO-5 (with flange), Outline No.6. See Mounting Hardware for desired mounting arrangement. This type is electrically identical with type 2N3439.

## 1A, 10W — 2N4064




Si n-p-n triple diffused type used in high-speed-switching and linear-amplifier applications, such as high-voltage differential and operational amplifiers, high-voltage inverters, and series regulators for industrial and military applications. JEDEC TO-5 (with flange), Outline No.6. See Mounting Hardware for desired mounting arrangement. This type is electrically identical with type 2N3440.

## 1A, 10W — 40346




Si n-p-n triple-diffused planar type used in low-power, high-voltage, general-purpose applications in military, industrial, and commercial equipment. This type is particularly useful in neon-indicator driver circuits and in high-voltage differential and high-voltage operational amplifiers. JEDEC TO-5, Outline No.5.

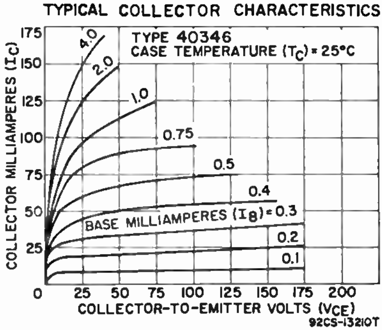
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage ($R_{BE}$ = 1000 Ω) | $V_{CER}$(sus) | 175 | V |
| Collector Current | $I_C$ | 1 | A |
| Base Current | $I_B$ | 0.5 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 50°C | $P_T$ | 1* | W |
| $T_C$ up to 25°C | $P_T$ | 10* | W |
| $T_A$ and $T_C$ above 50°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating ($T_A$-$T_C$) | | −65 to 200 | °C |

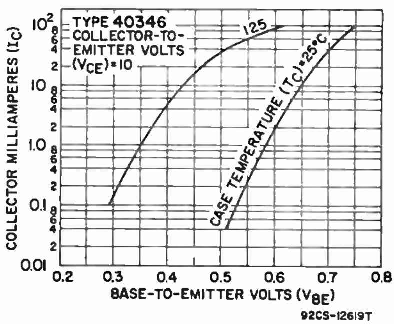
### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 1000 Ω, $I_C$ = 50 mA) | $V_{CER}$(sus) | 175 min | V |

TYPICAL COLLECTOR CHARACTERISTICS




TYPICAL TRANSFER CHARACTERISTICS

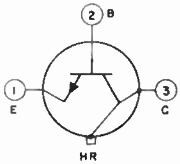


## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage ($I_B$ = 1 mA, $I_C$ = 10 mA) | $V_{CE}$(sat) | 0.5 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 10 V, $I_C$ = 10 mA) | $V_{BE}$ | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 100 V, $I_B$ = 0 | $I_{CEO}$ | 5 max | μA |
| $V_{CE}$ = 200 V, $V_{BE}$ = −1.5 V, $T_C$ = 25°C | $I_{CEV}$ | 10 max | μA |
| $V_{CE}$ = 200 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C | $I_{CEV}$ | 1 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 4 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 10 mA) | $h_{FE}$ | 25 min | |
| Small-Signal, Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 10 mA, f = 5 MHz) | $h_{fe}$ | 2 min | |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 15* max | °C/W |

* This value does not apply to type 40346V1.

## 40346V1 — 1A, 10W




Si n-p-n triple-diffused type used in high-voltage switching and linear-amplifier applications in military and commercial applications. This type is particularly useful in neon-indicator driver circuits and in differential and operational amplifiers. JEDEC TO-5 (with heat radiator), Outline No.8. This type is identical to type 40346 except for the following items:

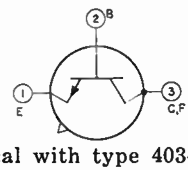
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 4 | W |

### CHARACTERISTICS

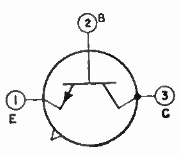
| | | | |
|---|---|---|---|
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 45 max | °C/W |

## 40346V2 — 1A, 10W




Si n-p-n triple-diffused type used in high-voltage switching and linear-amplifier applications in military and commercial applications. This type is particularly useful in neon-indicator driver circuits and in differential and operational amplifiers. JEDEC TO-5 (with flange), Outline No.6. See **Mounting Hardware** for desired mounting arrangement. This type is electrically identical with type 40346.

## 40385 — 1A, 10W



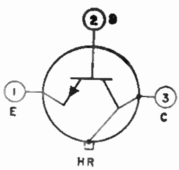

Si n-p-n triple-diffused type subjected to special preconditioning and reliability tests for high-reliability operation in high-power switching and amplifier applications in military and industrial equipment. JEDEC TO-5, Outline No.5. This type is a high-reliability version of type 2N3439.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 450 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 350 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 50 mA, $I_B$ = 0) | $V_{CEO}$(sus) | 350 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 50 mA, $I_B$ = 4 mA) | $V_{CE}$(sat) | 0.5 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 50 mA, $I_B$ = 4 mA) | $V_{BE}$(sat) | 1.3 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 300 V, $I_B$ = 0 | $I_{CEO}$ | 20 max | μA |
| $V_{CE}$ = 450 V, $V_{BE}$ = −1.5 V | $I_{CEV}$ | 500 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 6 V, $I_C$ = 0) | $I_{EBO}$ | 20 max | μA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 20 mA | $h_{FE}$ | 40 to 160 | |
| $V_{CE}$ = 10 V, $I_C$ = 2 mA | $h_{FE}$ | 30 min | |

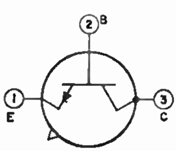



## 1A, 10W — 40390

Si n-p-n triple-diffused type with an attached heat radiator for printed-circuit-board use in high-speed switching and linear amplifier applications such as high-voltage differential and operational amplifiers, high-voltage inverters, and series regulators for industrial and military applications. JEDEC TO-5 (with heat radiator), Outline No.8. This type is identical with type 2N3440 except for the following items:

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 3.5 | W |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |

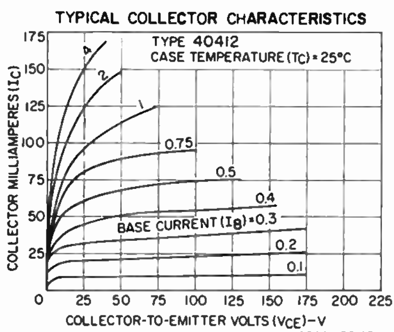


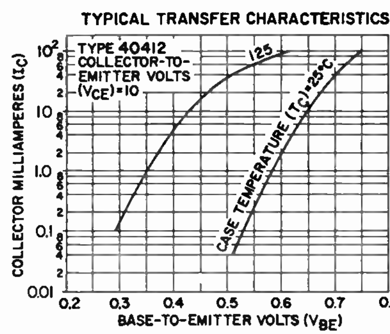

## 1A, 10W — 40412

Si n-p-n triple-diffused type used in high-voltage switching and linear-amplifier applications in military and commercial applications. This type is particularly useful in neon-indicator driver circuits and in differential and operational amplifiers. JEDEC TO-5, Outline No.5.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 10000 Ω) | $V_{CER}$(sus) | 250 | V |
| Collector Current | $I_C$ | 1 | A |
| Base Current | $I_B$ | 0.5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 10 • | W |
| $T_A$ up to 50°C | $P_T$ | 1 • | W |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |



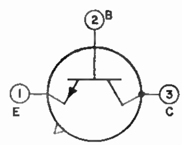



### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 10000 Ω, $I_C$ = 50 mA) | $V_{CER}$(sus) | 250 min | V |
| Collector-Cutoff Current: $R_{BE}$ = 10000 Ω, $V_{CE}$ = 100 V | $I_{CER}$ | 1 max | mA |
| $V_{CE}$ = 150 V, $V_{EB}$ = 1.5 V, $T_C$ = 150°C | $I_{CEV}$ | 2 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 3 V, $I_C$ = 0) | $I_{EBO}$ | 100 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 20 V, $I_C$ = 30 mA) | $h_{FE}$ | 40 min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 10 mA, f = 5 MHz) | $h_{fe}$ | 2 min | |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 10 ■ max | pF |
| Second-Breakdown Collector Current ($V_{CE}$ = 200 V) | $I_{S/b}$ | 50 min | mA |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 15 * max | °C/W |

* This value does not apply to type 40412V1.
■ This value applies only for type 40412.

## 40412V1 1A, 10W




Si n-p-n triple-diffused type used in high-voltage switching and linear-amplifier applications in military and commercial applications. This type is particularly useful in neon-indicator driver circuits and in differential and operational amplifiers. JEDEC TO-5 (with heat radiator), Outline No.8. This type is electrically identical with type 40412 except for the following items:

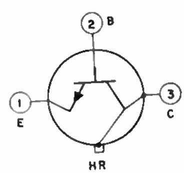
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Transistor Dissipation ($T_A$ up to 25°C) | $P_T$ | 4 | W |

### CHARACTERISTICS

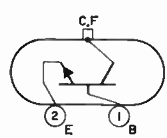
| | | | |
|---|---|---|---|
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 45 max | °C/W |

## 40412V2 1A, 10W




Si n-p-n triple-diffused type used in high-voltage switching and linear-amplifier applications in military and commercial applcations. This type is particularly useful in neon-indicator driver circuits and in differential and operational amplifiers. JEDEC TO-5 (with flange), Outline No.6. See Mounting Hardware for desired mounting arrangement. This type is electrically identical with type 40412.

## 2N3583 2A, 35W

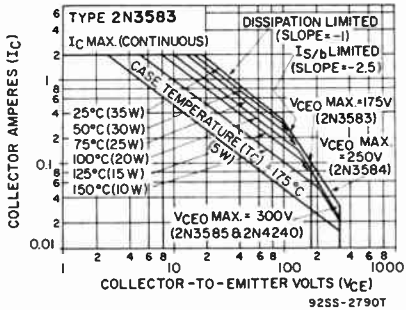



Si n-p-n triple-diffused type used in high-speed-switching and linear-amplifier applications such as high-voltage operational amplifiers, high-voltage switches, switching regulators, converters, inverters, deflection and high-fidelity amplifiers in military, industrial and commercial equipment. JEDEC TO-66, Outline No.25. See Mounting Hardware for desired mounting arrangement.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 250 | V |
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | 175 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 6 | V |
| Collector Current | $I_C$ | 2 | A |
| Peak Collector Current | $i_C$ | 5 | A |
| Base Current | $I_B$ | 1 | A |
| Transistor Dissipation | $P_T$ | See Chart, Maximum DC Operating Areas | |
| Operating Temperature Range | $T_C$(opr) | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 255 | °C |

MAXIMUM DC OPERATING AREAS

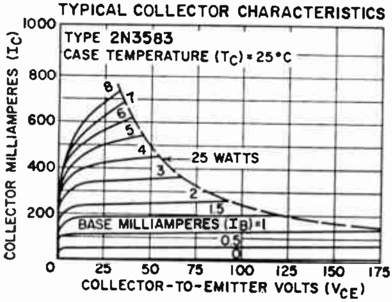



## CHARACTERISTICS (At case temperature = 25°C)

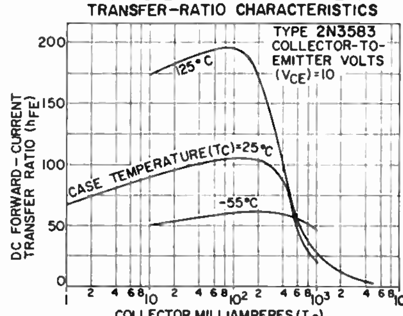
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 200 mA, $I_B$ = 0 | $V_{CEO}$(sus) | 175 min | V |
| $R_{BE}$ = 50 Ω, $I_C$ = 200 mA | $V_{CER}$(sus) | 250 min | V |
| Base-to-Emitter Voltage ($I_C$ = 1 A, $V_{CE}$ = 10 V) | $V_{BE}$ | 1.4 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 150 V, $I_B$ = 0, $T_C$ = 25°C | $I_{CEO}$ | 10 max | mA |
| $V_{BE}$ = −1.5 V, $V_{CE}$ = 225 V, $T_C$ = 25°C | $I_{CEV}$ | 1 max | mA |
| $V_{BE}$ = −1.5 V, $V_{CE}$ = 225 V, $T_C$ = 150°C | $I_{CEV}$ | 3 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 6 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | mA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 100 mA | $h_{FE}$ | 40 min | |
| $V_{CE}$ = 10 V, $I_C$ = 1 A | $h_{FE}$ | 10 min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 200 mA, f = 5 MHz) | $h_{fe}$ | 3 min | |
| Second-Breakdown Collector Current (Base forward-biased from zero up, $V_{CE}$ = 100 V) | $I_{S/b}$ | 350 min | mA |
| Second-Breakdown Energy (Base reverse-biased, $R_{BE}$ = 20 Ω, L = 100 μH, $V_{BE}$ = −4 V) | $E_{S/b}$ | 50 min | μJ |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 120 max | pF |
| Thermal Resistance, Junction-to-Case ($I_C$ = 500 mA) | $\theta_{J-C}$ | 5* max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 70 max | °C/W |

* This value does not apply to type 40374.

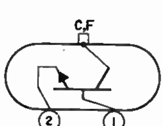
TYPICAL COLLECTOR CHARACTERISTICS




TYPICAL DC FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTICS




## 2A, 35W 2N3584




Si n-p-n triple-diffused type used in high-speed-switching and linear-amplifier applications such as high-voltage operational amplifiers, high-voltage switches, switching regulators, converters, inverters, deflection and high-fidelity amplifiers in military, industrial and commercial equipment. JEDEC TO-66, Outline No.25.

See Mounting Hardware for desired mounting arrangement. For Maximum DC Operating Areas Chart, refer to type 2N3583.

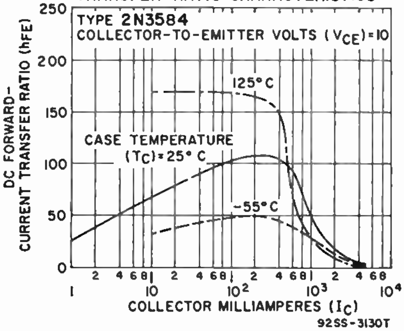
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 375 | V |
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | 250 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 6 | V |
| Collector Current | $I_C$ | 2 | A |
| Peak Collector Current | $i_c$ | 5 | A |
| Base Current | $I_B$ | 1 | A |
| Transistor Dissipation | $P_T$ | See Chart, Maximum DC Operating Areas | |
| Operating Temperature | $T_C$(opr) | —65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 255 | °C |

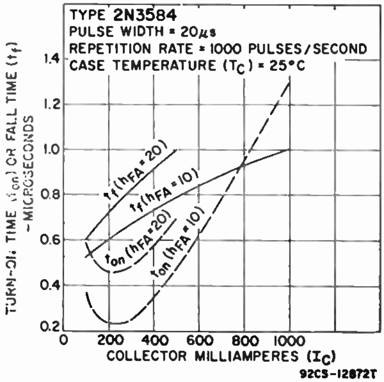
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: $I_C$ = 200 mA, $I_B$ = 0 | $V_{CEO}$(sus) | 250 min | |
| $R_{BE}$ = 50 Ω, $I_C$ = 200 mA | $V_{CER}$(sus) | 300 min | V |
| Base-to-Emitter Voltage ($I_C$ = 1 A, $V_{CE}$ = 10 V) | $V_{BE}$ | 1.4 max | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 1 A, $I_B$ = 125 mA) | $V_{CE}$(sat) | 0.75 max | V |
| Collector-Cutoff Current: $V_{CE}$ = 150 V, $I_B$ = 0, $T_C$ = 25°C | $I_{CEO}$ | 5 max | mA |
| $V_{BE}$ = —1.5 V, $V_{CE}$ = 300 V, $T_C$ = 25°C | $I_{CEV}$ | 1 max | mA |
| $V_{BE}$ = —1.5 V, $V_{CE}$ = 300 V, $T_C$ = 150°C | $I_{CEV}$ | 3 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 6 V, $I_C$ = 0) | $I_{EBO}$ | 0.5 max | mA |
| Static Forward-Current Transfer Ratio: $V_{CE}$ = 10 V, $I_C$ = 1 A | $h_{FE}$ | 25 to 100 | |
| $V_{CE}$ = 10 V, $I_C$ = 100 mA | $h_{FE}$ | 40 min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 200 mA, f = 5 MHz) | $h_{fe}$ | 3 min | |
| Second-Breakdown Collector Current (Base forward-biased from zero up, $V_{CE}$ = 100 V) | $I_{S/b}$ | 350 min | mA |
| Second-Breakdown Energy (Base reverse-biased, $R_{BE}$ = 20 Ω, L = 100 μH, $V_{BE}$ = —4 V) | $E_{S/b}$ | 200 min | μJ |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 120 max | pF |
| Turn-On Time, Saturated Switch ($V_{CC}$ = 30 V, $I_C$ = 1 A, $I_B$ = 100 mA) | $t_d + t_r$ | 3 max | μs |
| Storage Time ($V_{CC}$ = 30 V, $I_C$ = 1 A, $I_B$ = 100 mA) | $t_s$ | 4 max | μs |
| Fall Time ($V_{CC}$ = 30 V, $I_C$ = 1 A, $I_B$ = 100 mA) | $t_f$ | 3 max | μs |
| Thermal Resistance, Junction-to-Case ($I_C$ = 500 mA) | $\theta_{J\text{-}C}$ | 5 max | °C/W |
| Thermal Resistance, Junction-to-Ambient ($I_C$ = 500 mA) | $\theta_{J\text{-}A}$ | 70 max | °C/W |

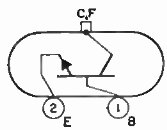
TYPICAL DC FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTICS




TYPICAL TURN-ON TIME AND FALL-TIME CHARACTERISTICS



## 2A, 35W — 2N3585




Si **n-p-n** triple-diffused type used in high-speed-switching and linear-amplifier applications such as high-voltage operational amplifiers, high-voltage switches, switching regulators, converters, inverters, deflection and high-fidelity amplifiers in military, industrial and commercial equipment. JEDEC TO-66, Outline No.25. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N3584 except for the following items:

### MAXIMUM RATINGS

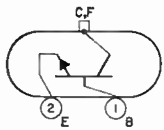
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 500 | V |
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}(sus)$ | 300 | V |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 200 mA, $I_B$ = 0 | $V_{CEO}(sus)$ | 300 min | V |
| $R_{BE}$ = 50 Ω, $I_C$ = 200 mA | $V_{CER}(sus)$ | 400 min | V |
| Collector-Cutoff Current: | | | |
| ($V_{BE}$ = −1.5 V, $V_{CE}$ = 400 V, $T_C$ = 25°C) | $I_{CEV}$ | 1 max | mA |
| Turn-On Time, Saturated Switch ($V_{CC}$ = 30 V, $I_C$ = 1 A, $I_B$ = 100 mA) | $t_d + t_r$ | 2* max | μs |

* This value does not apply to type 2N4240.

## 2A, 35W — 2N4240

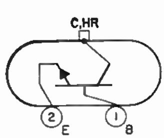



Si **n-p-n** triple-diffused type used in high voltage, high-speed-switching and linear-amplifier applications such as operational amplifiers, switching regulators, converters, inverters, deflection and high-fidelity amplifiers. JEDEC TO-66, Outline No.25. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N3585 except for the following items:

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage ($I_C$ = 750 mA, $I_B$ = 75 mA) | $V_{BE}(sat)$ | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 150 V, $I_B$ = 0 | $I_{CEO}$ | 5 max | mA |
| $V_{CE}$ = 400 V, $V_{BE}$ = −1.5 V | $I_{CEV}$ | 2 max | mA |
| $V_{CE}$ = 300 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C | $I_{CEV}$ | 5 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 750 mA) | $h_{FE}$ | 30 to 150 | |
| Second Breakdown Energy ($R_{BE}$ = 20 Ω, L = 100 μH, $V_{BE}$ = −4 V) | $E_{S/b}$ | 50 min | μJ |

## 2A, 35W — 40374




Si **n-p-n** triple-diffused type with an attached radiator for printed-circuit-board use in high-speed switching and linear amplifier applications such as high-voltage operational amplifiers, high-voltage switches, switching regulators, converters, inverters, deflection and high-fidelity amplifiers in military, industrial, and commercial equipment. JEDEC TO-66 (with heat radiator), Outline No.26. This type is identical with type 2N3583 except for the following item:

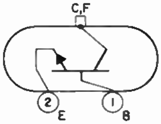
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 30 max | °C/W |

# 2N5239

**5A, 100W**

Si n-p-n multiple epitaxial type used for high-voltage, high-power in linear applications in industrial and commercial service. JEDEC TO-3, Outline No.2. See Mounting Hardware for desired mounting arrangement.

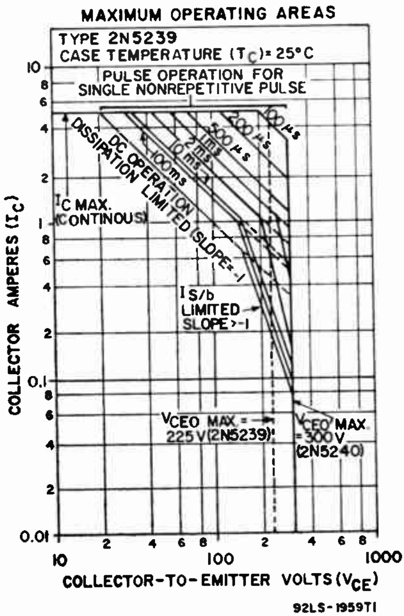


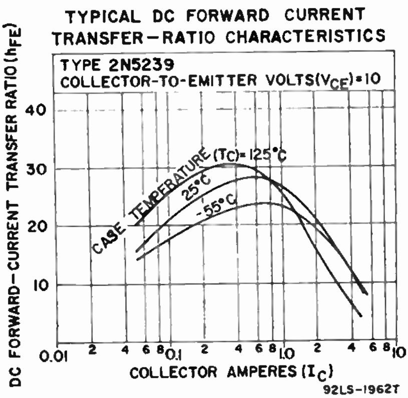

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 330 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $R_{BE} \leq 50\Omega$ | $V_{CER}(sus)$ | 250 | V |
| Base open | $V_{CEO}(sus)$ | 225 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 6 | V |
| Collector Current | $I_C$ | 5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C and $V_{CE}$ up to 150 V | $P_T$ | 100 | W |
| $T_C$ and $T_A$ up to 25°C and $V_{CE}$ above 150 V | | See curve page 300 | |
| $T_C$ and $T_A$ above 25°C and $V_{CE}$ above 150 V | $P_T$ | See Rating Chart | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J(opr)$ | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 230 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C = 0.1$ A, $I_B = 0$ | $V_{CEO}(sus)$ | 225 min | V |
| $I_C = 0.1$ A, $I_B = 0$, $R_{BE} = 50\ \Omega$ | $V_{CER}(sus)$ | 250 min | V |
| Emitter-to-Base Voltage ($I_B = 0.02$ A) | $V_{EBO}$ | 6 min | V |

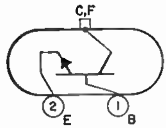


## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Base-to-Emitter Voltage ($V_{CE}$ = 10 V, $I_C$ = 2 A, $t_P \leq$ 350 μs, df = 2%) | $V_{BE}$ | 3 max | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 2 A, $I_B$ = 0.25 A, $t_P \leq$ 350 μs, df = 2%) | $V_{CE}(sat)$ | 2.5 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 200 V, $I_B$ = 0 | $I_{CEO}$ | 5 max | mA |
| $V_{CE}$ = 300 V, $V_{BE}$ = −1.5 V | $I_{CEV}$ | 4 max | mA |
| $V_{CE}$ = 300 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C | $I_{CEV}$ | 5 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | mA |
| Pulsed Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 0.4 A, $t_P \leq$ 350 μs, df = 2% | $h_{FE}$(pulsed) | 20 to 80 | |
| $V_{CE}$ = 10 V, $I_C$ = 2 A, $t_P \leq$ 350 μs, df = 2% | $h_{FE}$(pulsed) | 20 min | |
| Output Capacitance ($V_{CB}$ = 10 V, $I_C$ = 0, f = 1 MHz) | $C_{obo}$ | 150 max | pF |
| Second-Breakdown Collector Current ($V_{CE}$ = 150 V, non-repetitive pulse = 1 s, base forward-biased) | $I_{S/b}$ | 0.67 min | A |
| Second-Breakdown Energy ($V_{EB}$ = 4 V, $I_C$ = 4 A, $R_B$ = 50 Ω, L = 0.5 mH, base reverse-biased) | $E_{S/b}$ | 4 min | mJ |
| Gain-Bandwidth Product ($V_{CE}$ = 10 V, $I_C$ = 0.2 A, f = 1 MHz) | $f_T$ | 5 min | MHz |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 1.75 max | °C/W |

## 5A, 100W 2N5240




Si n-p-n multiple epitaxial type used for high-voltage, high-power in linear applications in industrial and commercial service. JEDEC TO-3, Outline No.2. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N5239 except for the following items:

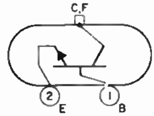
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 375 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $R_{BE} \leq$ 50 Ω | $V_{CER}(sus)$ | 350 | V |
| Base open | $V_{CEO}(sus)$ | 300 | V |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 0.1 A, $I_B$ = 0 | $V_{CEO}(sus)$ | 300 | V |
| $I_C$ = 0.1 A, $I_B$ = 0, $R_{BE}$ = 50 Ω | $V_{CER}(sus)$ | 350 | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 200 V, $I_B$ = 0 | $I_{CEO}$ | 2 max | mA |
| $V_{CE}$ = 375 V, $V_{BE}$ = −1.5 V | $I_{CEV}$ | 2 max | mA |
| $V_{CE}$ = 300 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C | $I_{CEV}$ | 3 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | mA |

## 5A, 100W 2N5838




Si n-p-n multiple epitaxial type used in inverters, deflection circuits, switching regulators, high-voltage bridge amplifiers, ignition circuits, and other high voltage switching applications. JEDEC TO-3, Outline No.2. See Mounting Hardware for desired mounting arrangement.

### MAXIMUM RATINGS

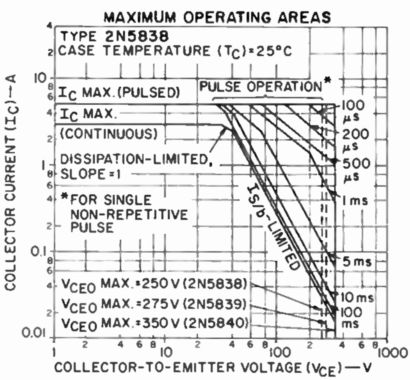
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 275 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| Base open | $V_{CEO}(sus)$ | 250 | V |
| $V_{BE}$ = −1.5 V | $V_{CEV}(sus)$ | 275 | V |
| $R_{BE} \leq$ 50 Ω | $V_{CER}(sus)$ | 275 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 6 | V |
| Collector Current | $I_C$ | 3 | A |
| Peak Collector Current | $i_C$ | 5 | A |
| Base Current | $I_B$ | 1.5 | A |

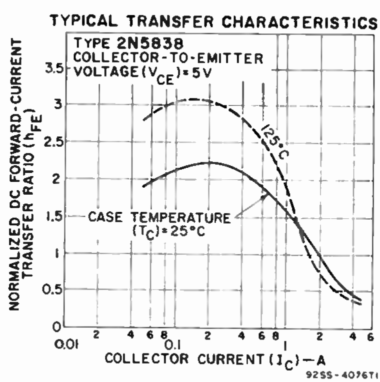
## MAXIMUM RATINGS (cont'd)

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C, $V_{CE}$ up to 40 V | $P_T$ | 100 | W |
| $T_C$ up to 25°C, $V_{CE}$ above 40 V | $P_T$ | See Rating Chart | |
| $T_C$ above 25°C, $V_{CE}$ above 40 V | $P_T$ | See Rating Chart and curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 230 | °C |

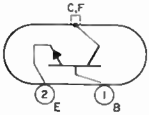
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 0.2 A, $t_p$ ≤ 350 μs, df = 2% | $V_{CEO}$(sus) | 250 min | V |
| $V_{BE}$ = −1.5 V, $I_C$ = 0.1 A, base-emitter junction reverse-biased, $t_p$ ≤ 350 μs, df = 2% | $V_{CEX}$(sus) | 275 min | V |
| $I_C$ = 0.2 A, $R_{BE}$ = 50 Ω, $t_p$ ≤ 350 μs, df = 2% | $V_{CER}$(sus) | 275 min | V |
| Emitter-to-Base Voltage ($I_C$ = 0.02 A) | $V_{EBO}$ | 6 min | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 3 A, $I_B$ = 0.375 A) | $V_{BE}$(sat) | 2 max | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 3 A, $I_B$ = 0.375 A) | $V_{CE}$(sat) | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 200 V | $I_{CEO}$ | 2 max | mA |
| $V_{CE}$ = 265 V, $V_{BE}$ = −1.5 V, base-emitter junction reverse biased | $I_{CEV}$ | 5 max | mA |
| $V_{CE}$ = 265 V, $V_{BE}$ = −1.5 V, base-emitter junction reverse biased, $T_C$ = 100°C | $I_{CEV}$ | 8 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 6 V) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 0.5 A | $h_{FE}$ | 20 min | |
| $V_{CE}$ = 2 V, $I_C$ = 3 A | $h_{FE}$ | 8 to 40 | |
| Magnitude of Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 0.2 A, f = 1 MHz) | $\|h_{fe}\|$ | 5 min | |
| Output Capacitance ($V_{EB}$ = 10 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 150 max | pF |
| Second-Breakdown Collector Current ($V_{CE}$ = 40 V, non-repetitive pulse = 1 s, base forward biased) | $I_{S/b}$ | 2.5 min | A |
| Second-Breakdown Energy ($V_{BE}$ = −4 V, $R_B$ = 50 Ω, L = 100 μH, base reverse biased) | $E_{S/b}$ | 0.45 min | mJ |
| Delay Time ($V_{CC}$ = 200 V, $I_C$ = 3 A, $I_{B1}$ = $I_{B2}$ = 0.375 A) | $t_d$ | 0.06 | μs |
| Rise Time ($V_{CC}$ = 200 V, $I_C$ = 3 A, $I_{B1}$ = $I_{B2}$ = 0.375 A) | $t_r$ | 0.8 typ; 1.5 max | μs |
| Storage Time ($V_{CC}$ = 200 V, $I_C$ = 3 A, $I_{B1}$ = $I_{B2}$ = 0.375 A) | $t_s$ | 1 typ; 3 max | μs |
| Fall Time ($V_{CC}$ = 200 V, $I_C$ = 3 A, $I_{B1}$ = $I_{B2}$ = 0.375 A) | $t_f$ | 0.4 typ; 1.5 max | μs |
| Thermal Resistance, Junction-to-Case ($V_{CE}$ = 10 V, $I_C$ = 5 A) | $\theta_{J-C}$ | 1.75 max | °C/W |



## 5A, 100W 2N5839




Si n-p-n multiple epitaxial type used in inverters, deflection circuits, switching regulators, high-voltage bridge amplifiers, ignition circuits and other high-voltage switching applications. JEDEC TO-3, Outline No.2. See **Mounting Hardware** for desired mounting arrangement. This type is identical with type 2N5838 except for the following items:

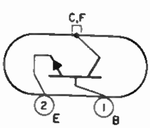
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 300 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| Base open | $V_{CEO}(sus)$ | 275 | V |
| $V_{BE} = -1.5$ V | $V_{CEV}(sus)$ | 300 | V |
| $R_{BE} \leq 50\ \Omega$ | $V_{CER}(sus)$ | 300 | V |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C = 0.2$ A, $t_p \leq 350\ \mu s$, df = 2% | $V_{CEO}(sus)$ | 275 min | V |
| $V_{BE} = -1.5$ V, $I_C = 0.1$ A, base-emitter junction reverse biased, $t_p \leq 350\ \mu s$, df = 2% | $V_{CEX}(sus)$ | 300 min | V |
| $I_C = 0.2$ A, $R_{BE} = 50\ \Omega$, $t_p \leq 350\ \mu s$, df = 2% | $V_{CER}(sus)$ | 300 min | V |
| Base-to-Emitter Saturation Voltage ($I_C = 2$ A, $I_B = 0.2$ A) | $V_{BE}(sat)$ | 2 max | V |
| Collector-to-Emitter Saturation Voltage ($I_C = 2$ A, $I_B = 0.2$ A) | $V_{CE}(sat)$ | 1.5 | V |
| Collector-Cutoff Current: | | | |
| $V_{CE} = 250$ V | $I_{CEO}$ | 2 max | mA |
| $V_{CE} = 290$ V, $V_{BE} = -1.5$ V, base-emitter junction reverse biased | $I_{CEV}$ | 2 max | mA |
| $V_{CE} = 290$ V, $V_{BE} = -1.5$ V, base-emitter junction reverse biased, $T_C = 100°C$ | $I_{CEV}$ | 5 max | mA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE} = 5$ V, $I_C = 0.5$ A | $h_{FE}$ | 20 min | |
| $V_{CE} = 3$ V, $I_C = 2$ A | $h_{FE}$ | 10 to 50 | |
| Delay Time ($V_{CC} = 200$ V, $I_C = 2$ A, $I_{B1} = I_{B2} = 0.2$ A) | $t_d$ | 0.07 | μs |
| Rise Time ($V_{CC} = 200$ V, $I_C = 2$ A, $I_{B1} = I_{B2} = 0.2$ A) | $t_r$ | 0.6 typ; 1.5 max | μs |
| Storage Time ($V_{CC} = 200$ V, $I_C = 2$ A, $I_{B1} = I_{B2} = 0.2$ A) | $t_s$ | 1.75 typ; 3.75 max | μs |
| Fall Time ($V_{CC} = 200$ V, $I_C = 2$ A, $I_{B1} = I_{B2} = 0.2$ A) | $t_f$ | 0.35 typ; 1.5 max | μs |

## 5A, 100W 2N5840




Si n-p-n multiple epitaxial type used in inverters, deflection circuits, switching regulators, high-voltage bridge amplifiers, ignition circuits, and other high-voltage switching applications. JEDEC TO-3, Outline No.2. See **Mounting Hardware** for desired mounting arrangement. This type is identical with type 2N5838 except for the following items:

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 375 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| Base open | $V_{CEO}(sus)$ | 350 | V |
| $V_{BE} = -1.5$ V | $V_{CEV}(sus)$ | 375 | V |
| $R_{BE} \leq 50\ \Omega$ | $V_{CER}(sus)$ | 375 | V |

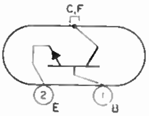
### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C = 0.2$ A, $t_p \leq 350\ \mu s$, df = 2% | $V_{CEO}(sus)$ | 350 min | V |
| $V_{BE} = -1.5$ V, $I_C = 0.1$ A, base-emitter junction reverse biased, $t_p \leq 350\ \mu s$, df = 2% | $V_{CEX}(sus)$ | 375 min | V |
| $I_C = 0.2$ A, $R_{BE} = 50\ \Omega$, $t_p \leq 350\ \mu s$, df = 2% | $V_{CER}(sus)$ | 375 min | V |

### CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Base-to-Emitter Saturation Voltage ($I_C$ = 2 A, $I_B$ = 0.2 A) | $V_{BE}$(sat) | 2 max | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 2 A, $I_B$ = 0.2 A) | $V_{CE}$(sat) | 1.5 | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 250 V | $I_{CEO}$ | 2 max | mA |
| $V_{CE}$ = 360 V, $V_{BE}$ = −1.5 V, base-emitter junction reverse biased | $I_{CEV}$ | 2 max | mA |
| $V_{CE}$ = 360 V, $V_{BE}$ = −1.5 V, base-emitter junction reverse biased, $T_C$ = 100°C | $I_{CEV}$ | 5 max | mA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 0.5 A | $h_{FE}$ | 20 min | |
| $V_{CE}$ = 3 V, $I_C$ = 2 A | $h_{FE}$ | 10 to 50 | |
| Delay Time ($V_{CC}$ = 200 V, $I_C$ = 2 A, $I_{B1}$ = $I_{B2}$ = 0.2 A) | $t_d$ | 0.07 | μs |
| Rise Time ($V_{CC}$ = 200 V, $I_C$ = 2 A, $I_{B1}$ = $I_{B2}$ = 0.2 A) | $t_r$ | 0.6 typ; 1.75 max | μs |
| Storage Time ($V_{CC}$ = 200 V, $I_C$ = 2 A, $I_{B1}$ = $I_{B2}$ = 0.2 A) | $t_s$ | 1.75 typ; 3 max | μs |
| Fall Time ($V_{CC}$ = 200 V, $I_C$ = 2 A, $I_{B1}$ = $I_{B2}$ = 0.2 A) | $t_f$ | 0.35 typ; 1.5 max | μs |

## 2N5804 8A, 110W




Si n-p-n triple-diffused type used for power-switching circuits, switching regulators, converters, inverters, and power amplifiers. JEDEC TO-3, Outline No.2. See Mounting Hardware for desired mounting arrangement.

### MAXIMUM RATINGS

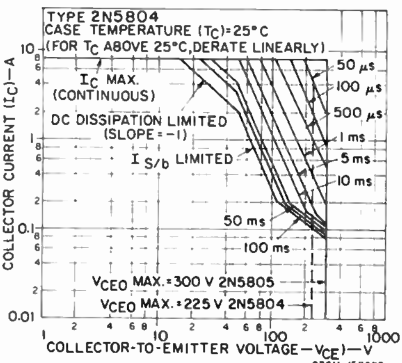
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 300 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE}$ = −1.5 V, $R_{BE}$ = 50 Ω | $V_{CEX}$(sus) | 300 | V |
| Base open | $V_{CEO}$(sus) | 225 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 6 | V |
| Collector Current | $I_C$ | 5 | A |
| Base Current | $I_B$ | 2 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C, $V_{CE}$ up to 50 V | $P_T$ | 110 | W |
| $T_C$ up to 25°C, $V_{CE}$ above 50 V | $P_T$ | See Rating Chart | |
| $T_C$ above 25°C, $V_{CE}$ above 50 V | $P_T$ | See Rating Chart and curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 230 | °C |

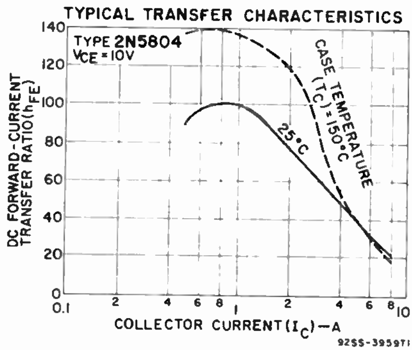
### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 0.2 A, $I_B$ = 0 | $V_{CEO}$(sus) | 225 min | V |
| $V_{BE}$ = −1.5 V, $I_C$ = 0.2 A, $R_{BE}$ = 50 Ω, $t_p$ = 8.33 ms, df = 50% | $V_{CEX}$(sus) | 300 min | V |
| Emitter-to-Base Voltage ($I_B$ = 0.03 A) | $V_{EBO}$ | 6 min | V |
| Base-to-Emitter Saturation Voltage ($V_{CE}$ = 10 V, $I_C$ = 5 A, $I_B$ = 0.5 A, $t_p$ ≦ 350 μs, df = 2%) | $V_{BE}$(sat) | 2 max | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 5 A, $I_B$ = 0.5 A, $t_p$ ≦ 350 μs, df = 2%) | $V_{CE}$(sat) | 2 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 150 V, $I_B$ = 0 | $I_{CEO}$ | 15 max | mA |
| $V_{CE}$ = 270 V, $V_{BE}$ = −1.5 V, base-emitter junction reverse biased | $I_{CEV}$ | 5 max | mA |
| $V_{CE}$ = 270 V, $V_{BE}$ = −1.5 V, base-emitter junction reverse biased, $T_C$ = 100°C | $I_{CEV}$ | 15 max | mA |
| $V_{CE}$ = 300 V, $R_{BE}$ = 50 Ω | $I_{CER}$ | 15 max | mA |
| Emitter-Cutoff Current: | | | |
| $V_{EB}$ = 6 V, $I_C$ = 0 | $I_{EBO}$ | 30 max | mA |
| $V_{EB}$ = 5 V, $I_C$ = 0 | $I_{EBO}$ | 5 max | mA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 0.5, $t_p$ ≦ 350 μs, df = 2% | $h_{FE}$(pulsed) | 25 to 250 | |
| $V_{CE}$ = 4 V, $I_C$ = 5 A | $h_{FE}$ | 10 to 100 | |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 450 | pF |

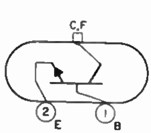
## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Second-Breakdown Collector Current ($V_{CE}$ = 50 V, base forward-biased, non-repetitive pulse = 1 s) | $I_{S/b}$ | 2.2 min | A |
| Second-Breakdown Energy ($V_{EB}$ = −4 V, $I_C$ = 5 A, $R_B$ = 20 Ω, L = 50 μH, base reverse-biased) | $E_{S/b}$ | 0.62 min | mJ |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 1 A, f = 5 MHz) | $h_{fe}$ | 3 min | |
| Turn-On Time ($V_{CE}$ = 200 V, $I_C$ = 5 A, $I_B$ = 0.5 A) | $t_d + t_r$ | 0.5 max | μs |
| Storage Time ($V_{CE}$ = 200 V, $I_C$ = 5 A, $I_B$ = 0.5 A) | $t_s$ | 3.5 max | μs |
| Fall Time ($V_{CE}$ = 200 V, $I_C$ = 5 A, $I_B$ = 0.5 A) | $t_f$ | 2 max | μs |
| Thermal Resistance, Junction-to-Case ($V_{CE}$ = 10 V, $I_C$ = 5 A) | $\theta_{J-C}$ | 1.6 max | °C/W |




## 8A, 110W 2N5805




Si n-p-n triple-diffused type used for power-switching circuits, switching regulators, converters, inverters, and power amplifiers. JEDEC TO-3, Outline No.2. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N5804 except for the following items:

## MAXIMUM RATINGS

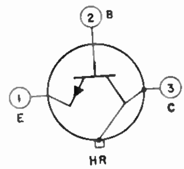
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 375 | V |
| Collector-to-Emitter Sustaining Voltage: $V_{BE}$ = −1.5 V, $R_{BE}$ = 50 Ω | $V_{CEX}$(sus) | 375 | V |
| Base open | $V_{CEO}$(sus) | 300 | V |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: $I_C$ = 0.2 A, $I_B$ = 0 | $V_{CEO}$(sus) | 300 min | V |
| $V_{BE}$ = −1.5 V, $I_C$ = 0.2 A, $I_B$ = 0, $R_{BE}$ = 50 Ω, $t_p$ = 8.33 ms, df = 2% | $V_{CEX}$(sus) | 375 min | V |
| Collector-Cutoff Current: $V_{CE}$ = 150 V, $I_B$ = 0 | $I_{CEO}$ | 5 max | mA |
| $V_{CE}$ = 340 V, $V_{BE}$ = −1.5 V | $I_{CEV}$ | 5 max | mA |
| $V_{CE}$ = 340 V, $V_{BE}$ = −1.5 V, $T_C$ = 100°C | $I_{CEV}$ | 15 max | mA |
| $V_{CE}$ = 375 V, $R_{BE}$ = 50 Ω | $I_{CER}$ | 15 max | mA |

# *High-Speed N-P-N (Switching) Types*

## 40389 1A, 3.5W




Si n-p-n triple-diffused planar type with an attached heat radiator for printed-circuit-board use in a wide variety of small-signal, medium-power applications (up to 20 MHz) in commercial and industrial equipment. JEDEC TO-5 (with heat radiator), Outline No.8. This type is identical with type 2N3053 except for the following items:

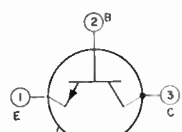
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 3.5 | W |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 50 max | °C/W |

## 2N699 1A, 5W




Si n-p-n planar triple-diffused-base type used in small-signal and medium-power applications in rf amplifier, mixer, oscillator and converter service and in power applications in small-signal af amplifiers and switching circuits in industrial and military equipment. JEDEC TO-5, Outline No.5.

### MAXIMUM RATINGS

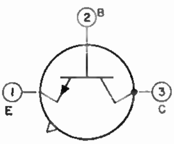
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 120 | V |
| Collector-to-Emitter Voltage ($R_{BE} \leqq 10\ \Omega$) | $V_{CER}$ | 80 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.6 | W |
| $T_C$ up to 25°C | $P_T$ | 2 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 175 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 120 min | V |
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 10 Ω, $I_C$ = 100 mA, tp ≦ 300 μs, df ≦ 2%) | $V_{CER}$(sus) | 80 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA, tp ≦ 300 μs, df ≦ 2%) | $V_{CE}$(sat) | 5 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA, tp ≦ 300 μs, df ≦ 2%) | $V_{BE}$(sat) | 1.3 max | V |
| Collector-Cutoff Current ($V_{CB}$ = 60 V, $I_E$ = 0) | $I_{CBO}$ | 2 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 2 V, $I_C$ = 0) | $I_{EBO}$ | 100 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 150 mA, tp ≦ 300 μs, df ≦ 2%) | $h_{FE}$ | 40 to 120 | |
| Small-Signal Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 1 mA, f = 1 kHz | $h_{fe}$ | 35 to 100 | |
| $V_{CE}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz | $h_{fe}$ | 45 min | |
| $V_{CE}$ = 10 V, $I_C$ = 50 mA, f = 20 MHz | $h_{fe}$ | 2.5 min | |
| Gain-Bandwidth Product | $f_T$ | 50 min | MHz |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0) | $C_{obo}$ | 20 max | pF |

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Small-Signal Short-Circuit Impedance: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 1 mA, f = 1 kHz | $h_{ib}$ | 30 max | Ω |
| $V_{CE}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz | $h_{ib}$ | 10 max | Ω |
| Voltage-Feedback Ratio: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 1 mA, f = 1 kHz | $h_{rb}$ | $2.5 \times 10^{-4}$ max | |
| $V_{CE}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz | $h_{rb}$ | $3 \times 10^{-4}$ max | |
| Output Conductance: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 1 mA, f = 1 kHz | $h_{ob}$ | 0.5 max | μmho |
| $V_{CE}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz | $h_{ob}$ | 1 max | μmho |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 75 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 250 max | °C/W |




## 1A, 5W — 2N1613

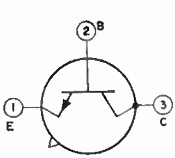
Si **n-p-n planar** type used in small-signal and medium-power applications in industrial and military equipment. JEDEC TO-5, Outline No.5. This type is identical with type 2N2102 except for the following items:

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 75 | V |
| Collector-to-Emitter Voltage ($R_{BE} \leqq 10\ \Omega$) | $V_{CER}$ | 50 | V |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.8 | W |
| $T_C$ up to 25°C | $P_T$ | 3 | W |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 265 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 75 min | V |
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $R_{BE}$ = 10 Ω, $t_p$ = 300 μs, df = 1.8%) | $V_{CER}(sus)$ | 50 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA, $t_p$ = 300 μs, df = 1.8%) | $V_{CE}(sat)$ | 1.5 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA, $t_p$ = 300 μs, df = 1.8%) | $V_{BE}(sat)$ | 1.3 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 60 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | 0.01 max | μA |
| $V_{CB}$ = 60 V, $I_E$ = 0, $T_A$ = 150°C | $I_{CBO}$ | 10 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 0.01 max | μA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 0.1 mA, $T_A$ = 25°C | $h_{FE}$ | 20 min | |
| $V_{CE}$ = 10 V, $I_C$ = 150 mA, $T_A$ = 25°C, $t_p$ = 300 μs, df = 1.8% | $h_{FE}$ | 40 to 120 | |
| $V_{CE}$ = 10 V, $I_C$ = 10 mA, $T_A$ = −55°C, $t_p$ = 300 μs, df = 1.8% | $h_{FE}$ | 20 min | |
| Small-Signal Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 1 mA, f = 1 kHz | $h_{fe}$ | 30 to 100 | |
| $V_{CE}$ = 10 V, $I_C$ = 50 mA, f = 20 MHz | $h_{fe}$ | 3 min | |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0) | $C_{obo}$ | 25 max | pF |
| Noise Figure ($V_{CE}$ = 10 V, $I_C$ = 0.3 mA, f = 1 kHz, $R_G$ = 510 Ω, circuit bandwidth = 1 Hz) | NF | 12 max | dB |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 58.3 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 219 max | °C/W |




## 1A, 5W — 2N1711

Si **n-p-n triple-diffused planar** type used in a wide variety of small-signal and medium-power applications in military and industrial equipment. It features exceptionally low noise characteristics. JEDEC TO-5, Outline No.5.

### MAXIMUM RATINGS

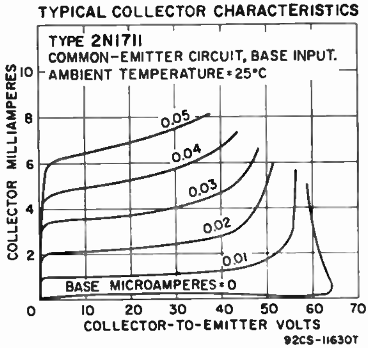
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 75 | V |
| Collector-to-Emitter Voltage ($R_{BE} \leqq 10\ \Omega$) | $V_{CER}$ | 50 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |

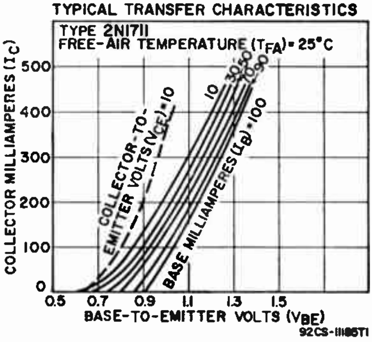
## MAXIMUM RATINGS (cont'd)

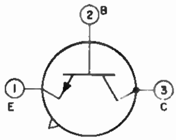
| | | | |
|---|---|---|---|
| Collector Current | $I_C$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.8 | W |
| $T_C$ up to 25°C | $P_T$ | 3 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | —65 to 200 | °C |
| Storage | $T_{STG}$ | —65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 300 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 75 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 7 min | V |
| Collector-to-Emitter Reach-Through Voltage ($V_{BE}$ (fl) = —1.5 V, $I_C$ = 0.1 mA) | $V_{RT}$ | 75 min | V |
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 10 Ω, $I_C$ = 100 mA, $t_p$ = 300 μs, df = 1.8%) | $V_{CER}$(sus) | 50 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA) | $V_{CE}$(sat) | 1.5 max | V |
| Base-to-Emitter Voltage Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA) | $V_{BE}$(sat) | 1.3 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 60 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | 0.01 max | μA |
| $V_{CB}$ = 60 V, $I_E$ = 0, $T_A$ = 150°C | $I_{CBO}$ | 10 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 0.005 max | μA |
| Pulsed Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 10 mA, $t_p$ = 300 μs, df = 1.8%) | $h_{FE}$(pulsed) | 75min | |
| $V_{CE}$ = 10 V, $I_C$ = 150 mA, $t_p$ = 300 μs, df = 1.8% | $h_{FE}$(pulsed) | 100 to 300 | |
| $V_{CE}$ = 10 V, $I_C$ = 500 mA, $t_p$ = 300 μs, df = 1.8%) | $h_{FE}$(pulsed) | 40 min | |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 0.01 mA, $T_C$ = 25°C | $h_{FE}$ | 20 min | |
| $V_{CE}$ = 10 V, $I_C$ = 0.1 mA, $T_C$ = 25°C | $h_{FE}$ | 35 min | |
| $V_{CE}$ = 10 V, $I_C$ = 10 mA, $T_C$ = —55°C | $h_{FE}$ | 35 min | |
| Small-Signal Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 1 mA, f = 1 kHz | $h_{fe}$ | 50 to 200 | |
| $V_{CE}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz | $h_{fe}$ | 70 to 300 | |
| $V_{CE}$ = 10 V, $I_C$ = 50 mA, f = 20 MHz | $h_{fe}$ | 3.5 min | |
| Input Capacitance ($V_{EB}$ = 0.5 V, $I_C$ = 0) | $C_{ibo}$ | 80 max | pF |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0) | $C_{obo}$ | 25 max | pF |
| Noise Figure ($V_{CE}$ = 10 V, $I_C$ = 0.3 mA, $R_G$ = 50Ω, f = 1 kHz, circuit bandwidth = 1 Hz) | NF | 8 max | dB |
| Input Resistance ($V_{CB}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz) | $h_{ib}$ | 4 to 8 | Ω |
| Voltage-Feedback Ratio ($V_{CB}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz) | $h_{rb}$ | 5 x $10^{-4}$ max | |
| Output Conductance ($V_{CB}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz) | $h_{ob}$ | 0.1 to 1 | μmho |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 58.3 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 219 max | °C/W |






## 1A, 5W 2N1893

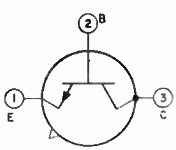
Si n-p-n triple-diffused planar type used in small-signal and medium-power applications in industrial and military equipment. JEDEC TO-5, Outline No.5. This type is identical with type 2N2405 except for the following items:

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 120 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $R_{BE} \leqq 10\ \Omega$ | $V_{CER}$(sus) | 100 | V |
| Base open | $V_{CEO}$(sus) | 80 | V |
| Collector-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 0.5 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.8 | W |
| $T_C$ up to 25°C | $P_T$ | 3 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C = 30$ mA, $I_B = 0$, $t_p = 300\ \mu$s, df = 1.8% | $V_{CEO}$(sus) | 80 min | V |
| $I_C = 100$ mA, $R_{BE} = 10\ \Omega$, $t_p = 300\ \mu$s, df = 1.8% | $V_{CER}$(sus) | 100 min | V |
| Collector-to-Emitter Saturation Voltage: | | | |
| $I_C = 150$ mA, $I_B = 15$ mA | $V_{CE}$(sat) | 5 max | V |
| $I_C = 50$ mA, $I_B = 5$ mA | $V_{CE}$(sat) | 1.2 max | V |
| Base-to-Emitter Saturation Voltage ($I_C = 150$ mA, $I_B = 15$ mA) | $V_{BE}$(sat) | 1.3 max | V |
| Collector-Cutoff Current ($V_{CB} = 90$ V, $I_E = 0$, $T_C = 150$°C) | $I_{CBO}$ | 15 max | $\mu$A |
| Small-Signal Forward-Current Transfer Ratio: | | | |
| $V_{CB} = 5$ V, $I_C = 1$ mA, f = 1 kHz | $h_{fe}$ | 30 to 100 | |
| $V_{CE} = 10$ V, $I_C = 5$ mA, f = 1 kHz | $h_{fe}$ | 20 min | |
| $V_{CB} = 10$ V, $I_C = 50$ mA, f = 20 MHz | $h_{fe}$ | 2.5 min | |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE} = 10$ V, $I_C = 0.1$ mA | $h_{FE}$ | 20 min | |
| $V_{CE} = 10$ V, $I_C = 10$ mA, $T_C = -55$°C | $h_{FE}$ | 45 min | |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE} = 10$ V, $I_C = 150$ mA, $t_p = 300\ \mu$s, df = 1.8%) | $h_{FE}$ (pulsed) | 40 to 120 | |
| Gain-Bandwidth Product | $f_T$ | 50 min | MHz |
| Input Capacitance ($V_{EB} = 0.5$ V, $I_C = 0$) | $C_{ibo}$ | 85 max | pF |
| Input Resistance ($V_{CB} = 5$ V, $I_C = 1$ mA, f = 1 kHz) | $h_{ib}$ | 20 to 30 | $\Omega$ |
| Voltage-Feedback Ratio: | | | |
| $V_{CB} = 5$ V, $I_C = 1$ mA, f = 1 kHz | $h_{rb}$ | $1.25 \times 10^{-4}$ max | |
| $V_{CB} = 10$ V, $I_C = 5$ mA, f = 1 kHz | $h_{rb}$ | $1.5 \times 10^{-4}$ max | |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 58.3 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 219 max | °C/W |




## 1A, 5W 2N2102

Si n-p-n triple-diffused planar type used in small-signal and medium-power applications in industrial and military equipment. This type features exceptionally low-noise low-leakage characteristics, high switching speed, and high pulse $h_{FE}$. JEDEC TO-5, Outline No.5.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 120 | V |
| Collector-to-Emitter Voltage: | | | |
| $R_{BE} \leqq 10\ \Omega$ | $V_{CER}$ | 80 | V |
| Base open | $V_{CEO}$ | 65* | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |

## MAXIMUM RATINGS (cont'd)

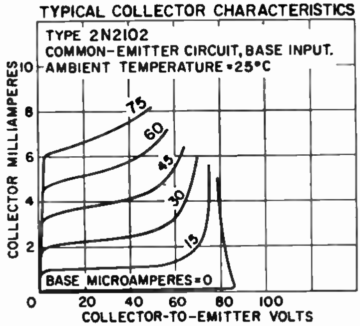
| | | | |
|---|---|---|---|
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 300 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 300 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

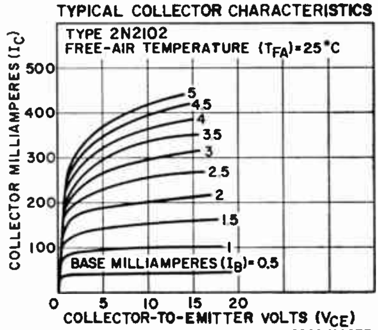
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 120 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 7 min | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 100 mA, $R_{BE}$ = 10 Ω, $t_p$ = 300 μs, df = 1.8% | $V_{CER}$(sus) | 80 min | V |
| $I_C$ = 100 mA, $I_B$ = 0, $t_p$ = 300 μs, df = 1.8% | $V_{CEO}$(sus) | 65* min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA, $t_p$ = 300 μs, df = 1.8%) | $V_{CE}$(sat) | 0.5 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA, $t_p$ = 300 μs, df = 1.8%) | $V_{BE}$(sat) | 1.1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 60 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | 0.002 max | μA |
| $V_{CB}$ = 60 V, $I_E$ = 0, $T_A$ = 150°C | $I_{CBO}$ | 2 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 0.005 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CB}$ = 10 V, $I_C$ = 0.01 mA, $T_C$ = 25°C) | $h_{FE}$ | 10* min | |
| Pulsed Static Forward-Current Transfer Ratio | | | |
| $V_{CE}$ = 10 V, $I_C$ = 150 mA, $T_C$ = 25°C, $t_p$ = 300 μs, df = 1.8% | $h_{FE}$(pulsed) | 40 to 120 | |
| $V_{CE}$ = 10 V, $I_C$ = 1 A, $T_C$ = 25°C, $t_p$ = 300 μs, df = 1.8% | $h_{FE}$(pulsed) | 10* min | |
| $V_{CE}$ = 10 V, $I_C$ = 10 mA, $T_C$ = −55°C, $t_p$ = 300 μs, df = 1.8% | $h_{FE}$(pulsed) | 20 min | |
| Small-Signal Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 1 mA, f = 1 kHz | $h_{fe}$ | 40 to 125 | |
| $V_{CE}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz | $h_{fe}$ | 45 to 190 | |
| $V_{CE}$ = 10 V, $I_C$ = 50 mA, f = 20 MHz | $h_{fe}$ | 6 min | |
| Input Capacitance ($V_{EB}$ = 0.5 V, $I_C$ = 0) | $C_{ibo}$ | 80 max | pF |
| Output Capacitance ($V_{CB}$ = 10 V, $I_C$ = 0) | $C_{obo}$ | 15 max | pF |
| Input Resistance: | | | |
| $V_{CB}$ = 5 V, $I_C$ = 1 mA, f = 1 kHz | $h_{ib}$ | 24 to 34 | Ω |
| $V_{CB}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz | $h_{ib}$ | 4 to 8 | Ω |
| Small-Signal Reverse-Voltage (Feedback) Transfer Ratio: | | | |
| $V_{CB}$ = 5 V, $I_C$ = 1 mA, f = 1 kHz | $h_{rb}$ | 3 x $10^{-4}$ max | |
| $V_{CB}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz | $h_{rb}$ | 3 x $10^{-4}$ max | |
| Output Conductance: | | | |
| $V_{CB}$ = 5 V, $I_C$ = 1 mA, f = 1 kHz | $h_{ob}$ | 0.1 to 0.5 | μmho |
| $V_{CB}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz | $h_{ob}$ | 0.1 to 1 | μmho |
| Noise Figure ($V_{CE}$ = 10 V, $I_C$ = 0.3 mA, f = 1 kHz, $R_G$ = 510 Ω, circuit bandwidth = 1 Hz) | NF | 6 max | dB |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 35 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 175 max | °C/W |

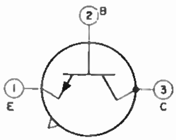
* This value applies only to type 2N2102.

TYPICAL COLLECTOR CHARACTERISTICS




TYPICAL COLLECTOR CHARACTERISTICS






## 1A, 5W

# 2N2270

Si n-p-n triple-diffused planar type used in rf-amplifiers, mixers, oscillators, and converters, and in af small-signal and power amplifiers. JEDEC TO-5, Outline No.5.

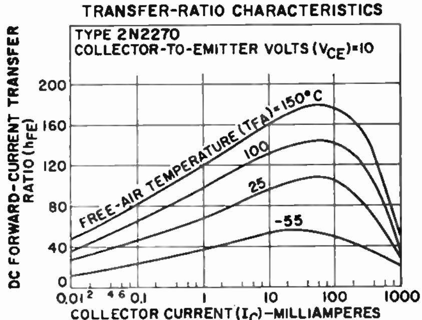
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 60 | V |
| Collector-to-Emitter Voltage: | | | |
| $R_{BE} \leq 10\ \Omega$ | $V_{CER}$ | 60 | V |
| Base open | $V_{CEO}$ | 45 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | —65 to 200 | °C |
| Storage | $T_{STG}$ | —65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

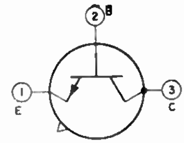
### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 60 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 7 min | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 100 mA, $t_p$ = 300 $\mu$s, df = 1.8% | $V_{CEO}$(sus) | 45 min | V |
| $I_C$ = 100 mA, $R_{BE}$ = 10 $\Omega$, $t_p$ = 300 $\mu$s, df = 1.8% | $V_{CER}$(sus) | 60 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA) | $V_{CE}$(sat) | 0.9 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA) | $V_{BE}$(sat) | 1.2 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 60 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 0.1 max | $\mu$A |
| $V_{CB}$ = 60 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 50 max | $\mu$A |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 0.1 max | $\mu$A |
| Pulsed Static Forward-Current Transfer Ratio: ($V_{CE}$ = 10 V, $I_C$ = 150 mA, $t_p$ = 300 $\mu$s, df = 1.8%) | $h_{FE}$(pulsed) | 50 to 200 | |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 1 mA) | $h_{FE}$ | 35 min | |
| Small-Signal Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz | $h_{fe}$ | 30 to 180 | |
| $V_{CE}$ = 10 V, $I_C$ = 50 mA, f = 20 MHz | $h_{fe}$ | 3 min | |
| Input Capacitance ($V_{EB}$ = 0.5 V, $I_C$ = 0) | $C_{ibo}$ | 80 max | pF |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0) | $C_{obo}$ | 15 max | pF |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 35 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 175 max | °C/W |

TYPICAL DC FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTICS



# 2N2405 1A, 5W




Si n-p-n triple-diffused planar type used in small-signal and medium power applications in industrial and military equipment. JEDEC TO-5, Outline No.5.

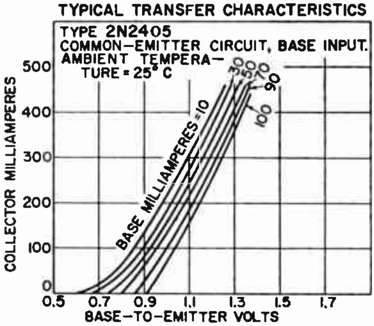
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage: | | | |
| $V_{BE} = -1.5$ V | $V_{CBV}$* | 120 | V |
| Emitter open | $V_{CBO}$ | 120 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $R_{BE} \leqq 500$ | $V_{CER}$* (sus) | 120 | V |
| $R_{BE} \leqq 10$ | $V_{CER}$ (sus) | 140 | V |
| Base open | $V_{CEO}$ (sus) | 90 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating ($T_J$) and Storage ($T_{STG}$) | | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

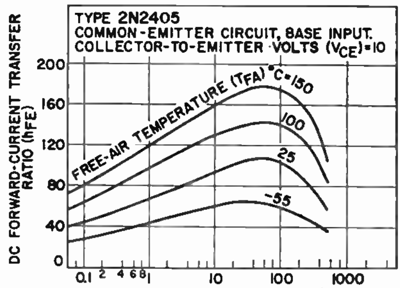
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 120 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.01 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 7 min | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 100 mA, $I_B$ = 0, $t_p$ = 300 μs, df = 1.8% | $V_{CEO}$ (sus) | 90 min | V |
| $I_C$ = 30 mA, $I_B$ = 0, $t_p$ = 300 μs, df = 1.8% | $V_{CEO}$ (sus) | 90 min | V |
| $I_C$ = 100 mA, $R_{BE}$ = 10 Ω, $t_p$ = 300 μs, df = 1.8% | $V_{CER}$ (sus) | 140 min | V |
| $I_C$ = 100 mA, $R_{BE}$ = 500 Ω, $t_p$ = 300 μs, df = 1.8% | $V_{CER}$ (sus) | 120 min | V |
| Collector-to-Emitter Saturation Voltage: | | | |
| $I_C$ = 150 mA, $I_B$ = 15 mA | $V_{CE}$ (sat) | 0.5 max | V |
| $I_C$ = 50 mA, $I_B$ = 5 mA | $V_{CE}$ (sat) | 0.2 max | V |
| Base-to-Emitter Saturation Voltage: | | | |
| $I_C$ = 150 mA, $I_B$ = 15 mA | $V_{BE}$ (sat) | 1.1 max | V |
| $I_C$ = 50 mA, $I_B$ = 5 mA | $V_{BE}$ (sat) | 0.9 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 90 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 0.01 max | μA |
| $V_{CB}$ = 90 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 10 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 0.01 max | μA |
| Small-Signal Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 5 mA, f = 1 kHz | $h_{fe}$ | 50 to 275 | |
| $V_{CE}$ = 10 V, $I_C$ = 50 mA, f = 20 MHz | $h_{fe}$ | 6 min | |
| Pulsed Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 500 mA, $T_A$ = 25°C, $t_p$ = 300 μs, df = 1.8% | $h_{FE}$ (pulsed) | 25 min | |
| $V_{CE}$ = 10 V, $I_C$ = 150 mA, $T_A$ = 25°C, $t_p$ = 300 μs, df = 1.8% | $h_{FE}$ (pulsed) | 60 to 200 | |

TYPICAL TRANSFER CHARACTERISTICS




92CS-11685T1

TYPICAL DC FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTICS

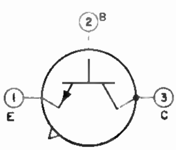



92CS-11648T

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 10 mA, $T_A$ = 25°C | $h_{FE}$ | 35 min | |
| $V_{CE}$ = 10 V, $I_C$ = 10 mA, $T_A$ = −55°C | $h_{FE}$ | 20 min | |
| Input Resistance: | | | |
| $V_{CB}$ = 5 V, $I_C$ = 1 mA, f = 1 kHz | $h_{ib}$ | 24 to 34 | Ω |
| $V_{CB}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz | $h_{ib}$ | 4 to 8 | Ω |
| Voltage-Feedback Ratio: | | | |
| $V_{CB}$ = 5 V, $I_C$ = 1 mA, f = 1 kHz | $h_{rb}$ | 3 x $10^{-4}$ | |
| $V_{CB}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz | $h_{rb}$ | 3 x $10^{-4}$ | |
| Output Conductance: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 1 mA, f = 1 kHz | $h_{ob}$ | 0.5 max | μmho |
| $V_{CE}$ = 10 V, $I_C$ = 5 mA, f = 1 kHz | $h_{ob}$ | 0.5 max | μmho |
| Noise Figure ($V_{CB}$ = 10 V, $I_C$ = 0.3 mA, $R_G$ = 500 Ω, BW = 15 kHz, reference signal frequency = 1 kHz | NF* | 6 max | dB |
| Input Capacitance ($V_{EB}$ = 0.5 V, $I_C$ = 0) | $C_{ibo}$ | 80 max | pF |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0) | $C_{obo}$ | 15 max | pF |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 35 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 175 max | °C/W |

* This value does not apply to type 2N1893.



## 1A, 5W 2N2895

Si n-p-n triple-diffused planar type used in a wide variety of small-signal and low-to-medium-power applications in military and industrial equipment. JEDEC TO-18, Outline No.12. For transfer-characteristics curves, refer to type 2N2102.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 120 | V |
| Collector-to-Emitter Voltage: | | | |
| $R_{BE}$ ≤ 10 Ω | $V_{CER}$ | 80 | V |
| Base open | $V_{CEO}$ | 65 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.5 | W |
| $T_C$ up to 25°C | $P_T$ | 1.8 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

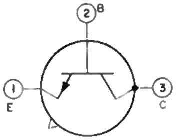
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 120 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 7 min | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 100 mA, $I_B$ = 0, $t_p$ = 300 μs, df = 1.8% | $V_{CEO}$(sus) | 65 min | V |
| $I_C$ = 100 mA, $I_B$ = 0, $R_{BE}$ = 10 Ω, $t_p$ = 300 μs, df = 1.8% | $V_{CER}$(sus) | 80 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA, $t_p$ = 300 μs, df = 1.8%) | $V_{CE}$(sat) | 0.6 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA, $t_p$ = 300 μs, df = 1.8%) | $V_{BE}$(sat) | 1.2 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 60 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 0.002 max | μA |
| $V_{CB}$ = 60 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 2 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 0.002 max | μA |
| Pulsed Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 150 mA, $t_p$ = 300 μs, df = 1.8% | $h_{FE}$(pulsed) | 40 to 120 | |
| $V_{CE}$ = 10 V, $I_C$ = 500 mA, $t_p$ = 300 μs, df = 1.8% | $h_{FE}$(pulsed) | 25 min | |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 0.01 mA | $h_{FE}$ | 20 min | |
| $V_{CE}$ = 10 V, $I_C$ = 10 mA | $h_{FE}$ | 35 min | |
| $V_{CE}$ = 10 V, $I_C$ = 10 mA, $T_C$ = −55°C | $h_{FE}$ | 20 min | |
| Small-Signal Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 5 mA, f = 1 kHz | $h_{fe}$ | 50 to 200 | |
| $V_{CE}$ = 10 V, $I_C$ = 50 mA, f = 20 MHz | $h_{fe}$ | 6 min | |
| Input Capacitance ($V_{EB}$ = 0.5 V, $I_C$ = 0, f = 0.14 MHz) | $C_{ibo}$ | 80 max | pF |

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0, f = 0.14 MHz) | $C_{obo}$ | 15 max | pF |
| Noise Figure ($V_{CE}$ = 10 V, $I_C$ = 0.3 mA, f = 1 kHz, $R_G$ = 510 Ω, circuit bandwidth = 1 Hz) | NF | 8 max | dB |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 97 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 350 max | °C/W |

# 2N2896 1A, 5W




Si n-p-n triple-diffused planar type used in a wide variety of small-signal and low-to-medium-power applications in military and industrial equipment. JEDEC TO-18, Outline No. 12. For transfer-characteristics curves, refer to type 2N2102.

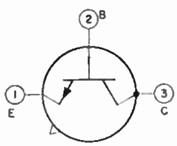
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 140 | V |
| Collector-to-Emitter Voltage: | | | |
| $R_{BE}$ = 10 Ω | $V_{CER}$ | 140 | V |
| Base open | $V_{CEO}$ | 90 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.5 | W |
| $T_C$ up to 25°C | $P_T$ | 1.8 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 140 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 7 min | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 100 mA, $I_B$ = 0, $t_p$ = 300 μs, df = 1.8% | $V_{CEO}$(sus) | 90 min | V |
| $I_C$ = 100 mA, $I_B$ = 0, $R_{BE}$ = 10 Ω, $t_p$ = 300 μs, df = 1.8% | $V_{CER}$(sus) | 140 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA, $t_p$ = 300 μs, df = 1.8% | $V_{CE}$(sat) | 0.6 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA, $t_p$ = 300 μs, df = 1.8% | $V_{BE}$(sat) | 1.2 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 90 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 0.01 max | μA |
| $V_{CB}$ = 90 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 10 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 0.01 max | μA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 150 mA, $t_p$ = 300 μs, df = 1.8%) | $h_{FE}$(pulsed) | 60 to 200 | |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 1 mA | $h_{FE}$ | 35 min | |
| $V_{CE}$ = 10 V, $I_C$ = 10 mA, $T_C$ = 55°C | $h_{FE}$ | 20 min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 50 mA, f = 20 MHz) | $h_{fe}$ | 6 min | |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0, f = 0.14 MHz) | $C_{obo}$ | 15 max | pF |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 97 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 350 max | °C/W |

# 2N2897 1A, 5W



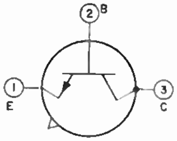

Si n-p-n triple-diffused planar type used in a wide variety of small-signal and low-to-medium-power applications in military and industrial equipment. JEDEC TO-18, Outline No.12.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 60 | V |
| Collector-to-Emitter Voltage: | | | |
| $R_{BE}$ = 10 Ω | $V_{CER}$ | 60 | V |
| Base open | $V_{CEO}$ | 45 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.5 | W |
| $T_C$ up to 25°C | $P_T$ | 1.8 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | —65 to 200 | °C |
| Storage | $T_{STG}$ | —65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 60 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 7 min | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 100 mA, $I_B$ = 0, $t_p$ = 300 μs, df = 1.8% | $V_{CEO}$(sus) | 45 min | V |
| $I_C$ = 100 mA, $I_B$ = 0, $R_{BE}$ = 10 Ω, $t_p$ = 300 μs, df = 1.8% | $V_{CER}$(sus) | 60 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA, $t_p$ = 300 μs, df = 1.8% | $V_{CE}$(sat) | 1 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA, $t_p$ = 300 μs, df = 1.8% | $V_{BE}$(sat) | 1.3 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 60 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | 0.05 max | μA |
| $V_{CB}$ = 60 V, $I_E$ = 0, $T_A$ = 150°C | $I_{CBO}$ | 50 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 0.05 max | μA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 150 mA, $t_p$ = 300 μs, df = 1.8%) | $h_{FE}$(pulsed) | 50 to 200 | |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 0.1 mA) | $h_{FE}$ | 35 min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 50 mA, f = 20 MHz) | $h_{fe}$ | 5 min | °C/W |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0, f = 0.14 MHz) | $C_{obo}$ | 15 max | pF |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 97 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 350 max | |




## 1A, 5W — 2N3053

Si n-p-n triple-diffused planar type used in a wide variety of small signal, medium-power applications (up to 20 MHz) in commercial and industrial equipment. JEDEC TO-5, Outline No.5.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 60 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE}$ = —1.5 V | $V_{CEV}$(sus) | 60 | V |
| $R_{BE}$ = 10 Ω | $V_{CER}$(sus) | 50 | V |
| Base open | $V_{CEO}$(sus) | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 0.7 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating ($T_A$-$T_C$) and Storage ($T_{STG}$) | | —65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 235 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

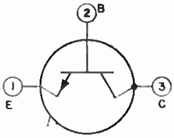
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 60 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 5 min | V |

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 100 mA, $R_{BE}$ = 10 Ω, $t_p$ = 300 μs, df = 1.8% | $V_{CER}$(sus) | 50 min | V |
| $I_C$ = 100 mA, $I_B$ = 0, $t_p$ = 300 μs, df = 1.8% | $V_{CEO}$(sus) | 40 min | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA) | $V_{BE}$(sat) | 1.7 max | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA) | $V_{CE}$(sat) | 1.4 max | V |
| Collector-Cutoff Current ($V_{CB}$ = 30 V, $I_E$ = 0) | $I_{CBO}$ | 0.25 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 4 V, $I_C$ = 0) | $I_{EBO}$ | 0.25 max | μA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 150 mA, $t_p$ = 300 μs, df = 1.8%) | $h_{FE}$(pulsed) | 50 to 250 | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 50 mA, f = 20 MHz) | $h_{fe}$ | 5 min | |
| Input Capacitance ($V_{EB}$ = 0.5 V, $I_C$ = 0) | $C_{ibo}$ | 80 max | pF |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0) | $C_{obo}$ | 15 max | pF |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 35* max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 175● max | °C/W |

* This value does not apply to type 40389.
● This value does not apply to type 40392.

# 2N3119 1A, 5W




Si n-p-n triple-diffused planar type used in high-voltage, high-frequency pulse-amplifier and high-voltage saturated-switching applications in industrial and military equipment. JEDEC TO-5, Outline No.5.

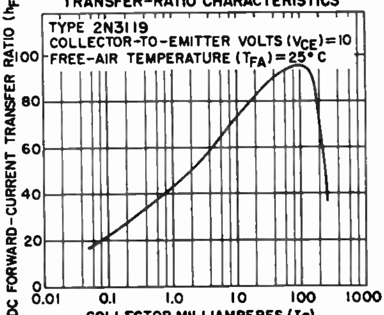
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 100 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 100 | V |
| Base open | $V_{CEO}$ | 80 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 0.5 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 4 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

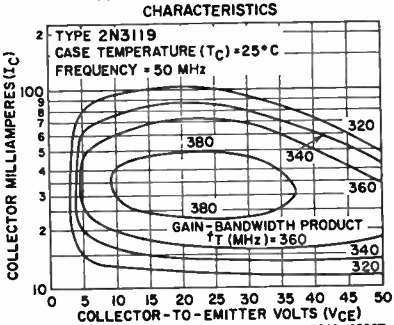
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 100 min | V |
| Collector-to-Emitter Breakdown Voltage: | | | |
| $V_{BE}$ = −1.5 V, $I_C$ = 0.1 mA | $V_{(BR)CEV}$ | 100 min | V |
| $I_C$ = 10 mA, $I_B$ = 0, $t_p$ = 300 μs, df = 1.8% | $V_{(BR)CEO}$(sus) | 80 min | V |

TYPICAL DC FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTICS



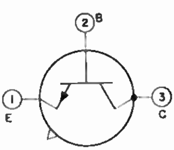

TYPICAL COLLECTOR-CURRENT CHARACTERISTICS



## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 100 mA, $I_B$ = 10 mA) | $V_{BE}$(sat) | 1.1 max | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 100 mA, $I_B$ = 10 mA) | $V_{CE}$(sat) | 0.5 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 60 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | 50 max | nA |
| $V_{CB}$ = 60 V, $I_E$ = 0, $T_A$ = 150°C | $I_{CBO}$ | 50 max | μA |
| Emitter-Cutoff Current ($V_{BE}$ = —3 V, $I_C$ = 0, $T_A$ = 25°C) | $I_{EBO}$ | 100 max | nA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 10 mA) | $h_{FE}$ | 40 min | |
| Pulsed Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 100 mA, $t_p$ = 300 μs, df = 1.8% | $h_{FE}$(pulsed) | 50 to 200 | |
| $V_{CE}$ = 10 V, $I_C$ = 250 mA, $t_p$ = 300 μs, df = 1.8% | $h_{FE}$(pulsed) | 20 min | |
| Gain-Bandwidth Product ($V_{CB}$ = 28 V, $I_C$ = 25 mA, f = 50 MHz) | $f_T$ | 250 min | MHz |
| Collector-to-Base Feedback Capacitance ($V_{CB}$ = 28 V, $I_C$ = 0, f = 1 MHz) | $C_{b'c}$ | 6 max | pF |
| Pulsed-Amplifier Rise Time ($V_{CC}$ = 80 V, $I_C$ = 10 mA) | | 20 max | ns |
| Saturated Switch Turn-On Time ($V_{CC}$ = 28 V, $I_C$ = 100 mA, $I_{B_1}$ = 10 mA) | $t_d + t_r$ | 40 max | ns |
| Saturated Switch Turn-Off Time ($V_{CC}$ = 28 V, $I_C$ = 100 mA, $I_{B_2}$ = —10 mA) | $t_s + t_f$ | 700 max | ns |

# 1A, 5W — 40366




Si n-p-n triple-diffused planar type subjected to special preconditioning tests for high-reliability operation in medium- and high-power switching and amplifier applications in military and industrial equipment. JEDEC TO-5, Outline No.5.

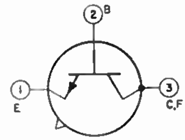
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage: | | | |
| $R_{BE} \leqq 10\ \Omega$ | $V_{CER}$ | 80 | V |
| Base open | $V_{CEO}$ | 65 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 5 | A |
| $T_A$ above 25°C | $P_T$ | 1 | A |
| $T_C$ and $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | —65 to 200 | °C |
| Storage | $T_{STG}$ | —65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($V_{EB}$ = 1.5 V, $I_C$ = 0.1 mA) | $V_{(BR)CBV}$ | 120 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA) | $V_{(BR)EBO}$ | 7 min | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $R_{BE}$ = 10 Ω, $I_C$ = 100 mA, tp = 300 μs, df = 1.8% | $V_{CER}$(sus) | 80 min | V |
| $I_C$ = 100 mA, $I_B$ = 0, tp = 300 μs, df = 1.8% | $V_{CEO}$(sus) | 65 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA, tp = 300 μs, df = 1.8%) | $V_{CE}$(sat) | 0.5 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA, tp = 300 μs, df = 1.8%) | $V_{BE}$(sat) | 1.1 max | V |
| Collector-Cutoff Current ($V_{CB}$ = 60 V, $I_E$ = 0) | $I_{CBO}$ | 2 max | nA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | nA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 0.01 mA | $h_{FE}$ | 10 min | |
| $V_{CE}$ = 10 V, $I_C$ = 0.1 mA | $h_{FE}$ | 20 min | |
| Pulsed Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 150 mA, tp = 300 μs, df = 1.8% | $h_{FE}$(pulsed) | 40 to 120 | |
| $V_{CE}$ = 10 V, $I_C$ = 500 mA, tp = 300 μs, df = 1.8% | $h_{FE}$(pulsed) | 25 min | |
| $V_{CB}$ = 10 V, $I_C$ = 1000 mA, tp = 300 μs, df = 1.8% | $h_{FE}$(pulsed) | 10 min | |

# 40392 — 1A, 5W




Si **n-p-n** triple-diffused planar type features a base comprised of a homogeneous-resistivity silicon material. This type is used in a wide variety of small-signal, medium-power applications at frequencies up to 20 MHz. JEDEC TO-5 (with flange), Outline No.6. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N3053 except for the following items:

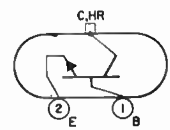
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 7 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Thermal Resistance, Junction-to-Case | $\theta_{J\text{-}C}$ | 25 max | °C/W |

# 40375 — 7A, 35W




Si **n-p-n** epitaxial type with an attached heat radiator for printed-circuit-board use in audio, ultrasonic, and rf circuits and in low-distortion power amplifiers, oscillators, switching regulators, series regulators, converters, and inverters. JEDEC TO-66 (with heat radiator), Outline No.26. This type is identical with type 2N3878 except for the following items:

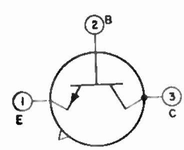
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 5.8 | W |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Thermal Resistance, Junction-to-Ambient | $\theta_{J\text{-}A}$ | 30 max | °C/W |

# 2N3262 — 2A, 10W




Si **n-p-n** triple-diffused planar type used in high-voltage, high-frequency pulse-amplifier and high-voltage saturated-switching applications in industrial and military equipment. JEDEC TO-39, Outline No.15.

## MAXIMUM RATINGS

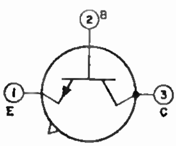
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 100 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE} = -1.5$ V | $V_{CEV}$ | 100 | V |
| Base open (sustaining voltage) | $V_{CEO}$(sus) | 80 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 1.5 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 8.75 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating ($T_A$-$T_C$) and Storage ($T_{STG}$) | | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($V_{BE} = -1.5$ V, $I_C = 0.25$ mA) | $V_{(BR)CEV}$ | 100 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E = 0.1$ mA, $I_C = 0$) | $V_{(BR)EBO}$ | 4 min | V |

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 500 mA, $R_{BE}$ = 10 Ω, $t_p$ = 15 μs, df = 1.5% | $V_{CER}$(sus) | 90 min | V |
| $I_C$ = 500 mA, $I_B$ = 0, $t_p$ = 15 μs, df = 1.5% | $V_{CEO}$(sus) | 80 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 1 A, $I_B$ = 100 mA) | $V_{CE}$(sat) | 0.6 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 1 A, $I_B$ = 100 mA) | $V_{BE}$(sat) | 1.4 max | V |
| Collector-Cutoff Current ($V_{CB}$ = 30 V, $I_E$ = 0, $T_A$ = 25°C) | $I_{CBO}$ | 0.1 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 3 V, $I_C$ = 0) | $I_{EBO}$ | 100 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 500 mA) | $h_{FE}$ | 40 min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 28 V, $I_C$ = 100 mA, f = 50 MHz) | $h_{fe}$ | 3 min | |
| Collector-to-Base Feedback Capacitance ($V_{CB}$ = 28 V, $I_C$ = 0, f = 1 MHz) | $C_{b'c}$ | 20 max | pF |
| Pulse-Amplifier Rise Time ($V_{CC}$ = 80 V, $I_C$ = 25 mA) | $t_r$ | 20 max | ns |
| Turn-On Time, Saturated Switch ($V_{CE}$ = 28 V, $I_C$ = 1 A, $I_{B1}$ = 100 mA, $I_{B2}$ = −100 mA) | $t_d + t_r$ | 40 max | ns |
| Turn-On Time, Saturated Swith ($V_{CE}$ = 28 V, $I_C$ = 1 A, $I_{B1}$ = 100 mA, $I_{B2}$ = −100 mA) | $t_s + t_f$ | 750 max | ns |




## 2A, 10W — 2N5320

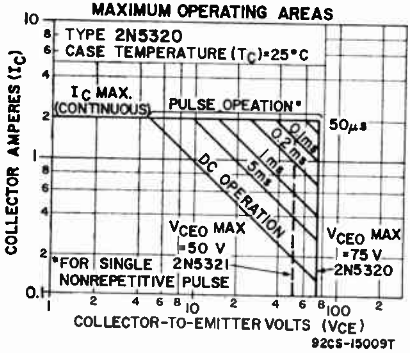
Si n-p-n triple-diffused planar type used for small-signal medium-power applications in military, industrial, and commercial equipment. JEDEC TO-5, Outline No.5.

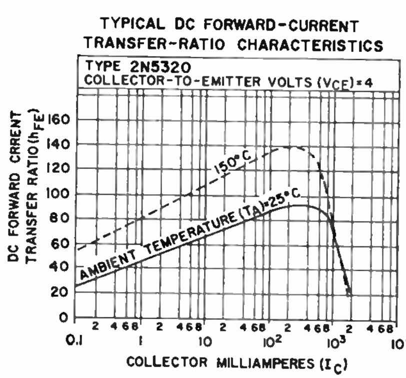
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 100 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE}$ = 1.5 V | $V_{CEV}$(sus) | 100 | V |
| $R_{BE}$ = 100 V | $V_{CER}$(sus) | 90 | V |
| Base open | $V_{CEO}$(sus) | 75 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 2 | A |
| Base Current | $I_B$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 10 | W |
| $T_C$ above 25°C | $P_T$ | Derate linearly at 0.057 | W/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Emitter-to-Base Breakdown Voltage ($I_B$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 7 min | V |



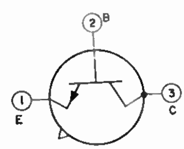



## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($V_{BE}$ = −1.5 V, $I_C$ = 0.1 mA, Base-emitter reverse biased) | $V_{(BR)CEV}$ | 100 min | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 100 V, $R_{BE}$ = 100 Ω | $V_{CER}(sus)$ | 90 min | V |
| $I_C$ = 100 V, $I_B$ = 0, base open | $V_{CEO}(sus)$ | 75 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 500 mA, $I_B$ = 50 mA) | $V_{CE}(sat)$ | 0.5 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 500 mA) | $V_{BE}$ | 1.1 max | V |
| Collector-Cutoff Current ($V_{CB}$ = 80 V, $I_E$ = 0) | $I_{CBO}$ | 0.5 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 0.1 max | μA |
| Pulsed Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 4 V, $I_C$ = 500 mA, $t_p \leq$ 300 μs, df $\leq$ 0.02 | $h_{FE}$(pulsed) | 30 to 130 | |
| $V_{CE}$ = 2 V, $I_C$ = 1000 mA, $t_p \leq$ 300 μs, df $\leq$ 0.02 | $h_{FE}$(pulsed) | 10 min | |
| Gain-Bandwidth Product ($V_{CE}$ = 4 V, $I_C$ = 50 mA) | $f_T$ | 50 min | MHz |
| Second-Breakdown Collector Current ($V_{CE}$ = 50 V, base forward-biased, non-repetitive pulse = 1 s) | $I_{S/b}$ | 200 min | mA |
| Turn-On Time ($V_{CE}$ = 30 V, $I_C$ = 500 mA, $I_B$ = 50 mA) | $t_d + t_r$ | 80 max | ns |
| Turn-Off Time ($V_{CE}$ = 30 V, $I_C$ = 500 mA, $I_B$ = 50 mA) | $t_s + t_f$ | 800 max | ns |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 17.5 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 150 max | °C/W |

# 2N5321 2A, 10W

Si n-p-n triple-diffused planar type used for small-signal medium-power applications in military, industrial, and commercial equipment. JEDEC TO-5, Outline No.5.



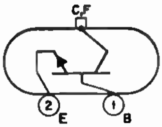

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 75 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE}$ = 1.5 V | $V_{CEV}(sus)$ | 75 | V |
| $R_{BE}$ = 100 V | $V_{CER}(sus)$ | 65 | V |
| Base open | $V_{CEO}(sus)$ | 50 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 2 | A |
| Base Current | $I_B$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 10 | |
| $T_C$ above 25°C | $P_T$ | Derate linearly at 0.057 | W/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 5 min | V |
| Collector-to-Emitter Breakdown Voltage ($V_{BE}$ = −1.5 V, $I_C$ = 0.1 mA, Base-emitter reverse biased) | $V_{(BR)CEV}$ | 75 min | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 100 mA, $R_{BE}$ = 100 Ω | $V_{CER}(sus)$ | 65 min | V |
| $I_C$ = 100 mA, base open | $V_{CEO}(sus)$ | 50 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 500 mA, $I_B$ = 50 mA) | $V_{CE}(sat)$ | 0.8 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 500 mA) | $V_{BE}$ | 1.4 max | V |
| Collector-Cutoff Current ($V_{CB}$ = 60 V, $I_E$ = 0) | $I_{CBO}$ | 5 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 4 V, $I_C$ = 0) | $I_{EBO}$ | 0.5 max | μA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 500 mA, $t_p \leq$ 300 μs, df $\leq$ 0.02) | $h_{FE}$(pulsed) | 40 to 250 | |
| Gain-Bandwidth Product ($V_{CE}$ = 4 V, $I_C$ = 50 mA) | $f_T$ | 50 min | MHz |
| Second-Breakdown Collector Current ($V_{CE}$ = 50 V, base forward-biased, non-repetitive pulse = 1 s) | $I_{S/b}$ | 200 min | mA |
| Turn-On Time ($V_{CE}$ = 30 V, $I_C$ = 500 mA, $I_B$ = 50 mA) | $t_d + t_r$ | 80 max | ns |
| Turn-Off Time ($V_{CE}$ = 30 V, $I_C$ = 500 mA, $I_B$ = 50 mA) | $t_s + t_f$ | 800 max | ns |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 17.5 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 150 max | °C/W |

## 7A, 35W — 2N3878




Si n-p-n epitaxial type used in af, rf, and ultrasonic applications such as low-distortion power amplifiers, oscillators, switching regulators, series regulators, converters, and inverters. JEDEC TO-66, Outline No.25. See Mounting Hardware for desired mounting arrangement.

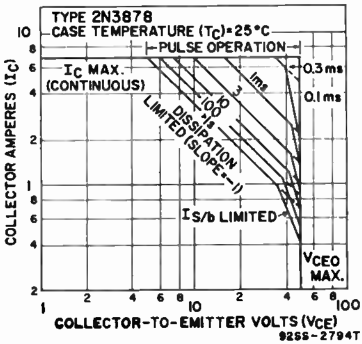
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 120 | V |
| Collector-to-Emitter Voltage: | | | |
| $R_{BE}$ = 50 Ω | $V_{CER}$(sus) | 65 | V |
| Base open (sustaining voltage) | $V_{CEO}$(sus) | 50 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 7 | A |
| Peak Collector Current | $i_C$ | 10 | A |
| Base Current | $I_B$ | 5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 35 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 255 | °C |

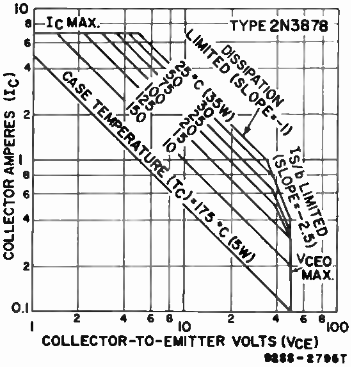
### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 0.2 A, $I_B$ = 0 | $V_{CEO}$(sus) | 50 min | V |
| $I_C$ = 0.2 A, $R_{BE}$ = 50 Ω | $V_{CER}$(sus) | 65 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 4 A, $I_B$ = 0.5 A) | $V_{CE}$(sat) | 2 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 2 V, $I_C$ = 4 A) | $V_{BE}$ | 2.5 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 40 V, $I_B$ = 0, $T_C$ = 25°C | $I_{CEO}$ | 5 max | mA |
| $V_{CE}$ = 100 V, $V_{BE}$ = −1.5 V, $T_C$ = 25°C | $I_{CEV}$ | 4 max | mA |
| $V_{CE}$ = 100 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C | $I_{CEV}$ | 4 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 4 V, $I_C$ = 0) | $I_{EBO}$ | 4 max | mA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 0.5 A | $h_{FE}$ | 50 to 200 | |
| $V_{CE}$ = 5 V, $I_C$ = 4 A | $h_{FE}$ | 20 min | |
| $V_{CE}$ = 2 V, $I_C$ = 4 A | $h_{FE}$ | 8 min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 0.5 A, f = 10 MHz) | $h_{fe}$ | 6 min | |
| Second-Breakdown Collector Current ($V_{CE}$ = 40 V, base forward-biased) | $I_{S/b}$ | 750 min | mA |
| Second-Breakdown Energy ($R_{BE}$ = 50 Ω, L = 125 μH, $V_{BE}$ = −4 V, base reverse-biased) | $E_{S/b}$ | 1 min | mJ |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 175 max | pF |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 5 max | °C/W |

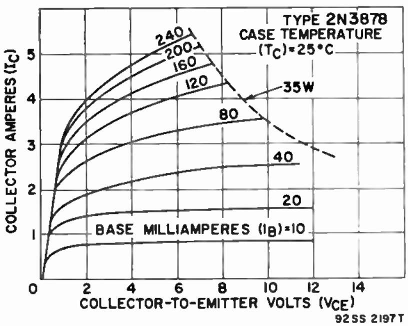
MAXIMUM PULSE OPERATING AREAS



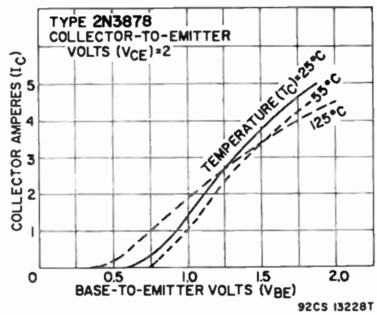

MAXIMUM DC OPERATING AREAS



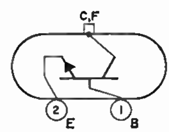
TYPICAL COLLECTOR CHARACTERISTICS




TYPICAL TRANSFER CHARACTERISTICS




# 2N3879 7A, 35W

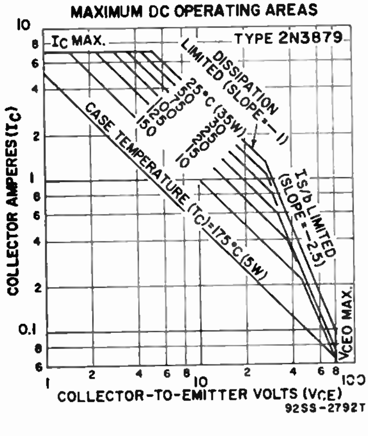



Si n-p-n epitaxial type used in af, rf, and ultrasonic applications such as low-distortion power amplifiers, oscillators, switching regulators, series regulators, converters and inverters. JEDEC TO-66, Outline No.25. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N3878 except for collector-to-emitter voltages of $V_{CER}$(sus) = 90 V and $V_{CEO}$(sus) = 75 V, and the following items:

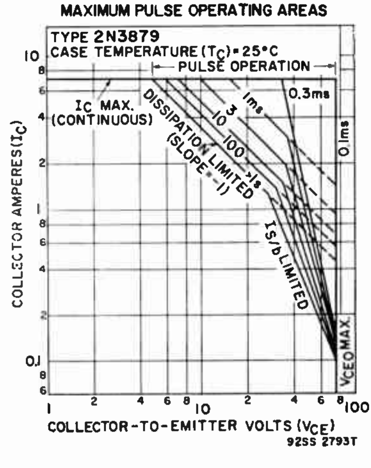
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage ($I_C$ = 4 A, $I_B$ = 0.4 A) | $V_{CE}$(sat) | 1.2 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 2 V, $I_C$ = 4 A) | $V_{BE}$ | 1.8 max | V |
| Emitter-Cutoff Current ($V_{EB}$ = 4 V, $I_C$ = 0) | $I_{EBO}$ | 2 max | mA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 0.5 A | $h_{FE}$ | 40 min | |
| $V_{CE}$ = 5 V, $I_C$ = 4 A | $h_{FE}$ | 20 to 80 | |
| $V_{CE}$ = 2 V, $I_C$ = 4 A | $h_{FE}$ | 12 min | |
| Second-Breakdown Collector Current ($V_{CE}$ = 40 V, base forward-biased) | $I_{S/b}$ | 500 min | mA |
| Delay Time ($V_{CC}$ = 30 V, $I_C$ = 4 A, $I_{B_1}$ = 0.4 A, $I_{B_2}$ = −0.4 A) | $t_d$ | 40 max | ns |
| Rise Time ($V_{CC}$ = 30 V, $I_C$ = 4 A, $I_{B_1}$ = 0.4 A, $I_{B_2}$ = −0.4 A) | $t_r$ | 400 max | ns |

MAXIMUM DC OPERATING AREAS

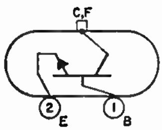



MAXIMUM PULSE OPERATING AREAS



## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Storage Time ($V_{CC}$ = 30 V, $I_C$ = 4 A, $I_{B_1}$ = 0.4 A, $I_{B_2}$ = −0.4 A) | $t_s$ | 800 max | ns |
| Fall Time ($V_{CC}$ = 30 V, $I_C$ = 4 A, $I_{B_1}$ = 0.4 A, $I_{B_2}$ = −0.4 A) | $t_f$ | 400 max | ns |




## 7A, 35W — 2N5202

Si n-p-n epitaxial type used in high-current, high-speed switching circuits. JEDEC TO-66, Outline No.25.

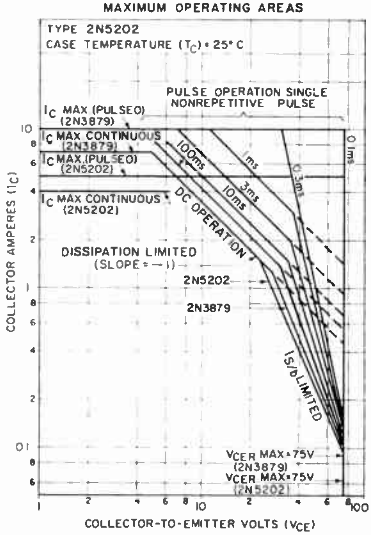
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 120 | V |
| Collector-to-Emitter Sustaining Voltage: $R_{BE}$ = 50 Ω | $V_{CER}$(sus) | 75 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 4 | A |
| Peak Collector Current | $i_C$ | 5 | A |
| Base Current | $I_B$ | 2 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 35 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 255 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: ($I_C$ = 0.2 A, $R_{BE}$ = 50 Ω) | $V_{CER}$(sus) | 75 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 1.2 V, $I_C$ = 4 V) | $V_{BE}$ | 1.9 max | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 4 A, $I_B$ = 0.4 A) | $V_{CE}$(sat) | 1.2 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 100 V, $V_{BE}$ = −1.5 V | $I_{CEV}$ | 10 max | mA |
| $V_{CE}$ = 100 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C | $I_{CEV}$ | 10 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 6 V, $I_C$ = 0) | $I_{EBO}$ | 10 max | mA |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 175 max | pF |

MAXIMUM OPERATING AREAS



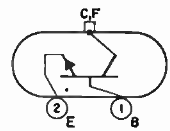
## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Second-Breakdown Collector Current ($V_{CE}$ = 40 V, non-repetitive pulse = 1 s, base forward-biased) | $I_{S/b}$ | 400 min | mA |
| Second-Breakdown Energy ($V_{BB}$ = −4 V, $R_B$ = 50 Ω, L = 50 μH) | $E_{S/b}$ | 0.4 min | mJ |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 1.2 V, $I_C$ = 4 A) | $h_{FE}$ | 10 to 100 | ns |
| Small-Signal, Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 0.5 A, f = 10 MHz) | $h_{fe}$ | 6 min | |
| Delay Time ($V_{CC}$ = 30 V, $I_C$ = 4 A, $I_{B1}$ = 0.4 A) | $t_d$ | 40 max | ns |
| Rise Time ($V_{CC}$ = 30 V, $I_C$ = 4 A, $I_{B1}$ = 0.4 A) | $t_r$ | 400 max | ns |
| Storage Time ($V_{CC}$ = 30 V, $I_C$ = 4 A, $I_{B2}$ = −0.4 A) | $t_s$ | 800 max | ns |
| Fall Time ($V_{CC}$ = 30 V, $I_C$ = 4 A, $I_{B2}$ = −0.4 A) | $t_f$ | 400 max | ns |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 5 max | °C/W |

# 2N5038

**20A, 140W**

Si n-p-n epitaxial type used for high-current, high-power, high-speed applications in switching and amplifier circuits in industrial and commercial equipment. JEDEC TO-3, Outlne No.2. See Mounting Hardware for desired mounting arrangement.




## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 150 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE}$ = −1.5 V, $R_{BE}$ = 100 Ω | $V_{CEX}$(sus) | 150 | V |
| $R_{BE}$ ≤ 50 Ω | $V_{CER}$(sus) | 110 | V |
| Base open | $V_{CEO}$(sus) | 90 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Peak Collector Current | $i_C$ | 30 | A |
| Collector Current | $I_C$ | 20 | A |
| Base Current | $I_B$ | 5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C, $V_{CE}$ up to 28 V | $P_T$ | 140 | W |
| $T_C$ up to 25°C, $V_{CE}$ above 28 V | $P_T$ | See curve page 300 | |
| $T_C$ above 25°C, $V_{CE}$ above 28 V | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 230 | °C |

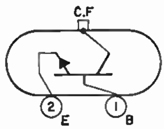
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 0.2 A, $I_B$ = 0, base open | $V_{CEO}$(sus) | 90 min | V |
| $V_{BE}$ = −1.5 V, $I_C$ = 0.2 A, $I_B$= 0, $R_{BE}$ = 100 Ω, base-emitter junction reverse biased | $V_{CEX}$(sus) | 150 min | V |
| $I_C$ = 0.2 A, $I_B$ = 0, $R_{BE}$ ≤ 50 Ω | $V_{CER}$(sus) | 110 min | V |
| Emitter-to-Base Voltage ($I_C$ = 0, $I_E$ = 0.05 A) | $V_{EBO}$ | 7 min | V |
| Collector-to-Emitter Saturation Voltage: | | | |
| $I_C$ = 12 A, $I_B$ = 1.2 A, $t_P$ ≤ 350 μs, df = 2% | $V_{CE}$(sat) | 1 max | V |
| $I_C$ = 20 A, $I_B$ = 5 A | $V_{CE}$(sat) | 2.5 max | V |
| Base-to-Emitter Saturation Voltage ($V_{CE}$ = 5 V, $I_C$ = 20 A, $I_B$ = 5 A) | $V_{BE}$(sat) | 3.3 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 5 V, $I_C$ = 12 A, $t_P$ ≤ 350 μs, df = 2%) | $V_{BE}$ | 1.8 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 70 V, $I_B$ = 0 | $I_{CEO}$ | 20 max | mA |
| $V_{CE}$ = 140 V, $V_{BE}$ = −1.5 V | $I_{CEV}$ | 50 max | mA |
| $V_{CE}$ = 100 V, $V_{BE}$ = −1.5 V | $I_{CEV}$ | 10 max | mA |
| $V_{CE}$ = 100 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C | $I_{CEV}$ | 10 max | mA |
| Emitter-Cutoff Current: | | | |
| $V_{EB}$ = 5 V, $I_C$ = 0 | $I_{EBO}$ | 5 max | mA |
| $V_{EB}$ = 7 V, $I_C$ = 0 | $I_{EBO}$ | 50 max | mA |
| Pulsed Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 2 A, $t_P$ ≤ 350 μs, df = 2% | $h_{FE}$(pulsed) | 50 to 200 | |
| $V_{CE}$ = 5 V, $I_C$ = 12 A, $t_P$ ≤ 350 μs, df = 2% | $h_{FE}$(pulsed) | 20 to 100 | |
| Magnitude of Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 2 A, f = 5 MHz) | $\lvert h_{fe} \rvert$ | 12 min | |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 500 max | pF |
| Second-Breakdown Collector Current: | | | |
| $V_{CE}$ = 28 V, base forward-biased, non-repetitive pulse = 1 s | $I_{S/b}$ | 5 min | A |
| $V_{CE}$ = 45 V, base forward-biased, non-repetitive pulse = 1 s | $I_{S/b}$ | 0.9 min | A |
| Second-Breakdown Energy ($V_{BE}$ = −4 V, $I_C$ = 12 A, $R_B$ = 20 Ω, L = 180 μH, base reverse biased) | $E_{S/b}$ | 13 min | mJ |

**CHARACTERISTICS (cont'd)**

| | | | |
|---|---|---|---|
| Gain-Bandwidth Product ($V_{CE}$ = 10 V, $I_C$ = 2 A, f = 5 MHz) | $f_T$ | 60 min | MHz |
| Turn-On-Time ($V_{CC}$ = 30 V, $I_C$ = 12 A, $I_{B1}$ = $I_{B2}$ = 1.2 A) | $t_d + t_r$ | 0.5 max | $\mu$s |
| Storage Time ($V_{CC}$ = 30 V, $I_C$ = 12 A, $I_{B1}$ = $I_{B2}$ = 1.2 A) | $t_s$ | 1.5 max | $\mu$s |
| Fall Time ($V_{CC}$ = 30 V, $I_C$ = 12 A, $I_{B1}$ = $I_{B2}$ = 1.2 A) | $t_f$ | 0.5 max | $\mu$s |
| Thermal Resistance, Junction-to-Case ($V_{CE}$ = 40 V, $I_C$ = 0.5 A) | $\theta_{J\text{-}C}$ | 1.25 max | °C/W |

## 20A, 140W — 2N5039




Si n-p-n epitaxial type used for high-current, high-power, high-speed applications in switching and amplifier circuits in industrial and commercial equipment. JEDEC TO-3, Outline No.2. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N5038 except for the following items:

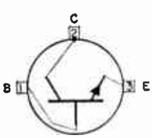
**MAXIMUM RATINGS**

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 120 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE}$ = −1.5 V, $R_{BE}$ = 100 Ω | $V_{CEX}$(sus) | 120 | V |
| $R_{BE}$ ≤ 50 Ω | $V_{CER}$(sus) | 95 | V |
| Base open | $V_{CEO}$(sus) | 75 | V |

**CHARACTERISTICS (At case temperature = 25°C)**

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 0.2 A, $I_B$ = 0, base open | $V_{CEO}$(sus) | 75 min | V |
| $V_{BE}$ = −1.5 V, $I_C$ = 0.2 A, $I_B$ = 0, $R_{BE}$ = 100 Ω, base-emitter junction reverse biased | $V_{CEX}$(sus) | 120 min | V |
| $I_C$ = 0.2 A, $I_B$ = 0, $R_{BE}$ ≤ 50 Ω | $V_{CER}$(sus) | 95 min | V |
| Collector-to-Emitter Saturation Voltage: | | | |
| $I_C$ = 10 A, $I_B$ = 1 A, $t_P$ ≤ 350 $\mu$s, df = 2% | $V_{CE}$(sat) | 1 max | V |
| $I_C$ = 20 A, $I_B$ = 5 A | $V_{CE}$(sat) | 2.5 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 5 V, $I_C$ = 10 A, $t_P$ ≤ 350 $\mu$s, df = 2%) | $V_{BE}$ | 1.8 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 55 V, $I_B$ = 0 | $I_{CEO}$ | 20 max | mA |
| $V_{CE}$ = 110 V, $V_{BE}$ = −1.5 V | $I_{CEV}$ | 50 max | mA |
| $V_{CE}$ = 85 V, $V_{BE}$ = −1.5 V | $I_{CEV}$ | 10 max | mA |
| $V_{CE}$ = 85 V, $V_{BE}$ = −1.5 V | $I_{CEV}$ | 10 max | mA |
| Emitter-Cutoff Current: | | | |
| $V_{EB}$ = 5 V, $I_C$ = 0 | $I_{EBO}$ | 15 max | mA |
| $V_{EB}$ = 7 V, $I_C$ = 0 | $I_{EBO}$ | 50 max | mA |
| Pulsed Static Forward-Current Transfer Ratio | | | |
| $V_{CE}$ = 5 V, $I_C$ = 2 A, $t_P$ ≤ 350 $\mu$s, df = 2% | $h_{FE}$(pulsed) | 30 to 150 | |
| $V_{CE}$ = 5 V, $I_C$ = 10 A, $t_P$ ≤ 350 $\mu$s, df = 2% | $h_{FE}$(pulsed) | 20 to 100 | |
| Turn-On-Time ($V_{CC}$ = 30 V, $I_C$ = 10 A, $I_{B1}$ = $I_{B2}$ = 1 A) | $t_d + t_r$ | 0.5 max | $\mu$s |
| Storage Time ($V_{CC}$ = 30 V, $I_C$ = 10 A, $I_{B1}$ = $I_{B2}$ = 1A) | $t_s$ | 1.5 max | $\mu$s |
| Fall Time ($V_{CC}$ = 30 V, $I_C$ = 10 A, $I_{B1}$ = $I_{B2}$ = 1 A) | $t_f$ | 0.5 max | $\mu$s |

## 25A, 125W — 2N3263




Si n-p-n epitaxial type used in high-power, high-speed, and high-current applications such as switching circuits, amplifiers, and power oscillators in aerospace, military, and industrial applications. Outline No.29.

**MAXIMUM RATINGS**

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 150 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 150 | V |
| $R_{BE}$ ≦ 50 Ω | $V_{CER}$(sus) | 110 | V |
| Base open (sustaining voltage) | $V_{CEO}$(sus) | 90 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 25 | A |

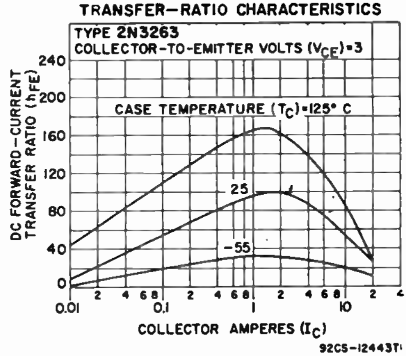
## MAXIMUM RATINGS (cont'd)

| | | | |
|---|---|---|---|
| Base Current | $I_B$ | 10 | A |
| Transistor Dissipation | $P_T$ | See Rating Chart | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |

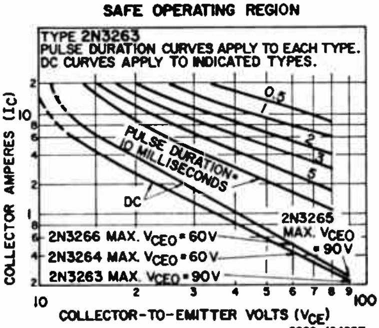
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 0.2 A, $I_B$ = 0 | $V_{CEO}$(sus) | 90 min | V |
| $I_C$ = 0.2 A, $R_{BE} \leq 50\ \Omega$ | $V_{CER}$(sus) | 110 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 15 A, $I_B$ = 1.2 A, $t_p \leq 350\ \mu s$, df ≤ 2%) | $V_{CE}$(sat) | 0.75 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 15 A, $I_B$ = 1.5 A, $t_p \leq 350\ \mu s$, df ≤ 2%) | $V_{BE}$(sat) | 1.6 max | V |
| Emitter-to-Base Voltage ($I_E$ = 0.02 A, $I_C$ = 0) | $V_{EBO}$ | 7 min | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 150 V, $V_{BE}$ = −1.5 V, $T_C$ = 25°C | $I_{CEV}$ | 20 max | mA |
| $V_{CB}$ = 80 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 4 max | mA |
| $V_{CB}$ = 80 V, $I_E$ = 0, $T_C$ = 125°C | $I_{CBO}$ | 4 max | mA |
| Emitter-Cutoff Current: | | | |
| $V_{EB}$ = 5 V, $I_C$ = 0, $T_C$ = 25°C | $I_{EBO}$ | 5 max | mA |
| $V_{EB}$ = 5 V, $I_C$ = 0, $T_C$ = 125°C | $I_{EBO}$ | 5 max | mA |
| Pulsed Static Forward-Current Transfer Ratio: | | | |
| ($V_{CE}$ = 3 V, $I_C$ = 5 A, $t_p \leq 350\ \mu s$, df ≤ 2% | $h_{FE}$(pulsed) | 40 min | |
| ($V_{CE}$ = 3 V, $I_C$ = 15 A, $t_p \leq 350\ \mu s$, df ≤ 2% | $h_{FE}$(pulsed) | 25 to 75 | |
| ($V_{CE}$ = 4 V, $I_C$ = 20 A, $t_p \leq 350\ \mu s$, df ≤ 2%) | $h_{FE}$(pulsed) | 20 min | |
| Collector-to-Base Feedback Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0, f = 1 MHz) | $C_{b'c}$ | 900 max | pF |
| Turn-On Time, Saturated Switch ($V_{CC}$ = 30 V, $I_C$ = 15 A, $I_{B_1}$ = 1.2 A, $I_{B_2}$ = −1.2 A) | $t_d + t_r$ | 0.5 max | μs |
| Fall Time, Saturated Switch ($V_{CC}$ = 30 V, $I_C$ = 15 A, $I_{B_1}$ = 1.2 A, $I_{B_2}$ = −1.2 A) | $t_f$ | 0.5 max | μs |
| Storage Time, Saturated Switch ($V_{CC}$ = 30 V, $I_C$ = 15 A, $I_{B_1}$ = 1.2 A, $I_{B_2}$ = −1.2 A) | $t_s$ | 1.5 max | μs |

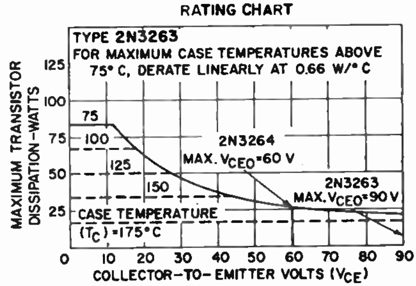
TYPICAL DC FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTICS




SAFE OPERATING REGION



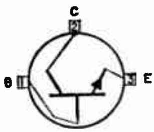

RATING CHART



## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Gain-Bandwidth Product ($V_{CE}$ = 10 V, $I_C$ = 3 A, f = 5 MHz) | $f_T$ | 20 min | MHz |
| Second-Breakdown Current, Safe Operating Region ($V_{CE}$ = 75 V) | $I_{S/b}$ | 350 min | mA |
| Second-Breakdown Energy, Safe Operating Region ($V_{BE}$ = −6 V, $I_C$ = 10 A, $R_{BE}$ = 20 Ω, L = 40 μH) | $E_{S/b}$ | 2 min | mJ |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 1.5 max | °C/W |

## 25A, 125W — 2N3264




Si n-p-n epitaxial type used in high-power, high-speed, and high-current applications, such as switching circuits, amplifiers, and power oscillators in aerospace, military, and industrial applications. Outline No.29. For curves of safe operating region, transfer characteristics, and static forward-current transfer ratio, refer to type 2N3263.

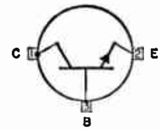
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 120 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 120 | V |
| $R_{BE}$ = 50 Ω | $V_{CER}$(sus) | 80 | V |
| Base open (sustaining voltage) | $V_{CEO}$(sus) | 60 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 25 | A |
| Base Current | $I_B$ | 10 | A |
| Transistor Dissipation | See Rating Chart for type 2N3263 | | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 0.2 A, $I_B$ = 0 | $V_{CEO}$(sus) | 60 min | V |
| $I_C$ = 0.2 A, $R_{BE}$ ≤ 50 Ω | $V_{CER}$(sus) | 80 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 15 A, $I_B$ = 1.2 A, $t_p$ ≤ 350 μs, df ≤ 2%) | $V_{CE}$(sat) | 1.2 max | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 15 A, $I_B$ = 1.5 A, $t_p$ ≤ 350 μs, df ≤ 2%) | $V_{BE}$(sat) | 1.8 max | V |
| Emitter-to-Base Voltage ($I_E$ = 0.02 A, $I_C$ = 0) | $V_{EBO}$ | 7 min | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 120 V, $V_{BE}$ = −1.5 V, $T_C$ = 25°C | $I_{CEV}$ | 20 max | mA |
| $V_{CB}$ = 60 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 10 max | mA |
| $V_{CB}$ = 60 V, $I_E$ = 0, $T_C$ = 125°C | $I_{CBO}$ | 10 max | mA |
| Emitter-Cutoff Current: | | | |
| $V_{EB}$ = 5 V, $I_C$ = 0, $T_C$ = 25°C | $I_{EBO}$ | 15 max | mA |
| $V_{EB}$ = 5 V, $I_C$ = 0, $T_C$ = 125°C | $I_{EBO}$ | 15 max | mA |
| Pulsed Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 3 V, $I_C$ = 5 A, $t_p$ ≤ 350 μs, df ≤ 2% | $h_{FE}$(pulsed) | 35 min | |
| $V_{CE}$ = 3 V, $I_C$ = 15 A, $t_p$ ≤ 350 μs, df ≤ 2% | $h_{FE}$(pulsed) | 20 to 80 | |
| $V_{CE}$ = 4 V, $I_C$ = 20 A, $t_p$ ≤ 350 μs, df ≤ 2% | $h_{FE}$(pulsed) | 15 min | |
| Collector-to-Base Feedback Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0, f = 1 MHz) | $C_{b'c}$ | 900 max | pF |
| Turn-On Time, Saturated Switch ($V_{CC}$ = 30 V, $I_C$ = 15 A, $I_{B_1}$ = 1.2 A, $I_{B_2}$ = −1.2 A) | $t_d + t_r$ | 0.5 max | μs |
| Fall Time, Saturated Switch ($V_{CC}$ = 30 V, $I_C$ = 15 A, $I_{B_1}$ = 1.2 A, $I_{B_2}$ = −1.2 A) | $t_f$ | 0.5 max | μs |
| Storage Time, Saturated Switch ($V_{CC}$ = 30 V, $I_C$ = 15 A, $I_{B_1}$ = 1.2 A, $I_{B_2}$ = −1.2 A) | $t_s$ | 1.5 max | μs |
| Gain-Bandwidth Product ($V_{CE}$ = 10 V, $I_C$ = 3 A, f = 5 MHz) | $f_T$ | 20 min | MHz |
| Second-Breakdown Current, Safe Operating Region ($V_{CE}$ = 75 V) | $I_{S/b}$ | 700 min | mA |
| Second-Breakdown Energy, Safe Operating Region ($V_{BE}$ = 6 V, $I_C$ = 10 A, $R_{BE}$ = 20 Ω, L = 40 μH) | $E_{S/b}$ | 2 min | mJ |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 1.5 max | °C/W |

## 2N3265 25A, 125W




Si n-p-n epitaxial type used in high-power, high-speed, and high-current applications such as switching circuits, amplifiers, and power oscillators in aerospace, military, and industrial applications. JEDEC TO-63, Outline No.24. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N3263 except for the following items:

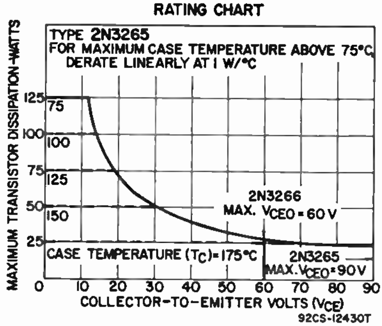
### MAXIMUM RATINGS

| | | |
|---|---|---|
| Transistor Dissipation | $P_T$ | See Rating Chart |

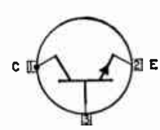
### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 1 max | °C/W |

RATING CHART




## 2N3266 25A, 125W




Si n-p-n epitaxial type used in high-power, high-speed, and high-current applications such as switching circuits, amplifiers, and power oscillators in aerospace, military, and industrial applications. JEDEC TO-63, Outline No.24. See Mounting Hardware for desired mounting arrangement. For curves of safe operating region, transfer characteristics, and static forward-current transfer ratio, refer to type 2N3263. This type is identical with type 2N3264 except for the following items:

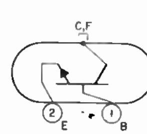
### MAXIMUM RATINGS

| | |
|---|---|
| Transistor Dissipation | See Rating Chart for Type 2N3265 |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 1 max | °C/W |

## 2N5671 30A, 140W




Si n-p-n epitaxial type used in switching control amplifiers, power gates, switching regulators, power-switching circuits, converters, inverters and control circuits. JEDEC TO-3, Outline No.2. See Mounting Hardware for desired mounting arrangement.

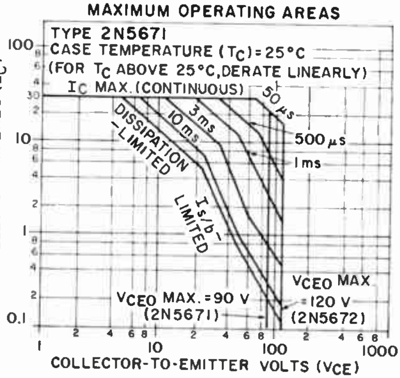
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 120 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| Base open | $V_{CEO}(sus)$ | 90 | V |
| $R_{BE} \leq 50\ \Omega$ | $V_{CER}(sus)$ | 110 | V |
| $V_{BE} = -1.5$ V, $R_{BE} \leq 50\ \Omega$ | $V_{CEX}(sus)$ | 120 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 30 | A |
| Base Current | $I_B$ | 10 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C, $V_{CE}$ up to 24 V | $P_T$ | 140 | W |
| $T_C$ up to 25°C, $V_{CE}$ up to 24 V | $P_T$ | See Rating Chart | |
| $T_C$ above 25°C, $V_{CE}$ above 24 V | $P_T$ | See Rating Chart and curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J(opr)$ | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 230 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

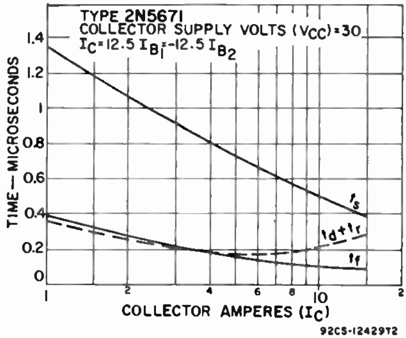
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C = 0.2$ A, IB = 0 | $V_{CEO}(sus)$ | 90 min | V |
| $I_C = 0.2$ A, $I_B = 0$, $R_{BE} \leq 50\ \Omega$ | $V_{CER}(sus)$ | 110 min | V |
| $V_{BE} = -1.5$ V, $I_C = 0.2$ A, $R_{BE} \leq 50\ \Omega$, base-emitter junction reverse biased | $V_{CEX}(sus)$ | 120 min | V |
| Base-to-Emitter Saturation Voltage ($I_C = 15$ A, $I_B = 1.2$ A) | $V_{BE}(sat)$ | 1.5 max | V |
| Base-to-Emitter Voltage ($V_{EC} = 5$ V, $I_C = 15$ A) | $V_{BE}$ | 1.6 max | V |
| Collector-to-Emitter Saturation Voltage ($I_C = 15$ A, $I_B = 1.2$ A) | $V_{CE}(sat)$ | 0.75 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE} = 80$ V, $I_B = 0$ | $I_{CEO}$ | 10 max | mA |
| $V_{CE} = 110$ V, $V_{BE} = -1.5$ V | $I_{CEV}$ | 12 max | mA |
| $V_{CE} = 100$ V, $V_{BE} = -1.5$ V, $T_C = 150$°C | $I_{CEV}$ | 15 max | mA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE} = 2$V, $I_C = 15$ A | $h_{FE}$ | 20 to 100 | |
| $V_{CE} = 5$ V, $I_C = 20$ A | $h_{FE}$ | 20 min | |
| Second-Breakdown Collector Current (base forward biased, non-repetitive pulse = 1 s): | | | |
| $V_{CE} = 24$ V | $I_{S/b}$ | 5.8 min | A |
| $V_{CE} = 45$ V | $I_{S/b}$ | 0.9 min | A |
| Second-Breakdown Energy ($V_{BE} = -4$ V, $I_C = 15$ A, $R_{BE} = 20\ \Omega$, L = 180 μH, base forward biased) | $E_{S/b}$ | 20 min | mJ |
| Gain-Bandwidth Product ($V_{CE} = 10$ V, $I_C = 2$A) | $f_T$ | 50 min | MHz |
| Output Capacitance ($V_{CB} = 10$ V, $I_E = 0$, f = 1 MHz) | $C_{obo}$ | 900 max | pF |
| Turn-On Time ($V_{CC} = 30$ V, $I_C = 15$ A, $I_{B1} = I_{B2} = 1.2$ A) | $t_d + t_r$ | 0.5 max | μs |
| Storage Time ($V_{CC} = 30$ V, $I_C = 15$ A, $I_{B1} = I_{B2} = 1.2$ A) | $t_s$ | 1.5 max | μs |
| Fall Time ($V_{CC} = 30$ V, $I_C = 15$ A, $I_{B1} = I_{B2} = 1.2$ A) | $t_f$ | 0.5 max | μs |
| Thermal Resistance, Junction-to-Case ($V_{CE} = 40$ V, $I_C = 0.5$ A) | $\theta_{J-C}$ | 1.25 max | °C/W |

MAXIMUM OPERATING AREAS




92CS-15650T

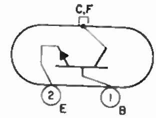
TYPICAL SATURATION CHARACTERISTICS
CONDUCTION RATING CHART




92CS-12429T2

# 2N5672 30A, 140W

Si n-p-n epitaxial type used in switching control amplifiers, power gates, switching regulators, power-switching circuits, converters, inverters and control circuits. JEDEC TO-3, Outline No.2. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N561 except for the following items.



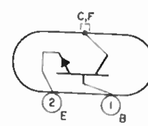

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 150 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| Base open | $V_{CEO}(sus)$ | 120 | V |
| $R_{BE} \leq 50\ \Omega$ | $V_{CER}(sus)$ | 140 | V |
| $V_{BE} = 1.5$ V, $R_{BE} \leq 50\ \Omega$ | $V_{CEX}(sus)$ | 150 | V |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C = 0.2$ A, $I_B = 0$ | $V_{CEO}(sus)$ | 120 | V |
| $I_C = 0.2$ A, $I_B = 0$, $R_{BE} \leq 50\ \Omega$ | $V_{CER}(sus)$ | 140 | V |
| $V_{BE} = -1.5$ V, $I_C = 0.2$ A, $R_{BE} \leq 50\ \Omega$, base-emitter junction reverse biased | $V_{CEX}(sus)$ | 150 | V |
| Collector-Cutoff Current: | | | |
| $V_{CE} = 80$ V, $I_B = 0$ | $I_{CEO}$ | 10 max | mA |
| $V_{CE} = 135$ V, $V_{BE} = -1.5$ V | $I_{CEV}$ | 10 max | mA |
| $V_{CE} = 100$ V, $V_{BE} = -1.5$ V, $T_C = 150$ °C | $I_{CEV}$ | 10 max | mA |

# 2N6032 50A, 140W




Si n-p-n epitaxial type used for switching and amplifier applications in military, industrial, and commercial equipment. JEDEC TO-3 (modified), Outline No. 73.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 120 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| Base open | $V_{CEO}(sus)$ | 90 | V |
| $R_{BE} \leq 50\ \Omega$ | $V_{CER}(sus)$ | 110 | V |
| $R_{BE} \leq 50\ \Omega$, $V_{BE} = -1.5$ V | $V_{CEX}(sus)$ | 120 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 50 | A |
| Base Current | $I_B$ | 10 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C and $V_{CE}$ up to 24 V | $P_T$ | 140 | |
| $T_C$ up to 25°C and $V_{CE}$ above 24 V | $P_T$ | See curve page 300 | |
| $T_C$ above 25°C and $V_{CE}$ above 24 V | $P_T$ | See Maximum Operating Curve and curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J(opr)$ | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 230 | °C |

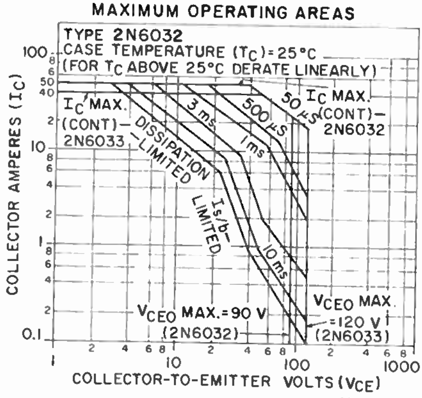
## CHARACTERISTICS (At case temperature = 25°C)

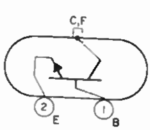
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C = 0.2$ A, $I_B = 0$ | $V_{CEO}(sus)$ | 90 min | V |
| $I_C = 0.2$ A, $I_B = 0$, $R_{BE} \leq 50\ \Omega$ | $V_{CER}(sus)$ | 110 min | V |
| $V_{BE} = -1.5$ V, $I_C = 0.2$ A, $I_B = 0$ | $V_{CEX}(sus)$ | 120 min | V |
| Base-to-Emitter Saturation Voltage ($I_C = 50$ A, $I_B = 5$ A) | $V_{BE}(sat)$ | 2 max | V |
| Base-to-Emitter Voltage ($V_{CE} = 2$ V, $I_C = 50$ A) | $V_{BE}$ | 2 max | V |
| Collector-to-Emitter Saturation Voltage ($I_C = 50$ A, $I_B = 5$ A) | $V_{CE}(sat)$ | 1.3 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE} = 80$ V, $I_B = 0$ | $I_{CEO}$ | 10 max | mA |
| $V_{CE} = 110$ V, $V_{BE} = -1.5$ V, base-emitter junction reverse biased | $I_{CEV}$ | 12 max | mA |
| $V_{CE} = 100$ V, $V_{BE} = -1.5$ V, base-emitter junction reverse biased, $T_C = 150$°C | $I_{CEV}$ | 15 max | mA |

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Emitter-Cutoff Current ($V_{EB}$ = 7 V, $I_C$ = 0) | $I_{EBO}$ | 10 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 2.6 V, $I_C$ = 50 A) | $h_{FE}$ | 10 to 50 | |
| Second-Breakdown Collector Current: | | | |
| $V_{CE}$ = 24 V, base forward biased, non-repetitive pulse = 1 s | $I_{S/b}$ | 5.8 min | A |
| $V_{CE}$ = 40 V, base forward biased, non-repetitive pulse = 1 s | $I_{S/b}$ | 0.9 min | A |
| Second-Breakdown Energy ($V_{BE}$ = −4 V, $I_C$ = 20 A, L = 310 μH, $R_{BE}$ = 5 Ω, base reverse biased) | $E_{S/b}$ | 62 min | mJ |
| Gain-Bandwidth Product ($V_{CE}$ = 10 V, $I_C$ = 2 A) | $f_T$ | 50 min | MHz |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 800 max | pF |
| Turn-On Time ($V_{CC}$ = 30 V, $I_C$ = 40 A, $I_{B1}$ = $I_{B2}$ = 4 V) | $t_d + t_r$ | 1 max | μs |
| Storage Time ($V_{CC}$ = 30 V, $I_C$ = 40 A, $I_{B1}$ = $I_{B2}$ = 4 V) | $t_s$ | 1.5 max | μs |
| Fall Time ($V_{CC}$ = 30 V, $I_C$ = 40 A, $I_{B1}$ = $I_{B2}$ = 4 V) | $t_f$ | 0.5 max | μs |
| Thermal Resistance, Junction-to-Case ($V_{CE}$ = 20 V, $I_C$ = 2.5 A) | $\theta_{J-C}$ | 1.25 max | °C/W |

MAXIMUM OPERATING AREAS




## 50A, 140W

# 2N6033

Si n-p-n epitaxial type used for switching and amplifier applications in military, industrial, and commercial equipment. JEDEC TO-3 (modified), Outline No. 73.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 150 | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| Base open | $V_{CEO}$(sus) | 120 | V |
| $R_{BE}$ ≤ 50 Ω | $V_{CER}$(sus) | 140 | V |
| $R_{BE}$ ≤ 50 Ω, $V_{BE}$ = −1.5 V | $V_{CEX}$(sus) | 150 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 40 | A |
| Base Current | $I_B$ | 10 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C and $V_{CE}$ up to 24 V | $P_T$ | 140 | |
| $T_C$ up to 25°C and $V_{CE}$ above 24 V | $P_T$ | See curve page 300 | |
| $T_C$ above 25°C and $V_{CE}$ above 24 V | $P_T$ | See Maximum Operating Curve | |

### MAXIMUM RATINGS (cont'd)

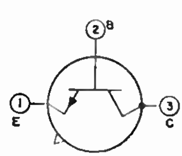
| | | | |
|---|---|---|---|
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 230 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 0.2 A, $I_B$ = 0 | $V_{CEO}$(sus) | 120 min | V |
| $I_C$ = 0.2 A, $I_B$ = 0, $R_{BE} \leq 50\ \Omega$ | $V_{CER}$(sus) | 140 min | V |
| $V_{BE}$ = −1.5 V, $I_C$ = 0.2 A, $I_B$ = 0 | $V_{CEX}$(sus) | 150 min | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 40 A, $I_B$ = 4 A) | $V_{BE}$(sat) | 2 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 2 V, $I_C$ = 40 A) | $V_{BE}$ | 2 max | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 40 A, $I_B$ = 4 A) | $V_{CE}$(sat) | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 80 V, $I_B$ = 0 | $I_{CEO}$ | 10 max | mA |
| $V_{CE}$ = 135 V, $V_{BE}$ = −1.5 V, base-emitter junction reverse biased | $I_{CEV}$ | 10 max | mA |
| $V_{CE}$ = 100 V, $V_{BE}$ = −1.5 V, base-emitter junction reverse biased, $T_C$ = 150°C | $I_{CEV}$ | 10 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 7 V, $I_C$ = 0) | $I_{EBO}$ | 10 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 2 V, $I_C$ = 40 A) | $h_{FE}$ | 10 to 50 | |
| Second-Breakdown Collector Current: | | | |
| $V_{CE}$ = 24 V, base forward biased, non-repetitive pulse = 1 s | $I_{S/b}$ | 5.8 min | A |
| $V_{CE}$ = 40 V, base forward biased, non-repetitive pulse = 1 s | $I_{S/b}$ | 0.9 min | A |
| Second-Breakdown Energy ($V_{BE}$ = −4 V, $I_C$ = 20 A, L = 310 µH, $R_{BE}$ = 5 Ω, base reverse biased) | $E_{S/b}$ | 62 min | mJ |
| Gain-Bandwidth Product ($V_{CE}$ = 10 V, $I_C$ = 2 A) | $f_T$ | 50 min | MHz |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 800 max | pF |
| Turn-On Time ($V_{CC}$ = 30 V, $I_C$ = 50 A, $I_{B1}$ = $I_{B2}$ = 5 V) | $t_d + t_r$ | 1 max | µs |
| Storage Time ($V_{CC}$ = 30 V, $I_C$ = 50 A, $I_{B1}$ = $I_{B2}$ = 5 V) | $t_s$ | 1.5 max | µs |
| Fall Time ($V_{CC}$ = 30 V, $I_C$ = 50 A, $I_{B1}$ = $I_{B2}$ = 5 V) | $t_f$ | 0.5 max | µs |
| Thermal Resistance, Junction-to-Case ($V_{CE}$ = 20 V, $I_C$ = 2.5 A) | $\theta_{J-C}$ | 1.25 max | °C/W |

# *Diffused-Junction N-P-N Types*

## 40084 1A, 1.8W




Si n-p-n triple-diffused planar type used in a wide variety of small and medium-power applications (up to 20 MHz) in industrial equipment. JEDEC TO-18, Outline No.12.

### MAXIMUM RATINGS

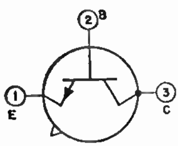
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 60 | V |
| Collector-to-Emitter Voltage: | | | |
| $R_{BE}$ = 10 Ω | $V_{CER}$ | 50 | V |
| Base open | $V_{CEO}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 1.8 | W |
| $T_A$ up to 25°C | $P_T$ | 0.5 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 225 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 60 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 5 min | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 100 mA, $R_{BE}$ = 10 Ω, $t_p$ = 300 μs, df = 1.8% | $V_{CER}(sus)$ | 50 min | V |
| $I_C$ = 100 mA, $I_B$ = 0, $t_p$ = 300 μs, df = 1.8% | $V_{CEO}(sus)$ | 40 min | V |
| Base-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA) | $V_{BE}(sat)$ | 1.7 max | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA) | $V_{CE}(sat)$ | 1.4 max | V |
| Collector-Cutoff Current ($V_{CB}$ = 30 V, $I_E$ = 0) | $I_{CBO}$ | 0.25 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 4 V, $I_C$ = 0) | $I_{EBO}$ | 0.25 max | μA |
| Input Capacitance ($V_{EB}$ = 0.5 V, $I_C$ = 0) | $C_{ibo}$ | 80 max | pF |
| Output Capacitance ($V_{CB}$ = 10 V, $I_E$ = 0) | $C_{obo}$ | 15 max | pF |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 150 mA, $t_p$ = 300 μs, df = 1.8%) | $h_{FE}$ | 50 to 250 | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 50 mA, f = 20 MHz) | $h_{fe}$ | 5 min | |
| Noise Figure ($R_G$ = 500 Ω, circuit bandwidth = 15 kHz, $V_{CE}$ = 10 V, $I_C$ = 0.3 mA, f = 1 kHz) | NF | 8 max | dB |
| Thermal Resistance: | | | |
| Junction-to-Case | $\Theta_{J-C}$ | 97 max | °C/W |
| Junction-to-Ambient | $\Theta_{J-A}$ | 350 max | °C/W |

## 1A, 5W

# 2N1479




Si n-p-n diffused-junction type used in power switching circuits such as dc-to-dc converters, inverters, choppers, solenoid and relay controls; in oscillators, regulators, and pulse amplifier circuits; and as class A and class B push-pull audio and servo amplifiers in industrial and military equipment. JEDEC TO-5, Outline No.5.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 60 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 60 | V |
| Base open (sustaining voltage) | $V_{CEO}(sus)$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 12 | V |
| Collector Current | $I_C$ | 1.5 | A |
| Emitter Current | $I_E$ | −1.75 | A |
| Base Current | $I_B$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating ($T_C$) and Storage ($T_{STG}$) | | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 50 mA, $I_B$ = 0) | $V_{CEO}(sus)$ | 40 min | V |
| Collector-to-Emitter Voltage ($V_{BE}$ = −1.5, $I_C$ = 0.25 mA) | $V_{CEV}$ | 60 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 200 mA) | $V_{BE}$ | 3 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 10 max | μA |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 500 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 12 V, $I_C$ = 0) | $I_{EBO}$ | 10 max | μA |
| Collector-to-Emitter Saturation Resistance ($I_C$ = 200 mA, $I_B$ = 20 mA) | $r_{CE}(sat)$ | 7 max | Ω |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 200 mA) | $h_{FE}$ | 20 to 60 | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 5 mA, f = 1 kHz) | $h_{fe}$ | 50 | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CB}$ = 28 V, $I_C$ = 5 mA) | $f_{hfb}$ | 50 max | kHz |

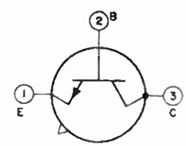
## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Gain-Bandwidth Product | $f_T$ | 1.5 | MHz |
| Output Capacitance ($V_{CB}$ = 40 V, $I_C$ = 0, f = 1 kHz) | $C_{obo}$ | 150 | pF |
| Thermal Time Constant | $\tau$ (thermal) | 10 | ms |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 35 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 200 max | °C/W |

## TYPICAL OPERATION IN POWER-SWITCHING CIRCUIT (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| DC Supply Voltage | $V_{CC}$ | 12 | V |
| DC Base-Bias Voltage | | −8.5 | V |
| Generator Resistance | $R_G$ | 50 | Ω |
| "On" DC Collector Current | $I_C$ | 200 | mA |
| "Turn-On" Base Current | $I_{B1}$ | 20 | mA |
| "Turn-Off" Base Current | $I_{B2}$ | −8.5 | mA |
| Delay Time | $t_d$ | 0.2 | μs |
| Rise Time | $t_r$ | 1 | μs |
| Storage Time | $t_s$ | 0.6 | μs |
| Fall Time | $t_f$ | 1 | μs |

# 2N1480 1A, 5W




Si n-p-n diffused-junction type used in power switching circuits such as dc-to-dc converters, inverters, choppers, solenoid and relay controls; in oscillators, regulators, and pulse amplifier circuits; and as class A and class B push-pull audio and servo amplifiers in industrial and military equipment. JEDEC TO-5, Outline No.5. This type is identical with type 2N1479 except for the following items:

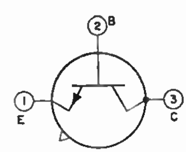
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 100 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 100 | V |
| Base open (sustaining voltage) | $V_{CEO}$(sus) | 55 | V |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 50 mA, $I_B$ = 0) | $V_{CEO}$(sus) | 55 min | V |
| Collector-to-Emitter Voltage ($V_{BE}$ = −1.5 V, $I_C$ = 0.25 mA) | $V_{CEV}$ | 100 min | V |

# 2N1481 1A, 5W

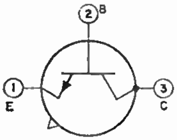



Si n-p-n diffused-junction type used in power switching circuits such as dc-to-dc converters, inverters, choppers, solenoid and relay controls; in oscillators, regulators, and pulse amplifier circuits; and as class A and class B push-pull audio and servo amplifiers in industrial and military equipment. JEDEC TO-5, Outline No.5. This type is identical with type 2N1479 except for the following items:

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 200 mA) | $h_{FE}$ | 35 to 100 | |
| Collector-to-Emitter Saturation Resistance ($I_C$ = 200 mA, $I_B$ = 10 mA) | $r_{CE}$(sat) | 7 max | Ω |

## 1A, 5W — 2N1482




Si n-p-n diffused-junction type used in power switching circuits such as dc-to-dc converters, inverters, choppers, solenoid and relay controls; in oscillators, regulators, and pulse amplifier circuits; and as class A and class B push-pull audio and servo amplifiers in industrial and military equipment. JEDEC TO-5, Outline No.5. This type is identical with type 2N1479 except for the following items:

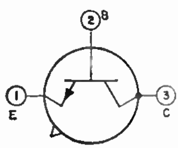
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 100 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 100 | V |
| Base open (sustaining voltage) | $V_{CEO}$(sus) | 55 | V |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 50 mA, $I_B$ = 0) | $V_{CEO}$(sus) | 55 min | V |
| Collector-to-Emitter Voltage ($V_{BE}$ = −1.5 V, $I_C$ = 0.25 mA) | $V_{CEV}$ | 100 min | V |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 200 mA) | $h_{FE}$ | 35 to 100 | |
| Collector-to-Emitter Saturation Resistance ($I_C$ = 200 mA, $I_B$ = 10 mA) | $r_{CE}$(sat) | 7 max | Ω |

## 1A, 5W — 2N1700




Si n-p-n diffused-junction type used in power-switching circuits such as dc-to-dc converters, inverters, choppers, solenoid and relay controls; in oscillators, regulators, and pulse-amplifier circuits; and as class A and class B push-pull audio and servo amplifiers in industrial and military equipment. JEDEC TO-5, Outline No.5. For typical operation in a power-switching circuit, refer to type 2N1479.

### MAXIMUM RATINGS

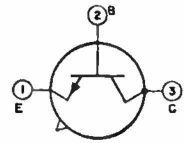
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 60 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 60 | V |
| Base open (sustaining voltage) | $V_{CEO}$(sus) | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 6 | V |
| Collector Current | $I_C$ | 1 | A |
| Base Current | $I_B$ | 0.75 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 50 mA, $I_B$ = 0) | $V_{CEO}$(sus) | 40 min | V |
| Collector-to-Emitter Voltage ($V_{BB}$ = −1.5 V, $I_C$ = 0.5 mA) | $V_{CEV}$ | 60 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 100 mA) | $V_{BE}$ | 2 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 75 max | μA |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 1000 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 6 V, $I_C$ = 0) | $I_{EBO}$ | 25 max | μA |
| Collector-to-Emitter Saturation Resistance ($I_C$ = 100 mA, $I_B$ = 10 mA) | $r_{CE}$(sat) | 10 max | Ω |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 100 mA) | $h_{FE}$ | 20 to 80 | |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 35 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 200 max | °C/W |

# 40367 1A, 5W

Si n-p-n single-diffused type featuring a base comprised of a homogeneous-resistivity silicon material. This type is subjected to special preconditioning tests for high-reliability operation in medium- and high-power switching and amplifier applications in military and industrial equipment. JEDEC TO-5, Outline No.5. This type is a high-reliability version of type 2N1482.




## MAXIMUM RATINGS

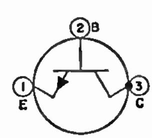
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 100 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE} = -1.5$ V | $V_{CEV}$ | 100 | V |
| Base open | $V_{CEO}$ | 55 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 12 | V |
| Collector Current | $I_C$ | 1.5 | A |
| Base Current | $I_B$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 255 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($V_{BE} = -1.5$ V, $I_C = 0.25$ mA) | $V_{(BR)CEV}$ | 100 min | V |
| Collector-to-Emitter Sustaining Voltage ($I_C = 50$ mA, $I_B = 0$) | $V_{CEO}$(sus) | 55 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C = 200$ mA, $I_B = 10$ mA) | $V_{CE}$(sat) | 1.4 max | V |
| Base-to-Emitter Voltage ($V_{CE} = 4$ V, $I_C = 200$ mA) | $V_{BE}$ | 3 max | V |
| Collector-Cutoff Current ($V_{CB} = 30$ V, $I_E = 0$) | $I_{CBO}$ | 4 max | µA |
| Emitter-Cutoff Current ($V_{EB} = 12$ V, $I_C = 0$) | $I_{EBO}$ | 2 max | µA |
| Static Forward-Current Transfer Ratio ($V_{CE} = 4$ V, $I_C = 200$ mA) | $h_{FE}$ | 35 to 100 | |

# 2N1701 2.5A, 25W

Si n-p-n diffused-junction type used in power-switching applications such as dc-to-dc converter, inverter, chopper, solenoid and relay control circuits; in oscillator, regulator, and pulse-amplifier circuits; and as class A and class B push-pull audio and servo amplifiers in industrial and military equipment. JEDEC TO-8, Outline No.10. See Mounting Hardware for desired mounting arrangement.




## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 60 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE} = -1.5$ V | $V_{CEV}$ | 60 | V |
| Base open (sustaining voltage) | $V_{CEO}$(sus) | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 6 | V |
| Collector Current | $I_C$ | 2.5 | A |
| Base Current | $I_B$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 25 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |

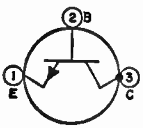
### MAXIMUM RATINGS (cont'd)

| | | | |
|---|---|---|---|
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 235 | °C |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $I_B$ = 0) | $V_{CEO}$(sus) | 40 min | V |
| Collector-to-Emitter Voltage ($V_{BE}$ = −1.5, $I_C$ = 0.75 mA) | $V_{CEV}$ | 60 min | V |
| Collector-to-Emitter Saturation Voltage: ($I_C$ = 2.5 A, $I_B$ = 1 A) | $V_{CE}$(sat) | 12.5 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 300 mA) | $V_{BE}$ | 3 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 100 max | μA |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 1500 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −6 V, $I_C$ = 0) | $I_{EBO}$ | 50 max | μA |
| Collector-to-Emitter Saturation Resistance ($I_C$ = 300 mA, $I_B$ = 30 mA) | $r_{CE}$(sat) | 5 max | Ω |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 4 V, $I_C$ = 300 mA | $h_{FE}$ | 20 to 80 | |
| $V_{CE}$ = 20 V, $I_C$ = 2.5 A | $h_{FE}$ | 5 min | |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 7 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 100 max | °C/W |

## 3A, 25W **2N1483**




Si n-p-n diffused-junction type used in dc-to-dc converters, inverters, choppers, dc and servo amplifiers, relay- and solenoid-actuating circuits in industrial and military equipment. JEDEC TO-8, Outline No.10. See Mounting Hardware for desired mounting arrangement.

### MAXIMUM RATINGS

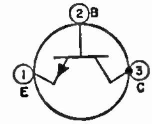
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 60 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 60 | V |
| Base open (sustaining voltage) | $V_{CEO}$(sus) | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 12 | V |
| Collector Current | $I_C$ | 3 | A |
| Emitter Current | $I_E$ | −3.5 | A |
| Base Current | $I_B$ | 1.5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 25 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating ($T_C$) and Storage ($T_{STG}$) | | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 235 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $I_B$ = 0) | $V_{CEO}$(sus) | 40 min | V |
| Collector-to-Emitter Voltage ($V_{BE}$ = −1.5 V, $I_C$ = 0.25 mA) | $V_{CEV}$ | 60 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 750 mA) | $V_{BE}$ | 3.5 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | 15 max | μA |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_A$ = 150°C | $I_{CBO}$ | 750 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 12 V, $I_C$ = 0) | $I_{EBO}$ | 15 max | μA |
| Collector-to-Emitter Saturation Resistance ($I_C$ = 750 mA, $I_B$ = 75 mA) | $r_{CE}$(sat) | 2.67 max | Ω |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 750 mA) | $h_{FE}$ | 20 to 60 | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CB}$ = 28 V, $I_C$ = 5 mA) | $f_{hfb}$ | 1.25 | MHz |
| Output Capacitance ($V_{CB}$ = 40 V, $I_E$ = 0) | $C_{obo}$ | 175 | pF |
| Thermal Time Constant | $\tau$(thermal) | 10 | ms |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 7 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 100 max | °C/W |

# 2N1484 3A, 25W

Si n-p-n diffused-junction type used in dc-to-dc converters, inverters, choppers, dc and servo amplifiers, relay- and solenoid-actuating circuits in industrial and military equipment. JEDEC TO-8, Outline No.10. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N1483 except for the following items:




## MAXIMUM RATINGS

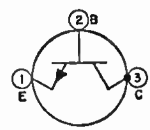
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 100 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 100 | V |
| Base open (sustaining voltage) | $V_{CEO}$(sus) | 55 | V |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $I_B$ = 0) | $V_{CEO}$(sus) | 55 min | V |
| Collector-to-Emitter Voltage ($V_{BE}$ = −1.5 V, $I_C$ = 0.25 mA) | $V_{CEV}$ | 100 min | V |

# 2N1485 3A, 25W

Si n-p-n diffused-junction type used in dc-to-dc converters, inverters, choppers, dc and servo amplifiers, relay- and solenoid-actuating circuits in industrial and military equipment. JEDEC TO-8, Outline No.10. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N1483 except for the following items:

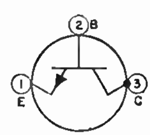



## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 750 mA) | $V_{BE}$ | 2.5 max | V |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 750 mA) | $h_{FE}$ | 35 to 100 | |
| Collector-to-Emitter Saturation Resistance ($I_C$ = 750 mA, $I_B$ = 40 mA) | $r_{CE}$(sat) | 1 max | Ω |

# 2N1486 3A, 25W

Si n-p-n diffused-junction type used in dc-to-dc converters, inverters, choppers, dc and servo amplifiers, relay- and solenoid-actuating circuits in industrial and military equipment. JEDEC TO-8, Outline No.10. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N1483 except for the following items:




## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 100 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 100 | V |
| Base open (sustaining voltage) | $V_{CEO}$(sus) | 55 | V |

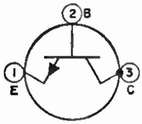
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $I_B$ = 0) | $V_{CEO}$(sus) | 55 min | V |
| Collector-to-Emitter Voltage ($V_{BE}$ = −1.5 V, $I_C$ = 0.25 mA) | $V_{CEV}$ | 100 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 750 mA) | $V_{BE}$ | 2.5 max | V |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 750 mA) | $h_{FE}$ | 35 to 100 | |

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Resistance ($I_C$ = 750 mA, $I_B$ = 40 mA) | $r_{CE}$(sat) | 1 max | Ω |

## 3A, 25W — 40368



Si **n-p-n single-diffused** type featuring a base comprised of a homogeneous-resistivity silicon material. This type is subjected to special preconditioning tests for high-reliability operation in medium- and high-power switching and amplifier applications in military and industrial equipment. JEDEC TO-8, **Outline** No.10. See **Mounting Hardware** for desired mounting arrangement. This type is a high-reliability version of type 2N1486.

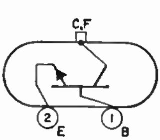
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 100 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 100 | V |
| Base open | $V_{CEO}$ | 55 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 12 | V |
| Collector Current | $I_C$ | 3 | A |
| Base Current | $I_B$ | 1.5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 25 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature | $T_P$ | 235 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($V_{BE}$ = −1.5 V, $I_C$ = 0.25 mA) | $V_{(BR)CEV}$ | 100 min | V |
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $I_B$ = 0) | $V_{CEO}$(sus) | 55 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 750 mA, $I_B$ = 10 mA) | $V_{CE}$(sat) | 0.75 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 750 mA) | $V_{BE}$ | 2.5 max | V |
| Collector-Cutoff Current ($V_{CB}$ = 30 V, $I_E$ = 0) | $I_{CBO}$ | 9 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 12 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 750 mA) | $h_{FE}$ | 35 to 100 | |

## 5A, 75W — 2N1702



Si **n-p-n diffused-junction** type used in power-switching applications such as dc-to-dc converter, inverter, chopper, and relay control circuits; in voltage and current regulator circuits; and in dc and servo amplifier circuits. Similar to JEDEC TO-3, **Outline** No.3. See **Mounting Hardware** for desired mounting arrangement.

### MAXIMUM RATINGS

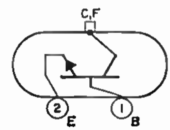
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 60 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 60 | V |
| Base open (sustaining voltage) | $V_{CEO}$(sus) | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 6 | V |
| Collector Current | $I_C$ | 5 | A |
| Base Current | $I_B$ | 2.5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 75 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $I_B$ = 0) | $V_{CEO}$(sus) | 40 min | V |
| Collector-to-Emitter Voltage ($V_{BE}$ = −1.5 V, $I_C$ = 1 mA) | $V_{CEV}$ | 60 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 800 mA) | $V_{BE}$ | 4 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 200 | µA |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 2000 | µA |
| Emitter-Cutoff Current ($V_{EB}$ = 6 V, $I_C$ = 0) | $I_{EBO}$ | 100 | µA |
| Collector-to-Emitter Saturation Resistance ($I_C$ = 800 mA, $I_B$ = 80 mA) | $r_{CE}$(sat) | 4 max | Ω |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 800 mA) | $h_{FE}$ | 15 to 60 | |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 2.33 max | °C/W |

# 2N1487 6A, 75W

Si n-p-n diffused-junction type used in dc-to-dc converters, inverters, choppers, voltage and current regulators, dc and servo amplifiers, relay- and solenoid-actuating circuits. JEDEC TO-3, Outline No.2. See Mounting Hardware for desired mounting arrangement.




### MAXIMUM RATINGS

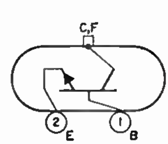
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 60 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 60 | V |
| Base open (sustaining voltage) | $V_{CEO}$(sus) | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 10 | V |
| Collector Current | $I_C$ | 6 | A |
| Emitter Current | $I_E$ | −8 | A |
| Base Current | $I_B$ | 3 | A |
| Transistor Dissipation: | | | |
| $T_{MF}$ at 25°C | $P_T$ | 75 | W |
| $T_{MF}$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating ($T_{MF}$) and Storage ($T_{STG}$) | | −65 to 200 | °C |

### CHARACTERISTICS (At mounting-flange temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $I_B$ = 0) | $V_{CEO}$(sus) | 40 min | V |
| Collector-to-Emitter Voltage ($V_{BE}$ = −1.5 V, $I_C$ = 0.5 mA) | $V_{CEV}$ | 60 min | V |
| Base-to-Emitter Saturation Voltage ($V_{CE}$ = 4 V, $I_C$ = 1.5 A) | $V_{BE}$ | 3.5 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | 25 max | µA |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_A$ = 150°C | $I_{CBO}$ | 1000 max | µA |
| Emitter-Cutoff Current ($V_{EB}$ = 10 V, $I_C$ = 0) | $I_{EBO}$ | 25 max | µA |
| Collector-to-Emitter Saturation Resistance ($I_C$ = 1.5 A, $I_B$ = 300 mA) | $r_{CE}$(sat) | 2 max | Ω |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 1.5 A) | $h_{FE}$ | 15 to 45 | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CB}$ = 12 V, $I_C$ = 100 mA) | $f_{hfb}$ | 1 | MHz |
| Output Capacitance ($V_{CB}$ = 40 V, $I_E$ = 0) | $C_{obo}$ | 200 | pF |
| Thermal Time Constant | $\tau$(thermal) | 12 | ms |
| Thermal Resistance, Junction-to-Mounting Flange | $\Theta_{J-MF}$ | 2.33 max | °C/W |

# 2N1488 6A, 75W

Si n-p-n diffused-junction type used in dc-to-dc converters, inverters, choppers, voltage and current regulators, dc and servo amplifiers, relay- and solenoid-actuating circuits. JEDEC TO-3, Outline No.2. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N1487 except for the following items:



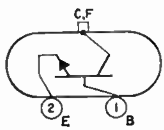
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 100 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE} = -1.5$ V | $V_{CEV}$ | 100 | V |
| Base open (sustaining voltage) | $V_{CEO}(sus)$ | 55 | V |

### CHARACTERISTICS (At mounting-flange temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C = 100$ mA, $I_B = 0$) | $V_{CEO}(sus)$ | 55 min | V |
| Collector-to-Emitter Voltage ($V_{BE} = -1.5$ V, $I_C = 0.5$ mA) | $V_{CEV}$ | 100 min | V |

## 6A, 75W 2N1489

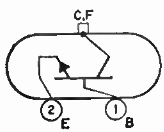



Si **n-p-n diffused-junction** type used in dc-to-dc converters, inverters, choppers, voltage and current regulators, dc and servo amplifiers, relay- and solenoid-actuating circuits. JEDEC TO-3, Outline No.2. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N1487 except for the following items:

### CHARACTERISTICS (At mounting-flange temperature = 25°C)

| | | | |
|---|---|---|---|
| Base-to-Emitter Voltage ($V_{CE} = 4$ V, $I_C = 1.5$ A) | $V_{BE}$ | 2.5 max | V |
| Static Forward-Current Transfer Ratio ($V_{CE} = 4$ V, $I_C = 1.5$ A) | $h_{FE}$ | 25 to 75 | |
| Collector-to-Emitter Saturation Resistance ($I_C = 1.5$ A, $I_B = 100$ mA) | $r_{CE}(sat)$ | 0.67 max | Ω |

## 6A, 75W 2N1490




Si **n-p-n diffused-junction** type used in dc-to-dc converters, inverters, choppers, voltage and current regulators, dc and servo amplifiers, relay- and solenoid-actuating circuits. JEDEC TO-3, Outline No.2. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N1487 except for the following items:

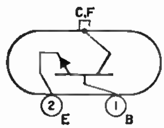
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 100 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE} = -1.5$ V | $V_{CEV}$ | 100 | V |
| Base open (sustaining voltage) | $V_{CEO}(sus)$ | 55 | V |

### CHARACTERISTICS (At mounting-flange temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($V_C = 100$ mA, $I_B = 0$) | $V_{CEO}(sus)$ | 55 min | V |
| Collector-to-Emitter Voltage ($V_{BE} = -1.5$ V, $I_C = 0.5$ mA) | $V_{CEV}$ | 100 min | V |
| Base-to-Emitter Voltage ($V_{CE} = 4$ V, $I_C = 1.5$ A) | $V_{BE}$ | 2.5 max | V |
| Static Forward-Current Transfer Ratio ($V_{CE} = 4$ V, $I_C = 1.5$ A) | $h_{FE}$ | 25 to 75 | |
| Collector-to-Emitter Saturation Resistance ($I_C = 1.5$ A, $I_B = 100$ mA) | $r_{CE}(sat)$ | 0.67 max | Ω |

## 6A, 75W 40369




Si n-p-n single-diffused type featuring a base comprised of a homogeneous-resistivity silicon material. This type is subjected to special preconditioning tests for high-reliabilitiy operation in medium- and high-power switching and amplifier applications in military and industrial equipment. JEDEC TO-3, Outline No.2. See **Mounting**

Hardware for desired mounting arrangement. This type is a high-reliability version of type 2N1490.

## MAXIMUM RATINGS

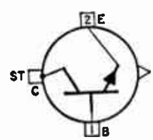
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 100 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 100 | V |
| Base open | $V_{CEO}$ | 55 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 10 | V |
| Collector Current | $I_C$ | 6 | A |
| Base Current | $I_B$ | 3 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 75 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 235 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($V_{BE}$ = −1.5 V, $I_C$ = 0.25 mA) | $V_{(BR)CEV}$ | 100 min | V |
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $I_B$ = 0) | $V_{CEO}$(sus) | 55 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 1300 mA, $I_B$ = 100 mA) | $V_{CE}$(sat) | 1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 1500 mA) | $V_{BE}$ | 2.5 max | V |
| Collector-Cutoff Current ($V_{CB}$ = 30 V, $I_E$ = 0) | $I_{CBO}$ | 10 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 10 V, $I_C$ = 0) | $I_{EBO}$ | 6 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 1500 mA) | $h_{FE}$ | 25 to 75 | |

# 2N2338 7.5A, 150W

Si **n-p-n diffused-junction** type used in dc-to-dc converters, inverters, choppers, and relay-control circuits; in oscillators and voltage- and current-regulator circuits; and in dc and servo-amplifier circuits. JEDEC TO-36, **Outline** No.14. See **Mounting Hardware** for desired mounting arrangement.




## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 60 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 60 | V |
| Base open | $V_{CEO}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 6 | V |
| Collector Current | $I_C$ | 7.5 | A |
| Base Current | $I_B$ | 5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 150 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lug-Soldering Temperature (10 s max) | T(lug) | 235 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage ($V_{BE}$ = −1.5 V, $I_C$ = 2 mA) | $V_{CEV}$ | 60 min | V |
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 200 mA, $I_B$ = 0) | $V_{CEO}$(sus) | 40 min | V |
| Collector-to-Emitter Saturation Voltage: | | | |
| $I_C$ = 6 A, $I_B$ = 1 A | $V_{CE}$(sat) | 3.5 max | V |
| $I_C$ = 3 A, $I_B$ = 0.3 A | $V_{CE}$(sat) | 1.5 max | V |
| Base-to-Emitter Saturation Voltage ($V_{CE}$ = 4 V, $I_C$ = 3 A) | $V_{BE}$ | 3 max | V |

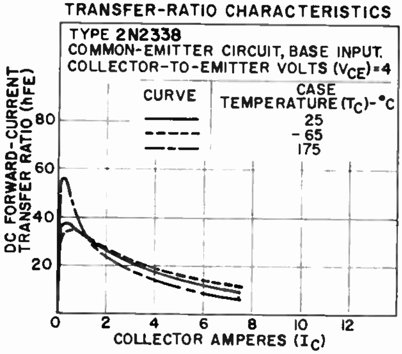
## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 0.2 max | mA |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 3 max | mA |
| $V_{CE}$ = 30 V, $I_B$ = 0 | $I_{CEO}$ | 5 max | mA |
| $V_{CE}$ = 60 V, $V_{BE}$ = −1.5 V, $T_C$ = 25°C | $I_{CEV}$ | 2 max | mA |
| $V_{CE}$ = 30 V, $V_{BE}$ = −1.5 V, $T_C$ = 200°C | $I_{CEV}$ | 50 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 6 V, $I_C$ = 0) | $I_{EBO}$ | 0.1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 3 A) | $h_{FE}$ | 15 to 60 | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 0.5 A, f = 1 kHz) | $h_{fe}$ | 12 to 72 | |
| Output Capacitance ($V_{CB}$ = 40 V, $I_E$ = 0, f = 0.1 MHz) | $C_{obo}$ | 600 max | pF |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CE}$ = 4 V, $I_C$ = 5 A) | $f_{hfe}$ | 0.015 min | MHz |
| Collector-to-Emitter Saturation Resistance ($I_C$ = 3 A, $I_B$ = 0.3 A) | $r_{CE}$(sat) | 0.5 max | Ω |
| Thermal Time Constant | $\tau$(thermal) | 30 | ms |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 1.17 max | °C/W |

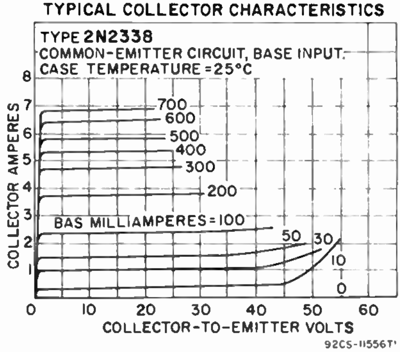
## TYPICAL OPERATION IN PULSE-RESPONSE TEST CIRCUIT

| | | | |
|---|---|---|---|
| DC Collector Supply Voltage | $V_{CC}$ | 24 | V |
| DC Base-Bias Voltage | | −6 | V |
| On DC Collector Current | $I_C$ | 10 | A |
| Turn-On DC Base Current | $I_{B1}$ | 2 | A |
| Base-Circuit Resistance | $R_{B1}$, $R_{B2}$ | 10 | Ω |
| Collector-Circuit Resistance | $R_C$ | 2 | Ω |
| Turn-On Time | $t_d + t_r$ | 4 | µs |
| Turn-Off Time | $t_s + t_f$ | 7 | µs |

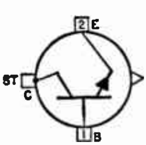
TYPICAL DC FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTICS




TYPICAL COLLECTOR CHARACTERISTICS




## 10A, 150W 2N2015




Si n-p-n diffused-junction type used in dc-to-dc converter, inverter, chopper, relay-control, oscillator, regulator, pulse-amplifier circuits; and class A and class B push-pull amplifiers for af and servo amplifier applications. JEDEC TO-36, Outline No.14. See Mounting Hardware for desired mounting arrangement.

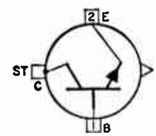
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 100 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 50 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 10 | V |
| Collector Current | $I_C$ | 10 | A |
| Emitter Current | $I_E$ | −13 | A |
| Base Current | $I_B$ | 6 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 150 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | °C |
| Operating ($T_C$) and Storage ($T_{STG}$) | | −65 to 200 | |
| Lug-Soldering Temperature (10 s max) | T(lug) | 235 | °C |

**CHARACTERISTICS (At case temperature = 25°C)**

| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage ($V_{BE}$ = −1.5 V, $I_C$ = 2 mA) | $V_{CEV}$ | 100 min | V |
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 200 mA, $I_B$ = 0) | $V_{CEO}$(sus) | 50 min | V |
| Collector-to-Emitter Voltage ($I_C$ = 5 A, $I_B$ = 0.5 A) | $V_{CE}$(sat) | 1.25 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 5 A) | $V_{BE}$ | 2.2 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 40 V, $I_B$ = 0 | $I_{CEO}$ | 0.2 max | mA |
| $V_{CE}$ = 100 V, $V_{BE}$ = −1.5 V | $I_{CEV}$ | 2 max | mA |
| $V_{CE}$ = 30 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C | $I_{CEV}$ | 2 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 10 V, $I_C$ = 0) | $I_{EBO}$ | 0.05 max | mA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 4 V, $I_C$ = 5 A | $h_{FE}$ | 15 to 50 | |
| $V_{CE}$ = 4 V, $I_C$ = 10 A | $h_{FE}$ | 7.5 min | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 1 A, f = 1 kHz) | $h_{fe}$ | 12 to 60 | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CE}$ = 4 V, $I_C$ = 5 A) | $f_{hfe}$ | 12 min | kHz |
| Collector-to-Emitter Saturation Resistance ($I_C$ = 5 A, $I_B$ = 0.5 A) | $r_{CE}$(sat) | 0.25 max | Ω |
| Output Capacitance ($V_{CB}$ = 40 V, $I_C$ = 50 μA, f = 1 MHz) | $C_{obo}$ | 400 max | pF |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 1.17 max | °C/W |

## 2N2016 10A, 150W




Si n-p-n diffused-junction type used in dc-to-dc converter, inverter, chopper, relay-control, oscillator, regulator, and pulse-amplifier circuits; and class A and class B push-pull amplifiers for af and servo amplifier applications. JEDEC TO-36, Outline No.14. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N2015 except for the following items:

**MAXIMUM RATINGS**

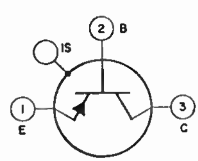
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 130 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 65 | V |

**CHARACTERISTICS (At case temperature = 25°C)**

| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage ($V_{BE}$ = −1.5 V, $I_C$ = 2 mA) | $V_{CEV}$ | 130 min | V |
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 200 mA, $I_B$ = 0) | $V_{CEO}$(sus) | 65 min | V |
| Collector-Cutoff Current ($V_{CE}$ = 130 V, $V_{BE}$ = −1.5 V) | $I_{CEV}$ | 2 max | mA |

# *Germanium Power Types*

## 2N274 −0.01A, 0.24W




Ge p-n-p alloy drift-field type used in rf and if amplifier, oscillator, mixer, and converter circuits, and in low-level video-amplifier circuits in industrial and military equipment. JEDEC TO-44, Outline No.17.

**MAXIMUM RATINGS**

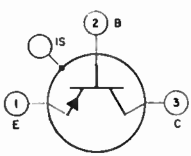
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −40 | V |
| Collector-to-Emitter Voltage ($V_{BE}$ = 0.5 V) | $V_{CEV}$ | −40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −0.5 | mA |
| Collector Current | $I_C$ | −10 | mA |

## MAXIMUM RATINGS (cont'd)

| | | | |
|---|---|---|---|
| Emitter Current | $I_E$ | 10 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 120 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| $T_A$ = 25°C (with heat sink) | $P_T$ | 240 | mW |
| $T_A$ above 25°C (with heat sink) | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 100 | °C |
| Storage | $T_{STG}$ | −65 to 100 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = −50 μA, $I_E$ = 0) | $V_{(BR)CBO}$ | −40 min | V |
| Collector-to-Base Reach-Through Voltage ($V_{EB}$ = −0.5 V) | $V_{RT}$ | −40 min | V |
| Collector-Cutoff Current ($V_{CB}$ = −12 V, $I_E$ = 0) | $I_{CBO}$ | −12 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −0.5 V, $I_C$ = 0) | $I_{EBO}$ | −12 max | μA |
| Small-Signal Forward-Current Transfer Ratio (f = 1 kHz, $V_{CE}$ = −12 V, $I_E$ = 1.5 mA) | $h_{fe}$ | 20 to 175 | |
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CB}$ = −12 V, $I_E$ = 1.5 mA) | $f_{hfb}$ | 30 | MHz |
| Output Capacitance ($V_{CB}$ = −12 V, $I_E$ = 0) | $C_{obo}$ | 3 max | pF |
| Input Resistance: | | | |
| $V_{CE}$ = −12 V, $I_E$ = 1.5 mA, f = 12.5 MHz | $R_{ie}$ | 150 | Ω |
| $V_{CE}$ = −12 V, $I_E$ = 1.5 mA, f = 1.5 MHz | $R_{ie}$ | 1350 | Ω |
| Output Resistance: | | | |
| $V_{CE}$ = −12 V, $I_E$ = 1.5 mA, f = 12.5 MHz | $R_{oe}$ | 4000 | Ω |
| $V_{CE}$ = −12 V, $I_E$ = 1.5 mA, f = 1.5 MHz | $R_{oe}$ | 70000 | Ω |
| Power Gain: | | | |
| $V_{CE}$ = −12 V, $I_E$ = 1.5 mA, f = 12.5 MHz | $G_{pe}$ | 17 to 27 | dB |
| $V_{CE}$ = −12 V, $I_E$ = 1.5 mA, f = 1.5 MHz | $G_{pe}$ | 40 to 50 | dB |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 0.31 max | °C/mW |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 0.62 max | °C/mW |




## —0.01A, 0.24W 2N384

Ge p-n-p alloy-junction drift-field type used in rf and if amplifier, oscillator, mixer, and converter circuits, and low-level video-amplifier circuits in industrial and military equipment. JEDEC TO-44, Outline No.17.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −40 | V |
| Collector-to-Emitter Voltage ($V_{BE}$ = 0.5 V) | $V_{CEV}$ | −40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −0.5 | V |
| Collector Current | $I_C$ | −10 | mA |
| Emitter Current | $I_E$ | 10 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 120 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| $T_C$ = 25°C (with heat sink) | $P_T$ | 240 | mW |
| $T_C$ above 25°C (with heat sink) | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 100 | °C |
| Storage | $T_{STG}$ | −65 to 100 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = −50 μA, $I_E$ = 0) | $V_{(BR)CBO}$ | −40 min | V |
| Collector-to-Base Reach-Through ($V_{EB}$ = −0.5 V) | $V_{RT}$ | −40 min | V |
| Collector-Cutoff Current ($V_{CB}$ = −12 V, $I_E$ = 0) | $I_{CBO}$ | −12 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −0.5 V, $I_C$ = 0) | $I_{EBO}$ | −12 max | μA |
| Small-Signal Forward-Current Transfer Ratio ($V_{CB}$ = −12 V, $I_E$ = 1.5 mA, f = 1 kHz) | $h_{fe}$ | 20 to 175 | |
| Small-Signal Forward-Current Transfer Ratio Cutoff Frequency ($V_{CB}$ = −12 V, $I_E$ = 1.5 mA) | $f_{hfb}$ | 100 | MHz |
| Input Resistance: | | | |
| $V_{CE}$ = −12 V, $I_E$ = 1.5 mA, f = 50 MHz | $R_{ie}$ | 30 | Ω |
| $V_{CE}$ = −12 V, $I_E$ = 1.5 mA, f = 12.5 MHz | $R_{ie}$ | 250 | Ω |

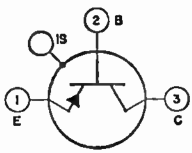
## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Output Resistance: | | | |
| $V_{CB}$ = −12 V, $I_E$ = 1.5 mA, f = 50 MHz | $R_{oe}$ | 5000 | Ω |
| $V_{CE}$ = −12 V, $I_E$ = 1.5 mA, f = 12.5 MHz | $R_{oe}$ | 16000 | Ω |
| Output Capacitance ($V_{CB}$ = −12 V, $I_E$ = 0) | $C_{obo}$ | 3 max | pF |
| Power Gain: | | | |
| $V_{CB}$ = −12 V, $I_E$ = 1.5 mA, f = 50 MHz | $G_{pe}$ | 15 to 21 | dB |
| $V_{CE}$ = −12 V, $I_E$ = 1.5 mA, f = 12.5 MHz | $G_{pe}$ | 24 to 32 | dB |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 0.31 max | °C/mW |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 0.62 max | °C/mW |

## TYPICAL OPERATION IN VIDEO-AMPLIFIER CIRCUIT

| | | | |
|---|---|---|---|
| DC Collector-to-Emitter Voltage | $V_{CE}$ | −12 | V |
| DC Emitter Current | $I_E$ | 5.8 | mA |
| Source Impedance | $R_S$ | 150 | Ω |
| Capacitive Load | | 16 | pF |
| Frequency Response | | 20 Hz to 10 MHz | |
| Pulse-Rise Time | $t_r$ | 0.035 | μs |
| Voltage Gain | | 26 | dB |
| Maximum Peak-to-Peak Output Voltage | | 20 | V |

# 2N1023 —0.01A, 0.24W




Ge p-n-p alloy-junction drift-field type used in rf and if amplifier, oscillator, mixer, and converter circuits, military equipment. JEDEC TO-44, Outline No.17.

## MAXIMUM RATINGS

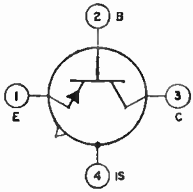
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −40 | V |
| Collector-to-Emitter Voltage ($V_{BE}$ = 0.5 V) | $V_{CEV}$ | −40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −0.5 | V |
| Collector Current | $I_C$ | −10 | mA |
| Emitter Current | $I_E$ | 10 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 120 | mW |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| $T_C$ up to 25°C (with heat sink) | $P_T$ | 240 | mW |
| $T_C$ above 25°C (with heat sink) | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating ($T_A$) and Storage ($T_{STG}$) | | −65 to 100 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = −50 μA, $I_E$ = 0) | $V_{(BR)CBO}$ | −40 min | V |
| Collector-to-Base Reach-Through Voltage ($V_{EB}$ = −0.5) | $V_{RT}$ | −40 min | V |
| Collector-Cutoff Current ($V_{CB}$ = −12 V, $I_E$ = 0) | $I_{CBO}$ | −12 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −0.5 V, $I_C$ = 0) | $I_{EBO}$ | −12 max | μA |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −12 V, $I_E$ = 1.5 mA, f = 1 kHz) | $h_{fe}$ | 20 to 175 | |
| Small-Signal Forward-Current Transfer Ratio Cutoff Frequency ($V_{CB}$ = −12 V, $I_E$ = 1.5 mA) | $f_{hfb}$ | 120 | MHz |
| Output Capacitance ($V_{CB}$ = −12 V, $I_E$ = 0) | $C_{obo}$ | 3 max | pF |
| Input Resistance (ac output circuit shorted): | | | |
| $V_{CB}$ = −12 V, $I_E$ = 1.5 mA, f = 50 MHz | $R_{ie}$ | 25 | Ω |
| $V_{CE}$ = −12 V, $I_E$ = 1.5 mA, f = 30 MHz | $R_{ie}$ | 100 | Ω |
| Output Resistance (ac input circuit shorted): | | | |
| $V_{CB}$ = −12 V, $I_E$ = 1.5 mA, f = 50 MHz | $R_{oe}$ | 8000 | Ω |
| $V_{CE}$ = −12 V, $I_E$ = 1.5 mA, f = 30 MHz | $R_{oe}$ | 8000 | Ω |
| Power Gain, Single-Tuned Unilateral Circuit): | | | |
| $V_{CB}$ = −12 V, $I_E$ = 1.5 mA, f = 50 MHz | $G_{pe}$ | 18 to 24 | dB |
| $V_{CE}$ = −12 V, $I_E$ = 1.5 mA, f = 30 MHz | $G_{pe}$ | 20 to 26 | dB |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 0.31 max | °C/mW |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 0.62 max | °C/mW |

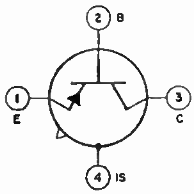
## TYPICAL OPERATION IN POWER-SWITCHING CIRCUIT

| | | | |
|---|---|---|---|
| DC Collector-to-Emitter Voltage | $V_{CE}$ | −12 | V |
| DC Emitter Current | $I_E$ | 5.8 | mA |
| Source Impedance | $R_S$ | 150 | Ω |
| Capacitive Load | | 16 | pF |
| Frequency Response | | 20 Hz to 11 MHz | |
| Pulse Rise Time | $t_r$ | 0.032 | μs |
| Voltage Gain | | 26 | dB |
| Maximum Peak-to-Peak Output Voltage | | 20 | V |



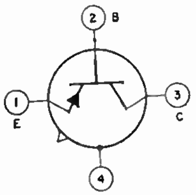

## —0.01A, 0.24W 2N1066

Ge p-n-p alloy-junction drift-field type used in rf and if amplifier, oscillator, mixer, and converter circuits, and low-level video-amplifier circuits in industrial and military equipment. JEDEC TO-33, Outline No.13. This type is electrically identical with type 2N1023.



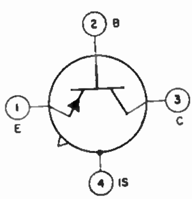

## —0.01A, 0.24W 2N1224

Ge p-n-p alloy-junction drift-field type used in rf and if amplifier, oscillator, mixer, and converter circuits, and low-level video-amplifier circuits in industrial and military equipment. JEDEC TO-33, Outline No.13. This type is electrically identical with type 2N274.




## —0.01A, 0.24W 2N1225

Ge p-n-p alloy-juncton drift-field type used in rf and if amplifier, oscillator, mixer, and converter circuits, and low-level video-amplifier circuits in industrial and military equipment. JEDEC TO-33, Outline No.13. This type is electrically identical with type 2N384. For collector-characteristics curves and video-amplifier circuit, refer to type 2N274.




## —0.01A, 0.24W 2N1226

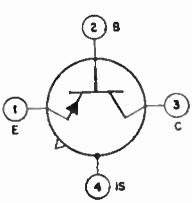
Ge p-n-p alloy-junction drift-field type used in rf and if amplifier, oscillator, mixer, and converter circuits, and low-level video-amplifier circuits in industrial and military equipment. JEDEC TO-33, Outline No.13. This type is identical with type 2N274 except for the following items:

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −60 | V |
| Collector-to-Emitter Voltage ($V_{BE}$ = 0.5 V) | $V_{CEV}$ | −60 | V |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = −50 μA, $I_E$ = 0) | $V_{(BR)CBO}$ | −60 min | V |
| Collector-to-Emitter Reach-Through Voltage ($V_{EB}$ = −0.5 V) | $V_{RT}$ | −60 min | V |



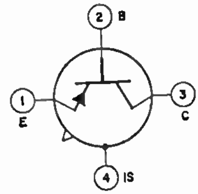

## —0.01A, 0.24W 2N1395

Ge p-n-p alloy-junction drift-field type used in rf and if amplifier, oscillator, mixer, and converter circuits, and low-level video-amplifier circuits in industrial and military equipment. JEDEC TO-33, Outline No.13. This type is identical with type 2N274 except for the following item:

### CHARACTERISTICS

| | | |
|---|---|---|
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −12 V, $I_E$ = 1.5 mA, f = 1 kHz) | $h_{fe}$ | 50 to 175 |

# 2N1396 —0.01A, 0.24W

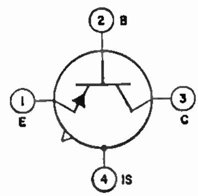



Ge p-n-p alloy-junction drift-field type used in rf and if amplifier, oscillator, mixer, and converter circuits, and low-level video-amplifier circuits in industrial and military equipment. JEDEC TO-33, Outline No.13. This type is identical with type 2N384 except for the following item:

### CHARACTERISTICS

| | | |
|---|---|---|
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −12 V, $I_E$ = 1.5 mA, f = 1 kHz) | $h_{fe}$ | 50 to 175 |

# 2N1397 —0.01A, 0.24W

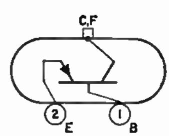



Ge p-n-p alloy-junction drift-field type used in rf and if amplifier, oscillator, mixer, and converter circuits, and low-level video-amplifier circuits in industrial and military equipment. JEDEC TO-33, Outline No.13. This type is identical with type 2N1023 except for the following item:

### CHARACTERISTICS

| | | |
|---|---|---|
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = −12 V, $I_E$ = 1.5 mA, f = 1 kHz) | $h_{fe}$ | 50 to 175 |

# 2N3732 —3A, 3W




Ge p-n-p diffused-collector graded-base type used in 114-degree 18-kV TV deflection systems as a horizontal driver. This type, together with types 2N3730 (vertical output), 2N3731 (horizontal output), and 1N4785 (damper) make up a complete transistor/damper-diode complement. JEDEC TO-3, Outline No.2.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage: | | | |
| Peak | $V_{CBO}$ | −100 | V |
| Continuous | $V_{CBO}$ | −60 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −0.5 | V |
| Collector Current | $I_C$ | −3 | A |
| Base Current | $I_B$ | ±0.5 | A |
| Transistor Dissipation: | | | |
| $T_{MF}$ up to 55°C | $P_T$ | 3 | W |
| $T_{MF}$ above 55°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 85 | °C |
| Storage | $T_{STG}$ | −65 to 85 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 230 | °C |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 5 A, $V_{EB}$ = 0) | $V_{(BR)CES}$ | −100 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −100 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | −0.5 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = −0.7 A, $I_B$ = −0.02 A) | $V_{CE}$(sat) | −2 max | V |

## CHARACTERISTICS (cont'd)

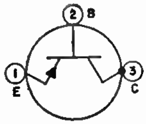
| | | | |
|---|---|---|---|
| Base-to-Emitter Voltage ($I_C$ = −0.7 A, $I_B$ = −0.02 A) | $V_{BE}$ | 0.5 | V |
| Collector-Cutoff Current ($V_{CB}$ = −10 V, $I_E$ = 0) | $I_{CBO}$ | −200 max | µA |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 1.5 max | °C/W |

## TYPICAL OPERATION IN HORIZONTAL-DEFLECTION AND HIGH-VOLTAGE CIRCUIT

| | | |
|---|---|---|
| DC Supply Voltage | 45 | V |
| Average Supply Current | 0.55 | A |
| Input Power: | | |
| Oscillator and driver circuits | 1.5 | W |
| Output Circuit: | | |
| At beam current = 0 | 18 | W |
| At beam current = 200 µA | 22 | W |
| DC High-Voltage Output: | | |
| At beam current = 0 | 18 | kV |
| At beam current = 200 µA | 17 | kV |
| Yoke Current (peak-to-peak) | 10 | A |
| Peak Yoke Energy | 2.5 | mJ |
| Retrace Time | 11.5 | µs |

# 2N1183
# 2N1183A
# 2N1183B

−3A, 7.5W



Ge p-n-p alloy-junction types intended for use in intermediate-power switching and low-frequency amplifier applications in industrial and military equipment. JEDEC TO-8, Outline No.10. See Mounting Hardware for desired mounting arrangement.

## MAXIMUM RATINGS

| | | *2N1183* | *2N1183A* | *2N1183B* | |
|---|---|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −45 | −60 | −80 | V |
| Collector-to-Emitter Voltage: | | | | | |
| $V_{BE}$ = 1.2 V | $V_{CEV}$ | −45 | −60 | −80 | V |
| $R_{BE}$ = 0 | $V_{CES}$ | −35 | −50 | −60 | V |
| Base open | $V_{CEO}$ | −20 | −30 | −40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −20 | −20 | −20 | A |
| Collector Current | $I_C$ | −3 | −3 | −3 | A |
| Emitter Current | $I_E$ | 3.5 | 3.5 | 3.5 | A |
| Base Current | $I_B$ | −0.5 | −0.5 | −0.5 | |
| Transistor Dissipation: | | | | | V |
| $T_A$ up to 25°C | $P_T$ | 1 | 1 | 1 | W |
| $T_A$ above 25°C | $P_T$ | | See curve page 300 | | |
| $T_C$ up to 25°C (with heat sink) | $P_T$ | 7.5 | 7.5 | 7.5 | W |
| $T_C$ above 25°C (with heat sink) | $P_T$ | | See curve page 300 | | |
| Temperature Range: | | | | | |
| Operating (Ambient) | $T_A$(opr) | | −65 to 100 | | °C |
| Storage | $T_{STG}$ | | −65 to 100 | | °C |

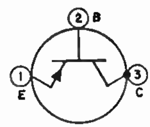
## CHARACTERISTICS (At mounting-flange temperature = 25°C.)

| | | | | | |
|---|---|---|---|---|---|
| Collector-to-Emitter Voltage: | | | | | |
| $I_C$ = −50 mA, $R_{BE}$ = 0 | $V_{CES}$ | −35 min | −50 min | −60 min | V |
| $V_{BE}$ = 1.2 V, $I_C$ = −250 mA | $V_{CEV}$ | −45 min | −60 min | −80 min | V |
| $I_C$ = −50 mA, $I_B$ = 0 | $V_{CEO}$ | −20 min | −30 min | −40 min | V |
| Emitter-to-Base Voltage: ($V_{CE}$ = −2 V, $I_C$ = −400 mA) | $V_{EB}$ | 1.5 max | 1.5 max | 1.5 max | V |
| Collector-Cutoff Current: | | | | | |
| $V_{CB}$ = −1.5 V, $I_E$ = 0 | $I_{CBO}$ | −30 max | −30 max | −30 max | µA |
| $V_{CB}$ = −45 V, $I_E$ = 0 | $I_{CBO}$ | −250 max | — | — | µA |
| $V_{CB}$ = −60 V, $I_E$ = 0 | $I_{CBO}$ | — | −250 max | — | µA |
| $V_{CB}$ = −80 V, $I_E$ = 0 | $I_{CBO}$ | — | — | −250 max | µA |
| Emitter-Cutoff Current ($V_{EB}$ = −20 V, $I_C$ = 0) | $I_{EBO}$ | −100 max | −100 max | −100 max | µA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −2 V, $I_C$ = −400 mA) | $h_{FE}$ | 20 to 60 | 20 to 60 | 20 to 60 | |

**CHARACTERISTICS (cont'd)**

| | | 2N1183 | 2N1183A | 2N1183B | |
|---|---|---|---|---|---|
| Small-Signal Forward-Current Transfer-Ratio Cutoff Frequency ($V_{CB}$ = −6 V, $I_E$ = 1 mA) | $f_{hfb}$ | 0.5 min | 0.5 min | 0.5 min | MHz |
| Collector Saturation Resistance ($I_C$ = −400 mA, $I_B$ = −40 mA) | | 1.25 max | 1.25 max | 1.25 max | Ω |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 10 max | 10 max | 10 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 75 max | 75 max | 75 max | °C/W |

# 2N1184
# 2N1184A —3A, 7.5W
# 2N1184B

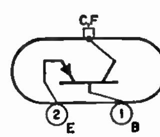



Ge p-n-p alloy-junction type intended for use in intermediate-power switching and low-frequency amplifier applications in industrial and military equipment. JEDEC TO-8, Outline No.10. See **Mounting Hardware** for desired mounting arrangement. These types are identical with types 2N1183, 2N1183A and 2N1183B, respectively, except for the following item:

**CHARACTERISTICS (At mounting-flange temperature = 25°C)**

| | | 2N1184 | 2N1184A | 2N1184B |
|---|---|---|---|---|
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −2 V, $I_C$ = −400 mA) | $h_{FE}$ | 40 to 120 | 40 to 120 | 40 to 120 |

# 2N176 −3A, 10W




Ge p-n-p alloy-junction type used in large-signal af amplifiers in class A power-output stages and class B push-pull amplifier stages in automobile radio receivers. JEDEC TO-3, Outline No.2.

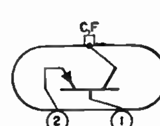
**MAXIMUM RATINGS**

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −40 | V |
| Collector Current | $I_C$ | −3 | A |
| Transistor Dissipation: $T_{MF}$ = 80°C | $P_T$ | 10 | W |
| Temperature Range: Operating (Mounting Flange) | $T_{MF}$(opr) | −65 to 90 | °C |

**CHARACTERISTICS (At mounting-flange temperature = 25°C)**

| | | | |
|---|---|---|---|
| Collector-Cutoff Current ($V_{CB}$ = −30 V, $I_E$ = 0) | $I_{CBO}$ | −3 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −2 V, $I_C$ = −0.5 A) | $h_{FE}$ | 63 min | |
| Power Gain (f = 0.001 MHz) | $G_{pe}$ | 35.5 | dB |
| Total Harmonic Distortion ($P_{oe}$ = 2 W) | | 2 max | % |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 1 max | °C/W |

# 2N351 −3A, 10W

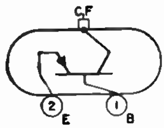



Ge p-n-p alloy-junction type used in large-signal af amplifiers in class A power-output stages and class B push-pull amplifier stages in automobile radio receivers. JEDEC TO-3, Outline No.2. This type is identical with type 2N176 except for the following items:

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −2 V, $I_C$ = −0.7 A) | $h_{FE}$ | 65 | |
| Power Gain (f = 0.001 MHz) | $G_{pe}$ | 33.5 | dB |
| Total Harmonic Distortion ($P_{oe}$ = 4 W) | THD | 5 max | % |

## −3A, 10W — 2N376

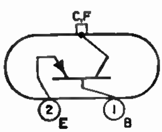


Ge p-n-p alloy-junction type used in large-signal af amplifiers in class A power-output stages and class B push-pull amplifier stages in automobile radio receivers. JEDEC TO-3, Outline No.2. This type is identical with type 2N176 except for the following items:

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −2 V, $I_C$ = −0.7 A) | $h_{FE}$ | 78 min | |
| Power Gain (f= 0.001 MHz) | $G_{pe}$ | 35 | dB |
| Total Harmonic Distortion ($P_{oe}$ = 4 W) | THD | 5 max | % |

## −10A, 30W — 2N3730



Ge p-n-p diffused-collector graded-base type used in 114-degree 18-kV TV deflection systems as a vertical-deflection output amplifier. This type, together with types 2N3731 (horizontal output), 2N3732 (horizontal driver), and 1N4785 (damper) make up a complete transistor/damper-diode complement. JEDEC TO-3, Outline No.2.

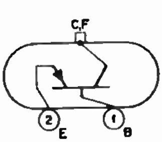
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage: | | | |
| Peak | $V_{CBO}$ | −200 | V |
| Continuous | $V_{CBO}$ | −60 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −0.5 | V |
| Collector Current | $I_C$ | −3 | A |
| Base Current | $I_B$ | ±0.5 | A |
| Transistor Dissipation: | | | |
| $T_{MF}$ up to 55°C | $P_T$ | 10 | W |
| $T_{MF}$ above 55°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 85 | °C |
| Storage | $T_{STG}$ | −65 to 85 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 230 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 5 mA, $V_{EB}$ = 0) | $V_{(BR)CES}$ | −200 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −100 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | −0.5 min | V |
| Collector-to-Emitter Saturation Voltage: | | | |
| $I_C$ = −0.7 A, $I_B$ = −0.02 A | $V_{CE}$(sat) | −2 max | V |
| $I_C$ = −0.05 A, $I_B$ = −0.005 A | $V_{CE}$(sat) | −1 max | V |
| Base-to-Emitter Voltage ($I_C$ = −0.7 A, $I_B$ = −0.02 A) | $V_{BE}$ | 0.5 typ | V |
| Collector-Cutoff Current ($V_{CB}$ = −10 V, $I_E$ = 0) | $I_{CBO}$ | −200 max | °C/W |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 1.5 max | μA |

## −6A, 30W — 2N1905



Ge p-n-p drift-field type intended for use in power-switching circuits, dc-to-dc converters, inverters, ultrasonic oscillators, and large-signal wide-band linear amplifiers. Similar to JEDEC TO-3, Outline No.4.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −100 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | −50 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −1.5* | V |
| Collector Current | $I_C$ | −6 | A |
| Emitter Current | $I_E$ | 6 | A |
| Base Current | $I_B$ | −1 | A |
| Transistor Dissipation: | | | |
| $T_{MF}$ up to 55°C | $P_T$ | 30 | W |
| $T_{MF}$ above 55°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 100 | °C |
| Storage | $T_{STG}$ | −65 to 100 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 255 | °C |

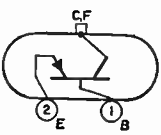
## CHARACTERISTICS (At mounting-flange temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = −10 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | −100 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = −100 mA, $I_B$ = 0) | $V_{(BR)CEO}$ | −50 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 5 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | −1.5 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = −5 A, $I_B$ = 0.25 A) | $V_{CE}$(sat) | −1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = −2 V, $I_C$ = −1 A) | $V_{BE}$ | − 0.38 typ; −0.5 max | V |
| Collector-Cutoff Current ($V_{CB}$ = 40 V, $I_E$ = 0) | $I_{CBO}$ | −1 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = −0.5 V, $I_C$ = 0) | $I_{EBO}$ | −1 max | mA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = −2 V, $I_C$ = −5 A | $h_{FE}$ | 30 min | |
| $V_{CE}$ = −2 V, $I_C$ = −1 A | $h_{FE}$ | 50 to 150 | |
| Collector-Cutoff Saturation Current ($V_{CB}$ = −0.5 V, $I_E$ = 0) | $I_{CBO}$(sat) | −100 | μA |
| Gain-Bandwidth Product ($V_{CE}$ = −5 V, $I_C$ = −0.5 A) | $f_T$ | 2 min | MHz |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 1.5 max | °C/W |

* This value may be exceeded provided that the power dissipated in the emitter under breakdown conditions is limited to 5 watts.

# 2N1906 −6A, 30W

Ge p-n-p drift-field type used in power-switching circuits, dc-to-dc converters, inverters, ultrasonic oscillators, and large-signal wide-band linear amplifiers. Similar to JEDEC TO-3, Outline No.4. This type is identical with type 2N1905 except for the following items.




## MAXIMUM RATINGS

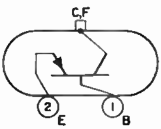
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −130 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | −60 | V |

## CHARACTERISTICS (At mounting-flange temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage ($I_C$ = −5 A, $I_B$ = −0.25 A) | $V_{CE}$(sat) | −0.5 max | V |
| Base-to-Emitter Voltage: | | | |
| $V_{CE}$ = −2 V, $I_C$ = −1 A | $V_{BE}$ | −0.5 max | V |
| $V_{CE}$ = −2 V, $I_C$ = −5 A | $V_{BE}$ | −0.9 max | V |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = −2 V, $I_C$ = −5 A | $h_{FE}$ | 75 max | |
| $V_{CE}$ = −2 V, $I_C$ = −1 A | $h_{FE}$ | 75 to 250 | |
| Gain Bandwidth Product ($V_{CE}$ = −5 V, $I_C$ = −0.5 A) | $f_T$ | 3 min | MHz |

# 2N2147 −5A, 12.5W

Ge p-n-p drift-field type used in high-fidelity amplifiers where wide frequency range and low distortion are required. JEDEC TO-3, Outline No.2.



## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −75 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | −50 | V |
| Emitter-to-Base Voltage* | $V_{EBO}$ | −1.5 | V |
| Collector Current | $I_C$ | −5 | A |
| Emitter Current | $I_E$ | 5 | A |
| Base Current | $I_B$ | −1 | A |
| Transistor Dissipation: | | | |
| $T_{MF}$ up to 81°C | $P_T$ | 12.5 | W |
| $T_{MF}$ above 81°C | $P_T$ | Derate linearly 0.66 | W/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 100 | °C |
| Storage | $T_{STG}$ | −65 to 100 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 255 | °C |

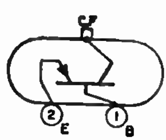
* This rating may be exceeded provided the combined dissipation in the emitter and collector does not exceed the maximum dissipation rating for the device.

## CHARACTERISTICS (At mounting-flange temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = −10 mA, $I_E$ = 0, $t_p$ = 300 μs, df = 0.01%) | $V_{(BR)CBO}$ | −75 min | V |
| Collector-to-Emitter Sustaining Voltage ($I_C$ = −100 mA, $I_B$ = 0) | $V_{CEO}$(sus) | −50 min | V |
| Collector-to-Emitter Saturation Voltage ($I_B$ = −250 mA, $I_C$ = −5 A) | $V_{CE}$(sat) | −0.6 max | V |
| Base-to-Emitter Voltage: | | | |
| $V_{CB}$ = −10 V, $I_C$ = −50 mA | $V_{BE}$ | −0.2 to −0.27 | V |
| $V_{CB}$ = −2 V, $I_C$ = 1 A | $V_{BE}$ | −0.5 max | V |
| Collector-Cutoff Current ($V_{CB}$ = −40 V, $I_E$ = 0) | $I_{CBO}$ | −1 max | mA |
| Collector-Cutoff Saturation Current ($V_{CB}$ = −0.5 V, $I_E$ = 0) | $I_{CBO}$(sat) | −70 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −1.5 V, $I_C$ = 0) | $I_{EBO}$ | −2.5 max | mA |
| Static Forward-Current Transfer Ratio | | | |
| $V_{CB}$ = −2 V, $I_C$ = −1 A | $h_{FE}$ | 100 to 300 | |
| $V_{CB}$ = −2 V, $I_C$ = −4 A | $h_{FE}$ | 75 min | |
| Gain-Bandwidth Product ($V_{CE}$ = −5 V, $I_C$ = −500 mA) | $f_T$ | 3 min; 4 typ | MHz |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 1.5 max | °C/W |

## TYPICAL OPERATION IN "SINGLE-ENDED PUSH-PULL" CLASS B AF-AMPLIFIER CIRCUIT (At mounting-flange temperature = 25°C)

| | | | |
|---|---|---|---|
| DC Collector Supply Voltage | $V_{CC}$ | −22 | V |
| Zero-Signal DC Collector Current | $I_C$ | −0.035 | A |
| Zero-Signal Base-Bias Voltage | | −0.24 | V |
| Peak Collector Current | $i_C$(peak) | −3.5 | A |
| Maximum-Signal DC Collector Current | $I_C$(max) | −1.1 | A |
| Input Impedance of Stage (per base) | | 75 | Ω |
| Load Impedance (speaker voice-coil) | $R_L$ | 4 | Ω |
| Maximum Collector Dissipation (per transistor) under worst-case conditions | | 12.5 | W |
| EIA Music Power Output Rating | | 45 | W |
| Power Gain | | 33 | dB |
| Maximum-Signal Power Output | $P_{OE}$ | 25 | W |
| Total Harmonic Distortion at Maximum-Signal Power Output | | 5 | % |




## −5A, 12.5W 2N2148

Ge p-n-p drift-field type used in high-fidelity amplifiers where wide frequency range and low distortion are required. JEDEC TO-3, Outline No.2. This type is identical with type 2N2147 except for the following items:

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −60 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | −40 | V |

## CHARACTERISTICS (At mounting-flange temperature = 25°C)

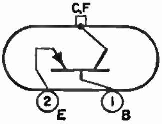
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = −10 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | −60 min | V |

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = −100 mA, $I_B$ = 0) | $V_{CEO}$(sus) | −40 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = −5 mA, $I_B$ = −250 mA) | $V_{CE}$(sat) | −0.75 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = −10 V, $I_C$ = −50 mA) | $V_{BE}$ | −0.21 to −0.28 | V |
| Collector-Cutoff Saturation Current ($V_{CB}$ = −0.5 V, $I_E$ = 0) | $I_{CBO}$(sat) | −100 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −1.5 V, $I_C$ = 0) | $I_{EBO}$ | −10 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −2 V, $I_C$ = −1 A) | $h_{FE}$ | 60 min | |
| Gain-Bandwidth Product ($V_{CE}$ = −5 V, $I_C$ = −500 mA) | $f_T$ | 3 min; 4 typ | MHz |

# 40022

**−5A, 12.5W**




Ge p-n-p alloy type used in class A and push-pull class B service in high-fidelity af power-amplifier applications. JEDEC TO-3, Outline No.2.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −32 | V |
| Collector-to-Emitter Voltage ($R_{BE}$ = 30 Ω) | $V_{CER}$ | −32 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −5 | V |
| Collector Current | $I_C$ | −5 | A |
| Base Current | $I_B$ | −1 | A |
| Transistor Dissipation: | | | |
| $T_{MF}$ up to 81°C | $P_T$ | 12.5 | W |
| $T_{MF}$ above 81°C | $P_T$ | Derate linearly 0.66 | W/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 100 | °C |
| Storage | $T_{STG}$ | −65 to 100 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 255 | °C |

## CHARACTERISTICS (At mounting-flange temperature = 25°C)

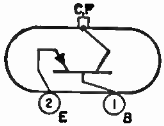
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage (Ic = −0.005 A, $I_E$ = 0) | $V_{(BR)CBO}$ | −32 min | V |
| Collector-to-Emitter Breakdown Voltage (Ic = −0.2 A, $R_{BE}$ = 33 Ω) | $V_{(BR)CER}$ | −32 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −0.002 A, Ic = 0) | $V_{(BR)EBO}$ | −5 min | V |
| Base-to-Emitter Voltage* ($V_{CB}$ = −10 V, $I_C$ = −0.05 A) | $V_{BE}$ | −0.18 | V |
| Collector-Cutoff Current ($V_{CB}$ = −30, $I_E$ = 0) | $I_{CBO}$ | −1 max | mA |
| Collector-Cutoff Saturation Current ($V_{CB}$ = −0.5 V, $I_E$ = 0) | $I_{CBO}$(sat) | −0.1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −2 V, Ic = −1 A) | $h_{FE}$ | 38 min; 70 typ | |
| Gain-Bandwidth Product ($V_{CE}$ = −5 V, Ic = −0.5 A) | $f_T$ | 300 | kHz |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 1.5 max | °C/W |

## TYPICAL OPERATION IN CLASS B AF-AMPLIFIER CIRCUIT

*Unless otherwise specified, values are for 2 transistors.*

| | | | |
|---|---|---|---|
| DC Collector-Supply Voltage | Vcc | −14 | V |
| Zero-Signal Base-Bias Voltage | | −0.18 | V |
| Zero-Signal DC Collector Current | Ic | −0.05 | A |
| Maximum-Signal DC Collector Current | Ic | −0.716 | A |
| Peak Collector Current | ic(peak) | −2.25 | A |
| Input Impedance of Stage (Per base) | Rs | 43 | Ω |
| Load Impedance (Speaker voice-coil) | $R_L$ | 4 | Ω |
| Maximum Collector Dissipation (Per transistor under worst-case conditions) | | 5 | W |
| Music Power Output | | 18 | W |
| Power Gain | $G_{PB}$ | 24 | dB |
| Total Harmonic Distortion | | 5 | % |
| Maximum-Signal Power Output | $P_{OB}$ | 10 | W |

* This characteristic does not apply to type 40254.




## −5A, 12.5W **40050**

Ge p-n-p alloy type for high-fidelity amplifiers and other commercial af amplifier applications. JEDEC TO-3, Outline No.2.

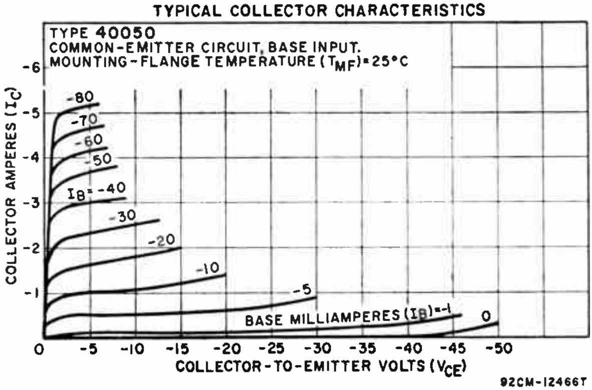
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −40 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | −40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −5 | V |
| Collector Current | $I_C$ | −5 | A |
| Base Current | $I_B$ | −1 | A |
| Transistor Dissipation: | | | |
| $T_{MF}$ up to 81°C | $P_T$ | 12.5 | W |
| $T_{MF}$ above 81°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 100 | °C |
| Storage | $T_{STG}$ | −65 to 100 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 255 | °C |

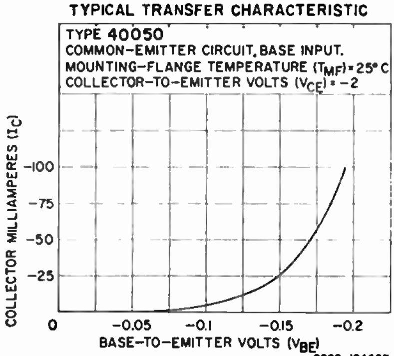
## CHARACTERISTICS (At mounting-flange temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = −5 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | −40 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = −0.6 A, $R_{BE}$ = 68 Ω) | $V_{(BR)CER}$ | −40 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −2 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | −5 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = −10 V, $I_C$ = −0.5 A) | $V_{BE}$ | −0.17 | V |
| Collector-Cutoff Current ($V_{CB}$ = −30 V, $I_E$ = 0) | $I_{CBO}$ | −0.5 max | mA |

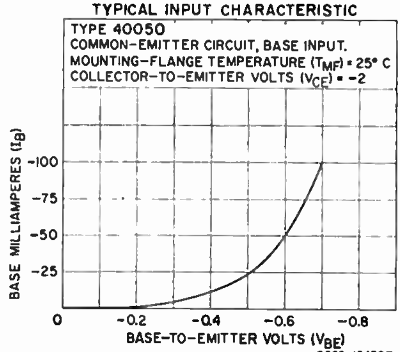
TYPICAL COLLECTOR CHARACTERISTICS




TYPICAL TRANSFER CHARACTERISTIC




TYPICAL INPUT CHARACTERISTIC



### CHARACTERISTICS (cont'd)

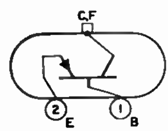
| | | | |
|---|---|---|---|
| Collector-Cutoff Saturation Current ($V_{CB}$ = −0.5 V, $I_E$ = 0) | $I_{CBO}$(sat) | −0.1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −2 V, $I_C$ = −1 A) | $h_{FE}$ | 50 min | |
| Gain-Bandwidth Product ($V_{CE}$ = 5 V, $I_C$ = −0.5 A) | $f_T$ | 500 | kHz |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 1.5 max | °C/W |

### TYPICAL OPERATION IN CLASS B AF-AMPLIFIER CIRCUIT

*Unless otherwise specified, values are for 2 transistors.*

| | | | |
|---|---|---|---|
| DC Collector-Supply Voltage | $V_{CC}$ | −18 | V |
| Zero-Signal Base-Bias Voltage | | −0.17 | V |
| Zero-Signal DC Collector Current | $I_C$ | −0.05 | A |
| Maximum-Signal DC Collector Current | $I_C$ | −0.8 | A |
| Peak Collector Current | $i_C$(peak) | −2.8 | A |
| Input Impedance of Stage (Per base) | $R_S$ | 32 | Ω |
| Load Impedance (Speaker voice-coil) | $R_L$ | 4 | Ω |
| Maximum Collector Dissipation (Per transistor under worst-case conditions) | | 7.5 | W |
| Power Gain | $G_{PB}$ | 28 | dB |
| Total Harmonic Distortion | | 5 | % |
| Music Power Output | | 25 | W |
| Maximum-Signal Power Output | $P_{OB}$ | 15 | W |

## 40051 −5A, 12.5W




Ge p-n-p alloy type for high-fidelity amplifiers and other commercial af amplifier applications. JEDEC TO-3, Outline No.2. This type is identical with type 40050 except for the following items:

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −50 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | −50 | V |

### CHARACTERISTICS (At mounting-flange temperature = 25°C)

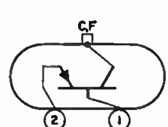
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = −5 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | −50 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = −0.6 A, $R_{BE}$ = 68 Ω) | $V_{(BR)CER}$ | −50 min | V |

### TYPICAL OPERATION IN CLASS B AF-AMPLIFIER CIRCUIT

*Unless otherwise specified, values are for 2 transistors.*

| | | | |
|---|---|---|---|
| DC Collector-Supply Voltage | $V_{CC}$ | −22 | V |
| Zero-Signal Base-Bias Voltage | | −0.17 | V |
| Zero-Signal DC Collector Current | $I_C$ | −0.05 | A |
| Maximum-Signal DC Collector Current | $I_C$ | −1.1 | A |
| Peak Collector Current | $i_C$(peak) | −3.5 | A |
| Input Impedance of Stage (Per base) | $R_S$ | 31 | Ω |
| Load Impedance (Speaker voice-coil) | $R_L$ | 4 | Ω |
| Maximum Collector Dissipation (Per transistor under worst-case conditions) | | 12.5 | W |
| Power Gain | $G_{PB}$ | 28 | dB |
| Total Harmonic Distortion | | 5 | % |
| Music Power Output | | 45 | W |
| Maximum-Signal Power Output | $P_{OB}$ | 25 | W |

## 40254 −5A, 12.5W



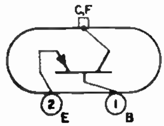

Ge p-n-p alloy type for class A af power-amplifier service in driver- and output-stage applications. JEDEC TO-3, Outline No.2. See Mounting Hardware for desired mounting arrangement. This type is identical with type 40022 except for the following items:

## CHARACTERISTICS (At mounting-flange temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-Cutoff Current ($V_{CB}$ = –30 V, $I_E$ = 0) | $I_{CBO}$ | –3 max | mA |
| Collector-Cutoff Saturation Current ($V_{CB}$ = –0.5 V, $I_E$ = 0) | $I_{CBO}$(sat) | –0.16 max | mA |

## TYPICAL OPERATION IN CLASS A AF-AMPLIFIER CIRCUIT

| | | | |
|---|---|---|---|
| DC Collector-Supply Voltage | $V_{CC}$ | –16 | V |
| DC Collector-to-Emitter Voltage | $V_{CE}$ | –13.2 | V |
| DC Collector Current | $I_C$ | –0.9 | A |
| Peak Collector Current | $i_C$(peak) | –1.8 | A |
| Input Impedance | $R_S$ | 15 | Ω |
| Collector Load Impedance | $R_L$ | 15 | Ω |
| Maximum Collector Dissipation | | 12 | W |
| Power Gain | $G_{PE}$ | 36 | dB |
| Total Harmonic Distortion ($P_{OE}$ = 5 W) | | 5 | % |
| Maximum-Signal Power Output | $P_{OE}$ | 5 | W |



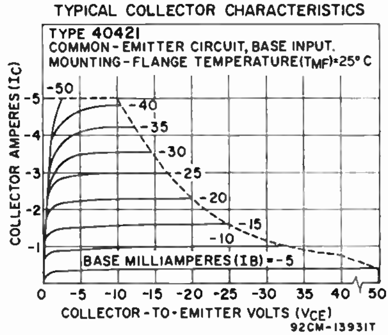

# –5A, 12.5W 40421

Ge p-n-p drift-field type used in high-fidelity af amplifier applications. JEDEC TO-3, Outline No.2.

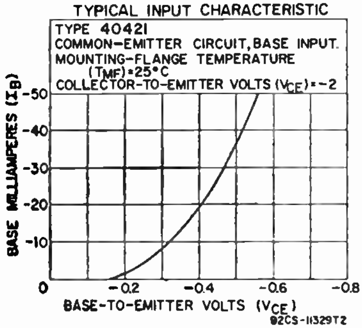
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | –75 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | –50 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | –1.5 | V |
| Collector Current | $I_C$ | –5 | A |
| Base Current | $I_B$ | –1 | A |
| Emitter Current | $I_E$ | 5 | A |
| Transistor Dissipation: | | | |
| $T_{MF}$ up to 81°C | $P_T$ | 12.5 | W |
| $T_{MF}$ above 81°C | $P_T$ | See curve page 300 | |

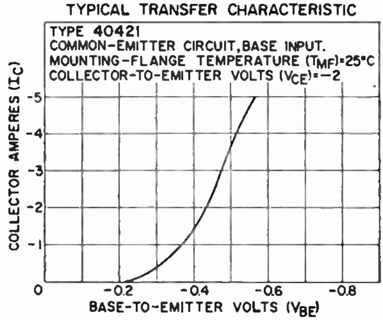
TYPICAL COLLECTOR CHARACTERISTICS




TYPICAL INPUT CHARACTERISTIC




TYPICAL TRANSFER CHARACTERISTIC



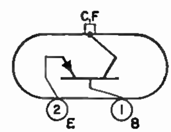
## MAXIMUM RATINGS (cont'd)

| | | | |
|---|---|---|---|
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | —65 to 100 | °C |
| Storage | $T_{STG}$ | —65 to 100 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 255 | °C |

## CHARACTERISTICS (At mounting-flange temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = —10 mA, $I_E$ = 0, $t_p \geqq$ 300 μs, df = 0.01%) | $V_{(BR)CBO}$ | —75 | V |
| Collector-to-Emitter Sustaining Voltage ($I_C$ = —100 mA, $I_B$ = 0) | $V_{CEO}$(sus) | —50 | V |
| Base-to-Emitter Voltage: | | | |
| $V_{CE}$ = —10 V, $I_C$ = —50 mA | $V_{BE}$ | 0.21 to 0.28 | V |
| $V_{CE}$ = —2 V, $I_C$ = —1 mA | $V_{BE}$ | 0.5 max | V |
| Collector-Cutoff Current ($V_{CB}$ = —40 V, $I_E$ = 0) | $I_{CBO}$ | —1 max | mA |
| Collector-Cutoff Saturation Current ($V_{CB}$ = —0.5 V, $I_E$ = 0) | $I_{CBO}$(sat) | —70 max | μA |
| Emitter-Cutoff Current ($V_{BE}$ = 1.5 V, $I_C$ = 0) | $I_{EBO}$ | —2.5 max | mA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = —2 V, $I_C$ = —1000 V | $h_{FE}$ | 62 to 175 | |
| $V_{CE}$ = —2 V, $I_C$ = —4000 V | $h_{FE}$ | 40 min | |
| Gain-Bandwidth Product ($V_{CE}$ = —5 V, $I_C$ = —500 mA) | $f_T$ | 2 min; 4 typ | MHz |
| Thermal Resistance, Junction-to-Mounting Flange | $\theta_{J-MF}$ | 1.5 max | °C/W |

# 40462 —5A, 12.5W




Ge p-n-p alloy-junction type used in high-fidelity class B af amplifier service in push-pull and "single-ended push-pull" circuits. JEDEC TO-3, Outline No.2.

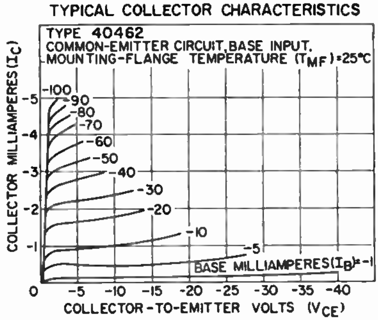
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | —40 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | —40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | —5 | V |
| Collector Current | $I_C$ | —5 | A |
| Base Current | $I_B$ | —1 | A |
| Transistor Dissipation: | | | |
| $T_{MF}$ up to 81°C | $P_T$ | 12.5 | W |
| $T_{MF}$ above 81°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | —65 to 100 | °C |
| Storage | $T_{STG}$ | —65 to 100 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 255 | °C |

## CHARACTERISTICS (At mounting-flange temperature = 25°C)

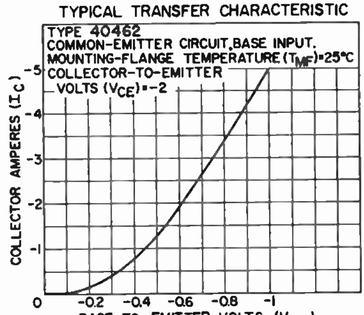
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = —0.005 A, $I_E$ = 0) | $V_{(BR)CBO}$ | —40 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = —0.6 A, $R_{BE}$ = 68 Ω) | $V_{(BR)CER}$ | —40 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = —2 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | —5 min | V |

TYPICAL COLLECTOR CHARACTERISTICS




92CS-13984T

TYPICAL TRANSFER CHARACTERISTIC



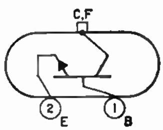

92CS-13982T

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage ($I_C$ = 5 A, $I_B$ = –0.5 A) | $V_{CE}(sat)$ | 1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = –10 V, $I_C$ = –0.05 A) | $V_{BE}$ | –0.19 | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = –30 V, $I_E$ = 0 | $I_{CBO}$ | –0.5 max | mA |
| $V_{CB}$ = –0.5 V, $I_E$ = 0 | $I_{CBO}(sat)$ | –0.1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = –2 V, $I_C$ = –1 A) | $h_{FE}$ | 50 min; 90 typ | |
| Gain-Bandwidth Product ($V_{CE}$ = 5 V, $I_C$ = –0.5 A) | $f_T$ | 600 | kHz |
| Thermal Resistance, Junction-to-Case | $\theta_{J\text{-}C}$ | 1.5 max | °C/W |

## TYPICAL OPERATION IN "SINGLE-ENDED PUSH-PULL" CLASS B AF-AMPLIFIER CIRCUIT (At mounting-flange temperature = 25°C)

| | | | |
|---|---|---|---|
| DC Collector Supply Voltage | $V_{CC}$ | 18 | V |
| Zero-Signal DC Collector Current | $I_C$ | –12 | mA |
| Zero-Signal Base-Bias Voltage | | –0.15 | V |
| Peak Collector Current | $I_{CM}$ | –2.8 | A |
| Maximum-Signal DC Collector Current | $I_C$ | –1 | A |
| Input Impedance of Stage (per base) | | 32 | Ω |
| Load Impedance (speaker voice-coil) | $R_L$ | 4 | Ω |
| Maximum Collector Dissipation (per transistor) under worst-case conditions | | 7.5 | W |
| EIA Music Power-Output Rating | | 25 | W |
| Power Gain | $G_{PE}$ | 25 | dB |
| Maximum-Signal Power Output | $P_{OE}$ | 15 | W |
| Total Harmonic Distortion at Maximum-Signal Power Output | | 5 | % |




# 40612

**–5A, 12.5W**

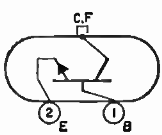
Ge p-n-p type used for output stages in high-fidelity amplifier circuits suitable for complementary-symmetry circuits. JEDEC TO-3, Outline No.2.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage $R_{BE}$ = 68 Ω | $V_{CER}(sus)$ | –25 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | –5 | V |
| Collector Current | $I_C$ | –5 | A |
| Base Current | $I_C$ | –1 | A |
| Transistor Dissipation $T_C$ = 25°C | $P_T$ | 12.5 | W |
| Temperature Range: | | | |
| Operating | T(opr) | –65 to 100 | °C |
| Storage | $T_{STG}$ | –65 to 100 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = –200 mA, $R_{BE}$ = 68 Ω) | $V_{CER}(sus)$ | –25 min | V |
| Collector-Cutoff Current ($V_{CB}$ = –30 V) | $I_{CBO}$ | –3 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = –5 V) | $I_{EBO}$ | –2 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = –2 V, $I_C$ = –1000 mA) | $h_{FE}$ | 30 to 150 | |




# 40623

**–5A, 12.5W**

Ge p-n-p type used for output stages in high-fidelity amplifier circuits suitable for complementary-symmetry circuits. JEDEC TO-3, Outline No.3.

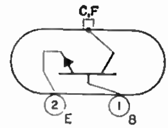
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage $R_{BE}$ = 68 Ω | $V_{CER}(sus)$ | –45 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | –5 | V |
| Collector Current | $I_C$ | –5 | A |
| Base Current | $I_B$ | –1 | A |
| Transistor Dissipation ($T_C$ = 25°C) | $P_T$ | 12.5 | W |
| Temperature Range: | | | |
| Operating | T(opr) | –65 to 100 | °C |
| Storage | $T_{STG}$ | –65 to 100 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = −200 mA, $R_{BE}$ = 68 Ω) | $V_{CER}$(sus) | −45 min | V |
| Collector-Cutoff Current ($V_{CB}$ = −30 V) | $I_{CBO}$ | −500 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −5 V) | $I_{EBO}$ | −2 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −2 V, $I_C$ = −1000 mA) | $h_{FE}$ | 50 to 170 | |

# 40626 −5A, 12.5W




Ge p-n-p type used for output stages in high-fidelity amplifier circuits suitable for complementary-symmetry circuits. JEDEC TO-3, **Outline** No.2.

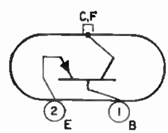
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 68 Ω) | $V_{CER}$(sus) | −55 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −5 | V |
| Collector Current | $I_C$ | −5 | A |
| Base Current | $I_B$ | −1 | A |
| Transistor Dissipation ($T_C$ = 25°C) | $P_T$ | 12.5 | W |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 100 | °C |
| Storage | $T_{STG}$ | −65 to 100 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = −200 mA, $R_{BE}$ = 68 Ω) | $V_{CER}$(sus) | −55 min | V |
| Collector-Cutoff Current ($V_{CB}$ = −30 V) | $I_{CBO}$ | −500 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −5 V) | $I_{EBO}$ | −2 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −2 V, $I_C$ = −1000 mA) | $h_{FE}$ | 50 to 170 | |

# 2N3731 −10A, 5W




Ge p-n-p diffused-collector graded-base type used in 114-degree 18-kV TV deflection systems as a horizontal output amplifier. This type, together with types 2N3730 (vertical output), 2N3732 (horizontal driver), and 1N4785 (damper) make up a complete transistor/damper-diode complement. JEDEC TO-3, **Outline** No.2.

## MAXIMUM RATINGS

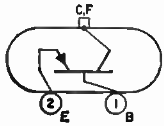
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage: | | | |
| Peak | $V_{CBO}$ | −320 | V |
| Continuous | $V_{CBO}$ | −60 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −2 | V |
| Collector Current | $I_C$ | −10 | A |
| Base Current | $I_B$ | +4, −1 | A |
| Transistor Dissipation: | | | |
| $T_{MF}$ up to 55°C | $P_T$ | 5 | W |
| $T_{MF}$ above 55°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 85 | °C |
| Storage | $T_{STG}$ | −65 to 85 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 230 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($I_C$ = −0.025 A, $V_{EB}$ = 0) | $V_{(BR)CES}$ | −320 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 100 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | −2 min | V |
| Collector-to-Emitter Saturation Voltage: | | | |
| $I_C$ = −6 A, $I_B$ = −0.4 A | $V_{CE}$(sat) | −1.5 max | V |
| $I_C$ = −3 A, $I_B$ = −0.2 A | $V_{CE}$(sat) | −1.5▲ max | V |
| Base-to-Emitter Voltage ($I_C$ = −6 A, | | | V |
| $I_B$ = −0.4 A) | $V_{BE}$ | −0.8 | μA |
| Collector-Cutoff Current ($V_{CB}$ = −10 V, $I_E$ = 0) | $I_{CBO}$ | −200 max | |
| Turn-off Time | $t_s + t_f$ | 1.2 max | μs |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 1.5 max | °C/W |

▲ This value does not apply to type 40439.

## −10A, 5W 2N4346




Ge p-n-p diffused-collector graded-base type used as a horizontal-output amplifier in conjunction with types 2N3730 (vertical output), 2N3732 (horizontal driver), and 1N4785 (damper) to provide a complete transistor/damper-diode complement. JEDEC TO-3, Outline No.2.

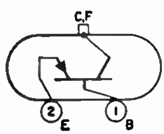
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage: | | | |
| Peak | $V_{CBO}$ | −320 | V |
| Continuous | $V_{CBO}$ | −60 | V |
| Collector Current | $I_C$ | −10 | A |
| Base Current | $I_B$ | +4, −1 | A |
| Transistor Dissipation: | | | |
| $T_{MF}$ up to 55°C | $P_T$ | 5 | W |
| $T_{MF}$ above 55°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 85 | °C |
| Storage | $T_{STG}$ | −65 to 85 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($I_C$ = −0.025 A, $V_{EB}$ = 0) | $V_{(BR)CES}$ | −320 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −100 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | −2 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 6 A, $I_B$ = −0.4 A) | $V_{CE}$(sat) | −0.75 max | V |
| Base-to-Emitter Voltage ($I_C$ = 6 A, $I_B$ = −0.4 A) | $V_{BE}$ | 0.8 | V |
| Collector-Cutoff Current ($V_{CB}$ = −10 V, $I_E$ = 0) | $I_{CBO}$ | −200 max | μA |
| Turn-Off Time | $t_s + t_f$ | 0.75 max | μs |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 1.5 max | °C/W |

## −10A, 5W 40439

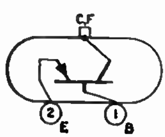



Ge p-n-p diffused-collector, graded-base type used in 114-degree 18-kV TV deflection systems as a horizontal-output amplifier. This type, together with types 2N3730 (vertical output), 2N3731 and 40440 (horizontal output), 2N3732 (horizontal driver), and 1N4785 and 40442 (damper), make up a complete transistor/damper-diode complement. JEDEC TO-3, Outline No.2. This type is identical with type 2N3731 except for the following item:

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Turn-Off Time | $t_s + t_f$ | 0.75 max | μs |

## −10A, 5W 40440




Ge p-n-p diffused-collector, graded-base type used in 114-degree 18kV TV deflection systems as a horizontal-output amplifier. This type, together with types 2N3730 (vertical output), 2N3731 and 40439 (horizontal output), 2N3732 (horizonal driver), and 1N4785 and 40442 (damper), make up a complete transistor/damper-diode complement. JEDEC TO-3, Outline No.2. This type is identical with type 2N3731 except for the following items:

### MAXIMUM RATINGS

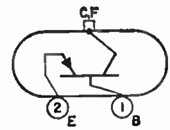
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage: | | | |
| Peak | $V_{CBO}$ | −200 | V |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($I_C$ = −0.025 mA, $V_{EB}$ = 0) | $V_{(BR)CES}$ | −200 | V |
| Collector-to-Emitter Saturation Voltage: | | | |
| $I_C$ = −6 A, $I_B$ = −0.4 A | $V_{CE}$(sat) | −0.75 max | V |
| $I_C$ = −3 A, $I_B$ = −0.2 A | $V_{CE}$(sat) | −0.75 max | V |
| Base-to-Emitter Voltage ($I_C$ = −6 A, $I_B$ = −0.4 A) | $V_{BE}$ | −1 | V |

# 2N2869/ 2N301

## −10A, 30W




Ge p-n-p alloy-junction type used in class A and class B af output-amplifier stages of automobile radio receivers and mobile communications equipment. JEDEC TO-3, Outline No.2.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −60 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | −50 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −10 | V |
| Collector Current | $I_C$ | −10 | A |
| Emitter Current | $I_E$ | 10 | A |
| Base Current | $I_B$ | −3 | A |
| Transistor Dissipation: | | | |
| $T_{MF}$ up to 55°C | $P_T$ | 30 | W |
| $T_{MF}$ above 55°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 100 | °C |
| Storage | $T_{STG}$ | −65 to 100 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 255 | °C |

## CHARACTERISTICS (At mounting-flange temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.005 A, $I_E$ = 0) | $V_{(BR)CBO}$ | −60 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = −0.6 A, $I_B$ = 0) | $V_{(BR)CEO}$ | −50 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = −2 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | −10 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = −5 A, $I_B$ = −0.5 A) | $V_{CE}$(sat) | −0.75 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = −2 V, $I_C$ = −1 A) | $V_{BE}$ | −0.5 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = −30 V, $I_E$ = 0 | $I_{CBO}$ | −0.5 max | mA |
| $V_{CB}$ = −0.5 V, $I_E$ = 0 | $I_{CBO}$(sat) | −0.1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −2 V, $I_C$ = −1 A) | $h_{FE}$ | 50 to 165 | |
| Gain-Bandwidth Product ($V_{CE}$ = −2 V, $I_C$ = −1 A) | $f_T$ | 200 min | kHz |

## TYPICAL OPERATION IN CLASS A POWER-AMPLIFIER CIRCUIT

| | | | |
|---|---|---|---|
| DC Collector-Supply Voltage | $V_{CC}$ | −14.4 | V |
| DC Collector-to-Emitter Voltage | $V_{CE}$ | −12.2 | V |
| DC Base-to-Emitter Voltage | $V_{BE}$ | −0.35 | V |
| Zero-Signal Collector Current | $I_C$ | −0.9 | A |
| Load Impedance | $R_L$ | 15 | Ω |
| Signal Frequency | f | 400 | Hz |
| Signal-Source Impedance | $R_S$ | 10 | Ω |
| Power Gain | | 38 | dB |
| Total Harmonic Distortion (at a power output of 5 W) | | 5 | % |
| Zero-Signal Collector Dissipation | | 11 | W |
| Maximum-Signal Power Output | $P_{OE}$ | 5 | W |
| Circuit Efficiency (at a power output of 5 W) | $\eta$ | 45 | % |

## TYPICAL OPERATION IN "SINGLE-ENDED PUSH-PULL" CLASS B AF-AMPLIFIER CIRCUIT

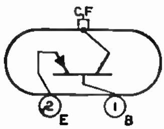
| | | | |
|---|---|---|---|
| DC Collector Supply Voltage | $V_{CC}$ | −14.4 | V |
| Zero-Signal DC Collector Current (per transistor) | $I_C$ | −0.05 | A |
| Zero-Signal Base-Bias Voltage | | −0.13 | V |
| Peak Collector Current (per transistor) | $i_c$(peak) | −2 | A |

### TYPICAL OPERATION (cont'd)

| | | | |
|---|---|---|---|
| Maximum-Signal DC Collector Current (per transistor) | $I_C$(max) | −0.64 | A |
| Signal Frequency | f | 400 | Hz |
| Input Impedance of Stage (per base) | $R_S$ | 10 | Ω |
| Load Impedance (per collector) | $R_L$ | 6 | Ω |
| Power Gain | | 30 | dB |
| Circuit Efficiency (at a power output of 12 W) | $\eta$ | 67 | % |
| Maximum-Signal Power Output | $P_{OE}$ | 12 | W |
| Total Harmonic Distortion (at maximum-signal power output of 12 W) | | 5 | % |
| Maximum Collector Dissipation (per transistor at a power output of 12 W) | | 3 | W |

## 2N2870/ 2N301A

**−10A, 30W**




Ge p-n-p alloy-junction type used in class A and class B af output-amplifier stages of automobile radio receivers and mobile communications equipment. JEDEC TO-3, Outsine No.2. This type is identical with type 2N2869/2N301 except for the following items:

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | −80 | V |

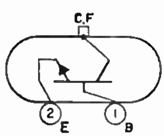
### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = −0.005 A, $I_E$ = 0) | $V_{(BR)CBO}$ | −80 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = −5 A, $I_B$ = −0.5 A) | $V_{CE}$(sat) | −0.5 max | V |

# *Special Audio Silicon Types*

## 40491

**0.15A, 3.8W**




Si n-p-n type used in class A af output-amplifier service in conjunction with types 40487 (mixer), 40488 (oscillator) 40489 (if amplifier), 40490 (af amplifier), and 40495 (line rectifier) to provide a complement for AM broadcast-band radio receivers. JEDEC TO-66 (with heat radiator), Outline No.27.

### MAXIMUM RATINGS

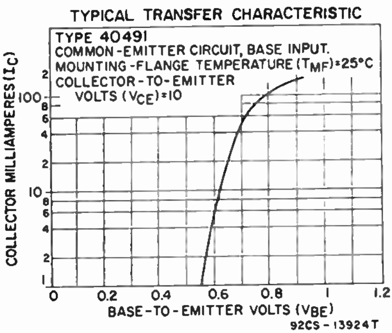
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 300 | V |
| Collector-to-Emitter Voltage ($I_C$ = 5 mA, $I_B$ = 0) | $V_{CEO}$ | 300 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2 | V |
| Collector Current | $I_C$ | 150 | mA |
| Emitter Current | $I_E$ | −150 | mA |
| Transistor Dissipation: | | | |
| $T_A$ up to 55°C | $P_T$ | 3.8 | W |
| $T_A$ above 55°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating | $T_A$ | −65 to 150 | °C |
| Storage | $T_{STG}$ | −65 to 150 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

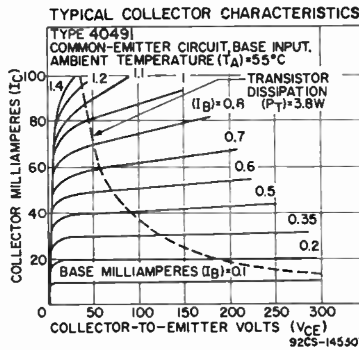
### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 300 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 5 mA, $I_B$ = 0) | $V_{(BR)CEO}$ | 300 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 2 min | V |

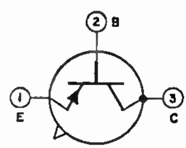
## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 300 V, $I_E$ = 0 | $I_{CBO}$ | 100 max | μA |
| $V_{CE}$ = 300 V, $I_B$ = 0 | $I_{CEO}$ | 5 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 50 mA) | $h_{FE}$ | 30 to 250 | |
| Gain-Bandwidth Product ($V_{CE}$ = 50 V, $I_C$ = 20 mA) | $f_T$ | 25 | MHz |
| Intrinsic-Base-Spreading Resistance ($V_{CE}$ = 50 V, $I_C$ = 20 mA, f = 100 MHz) | $r_{bb'}$ | 20 | Ω |
| Feedback Capacitance ($V_{CB}$ = 50 V, $I_E$ = 0) | $C_{cb}$ | 5 | pF |
| Thermal Resistance, Junction-to-Mounting Flange | $\theta_{J-FM}$ | 8 typ; 10 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 25 max | °C/W |




# 40406 —0.7A, 1W




Si p-n-p type used in the input stages in af-amplifier applications in industrial and commercial equipment. JEDEC TO-5, Outline No.5. For collector-characteristics and input-characteristics curves, refer to type 40319.

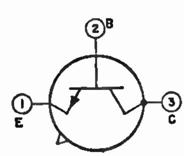
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | —50 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | —4 | V |
| Collector Current | $I_C$ | —0.7 | A |
| Base Current | $I_B$ | —0.2 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | —65 to 200 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = —100 mA, $I_B$ = 0) | $V_{CEO}$(sus) | —50 min | V |
| Base-to-Emitter Voltage ($I_C$ = —0.1 mA) | $V_{BE}$ | —0.8 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = —40 V, $I_B$ = 0, $T_C$ = 25°C | $I_{CEO}$ | —1 max | μA |
| $V_{CE}$ = —40 V, $I_B$ = 0, $T_C$ = 150°C | $I_{CEO}$ | —10 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = —4 V, $I_C$ = 0) | $I_{EBO}$ | —1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = —10 V, $I_C$ = —0.1 mA) | $h_{FE}$ | 30 to 200 | |
| Gain-Bandwidth Product ($V_{CB}$ = —4 V, $I_C$ = —50 mA) | $f_T$ | 100 | MHz |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 35 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 175 max | °C/W |

# 40309 0.7A, 5W



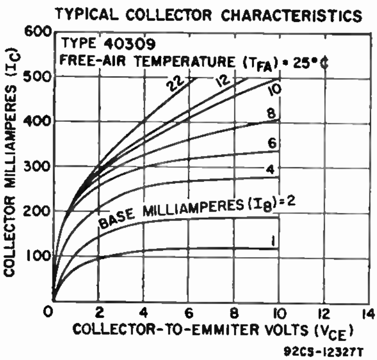

Si n-p-n type used in audio-amplifier driver stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. JEDEC TO-5, Outline No.5.

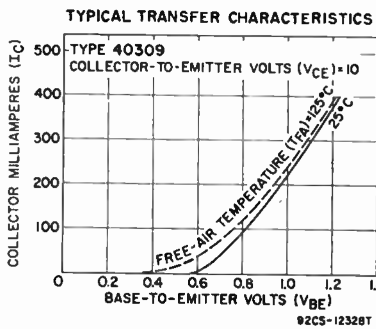
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | 18 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2.5 | V |
| Collector Current | $I_C$ | 0.7 | A |
| Base Current | $I_B$ | 0.2 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_A$ and $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |

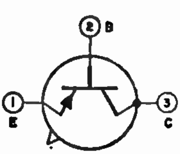
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 100 mA, $I_B$ = 0, $t_p$ = 300 μs, df ≦ 2%) | $V_{(BR)CEO}$ | 18 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 50 mA) | $V_{BE}$ | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 0.25 max | μA |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 1 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 2.5 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 50 mA) | $h_{FE}$ | 70 to 350 | |
| Gain-Bandwidth Product ($V_{CE}$ = 10 V, $I_C$ = 50 mA) | $f_T$ | 100 | MHz |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 35 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 175 max | °C/W |




## −0.7A, 5W 40319



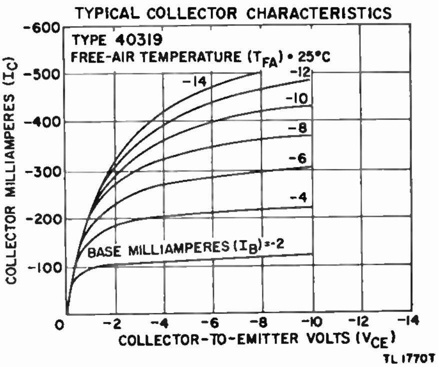

Si p-n-p type used in audio-amplifier driver stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. P-N-P construction permits complementary driver operating with a matching n-p-n type, such as 40314. JEDEC TO-5, Outline No.5.

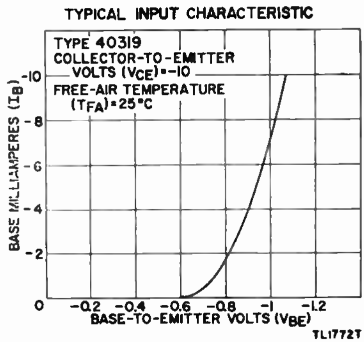
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | −40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −2.5 | V |
| Collector Current | $I_C$ | −0.7 | A |
| Base Current | $I_B$ | −0.2 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_A$ and $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

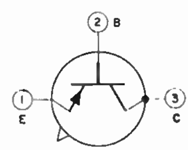
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = −100 mA, $I_B$ = 0, $t_p$ = 300 μs, df ≦ 2%) | $V_{CEO}$(sus) | −40 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = −150 mA, $I_B$ = −15 mA) | $V_{CE}$(sat) | −1.4 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = −4 V, $I_C$ = −50 mA) | $V_{BE}$ | −1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = −15 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | −0.25 max | μA |
| $V_{CB}$ = −15 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | −1 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = −2.5 V, $I_C$ = 0) | $I_{EBO}$ | −1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −4 V, $I_C$ = −50 mA) | $h_{FE}$ | 35 to 200 | |
| Gain-Bandwidth Product ($V_{CE}$ = −4 V, $I_C$ = −50 mA) | $f_T$ | 100 | MHz |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 35 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 175 max | °C/W |




# 40362 —0.7A, 5W

Si p-n-p used in audio-amplifier drive stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. P-N-P structure permits complementary driver operation with a matching n-p-n type such as 40361. JEDEC TO-5, Outline No.5. For collector-characteristics and input-characteristics curves, refer to type 40319.




## MAXIMUM RATINGS

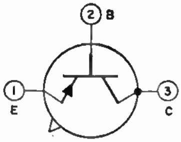
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 200 Ω) | $V_{CER}$(sus) | −70 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −4 | V |
| Collector Current | $I_C$ | −0.7 | A |
| Base Current | $I_B$ | −0.2 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_A$ and $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 200 Ω, $I_C$ = 100 mA) | $V_{CER}$(sus) | −70 min | V |
| Collector-to-Emitter Saturation Voltage ($I_B$ = 15 mA, $I_C$ = −150 mA) | $V_{CE}$(sat) | −1.4 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = −4 V, $I_C$ = −50 mA) | $V_{BE}$ | −1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = −60 V, $R_{BE}$ = 200 Ω, $T_C$ = 25°C | $I_{CER}$ | −1 max | μA |
| $V_{CE}$ = −60 V, $R_{BE}$ = 200 Ω, $T_C$ = 150°C | $I_{CER}$ | −100 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −4 V, $I_C$ = 0) | $I_{EBO}$ | −1 max | mA |

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −4 V, $I_C$ = −50 mA) | $h_{FE}$ | 35 to 200 | |
| Gain-Bandwidth Product ($V_{CE}$ = −4 V, $I_C$ = −50 mA) | $f_T$ | 100 | MHz |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 35 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 175 max | °C/W |




## −0.7A, 5W 40537

Si p-n-p double-diffused epitaxial planar type used as a driver in audio-amplifier circuits. JEDEC TO-5, Outline No.5.

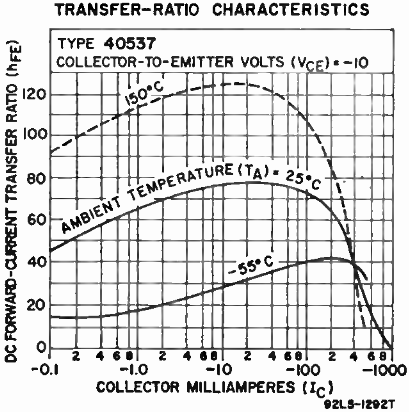
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 500 Ω) | $V_{CER}$(sus) | −55 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −5 | V |
| Collector Current | $I_C$ | −0.7 | A |
| Base Current | $I_B$ | −0.2 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_C$ above 25°C | $P_T$ | Derate linearly to 0 W at 200 °C | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_A$ above 25°C | $P_T$ | Derate linearly to 0 W at 200 °C | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

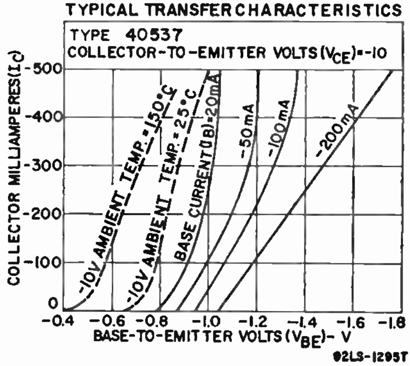
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = −100 mA, $R_{BE}$ = 500 Ω) | $V_{CER}$(sus) | −55 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = −50 mA, $I_B$ = −5 mA) | $V_{CE}$(sat) | −1.1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = −4 V, $I_C$ = −50 mA) | $V_{BE}$ | −1.8 | V |
| Collector-Cutoff Current ($V_{CE}$ = −45 V, $R_{BE}$ = 500 Ω) | $I_{CER}$ | −10 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −5 V, $I_C$ = 0) | $I_{EBO}$ | −1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −4 V, $I_C$ = −50 mA) | $h_{FE}$ | 50 to 300 | |
| Gain-Bandwidth Product ($V_{CE}$ = −4 V, $I_C$ = −50 mA) | $f_T$ | 100 | MHz |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 175 | °C/W |

TYPICAL DC FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTICS

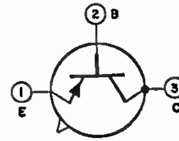



TYPICAL TRANSFER CHARACTERISTICS



## 40538 −0.7A, 5W

Si p-n-p double-diffused epitaxial planar type used in complementry-symmetry output stages. P-N-P structure permits complementary operation with a matching n-p-n type such as the 40539. JEDEC TO-5, Outline No.5. This type is identical to type 40537 except for the following items:

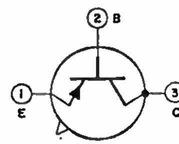



### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage ($I_C$ = −500 mA, $I_B$ = −50 mA) | $V_{CE}$(sat) | −2 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = −4 V, $I_C$ = −500 mA) | $V_{BE}$ | −2.7 max | V |
| Pulsed Forward-Current Transfer Ratio ($V_{CE}$ = −4 V, $I_C$ = −500 mA, $t_P$ = 300 μs, df < 2%) | $h_{FE}$(pulsed) | 15 to 90 | |

## 40634 −0.7A, 5W

Si p-n-p type used for driver applications in high-fidelity amplifier circuits. This type and type 40635 form a complementary pair of driver transistors suitable for quasi-complementary-symmetry circuits. JEDEC TO-5, Outline No.5.



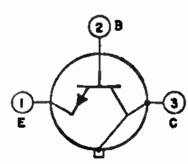

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage $R_{BE}$ = 100 Ω | $V_{CER}$(sus) | −75 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | −7 | V |
| Collector Current | $I_C$ | −0.7 | A |
| Base Current | $I_B$ | −0.2 | A |
| Transistor Dissipation: | | | |
| $T_C$ = 25°C | $P_T$ | 5 | W |
| $T_C$ = 25°C | $P_T$ | 1 | W |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = −100 mA, $R_{BE}$ = 100 Ω) | $V_{CER}$(sus) | −75 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = −150 mA, $I_B$ = −15 mA) | $V_{CE}$(sat) | −0.8 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = −4 V, $I_C$ = −150 mA) | $V_{BE}$ | −1.4 max | V |
| Collector-Cutoff Current ($V_{CE}$ = −65 V, $R_{BE}$ = 100 Ω) | $I_{CER}$ | −10 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = −4 V) | $I_{EBO}$ | −0.1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = −4 V, $I_C$ = −150 mA) | $h_{FE}$ | 50 to 250 | |

## 40409 0.7A, 3W




Si n-p-n type used in driver stages in af-amplifier applications in industrial and commercial equipment. This type and type 40410 together form a complementary pair of drivers. In a typical class AB circuit a complementary pair can drive two series-connected 40411 transistors to provide an audio output of 70 watts with a total harmonic distortion of less than 0.25 per cent at 1000 Hz. JEDEC TO-5 (with heat radiator), Outline No.8. For collector-characteristics and transfer-characteristics curves, refer to type 40309.

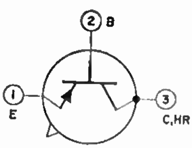
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE} \leqq 10\ \Omega$) | $V_{CER}(sus)$ | 90 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 0.7 | A |
| Base Current | $I_B$ | 0.2 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 50°C | $P_T$ | 3 | W |
| $T_A$ above 50°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J(opr)$ | −65 to 200 | °C |

## CHARACTERISTICS

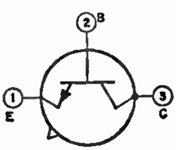
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE} = 100\ \Omega$, $I_C = 100$ mA) | $V_{CER}(sus)$ | 90 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C = 150$ mA, $I_B = 15$ mA) | $V_{CE}(sat)$ | 1.4 max | V |
| Base-to-Emitter Voltage ($V_{CE} = 4$ V, $I_C = 150$ mA) | $V_{BE}$ | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE} = 80$ V, $R_{BE} = 100\ \Omega$, $T_C = 25$°C | $I_{CER}$ | 1 max | μA |
| $V_{CE} = 80$ V, $R_{BE} = 100\ \Omega$, $T_C = 150$°C | $I_{CER}$ | 100 max | μA |
| Emitter-Cutoff Current ($V_{EB} = 4$ V, $I_C = 0$) | $I_{EBO}$ | 1 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE} = 4$ V, $I_C = 150$ mA) | $h_{FE}$ | 50 to 250 | |
| Gain-Bandwidth Product ($V_{CE} = 4$ V, $I_C = 50$ mA) | $f_T$ | 100 | MHz |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 50 max | °C/W |

## −0.7A, 3W 40410




Si **p-n-p** type used in driver stages in af-amplifier applications in industrial and commercial equipment. This type and type 40409 form a complementary pair of drivers. In a typical class AB circuit a complementary pair can drive two series-connected 40411 transistors to provide an audio output of 70 watts with a total harmonic distortion of less than 0.25 per cent at 1000 Hz. JEDEC TO-5 (with heat radiator), Outline No.8. This type is electrically identical with type 40409 except for the reversal of all polarity signs. For collector-characteristics and input-characteristics curves, refer to type 40319.

## 0.7A, 1W 40407

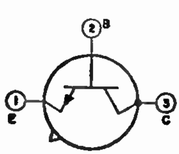



Si **n-p-n** type used in predriver stages in af-amplifier applications in industrial and commercial equipment. This type is recommended for use in a Darlington circuit with a type such as the 40408. JEDEC TO-5, Outline No.5. For collector-characteristics and transfer-characteristics curves, refer to type 40309. This type is identical with type 40406 except for reversal of all polarity signs and the following items:

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Base-to-Emitter Voltage ($V_{CE} = 10$ V, $I_C = 1$ mA) | $V_{BE}$ | 0.8 max | V |
| Static Forward-Current Transfer Ratio ($V_{CE} = 10$ V, $I_C = 1$ mA) | $h_{FE}$ | 40 to 200 | |

## 0.7A, 1W 40408




Si **n-p-n** type used in predriver stages in af-amplifier applications in industrial and commercial equipment. This type is recommended for use in a Darlington circuit with a type such as the 40407. JEDEC TO-5, Outline No.5. For collector-characteristics and transfer-characteristics curves, refer to type 40309.

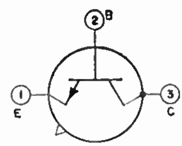
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | 90 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 0.7 | A |
| Base Current | $I_B$ | 0.2 | A |
| Tranistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $I_B$ = 0) | $V_{CEO}$(sus) | 90 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA) | $V_{CE}$(sat) | 1.4 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 10 mA) | $V_{BE}$ | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 80 V, $I_B$ = 0, $T_C$ = 25°C | $I_{CEO}$ | 1 max | μA |
| $V_{CE}$ = 80 V, $I_B$ = 0, $T_C$ = 150°C | $I_{CEO}$ | 250 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 4 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 10 mA) | $h_{FE}$ | 40 to 200 | |
| Gain-Bandwidth Product ($V_{CE}$ = 4 V, $I_C$ = 50 mA) | $f_T$ | 100 | MHz |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 35 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 175 max | °C/W |

## 40311 0.7A, 5W




Si **n-p-n** type used in audio-amplifier driver stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. JEDEC TO-5, **Outline No.5.**

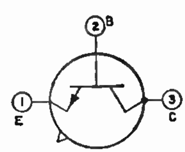
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | 30 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2.5 | V |
| Collector Current | $I_C$ | 0.7 | A |
| Base Current | $I_B$ | 0.2 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_A$ and $T_C$ above 25°C | $P_T$ | See curve page 116 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $I_B$ = 0, $t_p$ = 300 μs, df ≦ 2%) | $V_{CEO}$(sus) | 30 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 50 mA) | $V_{BE}$ | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 0.25 max | μA |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 1 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 2.5 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 50 mA) | $h_{FE}$ | 70 to 350 | |
| Gain-Bandwidth Product ($V_{CE}$ = 10 V, $I_C$ = 50 mA) | $f_T$ | 100 | MHz |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 35 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 175 max | °C/W |

## 40314 0.7A, 5W




Si **n-p-n** type used in audio-amplifier driver stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. JEDEC TO-5, **Outline No.5.**

### MAXIMUM RATINGS

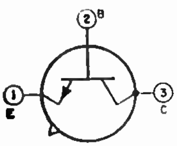
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2.5 | V |

### MAXIMUM RATINGS (cont'd)

| | | | |
|---|---|---|---|
| Collector Current | $I_C$ | 0.7 | A |
| Base Current | $I_B$ | 0.2 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_A$ and $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $I_B$ = 0, $t_p$ = 300 μs, df = 2%) | $V_{CEO}$(sus) | 40 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA) | $V_{CE}$(sat) | 1.4 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 50 mA) | $V_{BE}$ | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 0.25 max | μA |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 1 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 2.5 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 50 mA) | $h_{FE}$ | 35 to 150 | MHz |
| Gain-Bandwidth Product ($V_{CB}$ = 4 V, $I_C$ = 50 mA) | $f_T$ | 100 | °C/W |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 35 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 175 max | |




## 0.7A, 5W — 40315

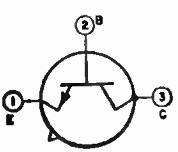
Si n-p-n type used in audio-amplifier inverter and driver stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. JEDEC TO-5, Outline No.5.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | 35 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2.5 | V |
| Collector Current | $I_C$ | 0.7 | A |
| Base Current | $I_B$ | 0.2 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_A$ and $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 100 mA, $I_B$ = 0, $t_p$ = 300 μs, df = 2%) | $V_{(BR)CEO}$ | 35 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 50 mA) | $V_{BE}$ | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 0.25 max | μA |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 1 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 2.5 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 50 mA) | $h_{FE}$ | 70 to 350 | |
| Gain-Bandwidth Product ($V_{CB}$ = 10 V, $I_C$ = 50 mA) | $f_T$ | 100 | MHz |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 35 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 175 max | °C/W |




## 0.7A, 5W — 40317

Si n-p-n type used in audio-amplifier inverter and driver stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. JEDEC TO-5, Outline No.5.

### MAXIMUM RATINGS

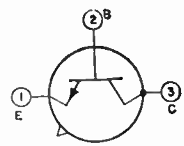
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2.5 | V |
| Collector Current | $I_C$ | 0.7 | A |
| Base Current | $I_B$ | 0.2 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_A$ and $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $I_B$ = 0, $t_p$ = 300 μs, df ≤ 2%) | $V_{CEO}$(sus) | 40 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 10 mA) | $V_{BE}$ | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 0.25 max | μA |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 1 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 2.5 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 10 mA) | $h_{FE}$ | 40 to 200 | |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 35 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 175 max | °C/W |

## 40320 0.7A, 5W

Si n-p-n type used in audio-amplifier and driver stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. JEDEC TO-5, Outline No.5.




### MAXIMUM RATINGS

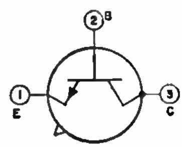
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2.5 | V |
| Collector Current | $I_C$ | 0.7 | A |
| Base Current | $I_B$ | 0.2 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_A$ and $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $I_B$ = 0, $t_p$ = 300 μs, df ≤ 2%) | $V_{CEO}$(sus) | 40 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 10 mA) | $V_{BE}$ | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 0.25 max | μA |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 1 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 2.5 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 10 mA) | $h_{FE}$ | 40 to 200 | |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 35 max | °C/W |

## 40323 0.7A, 5W

Si n-p-n type used in audio-amplifier inverter and driver stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. JEDEC TO-5, Outline No.5. For collector-characteristics and transfer-characteristics curves, refer to type 40309.



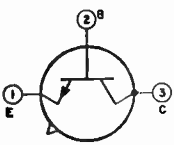
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | 18 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2.5 | V |
| Collector Current | $I_C$ | 0.7 | A |
| Base Current | $I_B$ | 0.2 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_A$ and $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 100 mA, $I_B$ = 0, $t_p$ = 300 μs, df ≦ 2%) | $V_{(BR)CEO}$ | 18 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 50 mA) | $V_{BE}$ | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 0.25 max | μA |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 1 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 2.5 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 50 mA) | $h_{FE}$ | 70 to 350 | |
| Gain-Bandwidth Product ($V_{CE}$ = 10 V, $I_C$ = 50 mA) | $f_T$ | 100 | MHz |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 35 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 175 max | °C/W |

# 0.7A, 5W 40326




Si n-p-n type used in audio-amplifier inverter and driver stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. JEDEC TO-5, Outline No.5. For collector-characteristics curves, refer to type 40309.

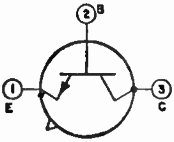
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2.5 | V |
| Collector Current | $I_C$ | 0.7 | A |
| Base Current | $I_B$ | 0.2 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_A$ and $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $I_B$ = 0, $t_p$ = 300 μs, df ≦ 2%) | $V_{CEO}$(sus) | 40 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 10 mA) | $V_{BE}$ | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 0.25 max | μA |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 1 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 2.5 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 10 mA) | $h_{FE}$ | 40 to 200 | |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 30 max | °C/W |

# 0.7A, 5W 40360




Si n-p-n type used in audio-amplifier inverter and driver stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. JEDEC TO-5, Outline No.5. For collector-characteristics and transfer-characteristics curves, refer to type 40309.

## MAXIMUM RATINGS

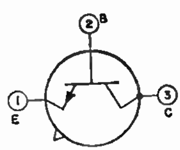
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}(sus)$ | 70 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 0.7 | A |
| Base Current | $I_B$ | 0.2 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_A$ and $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J(opr)$ | −65 to 200 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $I_B$ = 0) | $V_{CEO}(sus)$ | 70 min | V |
| Collector-to-Emitter Saturation Voltage ($I_B$ = 15 mA, $I_C$ = 150 mA) | $V_{CE}(sat)$ | 1.4 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 10 mA) | $V_{BE}$ | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 60 V, $I_B$ = 0, $T_C$ = 25°C | $I_{CEO}$ | 1 max | μA |
| $V_{CE}$ = 60 V, $I_B$ = 0, $T_C$ = 150°C | $I_{CEO}$ | 250 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 4 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 10 mA) | $h_{FE}$ | 40 to 200 | |
| Gain-Bandwidth Product ($V_{CE}$ = 4 V, $I_C$ = 50 mA) | $f_T$ | 100 | MHz |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 35 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 175 max | °C/W |

# 40361 0.7A, 5W

Si **n-p-n** type used in audio-amplifier inverter and driver stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. JEDEC TO-5, Outline No.5. For collector-characteristics and transfer-characteristics curves, refer to type 40309.



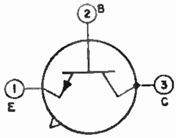

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 200 Ω) | $V_{CER}(sus)$ | 70 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 0.7 | A |
| Base Current | $I_B$ | 0.2 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_A$ and $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J(opr)$ | −65 to 200 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 200 Ω, $I_C$ = 100 mA) | $V_{CER}(sus)$ | 70 min | V |
| Collector-to-Emitter Saturation Voltage ($I_B$ = 15 mA, $I_C$ = 150 mA) | $V_{CE}(sat)$ | 1.4 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 50 mA) | $V_{BE}$ | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 60 V, $R_{BE}$ = 200 Ω, $T_C$ = 25°C | $I_{CER}$ | 1 max | μA |
| $V_{CE}$ = 60 V, $R_{BE}$ = 200 Ω, $T_C$ = 150°C | $I_{CER}$ | 100 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 4 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 50 mA) | $h_{FE}$ | 70 to 350 | |
| Gain-Bandwidth Product ($V_{CE}$ = 4 V, $I_C$ = 50 mA) | $f_T$ | 100 | MHz |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 35 max | °C/W |
| Thermal Resistance, Junction-to-Ambient | $\Theta_{J-A}$ | 175 max | °C/W |

## 0.7A, 5W — 40539




Si n-p-n triple-diffused planar type used in complementary-symmetry output stages. N-P-N structure permits complementary operation with a matching p-n-p type such as the 40538. JEDEC TO-5, Outline No.5.

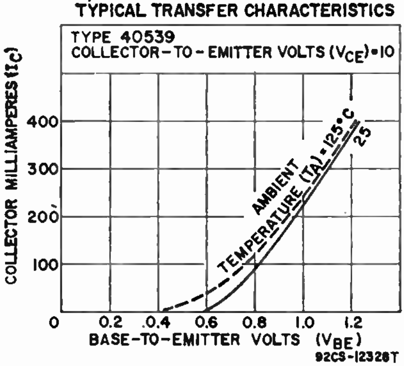
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | | | |
| $R_{BE}$ = 500 Ω | $V_{CER}(sus)$ | 55 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 0.7 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_C$ above 25°C | $P_T$ | Derate linearly to 0 W at 200 °C | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ above 25°C | $P_T$ | Derate linearly to 0 W at 200 °C | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

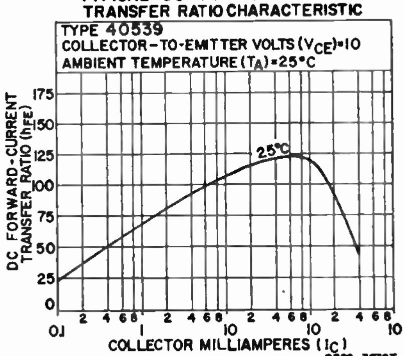
### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $R_{BE}$ = 500 Ω) | $V_{CER}(sus)$ | 55 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 500 mA, $I_B$ = 50 mA) | $V_{CE}(sat)$ | 2 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 500 mA) | $V_{BE}$ | 2.7 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 45 V, $R_{BE}$ = 500 Ω) | $I_{CER}$ | 10 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{EB}$ = 4 V, $I_C$ = 500 mA) | $h_{FE}$ | 15 to 90 | |
| Gain-Bandwidth Product ($V_{CE}$ = 4 V, $I_C$ = 50 mA) | $f_T$ | 100 | MHz |
| Thermal Resistance, Junction-to-Case | $θ_{J-C}$ | 35 | °C/W |

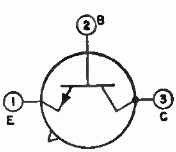
TYPICAL TRANSFER CHARACTERISTICS




TYPICAL DC FORWARD-CURRENT TRANSFER RATIO CHARACTERISTIC




## 0.7A, 5W — 40611




Si n-p-n type used for driver applications in high-fidelity amplifier circuits suitable for complementary-symmetry circuits. JEDEC TO-5, Outline No.5.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}(sus)$ | 25 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2.5 | V |

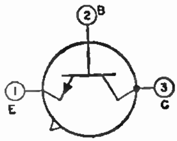
## MAXIMUM RATINGS (cont'd)

| | | | |
|---|---|---|---|
| Collector Current | $I_C$ | 0.7 | A |
| Base Current | $I_B$ | 0.2 | A |
| Transistor Dissipation: | | | |
| $T_C$ = 25°C | $P_T$ | 5 | W |
| $T_A$ = 25°C | $P_T$ | 1 | W |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA) | $V_{CEO}$(sus) | 25 min | V |
| Collector-Cutoff Current ($V_{CB}$ = 15 V) | $I_{CBO}$ | 0.5 max | μA |
| Collector-Cutoff Current ($V_{EB}$ = 2.5 V) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 59 mA) | $h_{FE}$ | 70 to 500 | |

# 40616 0.7A, 5W




Si **n-p-n** type used for driver applications in high-fidelity amplifier circuits suitable for complementary-symmetry circuits. JEDEC TO-5, Outline No.5.

## MAXIMUM RATINGS

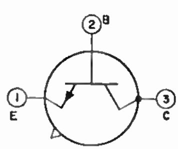
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | 32 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2.5 | V |
| Collector Current | $I_C$ | 0.7 | A |
| Base Current | $I_B$ | 0.2 | A |
| Transistor Dissipation: | | | |
| $T_C$ = 25°C | $P_T$ | 5 | W |
| $T_A$ = 25°C | $P_T$ | 1 | W |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |

## CHARACTERISTICS

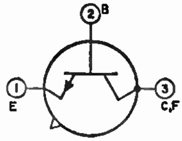
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA) | $V_{CEO}$(sus) | 32 min | V |
| Collector-Cutoff Current ($V_{CB}$ = 15 V) | $I_{CBO}$ | 0.5 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 50 mA) | $h_{FE}$ | 70 to 500 | |

# 40635 0.7A, 5W

Si **n-p-n** type used for driver applications in high-fidelity amplifier circuits. This type and type 40634 form a complementary pair of driver transistors suitable for quasi-complementary-symmetry circuits. JEDEC TO-5, Outline No.5. This type is electrically identical with type 40634 except for the reversal of all polarity signs.




# 40544 0.7A, 7W




Si **n-p-n** triple-diffused planar type used specifically as a driver in audio-amplifier circuits. JEDEC TO-5, Outline No.6.

## MAXIMUM RATINGS

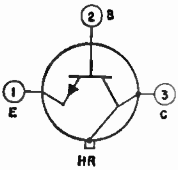
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage $R_{BE}$ = 100 Ω | $V_{CER}$(sus) | 50 | V |

## MAXIMUM RATINGS (cont'd)

| | | | |
|---|---|---|---|
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 0.7 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 7 | W |
| $T_A$ above 25°C | $P_T$ | Derate linearly to 0 W at 200 °C | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $R_{BE}$ = 100 Ω) | $V_{CER}$(sus) | 50 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA) | $V_{CE}$(sat) | 1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 50 mA) | $V_{BE}$ | 1.7 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 40 V, $R_{BE}$ = 100 Ω) | $I_{CER}$ | 10 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{EB}$ = 4 V, $I_C$ = 50 mA) | $h_{FE}$ | 35 to 200 | |
| Gain-Bandwidth Product ($V_{CE}$ = 4 V, $I_C$ = 50 mA) | $f_T$ | 100 | MHz |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 25 max | °C/W |




## 1A, 3.5W 40625

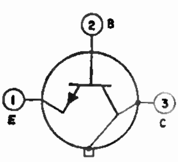
Si n-p-n type used for driver applications in high-fidelity amplifier circuits suitable for complementary-symmetry circuits. JEDEC TO-5 (with heat-radiator), Outline No.8.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | 45 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 1 | A |
| Transistor Dissipation ($T_A$ = 25°C) | $P_T$ | 3.5 | W |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA) | $V_{CEO}$(sus) | 45 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA) | $V_{CE}$(sat) | 0.5 max | V |
| Base-to-Emitter Voltage ($I_C$ = 150 mA, $V_{CE}$ = 4 V) | $V_{BE}$ | 1 max | V |
| Collector-Cutoff Current ($V_{CB}$ = 60 V) | $I_{CBO}$ | 0.25 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V) | $I_{EBO}$ | 1 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 150 mA) | $h_{FE}$ | 100 to 300 | |




## 1A, 3.5W 40628

Si n-p-n type used for driver applications in high-fidelity amplifier circuits suitable in complementary-symmetry circuits. JEDEC TO-5 (with heat-radiator), Outline No.8.

### MAXIMUM RATINGS

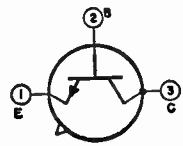
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | 55 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 1 | A |
| Transistor Dissipation ($T_A$ = 25°C) | $P_T$ | 3.5 | W |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA) | $V_{CEO}$(sus) | 55 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 150 mA, $I_B$ = 15 mA) | $V_{CE}$(sat) | 0.5 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 150 mA) | $V_{BE}$ | 1 max | V |
| Collector-Cutoff Current ($V_{CB}$ = 60 V) | $I_{CBO}$ | 0.25 max | µA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V) | $I_{EBO}$ | 1 max | µA |
| Static Forward-Current Transfer Ratio ($I_C$ = 150 mA, $V_{CE}$ = 10 V) | $h_{FE}$ | 100 to 300 | |

# 40321 1A, 5W

Si n-p-n high-voltage type for direct 117-volt line operation in audio-amplifier driver stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. JEDEC TO-5, Outline No.5.

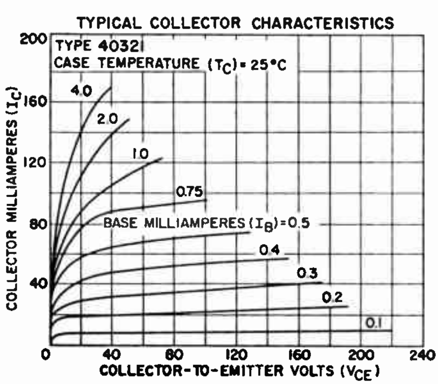


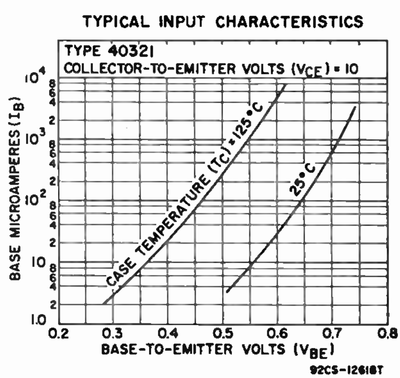

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 1000 Ω) | $V_{CER}$(sus) | 300 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 1 | A |
| Base Current | $I_B$ | 0.5 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 50°C | $P_T$ | 1 | W |
| $T_C$ up to 50°C | $P_T$ | 5 | W |
| $T_A$ and $T_C$ above 50°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 300 | °C |

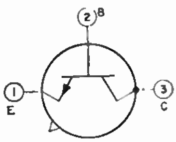
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 50 mA, $R_{BE}$ = 1000 Ω) | $V_{CER}$(sus) | 300 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 10 V, $I_C$ = 50 mA) | $V_{BE}$ | 2 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 150 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 100 max | µA |
| $V_{CE}$ = 150 V, $R_{BE}$ = 1000 Ω | $I_{CER}$ | 5 max | µA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 100 max | µA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 20 mA) | $h_{FE}$ | 25 to 200 | °C/W |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 30 max | |



## 1A, 5W — 40327




Si n-p-n high-voltage type used for direct operation from a line source in audio-amplifier driver stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. JEDEC TO-5, Outline No.5. For collector-characteristics and input-characteristics curves, refer to type 40321.

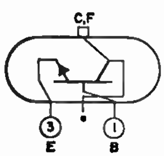
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 1000 Ω) | $V_{CER}$(sus) | 300 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 1 | A |
| Base Current | $I_B$ | 0.5 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 50°C | $P_T$ | 1 | W |
| $T_C$ up to 50°C | $P_T$ | 5 | W |
| $T_A$ and $T_C$ above 50°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | —65 to 200 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 50 mA, $R_{BE}$ = 1000 Ω) | $V_{CER}$(sus) | 300 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 10 V, $I_C$ = 50 mA) | $V_{BE}$ | 2 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 150 V, $T_C$ = 150°C, $I_E$ = 0 | $I_{CBO}$ | 100 max | μA |
| $V_{CE}$ = 150 V, $R_{BE}$ = 1000 Ω | $I_{CER}$ | 5 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 100 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 10 V, $I_C$ = 20 mA) | $h_{FE}$ | 40 to 250 | |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 30 max | °C/W |

## 4A, 36W — 40613




Si n-p-n type used for output stages in high-fidelity amplifier circuits suitable for complementary-symmetry circuits. This type features a base comprised of a homegeneous-resistivity and molded silicone plastic package with vertical leads. This type fits a standard TO-66 socket. Outline No.52.

### MAXIMUM RATINGS

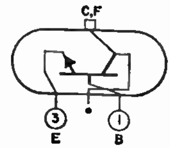
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | 25 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 4 | A |
| Base Current | $I_B$ | 2 | A |
| Transistor Dissipation: | | | |
| $T_C$ = 25°C | $P_T$ | 36 | W |
| $T_A$ = 25°C | $P_T$ | 1.8 | W |
| Temperature Range: | | | |
| Operating | T(opr) | —65 to 150 | °C |
| Storage | $T_{STG}$ | —65 to 150 | °C |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA) | $V_{CEO}$(sus) | 25 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 1000 mA) | $V_{BE}$ | 1.3 max | V |
| Collector-Cutoff Current ($V_{CB}$ = 25 V) | $I_{CBO}$ | 2 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 1000 mA) | $h_{FE}$ | 30 to 120 | |

## 40618 4A, 36W

Si n-p-n type used for output stages in high-fidelity amplifier circuits suitable for complementary-symmetry circuits. This type features a base comprised of a homegeneous-resistivity and molded silicone plastic package with vertical leads. This type fits a standard TO-66 socket. Outline No.52.




### MAXIMUM RATINGS

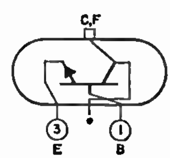
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | 30 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 4 | A |
| Base Current | $I_B$ | 2 | A |
| Transistor Dissipation: | | | |
| $T_C$ = 25°C | $P_T$ | 36 | W |
| $T_A$ = 25°C | $P_T$ | 1.8 | W |
| Temperature Range: | | | |
| Operating | T(opr) | —65 to 150 | °C |
| Storage | $T_{STG}$ | —65 to 150 | °C |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA) | $V_{CEO}$(sus) | 30 min | V |
| Collector-Cutoff Current ($V_{CB}$ = 30 V) | $I_{CBO}$ | 2 max | µA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 1000 mA) | $h_{FE}$ | 30 to 120 | |

## 40621 4A, 36W

Si n-p-n type used for output stages in high-fidelity circuits suitable for complementary-symmetry circuits. This type features a base comprised of a homegeneous-resistivity and molded silicone plastic package with vertical leads. This type fits a standard TO-66 socket. Outline No.52.



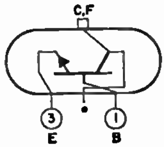

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | 32 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 4 | A |
| Base Current | $I_B$ | 2 | A |
| Transistor Dissipation: | | | |
| $T_C$ = 25°C | $P_T$ | 36 | W |
| $T_A$ = 25°C | $P_T$ | 1.8 | W |
| Temperature Range: | | | |
| Operating | T(opr) | —65 to 150 | °C |
| Storage | $T_{STG}$ | —65 to 150 | °C |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA) | $V_{CEO}$(sus) | 32 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 1500 mA, $I_B$ = 150 mA) | $V_{CE}$(sat) | 1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 1500 mA) | $V_{BE}$ | 1.5 max | V |
| Collector-Cutoff Current ($V_{CB}$ = 30 V) | $I_{CBO}$ | 0.5 max | µA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 1500 mA) | $h_{FE}$ | 25 to 100 | |

## 4A, 36W — 40622




Si **n-p-n** type used for output stages in high-fidelity amplifier circuits suitable for complementary-symmetry circuits. This type features a base comprised of a homegeneous-resistivity and molded silicone plastic package with vertical leads. This type fits a standard TO-66 socket. Outline No.52.

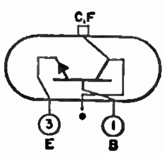
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 4 | A |
| Base Current | $I_B$ | 2 | A |
| Transistor Dissipation: | | | |
| $T_C = 25°C$ | $P_T$ | 36 | W |
| $T_A = 25°C$ | $P_T$ | 1.8 | W |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 150 | °C |
| Storage | $T_{STG}$ | −65 to 150 | °C |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA) | $V_{CEO}$(sus) | 40 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 1500 mA, $I_B$ = 150 mA) | $V_{CE}$(sat) | 1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 1500 mA) | $V_{BE}$ | 1.5 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 40 V, $R_{BE}$ = 100 Ω) | $I_{CER}$ | 500 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 1500 mA) | $h_{FE}$ | 25 to 100 | |

## 4A, 36W — 40629




Si **n-p-n** type used for output stages in high-fidelity amplifier circuits. This type features a base comprised of a homegeneous-resistivity and molded silicone plastic package with vertical leads. This type fits a standard TO-66 socket. Outline No.52.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage $R_{BE}$ = 100 Ω | $V_{CER}$(sus) | 35 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 4 | A |
| Base Current | $I_B$ | 2 | A |
| Transistor Dissipation: | | | |
| $T_C = 25°C$ | $P_T$ | 36 | W |
| $T_A = 25°C$ | $P_T$ | 1.8 | W |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 150 | °C |
| Storage | $T_{STG}$ | −65 to 150 | °C |

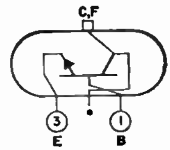
### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $R_{BE}$ = 100 Ω) | $V_{CER}$(sus) | 35 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 1000 mA, $I_B$ = 100 mA) | $V_{CE}$(sat) | 1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 1000 mA) | $V_{BE}$ | 1.3 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 30 V, $R_{BE}$ = 100 Ω) | $I_{CER}$ | 0.5 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 1000 mA) | $h_{FE}$ | 20 to 70 | |

# 40630

**4A, 36W**

Si **n-p-n** type used for output stages in high-fidelity amplifier circuits. This type features a base comprised of a homegeneous-resistivity and molded silicone package with vertical leads. This type fits a standard TO-66 socket. **Outline** No.52.




## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | | | |
| $R_{BE}$ = 100 Ω | $V_{CER}$(sus) | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 4 | A |
| Base Current | $I_B$ | 2 | A |
| Transistor Dissipation: | | | |
| $T_C$ = 25°C | $P_T$ | 36 | W |
| $T_A$ = 25°C | $P_T$ | 1.8 | W |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 150 | °C |
| Storage | $T_{STG}$ | −65 to 150 | °C |

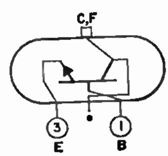
## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $R_{BE}$ = 100 Ω) | $V_{CER}$(sus) | 40 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 1500 mA, $I_B$ = 150 mA) | $V_{CE}$(sat) | 1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 1500 mA) | $V_{BE}$ | 1.4 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 35 V, $R_{BE}$ = 100 Ω) | $I_{CER}$ | 0.5 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 1500 mA) | $h_{FE}$ | 20 to 70 | |

# 40631

**4A, 36W**

Si **n-p-n** type used for output stages in high-fidelity amplifier circuits suitable for quasi-complementary-symmetry circuits. This type features a base comprised of a homegeneous-resistivity and molded silicone plastic package with vertical leads. This type fits a standard TO-66 socket. **Outline** No.52.



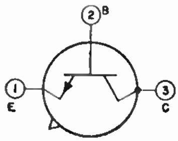

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | | | |
| $R_{BE}$ = 100 Ω | $V_{CER}$(sus) | 45 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 4 | A |
| Base Current | $I_B$ | 2 | A |
| Transistor Dissipation: | | | |
| $T_C$ = 25°C | $P_T$ | 36 | W |
| $T_A$ = 25°C | $P_T$ | 1.8 | W |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 150 | °C |
| Storage | $T_{STG}$ | −65 to 150 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $R_{BE}$ = 100 Ω) | $V_{CER}$(sus) | 45 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 2000 mA, $I_B$ = 200 mA) | $V_{CE}$(sat) | 1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 2000 mA) | $V_{BE}$ | 1.5 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 40 V, $R_{BE}$ = 100 Ω) | $I_{CER}$ | 0.5 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 2000 mA) | $h_{FE}$ | 20 to 70 | |

## 2A, 10W — 40594



Si n-p-n type used for driver applications in high-fidelity amplifier circuits. This type and type 40495 form a complementary pair of driver transistors suitable for quasi-complementary-symmetry circuits. JEDEC TO-5, Outline No.5.

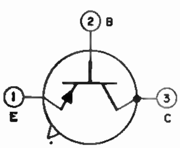
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage $R_{BE} = 100\ \Omega$ | $V_{CER}$(sus) | 95 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 2 | A |
| Base Current | $I_B$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_C = 25°C$ | $P_T$ | 10 | W |
| $T_A = 25°C$ | $P_T$ | 1.2 | W |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |

### CHARACTERISTICS

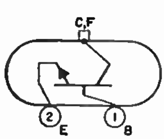
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C = 100$ mA, $R_{BE} = 100\ \Omega$) | $V_{CER}$(sus) | 95 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C = 300$ mA, $I_B = 30$ mA) | $V_{CE}$(sat) | 0.8 max | V |
| Base-to-Emitter Voltage ($V_{CB} = 4$ V, $I_C = 300$ mA) | $V_{BE}$ | 1.4 max | V |
| Collector-Cutoff Current ($V_{CE} = 85$ V, $R_{BE} = 100\ \Omega$) | $I_{CER}$ | 10 max | µA |
| Emitter-Cutoff Current ($V_{EB} = 4$ V) | $I_{EBO}$ | 0.1 max | µA |
| Static Forward Current Transfer Ratio ($V_{CB} = 4$ V, $I_C = 300$ mA) | $h_{FE}$ | 70 to 350 | |

## 2A, 10W — 40595



Si p-n-p type used for driver applications in high-fidelity amplifier circuits. This type and type 40495 form a complementary pair of driver transistors suitable for quasi-complementary-symmetry circuits. JEDEC TO-5, Outline No.5. This type is electrically identical with type 40594 except for the reversal of all polarity signs.

## 2A, 35W — 40328



Si n-p-n high-voltage type used for direct operation from a line source in audio-amplifier output stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. JEDEC TO-66, Outline No.25. See Mounting Hardware for desired mounting arrangement. For rating chart and collector-characteristics curves, refer to to type 40318.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE} = 500\ \Omega$) | $V_{CER}$(sus) | 300 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 6 | V |
| Collector Current | $I_C$ | 2 | A |
| Base Current | $I_B$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 35 | W |
| $T_C$ above 25°C | $P_T$ | See Rating Chart | |
| $T_C = 175°C$ | $P_T$ | 5 | W |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |

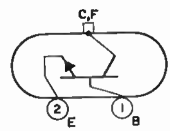
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 200 mA, $R_{BE}$ = 500 Ω) | $V_{CER}$(sus) | 300 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 10 V, $I_C$ = 1 A) | $V_{BE}$ | 1.5 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 150 V, $I_B$ = 0 | $I_{CEO}$ | 5 max | mA |
| $V_{CE}$ = 150 V, $V_{BE}$ = −1.5 V, $T_C$ = 25°C | $I_{CEV}$ | 10 max | mA |
| $V_{CE}$ = 150 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C | $I_{CEV}$ | 10 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 6 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | mA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 1 A | $h_{FE}$ | 20 min | |
| $V_{CE}$ = 10 V, $I_C$ = 20 mA | $h_{FE}$ | 40 min | |
| Second-Breakdown Collector Current ($V_{CE}$ = 150 V) | $I_{S/b}$ | 100 min | mA |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 5 max | °C/W |

# 40313

**2A, 35W**

Si n-p-n high-voltage type for direct 117-volt line operation in audio-amplifier output stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. JEDEC TO-66, Outline No.25. See Mounting Hardware for desired mounting arrangement.

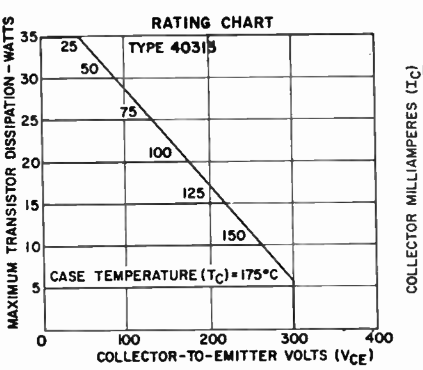


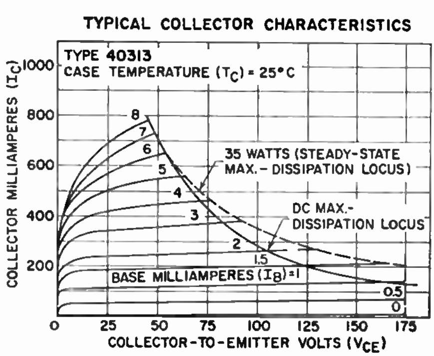

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 500 Ω) | $V_{CER}$(sus) | 300 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2.5 | V |
| Collector Current | $I_C$ | 2 | A |
| Base Current | $I_B$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 35 | W |
| $T_C$ above 25°C | $P_T$ | See Rating | Chart |
| $T_C$ = 175°C | $P_T$ | 5 | W |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 200 mA, $R_{BE}$ = 500 Ω) | $V_{CER}$(sus) | 300 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 10 V, $I_C$ = 0.1 A) | $V_{BE}$ | 1.5 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 150 V, $I_B$ = 0 | $I_{CEO}$ | 5 max | mA |
| $V_{CE}$ = 300 V, $V_{BE}$ = −1.5 V, $T_C$ = 25°C | $I_{CEV}$ | 10 max | mA |
| $V_{CE}$ = 300 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C | $I_{CEV}$ | 10 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 2.5 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | mA |

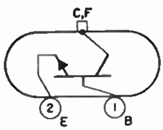


## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 100 mA | $h_{FE}$ | 40 to 250 | |
| $V_{CE}$ = 10 V, $I_C$ = 500 mA | $h_{FE}$ | 40 min | |
| Second-Breakdown Collector Current ($V_{CE}$ = 150 V) | $I_{S/b}$ | 150 min | mA |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 5 max | °C/W |

## 2A, 35W 40318



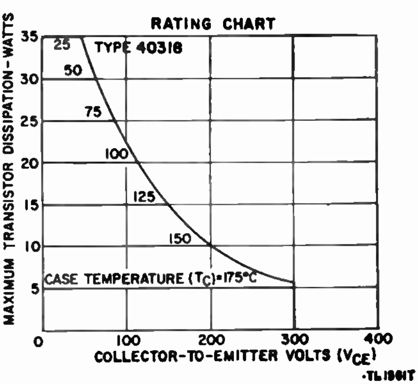

Si n-p-n high-voltage type for direct 117-volt line operation in audio-amplifier output stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. JEDEC TO-66, Outline No.25. See Mounting Hardware for desired mounting arrangement.

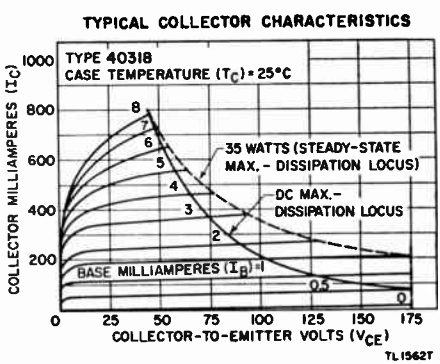
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 500 Ω) | $V_{CER}$(sus) | 300 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 6 | V |
| Collector Current | $I_C$ | 2 | A |
| Base Current | $I_B$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 35 | W |
| $T_C$ above 25°C | $P_T$ | See Rating | Chart |
| $T_C$ = 175°C | $P_T$ | 5 | W |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

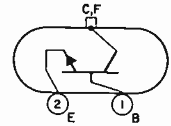
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 200 mA, $R_{BE}$ = 500 Ω) | $V_{CER}$(sus) | 300 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 10 V, $I_C$ = 0.5 A) | $V_{BE}$ | 1.5 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 150 V, $I_B$ = 0 | $I_{CEO}$ | 5 max | mA |
| $V_{CE}$ = 150 V, $V_{BE}$ = −1.5 V, $T_C$ = 25°C | $I_{CEV}$ | 5 max | mA |
| $V_{CE}$ = 150 V, $V_{BE}$ = −1.5 V, $T_C$ = 150°C | $I_{CEV}$ | 10 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 6 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | mA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 20 mA | $h_{FE}$ | 40 min | |
| $V_{CE}$ = 10 V, $I_C$ = 500 mA | $h_{FE}$ | 50 min | |
| Second-Breakdown Collector Current ($V_{CE}$ = 150 V) | $I_{S/b}$ | 100 min | mA |
| Second-Breakdown Energy ($V_{BE}$ = 4 V, $R_{BE}$ = 20 Ω, L = 100 μH) | $E_{S/b}$ | 50 min | μJ |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 5 max | °C/W |



# 40322 2A, 35W

Si n-p-n high-voltage type for direct 117-volt line operation in audio-amplifier output stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. JEDEC TO-66, Outline No.25. See Mounting Hardware for desired mounting arrangement. For rating chart and collector-characteristics curves, refer to type 40318.




## MAXIMUM RATINGS

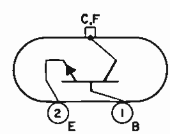
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 500 Ω) | $V_{CER}$(sus) | 300 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 6 | V |
| Collector Current | $I_C$ | 2 | A |
| Base Current | $I_B$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 35 | W |
| $T_C$ above 25°C | $P_T$ | See Rating Chart | |
| $T_C$ = 175°C | $P_T$ | 5 | W |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | —65 to 200 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 200 mA, $R_{BE}$ = 200 Ω, L = 5 mH) | $V_{CER}$(sus) | 300 min | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 150 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CEO}$ | 5 max | mA |
| $V_{CB}$ = 150 V, $V_{BE}$ = —1.5 V, $T_C$ = 25°C | $I_{CEV}$ | 10 max | mA |
| $V_{CE}$ = 150 V, $V_{BE}$ = —1.5 V, $T_C$ = 150°C | $I_{CEV}$ | 10 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 6 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | mA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 10 V, $I_C$ = 20 mA | $h_{FE}$ | 40 min | |
| $V_{CE}$ = 10 V, $I_C$ = 500 mA | $h_{FE}$ | 75 min | |
| Second-Breakdown Collector Current ($V_{CE}$ = 150 V) | $I_{S/b}$ | 100 min | mA |
| Second-Breakdown Energy ($V_{BE}$ = 4 V, $R_{BE}$ = 20 Ω, L = 100 μH) | $E_{S/b}$ | 50 min | μJ |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 5 max | °C/W |

# 40310 4A, 29W

Si n-p-n type used in audio-amplifier driver stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. JEDEC TO-66, Outline No.25. See Mounting Hardware for desired mounting arrangement.




## MAXIMUM RATINGS

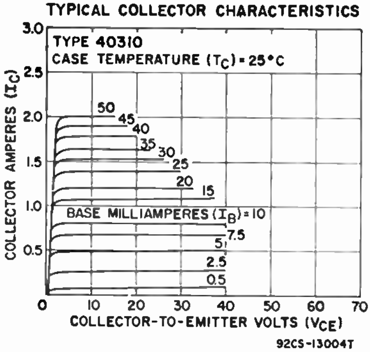
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | 35 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2.5 | V |
| Collector Current | $I_C$ | 4 | A |
| Base Current | $I_B$ | 2 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 29 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | —65 to 200 | °C |

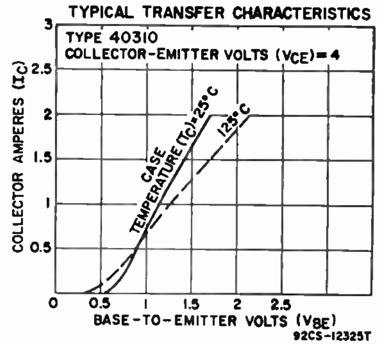
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 100 mA, $I_B$ = 0) | $V_{(BR)CEO}$ | 35 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 2 V, $I_C$ = 1 A) | $V_{BE}$ | 1.4 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 10 max | μA |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 5 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 2.5 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 2 V, $I_C$ = 1 A) | $h_{FE}$ | 20 to 120 | |

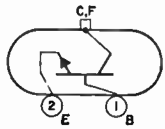
## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Gain-Bandwidth Product ($V_{CE}$ = 4 V, $I_C$ = 500 mA) | $f_T$ | 750 | kHz |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 6 max | °C/W |




## 4A, 29W **40312**



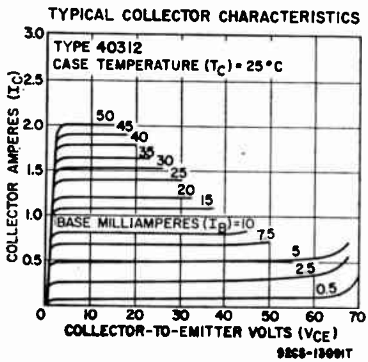

Si n-p-n type used in audio-amplifier output stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. JEDEC TO-66, Outline No.25 See Mounting Hardware for desired mounting arrangement.

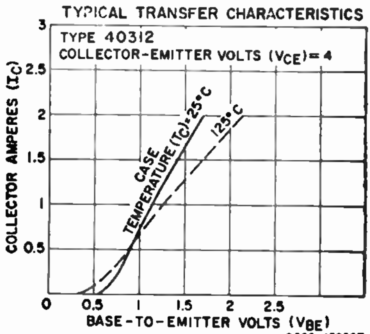
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 500 Ω) | $V_{CER}$(sus) | 60 | V |
| Emitter-to-Base Voltage | $V_{CBO}$ | 2.5 | V |
| Collector Current | $I_C$ | 4 | A |
| Base Current | $I_B$ | 2 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 29 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $R_{BE}$ = 500 Ω, tp = 300 μs, df = 2%) | $V_{CER}$(sus) | 60 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 2 V, $I_C$ = 1 A) | $V_{BE}$ | 1.4 max | V |



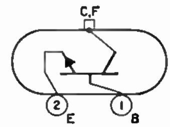



## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 10 max | μA |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 5 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 2.5 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 2 V, $I_C$ = 1 A) | $h_{FE}$ | 20 to 120 | |
| Gain-Bandwidth Product ($V_{CE}$ = 4 V, $I_C$ = 500 mA) | $f_T$ | 750 | kHz |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 6 max | °C/W |

# 40316 4A, 29W

Si **n-p-n** type used in audio-amplifier output stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. JEDEC TO-66, Outline No.25. See Mounting Hardware for desired mounting arrangement.




## MAXIMUM RATINGS

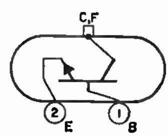
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 500 Ω) | $V_{CER}$(sus) | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 4 | A |
| Base Current | $I_B$ | 2 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 29 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $R_{BE}$ = 500 Ω) | $V_{CER}$(sus) | 40 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 2 V, $I_C$ = 1 A) | $V_{BE}$ | 1.4 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 10 max | μA |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 5 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 2 V, $I_C$ = 1 A) | $h_{FE}$ | 20 to 120 | |
| Gain-Bandwidth Product ($V_{CE}$ = 4 V, $I_C$ = 500 mA) | $f_T$ | 750 | kHz |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 6 max | °C/W |

# 40324 4A, 29W

Si **n-p-n** type used in audio-amplifier inverter and driver stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. JEDEC TO-66, Outline No.25. See Mounting Hardware for desired mounting arrangement. For collector-characteristics and transfer-characteristics curves, refer to type 40310.




## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | 35 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2.5 | V |
| Collector Current | $I_C$ | 4 | A |
| Base Current | $I_B$ | 2 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 29 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |

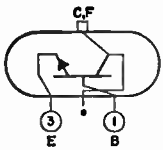
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 100 mA, $R_{BE}$ = 500 Ω) | $V_{(BR)CEO}$ | 35 min | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 2 V, $I_C$ = 1 A) | $V_{BE}$ | 1.4 max | V |

### CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 10 max | µA |
| $V_{CB}$ = 15 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 5 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 2.5 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 2 V, $I_C$ = 1 A) | $h_{FE}$ | 20 to 120 | |
| Gain-Bandwidth Product ($V_{CE}$ = 4 V, $I_C$ = 500 mA) | $f_T$ | 750 | kHz |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 6 max | °C/W |

## 6A, 50W — 40624




Si n-p-n type used for output stages in high-fidelity amplifier circuits suitable for complementary-symmetry circuits. This type features a base comprised of a homegeneous-resistivity and molded silicone plastic package with vertical leads. This type fits a standard TO-66 socekt. Outline No.52.

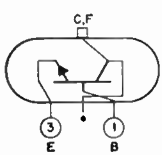
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | 45 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 6 | A |
| Base Current | $I_B$ | 3 | A |
| Transistor Dissipation: | | | |
| $T_C$ = 25°C | $P_T$ | 50 | W |
| $T_A$ = 25°C | $P_T$ | 1.8 | W |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 150 | °C |
| Storage | $T_{STG}$ | −65 to 150 | °C |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA) | $V_{CEO}$(sus) | 45 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 2500 mA, $I_B$ = 250 mA) | $V_{CE}$(sat) | 1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 2500 mA) | $V_{BE}$ | 1.7 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 45 V, $R_{BE}$ = 100 Ω) | $I_{CER}$ | 500 max | µA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 2500 mA) | $h_{FE}$ | 20 to 100 | |

## 6A, 50W — 40627




Si n-p-n type used for output stages in high-fidelity amplifier circuits suitable for complementary-symmetry circuits. This type features a base comprised of a homegeneous-resistivity and molded silicone plastic package with vertical leads. This type fits a standard TO-66 socket. Outline No.52.

### MAXIMUM RATINGS

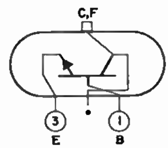
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage | $V_{CEO}$(sus) | 55 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 6 | A |
| Base Current | $I_B$ | 3 | A |
| Transistor Dissipation: | | | |
| $T_C$ = 25°C | $P_T$ | 50 | W |
| $T_A$ = 25°C | $P_T$ | 1.8 | W |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 150 | °C |
| Storage | $T_{STG}$ | −65 to 150 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA) | $V_{CEO}$(sus) | 55 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 2500 mA, $I_B$ = 250 mA) | $V_{CE}$(sat) | 1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 2500 mA) | $V_{BE}$ | 1.7 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 55 V, $R_{BE}$ = 100 Ω) | $I_{CER}$ | 500 max | μA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 2500 mA) | $h_{FE}$ | 20 to 100 | |

# 40632 6A, 50W

Si n-p-n type used for output stages in high-fidelity amplifier circuits suitable for quasi-complementary-symmetry circuits. This type features a base comprised of a homegeneous-resistivity and molded silicone plastic package with vertical leads. This type fits a standard TO-66 socket. Outline No.52.




## MAXIMUM RATINGS

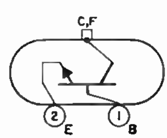
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage $R_{BE}$ = 100 Ω | $V_{CER}$(sus) | 60 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 6 | A |
| Base Current | $I_B$ | 3 | A |
| Transistor Dissipation: $T_C$ = 25°C | $P_T$ | 50 | W |
| $T_A$ = 25°C | $P_T$ | 1.8 | W |
| Temperature Range: Operating | T(opr) | −65 to 150 | °C |
| Storage | $T_{STG}$ | −65 to 150 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 100 mA, $R_{BE}$ = 100 Ω) | $V_{CER}$(sus) | 60 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 3000 mA, $I_B$ = 300 mA) | $V_{CE}$(sat) | 1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 3000 mA) | $V_{BE}$ | 1.4 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 50 V, $R_{BE}$ = 100 Ω) | $I_{CER}$ | 0.5 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 3000 mA) | $h_{FE}$ | 20 to 70 | |

# 40542 6A, 83W

Si n-p-n type featuring a base comprised of a homogeneous-resistivity silicon material and molded silicon plastic package with vertical leads. This type fits a standard TO-3 socket. It is used in complementary-symmetry output stages of audio-amplifier circuits. It permits complementary operation with a matching p-n-p type such as 40051. Outline No.50. See Mounting Hardware for desired mounting arrangement.




## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 100 Ω) | $V_{CER}$(sus) | 50 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 6 | A |

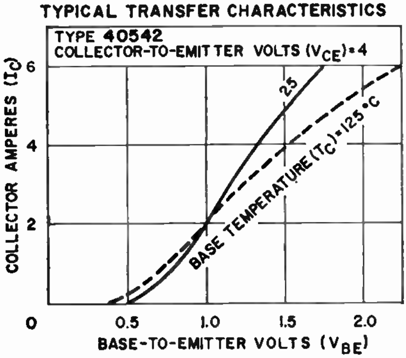
## MAXIMUM RATINGS (cont'd)

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 83 | W |
| $T_C$ above 25°C | $P_T$ | Derate linearly 0 W at 150 °C | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 150 | °C |
| Storage | $T_{STG}$ | −65 to 150 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 235 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

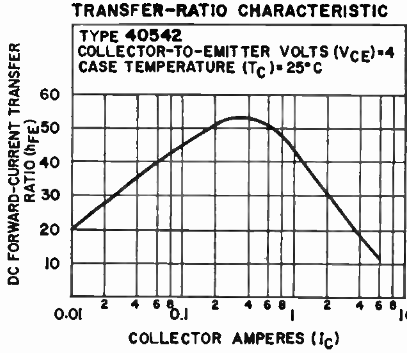
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 0.2 A, $R_{BE}$ = 100 Ω, $t_P$ = 300 μs, df = 1.8%) | $V_{CER}$(sus) | 50 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 2.5 A, $I_B$ = 0.25 A, $t_P$ = 300 μs, df = 1.8%) | $V_{CE}$(sat) | 1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 2.5 A, $t_P$ = 300 μs, df = 1.8%) | $V_{BE}$ | 1.7 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 40 V, $R_{BE}$ = 100 Ω) | $I_{CER}$ | 1 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | mA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 2.5 A, $t_P$ = 300 μs, df = 1.8%) | $h_{FE}$(pulsed) | 20 to 70 | |
| Gain-Bandwidth Product ($V_{CE}$ = 4 V, $I_C$ = 0.5 A) | $f_T$ | 0.8 to 2.8 | MHz |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 1.5 max | °C/W |

TYPICAL TRANSFER CHARACTERISTICS



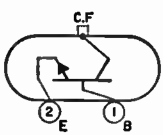

92SS-3603T

TYPICAL DC FORWARD-CURRENT TRANSFER-RATIO CHARACTERISTIC




92SS-3686T

## 7A, 35W 40364




Si n-p-n type used in audio-amplifier output stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. JEDEC TO-66, Outline No.25. See Mounting Hardware for desired mounting arrangement.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 150 Ω) | $V_{CER}$(sus) | 60 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 7 | A |
| Base Current | $I_B$ | 5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 35 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |

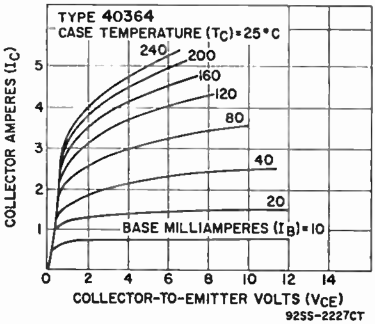
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 150 Ω, $I_C$ = 200 mA) | $V_{CER}$(sus) | 60 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 2.5 A, $I_B$ = 0.25 A) | $V_{CE}$(sat) | 2 max | V |

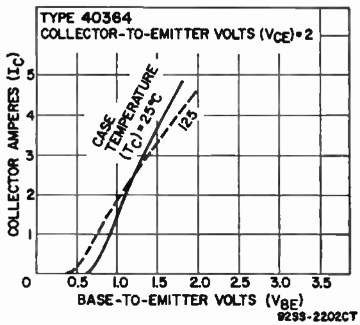
**CHARACTERISTICS (cont'd)**

| | | | |
|---|---|---|---|
| Base-to-Emitter Voltage ($V_{CE}$ = 5 V, $I_C$ = 2.5 A) | $V_{BE}$ | 1.8 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 50 V, $R_{BE}$ = 150 Ω, $T_C$ = 25°C | $I_{CER}$ | 0.5 max | mA |
| $V_{CE}$ = 50 V, $R_{BE}$ = 150 Ω, $T_C$ = 150°C | $I_{CER}$ | 2 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 4 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | mA |
| Static Forward-Current Transfer Ratio: | | | |
| $V_{CE}$ = 5 V, $I_C$ = 0.5 A | $h_{FE}$ | 35 to 175 | |
| $V_{CE}$ = 5 V, $I_C$ = 2.5 A | $h_{FE}$ | 20 min | |
| Gain-Bandwidth Product ($V_{CE}$ = 10 V, $I_C$ = 2.5 A) | $f_T$ | 15 | MHz |
| Second-Breakdown Collector Current ($V_{CE}$ = 40 V) | $I_{S/b}$ | 750 min | mA |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 5 max | °C/W |

TYPICAL COLLECTOR CHARACTERISTICS

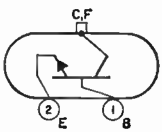



TYPICAL TRANSFER CHARACTERISTICS




## 40543 8A, 83W

Si **n-p-n** type featuring a base comprised of a homogeneous-resistivity silicon material and molded silicone plastic package with vertical leads. This type fits a standard TO-3 socket. It is designed specifically for amplifier applications. **Outline** No.50. See **Mounting Hardware** for desired mounting arrangement. This type is identical with type 40542 except for the following items:




**MAXIMUM RATINGS**

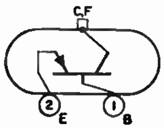
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 100 Ω) | $V_{CER}$(sus) | 60 | V |
| Collector Current | $I_C$ | 8 | A |

**CHARACTERISTICS (At case temperature = 25°C)**

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 0.2 A, $R_{BE}$ = 100 Ω, $t_P$ = 300 μs, df = 1.8%) | $V_{CER}$(sus) | 60 | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 3 A, $I_B$ = 0.3 A, $t_P$ = 300 μs, df = 1.8%) | $V_{CE}$(sat) | 1 | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 3 A, $t_P$ = 300 μs, df = 1.8%) | $V_{BE}$ | 1.7 | V |
| Collector-Cutoff Current ($V_{CE}$ = 50 V, $R_{BE}$ = 100 Ω) | $I_{CER}$ | 1 | mA |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 3 A, $t_P$ = 300 μs, df = 1.8%) | $h_{FE}$(pulsed) | 20 to 70 | |

## 40633 8A, 83W

Si **n-p-n** type used for output stages in high-fidelity amplifier circuits suitable for quasi-complementary-symmetry circuits. This type features a base comprised of a homegeneous-resistivity and molded silicone plastic package with vertical leads. This type fits a standard TO-3 socket. **Outline** No.50.



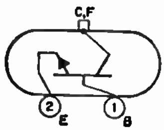
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage $R_{BE}$ = 100 Ω | $V_{CER}$(sus) | 75 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 8 | A |
| Base Current | $I_B$ | 6 | A |
| Transistor Dissipation: | | | |
| $T_C$ = 25°C | $P_T$ | 83 | W |
| $T_A$ = 25°C | $P_T$ | 2 | W |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 150 | °C |
| Storage | $T_{STG}$ | −65 to 150 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 200 mA, $R_{BE}$ = 100 Ω) | $V_{CER}$(sus) | 75 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 4000 mA, $I_B$ = 400 mA) | $V_{CE}$(sat) | 1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 4000 mA) | $V_{BE}$ | 1.4 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 65 V, $R_{BE}$ = 100 Ω) | $I_{CER}$ | 0.5 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 4000 mA) | $h_{FE}$ | 20 to 70 | |

## 15A, 117W 40325

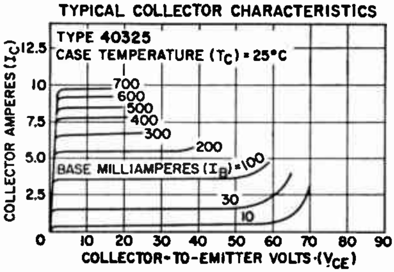



Si n-p-n type used in audio-amplifier output stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. JEDEC TO-3, Outline No.2. See Mounting Hardware for desired mounting arrangement.

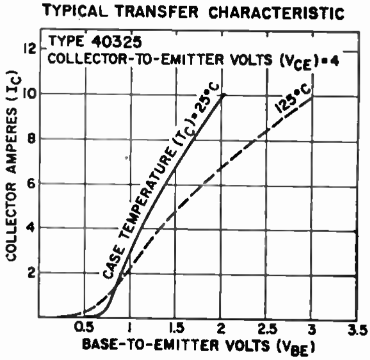
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 35 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 35 | V |
| Base open (sustaining voltage) | $V_{CEO}$(sus) | 35 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 5 | V |
| Collector Current | $I_C$ | 15 | A |
| Base Current | $I_B$ | 7 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 117 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |

TYPICAL COLLECTOR CHARACTERISTICS




TYPICAL TRANSFER CHARACTERISTIC

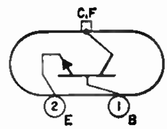


### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 200 mA, $I_B$ = 0) | $V_{(BR)CEO}$(sus) | 35 min | V |
| Collector-to-Base Breakdown Voltage ($I_C$ = 100 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 35 min | V |
| Collector-to-Emitter Saturation Voltage | | | V |
| ($I_C$ = 8 A, $I_B$ = 0.8 A) | $V_{CE}$(sat) | 1.5 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 8 A) | $V_{BE}$ | 2 max | |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_C$ = 25°C | $I_{CBO}$ | 5 max | |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_C$ = 150°C | $I_{CBO}$ | 10 max | |
| Emitter-Cutoff Current ($V_{EB}$ = 5 V, $I_C$ = 0) | $I_{EBO}$ | 10 max | °C/W |
| Static Forward-Current Transfer Ratio | | | mA |
| ($V_{CE}$ = 4 V, $I_C$ = 8 A) | $h_{FE}$ | 12 to 60 | mA |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 1.5 max | mA |

## 40363 15A, 115W

Si **n-p-n** type used in audio-amplifier output stages for economical high-quality performance. Designed to assure freedom from second breakdown in the operating region. JEDEC TO-3, Outline No.2. See **Mounting Hardware** for desired mounting arrangement. For collector-characteristics and transfer-characteristics cuves, refer to type 40325.



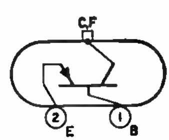

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 200 Ω) | $V_{CER}$(sus) | 70 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 15 | A |
| Base Current | $I_B$ | 7 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 115 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 200 Ω, $I_C$ = 200 mA) | $V_{CER}$(sus) | 70 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 4 A, $I_B$ = 0.4 A) | $V_{CE}$(sat) | 1.1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 4 A) | $V_{BE}$ | 1.8 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 60 V, $R_{BE}$ = 200 Ω, $T_C$ = 25°C | $I_{CER}$ | 0.5 max | mA |
| $V_{CE}$ = 60 V, $R_{BE}$ = 200 Ω, $T_C$ = 150°C | $I_{CER}$ | 2 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 4 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 4 A) | $h_{FE}$ | 20 to 70 | |
| Gain-Bandwidth Product ($V_{CE}$ = 4 V, $I_C$ = 3 A) | $f_T$ | 700 | kHz |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 1.5 max | °C/W |

## 40636 15A, 115W




Si **n-p-n** type used for output stages in high-fidelity amplifier circuits suitable for quasi-complementary-symmetry circuits. JEDEC TO-3, **Outline No.2.**

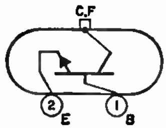
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage $R_{BE}$ = 100 Ω | $V_{CER}$(sus) | 95 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 7 | V |
| Collector Current | $I_C$ | 15 | A |
| Base Current | $I_B$ | 7 | A |
| Transistor Dissipation | | | |
| $T_C$ = 25°C | $P_T$ | 115 | W |
| Temperature Range: | | | |
| Operating | T(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 200 mA, $R_{BE}$ = 100 Ω) | $V_{CER}$(sus) | 95 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 4000 mA, $I_B$ = 400 mA) | $V_{CE}$(sat) | 1 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 4000 mA) | $V_{BE}$ | 1.4 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 85 V, $R_{BE}$ = 100 Ω) | $I_{CER}$ | 0.5 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 4 V) | $I_{EBO}$ | 1 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 4000 mA) | $h_{FE}$ | 20 to 70 | |

## 30A, 150W — 40411




Si n-p-n type features a base comprised of a homogeneous-resistivity silicon material. This type is used in output stages in af-amplifier applications in industrial and commercial equipment. In a typical class AB circuit, two series-connected 40411 transistors driven by a complementary pair of transistors (40409 and 40410) can provide an audio output of 70 watts with a total harmonic distortion of less than 0.25 per cent at 1000 Hz. JEDEC TO-3, Outline No.2. See Mounting Hardware for desired mounting arrangement.

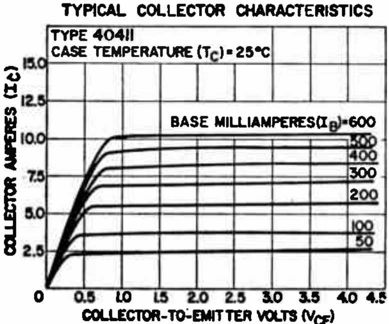
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ ≦ 100 Ω) | $V_{CER}$(sus) | 90 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 30 | A |
| Base Current | $I_B$ | 15 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 150 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

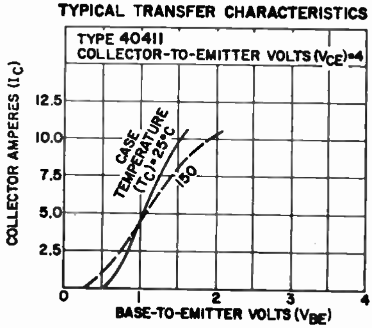
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 100 Ω, $I_C$ = 200 mA) | $V_{CER}$(sus) | 90 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 4 A, $I_B$ = 400 mA) | $V_{CE}$(sat) | 0.8 max | V |
| Base-to-Emitter Voltage ($V_{CE}$ = 4 V, $I_C$ = 4 A) | $V_{BE}$ | 1.2 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 80 V, $R_{BE}$ = 100 Ω, $T_C$ = 25°C | $I_{CER}$ | 0.5 max | mA |
| $V_{CE}$ = 80 V, $R_{BE}$ = 100 Ω, $T_C$ = 150°C | $I_{CER}$ | 2 max | mA |
| Emitter-Cutoff Current ($V_{EB}$ = 4 V, $I_C$ = 0) | $I_{EBO}$ | 5 max | mA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 4 V, $I_C$ = 4 A) | $h_{FE}$ | 35 to 100 | |
| Gain-Bandwidth Product ($V_{CE}$ = 4 V, $I_C$ = 4 A) | $f_T$ | 800 | kHz |
| Power-Rating Test (40 V at 5 A for 1 s max) | | 200 | W |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 1.17 max | °C/W |

TYPICAL COLLECTOR CHARACTERISTICS




92CS-13184T

TYPICAL TRANSFER CHARACTERISTICS



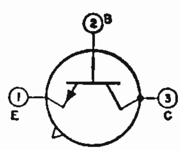

92CS-13188T

# Technical Data for RF Power Transistors

THIS section contains detailed technical data for all current RCA rf power transistors. The transistors are listed according to the numerical-alphabetical-numerical sequence of their type designations.

In selection of devices for use in new electronic equipment, a prospective user should refer to the appropriate section of the Selection Guide included earlier in the Manual.

## 2N1491 RF POWER TRANSISTOR



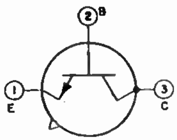

Si **n-p-n** triple-diffused type used in vhf applications for rf-amplifier, video-amplifier, oscillator, and mixer circuits in industrial and military equipment. JEDEC TO-39, Outline No.15.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 30 | V |
| Collector-to-Emitter Voltage ($V_{BE}$ = −0.5 V) | $V_{CEV}$ | 30 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 1 | V |
| Collector Current | $I_C$ | 100 | mA |
| Base Current | $I_B$ | 20 | mA |
| Emitter Current | $I_E$ | −100 | mA |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 3 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating ($T_C$) and Storage ($T_{STG}$) | | −65 to 175 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 30 min | V |
| Emitter-to-Base Floating Potential ($V_{CB}$ = 30 V, $I_E$ = 0) | $V_{EB}$(fl) | 0.5 max | V |
| Collector-Cutoff Current ($V_{CB}$ = 12 V, $I_E$ = 0) | $I_{CBO}$ | 10 max | µA |
| Emitter-Cutoff Current ($V_{EB}$ = 1 V, $I_C$ = 0) | $I_{EBO}$ | 100 max | µA |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 20 V, $I_C$ = 15 mA, f = 1 kHz) | $h_{fe}$ | 15 to 200 | |
| Gain-Bandwidth Product ($V_{CB}$ = 30 V, $I_C$ = 15 mA) | $f_T$ | 300 | MHz |
| Output Capacitance ($V_{CB}$ = 30 V, $I_E$ = 0, f = 0.15 MHz) | $C_{obo}$ | 5 max | pF |
| Small-Signal Power Gain ($V_{CB}$ = 15 V, $I_E$ = −15 mA, $P_{oe}$ = 10 mW, f = 70 MHz) | $G_{pe}$ | 13 min | dB |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 50 | °C/W |



## RF POWER TRANSISTOR 2N1492

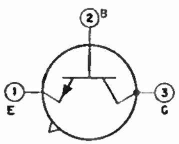
Si n-p-n triple-diffused type used in vhf applications for rf-amplifier, video-amplifier, oscillator, and mixer circuits in industrial and military equipment. JEDEC TO-39, Outline No.15. This type is identical with type 2N1491 except for the following items:

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 60 | V |
| Collector-to-Emitter Voltage ($V_{BE}$ = −0.5 V) | $V_{CEV}$ | 60 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2 | V |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 60 min | V |
| Emitter-to-Base Floating Potential ($V_{CB}$ = 60 V, $I_E$ = 0) | $V_{EB}(fl)$ | 0.5 max | V |
| Emitter-Cutoff Current ($V_{EB}$ = 2 V, $I_C$ = 0) | $I_{EBO}$ | 100 max | μA |
| Small-Signal Power Gain ($V_{CB}$ = 30 V, $I_E$ = −15 mA, $P_{oe}$ = 100 mW, f = 70 MHz) | $G_{pe}$ | 13 min | dB |



## RF POWER TRANSISTOR 2N1493

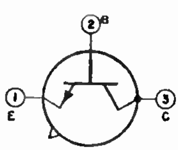
Si n-p-n triple-diffused type used in vhf applications for rf-amplifier, video-amplifier, oscillator, and mixer circuits in industrial and military equipment. JEDEC TO-39, Outline No.15. This type is identical with type 2N1491 except for the following items:

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 100 | V |
| Collector-to-Emitter Voltage ($V_{BE}$ = −0.5 V) | $V_{CEV}$ | 100 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4.5 | V |

### CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 100 min | V |
| Emitter-to-Base Floating Potential ($V_{CB}$ = 100 V, $I_E$ = 0) | $V_{EB}(fl)$ | 0.5 max | V |
| Emitter-Cutoff Current ($V_{EB}$ = 4.5 V, $I_C$ = 0) | $I_{EBO}$ | 100 max | μA |
| Small-Signal Power Gain ($V_{CB}$ = 50 V, $I_E$ = −25 mA, $P_{oe}$ = 500 mW, f = 70 MHz) | $G_{pe}$ | 10 min | dB |



## RF POWER TRANSISTOR 2N2631

Si n-p-n triple-diffused planar type used in large-signal vhf applications such as AM, FM, and cw service at frequencies up to 150 MHz in industrial and military equipment. JEDEC TO-39, Outline No.15. This type is identical with type 2N2876 except for the following items:

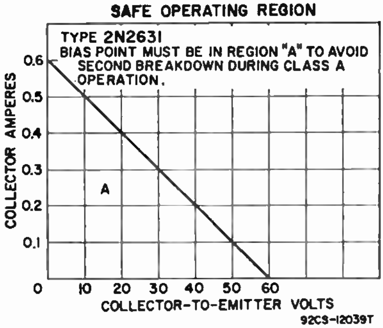
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector Current | $I_C$ | 1.5 | A |
| Transistor Dissipation: $T_C$ up to 25°C | $P_T$ | 8.75 | W |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

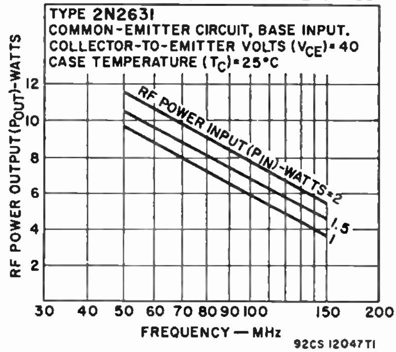
### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage ($I_C$ = 1.5 A, $I_B$ = 0.3 A) | $V_{CE}(sat)$ | 1 max | V |
| RF Power Output, Unneutralized ($V_{CE}$ = 28 V, $I_C$ = 0.375 A, $P_{IE}$ = 1 W, f = 50 MHz) | $P_{OE}$ | 7.5 min | W |

SAFE OPERATING REGION

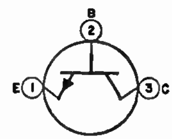



TYPICAL OPERATION CHARACTERISTICS




# 2N2876 RF POWER TRANSISTOR

Si n-p-n triple-diffused planer type used in large-signal vhf applications such as AM, FM, and cw service at frequencies up to 150 MHz in industrial and military equipment. JEDEC TO-60, Outline No.23. See Mounting Hardware for desired mounting arrangement.



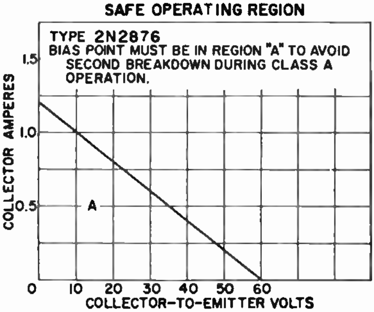

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 80 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE} = -1.5$ V | $V_{CEV}$ | 80 | V |
| Base open | $V_{CEO}$ | 60 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 2.5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 17.5 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$ (opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

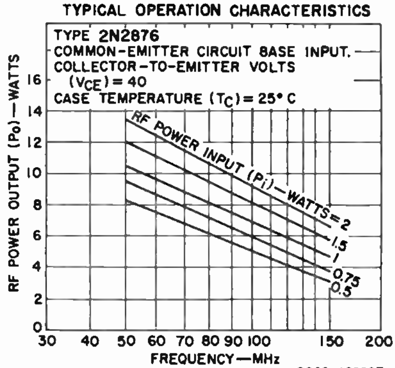
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.5 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 80 min | V |

SAFE OPERATING REGION



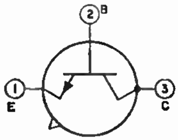

TYPICAL OPERATION CHARACTERISTICS



## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_C$ = 0.5 A, $I_B$ = 0, $t_p \leqq$ 5 µs, df $\leqq$ 1% | $V_{(BR)CEO}$(sus) | 60 min | V |
| $V_{BE}$ = −1.5 V, $I_C$ = 0.1 mA | $V_{(BR)CEV}$ | 80 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 2.5 A, $I_B$ = 0.5 A) | $V_{CE}$(sat) | 1 max | V |
| Collector-Cutoff Current ($V_{CB}$ = 30 V, $I_E$ = 0) | $I_{CBO}$ | 0.1 max | µA |
| Intrinsic Base-Spreading Resistance ($V_{CE}$ = 28 V, $I_C$ = 0.25 A, f = 400 MHz) | $r_{bb'}$ | 6 | Ω |
| RF Power Output, Unneutralized: | | | |
| $V_{CE}$ = 28 V, $I_C$ = 0.5 A, $P_{IE}$ = 2 W, f = 50 MHz | $P_{OE}$ | 10 min | W |
| $V_{CE}$ = 28 V, $I_C$ = 0.275 A, $P_{IE}$ = 1 W, f = 150 MHz | $P_{OE}$ | 3 min | W |
| Gain-Bandwidth Product ($V_{CE}$ = 28 V, $I_C$ = 250 mA) | $f_T$ | 200 | MHz |
| Collector-to-Case Capacitance | $C_c$ | 6 max | pF |
| Output Capacitance ($V_{CB}$ = 30 V, $I_E$ = 0, f = 0.14 MHz) | $C_{obo}$ | 20 max* | pF |

* This value applies only to type 2N2876.




## RF POWER TRANSISTOR 2N3118

Si n-p-n triple-diffused planar type for large-signal vhf class C and small-signal vhf class A amplifier applications in industrial and military communications equipment JEDEC TO-5, Outline No.5.

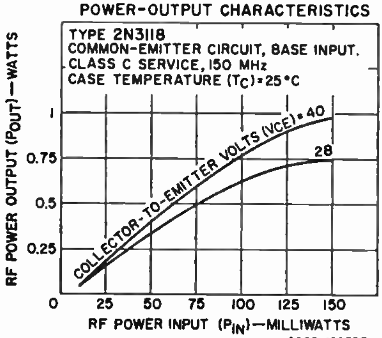
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 85 | V |
| Base open | $V_{CEO}$ | 60 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 0.5 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_C$ up to 25°C | $P_T$ | 4 | W |
| $T_A$ or $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

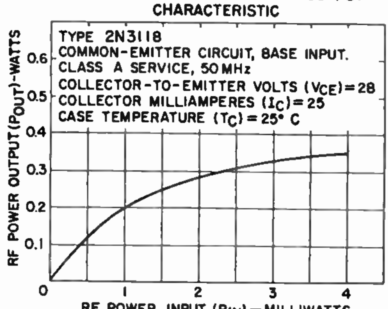
| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage: | | | |
| $V_{BE}$ = −1.5 V, $I_C$ = 0.1 mA | $V_{(BR)CEV}$ | 85 min | V |
| $I_C$ = 10 mA, $I_B$ = 0, $t_p$ = 300 µs, df = 1.8% | $V_{(BR)CEO}$(sus) | 60 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | 0.1 max | µA |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_A$ = 150°C | $I_{CBO}$ | 100 max | µA |
| Small-Signal Short-Circuit Input Impedance, Real Part ($V_{CE}$ = 28 V, $I_C$ = 25 mA, f = 50 MHz) | $R_e(h_{ie})$ | 25 to 75 | Ω |

TYPICAL LARGE-SIGNAL CLASS C RF POWER-OUTPUT CHARACTERISTICS




92CS-12273T

TYPICAL CLASS A RF POWER-OUTPUT CHARACTERISTIC



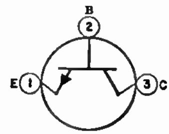

92CS-12278T

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Small-Signal Short-Circuit Output Impedance, Real Part ($V_{CE}$ = 28 V, $I_C$ = 25 mA, f = 50 MHz) | $\frac{1}{Y_{22}}$ (real) | 500 to 1000 | Ω |
| Pulsed Static Forward-Current Transfer Ratio ($V_{CE}$ = 28 V, $I_C$ = 25 mA, $t_p$ = 300 μs, df ≦ 1.8%) | $h_{FE}$(pulsed) | 50 to 275 | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 28 V, $I_C$ = 25 mA, f = 50 MHz) | $h_{fe}$ | 5 min | |
| $r_{bb'}C_{b'c}$ Product ($V_{CB}$ = 28 V, $I_C$ = 25 mA, f = 50 MHz) | $r_{bb'}C_{b'c}$ | 60 max | ps |
| Power Gain, Class A Service (with heat sink) ($V_{CE}$ = 28 V, $I_C$ = 25 mA, $P_{oe}$ = 0.2 W, f = 50 MHz) | $G_{pe}$ | 18 min | dB |
| Collector-to-Base Feedback Capacitance ($V_{CB}$ = 28 V, $I_C$ = 0, f = 1 MHz) | $C_{b'c}$ | 6 max | pF |
| Power Output, Class C Oscillator Service (with heat sink): | | | |
| $V_{CE}$ = 28 V, $P_{ie}$ = 0.1 W, f = 50 MHz | $P_{oe}$ | 1 min | W |
| $V_{CE}$ = 28 V, $P_{ie}$ = 0.1 W, f = 150 MHz | $P_{oe}$ | 0.4 min | W |

# 2N3229 RF POWER TRANSISTOR

Si n-p-n triple-diffused planar type used in large-signal, high-power AM, FM, and cw applications at vhf frequencies in industrial and military, communications equipment. JEDEC TO-60, Outline No.23. See Mounting Hardware for desired mounting arrangement.



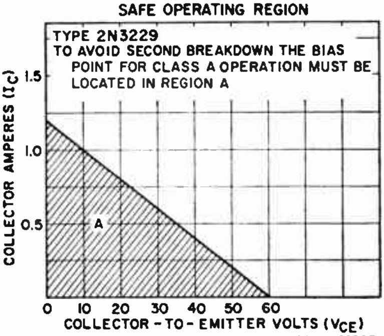

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 105 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 105 | V |
| Base open | $V_{CEO}$ | 60 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 2.5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 17.5 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

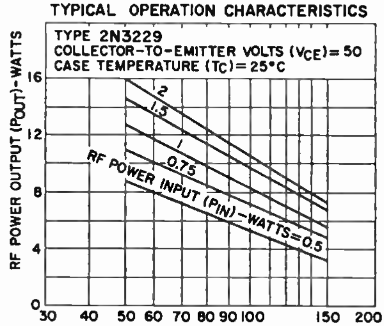
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.5 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 105 min | V |
| Collector-to-Emitter Breakdown Voltage: | | | |
| $V_{BE}$ = −1.5 V, $I_C$ = 0.1 mA | $V_{(BR)CEV}$ | 105 min | V |
| $I_C$ = 500 mA, $I_B$ = 0, $t_p$ ≦ 5 μs, df ≦ 1% | $V_{(BR)CEO}$(sus) | 60 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 2.5 A, $I_B$ = 500 mA) | $V_{CE}$(sat) | 1 max | V |

SAFE OPERATING REGION




92CS-12038T

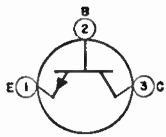
TYPICAL OPERATION CHARACTERISTICS




92CS-12427T

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-Cutoff Current ($V_{CB}$ = 30 V, $I_E$ = 0) | $I_{CBO}$ | 0.1 max | µA |
| Intrinsic Base-Spreading Resistance ($V_{CB}$ = 28 V, $I_C$ = 250 mA, f = 400 MHz) | $r_{bb'}$ | 6 | Ω |
| Gain-Bandwidth Product ($V_{CE}$ = 28 V, $I_C$ = 250 mA) | $f_T$ | 200 | MHz |
| Collector-to-Base Feedback Capacitance ($V_{CB}$ = 30 V, $I_E$ = 0, f = 140 kHz) | $C_{obo}$ | 20 max | pF |
| Collector-to-Case Capacitance | $C_C$ | 6 max | pF |
| RF Power Output, Unneutralized: | | | |
| $V_{CC}$ = 50 V, $I_C$ = 500 mA, $P_{IE}$ = 2 W, f = 50 MHz | $P_{OE}$ | 15 min | W |
| $V_{CC}$ = 50 V, $I_C$ = 250 mA, $P_{IE}$ = 1 W, f = 150 MHz | $P_{OE}$ | 5 min | W |




## RF POWER TRANSISTOR 2N3375

Si n-p-n "overlay" epitaxial planar type used in vhf-uhf applications in class A, B, or C amplifier, frequency-multiplier, or oscillator operations. JEDEC TO-60, Outline No.23. See Mounting Hardware for desired mounting arrangement.

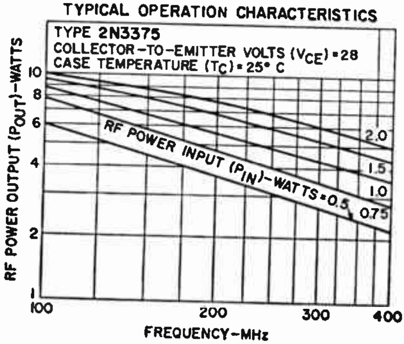
### MAXIMUM RATING

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 65 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 65 | V |
| Base open | $V_{CEO}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 1.5 | A |
| Base Current | $I_B$ | 0.2 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 11.6 | W |
| $T_C$ above 25°C | $P_T$ | Derate linearly to 0 at 200 | °C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

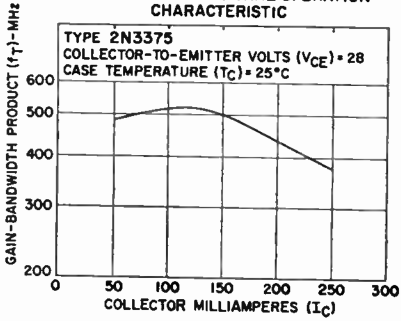
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)EBO}$ | 65 min | V |
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_C$ = 0 to 0.2 A, $I_B$ = 0, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CEO}$ | 40▲ min | V |
| $I_C$ = 0 to 0.2 A, $V_{BE}$ = −1.5 V, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CEV}$ | 65▲ min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 500 mA, $I_B$ = 100 mA) | $V_{CE}$(sat) | 1 max | V |
| Collector-Cutoff Current ($V_{CB}$ = 30 V, I = 0) | $I_{CEO}$ | 0.1 max | mA |

TYPICAL OPERATION CHARACTERISTICS




92CS-12571T

TYPICAL SMALL-SIGNAL OPERATION CHARACTERISTIC



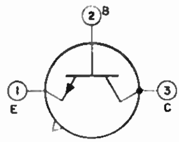

92CS-12569T

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| RF Power Output: | | | |
| Unneutralized Amplifier | | | |
| $V_{CE}$ = 28 V, $P_{IE}$ = 1 W, f = 100 MHz | $P_{OE}$ | 7.5● min | W |
| $V_{CE}$ = 28 V, $P_{IE}$ = 1 W, f = 400 MHz | $P_{OE}$ | 3* min | W |
| Collector-to-Case Capacitance | $C_c$ | 6 max | pF |
| Collector-to-Base Feedback Capacitance ($V_{CB}$ = 30 V, $I_E$ = 0, f = 1 MHz) | $C_{cb}$ | 10 max | pF |
| Gain-Bandwidth Product ($V_{CE}$ = 28 V, $I_C$ = 150 mA) | $f_T$ | 500 | MHz |
| Intrinsic Base-Spreading Resistance ($V_{CE}$ = 28 V, $I_C$ = 250 mA, f = 400 MHz) | $r_{bb}'$ | 10 | Ω |

▲ Measured at a current where the breakdown voltage is a minimum.
● For conditions given, minimum efficiency = 65 per cent.
* For conditions given, minimum efficiency = 40 per cent.

# 2N3553 RF POWER TRANSISTOR




Si n-p-n "overlay" epitaxial planar type used in class A, B, and C amplifiers, frequency multipliers, or oscillators in vhf-uhf applications. JEDEC TO-39, Outline No.15.

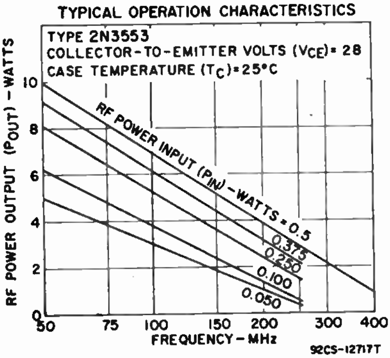
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 65 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 65 | V |
| Base open | $V_{CEO}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 0.33 | A |
| Peak Collector Current | $i_C$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 7 | W |
| $T_C$ above 25°C | $P_T$ | Derate linearly to 0 watts at 200 | °C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

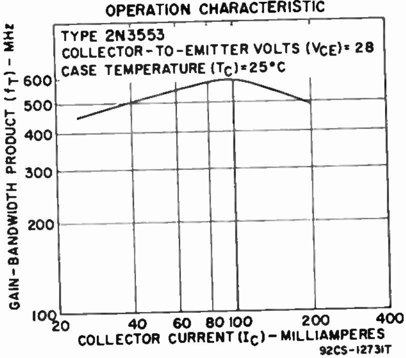
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.3 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 65 min | V |
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_C$ = 0 to 0.2 A, $I_B$ = 0, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CEO}$ | 40▲ min | V |
| $I_C$ = 0 to 0.2 A, $V_{BE}$ = −1.5 V, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CEV}$ | 65 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 250 mA, $I_B$ = 50 mA) | $V_{CE}$(sat) | 1 max | V |

TYPICAL OPERATION CHARACTERISTICS



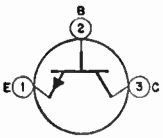

TYPICAL SMALL-SIGNAL OPERATION CHARACTERISTIC



## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-Cutoff Current ($V_{CE}$ = 30 V, $I_B$ = 0) | $I_{CEO}$ | 0.1 max | mA |
| Intrinsic Base-Spreading Resistance ($V_{CE}$ = 28 V, $I_C$ = 100 mA, f = 100 MHz) | $r_{bb'}$ | 12 | Ω |
| Gain-Bandwidth Product ($V_{CE}$ = 28 V, $I_C$ = 100 mA) | $f_T$ | 500 | MHz |
| Output Capacitance ($V_{CB}$ = 30 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 10 max | pF |
| RF Power Output: Unneutralized Amplifier—$V_{CC}$ = 28 V, $P_{IE}$ = 0.25 W, $R_G$ and $R_L$ = 50 Ω, f = 175 MHz | $P_{OE}$ | 2.5* min | W |

▲ Measured at a current where the breakdown voltage is a minimum.
* For conditions given, minimum efficiency = 50 per cent.




## RF POWER TRANSISTOR 2N3632

Si n-p-n "overlay" epitaxial planar type used in class A, B, and C amplifiers, frequency multipliers, or oscillators in vhf applications. JEDEC TO-60, Outline No.23. See Mounting Hardware for desired mounting arrangement.

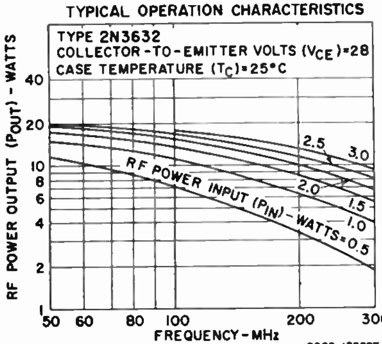
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 65 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 65 | V |
| Base open | $V_{CEO}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 3 | A |
| Peak Collector Current | $i_C$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 23 | W |
| $T_C$ above 25°C | $P_T$ | Derate linearly to 0 watts at 200 | °C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

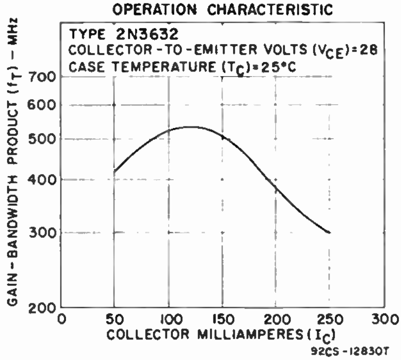
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.5 mA, $I_E$ = 0) | $V_{(BR)EBO}$ | 65 min | V |
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_C$ = 0 to 0.2 A, $I_B$ = 0, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CEO}$ | 40▲ min | V |
| $I_C$ = 0 to 0.2 A, $V_{BE}$ = −1.5 V, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CEV}$ | 65 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.25 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 0.5 A, $I_B$ = 0.1 A) | $V_{CE}$(sat) | 1 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 30 V, $I_B$ = 0) | $I_{CEO}$ | 0.25 max | mA |
| Gain-Bandwidth Product ($V_{CE}$ = 28 V, $I_C$ = 150 mA) | $f_T$ | 400 | MHz |

TYPICAL OPERATION CHARACTERISTICS




TYPICAL SMALL-SIGNAL OPERATION CHARACTERISTIC



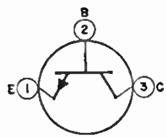
### CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Output Capacitance ($V_{CB}$ = 30 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 20 max | pF |
| RF Power Output, Unneutralized: | | | |
| $V_{CC}$ = 28 V, $P_{IE}$ = 3.5 W, $R_G$ and $R_L$ = 50 Ω, f = 175 MHz | $P_{OE}$ | 13.5* min | W |
| $V_{CC}$ = 28 V, $P_{IE}$ = 3 W, $R_G$ and $R_L$ = 50 Ω, f = 260 MHz | $P_{OE}$ | 10† | W |
| Intrinsic Base-Spreading Resistance ($V_{CE}$ = 28 V, $I_C$ = 250 mA, f = 200 MHz) | $r_{bb'}$ | 6.5 | Ω |

▲ Measured at a current where the breakdown voltage is a minimum.
* For conditions given, minimum efficiency = 70 per cent.
† For conditions given, minimum efficiency = 60 per cent.

## 2N3733 RF POWER TRANSISTOR

Si n-p-n "overlay" epitaxial planar type used in large-signal, high-power vhf-uhf applications in military and industrial communications equipment. Intended for class A, B, C amplifier, frequency-multiplier, or oscillator service. JEDEC TO-60, Outline No.23. See Mounting Hardware for desired mounting arrangement.



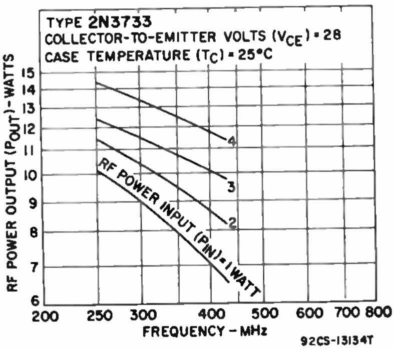

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 65 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 65 | V |
| Base open | $V_{CEO}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Peak Collector Current | $i_C$ | 3 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 23 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 230 | °C |

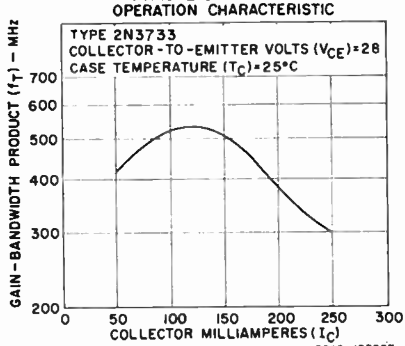
### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.5 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 65 min | V |
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_C$ = 0 to 200 mA, $V_{BE}$ = −1.5 V, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CEV}$ | 65 min | V |
| $I_C$ = 0 to 200 mA, $I_B$ = 0, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CEO}$ | 40 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.25 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |

TYPICAL OPERATION CHARACTERISTICS




TYPICAL SMALL-SIGNAL OPERATION CHARACTERISTIC

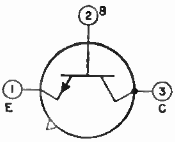


### CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage ($I_C$ = 0.5 A, $I_B$ = 100 mA) | $V_{CE}$(sat) | 1 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 30 V, $I_B$ = 0) | $I_{CEO}$ | 0.25 max | mA |
| Intrinsic Base-Spreading Resistance ($V_{CE}$ = 28 V, $I_C$ = 250 mA, f = 200 MHz) | $r_{bb'}$ | 6.5 | Ω |
| Gain-Bandwidth Product ($V_{CE}$ = 28 V, $I_C$ = 150 mA) | $f_T$ | 400 | MHz |
| Collector-to-Case Capacitance | $C_c$ | 6 max | pF |
| Output Capacitance ($V_{CB}$ = 30 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 20 max | pF |
| RF Power Output Amplifier, Unneutralized: | | | |
| $V_{CE}$ = 28 V, $P_{IE}$ = 4 W, $R_G$ and $R_L$ = 50 Ω, f = 260 MHz) | $P_{OE}$ | 14.5* | W |
| $V_{CE}$ = 28 V, $P_{IE}$ = 4 W, $R_G$ and $R_L$ = 50 Ω, f = 400 MHz) | $P_{OE}$ | 10† min | W |

* For conditions given, minimum efficiency = 60 per cent.
† For conditions given, minimum efficiency = 45 per cent.

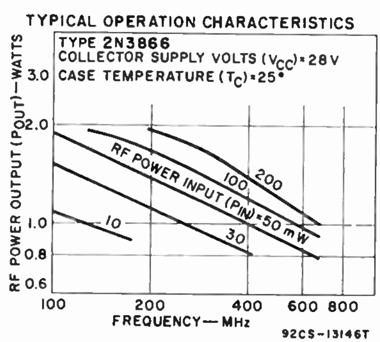
## RF POWER TRANSISTOR 2N3866

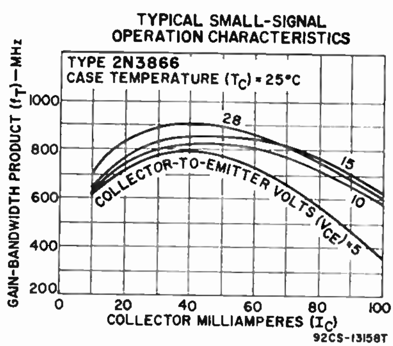



Si n-p-n "overlay" epitaxial planar type for vhf-uhf applications in class A, B, and C amplifiers, frequency multipliers, and oscillators in military and industrial communications equipment. JEDEC TO-39, Outline No.15.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 55 | V |
| Collector-to-Emitter Voltage: | | | |
| $R_{BE}$ = 10 Ω | $V_{CER}$ | 55 | V |
| Base open | $V_{CEO}$ | 30 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 3.5 | V |
| Collector Current | $I_C$ | 0.4 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |




### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 55 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 3.5 min | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 5 mA, $R_{BE}$ = 10 Ω | $V_{CER}$(sus) | 55 min | V |
| $I_C$ = 5 mA, $I_B$ = 0 | $V_{CEO}$(sus) | 30 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 100 mA, $I_B$ = 20 mA) | $V_{CE}$(sat) | 1 max | V |

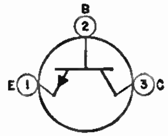
**CHARACTERISTICS (cont'd)**

| | | | |
|---|---|---|---|
| Collector-Cutoff Current ($V_{CE}$ = 28 V, $I_B$ = 0) | $I_{CEO}$ | 20 max | μA |
| Gain-Bandwidth Product ($V_{CE}$ = 15 V, $I_C$ = 25 mA) | $f_T$ | 800 | MHz |
| Output Capacitance ($V_{CB}$ = 30 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 3 max | pF |
| RF Power-Output Class C Amplifier, Unneutralized: | | | |
| $V_{CC}$ = 28 V, $P_{IE}$ = 0.05 W, f = 100 MHz | $P_{OE}$ | 1.8* | W |
| $V_{CC}$ = 28 V, $P_{IE}$ = 0.1 W, f = 250 MHz | $P_{OE}$ | 1.5● | W |
| $V_{CC}$ = 28 V, $P_{IE}$ = 0.1 W, f = 400 MHz | $P_{OE}$ | 1† min | W |

* For conditions given, minimum efficiency = 60 per cent.
● For conditions given, minimum efficiency = 50 per cent.
† For conditions given, minimum efficiency = 45 per cent.

# 2N4012 RF POWER TRANSISTOR

Si n-p-n "overlay" epitaxial planar type designed to provide high power as a frequency multiplier into the uhf or L-band frequency region in military and industrial communications equipment. JEDEC TO-60, Outline No.23. See Mounting Hardware for desired mounting arrangement.



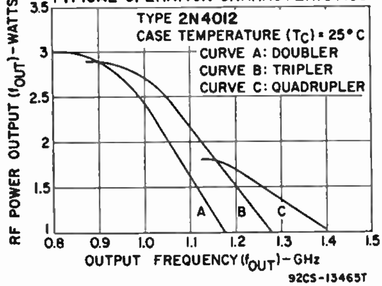

**MAXIMUM RATINGS**

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 65 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 65 | V |
| Base open | $V_{CEO}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 1.5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 11.6 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

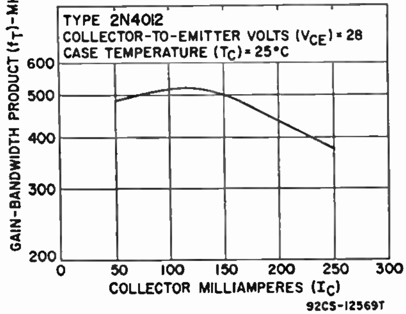
**CHARACTERISTICS**

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 65 min | V |
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_C$ = 0 to 200 mA, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CEO}$ | 40 min | V |
| $V_{BE}$ = −1.5 V, $I_C$ = 0 to 200 mA, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CEV}$ | 65 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 500 mA, $I_B$ = 100 mA) | $V_{CE}$(sat) | 1 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 30 V, $I_B$ = 0) | $I_{CEO}$ | 0.1 max | mA |
| Gain-Bandwidth Product ($V_{CE}$ = 28 V, $I_C$ = 150 mA) | $f_T$ | 500 | MHz |

TYPICAL OPERATION CHARACTERISTICS



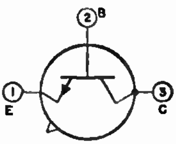

TYPICAL SMALL-SIGNAL OPERATION CHARACTERISTIC



## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Output Capacitance ($V_{CB}$ = 30 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 10 max | pF |
| Collector-to-Base Cutoff Frequency* ($V_{CE}$ = 28 V, $I_C$ = 0) | $f_c$ | 25 | GHz |
| RF Power Output, Multiplier: | | | |
| Tripler-$V_{CE}$ = 28 V, f = 1002 MHz, $P_{IE}$ = 1 W at 334 MHz | $P_{OE}$ | 2.5† min | W |
| Doubler-$V_{CE}$ = 28 V, f = 800 MHz, $P_{IE}$ = 1 W at 400 MHz | $P_{OE}$ | 3■ | W |

* Cutoff frequency is determined from Q measurement at 210 MHz. The cutoff frequency of the collector-to-base junction of the transistor, $f_c$ = Q x 210 MHz.
† For conditions given, minimum efficiency = 25 per cent.
■ For conditions given, minimum efficiency = 35 per cent.




## RF POWER TRANSISTOR 2N4427

Si n-p-n "overlay" epitaxial planar type used in class A, B, or C amplifier, frequency-multiplier, or oscillator circuits; it is used in output, driver, or pre-driver stages in vhf and uhf equipment. JEDEC TO-39, Outline No.15.

## MAXIMUM RATINGS

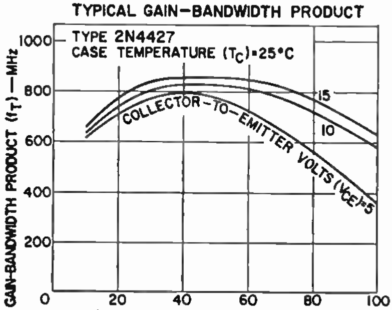
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 40 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 20 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2 | V |
| Collector Current | $I_C$ | 0.4 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 3.5 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | —65 to 200 | °C |
| Storage | $T_{STG}$ | —65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 40 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 2 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 100 mA, $I_B$ = 20 mA) | $V_{CE}$(sat) | 0.5 max | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 5 mA, $R_{BE}$ = 10 Ω | $V_{CER}$(sus) | 40 min | V |
| $I_C$ = 5 mA, $I_B$ = 0 | $V_{CEO}$(sus) | 20 min | V |
| Collector-Cutoff Current ($V_{CE}$ = 12 V, $I_B$ = 0) | $I_{CEO}$ | 20 max | μA |
| Output Capacitance ($V_{CB}$ = 12 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 4 max | pF |
| RF Power Output, Amplifier, Unneutralized ($V_{CC}$ = 12 V, $P_{IE}$ = 0.1 W, f = 175 MHz, $R_G$ and $R_L$ = 50 Ω) | $P_{OE}$ | 1* min | W |

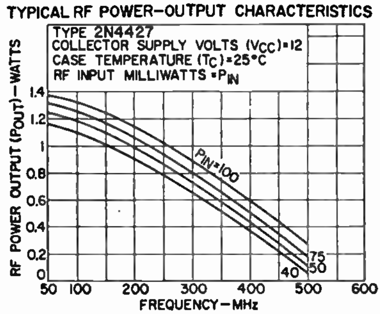
* For conditions given, minimum efficiency = 70 per cent.

TYPICAL GAIN-BANDWIDTH PRODUCT




92LS-1801T

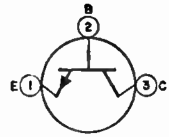
TYPICAL RF POWER-OUTPUT CHARACTERISTICS




92LS-1757T

# 2N4440 RF POWER TRANSISTOR

Si n-p-n "overlay" epitaxial planar type used in class A, B, and C amplifiers, frequency multipliers, or oscillators, for military and industrial communications. JEDEC TO-60, Outline No.23. See Mounting Hardware for desired mounting arrangement.



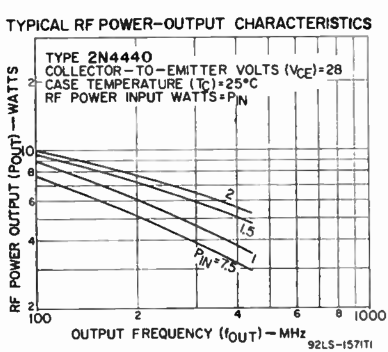

## MAXIMUM RATINGS

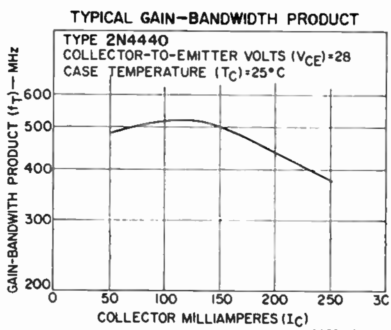
| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 65 | V |
| Base open | $V_{CEO}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 1.5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 11.6 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

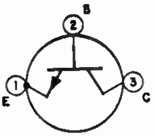
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 65 min | V |
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_B$ = 0, $I_C$ = 0 to 200 mA, pulsed through inductor L = 25 mH, df = 50% | $V_{(BR)CEO}$ | 40 min | V |
| $V_{BE}$ = −1.5 V, $I_C$ = 0 to 200 mA, pulsed through inductor L = 25 mH, df = 50% | $V_{(BR)CEV}$ | 65 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 500 mA, $I_B$ = 100 mA) | $V_{CE}$(sat) | 1 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 30 V, $I_B$ = 0) | $I_{CEO}$ | 0.1 max | V |
| Gain-Bandwidth Product ($V_{CE}$ = 28 V, $I_C$ = 150 mA) | $f_T$ | 500 | MHz |
| Output Capacitance ($V_{CB}$ = 30 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 10 max | pF |
| Collector-to-Case Capacitance | $C_c$ | 6 max | pF |
| Intrinsic Base-Spreading Resistance ($V_{CE}$ = 28 V, $I_C$ = 250 mA) | $r_{bb'}$ | 10 | Ω |
| RF Power Output, Amplifier, Unneutralized: | | | |
| $V_{CE}$ = 28 V, $P_{IE}$ = 1.7 W, $R_G$ and $R_L$ = 50 Ω, f = 225 MHz | $P_{OE}$ | 6.5* | W |
| $V_{CE}$ = 28 V, $P_{IE}$ = 1.7 W, $R_G$ and $R_L$ = 50 Ω, f = 400 MHz | $P_{OE}$ | 5 min▪ | W |

* For conditions given, minimum efficiency = 55 per cent.
▪ For conditions given, minimum efficiency = 45 per cent.



## RF POWER TRANSISTOR 2N4932




Si n-p-n "overlay" epitaxial planar type used in high-power class C rf amplifiers for international vhf mobile and portable communications service. JEDEC TO-60, Outline No.23. See Mounting Hardware for desired mounting arrangement.

### MAXIMUM RATINGS

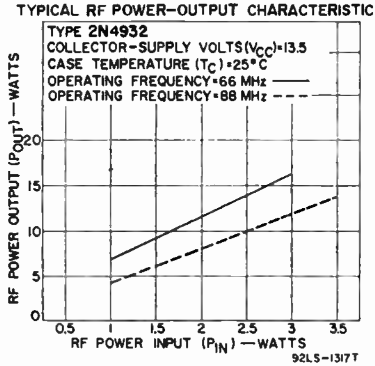
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 50 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE} = -1.5$ V | $V_{CEV}$ | 50 | V |
| Base open | $V_{CEO}$ | 25 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 3.3 | A |
| Peak Collector Current | $i_C$ | 10 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 70 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| RF Input Power: | | | |
| At 88 MHz | $P_{IE}$ | 3.5 | W |
| Below 88 MHz | $P_{IE}$ | Derate linearly by 0.022 W/MHz to 3 W | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

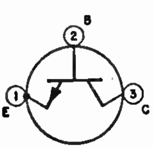
| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_C = 200$ mA, pulsed through an inductor L = 25 mH, df = 50%, $I_B = 0$ | $V_{(BR)CEO}$(sus) | 25 min | V |
| $I_C = 200$ mA, pulsed through an inductor L = 25 mH, df = 50%, $V_{BE} = -1.5$ V | $V_{(BR)CEV}$(sus) | 50 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E = 10$ mA, $I_C = 0$) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-Cutoff Current: | | | |
| $V_{CE} = 15$ V, $I_B = 0$ | $I_{CEO}$ | 1 max | mA |
| $V_{CB} = 40$ V, $I_E = 0$ | $I_{CBO}$ | 10 max | mA |
| Output Capacitance ($V_{CB} = 15$ V, $I_E = 0$) | $C_{obo}$ | 120 max | pF |
| RF Power Output ($V_{CC} = 13.5$ V, $P_{IE} = 3.5$ W, f = 88 MHz, $R_G$ and $R_L = 50\ \Omega$) | $P_{OE}$ | 12 • min | W |

• For conditions given, minimum efficiency = 70 per cent.

TYPICAL RF POWER-OUTPUT CHARACTERISTICS




## RF POWER TRANSISTOR 2N4933




Si n-p-n "overlay" epitaxial planar type used in high-power class C rf amplifiers for international vhf mobile and portable communications service. JEDEC TO-60, Outline No.23. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N4932 except for the following items:

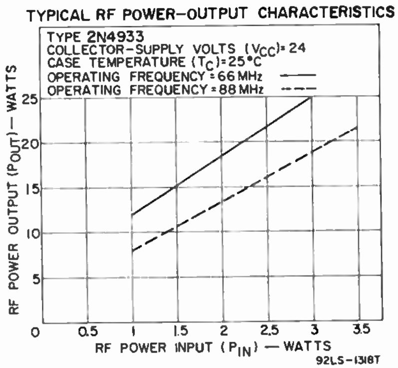
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 70 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE} = -1.5$ V | $V_{CEV}$ | 70 | V |
| Base open | $V_{CEO}$ | 35 | V |

## CHARACTERISTICS (At case temperature = 25°C)

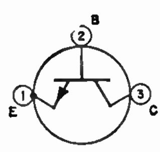
| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_C = 200$ mA, pulsed through inductor L = 25 mA, df = 50%, $I_B = 0$ | $V_{(BR)CEO}(sus)$ | 35 min | V |
| $I_C = 200$ mA, pulsed through inductor L = 25 mA, df = 50%, $V_{BE} = -1.5$ V | $V_{(BR)CEV}(sus)$ | 70 min | V |
| Collector-Cutoff Current: | | | |
| $V_{CE} = 30$ V, $I_B = 0$ | $I_{CEO}$ | 1 max | mA |
| $V_{CB} = 50$ V, $I_E = 0$ | $I_{CBO}$ | 10 max | mA |
| Output Capacitance ($V_{CB} = 30$ V, $I_E = 0$) | $C_{obo}$ | 85 max | pF |
| RF Power Output ($V_{CC} = 24$ V, $P_{IE} = 3.5$ W, f = 88 MHz, $R_G$ and $R_L = 50\ \Omega$) | $P_{OE}$ | 20 • min | W |

• For conditions given, minimum efficency = 70 per cent




# 2N5016 RF POWER TRANSISTOR

Si n-p-n "overlay" epitaxial planar type used in large-signal high-power class B and C rf amplifiers for military and industrial communications service (200 to 700 MHz). JEDEC TO-60, Outline No.23. See Mounting Hardware for desired mounting arrangement.




## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage: | | | |
| $V_{BE} = -1.5$ V | $V_{CEV}$ | 65 | V |
| $R_{BE} = 30\ \Omega$ | $V_{CER}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 4.5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 50°C | $P_T$ | 30 | W |
| $T_C$ above 50°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Case-Soldering Temperature (10 s max) | $T_C$ | 230 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

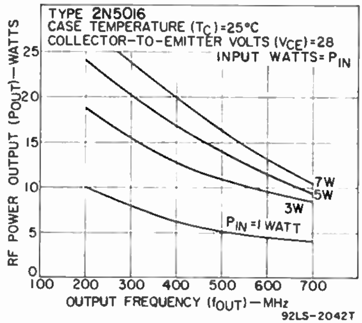
| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage: | | | |
| $R_{BE} = 30\ \Omega$, $I_B = 0$, $I_C = 200$ mA, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CER}$ | 40 min | V |
| $V_{BE} = -1.5$ V, $I_C = 200$ mA, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CEV}(sus)$ | 65 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E = 5$ mA, $I_C = 0$) | $V_{(BR)EBO}$ | 4 min | V |

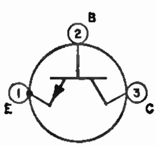
## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Saturation Voltage ($I_B$ = 40 mA, $I_C$ = 2000 mA) | $V_{CE}$(sat) | 1 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 30 V, $I_B$ = 0) | $I_{CEO}$ | 10 max | mA |
| Collector-to-Base Capacitance ($V_{CB}$ = 30 V, $I_E$ = 0, f = 1 MHz) | $C_{cb}$ | 25 | pF |
| Gain-Bandwidth Product ($V_{CE}$ = 15 V, $I_C$ = 500 mA) | $f_T$ | 600 | MHz |
| RF Power Output, Unneutralized: | | | |
| $V_{CE}$ = 28 V, $P_{IE}$ = 5 W, $R_G$ and $R_L$ = 50 Ω, f = 225 MHz | $P_{OE}$ | 23 * | W |
| $V_{CE}$ = 28 V, $P_{IE}$ = 5 W, $R_G$ and $R_L$ = 50 Ω, f = 400 MHz | $P_{OE}$ | 15 ▪ | W |
| Dynamic Input Impedance ($V_{CE}$ = 28 V, $P_{IE}$ = 5 W, $R_G$ and $R_L$ = 50 Ω, f = 400 MHz) | | 2.5 + j 5 ▪ | Ω |

* For conditions given, minimum efficiency = 60 per cent.
▪ For conditions given, minimum efficiency = 50 per cent.

TYPICAL POWER-OUTPUT CHARACTERISTICS




## RF POWER TRANSISTOR 2N5070

Si n-p-n "overlay" epitaxial planar type used in high-power class A or B service in a 2-to-30-MHz single-sideband power amplifier operating from a 28-volt power supply. JEDEC TO-60, Outline No.23. See Mounting Hardware for desired mounting arrangement.

## MAXIMUM RATINGS

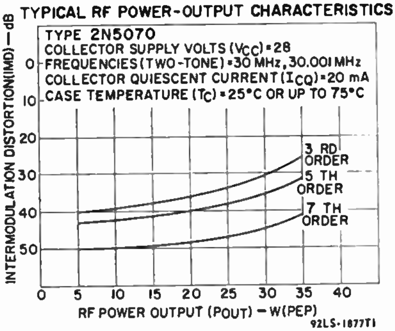
| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 65 | V |
| $R_{BE}$ = 5 Ω | $V_{CER}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 3.3 | A |
| Peak Collector Current | $i_C$ | 10 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 70 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Emitter-to-Base Breakdown Voltage ($I_E$ = 10 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE}$ = −1.5 V, $I_C$ = 200 mA | $V_{CEV}$(sus) | 65 min | V |
| $R_{BE}$ = 5 Ω, $I_C$ = 200 mA | $V_{CER}$(sus) | 40 min | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 30 V, $I_B$ = 0 | $I_{CEO}$ | 5 max | mA |
| $V_{CB}$ = 30 V, $I_E$ = 0 | $I_{CBO}$ | 10 max | mA |
| Output Capacitance ($V_{CB}$ = 1 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 85 max | pF |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 2.5 max | °C/W |

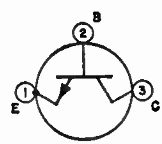
### TYPICAL OPERATION IN RF-AMPLIFIER CIRCUIT

| | | |
|---|---|---|
| Collector Supply Voltage | 28 | V |
| Collector Base Current | 20 | mA |
| RF Power Output: | | |
| Average | 12.5 min | W |
| Peak Envelope | 25 min | W |
| Intermodulation Distortion | 30 max | dB |
| Collector Efficiency | 40 min | % |



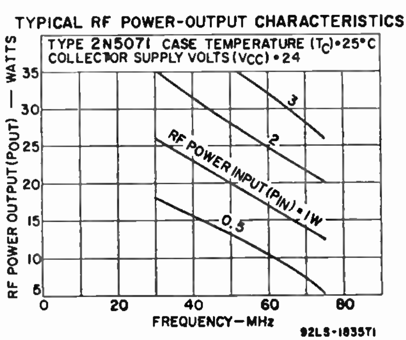

## 2N5071 RF POWER TRANSISTOR

Si n-p-n "overlay" epitaxial planar type used in high-power class A and C rf amplifiers for FM communications with a 24-volt power supply. It is used for narrow-band and wideband applications in the 30-to-76-MHz frequency range. JEDEC TO-60, Outline No.23. See Mounting Hardware for desired mounting arrangement. For maximum ratings, refer to type 2N5070.




### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Emitter-to-Base Breakdown Voltage ($I_E$ = 10 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE}$ = −1.5 V, $I_C$ = 200 mA | $V_{CEV}$(sus) | 65 min | V |
| $R_{BE}$ = 5 Ω, $I_C$ = 200 mA | $V_{CER}$ | 40 min | V |
| Collector-to-Emitter Cutoff Current ($V_{CE}$ = 30 V, $I_B$ = 0) | $I_{CEO}$ | 5 max | mA |
| Collector-to-Base Cutoff Current ($V_{CE}$ = 60 V, $I_E$ = 0) | $I_{CBO}$ | 10 max | mA |
| Output Capacitance ($V_{CB}$ = 30 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 85 max | pF |
| Power Output: | | | |
| Narrowband Amplifier ($V_{CE}$ = 24 V, $P_{IE}$ = 3 W, $R_G$ and $R_L$ = 50 Ω, f = 76 MHz) | $P_{OE}$ | 24● min | W |
| Wideband Amplifier ($V_{CE}$ = 24 V, $P_{IE}$ = 3 W, $R_G$ and $R_L$ = 50 Ω, f = 30 to 76 MHz) | $P_{OE}$ | 15* min | W |

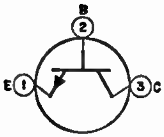


## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Thermal Resistance, Junction-to-Case | $\theta_{J\text{-}C}$ | 2.5 | °C/W |

• For conditions given, minimum efficiency = 60 per cent.
* For conditions given, minimum efficiency = 35 per cent.

## RF POWER TRANSISTOR 2N5090




Si n-p-n "overlay" epitaxial planar type used in class A, B, or C amplifier frequency-multiplier, or oscillator circuits; it is used in output, driver, or pre-driver, stages in vhf and uhf equipment. JEDEC TO-60, Outline No.23. See Mounting Hardware for desired mounting arrangement.

### MAXIMUM RATINGS

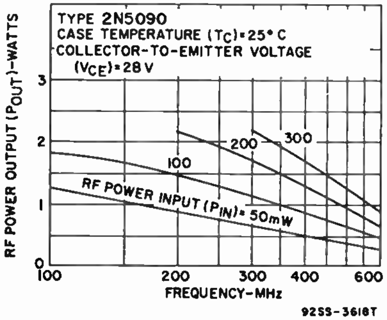
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 55 | V |
| Collector-to-Emitter Voltage: | | | |
| $R_{BE}$ = 10 Ω | $V_{CER}$ | 55 | V |
| Base open | $V_{CEO}$ | 30 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 3.5 | V |
| Collector Current | $I_C$ | 0.4 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 75°C | $P_T$ | 5 | W |
| $T_C$ above 75°C | $P_T$ | Derate linearly at 0.04 W/°C | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 55 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 3.5 min | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $I_C$ = 5 mA, $R_{BE}$ = 10 Ω, pulsed through inductor L = 25 mH, df = 50% | $V_{CER}$(sus) | 55 min | V |
| $I_C$ = 5 mA, $I_B$ = 0 | $V_{CEO}$(sus) | 30 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 100 mA, $I_B$ = 20 mA) | $V_{CE}$(sat) | 1 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 28 V, $I_B$ = 0) | $I_{CEO}$ | 20 max | μA |
| Gain-Bandwidth Product ($V_{CE}$ = 15 V, $I_C$ = 50 mA) | $f_T$ | 500 min | MHz |
| Collector-to-Base Capacitance ($V_{CB}$ = 30 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 3.5 max | pF |
| RF Power Output, Amplifier, Unneutralized ($V_{CE}$ = 28 V, $P_{IE}$ = 0.2 W, f = 400 MHz, $R_G$ and $R_L$ = 50 Ω) | $P_{OE}$ | 1.2* min | W |

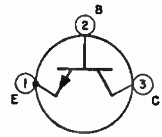
* For conditions given, minimum efficiency = 45 per cent.

TYPICAL RF POWER-OUTPUT CHARACTERISTICS



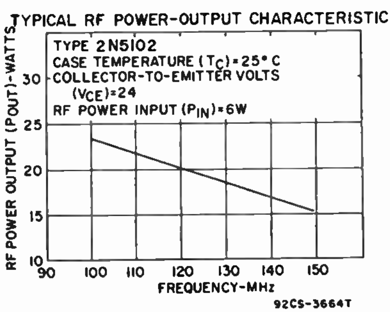
# 2N5102 RF POWER TRANSISTOR

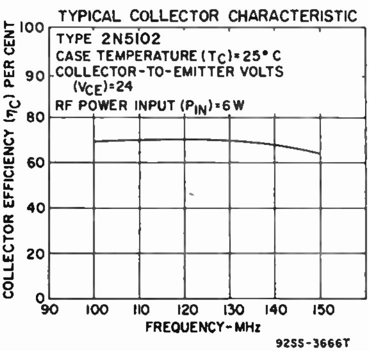
Si n-p-n "overlay" epitaxial planar type designed to provide high power as a class C rf amplifier for vhf aircraft communications service (108 to 150 MHz) with amplitude modulation and 24-volt power supply. JEDEC TO-60, Outline No.23. See Mounting Hardware for desired mounting arrangement.




## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 100 | V |
| $R_{BE}$ = 5 Ω | $V_{CER}$ | 50 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current: | | | |
| Peak | $i_C$ | 10 | A |
| Continuous | $I_C$ | 3.3 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 70 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |




## CHARACTERISTICS (At case temperature = 25°C)

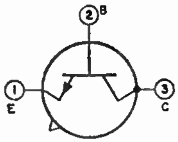
| | | | |
|---|---|---|---|
| Emitter-to-Base Breakdown Voltage ($I_E$ = 10 V, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE}$ = −1.5 V, $I_C$ = 600 mA, pulsed through an inductor L = 9 mH, df = 50% | $V_{CEV}$(sus) | 100 min | V |
| $R_{BE}$ = 5 Ω, $I_C$ = 200 mA, pulsed through an inductor L = 9 mH, df = 50% | $V_{CER}$(sus) | 50 min | V |
| Collector-Cutoff Current ($V_{CE}$ = 50 V, $R_{BE}$ = 5 Ω) | $I_{CER}$ | 10 max | mA |
| Collector-to-Base Capacitance ($V_{CB}$ = 30 V, $I_C$ = 0) | $C_{cb}$ | 85 max | pF |
| RF Power Output ($V_{CC}$ = 24 V, $P_{IE}$ = 6 W, $R_G$ and $R_L$ = 50 Ω, f = 136 MHz) | $P_{OE}$ | 15* min | W |
| Modulation● ($V_{CE}$ = 24 V, f = 118 MHz) | | 80 min | % |
| Load Mismatch■ ($V_{CE}$ = 24 V, f = 118 MHz) | | will not be damaged | |
| Dynamic Input Impedance ($V_{CE}$ = 24 V, $I_C$ = 1100 mA, $P_{OE}$ = 6 W, f = 150 MHz) | | 1.7 + j2.6 | Ω |

* Unmodulated carrier.

● Carrier Power, $P_{CAR}$ = 15 W; $V_{CC}$ modulation = 100%; $M = \frac{\sqrt{2(P_{AM} - P_{CAR})}}{P_{CAR}} \times 100\%$.

■ Under conditions of footnote (●), the transistor is subjected to all conditions of load mismatch from short circuit to open circuit.

## RF POWER TRANSISTOR 2N5108

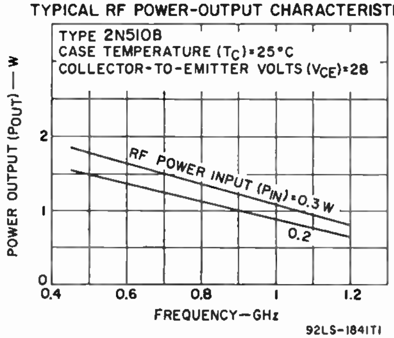



Si n-p-n "overlay" epitaxial planar type used as a high-power amplifiers, fundamental-frequency oscillator, and frequency multiplier. It may be used in final, driver, and pre-driver amplifier stages in uhf equipment and as a fundamental-frequency oscillator at 1.68 GHz. JEDEC TO-39, Outline No.15.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 55 | V |
| Collector-to-Emitter Voltage: | | | |
| $R_{BE}$ = 10 Ω | $V_{CER}$ | 55 | V |
| Base open | $V_{CEO}$ | 30 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 3 | V |
| Collector Current | $I_C$ | 0.4 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 3.5 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | –65 to 200 | °C |
| Storage | $T_{STG}$ | –65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

TYPICAL RF POWER-OUTPUT CHARACTERISTICS

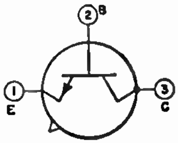



### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 55 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 3 min | V |
| Collector-to-Emitter Sustaining Voltage ($R_{BE}$ = 10 Ω, $I_C$ = 5 mA, pulsed through an inductor L = 2.5 mH, df = 50%) | $V_{CER}$(sus) | 55 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 100 mA, $I_B$ = 10 mA) | $V_{CE}$(sat) | 0.5 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 15 V, $I_B$ = 0 | $I_{CEO}$ | 20 max | µA |
| $V_{CE}$ = 50 V | $I_{CES}$ | 1 max | µA |
| Collector-to-Base Capacitance ($V_{CB}$ = 30 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 3 max | pF |
| Magnitude of Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 15 V, $I_C$ = 50 mA, f = 200 MHz) | $\|h_{fe}\|$ | 6 min | |
| RF Power Output, Common Emitter Amplifier ($V_{CE}$ = 28 V, $P_{IE}$ = 0.316 W, f = 1 GHz) | $P_{OE}$ | 1* min | W |
| RF Power Output, Fundamental Frequency Oscillator ($V_{CE}$ = 20 V, $V_{EB}$ = 1.5 V, f = 1.68 GHz) | $P_{OE}$ | 0.3† | W |

* For conditions given, minimum efficiency = 35 per cent.
† For conditions given, minimum efficiency = 15 per cent.

# 2N5109 RF POWER TRANSISTOR




Si n-p-n "overlay" epitaxial planar type designed to provide large dynamic range, low distortion, and low noise as a wide-band amplifier into the vhf range. JEDEC TO-39, Outline No.15.

## MAXIMUM RATINGS

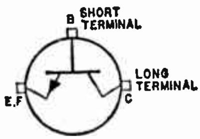
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 40 | V |
| Collector-to-Emitter Voltage ($R_{BE}$ = 10 Ω) | $V_{CER}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 3 | V |
| Collector Current | $I_C$ | 0.4 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 3.5 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 40 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 3 min | V |
| Collector-to-Emitter Sustaining Voltage: | | | |
| $R_{BE}$ = 10 Ω, $I_C$ = 5 mA, pulsed through an inductor L = 2.5 mH, df = 50% | $V_{CER}$(sus) | 40 min | V |
| $I_C$ = 5 mA, $I_B$ = 0 | $V_{CEO}$(sus) | 20 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 100 mA, $I_B$ = 10 mA) | $V_{CE}$(sat) | 0.5 max | V |
| Collector-Cutoff Current ($I_C$ = 0.1 mA, $I_E$ = 0) | $I_{CEO}$ | 20 max | μA |
| Collector-to-Base Capacitance ($V_{CB}$ = 15 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 3.5 max | pF |
| Static Forward-Current Transfer Ratio ($V_{CB}$ = 15 V, $I_C$ = 50 mA) | $h_{FE}$ | 70 min; 210 typ | |
| Small-Signal Forward-Current Transfer Ratio: | | | |
| $V_{CB}$ = 15 V, $I_C$ = 25 mA | $h_{fe}$ | 4.8 min | |
| $V_{CB}$ = 15 V, $I_C$ = 50 mA | $h_{fe}$ | 6 min | |
| $V_{CB}$ = 15 V, $I_C$ = 100 mA | $h_{fe}$ | 4.8 min | |
| Voltage Gain, Wideband ($V_{CB}$ = 15 V, $I_C$ = 50 mA, f = 50 to 216 MHz) | | 11 min | dB |
| Cross Modulation at 54 dBmV• Output ($V_{CB}$ = 15 V, $I_C$ = 50 mA) | | −57 | dB |
| Power Gain, Narrowband ($V_{CB}$ = 15 V, $I_C$ = 10 mA, $P_{IE}$ = −10 dB, f = 200 MHz) | | 11 min | dB |
| Noise Figure ($V_{CB}$ = 15 V, $I_C$ = 10 mA, f = 200 MHz) | NF | 3 | dB |

• 0 dBmV = 1 millivolt.

# 2N5470 RF POWER TRANSISTOR




Si n-p-n "overlay" epitaxial planar type used for vhf/microwave power amplifiers, microwave fundamental-frequency oscillators, and frequency multipliers. Outline No.54.

## MAXIMUM RATINGS

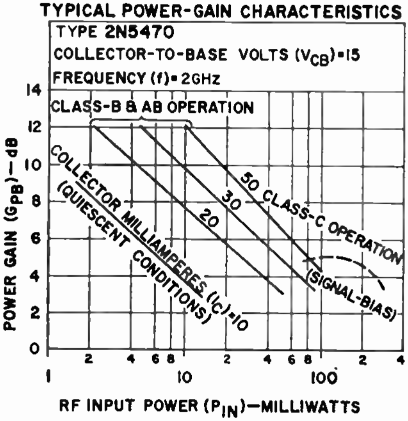
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 55 | V |
| Collector-to-Emitter Voltage ($R_{BE}$ = 10 Ω) | $V_{CER}$ | 55 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 3.5 | V |
| Peak Collector Current | $i_C$ | 0.4 | A |
| Collector Current | $I_C$ | 0.2 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 3.5 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |

**CHARACTERISTICS (At case temperature = 25°C)**

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 55 min | V |
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 5 mA, $R_{BE}$ = 10 Ω) | $V_{CER}(sus)$ | 55 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 3.5 min | V |
| Collector-to-Emitter Saturation Voltage ($I_B$ = 10 mA, $I_C$ = 100 mA) | $V_{CE}(sat)$ | 1 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 50 V, $I_B$ = 0) | $I_{CES}$ | 1 max | mA |
| Collector-to-Base Capacitance ($V_{CB}$ = 30 V, $I_E$ = 0, f = 1 MHz) | $C_{cb}$ | 3 max | pF |
| RF Power Output: | | | |
| Common-Base Amplifier: | | | |
| $V_{CB}$ = 28 V, $P_{IB}$ = 0.316 W, f = 2 GHz | $P_{OB}$* | 1 min | W |
| $V_{CB}$ = 28 V, $P_{IB}$ = 0.2 W, f = 1 GHz | $P_{OB}$▪ | 2 | W |
| Common-Base Oscillator ($V_{CB}$ = 24 V, $I_C$ = 80 mA) | $P_{OE}$ | 0.3 | W |

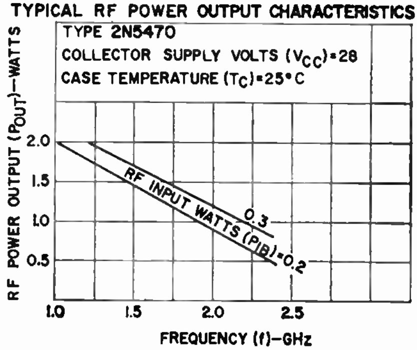
* For conditions given, minimum efficiency = 30 per cent.
▪ For conditions given, typical efficiency = 50 per cent.

TYPICAL POWER-GAIN CHARACTERISTICS

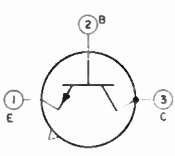



92SS-3795T

TYPICAL RF POWER OUTPUT CHARACTERISTICS




92SS-3790T




## RF POWER TRANSISTOR 2N5913

Si n-p-n "overlay" epitaxial planar type used for vhf/uhf mobile, portable, and vhf marine transmitters, as well as uhf, cb, sonobuoy, beacon, and other applications where intermediate power output is required at low supply voltage. JEDEC TO-39, Outline No.15.

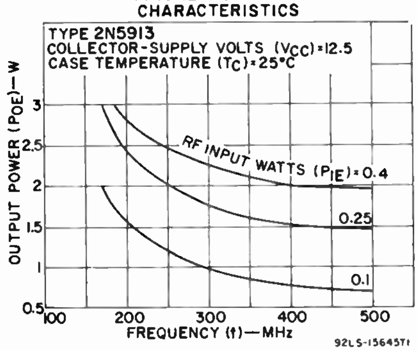
**MAXIMUM RATINGS**

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 36 | V |
| Collector-to-Emitter Breakdown Voltage: | | | |
| Base shorted to emitter | $V_{(BR)CES}$ | 36 | V |
| Base open | $V_{(BR)CEO}$ | 14 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 3.5 | V |
| Collector Current | $I_C$ | 0.33 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 75°C | $P_T$ | 3.5 | W |
| $T_C$ above 75°C | $P_T$ | Derate at 0.0028 | W/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

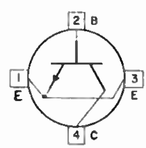
**CHARACTERISTICS (At case temperature = 25°C)**

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.5 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 36 min | V |
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_C$ = 25 mA, $I_B$ = 0, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CEO}$ | 14 min | V |
| $I_C$ = 25 mA, $V_{EB}$ = 0, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CES}$ | 36 min | V |
| Emitter-to-Base Breakdown Voltage $I_E$ = 0.5 mA, $I_C$ = 0 | $V_{(BR)EBO}$ | 3.5 min | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 12.5 V, $I_B$ = 0, $T_C$ = 100°C | $I_{CES}$ | 1 max | mA |
| $V_{CE}$ = 10 V, $I_B$ = 0 | $I_{CEO}$ | 0.3 max | mA |
| Power Output ($V_{CC}$ = 12.5 V, $P_{IE}$ = 0.1 W, f = 175 MHz) | $P_{OE}$ | 1.75 min | W |
| Large-Signal Common-Emitter Power Gain ($V_{CC}$ = 12.5 V, $P_{IE}$ = 0.1 W, f = 175 MHz | $G_{PE}$ | 12.4 min | dB |
| Collector Efficiency ($V_{CC}$ = 12.5 V, $P_{IE}$ = 0.1 W, f = 175 MHz) | $\eta_C$ | 50 min | % |
| Common-Base Output Capacitance ($V_{CB}$ = 12 V, f = 1 MHz) | $C_{obo}$ | 15 max | pF |
| Gain-Bandwidth Product ($V_{CE}$ = 12 V, $I_C$ = 200 mA) | $f_T$ | 900 | MHz |
| Thermal Resistance (Junction-to-Case) | $\theta_{J-C}$ | 35.7 | °C/W |

TYPICAL POWER-OUTPUT CHARACTERISTICS




# 2N5914 RF POWER TRANSISTOR




Si n-p-n "overlay" epitaxial planar type featuring a hermetic, ceramic-metal package having leads isolated from the mounting stud, used for high-power types for class-C amplifiers in vhf/uhf communications equipment. Outline No.68.

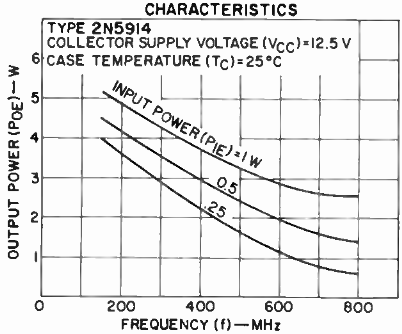
**MAXIMUM RATINGS**

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage | $V_{(BR)CBO}$ | 36 | V |
| Collector-to-Emitter Breakdown Voltage: | | | |
| Base connected to emitter | $V_{(BR)CES}$ | 36 | V |
| Base open | $V_{(BR)CEO}$ | 14 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 3.5 | V |
| Collector Current | $I_C$ | 0.5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 75°C | $P_T$ | 5.7 | W |
| $T_C$ above 75°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Case-Soldering Temperature (10 s max) | $T_C$ | 230 | °C |

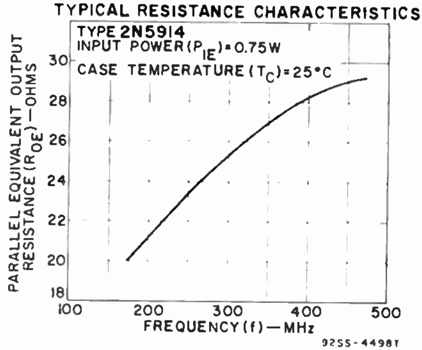
## CHARACTERISTICS (At case temperature = 25°C)

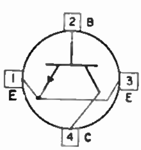
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.5 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 36 min | V |
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_C$ = 25 mA, $I_E$ = 0, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CEO}$ | 14 min | V |
| $I_C$ = 25 mA, $V_{BE}$ = 0, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CES}$ | 36 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.5 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 3.5 min | V |
| Collector-Cutoff Current ($V_{CE}$ = 10 V, $I_B$ = 0) | $I_{CEO}$ | 0.3 max | mA |
| Power Output ($V_{CC}$ = 12.5 V, $P_{IE}$ = 0.4 W, f = 470 MHz) | $P_{OE}$ | 2 min | W |
| Power Gain ($V_{CC}$ = 12.5 V, $P_{IE}$ = 0.4 W, f = 470 MHz) | $G_{PE}$ | 7 min | dB |
| Collector Efficiency ($V_{CC}$ = 12.5 V, $P_{IE}$ = 0.4 W, f = 470 MHz) | $\eta_C$ | 65 min | % |
| Load Mismatch ($V_{CC}$ = 12.5 V, $P_{IE}$ = 0.4 W, f = 470 MHz) | LM | GO/NO GO | |
| Collector-to-Base Capacitance ($V_{CC}$ = 12 V, $I_C$ = 0, f = 1 MHz) | $C_{obo}$ | 15 max | pF |
| Gain-Bandwidth Product ($V_{CC}$ = 12 V, $I_C$ = 200 mA) | $f_T$ | 900 | MHz |

TYPICAL POWER-OUTPUT CHARACTERISTICS




TYPICAL RESISTANCE CHARACTERISTICS




## RF POWER TRANSISTOR 2N5915

Si n-p-n "overlay" epitaxial planar type featuring a hermetic ceramic-metal package having leads isolated from the mounting stud, used for high-power types for class-C amplifiers in vhf/uhf communications equipment. Outline No.68.

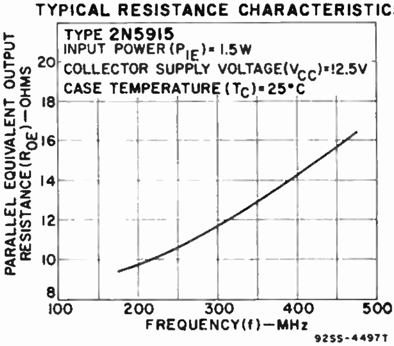
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage | $V_{(BR)CBO}$ | 36 | V |
| Collector-to-Emitter Breakdown Voltage: | | | |
| Base connected to emitter | $V_{(BR)CES}$ | 36 | V |
| Base open | $V_{(BR)CEO}$ | 14 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 3.5 | V |
| Collector Current | $I_C$ | 1.5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 75°C | $P_T$ | 10.7 | W |
| $T_C$ above 75°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Case-Soldering Temperature (10 s max) | $T_C$ | 230 | °C |

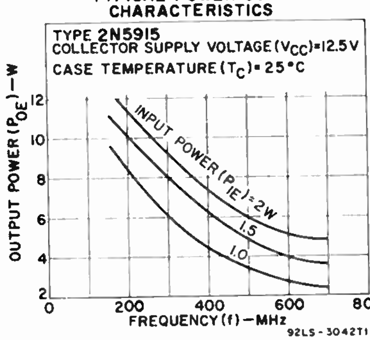
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 36 min | V |
| Collector-to-Emitter Breakdown Voltage: $I_C$ = 75 mA, $I_E$ = 0, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CEO}$ | 14 min | V |
| $I_C$ = 75 mA, $V_{BE}$ = 0, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CES}$ | 36 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 3.5 min | V |
| Collector-Cutoff Current ($V_{CE}$ = 10 V, $I_B$ = 0) | $I_{CEO}$ | 1 max | mA |
| Power Output ($V_{CC}$ = 12.5 V, $P_{IE}$ = 2 W, f = 470 MHz) | $P_{OE}$ | 6 min | W |
| Power Gain ($V_{CC}$ = 12.5 V, $P_{IE}$ = 2 W, f = 470 MHz) | $G_{PE}$ | 4.8 min | dB |
| Collector Efficiency ($V_{CC}$ = 12.5 V, $P_{IE}$ = 2 W, f = 470 MHz) | $\eta_C$ | 65 min | % |
| Load Mismatch ($V_{CC}$ = 12.5 V, $P_{IE}$ = 2 W, f = 470 MHz) | LM | GO/NO GO | |
| Collector-to-Base Capacitance ($V_{CB}$ = 12 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 30 max | pF |
| Gain-Bandwidth Product ($V_{CE}$ = 12 V, $I_C$ = 300 mA) | $f_T$ | 800 | MHZ |

TYPICAL RESISTANCE CHARACTERISTICS

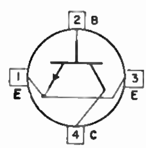



TYPICAL POWER OUTUT CHARACTERISTICS




# 2N5916 RF POWER TRANSISTOR

Si n-p-n "overlay" epitaxial planar type featuring a hermetic, ceramic-metal package having leads isolated from the mounting stud, used for large-signal and small-signal high-gain rf amplifiers and driver applications for vhf/uhf communications equipment. Outline No. 68.

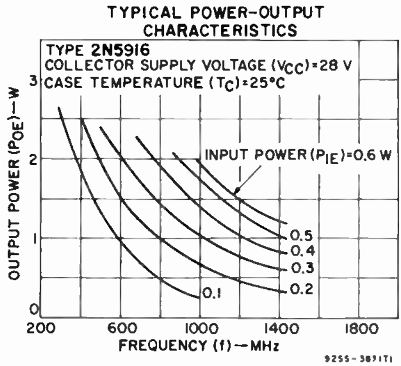


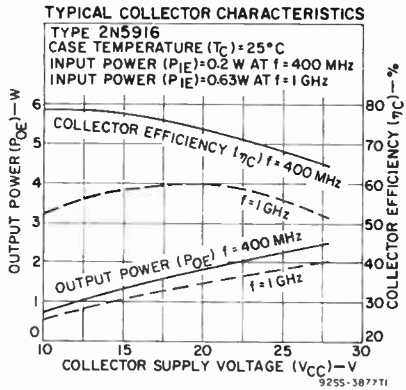

## MAXIMUM RATINGS

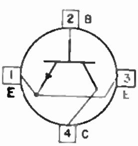
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 55 | V |
| Collector-to-Emitter Voltage | $V_{CEO}$ | 24 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 3.5 | V |
| Collector Current | $I_C$ | 0.2 | A |
| Transistor Dissipation: $T_C$ up to 100°C | $P_T$ | 4 | W |
| $T_C$ above 100°C | $P_T$ | Derate linearly at 0.04 | W/°C |
| Temperature Range: Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Case-Soldering Temperature (10 s max) | $T_C$ | 230 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage: $I_C$ = 5 mA, $V_{BE}$ = 0, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CES}$ | 55 min | V |
| $I_C$ = 5 mA, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CEO}$ | 24 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 3.5 min | V |
| Collector-to-Emitter Saturation Voltage ($I_B$ = 10 mA, $I_C$ = 100 mA) | $V_{CE}$(sat) | 0.5 max | V |
| Power Output ($V_{CC}$ = 28 V, $P_{IE}$ = 0.2 W, f = 400 MHz) | $P_{OE}$ | 2 min | W |
| Power Gain ($V_{CC}$ = 28 V, $P_{OE}$ = 2 W, f = 400 MHz) | $G_{PE}$ | 10 min | dB |
| Collector Efficiency ($V_{CC}$ = 28 V, $P_{IE}$ = 0.2 W, f = 400 MHz) | $\eta_C$ | 50 min | % |
| Collector-Base Capacitance ($V_{CB}$ = 30 V, f = 1 MHz) | $C_{cb}$ | 4.5 max | pF |
| Thermal Resistance (Junction-to-Case) | $\theta_{J-C}$ | 25 max | °C/W |

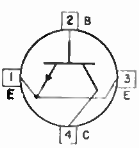



## RF POWER TRANSISTOR 2N5917

Si n-p-n "overlay" epitaxial planar type used for large-signal and small-signal high-gain rf amplifiers and driver applications for vhf/uhf communications equipment. Outline No.69. This type is electrically identical with type 2N5918.




## RF POWER TRANSISTOR 2N5918

Si n-p-n "overlay" epitaxial planar type featuring a hermetic, ceramic-metal package having leads isolated from the mounting stud, used in large-signal, high-power, broadband and narrow-band amplifiers in vhf/uhf communications equipment. Outline No.68.

## MAXIMUM RATINGS

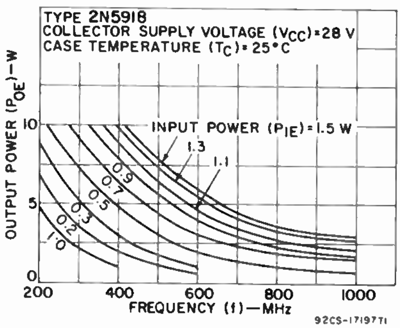
| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage | $V_{CEO}$ | 30 | V |
| Collector-to-Base Voltage | $V_{CBO}$ | 60 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 0.75 | A |

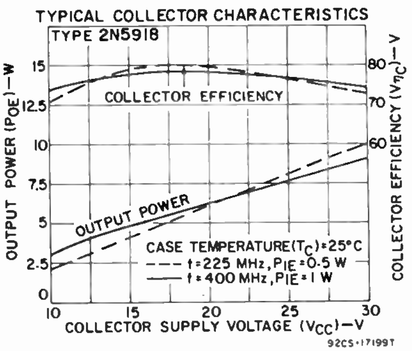
## MAXIMUM RATINGS (cont'd)

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_C$ up to 75°C | $P_T$ | 10 | W |
| $T_C$ above 75°C | $P_T$ | Derate linearly at 0.08 | W/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Case-Soldering Temperature (10 s max) | $T_C$ | 230 | °C |

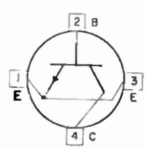
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage: | | | |
| $V_{BE}$ = 0, $I_C$ = 100 mA, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CES}$ | 60 min | V |
| $I_C$ = 100 mA, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CEO}$ | 30 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-to-Emitter Cutoff Current ($V_{CE}$ = 30 V, $V_{BE}$ = 0, base-emitter junction shorted) | $I_{CES}$ | 5 max | mA |
| Power Output ($V_{CC}$ = 28 V, $P_{IE}$ = 1.59 W, f = 400 MHz) | $P_{OE}$ | 10 min | W |
| Power Gain ($V_{CC}$ = 28 V, $P_{OE}$ = 10 W, f = 400 MHz) | $G_{PE}$ | 8 min | dB |
| Collector Efficiency ($V_{CC}$ = 28 V, $P_{OE}$ = 10 W, f = 400 MHz) | $\eta_C$ | 60 min | % |
| Collector-to-Base Output Capacitance ($V_{CB}$ = 30 V, f = 1 MHz) | $C_{obo}$ | 13 max | pF |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 12.5 max | °C/W |




# 2N5919 RF POWER TRANSISTOR



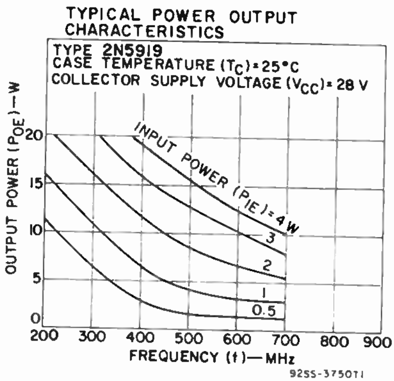

Si n-p-n "overlay" epitaxial planar type featuring a hermetic, ceramic-metal package having terminals isolated from the mounting stud, used for class C service in vhf/uhf communications equipment. Outline No.68.

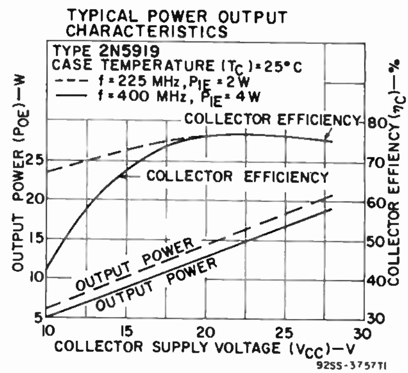
## MAXIMUM RATINGS

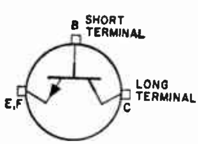
| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage | $V_{CEO}$ | 30 | V |
| Collector-to-Base Voltage | $V_{CBO}$ | 65 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 4.5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 75°C | $P_T$ | 25 | W |
| $T_C$ above 75°C | $P_T$ | Derate linearly at 0.2 | W/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Case-Soldering Temperature (10 s max) | $T_C$ | 230 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_C$ = 200 mA, $V_{BE}$ = 0, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CES}$ | 65 min | V |
| $I_C$ = 200 mA, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CEO}$ | 30 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 5 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-to-Emitter Saturation Voltage ($I_B$ = 400 mA, $I_C$ = 2000 mA) | $V_{CE}$(sat) | 1 max | V |
| Power Output ($V_{CC}$ = 28 V, $P_{IE}$ = 4 W, f = 400 MHz) | $P_{OE}$ | 16 min | W |
| Power Gain ($V_{CC}$ = 28 V, $P_{OE}$ = 16 W, f = 400 MHz) | $G_{PE}$ | 6 min | dB |
| Collector Efficiency ($V_{CC}$ = 28 V, $P_{IE}$ = 4 W, f = 400 MHz) | $\eta_C$ | 60 min | % |
| Collector-to-Base Output Capacitance ($V_{CB}$ = 30 V, f = 1 MHz) | $C_{obo}$ | 22 max | pF |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 5 max | °C/W |




# RF POWER TRANSISTOR 2N5920

Si n-p-n "overlay" epitaxial planar type used for uhf/microwave power amplifiers, microwave fundamental-frequency oscillators and frequency-multipliers. Outline No.54. See **Mounting Hardware** for desired mounting arrangement.

## MAXIMUM RATINGS

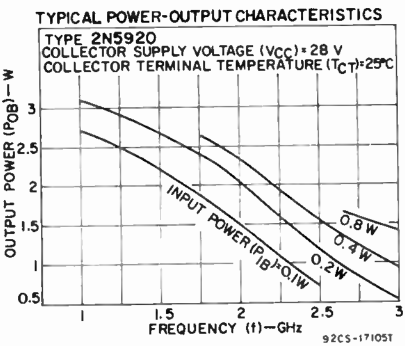
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 50 | V |
| Collector-to-Emitter Voltage: $R_{BE}$ = 10 Ω | $V_{CER}$ | 50 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 3.5 | V |
| Collector Current | $I_C$ | 0.275 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 75°C | $P_T$ | 4.15 | W |
| $T_C$ above 75°C | $P_T$ | Derate linearly at 0.033 | W/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Case-Soldering Temperature (10 s max) | $T_C$ | 230 | °C |

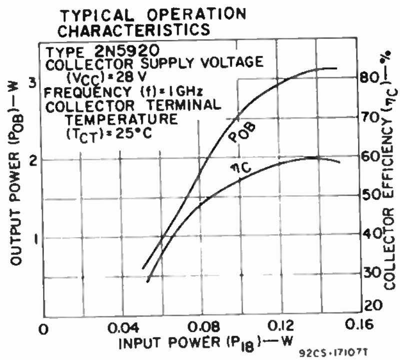
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_E$ = 0, $I_C$ = 1 mA) | $V_{(BR)CBO}$ | 50 min | V |

## CHARACTERISTICS (cont'd)

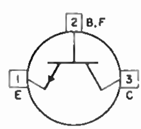
| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 5 mA, $R_{BE}$ = 10 Ω) | $V_{CER}$(sus) | 50 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 3.5 min | V |
| Collector-to-Emitter Saturation Voltage ($I_B$ = 10 mA, $I_C$ = 100 mA) | $V_{CE}$(sat) | 1 max | V |
| Power Output ($P_{IB}$ = 0.2 W, $V_{CC}$ = 28 V, f = 2 GHz) | $P_{OB}$ | 2 min | W |
| Power Gain ($P_{IB}$ = 0.2 W, $P_{OB}$ = 2 W, $V_{CC}$ = 28 V, f = 2 GHz) | $G_{PB}$ | 10 min | dB |
| Collector Efficiency ($P_{IB}$ = 0.2 W, $P_{OB}$ = 2 W, $V_{CC}$ = 28 V, f = 2 GHz) | $\eta_C$ | 40 min | % |
| Collector-to-Base Capacitance ($V_{CB}$ = 30 V, f = 1 MHz) | $C_{obo}$ | 3 max | pF |
| Thermal Resistance, Junction-to-Collector Terminal ($V_{CE}$ = 10 V, $I_C$ = 100 mA) | $\theta_{J-CT}$ | 30 max | °C/W |




# 2N5921 RF POWER TRANSISTOR

Si n-p-n "overlay" epitaxial planar type used for uhf/microwave power amplifiers, microwave fundamental-frequency oscillators and frequency oscillators and frequency multipliers. Outline No.70. See Mounting Hardware for desired mounting arrangement.




## MAXIMUM RATINGS

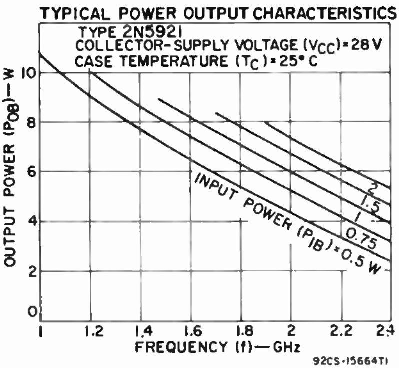
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 50 | V |
| Collector-to-Emitter Voltage: $R_{BE}$ = 10 Ω | $V_{CER}$ | 50 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 3.5 | V |
| Collector Current | $I_C$ | 0.7 | A |
| Transistor Dissipation: $T_C$ up to 100°C | $P_T$ | 8.3 | W |
| $T_C$ above 100°C | $P_T$ | Derate linearly at 0.083 | W/°C |
| Temperature Range: Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Case-Soldering Temperature (10 s max) | $T_C$ | 230 | °C |

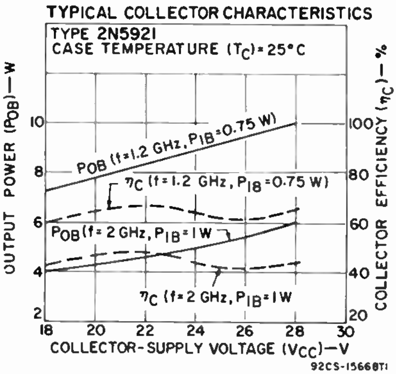
## CHARACTERISTICS (At case temperature = 25°C)

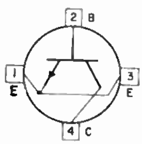
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_E$ = 0, $I_C$ = 1 mA) | $V_{(BR)CBO}$ | 50 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 10 mA, $R_{BE}$ = 10 Ω) | $V_{(BR)CER}$ | 50 min | V |

## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 3.5 min | V |
| Collector-to-Emitter Saturation Voltage ($I_B$ = 20 mA, $I_C$ = 100 mA) | $V_{CE}(sat)$ | 1 max | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 45 V, $I_B$ = 0 | $I_{CES}$ | 1 max | mA |
| $V_{CE}$ = 45 V, $T_C$ = 100°C | $I_{CES}$ | 5 max | mA |
| Output Power ($V_{CC}$ = 28 V, $P_{IB}$ = 1 W, f = 2 GHz) | $P_{OB}$ | 5 min | W |
| Power Gain ($V_{CC}$ = 28 V, $P_{OB}$ = 5 W, f = 2 GHz) | $G_{PB}$ | 7 min | dB |
| Collector Efficiency ($V_{CC}$ = 28 V, $P_{OB}$ = 5 W, f = 2 GHz) | $\eta_C$ | 40 min | % |
| Collector-to-Base Capacitance ($V_{CB}$ = 30 V, f = 1 MHz) | $C_{obo}$ | 8.5 max | pF |
| Thermal Resistance, Junction-to-Flange | $\Theta_{J-F}$ | 12 max | °C/W |




## RF POWER TRANSISTOR 2N5992

Si n-p-n "overlay" epitaxial planar type featuring a hermetic, metal package having leads isolated from the mounting stud, used for 12.5-volt amplifiers in vhf communications equipment. Outline No.68.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 65 | V |
| Collector-to-Emitter Voltage: | | | |
| Base shorted-to-emitter | $V_{(BR)CES}$ | 65 | V |
| Base open | $V_{(BR)CEO}$ | 30 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 3.5 | V |
| Collector Current | $I_C$ | 5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 75°C | $P_T$ | 35.7 | W |
| $T_C$ above 75°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

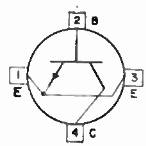
| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_B$ = 0, $I_C$ = 200 mA, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CEO}$ | 30 min | V |
| $V_{BE}$ = 0, $I_C$ = 200 mA, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CES}$ | 65 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 10 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 3.5 min | V |

### CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Cutoff Current ($V_{CE}$ = 60 V, $V_{BE}$ = 0, base-to-emitter shorted, $T_C$ = 25 to 100°C) | $I_{CES}$ | 10 max | mA |
| Power Input: | | | |
| $V_{CC}$ = 12.5 V, $P_{OE}$ = 7 W, f = 66 MHz | $P_{IE}$ | 0.35 typ; 0.5 max | W |
| $V_{CC}$ = 12.5 V, $P_{OE}$ = 7 W, f = 88 MHz | $P_{IE}$ | 0.5 typ; 0.7 max | W |
| Power Gain: | | | |
| $V_{CC}$ = 12.5 V, $P_{OE}$ = 7 W, f = 66 MHz | $G_{PE}$ | 11.5 min; 13 max | dB |
| $V_{CC}$ = 12.5 V, $P_{OE}$ = 7 W, f = 88 MHz | $G_{PE}$ | 10 min; 11.5 max | dB |
| Collector Efficiency: | | | |
| $V_{CC}$ = 12.5 V, $P_{OE}$ = 7 W, f = 66 MHz | $\eta_C$ | 55 min; 60 typ | % |
| $V_{CC}$ = 12.5 V, $P_{OE}$ = 7 W, f = 88 MHz | $\eta_C$ | 60 min; 70 typ | % |
| Modulation‡: | | | |
| $V_{CC}$ = 12.5 V, $P_{OE}$ = 7 W, f = 66 MHz | m | 90 min; 97 typ | % |
| $V_{CC}$ = 12.5 V, $P_{OE}$ = 7 W, f = 88 MHz | m | 90 min; 95 typ | % |
| Load Mismatch‡ ($V_{CC}$ = 12.5 V, $P_{OE}$ = 7 W, f = 66 MHz) | LM | GO/NO GO | |
| Collector-to-Base Capacitance ($V_{CB}$ = 12.5 V, f = 66 MHz) | $C_{obo}$ | 60 typ; 70 max | pF |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 3.5 max | °C/W |

‡ Input power and collector supply voltage are modulated.

## 2N5993 RF POWER TRANSISTOR



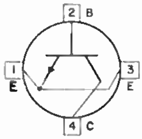

Si n-p-n "overlay" epitaxial planar type featuring a hermetic, metal package having leads isolated from the mounting stud, used for 12.5-volt amplifiers in vhf communications equipment. Outline No.68.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 36 | V |
| Collector-to-Emitter Voltage: | | | |
| Base shorted-to-emitter | $V_{(BR)CES}$ | 36 | V |
| Base open | $V_{(BR)CEO}$ | 18 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 3.5 | V |
| Collector Current | $I_C$ | 5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 75°C | $P_T$ | 35.7 | W |
| $T_C$ above 75°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_B$ = 0, $I_C$ = 200 mA, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CEO}$ | 18 min | V |
| $V_{BE}$ = 0, $I_C$ = 200 mA, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CES}$ | 36 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 10 mA) | $V_{(BR)EBO}$ | 3.5 min | V |
| Collector-to-Base Breakdown Voltage ($I_E$ = 0, $I_E$ = 15 mA) | $V_{(BR)CBO}$ | 36 min | V |
| Collector-Cutoff Current ($V_{CE}$ = 10 V, $I_B$ = 0) | $I_{CEO}$ | 5 max | mA |
| Power Output: | | | |
| $V_{CC}$ = 12.5, $P_{IE}$ = 1 W, f = 66 MHz | $P_{OE}$ | 18 min; 20 typ | W |
| $V_{CC}$ = 12.5, $P_{IE}$ = 1.75 W, f = 88 MHz | $P_{OE}$ | 18 min; 20 typ | W |
| Power Gain: | | | |
| $V_{CC}$ = 12.5 V, $P_{IE}$ = 1 W, f = 66 MHz | $G_{PE}$ | 12.5 min; 13 typ | dB |
| $V_{CC}$ = 12.5 V, $P_{IE}$ = 1.75 W, f = 88 MHz | $G_{PE}$ | 10.1 min; 10.6 typ | dB |
| Collector Efficiency: | | | |
| $V_{CC}$ = 12.5 V, $P_{IE}$ = 1 W, f = 66 MHz | $\eta_C$ | 65 min; 80 typ | % |
| $V_{CC}$ = 12.5 V, $P_{IE}$ = 1.75 W, f = 88 MHz | $\eta_C$ | 65 min; 80 typ | % |
| Load Mismatch ($V_{CC}$ = 12.5 V, $P_{IE}$ = 1 W, f = 66 MHz) | LM | GO/NO GO | |
| Collector-to-Base Capacitance (Vcc = 12 V, $I_C$ = 0, f = 1 MHz) | $C_{obo}$ | 100 max | pF |




## RF POWER TRANSISTOR 2N5994

Si n-p-n "overlay" epitaxial planar type featuring a hermetic, metal ceramic-metal package having leads isolated from the mounting stud, used for 12.5-volt and 28-volt fm amplifiers in vhf communications equipment. Outline No.68.

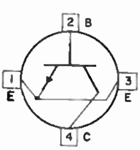
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage: | | | |
| Base shorted-to-emitter | $V_{(BR)CES}$ | 65 | A |
| Base open | $V_{CEO}$ | 30 | V |
| Collector-to-Base Voltage | $V_{CBO}$ | 65 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 3.5 | V |
| Collector Current | $I_C$ | 5 | V |
| Transistor Dissipation: | | | |
| $T_C$ up to 75°C | $P_T$ | 35.7 | W |
| $T_C$ above 75°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Case-Soldering Temperature (10 s max) | $T_C$ | 230 | °C |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_C$ = 200 mA, pulsed through an inductor = 25 mH, df = 50% | $V_{(BR)CEO}$ | 30 min | V |
| $I_C$ = 200 mA, pulsed through an inductor = 25 mH, df = 50% | $V_{(BR)CES}$ | 65 min | V |
| Collector-Cutoff Current ($V_{CE}$ = 60 V, $V_{BE}$ = 0, $T_C$ = 25 to 100°C) | $I_{CES}$ | 5 max | mA |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 5 mA) | $V_{(BR)EBO}$ | 3.5 min | V |
| Power Input ($V_{CC}$ = 12.5 V, $P_{OE}$ = 15 W, f = 118 MHz) | $P_{IE}$ | 3 max | W |
| Power Gain ($V_{CC}$ = 12.5 V, $P_{OE}$ = 15 W, f = 118 MHz) | $G_{PE}$ | 7 min | dB |
| Collector Efficiency ($V_{CC}$ = 12.5 V, $P_{OE}$ = 15 W, f = 118 MHz) | $\eta_C$ | 70 min | % |
| Modulation‡ ($V_{CC}$ = 12.5 V, $P_{OE}$ = 15 W, f = 118 MHz) | m | 90 min | % |
| Lead Mismatch‡ ($V_{CC}$ = 12.5 V, $P_{OE}$ = 15 W, f = 118 MHz) | LM | GO/NO GO | |
| Collector-to-Base Capacitance ($V_{CB}$ = 12.5 V, f = 1 MHz) | $C_{obo}$ | 70 max | pF |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 3.5 max | °C/W |

‡ Input power and collector supply voltage are modulated.




## RF POWER TRANSISTOR 2N5995

Si n-p-n "overlay" epitaxial planar type featuring a hermetic, ceramic-metal package having leads isolated from the mounting stud, used for 12.5-volt applications in vhf communications equipment. Outline No.68.

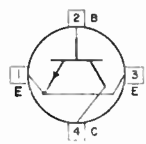
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 36 | V |
| Collector-to-Emitter Breakdown Voltage: | | | |
| Base connected to emitter | $V_{(BR)CES}$ | 36 | V |
| Base open | $V_{(BR)CEO}$ | 14 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 3.5 | V |
| Collector Current | $I_C$ | 1.5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 75°C | $P_T$ | 10.7 | W |
| $T_C$ above 75°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Case-Soldering Temperature (10 s max) | $T_C$ | 230 | °C |

**CHARACTERISTICS** (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 5 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 36 min | V |
| Collector-to-Emitter Breakdown Voltage: $I_E$ = 0, $I_C$ = 75 mA, pulsed through an inductor = 25 mH, df = 50% | $V_{(BR)CEO}$ | 14 min | V |
| $V_{BE}$ = 0, $I_C$ = 75 mA, pulsed through an inductor = 25 mH, df = 50% | $V_{(BR)CES}$ | 36 min | V |
| Emitter-to-Base Breakdown Voltage $I_E$ = 2 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 3.5 min | V |
| Collector-Cutoff Current $V_{CE}$ = 12.5 V, $V_{BE}$ = 0, $T_C$ = 100°C | $I_{CES}$ | 5 max | mA |
| $V_{CE}$ = 10 V, $I_B$ = 0 | $I_{CEO}$ | 2.5 max | mA |
| Power Output ($V_{CC}$ = 12.5 V, $P_{IE}$ = 0.75 W, f = 175 MHz) | $P_{OE}$ | 7 min | W |
| Power Gain ($V_{CC}$ = 12.5 V, $P_{IE}$ = 0.75 W, f = 175 MHz) | $G_{PE}$ | 9.7 min | dB |
| Collector Efficiency ($V_{CC}$ = 12.5 V, $P_{IE}$ = 0.75 W, f = 175 MHz) | $\eta_C$ | 65 min | % |
| Load Mismatch ($V_{CC}$ = 12.5 V, $P_{IE}$ = 0.75 W, f = 175 MHz) | LM | GO/NO GO | |
| Collector-to-Base Capacitance ($V_{CC}$ = 12 V, f = 1 MHz) | $C_{obo}$ | 80 max | pF |

# 2N5996 RF POWER TRANSISTOR




Si n-p-n "overlay" epitaxial planar type featuring a hermetic, ceramic-metal package having leads isolated from the mounting stud, used for 12.5-volt applications in vhf communications equipment. Outline No.68.

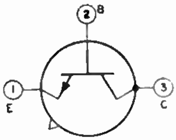
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 36 | V |
| Collector-to-Emitter Breakdown Voltage: Base connected to emitter | $V_{(BR)CES}$ | 36 | V |
| Base open | $V_{(BR)CEO}$ | 18 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 3.5 | V |
| Collector Current | $I_C$ | 5 | A |
| Transistor Dissipation: $T_C$ up to 75°C | $P_T$ | 35.7 | W |
| $T_C$ above 75°C | $P_T$ | See curve page 300 | |
| Temperature Range: Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Case-Soldering Temperature (10 s max) | $T_C$ | 230 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 15 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 36 min | V |
| Collector-to Emitter Breakdown Voltage: $I_E$ = 0, $I_C$ = 200 mA, pulsed through an inductor = 25 mH, df = 50% | $V_{(BR)CEO}$ | 18 min | V |
| $V_{BE}$ = 0, $I_C$ = 200 mA, pulsed through an inductor = 25 mH, df = 50% | $V_{(BR)CES}$ | 36 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 10 V, $I_C$ = 0) | $V_{(BR)EBO}$ | 3.5 min | V |
| Collector-Cutoff Current: $V_{CE}$ = 12.5 V, $V_{BE}$ = 0 | $I_{CES}$ | 10 max | mA |
| $V_{CE}$ = 10 V, $I_B$ = 0 | $I_{CEO}$ | 5 max | mA |
| Power Output ($V_{CC}$ = 12.5 V, $P_{IE}$ = 5.3 W, f = 175 MHz) | $P_{OE}$ | 15 min | W |
| Power Gain ($V_{CC}$ = 12.5 V, $P_{IE}$ = 5.3 W, f = 175 MHz) | $G_{PE}$ | 4.5 min | dB |
| Collector Efficiency ($V_{CC}$ = 12.5 V, $P_{IE}$ = 5.3 W, f = 175 MHz) | $\eta_C$ | 75 min | % |
| Load Mismatch ($V_{CC}$ = 12.5 V, $P_{IE}$ = 5.3 W, f = 175 MHz) | LM | GO/NO GO | |
| Collector-to-Base Capacitance ($V_{CC}$ = 12 V, f = 1 MHz) | $C_{obo}$ | 100 max | pF |

# RF POWER TRANSISTOR 40080




Si n-p-n triple-diffused planar type designed for oscillator applications, in conjunction with transistor types 40081 (driver) and 40082 (power amplifier) in a 5-watt input, 27-MHz citizens-band transmitter. JEDEC TO-39, Outline No.15.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage | $V_{CEO}$ | 30 | V |
| Peak Collector Current | $i_C$ | 0.25 | A |
| Transistor Dissipation: | | | |
| $T_A$ up to 25°C | $P_T$ | 0.5 | W |
| $T_A$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

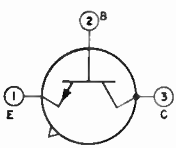
## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage ($I_C$ = 10 mA, $I_B$ = 0) | $V_{CEO}$ | 30 min | V |
| Collector-Cutoff Current ($V_{CB}$ = 15 V, $I_E$ = 0) | $I_{CBO}$ | 10 max | μA |
| RF Power Output ($V_{CC}$ = 12 V, $I_C$ = 32 mA, f = 27 MHz) | $P_{oe}$ | 100 min | mW |
| Collector-to-Base Capacitance ($V_{CB}$ = 30 V, f = 1 MHz) | $C_{obo}$ | 6 max | pF |
| Thermal Resistance, Junction-to-Ambient | $\theta_{J-A}$ | 350 | °C/W |

## TYPICAL OPERATION IN A CITIZENS-BAND TRANSMITTER

| | | | |
|---|---|---|---|
| DC Collector-Supply Voltage | $V_{CC}$ | 13.8 | V |
| DC Collector Current: | | | |
| No modulation | $I_C$ | 15 | mA |
| 100% modulation | $I_C$ | 15 | mA |

# RF POWER TRANSISTOR 40081




Si n-p-n triple-diffused planar type designed for driver applications, in conjunction with transistor types 40080 (oscillator) and 40082 (power amplifier), in a 5-watt input, 27-MHz citizens-band transmitter, JEDEC TO-5, Outline No.5.

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage ($V_{BE}$ = −0.5 V) | $V_{CEV}$ | 60 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2 | V |
| Peak Collector Current | $i_C$ | 0.25 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 2 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

## CHARACTERISTICS

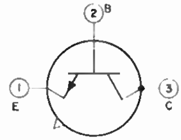
| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage ($V_{BE}$ = −0.5 V, $I_C$ = 100 μA) | $V_{CEV}$ | 60 min | V |
| Emitter-to-Base Voltage ($I_E$ = 500 μA, $I_C$ = 0) | $V_{EBO}$ | 2 min | V |
| Collector-Cutoff Current ($V_{CB}$ = 15 V, $I_E$ = 0) | $I_{CBO}$ | 10 max | μA |
| RF Power Output ($V_{CC}$ = 12 V, $I_C$ = 85 mA max, $P_{ie}$ = 75 mW, f = 27 MHz) | $P_{oe}$ | 400 min | mW |
| Collector-to-Base Capacitance ($V_{CB}$ = 30 V, f = 1 MHz) | $C_{obo}$ | 6 max | pF |
| Thermal Resistance, Junction-to-Case | $\theta_{J-A}$ | 87.5 | °C/W |

## TYPICAL OPERATION IN A CITIZENS-BAND TRANSMITTER

| | | | |
|---|---|---|---|
| DC Collector-Supply Voltage | $V_{CC}$ | 13.8 | V |
| DC Collector Current: | | | |
| No modulation | $I_C$ | 55 | mA |
| 100% modulation | $I_C$ | 50 | mA |

## 40082 RF POWER TRANSISTOR

Si n-p-n triple-diffused planar type designed for power-amplifier applications, in conjunction with transistor types 40080 (oscillator) and 40081 (driver), in a 5-watt, 27-MHz citizens-band transmitter. JEDEC TO-39, Outline No.15.




### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage ($V_{BE}$ = −0.5 V) | $V_{CEV}$ | 60 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2.5 | V |
| Peak Collector Current | $i_C$ | 1.5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 5 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

### CHARACTERISTICS

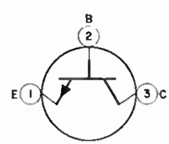
| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage ($V_{BE}$ = −0.5 V, $I_C$ = 500 μA) | $V_{CEV}$ | 60 min | V |
| Emitter-to-Base Voltage ($I_E$ = 500 μA, $I_C$ = 0) $I_C$ = 0) | $V_{EBO}$ | 2.5 min | V |
| Collector-Cutoff Current ($V_{CB}$ = 15 V, $I_E$ = 0) | $I_{CBO}$ | 10 max | μA |
| RF Power Output ($V_{CC}$ = 12 V, $I_C$ = 415 mA max, $P_{IE}$ = 350 mW, f = 27 MHz) | $P_{OE}$ | 3 min | W |
| Collector-to-Base Capacitance ($V_{CB}$ = 30 V, f = 1 MHz) | $C_{obo}$ | 20 max | pF |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 35 | °C/W |

### TYPICAL OPERATION IN A CITIZENS-BANO TRANSMITTER

| | | | |
|---|---|---|---|
| DC Collector-Supply Voltage | $V_{CC}$ | 13.8 | V |
| DC Collector Current: | | | |
| No modulation | $I_C$ | 330 | mA |
| 100% modulation | $I_C$ | 330 | mA |
| Power Output: | | | |
| No modulation (adjusted for legal maximum-power output) | $P_{OE}$ | 3.5 | W |
| 100% modulation | $P_{OE}$ | 4.8 | W |

## 40279 RF POWER TRANSISTOR

Si n-p-n "overlay" epitaxial planar type used in ultra-high-reliability vhf-uhf applications in space, military, and industrial communications equipment. Used in class A, B, and C amplifiers, frequency multipliers, or oscillators. This device is subjected to special preconditioning tests for selection in high-reliability, large-signal, and high-power applications. JEDEC TO-60, Outline No 23. See Mounting Hardware for desired mounting arrangement.



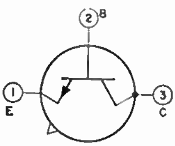

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 65 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 65 | V |
| Base open | $V_{CEO}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 1.5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 11.6 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 65 min | V |
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_C$ = 0 to 200 mA, $I_B$ = 0, pulsed through inductor L = 25 mH, df = 50% | $V_{(BR)CEO}$ | 40 min | V |
| $V_{BE}$ = −1.5 V, $I_C$ = 0 to 200 mA, pulsed through inductor L = 25 mH, df = 50% | $V_{(BR)CEV}$ | 65 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 0.5 A, $I_B$ = 0.1 A) | $V_{CE}$(sat) | 1 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 30 V, $I_B$ = 0) | $I_{CEO}$ | 0.1 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 5 V, $I_C$ = 150 mA) | $h_{FE}$ | 10 min | |
| Output Capacitance ($V_{CB}$ = 30 V, $I_E$ = 0) | $C_{obo}$ | 10 max | pF |
| RF Power Output, Unneutralized Amplifier: | | | |
| $V_{CE}$ = 28 V, $P_{IE}$ = 1 W, $R_G$ and $R_L$ = 50 Ω, f = 100 MHz | $P_{OE}$ | 7.5* min | W |
| $V_{CE}$ = 28 V, $P_{IE}$ = 1 W, $R_G$ and $R_L$ = 50 Ω, f = 400 MHz | $P_{OE}$ | 3† min | W |

* For conditions given, minimum efficiency = 65 per cent
† For conditions given, minimum efficiency = 40 per cent




## RF POWER TRANSISTOR 40280

Si n-p-n "overlay" epitaxial planar type used in vhf class C amplifier service requiring low supply voltages and high power output in industrial and military communications equipment. JEDEC TO-39, Outline No.15.

### MAXIMUM RATINGS

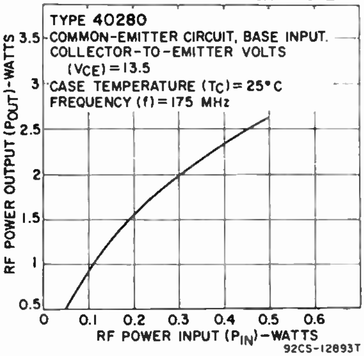
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 36 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 36 | V |
| Base open | $V_{CEO}$ | 18 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 0.5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 7 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230* | °C |

### CHARACTERISTICS (At case temperature = 25°C)

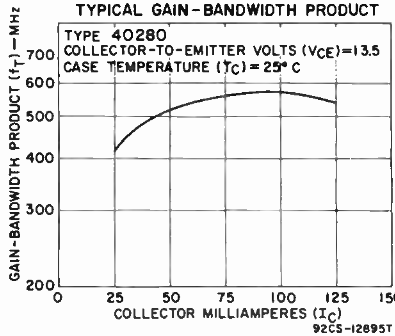
| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.25 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 36 min | V |
| Collector-to-Emitter Breakdown Voltage ($I_C$ = 200 mA, $I_B$ = 0, pulsed through inductor L = 25 mH, df = 50%) | $V_{(BR)CEV}$ | 36 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 200 mA, $I_B$ = 0, pulsed through inductor L = 25 mH, df = 50%) | $V_{CEO}$(sus) | 18 min | V |
| Collector-Cutoff Current ($V_{CE}$ = 15 V, $I_B$ = 0) | $I_{CEO}$ | 100 max | μA |
| Gain-Bandwidth Product ($V_{CE}$ = 13.5 V, $I_C$ = 100 mA) | $f_T$ | 550 | MHz |
| Output Capacitance ($V_{CB}$ = 13.5 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 15 max | pF |
| Input Resistance, Real Part ($V_{CE}$ = 13.5 V, $I_C$ = 100 mA, f = 175 MHz) | $R_e(h_{ie})$ | 10 | Ω |
| Power Output, Class C Amplifier, Unneutralized ($V_{CE}$ = 13.5 V, $P_{IE}$ = 0.125 W, f = 175 MHz, $R_G$ and $R_L$ = 50 Ω) | $P_{OE}$ | 1† min | W |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 25 max | °C/W |

* For types 40281 and 40282 this value is maximum Pin-Soldering Temperature.
† For conditions given, minimum efficiency = 60 per cent.

TYPICAL RF POWER-OUTPUT CHARACTERISTIC

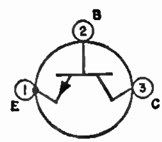



TYPICAL GAIN-BANDWIDTH PRODUCT




# 40281 RF POWER TRANSISTOR

Si n-p-n "overlay" epitaxial planar type used in vhf class C amplifier service requiring low supply voltages and high power output in industrial and military communications equipment. JEDEC TO-60, Outline No.23. See Mounting Hardware for desired mounting arrangement. This type is identical with type 40280 except for the following items:




## MAXIMUM RATINGS

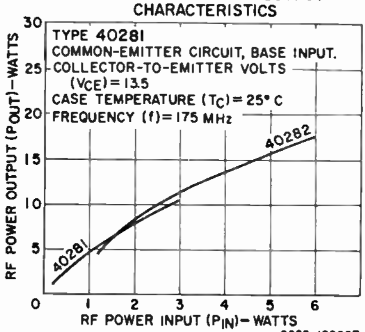
| | | | |
|---|---|---|---|
| Collector Current | $I_C$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 11.6 | W |

## CHARACTERISTICS (At case temperature = 25°C)

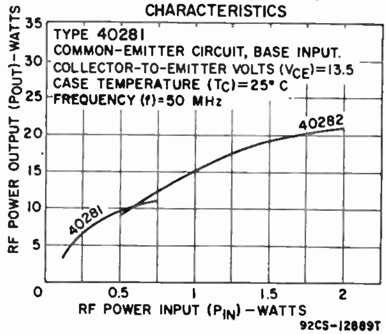
| | | | |
|---|---|---|---|
| Gain-Bandwidth Product ($V_{CE}$ = 13.5 V, $I_C$ = 400 mA) | $f_T$ | 400 | MHz |
| Output Capacitance ($V_{CB}$ = 13.5 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 22 max | pF |
| Collector-to-Case Capacitance | $C_c$ | 5 max | pF |
| Input Resistance, Real Part ($V_{CE}$ = 13.5 V, $I_C$ = 400 mA, f = 175 MHz) | $R_e(h_{ie})$ | 7 | Ω |
| ower Output, Class C Amplifier, Unneutralized ($V_{CE}$ = 13.5 V, $P_{IE}$ = 1 W, f = 175 MHz, $R_G$ and $R_L$ = 50 Ω) | $P_{OE}$ | 4† min | W |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 15 max | °C/W |

† For conditions given, minimum efficiency = 70 per cent.

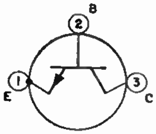
TYPICAL RF POWER-OUTPUT CHARACTERISTICS




TYPICAL RF POWER-OUTPUT CHARACTERISTICS



## RF POWER TRANSISTOR 40282




Si n-p-n "overlay" epitaxial planar type used in vhf class C amplifier service requiring low supply voltages and high power output in industrial and military communications equipment. JEDEC TO-60, Outline No.23. See Mounting Hardware for desired mounting arrangement. This type is identical with type 40280 except for the following items:

### MAXIMUM RATINGS

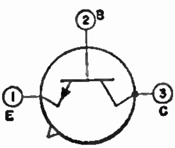
| | | | |
|---|---|---|---|
| Collector Current | $I_C$ | 2 | A |
| Transistor Dissipation: $T_C$ up to 25°C | $P_T$ | 23.2 | W |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.5 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 36 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.25 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-Cutoff Current ($V_{CE}$ = 15 V, $I_B$ = 0) | $I_{CEO}$ | 250 max | µA |
| Gain-Bandwidth Product ($V_{CE}$ = 13.5 V, $I_C$ = 800 mA) | $f_T$ | 350 | MHz |
| Output Capacitance ($V_{CB}$ = 13.5 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 45 max | pF |
| Collector-to-Case Capacitance | $C_c$ | 5 max | pF |
| Input Resistance, Real Part ($V_{CE}$ = 13.5 V, $I_C$ = 800 mA, f = 175 MHz) | $R_e(h_{ie})$ | 5 | Ω |
| Power Output, Class C Amplifier, Unneutralized ($V_{CE}$ = 13.5 V, $P_{IE}$ = 4 W, f = 175 MHz, $R_G$ and $R_L$ = 50 Ω) | $P_{OE}$ | 12† min | W |
| Thermal Resistance, Junction-to-Case | $\Theta_{J-C}$ | 7.5 max | °C/W |

† For conditions given, minimum efficiency = 80 per cent.

## RF POWER TRANSISTOR 40290




Si n-p-n "overlay" epitaxial planar type used in vhf class C amplifier service requiring low supply voltages and high power output in aircraft, military, and industrial communications equipment. JEDEC TO-39, Outline No.15.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage: $V_{BE}$ = −1.5 V | $V_{CEV}$ | 50 | V |
| f = 100 MHz | $V_{CES}$(RF) | 90 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 0.5 | A |
| Transistor Dissipation: $T_C$ up to 25°C | $P_T$ | 7 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230* | °C |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage: $I_C$ = 200 mA, $V_{BE}$ = −1.5 V, $R_{BE}$ = 39 Ω, pulsed through inductor L = 25 mH, df = 50% | $V_{(BR)CEV}$ | 50 min | V |
| $I_C$ = 50 mA, $V_{BE}$ = −2 V, f ≤ 100 MHz | $V_{(BR)CES}$(RF) | 90 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-Cutoff Current ($V_{CE}$ = 15 V, $I_B$ = 0) | $I_{CEO}$ | 100 max | µA |
| Gain-Bandwidth Product ($V_{CE}$ = 12.5 V, $I_C$ = 100 mA) | $f_T$ | 500 | MHz |
| Output Capacitance ($V_{CB}$ = 12.5 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 17 max | pF |
| Input Resistance, Real Part ($V_{CE}$ = 12.5 V, $I_C$ = 100 mA, f = 135 MHz) | $R_e(h_{ie})$ | 12 | Ω |

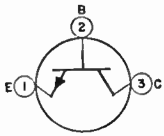
**CHARACTERISTICS (cont'd)**

| | | | |
|---|---|---|---|
| Power Output, Class C Amplifier, Unneutralized ($V_{CE}$ = 12.5 V, $P_{IE}$ = 0.5 W, f = 135 MHz, $R_G$ and $R_L$ = 50 Ω) | $P_{OE}$ | 2† min | W |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 25 max | °C/W |

* For type 40291 this value is maximum Pin-Soldering Temperature.
† For conditions given, minimum efficiency = 70 per cent.

## 40291 RF POWER TRANSISTOR

Si n-p-n "overlay" epitaxial planar type used in vhf class C amplifier service requiring low supply voltages and high power output in aircraft, military, and industrial communications equipment. JEDEC TO-60, Outline No.23. See **Mounting Hardware** for desired mounting arrangement. This type is identical with type 40290 except for the following items:




**MAXIMUM RATINGS**

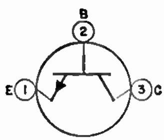
| | | | |
|---|---|---|---|
| Transistor Dissipation ($T_C$ up to 25°C) | $P_T$ | 11.6 | W |

**CHARACTERISTICS (At case temperature = 25°C)**

| | | | |
|---|---|---|---|
| Collector-to-Case Capacitance | $C_c$ | 6 max | pF |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 15 max | °C/W |

## 40292 RF POWER TRANSISTOR

Si n-p-n "overlay" epitaxial planar type used in vhf class C amplifier service requiring low supply voltages and high power output in aircraft, military, and industrial communications equipment. JEDEC TO-60, Outline No.23. See **Mounting Hardware** for desired mounting arrangement.




**MAXIMUM RATINGS**

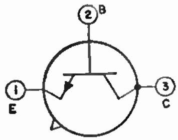
| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 50 | V |
| f = 100 MHz | $V_{CES}$(RF) | 90 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 1.25 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 23.2 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 230 | °C |

**CHARACTERISTICS (At case temperature = 25°C)**

| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage: | | | |
| $I_C$ = 200 mA, $V_{BE}$ = −1.5 V, $R_{BE}$ = 39 Ω, pulsed through inductor L = 25 mH, df = 50% | $V_{(BR)CEV}$ | 50 min | V |
| $I_C$ = 50 mA, $V_{BE}$ = 0, f ≤ 100 MHz | $V_{(BR)CES}$(RF) | 90 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.25 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-Cutoff Current ($V_{CE}$ = 15 V, $I_B$ = 0) | $I_{CEO}$ | 250 max | µA |
| Gain-Bandwidth Product ($V_{CE}$ = 12.5 V, $I_C$ = 400 mA) | $f_T$ | 300 | MHz |
| Collector-to-Case Capacitance | $C_c$ | 6 max | pF |
| Output Capacitance ($V_{CB}$ = 12.5 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 30 max | pF |
| Input Resistance, Real Part ($V_{CE}$ = 12.5 V, $I_C$ = 400 mA, f = 135 MHz) | $R_e(h_{ie})$ | 6.5 | Ω |
| Power Output, Class C Amplifier, Unneutralized ($V_{CE}$ = 12.5 V, $P_{IE}$ = 2 W, f = 135 MHz, $R_G$ and $R_L$ = 50 Ω) | $P_{OE}$ | 6† min | W |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 7.5 max | °C/W |

† For conditions given, minimum efficiency = 70 per cent.

## RF POWER TRANSISTOR 40305




Si n-p-n "overlay" epitaxial planar type subjected to special preconditioning tests for high-reliability, large-signal, high-power vhf-uhf applications in class A, B, and C amplifier, frequency-multiplier, and oscillator circuits in aerospace, industrial and military equipment. JEDEC TO-39, Outline No.15.

### MAXIMUM RATINGS

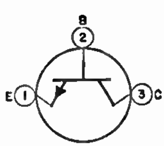
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 65 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 65 | V |
| Base open | $V_{CEO}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 7 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230* | °C |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.3 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 65 min | V |
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_C$ = 0 to 200 mA, $I_B$ = 0, pulsed through inductor L = 25 mH, df = 50% | $V_{(BR)CEO}$ | 40 min | V |
| $I_C$ = 0 to 200 mA, $V_{BE}$ = −1.5 V, pulsed through inductor L = 25 mH, df = 50% | $V_{(BR)CEV}$ | 65 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 250 mA, $I_B$ = 50 mA) | $V_{CE}$(sat) | 1 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 30 V, $I_B$ = 0) | $I_{CEO}$ | 0.1 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 5 V, $I_C$ = 150 mA) | $h_{FE}$ | 10 min | |
| Output Capacitance ($V_{CB}$ = 30 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 10 max | pF |
| RF Power Output, Amplifier, Unneutralized: ($V_{CE}$ = 28 V, $P_{IE}$ = 0.25 W, f = 175 MHz, $R_G$ and $R_L$ = 50 Ω) | $P_{OE}$ | 2.5† min | W |

* For type 40306 this value is maximum Pin-Soldering Temperature.
† For conditions given, minimum efficiency = 50 per cent.

## RF POWER TRANSISTOR 40306




Si n-p-n "overlay" epitaxial planar type subjected to special preconditioning tests for high-reliability, large-signal, high-power vhf-uhf applications in class A, B, and C amplifier, frequency-multiplier, and oscillator circuits in aerospace, industrial and military equipment. JEDEC TO-60, Outline No.23. See Mounting Hardware for desired mounting arrangement. This type is identical with type 40305 except for the following items:

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector Current | $I_C$ | 1.5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 11.6 | W |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 65 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 500 mA, $I_B$ = 100 mA) | $V_{CE}$(sat) | 1 max | V |

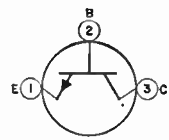
### CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| RF Power Output, Amplifier, Unneutralized: | | | |
| $V_{CE}$ = 28 V, $P_{IE}$ = 1 W, f = 100 MHz, $R_G$ and $R_L$ = 50 Ω | $P_{OE}$ | 7.5* min | W |
| $V_{CE}$ = 28 V, $P_{IE}$ = 1 W, f = 400 MHz, $R_G$ and $R_L$ = 50 Ω | $P_{OE}$ | 3† min | W |

* For conditions given, minimum efficiency = 65 per cent.
† For conditions given, minimum efficiency = 40 per cent.

## 40307 RF POWER TRANSISTOR

Si n-p-n "overlay" epitaxial planar type subjected to special preconditioning tests for high-reliability, large-signal, high-power vhf-uhf applications in class A, B, and C amplifier, frequency-multiplier, and oscillator circuits in aerospace, industrial and military equipment. JEDEC TO-60, Outline No.23. See Mounting Hardware for desired mounting arrangement.




### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 65 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 65 | V |
| Base open | $V_{CEO}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 3 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 23 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Pin-Soldering Temperature (10 s max) | $T_P$ | 230 | °C |

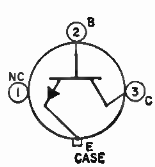
### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.5 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 65 min | V |
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_C$ = 0 to 200 mA, $I_B$ = 0, pulsed through inductor L = 25 mH, df = 50% | $V_{(BR)CEO}$ | 40 min | V |
| $I_C$ = 0 to 200 mA, $V_{BE}$ = −1.5 V, pulsed through inductor L = 25 mH, df = 50% | $V_{(BR)CEV}$ | 65 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.25 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-to-Emitter Saturation Voltage ($I_C$ = 500 mA, $I_B$ = 100 mA) | $V_{CE}$(sat) | 1 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 30 V, $I_B$ = 0) | $I_{CEO}$ | 0.25 max | μA |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 5 V, Ic = 300 mA) | $h_{FE}$ | 10 min | |
| Output Capacitance ($V_{CB}$ = 30 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 20 max | pF |
| RF Power Output, Amplifier, Unneutralized: ($V_{CE}$ = 28 V, $P_{IE}$ = 3.5 W, f = 175 MHz, $R_G$ and $R_L$ = 50 Ω) | $P_{OE}$ | 13.5† min | W |

† For conditions given, minimum efficiency = 70 per cent.

## 40340 RF POWER TRANSISTOR

Si n-p-n "overlay" epitaxial planar type used in high-power class C amplifier applications at frequencies to 100 MHz. JEDEC TO-60, Outline No.23. See Mounting Hardware for desired mounting arrangement.



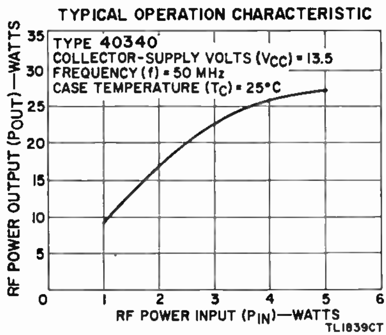
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 60 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 60 | V |
| Base open | $V_{CEO}$ | 25 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Peak Collector Current | $I_C$(peak) | 10 | A |
| Continuous Collector Current | $I_C$ | 3.3 | A |
| Transistor Dissipation ($T_C$ = 25°C) | $P_T$ | 70 | W |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | 200 | °C |

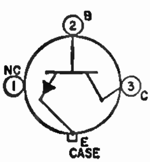
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_C$ = 200 mA, $V_{BE}$ = −1.5 V, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CEV}$ | 60 min | V |
| $I_C$ = 200 mA, $I_B$ = 0, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CEO}$ | 25 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 10 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 15 V, $I_B$ = 0 | $I_{CEO}$ | 1 max | mA |
| $V_{CB}$ = 40 V, $I_E$ = 0 | $I_{CBO}$ | 10 max | mA |
| Output Capacitance ($V_{CB}$ = 15 V, $I_E$ = 0) | $C_{obo}$ | 120 max | pF |
| RF Power Output ($V_{CE}$ = 13.5 V, $P_{IE}$ = 5 W, f = 50 MHz, $R_G$ and $R_L$ = 50 Ω) | $P_{OE}$ | 25* min | W |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 2.5 max | °C/W |

* For conditions given, minimum efficiency = 65 per cent.




## RF POWER TRANSISTOR 40341




Si n-p-n "overlay" epitaxial planar type used in high-power class C amplifier applications at frequencies to 100 MHz. JEDEC TO-60, Outline No.23. See Mounting Hardware for desired mounting arrangement. This type is identical with type 40340 except for the following items:

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 70 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 70 | V |
| Base open | $V_{CEO}$ | 35 | V |

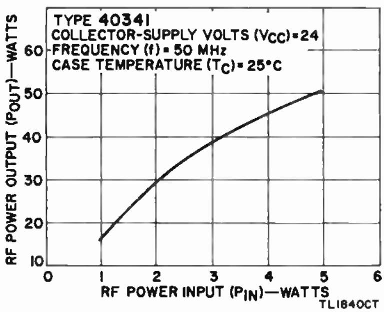
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Emitter Breakdown Voltage: | | | |
| $I_C$ = 200 mA, $V_{BE}$ = −1.5 V, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CEV}$ | 70 min | V |
| $I_C$ = 200 mA, $I_B$ = 0, pulsed through an inductor L = 25 mH, df = 50% | $V_{(BR)CEO}$ | 35 min | V |

### CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| Collector-Cutoff Current: | | | |
| $V_{CE}$ = 30 V, $I_B$ = 0 | $I_{CEO}$ | 1 max | mA |
| $V_{CB}$ = 50 V, $I_E$ = 0 | $I_{CBO}$ | 10 max | mA |

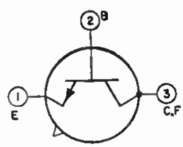
TYPICAL OPERATION CHARACTERISTIC




| | | | |
|---|---|---|---|
| Output Capacitance ($V_{CB}$ = 30 V, $I_E$ = 0) | $C_{obo}$ | 85 max | pF |
| RF Power Output ($V_{CE}$ = 24 V, $P_{IE}$ = 3 W, f = 50 MHz, $R_G$ and $R_L$ = 50 Ω) | $P_{OE}$ | 30* min | W |

* For conditions given, minimum efficiency = 60 per cent.

## 40446 RF POWER TRANSISTOR




Si n-p-n triple diffused planar type used in power-amplifier applications, in conjunction with types 40080 (oscillator), 40081 (driver), and 40082 (power amplifier), in a 5-watt-input, 27 - MHz citizens-band transmitter. JEDEC TO-5 (with flange), Outline No.6. See Mounting Hardware for desired mounting arrangement. This type is identical with type 40082 except for the following items:

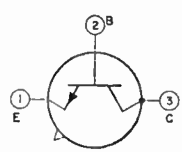
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 10 | W |

### CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 17.5 | °C/W |

## 40577 RF POWER TRANSISTOR



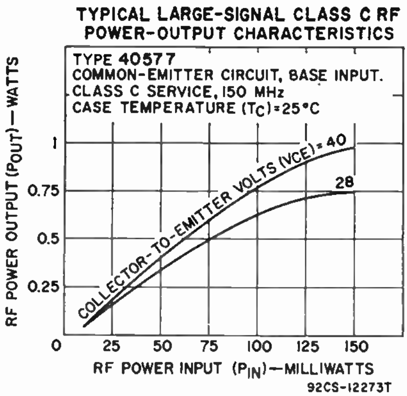

Si n-p-n "overlay" triple-diffused type is subjected to special preconditioning tests for high-reliability operation in high-power vhf applications in military and industrial equipment. JEDEC TO-5, Outline No.5. This type is a high-reliability version of type 2N3118.

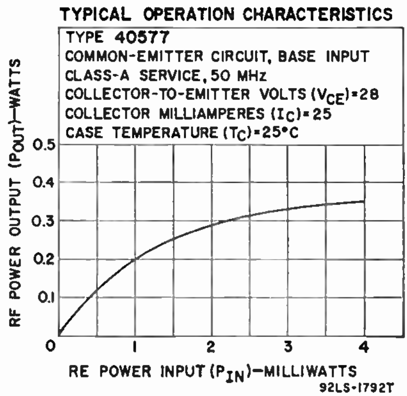
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V | $V_{CEV}$ | 85 | V |
| Base open | $V_{CEO}$ | 60 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 0.5 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 3 | W |
| $T_A$ up to 25°C | $P_T$ | 5 | W |
| $T_C$ above 25°C | | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

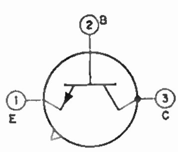
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-to-Emitter Breakdown Sustaining Voltage ($I_C$ = 10 mA, $I_B$ = 0, $t_P$ = 300 μs, df < 1.8%) | $V_{(BR)CEO}$(sus) | 60 min | V |
| Reverse Collector-to-Emitter Breakdown Voltage ($V_{BE}$ = 1.5 V, $I_C$ = 0.1 mA) | $V_{(BR)CEX}$ | 85 min | V |
| Collector-Cutoff Current: | | | |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_A$ = 25°C | $I_{CBO}$ | 10 max | nA |
| $V_{CB}$ = 30 V, $I_E$ = 0, $T_A$ = 150°C | $I_{CBO}$ | 5 max | μA |
| Output Capacitance ($V_{CB}$ = 28 V, $I_C$ = 0, f = 1 MHz) | $C_{obo}$ | 6 max | pF |
| $r_{bb'}C_{b'c}$ Product ($V_{CE}$ = 28 V, $I_C$ = 25 mA, f = 50 MHz) | $r_{bb'}C_{b'c}$ | 60 max | ps |
| Pulsed Static Forward-Current Transfer Ratio: ($V_{CE}$ = 5 V, $I_C$ = 100 mA, $t_P$ = 300 μs, df < 1.8%) | $h_{FE}$(pulsed) | 50 to 275 | |
| Small-Signal Forward-Current Transfer Ratio ($V_{CE}$ = 28 V, $I_C$ = 25 mA, f = 50 MHz) | $h_{fe}$ | 5 min | |
| Small-Signal Short-Circuit Input Impedance Real Part ($V_{CE}$ = 28 V, $I_C$ = 25 mA, f = 50 MHz) | $R_e(h_{ie})$ | 25 to 75 | Ω |
| Small-Signal Short-Circuit Output Impedance Real Part ($V_{CE}$ = 28 V, $I_C$ = 25 mA, f = 50 MHz) | $\frac{1}{Y_{22}}$ (real) | 500 to 1000 | |
| Power Output, Class C Service (with heat sink): | | | |
| $V_{CE}$ = 28 V, $P_{in}$ = 0.1 W, f = 50 MHz | $P_{oe}$ | 1 min | W |
| $V_{CE}$ = 28 V, $P_{in}$ = 0.1 W, f = 150 MHz | $P_{oe}$ | 0.4 min | W |
| Power Gain, Class A Service (with heat sink) ($V_{CE}$ = 28 V, $I_C$ = 25 mA, $P_{out}$ = 0.2 W, f = 50 MHz) | $G_{pe}$ | 18 min | dB |




## RF POWER TRANSISTOR 40578

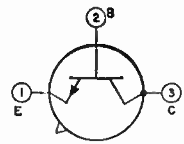



Si n-p-n "overlay" epitaxial planar type subjected to special preconditioning tests for high-reliability, class A, B, and C amplifier, frequency multiplier, or oscillator operation, driver or pre-driver stages, vhf-uhf applications in space, military, and industrial communications equipment. JEDEC TO-39, Outline No.15. This type is identical to type 2N3866 except for the following item:

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-Cutoff Current ($V_{CE}$ = 28 V, $I_B$ = 0) | $I_{CEO}$ | 100 max | nA |

# 40581 RF POWER TRANSISTOR

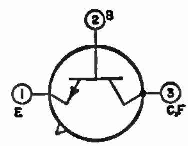



Si n-p-n triple-diffused planar type used for power-amplifier applications in conjunction with transistor types 40080 (oscillator), and 40081 (driver), in a 5-watt, 27-MHz citizens-band transmitter. JEDEC TO-39, Outline No.15. This type is identical to type 40082 except for the following item:

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| RF Power Output ($V_{CC}$ = 12 V, $I_C$ = 415 mA, $P_{IE}$ = 350 mW, f = 27 MHz) | $P_{OE}$ | 3.5 min | W |

# 40582 RF POWER TRANSISTOR




Si n-p-n triple-diffused planar type used for power-amplifier applications in conjunction with transistor types 40080 (oscillator), and 40081 (driver), in a 5-watt, 27-MHz citizens-band transmitter. JEDEC TO-39, Outline No.6. See Mounting Hardware for desired arrangement. This type is identical with type 40082 except for the following items:

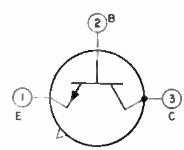
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Transistor Dissipation | | | |
| $T_C$ up to 25°C | $P_T$ | 10 | W |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| RF Power Output ($V_{CC}$ = 12 V, $I_C$ = 415 mA, f = 27 MHz, $P_{IE}$ = 350 mW) | $P_{OE}$ | 3.5 min | W |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 17.5 | °C/W |

# 40605 RF POWER TRANSISTOR




Si n-p-n "overlay" epitaxial planar type used in class A, B, or C amplifier, frequency multiplier, and oscillator service in vhf-uhf equipment. This type is subjected to special preconditioning tests for high-reliability operation in critical aerospace and industrial equipment. JEDEC TO-39. Outline No.15.

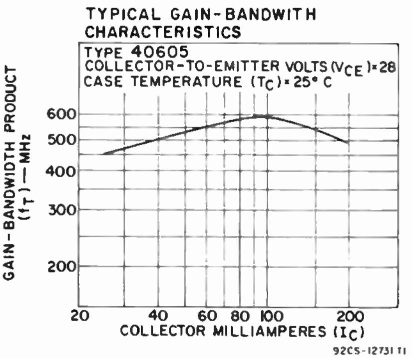
## MAXIMUM RATINGS

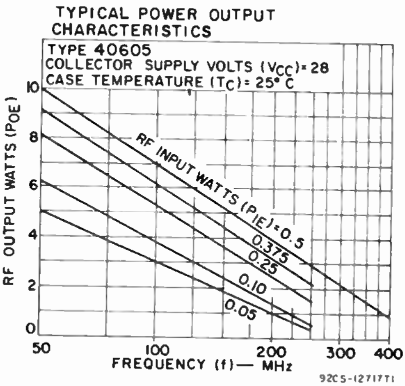
| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 65 | V |
| Collector-to-Emitter Voltage: | | | |
| $V_{BE}$ = −1.5 V, $R_{BE}$ = 33 Ω | $V_{CEX}$ | 65 | V |
| Base open | $V_{CEO}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 4 | V |
| Collector Current | $I_C$ | 0.33 | A |
| Peak Collector Current | $I_{Cpk}$ | 1 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 7 | W |
| $T_C$ above 25°C | $P_T$ | Derate linearly at 0.04 | W/°C |
| $T_A$ up to 25°C | $P_T$ | 1 | W |
| $T_A$ above 25°C | $P_T$ | Derate linearly at 5.71 | mW/°C |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

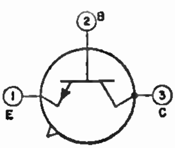
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.3 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 65 min | V |
| Collector-to-Emitter Breakdown Voltage: | | | |
| Base open, $I_C$ = 200 mA, $I_B$ = 0, pulsed through an inductor L = 25 mH | $V_{(BR)CEO}$ | 40▲ min | V |
| $R_{BE}$ = 33 Ω, $I_C$ = 200 mA, $V_{BE}$ = −1.5 V, pulsed through an inductor L = 25 mH | $V_{(BR)CEX}$ | 65▲ min | V |
| Emitter-to-Base Breakdown Voltage $I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 4 min | V |
| Collector-to-Emitter Saturation Voltage ($I_B$ = 50 mA, $I_C$ = 250 mA) | $V_{CE}$(sat) | 1 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 30 V, $I_B$ = 0) | $I_{CEO}$ | 0.1 max | μA |
| Power Output $V_{CC}$ = 28 V, $P_{IE}$ = 0.25 W, f = 175 MHz) | $P_{OE}$ | 2.5‡ min | W |
| Collector-to-Base Capacitance ($V_{CB}$ = 30 V, $I_C$ = 0, f = 1 MHz) | $C_{obo}$ | 10 | pF |
| Gain-Bandwidth Product ($V_{CE}$ = 28 V, $I_C$ = 125 mA) | $f_T$ | 350 min | MHz |

▲ Measured at a current where the breakdown voltage is a minimum.
‡ For conditions given, minimum efficiency = 50%.




## RF POWER TRANSISTOR 40608

Si n-p-n "overlay" epitaxial type used for operation as a class A wide-band power amplifier in vhf circuits. JEDEC TO-39, Outline No.15.

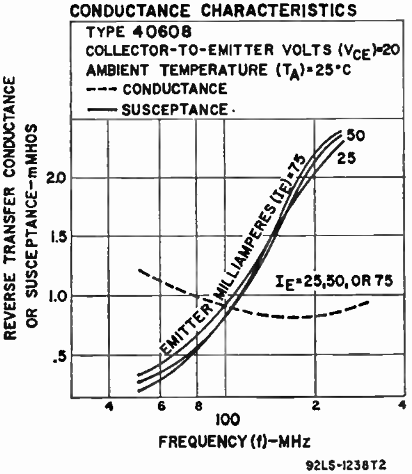
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Base Voltage | $V_{CBO}$ | 40 | V |
| Collector-to-Emitter Voltage ($V_{BE}$ = 100 Ω) | $V_{CER}$ | 40 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 2 | V |
| Collector Current | $I_C$ | 0.4 | A |
| Transistor Dissipation: | | | |
| $T_C$ up to 25°C | $P_T$ | 3.5 | W |
| $T_C$ above 25°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 230 | °C |

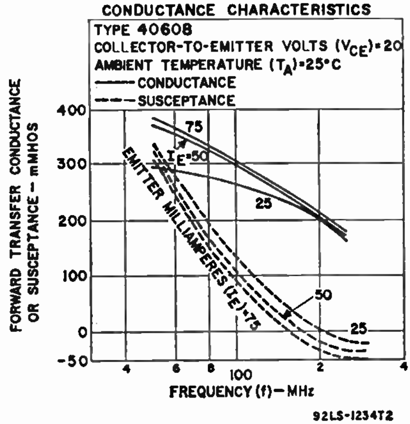
## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Collector-to-Base Breakdown Voltage ($I_C$ = 0.1 mA, $I_E$ = 0) | $V_{(BR)CBO}$ | 40 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 0.1 mA, $I_C$ = 0) | $V_{(BR)EBO}$ | 2 min | V |
| Collector-to-Emitter Sustaining Voltage ($I_C$ = 50 mA, $R_{BE}$ = 100 Ω pulsed through inductor L = 20 mH, df = 50%) | $V_{CER}$(sus) | 40 min | V |
| Collector-to-Emitter Saturation Voltage ($I_B$ = 10 mA, $I_C$ = 50 mA) | $V_{CE}$(sat) | 1 max | V |
| Collector-Cutoff Current ($V_{CE}$ = 20 V, $I_B$ = 0) | $I_{CEO}$ | 100 max | μA |
| Collector-to-Base Capacitance ($V_{CB}$ = 30 V, $I_E$ = 0, f = 1 MHz) | $C_{obo}$ | 3 max | pF |
| Gain-Bandwidth Product ($V_{CE}$ = 15 V, $I_C$ = 50 mA) | $f_T$ | 700 min | MHz |
| Static Forward-Current Transfer Ratio ($V_{CE}$ = 15 V, $I_C$ = 50 mA) | $h_{FE}$ | 35 to 120 | |
| Voltage Gain ($V_{CE}$ = 15 V, $I_C$ = 50 mA) | VG | 11 min | dB |
| Cross Modulation at 46 dB mV ($V_{CE}$ = 15 V, $I_C$ = 50 mA, $R_G$ and $R_L$ = 75 Ω) | CM | −57 | dB |

TYPICAL REVERSE-TRANSFER CONDUCTANCE CHARACTERISTICS

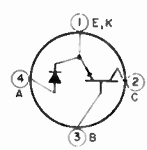



TYPICAL FORWARD-TRANSFER CONDUCTANCE CHARACTERISTICS




# 40675 RF POWER TRANSISTOR

Si n-p-n "overlay" epitaxial planar type used in linear applications to provide high power in class A or B rf amplifier service. It is intended for 2 to 30 MHz single-sideband power amplifiers operating from a 28-volt power supply. Outline No.49.

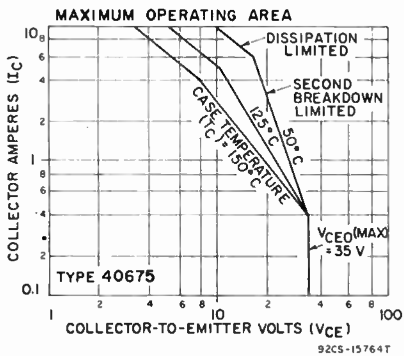


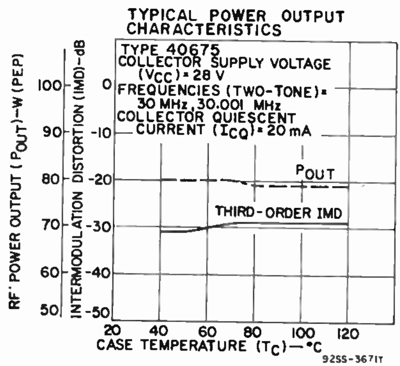

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| Reverse bias = −1.5 V | $V_{CEV}$ | 65 | V |
| Base open | $V_{CEO}$ | 35 | V |
| Emitter-to-Base Voltage | $V_{EBO}$ | 3.5 | V |
| Collector Current | $I_C$ | 10 | A |
| Peak Collector Current | $i_C$ | 30 | A |
| Diode Current (DC max) | $I_F$ | 100 | mA |
| Transistor Dissipation: | | | |
| $T_C$ up to 50°C | $P_T$ | 100 | W |
| $T_C$ above 50°C | $P_T$ | See curve page 300 | |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −65 to 200 | °C |
| Storage | $T_{STG}$ | −65 to 200 | °C |
| Case-Soldering Temperature (10 s max) | $T_C$ | 230 | °C |

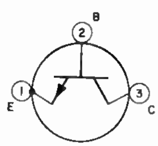
**CHARACTERISTICS (At case temperature = 25°C)**

| | | | |
|---|---|---|---|
| Collector-to-Emitter Sustaining Voltage: | | | |
| $V_{BE}$ = −1.5 V, $I_C$ = 200 mA, pulsed through inductor L = 25 mH, df = 50% | $V_{CEV}(sus)$ | 65 min | V |
| $I_C$ = 200 mA, pulsed through inductor L = 25 mH, df = 50% | $V_{CEO}(sus)$ | 35 min | V |
| Emitter-to-Base Breakdown Voltage ($I_E$ = 20 mA) | $V_{(BR)EBO}$ | 3.5 min | V |
| Collector-to-Emitter Cutoff Current: | | | |
| $V_{CE}$ = 60 V | $I_{CES}$ | 30 max | mA |
| $V_{CE}$ = 30 V | $I_{CEO}$ | 30 max | mA |
| Compensating Diode Forward Voltage Drop ($I_D$ = 10 mA) | $V_F$ | 0.8 max | V |
| Collector-to-Base ($V_{CB}$ = 30 V, f = 1 MHz) | $C_{cb}$ | 250 max | pF |
| RF Power Output: | | | |
| Average ($V_{CE}$ = 28 V, Quiescent $I_C$ = 20 mA) | $P_{OE}$ | 37.5 min | W |
| Peak ($V_{CE}$ = 28 V, Quiescent $I_C$ = 20 mA) | $P_{OE}$ | 75 min | W |
| Collector Efficiency ($V_{CE}$ = 28 V, Quiescent $I_C$ = 20 mA) | $\eta_C$ | 40 min | % |
| Intermodulation Distortion ($V_{CE}$ = 28 V, Quiescent $I_C$ = 20 mA) | IMD | 30 max | dB |
| Power Gain ($V_{CE}$ = 28 V, Quiescent $I_C$ = 20 mA) | $G_{PE}$ | 13 min | dB |
| Thermal Resistance, Junction-to-Case | $\theta_{J-C}$ | 1.5 max | °C/W |



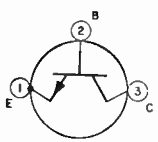




## RF POWER TRANSISTOR 40665




Si n-p-n "overlay" epitaxial type used in class A, B, and C amplifiers, frequency multipliers and oscillators designed for use in vhf applications. JEDEC TO-60, Outline No.23. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N3632.

## RF POWER TRANSISTOR 40666




Si n-p-n "overlay" epitaxial type used in class A, B, and C amplifiers, frequency multipliers and oscillators designed for use in vhf applications. JEDEC TO-60, Outline No.23. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N3375.

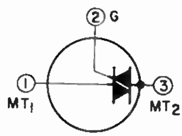
# Technical Data for Thyristors

THIS section contains detailed data for all current RCA triacs, silicon controlled rectifiers (SCR's), and diacs. These devices are listed in order of ascending current (and voltage) ratings.

In selection of devices for use in new electronic equipment, a prospective user should refer to the appropriate section of the Selection Guide included earlier in the Manual. For the reader who requires data on specific types, a complete numerical-alphabetical-numerical index to all current RCA solid-state devices is provided immediately following the Circuits Section in the back of the Manual.

## Triacs

### 40769 0.5A, 200V
### 40770 0.5A, 400V




Si gate-controlled full-wave types used for control-system application in airborne and ground-support type equipment. JEDEC TO-5 (modified), Outline No.7. See Mounting Hardware for desired mounting arrangement.

**MAXIMUM RATINGS (For sinusoidal supply voltage up to 400 Hz with resistive or inductive load)**

| | 40769 | | 40770 | |
|---|---|---|---|---|
| $V_{DROM}$* ($T_J$ = −50 to 100°) | 200 | | 400 | V |
| $I_{T(RMS)}$ (conduction angle = 360°): | | | | |
| $T_C$ = 90°C | | 0.5 | | A |
| $T_A$ = 25°C without heat sink | | 0.4 | | A |
| $I_{TSM}$ (1 cycle sinusoidal principal voltage): | | | | |
| 400 Hz | | 50 | | A |
| 60 Hz | | 25 | | A |
| di/dt ($V_{DM}$ = $V_{DROM}$, $I_{GT}$ = 60 mA, $t_r$ = 0.1 μs) | | 100 | | A/μs |
| $I_{GTM}$‡ (1 μs max) | | 1 | | A |
| $P_{GM}$ (1 μs max) | | 10 | | W |
| $P_{G(AV)}$ ($T_C$ = 60°) | | 0.15 | | W |
| $P_{G(AV)}$ ($T_A$ = 25°C without heat sink) | | 0.05 | | W |
| $T_{STG}$ | | −50 to 150 | | °C |
| $T_C$ | | −50 to 100 | | °C |
| $T_L$ (10 s max) | | 225 | | °C |

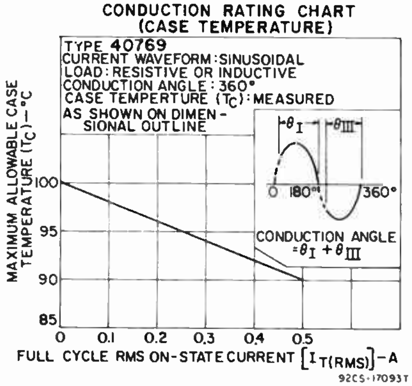
**CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)**

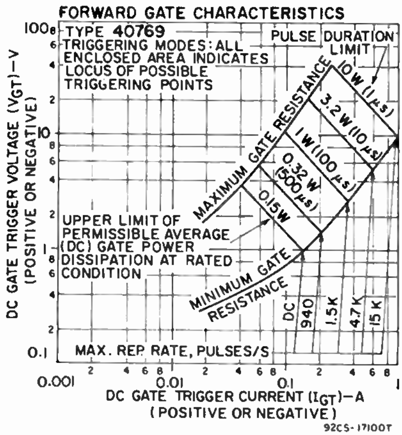
| | | |
|---|---|---|
| $I_{DROM}$* ($T_J$ = 100°C, $V_{DROM}$ = max rated value | 0.2 typ; 0.75 max | mA |
| $V_{TM}$* ($i_T$ = 30 A peak) | 1.7 typ; 2.2 max | V |
| $I_{HO}$* (initial principal current = 150 mAdc, $v_D$ = 12 V | 7 typ; 15 max | mA |

## CHARACTERISTICS (cont'd)

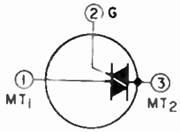
| | | |
|---|---|---|
| Commutating dv/dt* ($v_D$ = $V_{DROM}$, $I_{T(RMS)}$ = 0.5 A, commutating di/dt = 1.8 A/ms, gate unenergized, $T_C$ = 90°C | 1 min; 4 typ | V/µs |
| Critical dv/dt* ($v_D$ = $V_{DROM}$, exponential voltage rise, $T_C$ = 100°C) | 10 min; 100 typ | V/µs |
| $I_{GT}$*‡ ($v_D$ = 12 Vdc, $R_L$ = 30 Ω): | | |
| I+ mode, $V_{MT2}$ positive, $V_G$ positive | 3.5 typ; 10 max | mA |
| I- mode, $V_{MT2}$ positive, $V_G$ negative | 7 typ; 10 max | mA |
| III+ mode, $V_{MT2}$ negative, $V_G$ positive | 7 typ; 10 max | mA |
| III- mode, $V_{MT2}$ negative, $V_G$ negative | 3.5 typ; 10 max | mA |
| $V_{GT}$*‡ ($v_D$ = 12 Vdc, $R_L$ = 30 Ω) | 1 typ; 2.2 max | V |
| $V_{GT}$*‡ ($v_D$ = $V_{DROM}$, $R_L$ = 125 Ω, $T_C$ = 100°C | 0.15 min | V |
| $t_{gt}$ ($v_D$ = $V_{DROM}$, $I_{GT}$ = 60 mA, $t_r$ = 0.1 µs, $i_T$ = 10 A peak) | 1.8 typ; 2.5 max | µs |
| $\theta_{J-C}$ | 8.5 max | °C/W |

* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.
‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.




## 0.5A, 200V — 40771
## 0.5A, 400V — 40772



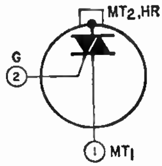

Si gate-controlled full-wave types used for control-system application in airborne and ground-support type equipment. JEDEC TO-5 (modified), Outline No.7. See Mounting Hardware for desired mounting arrangement. Types 40771 and 40772 are identical with types 40769 and 40770, respectively, except for the following items:

## CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

| | 40771 | 40772 | |
|---|---|---|---|
| $I_{HO}$* (initial principal current = 150 mAdc, $v_D$ = 12 V) | 15 typ; 30 max | | mA |
| $I_{GT}$* ($v_D$ = 12 Vdc, $R_L$ = 30 Ω): | | | |
| I+ mode, $V_{MT2}$ positive, $V_G$ positive | 5 typ; 25 max | | mA |
| I- mode, $V_{MT2}$ positive, $V_G$ negative | 10 typ; 40 max | | mA |
| III+ mode, $V_{MT2}$ negative, $V_G$ positive | 10 typ; 40 max | | mA |
| III- mode, $V_{MT2}$ negative, $V_G$ negative | 5 typ; 25 max | | mA |

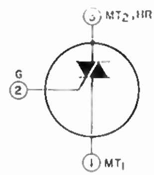
* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.

## 40531–40536 2.5A, 100V—400V




Si gated bidirectional types used for power-control and power-switching applications. JEDEC TO-5 (with heat radiator), Outline No.8. Types 40531, 40532, 40533, 40534, 40535, and 40536 are electrically identical with types 40525, 40526, 40527, 40528, 40529, and 40530, respectively.

## 40767 1.6A, 100V



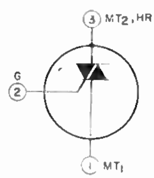

Si gate-controlled full-wave type used for switching from an off-state to an on-state for either polarity of applied voltage with positive or negative gate triggering voltages. This type can be controlled with economical transistor circuits for use in low-power phase control and load-switching applications. JEDEC TO-5 (with heat radiator), Outline No.8. This type is identical with type 40525 except for the following items:

**CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)**

$I_{GT}$ ($v_D$ = 12 Vdc, $R_L$ = 30 Ω):

| | | |
|---|---|---|
| $I^+$ mode, $V_{MT2}$ positive, $V_G$ positive | 1 typ; 4 max | mA |
| $I^-$ mode, $V_{MT2}$ positive, $V_G$ negative | 2 typ; 4 max | mA |
| $III^+$ mode, $V_{MT2}$ negative, $V_G$ positive | 2 typ; 4 max | mA |
| $III^-$ mode, $V_{MT2}$ negative, $V_G$ negative | 1 typ; 4 max | mA |

## 40761 1.6A, 400V



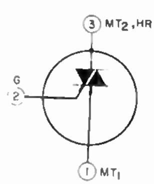

Si gate-controlled full-wave type used for switching from an off-state to an on-state for either polarity of applied voltage with positive or negative gate triggering voltages. This type can be controlled with economical transistor circuits for use in low-power phase control and load-switching applications. JEDEC TO-5 (with heat radiator), Outline No.8. This type is identical with type 40526 except for the following items:

**CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)**

$I_{GT}$ ($v_D$ = 12 Vdc, $R_L$ = 30 Ω):

| | | |
|---|---|---|
| $I^+$ mode, $V_{MT2}$ positive, $V_G$ positive | 1 typ; 4 max | mA |
| $I^-$ mode, $V_{MT2}$ positive, $V_G$ negative | 2 typ; 4 max | mA |
| $III^+$ mode, $V_{MT2}$ negative, $V_G$ positive | 2 typ; 4 max | mA |
| $III^-$ mode, $V_{MT2}$ negative, $V_G$ negative | 1 typ; 4 max | mA |

## 40762 1.6A, 400V

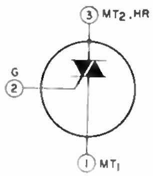



Si gate-controlled full-wave type used for switching from an off-state to an on-state for either polarity of applied voltage with positive or negative gate triggering voltages. This type can be controlled with economical transistor circuits for use in low-power phase control and load-switching applications. JEDEC TO-5 (with heat radiator), Outline No.8. This type is identical with type 40527 except for the following items:

**CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)**

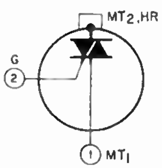
| | | |
|---|---|---|
| $I_{GT}$ ($v_D$ = 12 Vdc, $R_L$ = 30 Ω): | | |
| $I^+$ mode, $V_{MT2}$ positive, $V_G$ positive | 1 typ; 4 max | mA |
| $I^-$ mode, $V_{MT2}$ positive, $V_G$ negative | 2 typ; 4 max | mA |
| $III^+$ mode, $V_{MT2}$ negative, $V_G$ positive | 2 typ; 4 max | mA |
| $III^-$ mode, $V_{MT2}$ negative, $V_G$ negative | 1 typ; 4 max | mA |

## 1.9A, 100V—600V 40684–40687




Si gate-controlled full-wave types used for low-power phase-control and load-switching applications. Outline No.8. Types 40684, 40685, 40686, and 40687 are electrically identical with types 2N5754, 2N5755, 2N5756, and 2N5757, respectively.

## 2.2A, 200V 40509
## 2.2A, 400V 40510




Si gate-controlled full-wave types used for the control of ac loads in applications such as heating controls, motor controls, light dimmers, and power switching systems. Outline No.8. Types 40509 and 40510 are identical with types 40485 and 40486, respectively, except for the following items:

**MAXIMUM RATINGS (For sinusoidal supply voltage at 50/60 Hz with resistive or inductive load)**

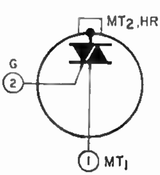
| | 40509 | 40510 |
|---|---|---|
| $I_{T(RMS)}$ ($T_A$ up to 100°C, conduction angle = 360°) | See Rating Chart (Ambient Temperature) | |

**CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)**

| | | |
|---|---|---|
| Commutating dv/dt* ($V_D$ = $V_{DROM}$, commutating di/dt = 3.2 A/ms): | | |
| $I_{T(RMS)}$ and $T_A$ specified by curve A in Rating Chart (Ambient Temperature) | 3 min; 10 typ | V/$\mu$s |
| $I_{T(RMS)}$ and $T_A$ specified by curve B in Rating Chart (Ambient Temperature) | 4 min; 12 typ | V/$\mu$s |
| $\theta_{J-A}$ | See Rating Chart (Ambient Temperature) | |

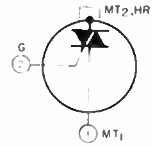
* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.

## 2.2A, 200V 40511
## 2.2A, 400V 40512




Si gated bidirectional integral-trigger types used for power-control and power-switching applications. Outline No.8. Types 40511 and 40512 are electrically identical with types 40431 and 40432, respectively.

# 40731 2.3, 200V
# 40732 2.3, 400V




Si gate-controlled full-wave ac-switching types with the RCA-CA3059 integrated-circuit zero-voltage switch as a triggering circuit. Outline No. 8. Types 40731 and 40732 are identical with types 40729 and 40730, respectively, except for the following items:

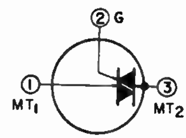
## MAXIMUM RATINGS (For sinusoidal supply voltage at f = 50/60 Hz with resistive or inductive load)

| | 40731 | 40732 | |
|---|---|---|---|
| $I_{T(RMS)}$ ($T_A$ = 100°C, conduction angle = 360°) | 2.3 | | A |

## CHARACTERISTICS (At maximum electrical ratings = 25°C)

| | | |
|---|---|---|
| $V_{TM}$ ($i_T$ = 30 A) | 1.6 typ; 2.25 max | V |

# 2N5754–2N5757 2.5A, 100V—600V




Si gate-controlled full-wave types used for low-power phase-control and load-switching applications. Outline No.60.

## MAXIMUM RATINGS (For sinusoidal supply voltage at f = 50/60 Hz with resistive or inductive load)

| | 2N5754 | 2N5755 | 2N5756 | 2N5757 | |
|---|---|---|---|---|---|
| $V_{DROM}$* ($T_J$ = 65°C to 100°C) | 100 | 200 | 400 | 600 | V |
| $I_{T(RMS)}$ ($T_C$ = 70°C, conduction angle = 360°) | | 2.5 | | | A |
| $I_{TSM}$: | | | | | |
| 1 cycle of principal voltage at 60 Hz | | 25 | | | A |
| 1 cycle of principal voltage at 50 Hz | | 21 | | | A |
| $I_{GTM}$ (1 μs max) | | 1 | | | A |
| $P_{GM}$‡ (1 μs max) | | 10 | | | W |
| $P_{G(AV)}$: | | | | | |
| $T_C$ = 60°C | | | | | |
| $T_A$ = 25°C | | 0.05 | | | W |
| $T_{STG}$ | | −65 to 150 | | | °C |
| $T_C$(opr) | | −65 to 100 | | | °C |
| $T_L$ (10 s max) | | 225 | | | °C |

## CHARACTERISTICS (At maximum electrical ratings = 25°C)

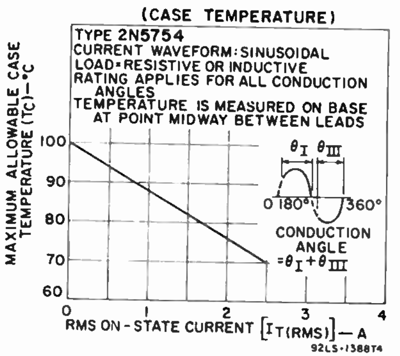
| | | |
|---|---|---|
| $I_{DROM}$ ($T_J$ = 100°C, $V_{DROM}$ = max rated value) | 0.2 typ; 0.75 max | mA |
| $V_{TM}$: | | |
| $i_T$ = 10 A | 2.2 typ; 2.6 max | V |
| $i_T$ = 3.5 A | 1.8 max | V |
| $I_{HO}$ (initial principal current = 150 mA (dc) $V_D$ = 12 V): | | |
| $T_C$ = 25°C | 6 typ; 35 max | mA |
| $T_C$ = −65°C | 20 typ; 82 max | mA |
| dv/dt ($V_D$ = $V_{DROM}$, exponential voltage rise $T_C$ = 100°C) | 10 min; 100 typ | V/μs |
| $I_{GT}$ ($V_D$ = 12 Vdc, $R_L$ = 30 Ω): | | |
| I + mode, $V_{MT2}$ positive, $V_G$ positive | 5 typ; 25 max | mA |
| I − mode, $V_{MT2}$ positive, $V_G$ negative | 10 typ; 40 max | mA |
| III + mode, $V_{MT2}$ negative, $V_G$ positive | 10 typ; 40 max | mA |
| III − mode, $V_{MT2}$ negative, $V_G$ negative | 5 typ; 25 max | mA |

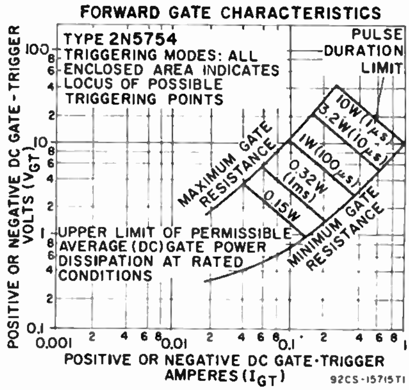
## CHARACTERISTICS (cont'd)

| | | |
|---|---|---|
| $I_{GT}$ ($V_D$ = 12 Vdc, $R_L$ = 30 Ω, $T_C$ = −65 °C): | | |
| I + mode, $V_{MT2}$ positive, $V_G$ positive | 30 typ; 60 max | mA |
| I − mode, $V_{MT2}$ positive, $V_G$ negative | 40 typ; 100 max | mA |
| III + mode, $V_{MT2}$ negative, $V_G$ positive | 40 typ; 100 max | mA |
| III − mode, $V_{MT2}$ negative, $V_G$ positive | 30 typ; 60 max | mA |
| $V_{GT}$ ($V_D$ = 12 Vdc, $R_L$ = 30 Ω): | | |
| $T_C$ = 25°C | 0.9 typ; 2.2 max | V |
| $T_C$ = −65°C | 1.5 typ; 3 max | V |
| $V_{GT}$ ($V_D$ = $V_{DROM}$, $R_L$ = 125 Ω, $T_C$ = 100°C) | 0.2 min | V |
| $\theta_{J-C}$ (steady-state) | 8.5 max | °C/W |

• For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.

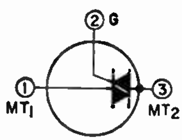
‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.




# 40525–40530

**2.5A, 100V—400V**




Si gate-controlled full-wave types used for switching from a blocking state to a conducting state for either polarity of applied voltage with positive or negative gate triggering. These types can be controlled with economical transistor circuits for use in low-power phase-control and load-switching applications. JEDEC TO-5 (modified), Outline No.5.

**MAXIMUM RATINGS (For sinusoidal ac supply voltage at f = 50 and 60 Hz with resistive or inductive load)**

| | 40525 | 40526 | 40527 | 40528 | 40529 | 40530 | |
|---|---|---|---|---|---|---|---|
| $V_{DROM}$• (gate open): | | | | | | | |
| $T_J$ = −40 to 90°C | 100 | 200 | 400 | — | — | — | V |
| $T_J$ = −40 to 100°C | — | — | — | 100 | 200 | 400 | V |
| $I_{T(RMS)}$ (conduction angle = 360°) | | | | | | | |
| $T_C$ = 60°C | | 2.5 | | — | — | — | A |
| $T_C$ = 70°C | — | — | — | | 2.5 | | A |
| $T_A$ = 25°C | | 0.35 | | | 0.4 | | A |
| $I_{TSM}$ (1 cycle of principal voltage) | | | | 25 | | | A |

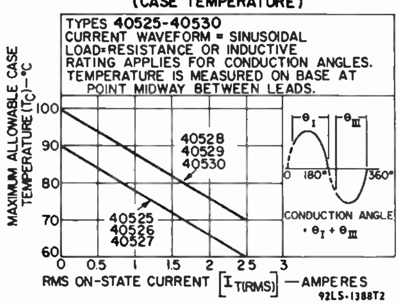
## MAXIMUM RATINGS (cont'd)

<table>
<tr><th></th><th>40525</th><th>40526</th><th>40527</th><th>40528</th><th>40529</th><th>40530</th><th></th></tr>
<tr><td>$I_{GTM}$■ (1 µs max)</td><td colspan="6">0.5</td><td>A</td></tr>
<tr><td>$P_{GM}$■ (1 µs max)</td><td colspan="6">10</td><td>W</td></tr>
<tr><td>$P_{G(AV)}$:</td><td colspan="6"></td><td></td></tr>
<tr><td>$T_A$ = 25°C</td><td colspan="6">0.05</td><td>W</td></tr>
<tr><td>$T_C$ = 60°C</td><td colspan="6">0.15</td><td>W</td></tr>
<tr><td>$T_{stg}$●</td><td colspan="6">−40 to 150</td><td>°C</td></tr>
<tr><td>$T_C$●</td><td colspan="6">−40 to 100</td><td>°C</td></tr>
</table>

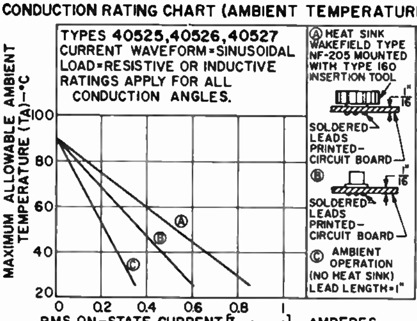
## CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

<table>
<tr><th></th><th>40525</th><th>40526</th><th>40527</th><th>40528</th><th>40529</th><th>40530</th><th></th></tr>
<tr><td>$I_{DROM}$ (gate open, $V_{DROM}$ = max rated value):</td><td colspan="6"></td><td></td></tr>
<tr><td>$T_J$ = 100°C</td><td>—</td><td>—</td><td>—</td><td colspan="3">0.2 typ; 0.75 max</td><td>mA</td></tr>
<tr><td>$T_J$ = 90°C</td><td colspan="3">0.2 typ; 0.75 max</td><td>—</td><td>—</td><td>—</td><td>mA</td></tr>
<tr><td>$v_T$● ($i_T$ = 10 A peak)</td><td colspan="6">1.7 typ; 2.2 max</td><td>V(peak)</td></tr>
<tr><td>$I_{HO}$● (initial principal current = 150 mAdc)</td><td colspan="3">2 typ; 5 max</td><td colspan="3">6.5 typ; 15 max</td><td>mA(dc)</td></tr>
<tr><td>Critical dv/dt● ($v_D$ = $V_{DROM}$, exponential voltage rise, gate open):</td><td colspan="6"></td><td></td></tr>
<tr><td>$T_C$ = 100°C</td><td>—</td><td>—</td><td>—</td><td colspan="3">10</td><td>V/µs</td></tr>
<tr><td>$T_C$ = 90°C</td><td colspan="3">5</td><td>—</td><td>—</td><td>—</td><td>V/µs</td></tr>
<tr><td>$I_{GT}$●■ ($v_D$ = 6 Vdc, $R_L$ = 39 Ω):</td><td colspan="6"></td><td></td></tr>
<tr><td>I+ mode, $V_{MT2}$ positive, $V_G$ positive</td><td colspan="3">1 typ; 3 max</td><td colspan="3">3.5 typ; 10 max</td><td>mA(dc)</td></tr>
<tr><td>I- mode, $V_{MT2}$ positive, $V_G$ negative</td><td colspan="3">2 typ; 3 max</td><td colspan="3">7 typ; 10 max</td><td>mA(dc)</td></tr>
<tr><td>III+ mode, $V_{MT2}$ negative, $V_G$ positive</td><td colspan="3">2 typ; 3 max</td><td colspan="3">7 typ; 10 max</td><td>mA(dc)</td></tr>
<tr><td>III- mode, $V_{MT2}$ negative, $V_G$ negative</td><td colspan="3">1 typ; 3 max</td><td colspan="3">3.5 typ; 10 max</td><td>mA(dc)</td></tr>
</table>

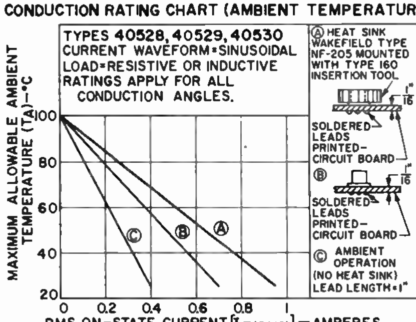
CONDUCTION RATING CHART (CASE TEMPERATURE)




CONDUCTION RATING CHART (AMBIENT TEMPERATURE)




CONDUCTION RATING CHART (AMBIENT TEMPERATURE)

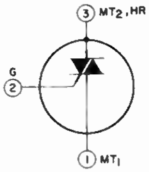


## CHARACTERISTICS (cont'd)

| | | | |
|---|---|---|---|
| $V_{GT}$●■: | | | |
| $v_D$ = 6 Vdc, $R_L$ = 39 Ω | 1 typ; 2.2 max | | V |
| $v_D$ = $V_{DROM}$, $R_L$ = 125 Ω, $T_C$ = 100°C | — — — | 0.15 min | V |
| $v_D$ = $V_{DROM}$, $R_L$ = 125 Ω, $T_C$ = 90°C | 0.15 min | — — — | V |

● For either polarity of main-terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1

■ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.




# 2.5A, 100V—400V 40693–40695

Si gate-controlled full-wave ac-switching types used with the RCA-CA3059 integrated-circuit zero-voltage switch as a triggering circuit. Outline No. 8.

## MAXIMUM RATINGS (For sinusoidal supply voltage at f = 50/60 Hz with resistive or inductive load)

| | 40693 | 40694 | 40695 | |
|---|---|---|---|---|
| $V_{DROM}$* (Gate open, $T_J$ = −65°C to 100°C) | 100 | 200 | 400 | V |
| $I_{T(RMS)}$ ($T_A$ = 70°C, conduction angle = 360°) | | 2.5 | | A |
| $I_{TSM}$: | | | | |
| 1 cycle of principal voltage at 60 Hz | | 25 | | A |
| 1 cycle of principal voltage at 50 Hz | | 21 | | A |
| $I_{GTM}$‡ (1 μs max.) | | 1 | | A |
| $P_{GM}$‡ (1 μs max.) | | 10 | | W |
| $P_{G(AV)}$: | | | | |
| $T_C$ = 60°C | | 0.15 | | W |
| $T_A$ = 25°C | | 0.05 | | W |
| $T_{STG}$ | | −65 to 150 | | °C |
| $T_C$(opr) | | −65 to 100 | | °C |
| $T_L$ (10 s max.) | | 225 | | °C |

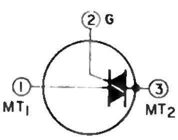
## CHARACTERISTICS (At maximum electrical ratings = 25°C)

| | 40693 | 40694 | 40695 | |
|---|---|---|---|---|
| $I_{DROM}$ ($T_J$ = 100°C) | | 0.2 typ; 0.75 max | | mA |
| $V_{TM}$: | | | | |
| $i_T$ = 10 A | | 2.2 typ; 2.6 max | | V |
| $i_T$ = 3.5 A | | 1.8 max | | V |
| $I_{HO}$ (Gate open, initial principal current = 150 mA, $V_D$ = 12 V): | | | | |
| $T_C$ = 25°C | | 6 typ; 25 max | | mA |
| $T_C$ = −65°C | | 20 typ; 82 max | | mA |
| dv/dt ($V_D$ = $V_{DROM}$, exponential voltage rise, gate open, $T_C$ = 100°C) | | 10 min; 100 typ | | V/μs |
| $I_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω): | | | | |
| I+ mode, $V_{MT2}$ positive, $V_G$ positive | | 45 max | | mA |
| III+ mode, $V_{MT2}$ negative, $V_G$ positive | | 45 max | | mA |
| $V_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω) | | 1.5 max | | V |
| $\theta_{J-C}$ (steady-state) | | 8.5 max | | °C/W |

* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.

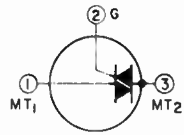
‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.

# 2.5, 100V—400V 40696–40698




Si gate-controlled full-wave ac-switching types used with the RCA-CA3059 integrated-circuit zero-voltage switch as a triggering circuit. Outline No. 5. Types 40696, 40697, and 40698 are electrically identical with types 40693, 40694, and 40695, respectively.

## 40766 2.5A, 100V

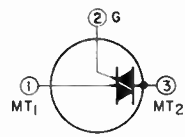



Si gate-controlled full-wave type used for switching from an off-state to an on-state for either polarity of applied voltage with positive or negative gate triggering voltages. This type can be controlled with economical transistor circuits for use in low-power phase control and load-switching applications. JEDEC TO-5 (modified), Outline No.5. This type is identical with type 40525 except for the following items:

### CHARACTERISTICS (At maximum electrical ratings at $T_C = 25°C$)

| | | |
|---|---|---|
| $I_{GT}$ ($v_D$ = 12 Vdc, $R_L$ = 30 Ω): | | |
| $I^+$ mode, $V_{MT2}$ positive, $V_G$ positive | 1 typ; 4 max | mA |
| $I^-$ mode, $V_{MT2}$ positive, $V_G$ negative | 2 typ; 4 max | mA |
| $III^+$ mode, $V_{MT2}$ negative, $V_G$ positive | 2 typ; 4 max | mA |
| $III^-$ mode, $V_{MT2}$ negative, $V_G$ negative | 1 typ; 4 max | mA |

## 40691 2.5A, 200V

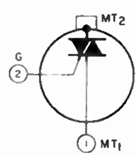



Si gate-controlled full-wave type used for switching from an off-state to an on-state for either polarity of applied voltage with positive or negative gate triggering voltages. This type can be controlled with economical transistor circuits for use in low-power phase control and load-switching applications. JEDEC TO-5 (modified), Outline No.5. This type is identical with type 40526 except for the following items:

### CHARACTERISTICS (At maximum electrical ratings at $T_C = 25°C$)

| | | |
|---|---|---|
| $I_{GT}$ ($v_D$ = 12 Vdc, $R_L$ = 30 Ω): | | |
| I + mode, $V_{MT2}$ positive, $V_G$ positive | 1 typ; 4 max | mA |
| I − mode, $V_{MT2}$ positive, $V_G$ negative | 2 typ; 4 max | mA |
| III + mode, $V_{MT2}$ negative, $V_G$ positive | 2 typ; 4 max | mA |
| III − mode, $V_{MT2}$ negative, $V_G$ negative | 1 typ; 4 max | mA |

## 40773 2.5A, 200V
## 40774 2.5A, 400V




Si gate-controlled full-wave types used for control-systems application in airborne and ground-support type equipment. JEDEC TO-5 (modified), Outline No.7. See Mounting Hardware for desired mounting arrangement.

### MAXIMUM RATINGS (For sinusoidal supply voltage up to 400 Hz with resistive or inductive load)

| | 40773 | | 40774 | |
|---|---|---|---|---|
| $V_{DROM}$* ($T_J$ = −50 to 100°C) | 200 | | 400 | V |
| $I_{T(RMS)}$ (conduction angle = 360°): | | | | |
| $T_C$ = 90°C | | 2.5 | | A |
| $T_A$ = 25°C without heat sink | | 0.5 | | A |
| $I_{TSM}$ (1 cycle sinusoidal principal voltage): | | | | |
| 400 Hz | | 200 | | A |
| 60 Hz | | 100 | | A |
| di/dt ($V_{DM}$ = $V_{DROM}$, $I_{GT}$ = 80 mA, $t_r$ = 0.1 μs) | | 150 | | A/μs |
| $I_{GTM}$‡ (1 μs max) | | 4 | | A |

## MAXIMUM RATINGS (cont'd)

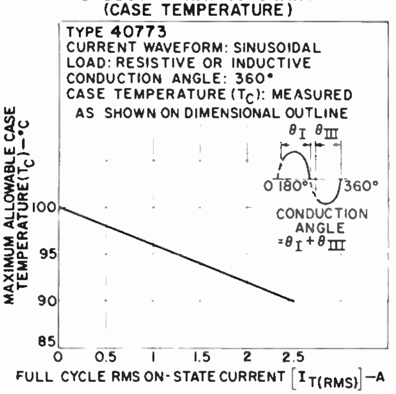
| | | |
|---|---|---|
| $P_{GM}$ (1 μs max, $I_{GTM}$ < 4 A) | 16 | W |
| $P_{G(AV)}$ | 0.2 | W |
| $T_{STG}$ | −50 to 150 | °C |
| $T_C$ | −50 to 100 | °C |
| $T_L$ (10 s max) | 225 | °C |

## CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

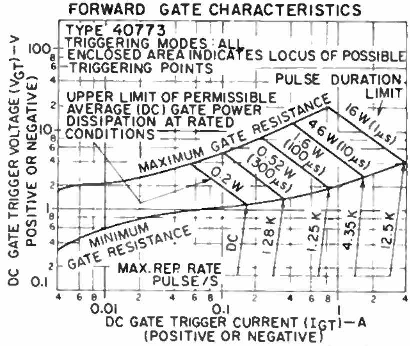
| | | |
|---|---|---|
| $I_{DROM}$* ($T_J$ = 100°C, $V_{DROM}$ = max rated value) | 0.2 typ; 4 max | mA |
| $V_{TM}$* ($i_T$ = 30 A peak) | 1.6 typ; 2.25 max | V |
| $I_{HO}$* (initial principal current = 150 mAdc, $v_D$ = 12 V | 15 typ; 30 max | mA |
| Commutating dv/dt* ($v_D$ = $V_{DROM}$, $I_{T(RMS)}$ = 2.5 A, commutating di/dt = 8.9 A/ms, gate unenergized, $T_C$ = 90°C | 3 min; 10 typ | V/μs |
| Critical dv/dt* ($v_D$ = $V_{DROM}$, exponential voltage rise, $T_C$ = 100°C) | 30 min; 150 typ | V/μs |
| $I_{GT}$*‡ ($v_D$ = 12 Vdc, $R_L$ = 30 Ω): | | |
| I+ mode, $V_{MT2}$ positive, $V_G$ positive | 15 typ; 25 max | mA |
| I− mode, $V_{MT2}$ positive, $V_G$ negative | 25 typ; 40 max | mA |
| III+ mode, $V_{MT2}$ negative, $V_G$ positive | 25 typ; 40 max | mA |
| III− mode, $V_{MT2}$ negative, $V_G$ negative | 15 typ; 25 max | mA |
| $V_{GT}$*‡ ($v_D$ = 12 Vdc, $R_L$ = 30 Ω) | 1 typ; 2.2 max | V |
| $V_{GT}$*‡ ($v_D$ = $V_{DROM}$, $R_L$ = 125 Ω, $T_C$ = 100°C) | 0.2 min | V |
| $t_{gt}$ ($v_D$ = $V_{DROM}$, $I_{GT}$ = 80 mA, $t_r$ = 0.1 μs, $i_T$ = 10 A peak) | 1.8 typ; 2.5 max | μs |
| $\theta_{J-C}$ (steady-state) | 4 max | °C/W |

* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.
‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.

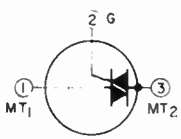
CONDUCTION RATING CHART (CASE TEMPERATURE)




FORWARD GATE CHARACTERISTICS




## 2.5A, 400V — 40692



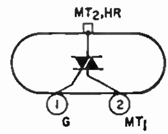

Si gate-controlled full-wave type used for switching from an off-state to an on-state for either polarity of applied voltage with positive or negative gate triggering voltages. This type can be controlled with economical transistor circuits for use in low-power phase control and load-switching applications. JEDEC TO-5 (modified), Outline No.5. This type is identical with type 40527 except for the following items:

## CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

| | | |
|---|---|---|
| $I_{GT}$ ($v_D$ = 12 Vdc, $R_L$ = 30 Ω): | | |
| I + mode, $V_{MT2}$ positive, $V_G$ positive | 1 typ; 4 max | mA |
| I − mode, $V_{MT2}$ positive, $V_G$ negative | 2 typ; 4 max | mA |
| III + mode, $V_{MT2}$ negative, $V_G$ positive | 2 typ; 4 max | mA |
| III − mode, $V_{MT2}$ negative, $V_G$ negative | 1 typ; 4 max | mA |

# 40502 3.3A, 200V
# 40503 3.3A, 400V

Si gate-controlled full-wave types for the control of ac loads in applications such as heating controls, motor controls, light dimmers, and power switching systems. JEDEC TO-66 (with heat radiator), Outline No.26. Types 40502 and 40503 are identical with types 40429 and 40430, respectively, except for the following items:

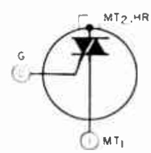



## CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

| | 40502 | 40503 | |
|---|---|---|---|
| $I_{DROM}$* ($T_J$ = 100°C, $V_{DROM}$ = max rated value) | 0.1 typ; 1.2 max | 0.2 typ; 1.2 max | mA |
| Commutating dv/dt* ($V_D$ = $V_{DROM}$, commutating di/dt = 3.2 A/ms, $T_C$ = 75°C): | | | |
| $I_{T(RMS)}$ and $T_A$ specified by curve A in Rating Chart (Ambient Temperature) | 3 min; 10 typ | | V/µs |
| $I_{T(RMS)}$ and $T_A$ specified by curve B in Rating Chart (Ambient Temperature) | 4 min; 12 typ | | V/µs |

* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.

# 40733 4.2, 200V
# 40734 4.2, 200V




Si gate-controlled full-wave ac-switching types used with the RCA-CA3059 integrated-circuit zero-voltage switch as a triggering circuit. Outline No. 59.

## MAXIMUM RATINGS (For sinusoidal supply voltage at f = 50/60 Hz with resistive or inductive load)

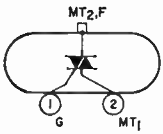
| | 40733 | 40734 | |
|---|---|---|---|
| $V_{DROM}$* (Gate open, $T_J$ = −65°C to 100°C) | 200 | 400 | V |
| $I_{T(RMS)}$ ($T_C$ = 75°C, conduction angle = 360°) | 4.2 | | A |
| $I_{TSM}$ (1 cycle of principal voltage) | 100 | | A |
| $I_{GTM}$‡ (1 µs max.) | 4 | | A |
| $P_{GM}$‡ (1 µs max.) | 16 | | W |
| $P_{G(AV)}$ | 0.2 | | W |
| $T_{STG}$ | −65 to 150 | | °C |
| $T_C$ (opr) | −65 to 100 | | °C |
| $T_L$ (10 s max.) | 225 | | °C |

## CHARACTERISTICS (At maximum electrical ratings = 25°C)

| | 40733 | 40734 | |
|---|---|---|---|
| $I_{DROM}$ ($T_J$ = 100°C) | 0.1 typ<br>4 max | 0.2 typ<br>4 max | mA |
| $V_{TM}$ ($i_T$ = 30 A) | 1.6 typ; 2.25 max | | V |
| $I_{HO}$ (Gate open, initial principal current = 150 mA) | 15 typ; 30 max | | mA |
| dv/dt ($V_D$ = $V_{DROM}$, exponential voltage rise, gate open, $T_C$ = 100°C) | 30 min<br>150 typ | 20 min<br>100 typ | V/µs |
| $I_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω): | | | |
| I+ mode, $V_{MT2}$ positive, $V_G$ positive | 45 max | | mA |
| III+ mode, $V_{MT2}$ negative, $V_G$ positive | 45 max | | mA |
| $V_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω) | 1.5 max | | V |
| $\theta_{J-HS}$ | 7 max | | °C/W |

* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.
‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.

## 6A, 200V 40429
## 6A, 400V 40430




Si gate-controlled full-wave types used for the control of ac loads in applications such as heating controls, motor controls, light dimmers, and power switching systems. JEDEC TO-66, Outline No.25. See Mounting Hardware for desired mounting arrangement.

### MAXIMUM RATINGS (For sinusoidal ac supply voltage at f = 50/60 Hz with resistive or inductive load)

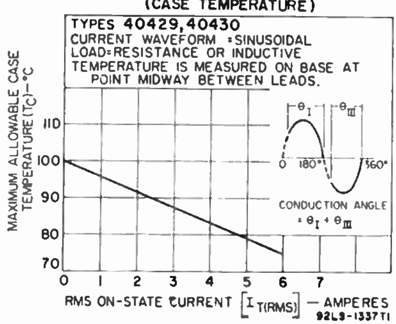
<table>
<tr><th></th><th>40429</th><th>40430</th><th></th></tr>
<tr><td>$V_{DROM}$* ($T_J$ = −65°C to 100°C)</td><td>200</td><td>400</td><td>V</td></tr>
<tr><td>$I_{T(RMS)}$ ($T_C$ = 75°C, conduction angle = 360°)</td><td colspan="2">6</td><td>A</td></tr>
<tr><td>$I_{T(RMS)}$ ($T_A$ up to 100°C, conduction angle = 360°)</td><td colspan="3">See Rating Chart (Ambient Temperature)</td></tr>
<tr><td>$I_{TSM}$ (1 cycle of principal voltage)</td><td colspan="2">100</td><td>A</td></tr>
<tr><td>$I_{GTM}$ (1 μs max)</td><td colspan="2">4</td><td>A</td></tr>
<tr><td>$P_{GM}$ (1 μs max, $I_{GTM} \leq$ 4 A peak)</td><td colspan="2">16</td><td>W</td></tr>
<tr><td>$P_{G(AV)}$</td><td colspan="2">0.2</td><td>W</td></tr>
<tr><td>$T_{STG}$</td><td colspan="2">−65 to 150</td><td>°C</td></tr>
<tr><td>$T_C$</td><td colspan="2">−65 to 100</td><td>°C</td></tr>
</table>

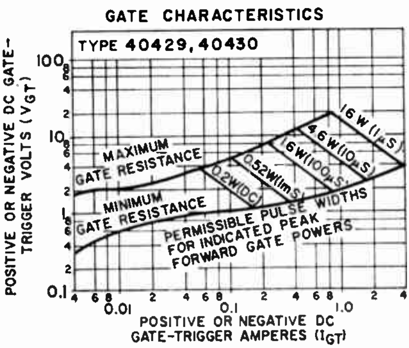
### CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

<table>
<tr><th></th><th>40429</th><th>40430</th><th></th></tr>
<tr><td>$I_{DROM}$* ($T_J$ = 100°C, $V_{DROM}$ = max rated value)</td><td>0.1 typ; 4 max</td><td>0.2 typ; 4 max</td><td>mA</td></tr>
<tr><td>$v_{TM}$* ($i_T$ = 30 A peak)</td><td colspan="2">1.8 typ; 2.25</td><td>V</td></tr>
<tr><td>$I_{HO}$* (initial principal = 150 mA dc)</td><td colspan="2">15 typ; 30 max</td><td>mA</td></tr>
<tr><td>Commutating dv/dt* ($V_D$ = $V_{DROM}$, $I_{T(RMS)}$ = 6 A, commutating di/dt = 3.2 A/ms, gate unenergized at $T_C$ = 75°C)</td><td colspan="2">3 min; 10 typ</td><td>V/μs</td></tr>
<tr><td>Critical dv/dt* ($V_D$ = $V_{DROM}$, exponential voltage rise, $T_C$ = 100°C)</td><td>30 min; 150 typ</td><td>20 min; 100 max</td><td>V/μs</td></tr>
<tr><td>$I_{GT}$*‡ ($V_D$ = 12 Vdc, $R_L$ = 12 Ω):</td><td colspan="2"></td><td></td></tr>
<tr><td>I+ mode, $V_{MT2}$ positive, $V_G$ positive</td><td colspan="2">15 typ; 25 max</td><td>mA</td></tr>
<tr><td>I− mode, $V_{MT2}$ positive, $V_G$ negative</td><td colspan="2">25 typ; 40 max</td><td>mA</td></tr>
<tr><td>III+ mode, $V_{MT2}$ negative, $V_G$ positive</td><td colspan="2">25 typ; 40 max</td><td>mA</td></tr>
<tr><td>III− mode, $V_{MT2}$ negative, $V_G$ negative</td><td colspan="2">15 typ; 40 max</td><td>mA</td></tr>
<tr><td>$V_{GT}$*‡ ($V_D$ = 12 Vdc, $R_L$ = 12 Ω)</td><td colspan="2">1 typ; 2.2 max</td><td>V</td></tr>
<tr><td>$V_{GT}$*‡ ($V_D$ = $V_{DROM}$, $R_L$ = 125 Ω, $T_C$ = 100°C)</td><td colspan="2">0.2 min</td><td>V</td></tr>
<tr><td>$t_{gt}$ ($V_D$ = $V_{DROM}$, $I_{GT}$ = 80 mA, $t_r$ = 0.1 μs, $i_T$ = 10 A)</td><td colspan="2">2.2</td><td>μs</td></tr>
<tr><td>$\theta_{J-C}$ (steady-state)</td><td colspan="2">4 max</td><td>°C/W</td></tr>
<tr><td>$\theta_{J-A}$</td><td colspan="3">See Rating Chart (Ambient Temperature)</td></tr>
</table>

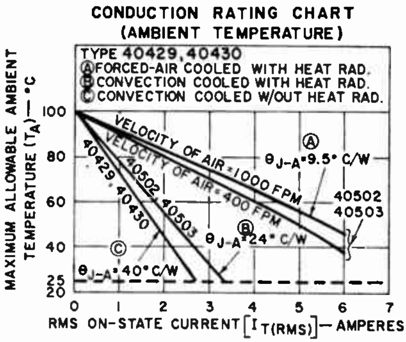
* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.
‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.
● This characteristic does not apply to types 40502 and 40503.

CONDUCTION RATING CHART (CASE TEMPERATURE)





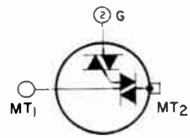

92SS-3785T




92LS-2049T1

# 40431 6A, 200V
# 40432 6A, 400V

Si gate-controlled full-wave types used for phase control of ac loads in applications such as light dimming, universal and induction motor control, and heater control. These devices have integral triggers. JEDEC TO-5 (modified), Outline No.7. See Mounting Hardware for desired mounting arrangement.




## MAXIMUM RATINGS (For sinusoidal ac supply voltage at f = 50 and 60 Hz with resistive or inductive load)

| | 40431 | | 40432 | |
|---|---|---|---|---|
| $V_{DROM}$ (gate open, $T_J$ = −40°C to 100°C) | 200 | | 400 | V |
| $I_{T(RMS)}$ ($T_C$ = 75°C, conduction angle = 360°) | | 6 | | A |
| $I_{TSM}$ (1 cycle of principal voltage) | | 100 | | A |
| $I_{GTM}$ (2 μs max) | | 1 | | A |
| $P_{GM}$ (2 μs max, $I_{GTM}$ ≤ 1 A peak) | | 20 | | W |
| $P_{G(AV)}$ | | 0.2 | | W |
| $T_{stg}$*▲ | | −40 to 150 | | °C |
| $T_C$*▲ | | −40 to 100 | | °C |

## CHARACTERISTICS (At maximum electrical rating at $T_C$ = 25°C)

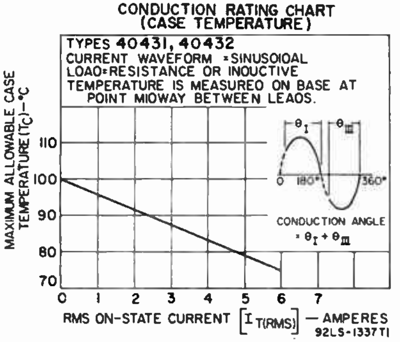
| | 40431 | | 40432 | |
|---|---|---|---|---|
| $I_{DROM}$● (gate open, $T_J$ = 100°C, $V_{DROM}$ = max rated value) | 0.1 typ<br>2 max | | 0.2 typ<br>4 max | mA<br>mA |
| $v_T$● ($i_T$ = 30 A) | | 1.6 typ; 2.25 max | | V(peak) |
| $I_{HO}$ (initial principal current = 150 mAdc) | | 10 typ; 30 max | | mA(dc) |
| Commutating dv/dt● ($v_D$ = $V_{DROM}$, $I_{T(RMS)}$ = 6 A, commutating di/dt = 4 A/ms, gate open): | | | | |
| $T_C$ = 75°C | | 5 | | V/μs |
| $T_C$ = 50°C | | 8 | | V/μs |
| Critical dv/dt● ($v_D$ = $V_{DROM}$, exponential voltage rise, gate open, $T_C$ = 100°C) | 30 | | 20 | V/μs |
| $V_{GTM}$ | | 20 min, 35 typ, 40 max | | V |
| \|$V_{GM^+}$\| − \|$V_{GM^-}$\| | | ±1 typ; ±3 max | | V |
| $I_{GTM}$‡ | | 40 typ; 200 max | | μA |
| Gate Trigger Capacitance ($V_D$ = 6 Vdc, $R_L$ = 12 Ω, $T_C$ = 100°C) | | 0.1 to 2 | | μF |
| $t_{gt}$ ($v_D$ = $V_{DROM}$, $I_{GT}$ = 80 mA, $t_r$ = 0.1 μs, $i_T$ = 10 A peak) | | 2.2 | | μs |

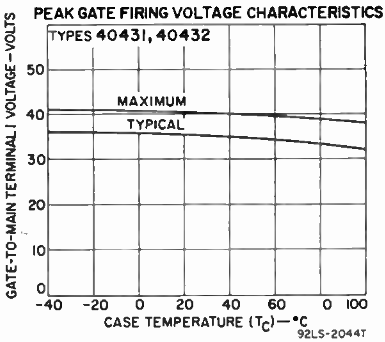
● For either polarity of main-terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.

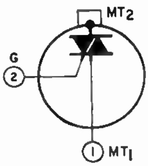
▪ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.

* For information on the reference point of temperature measurement, see section on Outlines.

▲ When these devices are soldered directly to the heat sink, a 60-90 solder should be used. Exposure time should be just sufficient to cause the solder to flow freely.




## 6A, 200V 40485
## 6A, 400V 40486

Si gate-controlled full-wave types used for the control of ac loads in applications such as heating controls, motor controls, light dimmers, and power switching systems. Outline No.7.

### MAXIMUM RATINGS (For sinusoidal ac supply voltage at 50/60 Hz with resistive or inductive load)

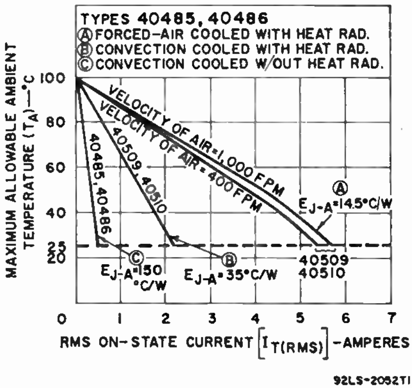
| | 40485 | 40486 | |
|---|---|---|---|
| $V_{DROM}$* ($T_J$ = −65°C to 100°C) | 200 | 400 | V |
| $I_{T(RMS)}$▲ ($T_C$ = 75°C, conduction angle = 360°) | 6 | | A |
| $I_{T(RMS)}$● ($T_A$ up to 100°C, conduction angle = 360°) | See Rating Chart (Ambient Temperature) | | |
| $I_{TSM}$ (1 cycle of principal voltage) | 100 | | A |
| $I_{GTM}$ (1 μs max) | 4 | | A |
| $P_{GM}$ (1 μs max, $I_{GTM} \leq$ 4 A peak) | 16 | | W |
| $P_{G(AV)}$ | 0.2 | | W |
| $T_{STG}$■ | −65 to 150 | | °C |
| $T_C$(opr)■ | −65 to 100 | | °C |
| $T_C$(soldering)■ | 225 | | °C |

### CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

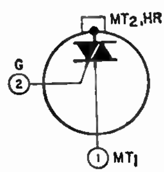
| | 40485 | 40486 | |
|---|---|---|---|
| $I_{DROM}$ ($T_J$ = 100°C, $V_{DROM}$ = max rated value) | 0.1 typ; 4 max | 0.2 typ; 4 max | mA |
| $v_{TM}$ ($i_T$ = 30 A peak) | 1.6 typ; 2.25 max | | V |
| $I_{HO}$ (initial principal current = 150 mAdc) | 15 typ; 30 max | | A |
| Commutating dv/dt ($V_D$ = $V_{DROM}$, $I_{T(RMS)}$ = 6 A, commutating di/dt = 3.2 A/ms, gate unenergized at $T_C$ = 75°C) | 3 min; 10 typ | | V/μs |
| Critical dv/dt ($V_D$ = $V_{DROM}$, exponential voltage rise, $T_C$ = 100°C) | 30 min; 150 typ | 20 min; 100 typ | V/μs |
| $I_{GT}$*‡ ($V_D$ = 12 Vdc, $R_L$ = 12 Ω): | | | |
| I+ mode, $V_{MT2}$ positive, $V_G$ positive | 15 typ; 25 max | | mA |
| I− mode, $V_{MT2}$ positive, $V_G$ negative | 25 typ; 40 max | | mA |
| III+ mode, $V_{MT2}$ negative, $V_G$ positive | 25 typ; 40 max | | mA |
| III− mode, $V_{MT2}$ negative, $V_G$ negative | 15 typ; 25 max | | mA |
| $V_{GT}$*‡ ($V_D$ = 12 Vdc, $R_L$ = 12 Ω) | 1 typ; 2.2 max | | V |
| $V_{GT}$*‡ ($V_D$ = $V_{DROM}$, $R_L$ = 125 Ω, $T_C$ = 100°C) | 0.2 min | | V |
| $t_{gt}$ ($V_D$ = $V_{DROM}$, $I_{GT}$ = 80 mA, $t_r$ = 0.1 μs, $i_T$ = 10 A) | 2.2 | | μs |
| $\theta_{J-C}$▲● (steady-state) | 4 max | | °C/W |

* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.
‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.
▲ This characteristic does not apply to types 40509 and 40510.
● This characteristic does not apply to types 40638 and 40639.
■ When soldered directly to heat sink, a 60/40 solder should be used. Case heating time should be a minimum . . . sufficient to allow the solder to flow freely.

CONDUCTION RATING CHART
(AMBIENT TEMPERATURE)




# 40638 — 6A, 200V
# 40639 — 6A, 400V




Si gate-controlled full-wave types used for the control of ac loads in applications such as heating controls, motor controls, light dimmers, and power switching systems. These types have integral heat spreaders. Outline No.59. Types 40638 and 40639 are identical with types 40485 and 40486, respectively, except for the following items:

**MAXIMUM RATINGS (For sinusoidal ac supply voltage at 50/60 Hz with resistive or inductive load)**

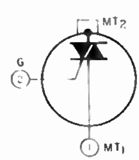
| | 40638 | 40639 | |
|---|---|---|---|
| $I_{T(RMS)}$ ($T_C$ = 75°C, conduction angle = 360°) | 4 | | A |

**CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)**

| | | |
|---|---|---|
| $I_{DROM}$* ($T_J$ = 100°C, $V_{DROM}$ = max rated value) | 0.2 typ; 4 max | mA |
| Commutating dv/dt* ($V_D$ = $V_{DROM}$, commutating dv/dt = 3.2 A/ms, $I_{T(RMS)}$ and $T_{HS}$ specified in Rating Chart (Heat Sink Temperature) | 3 min; 10 typ | V/μs |
| $\theta_{J-HS}$ | 7 max | °C/W |

* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.

# 40725 — 6A, 200V
# 40726 — 6A, 400V




Si gate-controlled full-wave ac-switching types used with the RCA-CA3059 integrated-circuit zero-voltage switch as a triggering circuit. Outline No. 7.

**MAXIMUM RATINGS (For sinusoidal supply voltage at f = 50/60 Hz with resistive or inductive load)**

| | 40725 | 40726 | |
|---|---|---|---|
| $V_{DROM}$* (Gate open, $T_J$ = −65°C to 100°C) | 200 | 400 | V |

## MAXIMUM RATINGS (cont'd)

| | 40725 | 40726 | |
|---|---|---|---|
| $I_{T(RMS)}$ ($T_C$ = 75°C, conduction angle = 360°) | 6 | | A |
| $I_{TSM}$ (1 cycle of principal voltage) | 100 | | A |
| $I_{GTM}$‡ (1 μs max.) | 4 | | A |
| $P_{GM}$‡ (1 μs max.) | 16 | | W |
| $P_{G(AV)}$ | 0.2 | | W |
| $T_{STG}$ | −65 to 150 | | °C |
| $T_C$(opr) | −65 to 100 | | °C |
| $T_L$ (10 s max.) | 225 | | °C |

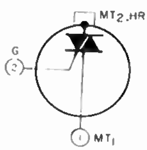
## CHARACTERISTICS (At maximum electrical ratings = 25°C)

| | 40725 | 40726 | |
|---|---|---|---|
| $I_{DROM}$ ($T_J$ = 100°C) | 0.1 typ<br>4 max | 0.2 typ<br>4 max | mA |
| $V_{TM}$ ($i_T$ = 30 A) | 1.6 typ; 2.25 max | | V |
| $I_{HO}$ (Gate open, initial principal current = 150 mA | 15 typ; 30 max | | mA |
| dv/dt ($V_D$ = $V_{DROM}$, exponential voltage rise, gate open, $T_C$ = 100°C) | 30 min<br>150 typ | 20 min<br>100 typ | V/μs |
| $I_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω): | | | |
| I+ mode, $V_{MT2}$ positive, $V_G$ positive | 45 max | | mA |
| III+ mode, $V_{MT2}$ negative, $V_G$ positive | 45 max | | mA |
| $V_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω) | 1.5 max | | V |
| $\theta_{J-C}$ (steady-state) | 4 max | | °C/W |

* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.

‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.

## 6A, 200V 40727
## 6A, 400V 40728

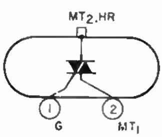



Si gate-controlled full-wave ac-switching types used with the RCA-CA3059 integrated-circuit zero-voltage switch as a triggering circuit. Outline No. 25. Types 40727 and 40728 are identical with types 40725 and 40726, respectively, except for the following item:

## CHARACTERISTICS (At maximum electrical ratings = 25°C)

| | 40727 | 40728 | |
|---|---|---|---|
| $V_{TM}$ ($i_T$ = 30 A) | 1.8 typ; 2.25 max | | V |

## 6A, 200V 40729
## 6A, 400V 40730




Si gate-controlled full-wave ac-switching types used with the RCA-CA3059 integrated-circuit zero-voltage switch as a triggering circuit. Outline No. 26.

## MAXIMUM RATINGS (For sinusoidal supply voltage at f = 50/60 Hz with resistive or inductive load)

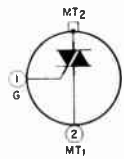
| | 40729 | 40730 | |
|---|---|---|---|
| $V_{DROM}$* (Gate open, $T_J$ = −65°C to 100°C) | 200 | 400 | V |
| $I_{T(RMS)}$ ($T_C$ = 75°C, conduction angle = 360°) | 6 | | A |
| $I_{TSM}$ (1 cycle of principal voltage) | 100 | | A |
| $I_{GTM}$‡ (1 μs max.) | 4 | | A |
| $P_{GM}$‡ (1 μs max.) | 16 | | W |
| $P_{G(AV)}$ | 0.2 | | W |
| $T_{STG}$ | −65 to 150 | | °C |
| $T_C$(opr) | −65 to 100 | | °C |

**CHARACTERISTICS (At maximum electrical ratings = 25°C)**

| | | | |
|---|---|---|---|
| $I_{DROM}$ ($T_J$ = 100°C) | 0.1 typ<br>1.2 max | 0.2 typ<br>1.2 max | mA |
| $V_{TM}$ ($i_T$ = 30 A) | 1.8 typ; 2.25 max | | V |
| $I_{HO}$ (Gate open, initial principal current = 150 mA) | 15 typ; 30 max | | mA |
| dv/dt ($V_D$ = $V_{DROM}$, exponential voltage rise, gate open, $T_C$ = 100°C) | 30 min<br>150 typ | 20 min<br>100 typ | V/μs |
| $I_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω): | | | |
| I+ mode, $V_{MT2}$ positive, $V_G$ positive | 45 max | | mA |
| III+ mode, $V_{MT2}$ negative, $V_G$ positive | 45 max | | mA |
| $V_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω) | 1.5 max | | V |

* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.
‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.

# 40775 6A, 200V
# 40776 6A, 400V

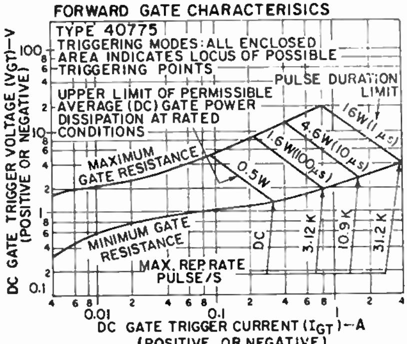



Si gate-controlled full-wave types used for control-systems application in airborne and ground-support type equipment. Outline No.36. See Mounting Hardware for desired mounting arrangement.

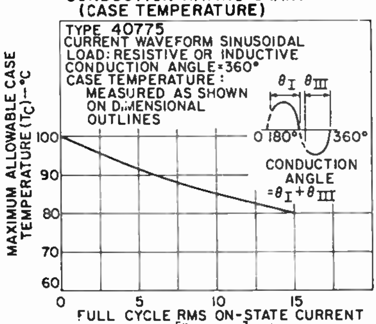
**MAXIMUM RATINGS (For sinusoidal supply voltage up to 400 Hz with resistive or inductive load)**

| | 40775 | 40776 | |
|---|---|---|---|
| $V_{DROM}$* ($T_J$ = 50 to 100°C) | 200 | 400 | V |
| $I_{T(RMS)}$ ($T_C$ = 90°C, conduction angle = 360°C) | 6 | | A |
| $I_{TSM}$: | | | |
| 1 cycle sinusoidal principal voltage at 400 Hz | 200 | | A |
| 1 cycle sinusoidal principal voltage at 60 Hz | 100 | | A |
| di/dt ($V_{DM}$ = $V_{DROM}$, $I_{GT}$ = 160 mA, $t_r$ = 0.1 μs) | 150 | | A/μs |
| $I_{GTM}$‡ (1 μs max) | 4 | | A |
| $P_{GM}$ ($I_{GTM}$ ≤ 4 A, 1 μs max) | 16 | | W |
| $P_{G(AV)}$ | 0.2 | | W |
| $T_{STG}$ | −50 to 150 | | °C |
| $T_C$(opr) | −50 to 100 | | °C |
| $T_T$ (10 s max) | 225 | | °C |

FORWARD GATE CHARACTERISICS




CONDUCTION RATING CHART (CASE TEMPERATURE)



## CHARACTERISTICS (At maximum electrical ratings at $T_c = 25°C$)

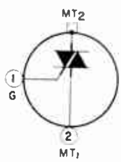
| | | | |
|---|---|---|---|
| $I_{DROM}$ ($T_J = 100°C$, $V_{DROM}$ = max rated value) | | 0.1 typ; 2 max | mA |
| $V_{TM}$ ($i_T$ = 21 A peak) | | 1.4 typ; 1.8 max | V |
| $I_{HO}$ (Initial principal current = 500 mA, $v_D$ = 12 V) | | 20 typ; 75 max | mA |
| Commutating dv/dt ($v_D = V_{DROM}$, $I_{T(RMS)}$ = rated value, gate unenergized, commutating di/dt = 21.4 A/ms, $T_C$ = 90°C) | | 5 min; 10 typ | V/μs |
| Critical dv/dt ($v_D = V_{DROM}$, exponential voltage rise, $T_C$ = 100°C) | | 30 min; 150 typ | V/μs |
| $I_{GT}$ ($v_D$ = 12 Vdc, $R_L$ = 30 Ω): | | | |
| I⁺ mode, $V_{MT2}$ positive, $V_G$ positive | | 20 typ; 50 max | mA |
| I⁻ mode, $V_{MT2}$ positive, $V_G$ negative | | 35 typ; 80 max | mA |
| III⁺ mode, $V_{MT2}$ negative, $V_G$ positive | | 35 typ; 80 max | mA |
| III⁻ mode, $V_{MT2}$ negative, $V_G$ negative | | 20 typ; 50 max | mA |
| $V_{GT}$ ($v_D$ = 12 Vdc, $R_L$ = 30 Ω) | | 1 typ; 2.5 max | |
| $V_{GT}$ ($v_D = V_{DROM}$, $R_L$ = 125 Ω, $T_C$ = 100°C) | | 0.2 min | V |
| $t_{gt}$ ($v_D = V_{DROM}$, $I_{GT}$ = 160 mA, $t_r$ = 0.1 μs, $i_T$ = 25 A peak) | | 1.6 typ; 2.5 max | μs |
| $\theta_{J-C}$ (steady-state) | | 1 max | °C/W |
| $\theta_{J-A}$ (steady-state) | | 33 max | °C/W |

* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.

‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.

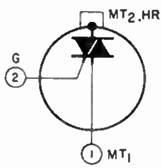
## 6A, 200V 40777

## 6A, 400V 40778




Si gate-controlled full-wave types used for control-systems application in airborne and ground-support type equipment. Outline No.37. See Mounting Hardware for desired mounting arrangement. Types 40777 and 40778 are electrically identical with types 40775 and 40776, respectively.

## 6A, 450V 40667

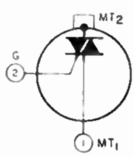



Si gate-controlled full wave type used for 240-volt line light-dimmer and resistive load-control applications. It employs an integral heat spreader to provide efficient heat transfer to an external heat sink. See Mounting Hardware for desired mounting arrangement. Outline No.59. This type is identical with type 40664 except for the following item:

### CHARACTERISTICS

| | | |
|---|---|---|
| $\theta_{J-HS}$, Steady-State | 5.5 max | °C/W |

## 6A, 450V 40723




Si gate-controlled full-wave ac-switching type used with the RCA-CA3059 integrated-circuit zero-voltage switch as a triggering circuit. Outline No. 7.

### MAXIMUM RATINGS (For sinusoidal supply voltage at f = 50/60 Hz with resistive or inductive load)

| | | |
|---|---|---|
| $V_{DROM}$* (Gate open, $T_J$ = −65°C to 100°C) | 450 | V |
| $I_{T(RMS)}$ ($T_C$ = 75°C, conduction angle = 360°) | 6 | A |
| $I_{TSM}$: | | |
| 1 cycle of principal voltage at 60 Hz | 100 | A |
| 1 cycle of principal voltage at 50 Hz | 84 | A |
| $I_{GTM}$‡ (1 μs max.) | 4 | A |
| $P_{GM}$‡ (1 μs max.) | 16 | W |
| $P_{G(AV)}$ | 0.2 | W |

## MAXIMUM RATINGS (cont'd)

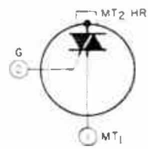
| | | |
|---|---|---|
| $T_{STG}$ | −65 to 150 | °C |
| $T_C$(opr) | −65 to 100 | °C |
| $T_L$ (10 s max.) | 225 | °C |

## CHARACTERISTICS (At maximum electrical ratings = 25°C)

| | | |
|---|---|---|
| $I_{DROM}$ ($T_J$ = 100°C) | 0.2 typ; 4 max | mA |
| $V_{TM}$ ($i_T$ = 10 A) | 1.1 typ; 2.25 max | V |
| dv/dt ($V_D$ = $V_{DROM}$, exponential voltage rise, gate open, $T_C$ = 100°C) | 10 min; 100 typ | V/μs |
| $I_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω): | | |
| I+ mode, $V_{MT2}$ positive, $V_G$ positive | 45 max | mA |
| III+ mode, $V_{MT2}$ negative, $V_G$ positive | 45 max | mA |
| $V_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω) | 1.5 max | V |
| $\theta_{J-C}$ (steady-state) | 4 max | °C/W |

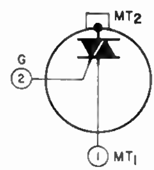
* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.
‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.

# 40724 6A, 450V




Si gate-controlled full-wave ac-switching type used with the RCA-CA3059 integrated-circuit zero-voltage switch as a triggering circuit. Outline No. 59. This type is electrically identical with type 40723.

# 40664 6A, 450V




Si gate-controlled full wave type used for 240-volt line light-dimmer and resistive load-control applications. Outline No.7.

## MAXIMUM RATINGS (For sinusoidal supply voltage at 50/60 Hz with resistive or inductive load)

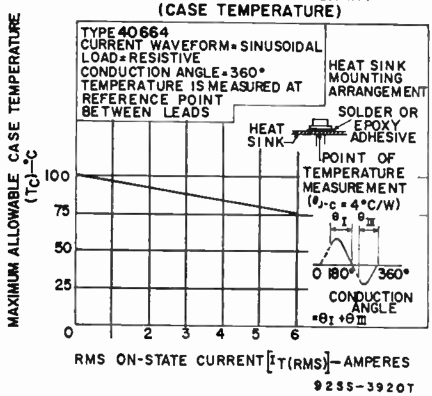
| | | |
|---|---|---|
| $V_{DROM}$* ($T_J$ = −65°C to 100°C) | 450 | V |
| $I_{T(RMS)}$ ($T_C$ = 75°C, conduction angle = 360°C) | 6 | A |
| $I_{TSM}$: | | |
| 1 cycle of principal voltage at 60 Hz | 100 | A |
| 1 cycle of principal voltage at 50 Hz | 84 | A |
| $I_{GTM}$‡ (1 μs max) | 4 | A |
| $P_{GM}$‡ (1 μs max, $I_{GTM}$ ≤ 4 A peak) | 16 | W |
| $P_{G(AV)}$ | 0.2 | W |
| $T_{STG}$▲ | −65 to 150 | °C |
| $T_C$▲(opr) | −65 to 100 | °C |
| $T_C$▲(soldering) | 225 | °C |

## CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

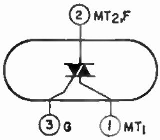
| | | |
|---|---|---|
| $I_{DROM}$* ($T_J$ = 100°C, $V_{DROM}$ = max. rated value) | 0.2 typ; 4 max | mA |
| $v_{TM}$* ($i_T$ = 10 A peak) | 1.1 typ; 2.25 | V |
| Critical dv/dt* ($V_D$ = $V_{DROM}$, exponential voltage rise, gate open, $T_C$ = 100°C) | 10 min; 100 typ | V/μs |
| $I_{GT}$* ($V_D$ = 12 Vdc, $R_L$ = 30 Ω): | | |
| I+ mode, $V_{MT2}$ positive, $V_G$ positive | 15 typ; 50 max | mA |
| III− mode, $V_{MT2}$ negative, $V_G$ negative | 15 typ; 50 max | mA |
| $V_{GT}$* ($V_D$ = 12 Vdc, $R_L$ = 30 Ω) | 1 typ; 4 max | V |
| $\theta_{J-C}$●(steady-state) | 4 max | °C/W |

* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.
‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.
● This characteristic does not apply to type 40667.
▲ When soldered directly to the heat sink, a 60/40 solder should be used. Case heating time should be a minimum . . . sufficient to allow the solder to flow freely.

CONDUCTION RATING CHART
(CASE TEMPERATURE)




## 8A, 200V — 40668
## 8A, 400V — 40669




Si gate-controlled full-wave types used for the control of ac loads in such applications as motor controls, light dimmers, heating controls, and power-switching systems. See Mounting Hardware for desired mounting arrangement. Outline No.53.

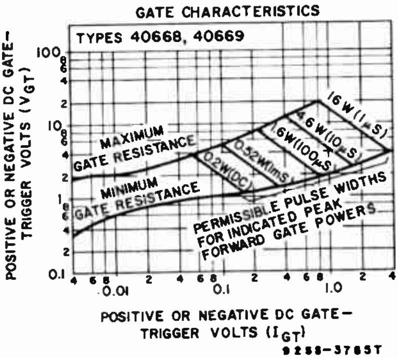
### MAXIMUM RATINGS (For sinusoidal ac supply voltage at f = 50/60 Hz with resistive or inductive load)

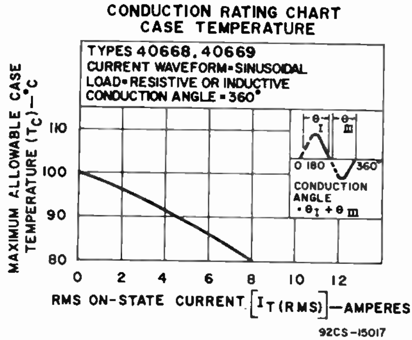
| | 40668 | 40669 | |
|---|---|---|---|
| $V_{DROM}$* ($T_J$ = −65°C to 100°C) | 200 | 400 | V |
| $I_{T(RMS)}$ ($T_C$ = 80°C, conduction angle = 360°) | 8 | | A |
| $I_{TSM}$: | | | |
| 1 cycle of principal voltage at 60 Hz | 100 | | A |
| 1 cycle of principal voltage at 50 Hz | 85 | | A |
| $I_{GTM}$‡ (10 μs max) | 4 | | A |
| $P_{GM}$‡ (10 μs max, $I_{GTM} \leq$ 4 A peak) | 16 | | W |
| $P_{G(AV)}$ | 0.2 | | W |
| $T_{STG}$ | −65 to 150 | | °C |
| $T_C$(opr) | −65 to 100 | | °C |

### CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

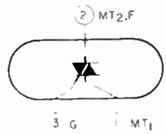
| | 40668 | 40669 | |
|---|---|---|---|
| $I_{DROM}$* ($T_J$ = 100°C, $V_{DROM}$ = max rated value) | 0.1 typ; 2 max | | mA |
| $V_{TM}$* ($i_T$ = 30 A) | 1.7 typ; 2 max | | V |
| $I_{HO}$* (initial principal current = 150 mA dc) | 15 typ; 30 max | | mA |
| Commutating dv/dt* ($v_D = V_{DROM}$, $I_{T(RMS)}$ = 8 A, commutating di/dt = 4.3 A/ms, gate unenergized at $T_C$ = 80°C) | 4 min; 10 typ | | V/μs |
| Critical dv/dt* ($v_D = V_{DROM}$, exponential voltage rise, gate open, $T_C$ = 100°C) | 100 min; 300 typ | 75 min; 250 typ | V/μs |
| $I_{GT}$*‡ ($v_D$ = 12 V, $R_L$ = 12 Ω): | | | |
| I+ mode, $V_{MT2}$ positive, $V_G$ positive | 10 typ; 25 max | | mA |
| I− mode, $V_{MT2}$ positive, $V_G$ negative | 20 typ; 60 max | | mA |
| III+ mode, $V_{MT2}$ negative, $V_G$ positive | 30 typ; 60 max | | mA |
| III− mode, $V_{MT2}$ negative, $V_G$ negative | 15 typ; 25 max | | mA |
| $V_{GT}$*‡ ($v_D$ = 12 V, $R_L$ = 12 Ω) | 1.25 typ; 2.5 max | | V |
| $V_{GT}$*‡ ($v_D = V_{DROM}$, $R_L$ = 125 Ω, $T_C$ = 100°C) | 0.2 min | | V |
| $t_{gt}$ ($v_D = V_{DROM}$, $I_{GT}$ = 80 mA, $t_r$ = 0.1 μs, $i_T$ = 10 A peak) | 2.2 | | μs |
| $\theta_{J-C}$ | 2.2 max | | °C/W |
| $\theta_{J-A}$ | 60 max | | °C/W |

* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.
‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.




# 40721 8A, 200V
# 40722 8A, 400V




Si gate-controlled full-wave ac-switching types used with the RCA-CA3059 integrated-circuit zero-voltage switch as a triggering circuit. Outline No. 53.

## MAXIMUM RATINGS (For sinusoidal supply voltage at f = 50/60 Hz with resistive or inductive load)

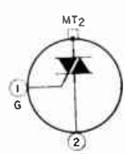
| | 40721 | | 40722 | |
|---|---|---|---|---|
| $V_{DROM}$* (Gate open, $T_J$ = −65°C to 100°C) | 200 | | 400 | V |
| $I_{T(RMS)}$ ($T_C$ = 80°C, conduction angle = 360°) | | 8 | | A |
| $I_{TSM}$: | | | | |
| 1 cycle of principal voltage at 60 Hz | | 100 | | A |
| 1 cycle of principal voltage at 50 Hz | | 85 | | A |
| $I_{GTM}$‡ (10 μs max.) | | 4 | | A |
| $P_{GM}$‡ (10 μs max.) | | 16 | | W |
| $P_{G(AV)}$ | | 0.2 | | W |
| $T_{STG}$ | | −65 to 150 | | °C |
| $T_C$(opr) | | −65 to 100 | | °C |

## CHARACTERISTICS (At maximum electrical ratings = 25°C)

| | 40721 | | 40722 | |
|---|---|---|---|---|
| $I_{DROM}$ ($T_J$ = 100°C) | | 0.1 typ; 2 max | | mA |
| $V_{TM}$ ($i_T$ = 30 A) | | 1.7 typ; 2 max | | V |
| $I_{HO}$ (Gate open, initial principal current = 150 mA, $V_D$ = 12 V) | | 15 typ; 30 max | | mA |
| dv/dt ($V_D$ = $V_{DROM}$, exponential voltage rise, gate open, $T_C$ = 100°C) | 100 min<br>300 typ | | 75 min<br>250 typ | V/μs |
| $I_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω): | | | | |
| I+ mode, $V_{MT2}$ positive, $V_G$ positive | | 45 max | | mA |
| III+ mode, $V_{MT2}$ negative, $V_G$ positive | | 45 max | | mA |
| $V_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω) | | 1.5 max | | V |
| $\Theta_{J-C}$ | | 2.2 max | | °C/W |

* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.
‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.

# 2N5567 10A, 200V
# 2N5568 10A, 400V




Si gate-controlled full-wave types used for control of ac loads in applications such as heating controls, motor controls, arc-welding equipment, light dimmers, and power switching systems. See Mounting Hardware for desired mounting arrangement. Outline No.36.

## MAXIMUM RATINGS (For sinusoidal supply voltage at 50/60 Hz with resistive or inductive load)

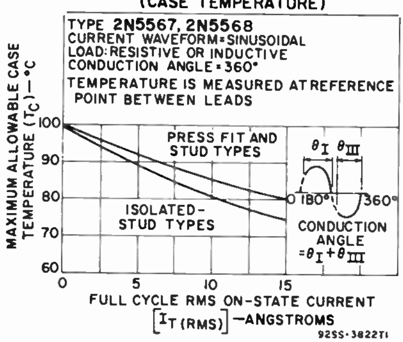
| | 2N5567 | | 2N5568 | |
|---|---|---|---|---|
| $V_{DROM}$* ($T_J$ = −65°C to 100°C) | 200 | | 400 | V |
| $I_{T(RMS)}$ ($T_C$ = 85°C, conduction angle = 360°) | | 10 | | A |
| $I_{TSM}$: | | | | |
| 1 cycle of principal voltage at 60 Hz | | 100 | | A |
| 1 cycle of principal voltage at 50 Hz | | 85 | | A |
| $I_{GTM}$‡ (1 μs max) | | 4 | | A |
| di/dt ($V_{DM}$ = $V_{DROM}$, $I_{GT}$ = 160 mA, $t_r$ = 0.1 μs) | | 150 | | A/μs |
| $P_{GM}$‡ (1 μs max, $I_{GTM}$ ≤ 4 A peak) | | 16 | | W |
| $P_{G(AV)}$ | | 0.5 | | W |
| $T_{STG}$ | | −65 to 150 | | °C |
| $T_C$(opr) | | −65 to 100 | | °C |
| $T_T$ (10 s max) | | 225 | | °C |

## CHARACTERISTICS

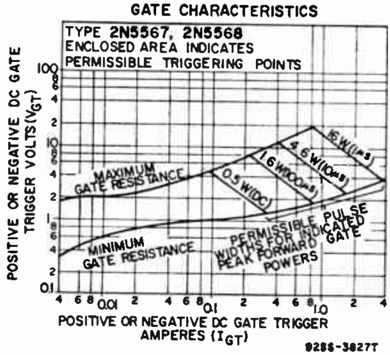
| | 2N5567 | | 2N5568 | |
|---|---|---|---|---|
| $I_{DROM}$* ($T_J$ = 100°C, $V_{DROM}$ = max rated value | | 0.1 typ; 2 max | | mA |
| $v_{TM}$* ($i_T$ = 14 A peak, $T_C$ = 25°C) | | 1.35 typ; 1.65 max | | V |
| $I_{HO}$* (initial principal current = 500 mAdc): | | | | |
| $T_C$ = 25°C | | 15 typ; 30 max | | mA |
| $T_C$ = −65°C | | 75 typ; 200 max | | mA |
| Commutating dv/dt* ($v_D$ = $V_{DROM}$, $I_{T(RMS)}$ = 10 A, commutating di/dt = 5.4 A/ms, gate unenergized at $T_C$ = 85°C) | | 2 min; 5 typ | | V/μs |
| Critical dv/dt* ($v_D$ = $V_{DROM}$, exponential voltage rise, $T_C$ = 100°C) | 30 min; 150 typ; | | 20 min; 100 typ | V/μs |
| $I_{GT}$*‡ ($v_D$ = 12 Vdc, $R_L$ = 30 Ω, $T_C$ = 25°C): | | | | |
| I⁺ mode, $V_{MT2}$ positive, $V_G$ positive | | 10 typ; 25 max | | mA |
| I⁻ mode, $V_{MT2}$ positive, $V_G$ negative | | 20 typ; 40 max | | mA |
| III⁺ mode, $V_{MT2}$ negative, $V_G$ positive | | 20 typ; 40 max | | mA |
| III⁻ mode, $V_{MT2}$ negative, $V_G$ negative | | 10 typ; 25 max | | mA |
| $I_{GT}$*‡ ($v_D$ = 12 Vdc, $R_L$ = 30 Ω, $T_C$ = −65°C) | | | | |
| I⁺ mode, $V_{MT2}$ positive, $V_G$ positive | | 45 typ; 100 max | | mA |
| I⁻ mode, $V_{MT2}$ positive, $V_G$ negative | | 80 typ; 150 max | | mA |
| III⁺ mode, $V_{MT2}$ negative, $V_G$ positive | | 80 typ; 150 max | | mA |
| III⁻ mode, $V_{MT2}$ negative, $V_G$ negative | | 45 typ; 100 max | | mA |
| $V_{GT}$*‡ ($v_D$ = 12 Vdc, $R_L$ = 30Ω): | | | | |
| $T_C$ = 25°C | | 1 typ; 2.5 max | | V |
| $T_C$ = −65°C | | 2 typ; 4 max | | V |
| $V_{GT}$*‡ ($v_D$ = $V_{DROM}$, $R_L$ = 125 Ω, $T_C$ = 100°C) | | 0.2 min | | V |
| $t_{gt}$ ($v_D$ = $V_{DROM}$, $I_{GT}$ = 160 mA, 0.1 μs, tr, $i_T$ = 15 A peak, $T_C$ = 25°C) | | 1.6 typ; 2.5 max | | μs |
| $\Theta_{J-C}$(steady-state) | | 1 max | | °C/W |

* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.
‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.

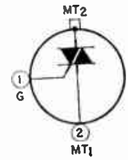
CONDUCTION RATING CHART (CASE TEMPERATURE)




GATE CHARACTERISTICS

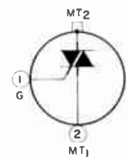


# 2N5569 10A, 200V
# 2N5570 10A, 400V




Si gate-controlled full-wave types used for control of ac loads in applications such as heating controls, motor controls, arc-welding equipment, light dimmers, and power switching systems. See Mounting Hardware for desired mounting arrangement. Outline No.37. Types 2N5569 and 2N5570 are identical with types 2N5567 and 2N5568, respectively.

# 40717 10A, 200V
# 40718 10A, 400V




Si gate-controlled full-wave ac-switching types used with the RCA-CA3059 integrated-circuit zero-voltage switch as a triggering circuit. Outline No. 36.

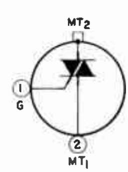
## MAXIMUM RATINGS (For sinusoidal supply voltage at f = 50/60 Hz with resistive or inductive load)

| | 40717 | | 40718 | |
|---|---|---|---|---|
| $V_{DROM}$* (Gate open, $T_J$ = −65°C to 100°C) | 200 | | 400 | V |
| $I_{T(RMS)}$ ($T_C$ = 85°C, conduction angle = 360°) | | 10 | | A |
| $I_{TSM}$: | | | | |
| 1 cycle of principal voltage at 60 Hz | | 100 | | A |
| 1 cycle of principal voltage at 50 Hz | | 85 | | A |
| $I_{GTM}$‡ (1 μs max.) | | 4 | | A |
| $P_{GM}$‡ (1 μs max.) | | 16 | | W |
| $P_{G(AV)}$ | | 0.5 | | W |
| $T_{STG}$ | | −65 to 150 | | °C |
| $T_C$(opr) | | −65 to 100 | | °C |
| $T_L$ (10 s max.) | | 225 | | °C |

## CHARACTERISTICS (At maximum electrical ratings = 25°C)

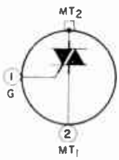
| | 40717 | | 40718 | |
|---|---|---|---|---|
| $I_{DROM}$ ($T_J$ = 100°C) | | 0.1 typ; 2 max | | mA |
| $V_{TM}$ ($i_T$ = 14 A) | | 1.35 typ; 1.65 max | | V |
| $I_{HO}$ (Gate open, initial principal current = 500 mA, $V_D$ = 12 V): | | | | |
| $T_C$ = 25°C | | 15 typ; 30 max | | mA |
| $T_C$ = −65°C | | 75 typ; 200 max | | mA |
| dv/dt ($V_D$ = $V_{DROM}$, exponential voltage rise, gate open, $T_C$ = 100°C) | 300 min<br>150 typ | | 20 min<br>100 typ | V/μs |
| $I_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω): | | | | |
| I+ mode, $V_{MT2}$ positive, $V_G$ positive | | 45 max | | mA |
| III+ mode, $V_{MT2}$ negative, $V_G$ positive | | 45 max | | mA |
| $V_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω) | | 1.5 max | | V |
| $\theta_{J-C}$ (steady-state) | | 1 max | | °C/W |

# 40719 10A, 200V
# 40720 10A, 400V




Si gate-controlled full-wave ac-switching types used with the RCA-CA3059 integrated-circuit zero-voltage switch as a triggering circuit. Outline No. 37. Types 40719 and 40720 are electrically identical with types 40717 and 40718, respectively.

## 10A, 200V 40779
## 10A, 400V 40780

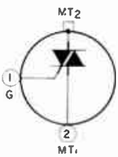



Si gate-controlled full-wave types used for control-systems application in airborne and ground-support type equipment. Outline No.36. See Mounting Hardware for desired mounting arrangement. Types 40779 and 40780 are identical with types 40775 and 40776, respectively, except for the following items:

**CHARACTERISTICS (At maximum electrical ratings at $T_C = 25°C$)**

| | 40779 | 40780 | |
|---|---|---|---|
| Commutating dv/dt ($v_D = V_{DROM}$, $I_{T(RMS)}$ = rated value, gate unenergized commutating di/dt = 36 A/ms, $T_C = 85°C$) | 5 min; 10 typ | | V/μs |

## 10A, 200V 40781
## 10A, 400V 40782

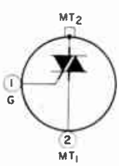



Si gate-controlled full-wave types used for control-systems application in airborne and ground-support type equipment. Outline No.37. See Mounting Hardware for desired mounting arrangement. Types 40781 and 40782 are identical with types 40775 and 40776, respectively, except for the following items:

**CHARACTERISTICS (At maximum electrical ratings at $T_C = 25°C$)**

| | 40781 | 40782 | |
|---|---|---|---|
| Commutating dv/dt ($v_D = V_{DROM}$, $I_{T(RMS)}$ = rated value, gate unenergized, commutating di/dt = 36 A/ms, $T_C = 85°C$) | 5 min; 10 typ | | V/μs |

## 10A, 200V—600V 40799–40801

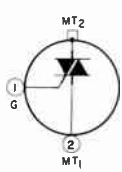



Si gate-controlled full-wave types used for control of ac loads in applications such as heating controls, motor controls, arc-welding equipment, light dimmers, and power switching systems. Outline No.71. See Mounting Hardware for desired mounting arrangement. Types 40799, 40780, and 40801, are identical with types 2N5567, 2N5568, and 40795, respectively, except for the following item:

**CHARACTERISTICS (At maximum electrical ratings at $T_C = 25°C$)**

| | 40799 | 40800 | 40801 | |
|---|---|---|---|---|
| $\theta_{J-HS}$ (steady-state) | | 1.1 max | | °C/W |

## 10A, 600V 40795




Si gate-controlled full-wave type used for control of ac loads in applications such as heating controls, motor controls, arc-welding equipment, light dimmers, and power switching systems. Outline No.36. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N5567 except for the following items:

**MAXIMUM RATINGS** (For sinusoidal supply voltage at 50/60 Hz with resistive or inductive load)

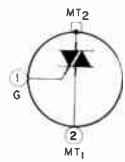
| | | |
|---|---|---|
| $V_{DROM}$‡ ($T_J$ = −65 to 100°C) | 600 | V |

**CHARACTERISTICS** (At maximum electrical ratings at $T_C$ = 25°C)

| | | |
|---|---|---|
| Critical dv/dt‡ ($v_D$ = $V_{DROM}$, exponential voltage rise, $T_C$ = 100°C) | 10 min; 75 typ | V/µs |

‡ For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.

## 40796 10A, 600V




Si gate-controlled full-wave type used for control of ac loads in applications such as heating controls, motor controls, arc-welding equipment, light dimmers, and power switching systems. Outline No.37. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N5567 except for the following items:

**MAXIMUM RATINGS** (For sinusoidal supply voltage at 50/60 Hz with resistive or inductive load)

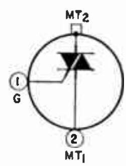
| | | |
|---|---|---|
| $V_{DROM}$‡ ($T_J$ = −65 to 100°C) | 600 | V |

**CHARACTERISTICS** (At maximum electrical ratings at $T_C$ = 25°C)

| | | |
|---|---|---|
| Critical dv/dt‡ ($v_D$ = $V_{DROM}$, exponential voltage rise, $T_C$ = 100°C) | 10 min; 75 typ | V/µs |

‡ For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.

## 2N5571 15A, 200V
## 2N5572 15A, 400V




Si gate-controlled full-wave types used for control of ac loads in applications such as heating controls, motor controls, arc-welding equipment, light dimmers, and power switching systems. See Mounting Hardware for desired mounting arrangement. Outline No.36. For gate characteristics curves, refer to types 2N5567 and 2N5568.

**MAXIMUM RATINGS** (For sinusoidal supply voltage at 50/60 Hz with resistive or inductive load)

| | 2N5571 | 2N5572 | |
|---|---|---|---|
| $V_{DROM}$* ($T_J$ = −65°C to 100°C) | 200 | 400 | V |
| $I_{T(RMS)}$ ($T_C$ = 80°C, conduction angle = 360°) | 15 | | A |
| $I_{TSM}$: | | | |
| 1 cycle of principal voltage at 60 Hz | 100 | | A |
| 1 cycle of principal voltage at 50 Hz | 85 | | A |
| di/dt ($V_{DM}$ = $V_{DROM}$, $I_{GT}$ = 160 mA, $t_r$ = 0.1 µs) | 150 | | A/µs |
| $I_{GTM}$‡ (1 µs max) | 4 | | A |
| $P_{GM}$‡ (1 µs max, $I_{GTM}$ ≤ 4 A peak) | 16 | | W |
| $P_{G(AV)}$ | 0.5 | | W |
| $T_{STG}$ | −65 to 150 | | °C |
| $T_C$(opr) | −65 to 100 | | °C |
| $T_T$ (10 s max) | 225 | | °C |

**CHARACTERISTICS**

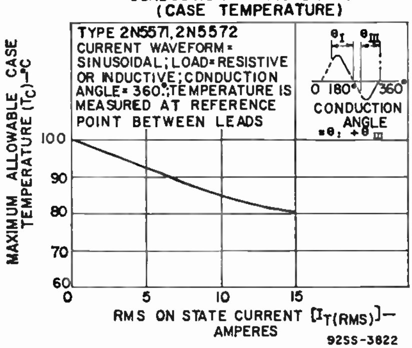
| | | | |
|---|---|---|---|
| $I_{DROM}$* ($T_J$ = 100°C, $V_{DROM}$ = max. rated value) | 0.2 typ; 2 max | | mA |
| $v_{TM}$* ($i_T$ = 21 A peak, $T_C$ = 25°C) | 1.4 typ; 1.8 max | | V |

## CHARACTERISTICS (cont'd)

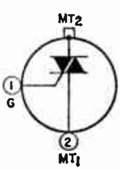
| | | |
|---|---|---|
| $I_{HO}$* (initial principal current = 500 mAdc): | | |
| $T_C$ = 25°C | 20 typ; 75 max | mA |
| $T_C$ = −65°C | 75 typ; 300 max | mA |
| Commutating dv/dt* ($v_D$ = $V_{DROM}$, $I_{T\,(RMS)}$ = 15 A, commutating di/dt = 8 A/ms, gate unenergized at $T_C$ = 80°C) | 2 min; 10 typ | V/μs |
| Critical dv/dt* ($v_D$ = $V_{DROM}$, exponential voltage, gate open, $T_C$ = 100°C) | 30 min; 150 typ 20 min; 100 typ | V/μs |
| $I_{GT}$*‡ ($v_D$ = 12 Vdc, $R_L$ = 30 Ω, $T_C$ = 25°C): | | |
| I+ mode, $V_{MT2}$ positive, $V_G$ positive | 20 typ; 50 max | mA |
| I− mode, $V_{MT2}$ positive, $V_G$ negative | 35 typ; 80 max | mA |
| III+ mode, $V_{MT2}$ negative, $V_G$ positive | 35 typ; 80 max | mA |
| III− mode, $V_{MT2}$ negative, $V_G$ negative | 20 typ; 50 max | mA |
| $I_{GT}$*‡ ($v_D$ = 12 Vdc, $R_L$ = 30 Ω, $T_C$ = −65°C): | | |
| I+ mode, $V_{MT2}$ positive, $V_G$ positive | 75 typ; 150 max | mA |
| I− mode, $V_{MT2}$ positive, $V_G$ negative | 100 typ; 200 max | mA |
| III+ mode, $V_{MT2}$ negative, $V_G$ positive | 100 typ; 200 max | mA |
| III− mode, $V_{MT2}$ negative, $V_G$ negative | 75 typ; 150 max | mA |
| $V_{GT}$*‡: | | |
| $v_D$ = 12 Vdc, $R_L$ = 30 Ω, $T_C$ = 25°C | 1 typ; 2.5 max | V |
| $v_D$ = 12 Vdc, $R_L$ = 30 Ω, $T_C$ = −65°C | 2 typ; 4 max | V |
| $v_D$ = $V_{DROM}$, $R_L$ = 125 Ω, $T_C$ = 100°C | 0.2 min | V |
| $t_{gt}$ ($v_D$ = $V_{DROM}$, $I_{GT}$ = 160 mA, $t_r$ = 0.1 μs, $i_T$ = 25 A peak, $T_C$ = 25°C) | 1.6 typ; 2.5 max | μs |
| $\theta_{J-C}$ (steady-state) | 1 max | °C/W |

* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.
‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.

CONDUCTION RATING CHART
(CASE TEMPERATURE)



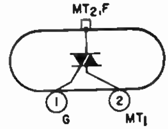

## 15A, 200V 2N5573
## 15A, 400V 2N5574




Si gate-controlled full-wave types used for control of ac loads in applications such as heating controls, motor controls, arc-welding equipment, light dimmers, and power switching systems. See Mounting Hardware for desired mounting arrangement. Outline No.37. Types 2N5573 and 2N5574 are identical with types 2N5571 and 2N5572, respectively.

# 40575 15A, 200V
# 40576 15A, 400V

Si gate-controlled full-wave types used for the control of ac loads in applications such as space heater, oven, and furnace controls. See Mounting Hardware for desired mounting arrangement. JEDEC TO-66, Outline No.25.




## MAXIMUM RATINGS (For sinusoidal supply voltage at 50/60 Hz with resistive or inductive load)

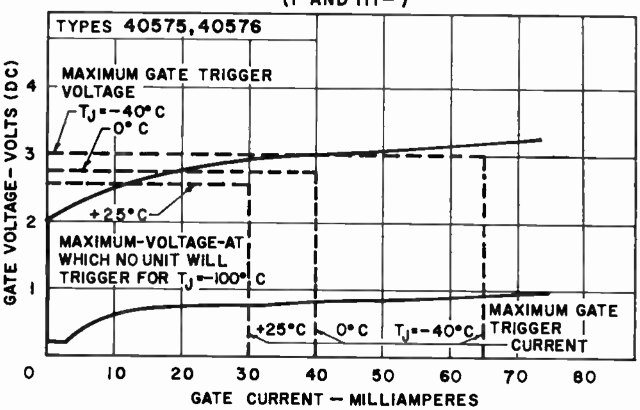
| | 40575 | | 40576 | |
|---|---|---|---|---|
| $V_{DROM}$* ($T_J$ = −40°C to 100°C) | 200 | | 400 | V |
| $I_{T(RMS)}$ ($T_C$ = 70°C, conduction angle of 360°) | | 15 | | A |
| $I_{TSM}$ (1 cycle sinusoidal principal voltage) | | 100 | | A |
| $I_{GTM}$‡ (2 μs max.) | | 1 | | A |
| $P_{GM}$ (2 μs max, $I_{GTM} \leq$ 1 A peak) | | 20 | | W |
| $P_{G(AV)}$ | | 0.45 | | W |
| $T_{STG}$ | | −40 to 150 | | °C |
| $T_C$(opr) | | −40 to 100 | | °C |

## CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

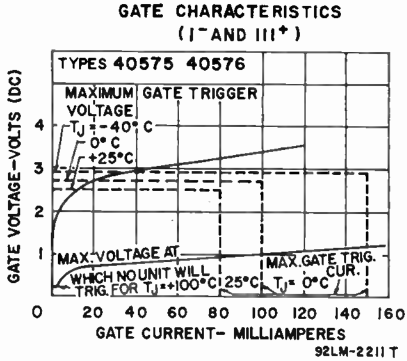
| | | |
|---|---|---|
| $I_{DROM}$* ($T_J$ = 100°C, $V_{DROM}$ = max rated value) | 0.2 typ; 4 max | mA |
| $v_{TM}$* ($i_T$ = 30 A peak) | 1.6 typ; 2 max | V(peak) |
| $I_{HO}$* (initial principal current = 150 mAdc) | 15 typ; 60 max | mA(dc) |
| Commutating dv/dt* ($v_D$ = $V_{DROM}$, $I_{T(RMS)}$ = 15 A, commutating di/dt = 8A/ms, gate unenergized at $T_C$ = 70°C) | 10 | V/μs |
| Critical dv/dt* ($v_D$ = $V_{DROM}$, exponential voltage rise, $T_C$ = 100°C) | 40 | V/μs |
| $I_{GT}$*‡ ($v_D$ = 6 Vdc, $R_L$ = 12 Ω): | | |
| I+ mode, $V_{MT2}$ positive, $V_G$ positive | 15 typ; 30 max | mA(dc) |
| I− mode, $V_{MT2}$ positive, $V_G$ negative | 35 typ; 80 max | mA(dc) |
| III+ mode, $V_{MT2}$ negative, $V_G$ positive | 35 typ; 80 max | mA(dc) |
| III− mode, $V_{MT2}$ negative, $V_G$ negative | 15 typ; 30 max | mA(dc) |
| $V_{GT}$*‡ ($v_D$ = 6 Vdc, $R_L$ = 12 Ω) | 1 typ; 2.5 max | V(dc) |
| $V_{GT}$*‡ ($v_D$ = $V_{DROM}$, $R_L$ = 125 Ω, $T_C$ = 100°C) | 0.2 min | V(dc) |
| $t_{gt}$ ($v_D$ = $V_{DROM}$, $I_{GT}$ = 160 mA, $t_r$ = 0.1 μs, $i_T$ = 25 A peak) | 3 | μs |
| $\theta_{J-C}$ | 1.3 max | °C/W |

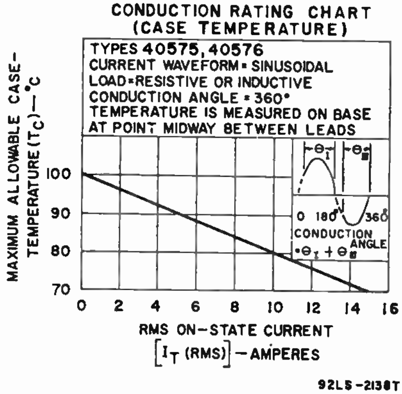
* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.
‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.

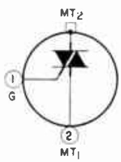
GATE CHARACTERISTICS
(I+ AND III−)




92LM-1349T1




## 15A, 200V 40711

## 15A, 400V 40712

Si gate-controlled full-wave ac-switching types used with the RCA-CA3059 integrated-circuit zero-voltage switch as a triggering circuit. Outline No. 36.

### MAXIMUM RATINGS (For sinusoidal supply voltage at f = 50/60 Hz with resistive or inductive load)

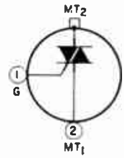
| | 40711 | 40712 | |
|---|---|---|---|
| $V_{DROM}$* (Gate open, $T_J$ = −65°C to 100°C) | 200 | 400 | V |
| $I_{T(RMS)}$ ($T_C$ = 80°C, conduction angle = 360°) | 15 | | A |
| $I_{TSM}$: | | | |
| 1 cycle of principal voltage at 60 Hz | 100 | | A |
| 1 cycle of principal voltage at 50 Hz | 85 | | A |
| $I_{GTM}$‡ (1 μs max.) | 4 | | A |
| $P_{GM}$‡ (1 μs max.) | 16 | | W |
| $P_{G(AV)}$ | 0.5 | | W |
| $T_{STG}$ | −65 to 150 | | °C |
| $T_C$(opr) | −65 to 100 | | °C |
| $T_L$ (10 s max.) | 225 | | °C |

### CHARACTERISTICS (At maximum electrical ratings = 25°C)

| | 40711 | 40712 | |
|---|---|---|---|
| $I_{DROM}$ ($T_J$ = 100°C) | 0.2 typ; 2 max | | mA |
| $V_{TM}$ ($i_T$ = 21 A) | 1.4 typ; 1.8 max | | V |
| $I_{HO}$ (Gate open, initial principal current = 150 mA, $V_D$ = 12 V): | | | |
| $T_C$ = 25°C | 20 typ; 75 max | | mA |
| $T_C$ = −65°C | 75 typ; 300 max | | mA |
| dv/dt ($V_D$ = $V_{DROM}$, exponential voltage rise, gate open, $T_C$ = 100°C) | 30 min<br>150 typ | 20 min<br>100 typ | V/μs |
| $I_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω): | | | |
| I+ mode, $V_{MT2}$ positive, $V_G$ positive | 45 max | | mA |
| III+ mode, $V_{MT2}$ negative, $V_G$ positive | 45 max | | mA |
| $V_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω) | 1.5 max | | V |
| $\theta_{J-C}$ (steady-state) | 1 max | | °C/W |

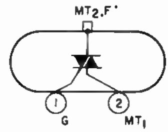
* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.
‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.

## 40713 15A, 200V
## 40714 15A, 400V




Si gate-controlled full-wave ac-switching types used with the RCA-CA3059 integrated-circuit zero-voltage switch as a triggering circuit. Outline No. 37. Types 40713 and 40714 are electrically identical with types 40711 and 40712, respectively.

## 40715 15A, 200V
## 40716 15A, 400V




Si gate-controlled full-wave ac-switching types used with the RCA-CA3059 integrated-circuit zero-voltage switch as a triggering circuit. Outline No. 25.

### MAXIMUM RATINGS (For sinusoidal supply voltage at f = 50/60 Hz with resistive or inductive load)

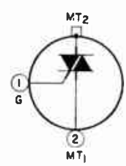
| | 40715 | | 40716 | |
|---|---|---|---|---|
| $V_{DROM}$* (Gate open, $T_J$ = −40°C to 100°C) | 200 | | 400 | V |
| $I_{T(RMS)}$ ($T_C$ = 70°C, conduction angle = 360°) | | 15 | | A |
| $I_{TSM}$: | | | | |
| 1 cycle of principal voltage at 60 Hz | | 100 | | A |
| 1 cycle of principal voltage at 50 Hz | | 85 | | A |
| $I_{GTM}$‡ (1 μs max.) | | 4 | | A |
| $P_{GM}$‡ (1 μs max.) | | 16 | | W |
| $P_{G(AV)}$ | | 0.45 | | W |
| $T_{STG}$ | | −40 to 150 | | °C |
| $T_C$(opr) | | −40 to 100 | | °C |
| $T_L$ (10 s max.) | | 225 | | °C |

### CHARACTERISTICS (At maximum electrical ratings = 25°C)

| | 40715 | | 40716 | |
|---|---|---|---|---|
| $I_{DROM}$ ($T_J$ = 100°C) | | 0.2 typ; 4 max | | mA |
| $V_{TM}$ ($i_T$ = 30 A) | | 1.6 typ; 2 max | | V |
| $I_{HO}$ (Gate open, initial principal current = 150 mA) | | 15 typ; 60 max | | mA |
| dv/dt ($V_D$ = $V_{DROM}$, exponential voltage rise, gate open, $T_C$ = 100°C) | 30 min<br>150 typ | | 20 min<br>100 typ | V/μs |
| $I_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω): | | | | |
| I+ mode, $V_{MT2}$ positive, $V_G$ positive | | 45 max | | mA |
| III+ mode, $V_{MT2}$ negative, $V_G$ positive | | 45 max | | mA |
| $V_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω) | | 1.5 max | | V |
| $\theta_{J-C}$ | | 1.3 max | | °C/W |

* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.
‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.

## 40783 15A, 200V
## 40784 15A, 400V

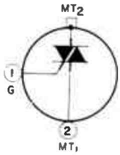



Si gate-controlled full-wave types used for control-systems application in airborne and ground-support type equipment. Outline No.36. See Mounting Hardware for desired mounting arrangement. Types 40783 and 40784 are identical with types 40775 and 40776, respectively, except for the following items:

### CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

| | 40783 | | 40784 | |
|---|---|---|---|---|
| Commutating dv/dt ($v_D$ = $V_{DROM}$, $I_{T(RMS)}$ = rated value, gate unenergized, commutating di/dt = 53.3 A/ms, $T_C$ = 80°C) | | 5 min; 10 typ | | V/μs |

## 15A, 200V 40785
## 15A, 400V 40786

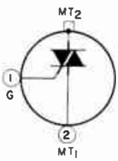



Si gate-controlled full-wave types used for control-systems application in airborne and ground-support type equipment. Outline No.37. See **Mounting Hardware** for desired mounting arrangement. Types 40785 and 40786 are identical with types 40775 and 40776, respectively, except for the following items:

**CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)**

| | 40785 | 40786 | |
|---|---|---|---|
| Commutating dv/dt ($v_D$ = $V_{DROM}$, $I_{T(RMS)}$ = rated value, gate unenergized, commutating di/dt = 53.3 A/ms, $T_C$ = 80°C) | 5 min; 10 typ | | V/µs |

## 15A, 200V—600V 40802–40804




Si gate-controlled full-wave types used for control of ac loads in applications such as heating controls, motor controls, arc-welding equipment, light dimmers, and power switching systems. Outline No.71. See **Mounting Hardware** for desired mounting arrangement. Types 40802, 40803, and 40804 are identical with types 2N5571, 2N5572, and 40797, respectively, except for the following items:

**MAXIMUM RATINGS (For sinusoidal supply voltage at 50/60 Hz with resistive or inductive load)**

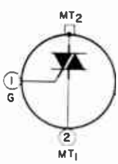
| | 40802 | 40803 | 40804 | |
|---|---|---|---|---|
| $I_{T(RMS)}$ (conduction angle = 360°, $T_C$ = 75°C) | | 15 | | A |

**CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)**

| | | |
|---|---|---|
| Commutating dv/dt‡ ($v_D$ = $V_{DROM}$, $I_{T(RMS)}$ = 15 A, commutating di/dt = 8 A/ms, gate unenergized, $T_C$ = 75°C) | 2 min; 10 typ | V/µs |
| $\theta_{J-H}$ (steady-state) | 1.1 max | °C/W |

‡ For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.

## 15A, 600V 40797




Si gate-controlled full-wave type used for control of ac loads in applications such as heating controls, motor controls, arc-welding equipment, light dimmers, and power switching systems. Outline No.36. See **Mounting Hardware** for desired mounting arrangement. This type is identical with type 2N5571 except for the following items:

**MAXIMUM RATINGS (For sinusoidal supply voltage at 50/60 Hz with resistive or inductive load)**

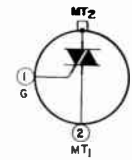
| | | |
|---|---|---|
| $V_{DROM}$‡ ($T_J$ = −65 to 100°C) | 600 | V |

**CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)**

| | | |
|---|---|---|
| Critical dv/dt‡ ($v_D$ = $V_{DROM}$, exponential voltage rise, $T_C$ = 100°C) | 10 min; 75 typ | V/µs |

‡ For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.

# 40798 15A, 600V




Si gate-controlled full-wave type used for control of ac loads in applications such as heating controls, motor controls, arc-welding equipment, light dimmers, and power switching systems. Outline No.37. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N5571 except for the following items:

**MAXIMUM RATINGS (For sinusoidal supply voltage at 50/60 Hz with resistive or inductive load)**

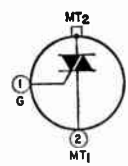
| | | |
|---|---|---|
| $V_{DROM}$‡ ($T_J$ = −65 to 100°C) | 600 | V |

**CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)**

| | | |
|---|---|---|
| Critical dv/dt‡ ($v_D = V_{DROM}$, exponential voltage rise, $T_C$ = 100°C) | 10 min; 75 typ | V/µs |

‡ For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.

# 40660 30A, 200V
# 40661 30A, 400V

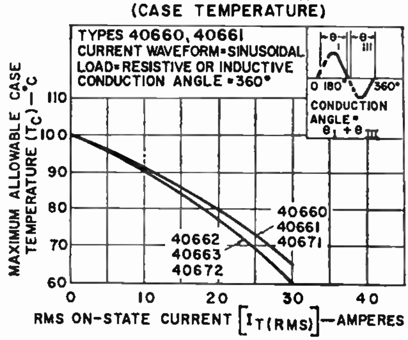



Si gate-controlled full-wave types used for the control of ac loads in applications such as heating controls, motor controls, arc welding equipment, light dimmers, power switching systems, air-conditioning and photocopying equipment. See Mounting Hardware for desired mounting arrangement. Outline No.36.

**MAXIMUM RATINGS (For sinusoidal supply voltage at 50/60 Hz with resistive or inductive load)**

| | 40660 | 40661 | |
|---|---|---|---|
| $V_{DROM}$* ($T_J$ = −65°C to 100°C) | 200 | 400 | V |
| $I_{T(RMS)}$ ($T_C$ = 65°C, conduction angle = 360°) | 30 | 30 | A |
| $I_{TSM}$: | | | |
| 1 cycle of principal voltage at 60 Hz | 300 | 300 | A |
| 1 cycle of principal voltage at 50 Hz | 265 | 265 | A |
| di/dt ($v_{DM} = V_{DROM}$, $I_{GT}$ = 200 mA, $t_r$ = 0.1 µs) | 100 | 100 | A/µs |
| $I_{GTM}$‡ (1 µs max) | 12 | 12 | A |
| $P_{GM}$‡ (10 µs max, $I_{GTM} \leq$ 4 A peak) | 40 | 40 | W |
| $P_{G(AV)}$ | 0.75 | 0.75 | W |

CONDUCTION RATING CHART
(CASE TEMPERATURE)




92SS-3812T1

## MAXIMUM RATINGS (cont'd)

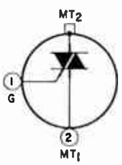
| | 40660 | 40660 / 40661 | 40661 | |
|---|---|---|---|---|
| $T_{STG}$ | | −65 to 150 | | °C |
| $T_C$(opr) | | −65 to 100 | | °C |

## CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

| | 40660 | 40660 / 40661 | 40661 | |
|---|---|---|---|---|
| $I_{DROM}$* ($T_J$ = 100°C, $V_{DROM}$ = max rated value) | | 0.2 typ; 4 max | | mA |
| $v_{TM}$* ($i_T$ = 100 A peak) | | 2.1 typ; 2.5 max | | V |
| $I_{HO}$* (initial principal current = 150 mAdc) | | 25 typ; 60 max | | mA |
| Commutating dv/dt* ($v_D$ = $V_{DROM}$, $I_{T(RMS)}$ = 30 A, commutating di/dt = 16 A/ms, gate unenergized at $T_C$ = 65°C) | | 3 min; 20 typ | | V/$\mu$s |
| Critical dv/dt* ($v_D$ = $V_{DROM}$, exponential voltage rise, $T_C$ = 100°C) | 40 min; 200 typ | | 25 min; 150 typ | V/$\mu$s |
| $I_{GT}$*‡ ($v_D$ = 12 Vdc, $R_L$ = 12 Ω): | | | | |
| I+ mode, $V_{MT2}$ positive, $V_G$ positive | | 15 typ; 50 max | | mA |
| I− mode, $V_{MT2}$ positive, $V_G$ negative | | 30 typ; 80 max | | mA |
| III+ mode, $V_{MT2}$ negative, $V_G$ positive | | 40 typ; 80 max | | mA |
| III− mode, $V_{MT2}$ negative, $V_G$ positive | | 20 typ; 50 max | | mA |
| $V_{GT}$*‡ ($v_D$ = 12 Vdc, $R_L$ = 12 Ω) | | | | |
| $V_{GT}$*‡ ($v_D$ = $V_{DROM}$, $R_L$ = 125 Ω, | | | | |
| $T_C$ = 100°C) | | 0.2 min | | V |
| $t_{gt}$ ($v_D$ = $V_{DROM}$, $I_{GT}$ = 120 mA, $t_r$ = 0.1 $\mu$s, $i_T$ = 43 A peak) | | 3 | | $\mu$s |
| $\theta_{J-C}$(steady-state) | | 0.8 max | | °C/W |

* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.
‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.

## 30A, 200V 40662
## 30A, 400V 40663




Si gate-controlled full wave types used for the control of ac loads in applications such as heating controls, motor controls, arc-welding equipment, light dimmers, and power switching system. See Mounting Hardware for desired mounting arrangement. Outline No.37. Types 40662 and 40663 are identical with types 40660 and 40661 respectively, except for the following items:

### MAXIMUM RATINGS (For sinusoidal supply voltage at 50/60 Hz with resistive or inductive load)

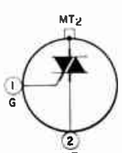
| | 40662 | 40662 / 40663 | 40663 | |
|---|---|---|---|---|
| $I_{T(RMS)}$ ($T_C$ = 60°C, conduction angle = 360°) | | 30 | | A |

### CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

| | | |
|---|---|---|
| Commutating dv/dt* ($v_D$ = $V_{DROM}$, $I_{T(RMS)}$ = 30 A, commutating di/dt = 16 A/ms, gate unenergized at $T_C$ = 65°C) | 3 min; 20 typ | V/$\mu$s |
| $\theta_{J-C}$(steady-state) | 0.9 max | °C/W |

* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.

## 30A, 200V 40705
## 30A, 400V 40706




Si gate-controlled full-wave ac-switching types used with the RCA-CA3059 integrated-circuit zero-voltage switch as a triggering circuit. Outline No. 36.

**MAXIMUM RATINGS (For sinusoidal supply voltage at f = 50/60 Hz with resistive or inductive load)**

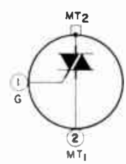
| | 40705 | | 40706 | |
|---|---|---|---|---|
| $V_{DROM}$* (Gate open, $T_J$ = −50°C to 100°C) | 200 | | 400 | V |
| $I_{T(RMS)}$ ($T_C$ = 65°C, conduction angle = 360°) | | 30 | | A |
| $I_{TSM}$: | | | | |
| 1 cycle of principal voltage at 60 Hz | | 300 | | A |
| 1 cycle of principal voltage at 50 Hz | | 265 | | A |
| $I_{GTM}$‡ (1 μs max.) | | 12 | | A |
| $P_{GM}$‡ (1 μs max.) | | 40 | | W |
| $P_{G(AV)}$ | | 0.75 | | W |
| $T_{STG}$ | | −65 to 150 | | °C |
| $T_C$(opr) | | −65 to 100 | | °C |
| $T_L$ (10 s max.) | | 225 | | °C |

**CHARACTERISTICS (At maximum electrical ratings = 25°C)**

| | | | | |
|---|---|---|---|---|
| $I_{DROM}$ ($T_J$ = 100°C) | | 0.2 typ; 4 max | | mA |
| $V_{TM}$ ($i_T$ = 100 A) | | 2.1 typ; 2.5 max | | V |
| $I_{HO}$ (Gate open, initial principal current = 150 mA, $V_D$ = 12 V) | | 25 typ; 60 max | | mA |
| dv/dt ($V_D$ = $V_{DROM}$, exponential voltage rise, gate open, $T_C$ = 100°C) | 40 min<br>200 typ | | 25 min<br>150 typ | V/μs |
| $I_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω): | | | | |
| I+ mode, $V_{MT2}$ positive, $V_G$ positive | | 45 max | | mA |
| III+ mode, $V_{MT2}$ negative, $V_G$ positive | | 45 max | | mA |
| $V_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω) | | 1.5 max | | V |

* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.
‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.

# 40707 30A, 200V
# 40708 30A, 400V

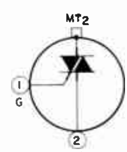



Si gate-controlled full-wave ac-switching types used with the RCA-CA3059 integrated-circuit zero-voltage switch as a triggering circuit. Outline No. 37. Types 40707 and 40708 are identical with types 40705 and 40706, respectively, except for the following items:

**MAXIMUM RATINGS (For sinusoidal supply voltage at f = 50/60 Hz with resistive or inductive load)**

| | 40707 | | 40708 | |
|---|---|---|---|---|
| $I_{T(RMS)}$ ($T_C$ = 60°C, conduction angle = 360°) | | 30 | | A |

# 40805–40807 30A, 200V—600V



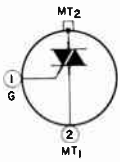

Si gate-controlled full-wave types used for the control of ac loads in applications such as heating controls, motor controls, arc-welding equipment, light dimmers, power switching systems, air-conditioning and photocopying equipment. Outline No.71. See **Mounting Hardware** for desired mounting arrangement. Types 40805, 40806 and 40807 are identical with types 40660, 40661, and 40671, respectively, except for the following items:

**MAXIMUM RATINGS** (For sinusoidal supply voltage at f = 50/60 Hz with resistive or inductive load)

| | 40805 | 40806 | 40807 | |
|---|---|---|---|---|
| $I_{T(RMS)}$ ($T_C$ = 55°C) | | 30 | | A |

**CHARACTERISTICS** (At maximum electrical ratings at $T_C$ = 25°C)

| | | |
|---|---|---|
| Commutating dv/dt ($v_D$ = $V_{DROM}$, $I_{T(RMS)}$ = 30 A, commutating di/dt = 16 A/ms, gate unenergized, $T_C$ = 55°C) | 3 min; 20 typ | V/μs |




## 30A, 600V — 40671

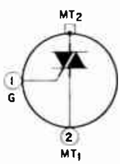
Si gate-controlled full-wave type used for the control of ac loads in applications such as heating controls, motor controls, arc welding equipment, industrial lighting control, power switching systems, air-conditioning and photocopying equipment. Outline No.36. See Mounting Hardware for desired mounting arrangement. This type is identical with type 40660 except for the following items:

**MAXIMUM RATINGS** (For sinusoidal supply voltage at f = 50/60 Hz with resistive or inductive load)

| | | |
|---|---|---|
| $V_{DROM}$ ($T_J$ = −65 to 100 °C) | 600 | V |

**CHARACTERISTICS** (At maximum electrical ratings at $T_C$ = 25°C)

| | | |
|---|---|---|
| Critical dv/dt ($v_D$ = $V_{DROM}$, exponential voltage rise, $T_C$ = 100°C) | 20 min; 100 typ | V/μs |




## 30A, 600V — 40672

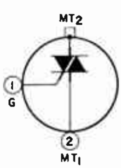
Si gate-controlled full-wave type used for control of ac loads in applications such as heating controls, motor controls, arc welding equipment, industrial lighting control, power switching systems, air-conditioning and photocopying equipment. Outline No.37. See Mounting Hardware for desired mounting arrangement. This type is identical with type 40662 except for the following items:

**MAXIMUM RATINGS** (For sinusoidal supply voltage at f = 50/60 Hz with resistive or inductive load)

| | | |
|---|---|---|
| $V_{DROM}$ ($T_J$ = −65 to 100°C) | 600 | V |

**CHARACTERISTICS**

| | | |
|---|---|---|
| Critical dv/dt ($v_D$ = $V_{DROM}$, exponential voltage rise, $T_C$ = 100°C) | 20 min; 100 typ | V/μs |




## 30A, 600V — 40709

Si gate-controlled full-wave ac-switching type used with the RCA-CA3059 integrated-circuit zero-voltage switch as a triggering circuit. Outline No. 36.

**MAXIMUM RATINGS** (For sinusoidal supply voltage at f = 50/60 Hz with resistive or inductive load)

| | | |
|---|---|---|
| $V_{DROM}$* (Gate open, $T_J$ = −50°C to 100°C) | 600 | V |
| $I_{T(RMS)}$ ($T_C$ = 65°C, conduction angle = 360°) | 30 | A |

**MAXIMUM RATINGS (cont'd)**

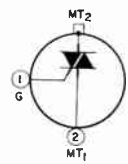
| | | |
|---|---|---|
| $I_{TSM}$: | | |
| 1 cycle of principal voltage at 60 Hz | 300 | A |
| 1 cycle of principal voltage at 50 Hz | 265 | A |
| $I_{GTM}$‡ (1 $\mu$s max.) | 12 | A |
| $P_{GM}$‡ (1 $\mu$s max.) | 40 | W |
| $P_{G(AV)}$ | 0.75 | W |
| $T_{STG}$ | −65 to 150 | °C |
| $T_C$(opr) | −65 to 100 | °C |
| $T_L$ (10 s max.) | 225 | °C |

**CHARACTERISTICS (At maximum electrical ratings = 25°C)**

| | | |
|---|---|---|
| $I_{DROM}$ ($T_J$ = 100°C) | 0.2 typ; 4 max | mA |
| $V_{TM}$ ($i_T$ = 100 A) | 2.1 typ; 2.5 max | V |
| $I_{HO}$ (Gate open, initial principal current = 150 mA, $V_D$ = 12 V) | 25 typ; 60 max | mA |
| dv/dt ($V_D$ = $V_{DROM}$, exponential voltage rise, gate open, $T_C$ = 100°C) | 20 min; 100 typ | V/$\mu$s |
| $I_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω): | | |
| I+ mode, $V_{MT2}$ positive, $V_G$ positive | 45 max | mA |
| III+ mode, $V_{MT2}$ negative, $V_G$ positive | 45 max | mA |
| $V_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω) | 1.5 max | V |

* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.
‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.

## 40710 TRIAC

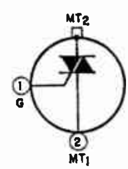



Si gate-controlled full-wave ac-switching type used with the RCA-CA3059 integrated-circuit zero-voltage switch as a triggering circuit. Outline No. 37. This type is identical with type 40709 except for the following item:

**MAXIMUM RATINGS (For sinusoidal supply voltage at f = 50/60 Hz with resistive or inductive load)**

| | | |
|---|---|---|
| $I_{T(RMS)}$ ($T_C$ = 60°C, conduction angle = 360°) | 30 | A |

## 2N5441–2N5443 40A, 200V—600V




Si gate-controlled full-wave types used for the control of ac loads in applications such as heating controls, motor controls, arc welding equipment, light dimmers, power switching systems, air-conditioning, and photocopying equipment. See Mounting Hardware for desired mounting arrangement. Outline No.36.

**MAXIMUM RATINGS (For sinusoidal supply voltage at 50/60 Hz with resistive or inductive load)**

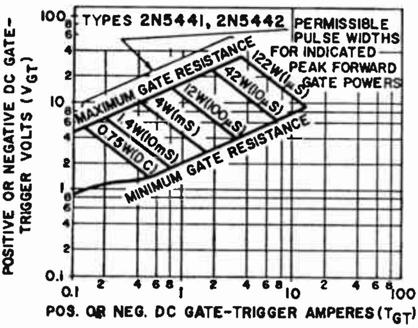
| | 2N5441 | 2N5442 | 2N5443 | |
|---|---|---|---|---|
| $V_{DROM}$• ($T_J$ = −50 to 110°C) | 200 | 400 | 600 | V |
| $I_{T(RMS)}$ ($T_C$ = 70°C, conduction angle = 360°C) | | 40 | | A |
| $I_{TSM}$ (1 cycle of sinusoidal principal voltage): | | | | |
| 60 Hz | | 300 | | A |
| 50 Hz | | 265 | | A |
| di/dt ($V_{DM}$ = $V_{DROM}$, $I_{GT}$ = 200 mA, $t_r$ = 0.1 $\mu$s) | | 100 | | A/$\mu$s |
| $I_{GTM}$‡ (1 $\mu$s max) | | 12 | | A |
| $P_{GM}$ (1 $\mu$s max, $I_{GTM}$ ≦ 4 A) | | 40 | | W |
| $P_{G(AV)}$ | | 0.75 | | W |
| $T_{STG}$ | | −65 to 150 | | °C |
| $T_C$ (opr) | | −65 to 110 | | °C |
| $T_T$ (10 s max) | | 225 | | °C |

**CHARACTERISTICS (At maximum electrical ratings at $T_C = 25°C$)**

| | | | | |
|---|---|---|---|---|
| $I_{DROM}$● ($T_J = 110°C$, $V_{DROM}$ = max rated value) | | 0.2 typ; 4 max | | mA |
| $V_{TM}$● ($i_T$ = 100 A peak) | | 1.7 typ; 2 max | | V |
| $V_{TM}$● ($i_T$ = 56 A peak) | | 1.5 typ; 1.85 max | | V |
| $I_{HO}$● (initial principal current = 500 mAdc, $v_D$ = 12 V): | | | | |
| $T_C = 25°C$ | | 25 typ; 60 max | | mA |
| $T_C = -65°C$ | | 100 max | | mA |
| Commutating dv/dt● ($v_D = V_{DROM}$, $I_{T(RMS)}$ = 40 A, commutating di/dt = 22 A/ms, gate unenergized, $T_C = 70°C$) | | 5 min; 30 typ | | V/µs |
| Critical dv/dt● ($v_D = V_{DROM}$, exponential voltage rise, $T_C = 110°C$) | 50 min; 200 typ | 30 min; 150 typ | 20 min; 100 typ | V/µs |
| $I_{GT}$●‡ ($v_D$ = 12 Vdc, $R_L = 30\ \Omega$): | | | | |
| I + mode, $V_{MT2}$ positive, $V_G$ positive | | 15 typ; 50 max | | mA |
| I − mode, $V_{MT2}$ positive, $V_G$ negative | | 30 typ; 80 max | | mA |
| III + mode, $V_{MT2}$ negative, $V_G$ positive | | 40 typ; 80 max | | mA |
| III − mode, $V_{MT2}$ negative, $V_G$ negative | | 20 typ; 50 max | | mA |
| $I_{GT}$●‡ ($v_D$ = 12 Vdc, $R_L = 30\ \Omega$, $T_C = -65°C$): | | | | |
| I + mode, $V_{MT2}$ positive, $V_G$ positive | | 125 max | | mA |
| I − mode, $V_{MT2}$ positive, $V_G$ negative | | 240 max | | mA |
| III + mode, $V_{MT2}$ negative, $V_G$ positive | | 240 max | | mA |
| III − mode, $V_{MT2}$ negative, $V_G$ negative | | 125 max | | mA |
| $V_{GT}$●‡ ($v_D$ = 12 Vdc, $R_L = 30\Omega$): | | | | |
| $T_C = 25°C$ | | 1.35 typ; 2.5 max | | V |
| $T_C = -65°C$ | | 1.8 typ; 3.4 max | | V |
| $v_D = V_{DROM}$, $R_L = 125\ \Omega$, $T_C = 110°C$ | | 0.2 min | | V |
| $t_{gt}$ ($v_D = V_{DROM}$, $I_{GT}$ = 200 mA, $t_r$ = 0.1 µs, $i_T$ = 60 A peak) | | 1.7 typ; 3 max | | µs |
| $\theta_{J-C}$ (steady-state) | | 0.8 max | | °C/W |

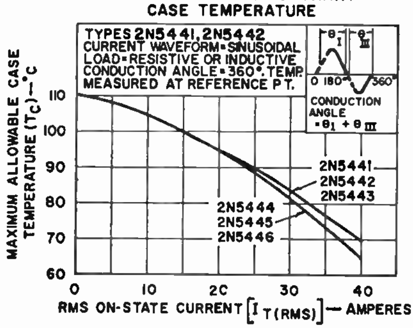
● For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.
‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.

GATE CHARACTERISTICS



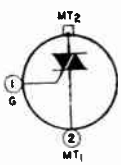

92CS-15198T2

CONDUCTION RATING CHART CASE TEMPERATURE




92LS-2266T1

## 40A, 200V— 600V 2N5444–2N5446




Si gate-controlled full-wave types used for the control of ac loads in applications such as heating controls, motor controls, arc welding equipment, light dimmers, power switching systems, air-conditioning and photocopying equipment. See Mounting Hardware for desired mounting arrangement. Outline No.37. Types 2N5444, 2N5445, and 2N5446 are identical with types 2N5441, 2N5442, and 2N5443 respectively, except for the following items:

**MAXIMUM RATINGS (For sinusoidal supply voltage at 50/60 Hz with resistive or inductive load)**

| | 2N5444 | 2N5445 | 2N5446 | |
|---|---|---|---|---|
| $I_{T(RMS)}$ ($T_C$ = 65°C, conduction angle = 360°) | | 40 | | A |

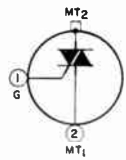
**CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)**

| | | | | |
|---|---|---|---|---|
| Commutating dv/dt* ($v_D$ = $V_{DROM}$, $I_{T(RMS)}$ = 40 A, commutating di/dt = 22 A/ms, gate unenergized at $T_C$ = 65°C) | | 5 min; 30 typ | | V/μs |
| $\theta_{J-C}$ | | 0.9 max | | °C/W |

* For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.

## 40688–40690

**40A, 200V—600V**




Si gate-controlled full-wave types used for the control of ac loads in applications such as heating controls, motor controls, arc welding equipment, light dimmers, power switching systems, air conditioning and photocopying equipment. Outline No.71. See Mounting Hardware for desired mounting arrangement. Types 40688, 40689, and 40690 are identical with types 2N5441, 2N5542, and 2N5443, respectively, except for the following items:

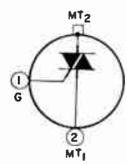
**CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)**

| | 40688 | 40689 | 40690 | |
|---|---|---|---|---|
| Commutating dv/dt‡ ($v_D$ = $V_{DROM}$, $I_{T(RMS)}$ = 40 A, commutating di/dt = 22 A/ms, gate unenergized, $T_C$ = 60°C) | | 5 min; 30 typ | | V/μs |
| $\theta_{J-HS}$ (steady-state) | | 1 max | | °C/W |

‡ For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.

## 40699–40701

**40A, 200V—600V**




Si gate-controlled full-wave ac-switching types used with the RCA-CA3059 integrated-circuit zero-voltage switch as a triggering circuit. Outline No. 36.

**MAXIMUM RATINGS (For sinusoidal supply voltage at f = 50/60 Hz with resistive or inductive load)**

| | 40699 | 40700 | 40701 | |
|---|---|---|---|---|
| $V_{DROM}$* (Gate open, $T_J$ = −50°C to 110°C) | 200 | 400 | 600 | V |
| $I_{T(RMS)}$ ($T_C$ = 70°C, conduction angle = 360°) | | 40 | | A |
| $I_{TSM}$: | | | | |
| 1 cycle of principal voltage at 60 Hz | | 300 | | A |
| 1 cycle of principal voltage at 50 Hz | | 265 | | A |
| $I_{GTM}$‡ (1 μs max.) | | 12 | | A |
| $P_{GM}$‡ (1 μs max.) | | 40 | | W |
| $P_{G(AV)}$ | | 0.75 | | W |
| $T_{STG}$ | | −65 to 150 | | °C |
| $T_C$(opr) | | −65 to 110 | | °C |
| $T_L$ (10 s max.) | | 225 | | °C |

**CHARACTERISTICS (At maximum electrical ratings = 25°C)**

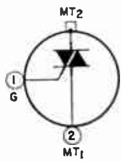
| | | | | |
|---|---|---|---|---|
| $I_{DROM}$ ($T_J$ = 110°C) | | 0.2 typ; 4 max | | mA |
| $V_{TM}$: | | | | |
| $i_T$ = 100 A | | 1.7 typ; 2 max | | V |
| $i_T$ = 56 A | | 1.5 typ; 1.85 max | | V |

## CHARACTERISTICS (cont'd)

| | | | | |
|---|---|---|---|---|
| $I_{HO}$ (Gate open, initial principal current = = 500 mA, $V_D$ = 12 V): | | | | |
| $T_C$ = 25°C | | 25 typ; 60 max | | mA |
| $T_C$ = −65°C | | 100 max | | mA |
| dv/dt ($V_D$ = $V_{DROM}$, exponential voltage rise, gate open, $T_C$ = 110°C) | 50 min 200 typ | 30 min 150 typ | 20 min 100 typ | V/µs |
| $I_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω): | | | | |
| I+ mode, $V_{MT2}$ positive, $V_G$ positive | | 45 max | | mA |
| III+ mode, $V_{MT2}$ negative, $V_G$ positive | | 45 max | | mA |
| $V_{GT}$ ($V_D$ = 12 V, $R_L$ = 30 Ω) | | 1.5 max | | V |
| $\theta_{J-C}$ (steady-state) | | 0.8 max | | °C/W |

• For either polarity of main terminal 2 voltage ($V_{MT2}$) with reference to main terminal 1.
‡ For either polarity of gate voltage ($V_G$) with reference to main terminal 1.

## 40A, 200V—600V 40702–40704




Si gate-controlled full-wave ac-switching types used with the RCA-CA3059 integrated-circuit zero-voltage switch as a triggering circuit. Outline No. 37. Types 40702, 40703, and 40704 are identical with types 40699, 40700, and 40701 respectively, except for the following items:

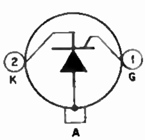
### MAXIMUM RATINGS (For sinusoidal supply voltage at f = 50/60 Hz with resistive or inductive load)

| | 40702 | 40703 | 40704 | |
|---|---|---|---|---|
| $I_{T(RMS)}$ ($T_C$ = 65°C, conduction angle = 360°) | | 40 | | A |

### CHARACTERISTICS (At maximum electrical ratings = 25°C)

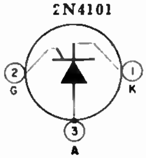
| | | | | |
|---|---|---|---|---|
| $\theta_{J-C}$ (steady-state) | | 0.9 max | | °C/W |

# *Silicon Controlled Rectifiers*




2N4101

## 5A, 700V 2N4101
## 2A, 700V 2N4102




2N4102

Si all-diffused three-junction types for use in power-control and power-switching applications. 2N4101: JEDEC TO-66, Outline No.25. 2N4102: JEDEC TO-8, Outline No.10. For type 2N4101, see Mounting Hardware for desired mounting arrangement. For rating chart for type 2N4102, refer to type 2N3528. These types are identical with type 2N3228 except for the following items:

**MAXIMUM RATINGS** (For sinusoidal ac supply voltage at f = 50 to 400 Hz with resistive or inductive load)

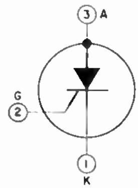
| | 2N4101 | 2N4102 | |
|---|---|---|---|
| $V_{RSOM}$ | 700 | | V |
| $V_{RROM}$ | 600 | | V |
| $V_{DROM}$ | 700 | | V |
| $I_{T(AV)}$ (conduction angle = 180°, $T_C$ = 75°C) | 3.2 | | A |
| $I_{T(AV)}$ (conduction angle = 180°, $T_A$ = 25°C) | | 1.3 | A |
| $I_{T(RMS)}$ ($T_A$ = 25°C) | | 2 | A |
| $I_{T(RMS)}$ ($T_C$ = 75°C) | 5 | | A |

**CHARACTERISTICS** (At maximum electrical ratings at $T_C$ = 25°C)

| | 2N4101 | 2N4102 | |
|---|---|---|---|
| $v_{F(BO)O}$ ($T_C$ = 100°C) | 600 min | | V |
| $I_{DOM}$ ($V_{DO} = v_{F(BO)O}$, $T_C$ = 100°C) | 0.4 typ; 4 max | | mA |
| $I_{RROM}$ ($V_{RO} = V_{RSOM}$, $T_C$ = 100°C) | 0.2 typ; 2 max | | mA |
| $\theta_{J-A}$ | | 40 max | °C/W |

# 40810–40813

**2.5A, 100V—600V**



Si all-diffused types used in capacitor-discharge ignition circuits, high-voltage generators, and power switching and control applications. JEDEC TO-5 (modified), Outline No. 60.

**MAXIMUM RATINGS**

| | 40810 | 40811 | 40812 | 40813 | |
|---|---|---|---|---|---|
| $V_{RSOM}$ | 150 | 250 | 500 | 700 | V |
| $V_{DSOM}$ | 150 | 250 | 500 | 700 | V |
| $V_{RROM}$ | 100 | 200 | 400 | 600 | V |
| $V_{DROM}$ | 100 | 200 | 400 | 600 | V |
| $I_{TSM}$ (1 cycle of principal voltage): | | | | | |
| 60 Hz, sinusoidal | 50 | | | | A |
| 50 Hz, sinusoidal | 40 | | | | A |
| $I_{T(RMS)}$ | 2.5 | | | | A |
| $I_{T(AV)}$ | 1.5 | | | | A |
| $P_{GM}$ | 10 | | | | W |
| $P_{G(AV)}$ | 2 | | | | W |
| $T_{STG}$ | 40 to 150 | | | | °C |
| $T_C$ | 40 to 100 | | | | °C |
| $T_L$ (10 s max) | 225 | | | | °C |

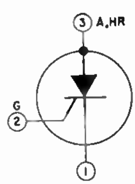
**CHARACTERISTICS** (At maximum electrical ratings at $T_C$ = 25°C)

| | 40810, 40811 | 40812, 40813 | |
|---|---|---|---|
| $I_{DOM}$ ($V_{DO} = V_{DROM}$, $T_C$ = 100°C) | 0.2 typ; 1.5 max | | mA |
| $I_{RROM}$ ($V_{RO} = V_{RROM}$, $T_C$ = 100°C) | 0.1 typ; 1.5 max | | mA |
| $v_T$ ($i_T$ = 30 A) | 2.6 typ; 3.5 max | | V |
| $I_{GT}$ ($V_D$ = 12 Vdc, $R_L$ = 30 Ω) | 5 typ; 15 max | | mA |
| $V_{GT}$ ($V_D$ = 12 Vdc, $R_L$ = 30 Ω) | 0.9 typ; 2 max | | V |
| $i_{HO}$ | 9 typ; 20 max | | mA |
| dv/dt | 10 min; 200 typ | 10 min; 100 typ | V/µs |
| $t_{gt}$ ($V_D = V_{DROM}$, $I_{GT}$ = 200 mA, $t_r$ = 0.1 µs, $i_T$ = 4.5 A | 0.5 typ; 2 max | | µs |
| $t_q$ ($V_{DX} = V_{DROM}$, $I_{GT}$ = 200 mA at $t_r$, $i_T$ = 2 A at $t_d$ = 50 µs, −di/dt = −30 A/µs, dv/dt = 20 V/µs, $T_C$ = 75°C) | 15 typ; 50 max | | µs |
| $\theta_{J-C}$ | 8 max | | °C/W |
| $\theta_{J-A}$ | 150 max | | °C/W |

# 40658 40659

**3.3A, 200V**

**3.3A, 400V**



Si all-diffused three-junction types for use in capacitor-discharge igniton systems, high-voltage generators, and power-switching and control applications. Outline No.8. Types 40658 and 40659 are identical with types 40654 and 40655, respectively, except for the following items:

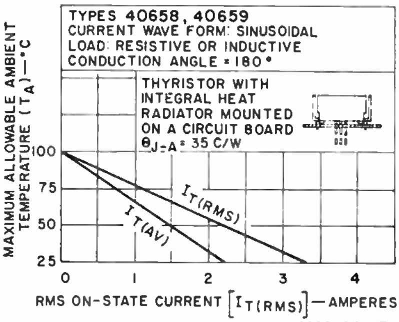
**MAXIMUM RATINGS (For sinusoidal ac supply voltage at f = 50 to 400 Hz with resistive or inductive load)**

| | 40658 | 40659 | |
|---|---|---|---|
| $I_{T(RMS)}$ ($T_A$ up to 100°C, conduction angle = 180°) | See Conduction Rating Chart (Ambient Temperature) | | |

**CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)**

| | 40658 | 40659 | |
|---|---|---|---|
| $I_{DOM}$ ($V_{DO} = V_{DROM}$) | 0.1 typ; 1.5 max | 0.2 typ; 1.5 max | mA |
| $I_{RROM}$ ($V_{RO} = V_{RROM}$) | 0.05 typ; 1.5 max | 0.1 typ; 1.5 max | mA |
| $\theta_{J-A}$ | 35 max | | °C/W |

CONDUCTION RATING CHART (AMBIENT TEMPERATURE)

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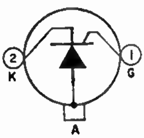


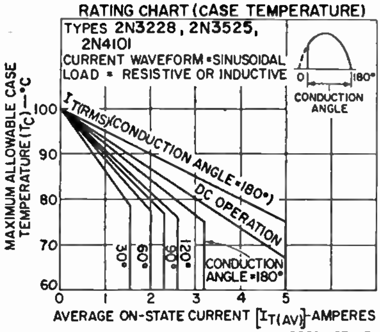

## 5A, 200V 2N3228

Si all-diffused three-junction types for use in power-control and power-switching applications. JEDEC TO-66, Outline No.25. See Mounting Hardware for desired mounting arrangement.

**MAXIMUM RATINGS (For sinusoidal ac supply voltage at f = 50 to 400 Hz with resistive or inductive load)**

| | | |
|---|---|---|
| $V_{RSOM}$ | 330 | V |
| $V_{RROM}$ | 200 | V |
| $V_{DROM}$ | 600 | V |
| $I_{T(AV)}$ (conduction angle = 180°, $T_C$ = 75°C) | 3.2 | A |
| $I_{T(RMS)}$ | 5 | A |

RATING CHART (CASE TEMPERATURE)




92CS-12748T1

## MAXIMUM RATINGS (cont'd)

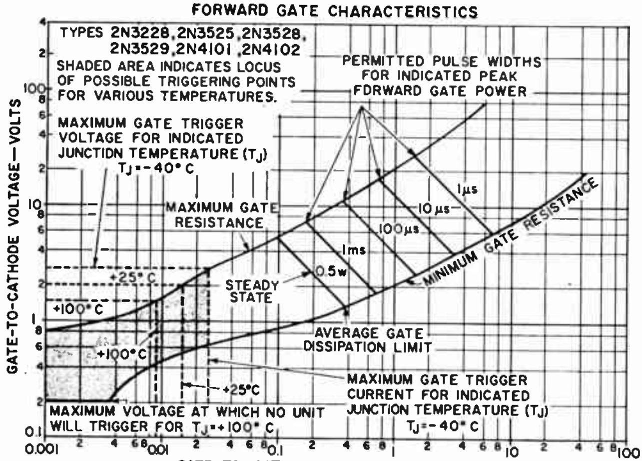
| | | |
|---|---|---|
| $I_{TSM}$ (1 cycle of principal voltage) | 60 | A |
| $[I_{TS(RMS)}]^2 t$ (1 to 8.3 ms) | 15 | $A^2s$ |
| $di_T/dt$ ($V_D = v_{F(BO)O}$, $I_{GT}$ = 200 mA, $t_r$ = 0.5 $\mu$s) | 200 | A/$\mu$s |
| $P_{G(AV)}$ | 0.5 | W |
| $P_{GM}$ (peak, forward, or reverse for 10 $\mu$s) | 13 | W |
| $T_{STG}$ | −40 to 125 | °C |
| $T_C$ | −40 to 125 | °C |

## CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

| | | |
|---|---|---|
| $v_{F(BO)O}$ ($T_C$ = 100°C) | 200 min | V |
| $I_{DOM}$ ($V_{DO} = v_{F(BO)O}$ min value, $T_C$ = 100°C) | 0.1 typ; 1.5 max | mA |
| $I_{RROM}$ ($V_{RO} = V_{RSOM}$, $T_C$ = 100°C) | 0.05 typ; 0.75 max | mA |
| $v_T$ (on-state current = 30 A) | 2.15 typ; 2.8 max | V |
| $I_{GT}$ | 8 typ; 15 max | mA (dc) |
| $V_{GT}$ | 1.2 typ; 2 max | V (dc) |
| $i_{HO}$ | 10 typ; 20 max | mA |
| Critical dv/dt ($V_D = v_{(FBO)O}$ min value, exponential rise, $T_C$ = 100°C) | 10 min; 200 typ | V/$\mu$s |
| $t_{gt}$ ($V_D = v_{F(BO)O}$ min value, $i_T$ = 4.5, $I_{GT}$ = 200 mA, $t_r$ = 0.1 $\mu$s) | 0.75 min; 1.5 typ | $\mu$s |
| $t_q$ ($i_T$ = 2 A, pulse width = 50 $\mu$s, $dv_D/dt$ = 20 V/$\mu$s, $di_T/dt$ = 30 A/$\mu$s, $I_{GT}$ = 200 mA, $T_C$ = 75°C) | 15 typ; 50 max | $\mu$s |
| $\theta_{J-C}$* | 4 max | °C/W |

* This characteristic does not apply to types 2N3528, 2N3529, and 2N4102.

FORWARD GATE CHARACTERISTICS

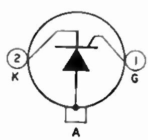



92SS-2998T

# 2N3525

**5A, 400V**

Si all-diffused three-junction type for use in power-control and power-switching applications. See Mounting Hardware for desired mounting arrangement. JEDEC TO-66, Outline No.25. This type is identical with type 2N3228 except for the following items:



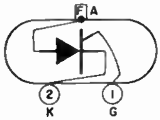

## MAXIMUM RATINGS (For sinusoidal ac supply voltage at f = 50 to 400 Hz with resistive or inductive load)

| | | |
|---|---|---|
| $V_{RSOM}$ | 660 | V |
| $V_{RROM}$ | 400 | V |
| $V_{DROM}$ | 600 | V |

## CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

| | | |
|---|---|---|
| $V_{F(BO)O}$ ($T_C$ = 100°C) | 400 min | V |
| $I_{DOM}$ ($V_{DO}$ = $V_{F(BO)O}$) | 0.2 typ; 3 max | mA |
| $I_{RROM}$ ($V_{RO}$ = $V_{RROM}$, $T_C$ = 100°C) | 0.1 typ; 1.5 max | mA |

# 5A, 600V 40640




Si type used for horizontal deflection circuits of large-screen color-TV receivers. This type and type 40642 (silicon rectifier), are the trace circuit components. They provide bipolar switching action for controlling the horizontal yoke current during the picture tube beam-trace interval, JEDEC TO-66, Outline No.25.

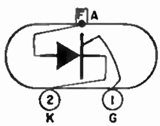
## MAXIMUM RATINGS

| | | |
|---|---|---|
| $V_{DROM}$ | 600 | V |
| $V_{RROM}$ | 5 | V |
| $I_{T(AV)}$ (60 Hz dc at conduction angle = 180, $T_C$ = 60°C) | 3.2 | A |
| $I_{T(RMS)}$ | 5 | A |
| $I_{TSM}$ | 80 | A |
| Critical di/dt ($V_D$ = $V_{F(BO)O}$ rated value, $I_{GT}$ = 50 mA, $t_r$ = 0.1 μs) | 200 | A/μs |
| $P_{GM}$ (peak (forward or reservse) 10 s max) | 25 | W |
| $T_{STG}$ | —40 to 150 | |
| $T_C$ | —40 to 100 | °C |

## CHARACTERISTICS (At maximum electrical rating at $T_C$ = 25°C)

| | | |
|---|---|---|
| $V_{F(BO)O}$ ($T_C$ = 80°C) | 550 min | V |
| $I_{DOM}$ ($T_C$ = 80°C) | 0.5 typ; 1.5 max | mA |
| $v_T$ (on-state = 30 A) | 2.2 typ; 3 max | V |
| $I_{GT}$ | 15 typ; 30 max | mA (dc) |
| $V_{GT}$ | 1.8 typ; 4 max | V (dc) |
| $\theta_{J-C}$ | 4 max | °C/W |
| $t_q$ ($I_{TM}$ = 6 A ($t_r$ = 25 μs, di/dt = 2.5 A/μs), $V_D$ = 0 V (prior to turn on), $V_D$ = 400 V (reapplied at 175 V/μs), $V_R$ = 0.8 V (min), $I_{GT}$ = 100 mA, $V_{GK}$(bias) = —30 V (68 Ω source), f = 15.75 kHz, $T_C$ = 70°C | 2.5 | μs |

# 5A, 600V 40641




Si type used for horizontal deflection circuits of large-screen color-TV receivers. This type and type 40643 (silicon rectifier), are the commutating (retrace) circuit components. They control the yoke current during the retrace interval. JEDEC TO-66, Outline No.25. This type is identical with type 40640 except for the following items:

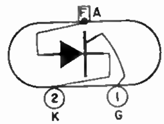
## CHARACTERISTICS (At maximum electrical rating at $T_C$ = 25°C)

| | | |
|---|---|---|
| $V_{F(BO)O}$ ($T_C$ = 100°C) | 400 min | V |
| $I_{DOM}$ ($T_C$ = 100°C) | 0.5 typ; 1.5 max | mA |
| $t_q$ ($I_{TM}$ = 13 A, (½ sine wave, 7 μs base, initial di/dt = 20 A/μs to 3 A), $V_D$ = 350 V (prior to turn on), dV/dt = 400 V/μs (to 100 V), $V_R$ = 0.8 V (min), $I_{GT}$ = 100 mA ($t_p$ = 3 μs, $t_r$ = 0.2 μs), $V_{GK}$ (bias) = —2.5 V (47 Ω source during turn off), f = 15.75 kHz, $T_C$ = 70°C | 4.5 max | μs |

# 40553–40555

## 5A, 700V

Si all-diffused three-junction types for use in inverter applications such as ultrasonics and fluorescent lighting. See Mounting Hardware for desired mounting arrangement. JEDEC TO-66, Outline No.25.



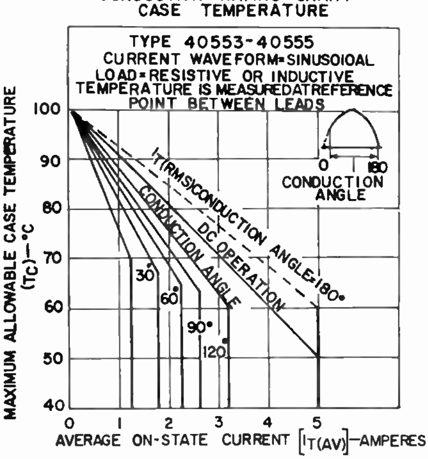

**MAXIMUM RATINGS** (For sinusoidal ac supply voltage at low to ultrasonic frequencies with resistive or inductive load)

| | 40553 | 40554 | 40555 | |
|---|---|---|---|---|
| $V_{RSOM}$ | 330 | 660 | 700 | V |
| $V_{RROM}$ | 200 | 400 | 600 | V |
| $V_{DROM}$ | | 700 | | V |
| $I_{T(AV)}$ ($T_C$ = 60°C, 60 Hz at conduction angle = 180°) | | 3.2 | | A |
| $I_{T(RMS)}$ | | 5 | | A |
| $I_{TSM}$ (1 cycle of voltage) | | 80 | | A |
| $[I_{TS(RMS)}]^2$ t (at 8.3 ms) | | 25 | | $A^2s$ |
| Critical di/dt ($V_D$ = $V_{F(BO)O}$, $I_{GT}$ = 50 mA, $t_r$ = 0.1 μs) | | 200 | | A/μs |
| $P_{GM}$ (10 μs) | | 13 | | W |
| $P_{G(AV)}$ | | 0.5 | | W |
| $T_{STG}$ | | 40 to 150 | | °C |
| $T_C$(opr) | | 40 to 100 | | °C |

**CHARACTERISTICS** (At maximum electrical ratings at $T_C$ = 25°C)

| | 40553 | 40554 | 40555 | |
|---|---|---|---|---|
| $V_{F(BO)O}$ ($T_C$ = 100°C) | 200 min | 400 min | 600 min | V |
| $I_{DOM}$ ($V_{DO}$ = $V_{F(BO)O}$) | | 0.5 typ; 3 max | | mA |
| $I_{RROM}$ ($V_{RO}$ = $V_{RROM}$) | | 0.3 typ; 1.5 max | | mA |
| $v_{TM}$ ($i_T$ = 30 A) | | 2.2 typ; 3 max | | V |
| $I_{GT}$ | | 15 typ; 40 max | | mA(dc) |
| $V_{GT}$ | | 1.8 typ; 3.5 max | | V(dc) |
| $I_{HO}$ | | 20 typ; 50 max | | mA |
| Critical dv/dt ($V_{DO}$ = $V_{F(BO)O}$, $T_C$ = 80°C) | | 100 min; 250 typ | | V/μs |
| $t_{gt}$ ($V_D$ = $V_{F(BO)O}$, $I_{TM}$ = 2 A, $I_{GT}$ = 300 mA, $t_r$ = 0.1) | | 0.7 | | μs |
| $t_q$ ($V_D$ = $V_{F(BO)O}$, $i_T$ = 2 A, $t_p$ = 50 μs, $V_R$ = 80 V min, $t_r$ = 0.1 μs, dv/dt = 100 V/μs, $di_R/dt$ = 10 A/μs, $I_{GT}$ = 100 mA at $t_{on}$, $V_{GT}$ = OV at $t_{off}$, $T_C$ = 80°C) | | 4 typ; 6 max | | μs |

CONDUCTION RATING CHART
CASE TEMPERATURE

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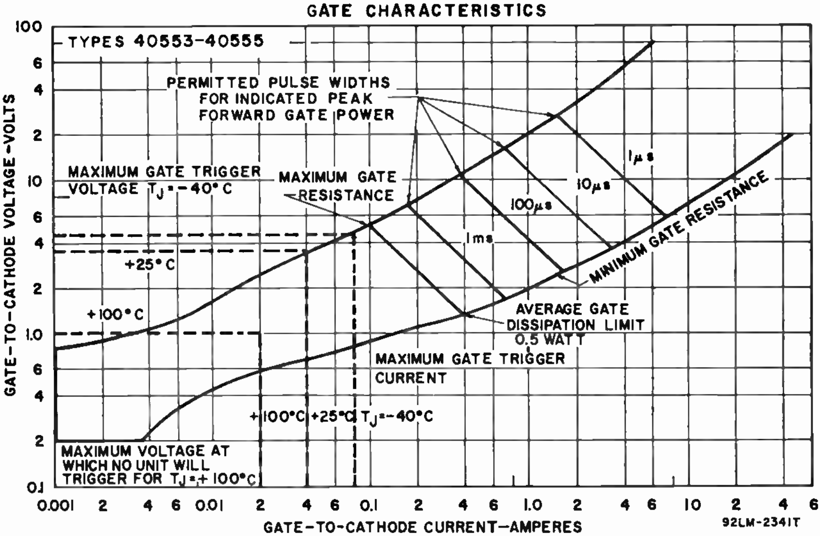
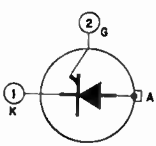



## 7A, 200V — 40378

## 7A, 400V — 40379



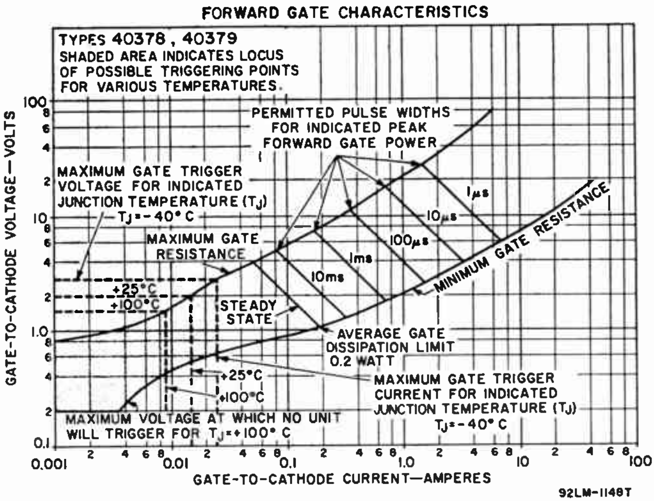

Si all-diffused three-junction types for use in power-control and power-switching applications. Outline No.35.

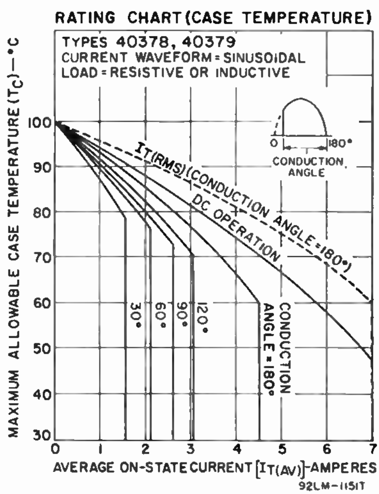
### MAXIMUM RATINGS (For sinusoidal ac supply voltage at f = 50 to 400 Hz with resistive or inductive load)

| | 40378 | 40379 | |
|---|---|---|---|
| $V_{RSOM}$ | 330 | 660 | V |
| $V_{RROM}$ | 200 | 400 | V |
| $V_{DROM}$ | 600 | 600 | V |
| $I_{T(AV)}$ (conduction angle = 180°, $T_C$ = 60°C) | 4.5 | 4.5 | A |
| $I_{T(RMS)}$ | 7 | 7 | A |
| $I_{TSM}$ (1 cycle of principle voltage) | 80 | 80 | A |
| $P_{GM}$ (peak, forward or reverse, for 10 μs) | 13 | 13 | W |
| $P_{G(AV)}$ | 0.2 | 0.2 | W |
| $T_{stg}$ | −40 to 150 | −40 to 150 | °C |
| $T_C$ | −40 to 100 | −40 to 100 | °C |

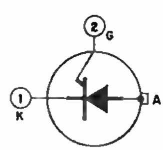
### CHARACTERISTICS (At maximum electrical rating at $T_C$ = 25°C)

| | 40378 | 40379 | |
|---|---|---|---|
| $v_{F(BO)O}$ ($T_C$ = 100°C) | 200 min | 400 min | V |
| $I_{DOM}$ ($T_C$ = 100°C, $V_D$ = $v_{F(BO)O}$ min value) | 0.1 typ | 0.2 typ | mA |
| | 1 max | 2 max | mA |
| $I_{RROM}$ ($T_C$ = 100°C, $V_{RO}$ = $V_{RROM}$) | 0.05 typ | 0.1 typ | mA |
| | 0.5 max | 1 max | mA |
| $v_T$ (on-state current = 30 A) | 1.9 typ; 2.5 max | 1.9 typ; 2.5 max | V |
| $I_{GT}$ | 8 typ; 15 max | 8 typ; 15 max | mA(dc) |
| $V_{GT}$ | 1.2 typ; 2 max | 1.2 typ; 2 max | V(dc) |
| $i_{HO}$ | 12 | 12 | mA |
| Critical dv/dt ($V_D$ = $v_{F(BO)O}$ min value, exponential rise, $T_C$ = 100°C) | 10 min | 20 min | V/μs |
| | 200 typ | 200 typ | V/μs |
| $\theta_{J-C}$ | 5 max | 5 max | °C/W |

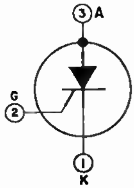



# 40507 — 7A, 200V
# 40508 — 7A, 400V




Si all-diffused three-junction types used in power-control and power-switching applications. Outline No.8. Types 40507 and 40508 are electrically identical with types 40378 and 40379, respectively.




# 7A, 200V 40654
# 7A, 400V 40655

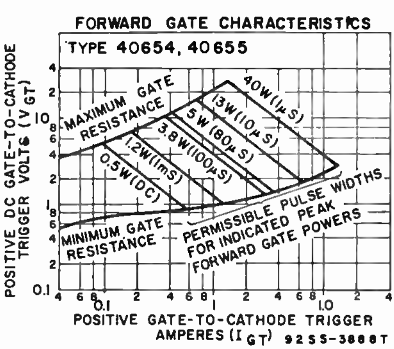
Si all-diffused three-junction types for use in capacitor-discharge ignition systems, high-voltage generators, and power-switching and control applications. Outline No.60.

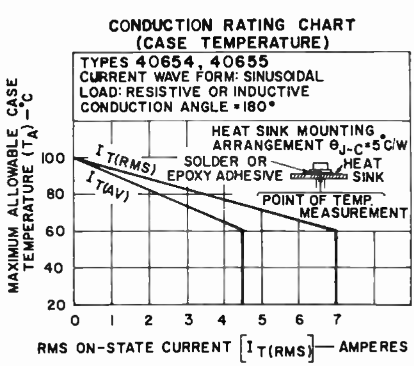
## MAXIMUM RATINGS (For sinusoidal ac supply voltage at f = 50 to 400 Hz with resistive or inductive load)

| | 40654 | 40655 | |
|---|---|---|---|
| $V_{RSOM}$‡ | 200 | 400 | V |
| $V_{DSOM}$‡ | 250 | 500 | |
| $V_{RROM}$‡ | 200 | 400 | |
| $V_{DROM}$‡ | 200 | 400 | |
| $I_{TSM}$ (1 cycle of principal voltage at 60 Hz) | 80 | | A |
| $I_{TRM}$: | | | |
| df = 0.1%, $T_C$ = 75°C, $t_p$ = 2.5 μs min | 100 | — | A |
| $t_p$ = 5 μs min | — | 100 | A |
| $I_{T(RMS)}$: | | | |
| $T_C$ = 60°C, conduction angle = 180° ▲ | 7 | | A |
| $T_A$ up to 100°C, conduction angle = 180° * | See Conduction Rating Chart (Ambient Temperature) | | |
| $P_{GM}$● | 40 | | W |
| $P_{G(AV)}$● | 0.5 | | W |
| $T_{STG}$■ | −65 to 150 | | °C |
| $T_C$(opr)■ | −65 to 100 | | °C |
| $T_S$■ (10 s max) | 225 | | °C |

## CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

| | 40654 | 40655 | |
|---|---|---|---|
| $v_{F(BO)O}$ ($T_C$ = 100°C) | 250 min | 500 min | V |
| $I_{DOM}$ ($V_{DO} = V_{DROM}$, $T_C$ = 100°C) | 0.1 typ; 0.5 max | 0.2 typ; 0.5 max | mA |
| $I_{RROM}$ ($V_{RO} = V_{RROM}$, $T_C$ = 100°C) | 0.05 typ; 0.5 max | 0.1 typ; 0.5 max | mA |
| $v_T$ ($i_T$ = 30 A) | 1.9 typ; 2.6 max | | V |
| $I_{GT}$ ($V_D$ = 12 Vdc, $R_L$ = 30 Ω) | 6 typ; 15 max | | mA |
| $V_{GT}$ ($V_D$ = 12 Vdc, $R_L$ = 30 Ω) | 0.65 typ; 1.5 max | | V |
| $i_{HO}$ | 9 typ; 20 max | | mA |
| Critical dv/dt ($V_{DO} = V_{F(BO)O}$) | 20 min; 200 typ | | V/μs |
| $t_{gt}$ ($V_D = V_{F(BO)O}$, $i_T$ = 4.5 A, $I_{GT}$ = 200 mA, $t_r$ = 0.1 μs) | 1.5 | | μs |
| $t_q$ ($V_D = V_{F(BO)O}$, $i_T$ = 2 A, $t_p$ = 50 μs, dv/dt = −20 V/μs, $di_T/dt$ = −30 A/μs, $I_{GT}$ = 200 mA at $t_{on}$, $T_C$ = 75°C) | 15 typ; 50 max | | μs |
| $\theta_{J-C}$ | 5 max | | °C/W |
| $\theta_{J-A}$* | 75 max | | °C/W |

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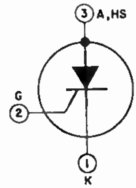
‡ This value does not apply if there is a positive gate signal. Gate must be open, terminated, or have negative bias.
● Any values of peak gate current or peak gate voltage to give the maximum gate power are permissible.
■ When this device is soldered directly to the heat sink, a 60/40 solder should be used. Case heating time should be minimum . . . sufficient to allow the solder to flow freely.
▲ This characteristic does not apply to types 40658 and 40659.
* This characteristic does not apply to types 40656 and 40657.

## 40656 7A, 200V
## 40657 7A, 400V



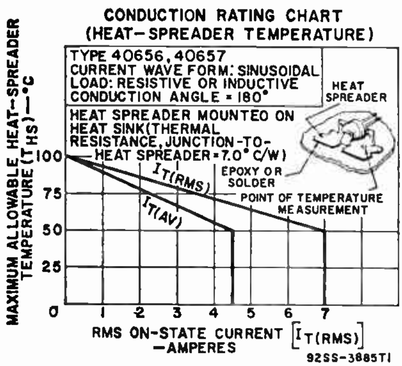

Si all-diffused three-junction types for use in capacitor-discharge ignition systems, high-voltage generators, and power-switching and control applications. See Mounting Hardware for desired mounting arrangement. Outline No.59. Types 40656 and 40657 are identical with types 40654 and 40655, respectively, except for the following items:

### MAXIMUM RATINGS (For sinusoidal ac supply voltage at f = 50 to 400 Hz with resistive or inductive load)

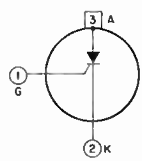
| | 40656 | 40657 |
|---|---|---|
| $I_{T(RMS)}$ ($T_C$ = 60°C, conduction angle = 180°) | See Conduction Rating Chart (Heat-Spreader Temperature) | |

### CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

| | 40656 | 40657 | |
|---|---|---|---|
| $I_{DOM}$ ($V_{DO}$ = $V_{DROM}$) | 0.1 typ; 1.5 max | 0.2 typ; 1.5 max | mA |
| $I_{RROM}$ ($V_{RO}$ = $V_{RROM}$) | 0.05 typ; 1.5 max | 0.1 typ; 1.5 max | mA |
| $\theta_{J-HS}$ | 7 max | | °C/W |




## 40737 10A, 100V




Si all-diffused type used for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits. Outline No.36.

### MAXIMUM RATINGS

| | | |
|---|---|---|
| $V_{RSOM}$ | 100 | V |
| $V_{DSOM}$ | 150 | V |
| $V_{RROM}$ | 100 | V |
| $V_{DROM}$ | 100 | V |

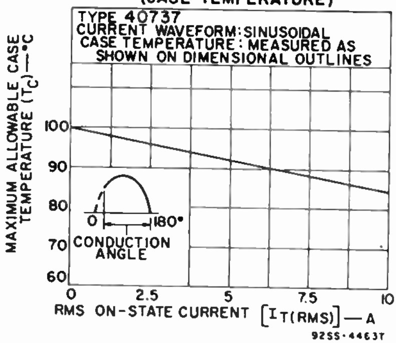
## MAXIMUM RATINGS (cont'd)

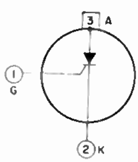
| | | |
|---|---|---|
| $I_{TSM}$ (1 cycle of sinusoidal principal voltage): | | |
| 50 Hz | 85 | A |
| 60 Hz | 100 | A |
| $I_{T(AV)}$ ($T_C$ = 85°C, conduction angle = 180°) | 6.3 | A |
| $I_{T(RMS)}$ ($T_C$ = 85°C, conduction angle = 180°) | 10 | A |
| di/dt ($V_{DM}$ = $v_{B(OO)}$, $I_{GT}$ = 200 mA, $t_r$ = 0.5 μs) | 200 | A/μs |
| $P_{GM}$ (10 μs max) | 40 | W |
| $P_{G(AV)}$ (10 ms max) | 0.5 | W |
| $T_{STG}$ | −65 to 150 | °C |
| $T_C$(opr) | −65 to 100 | °C |
| $T_S$ (10 s max) | 225 | °C |

## CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

| | | |
|---|---|---|
| $v_{(BO)O}$ ($T_C$ = 100°C) | 100 | V |
| $I_{DOM}$ ($V_{DO}$ = $V_{DROM}$, $T_C$ = 100°C) | 0.2 typ; 3 max | mA |
| $I_{RROM}$ ($V_{RO}$ = $V_{RROM}$) | 0.1 typ; 3 max | mA |
| $v_T$ ($i_T$ = 100 A, $T_C$ = 25°C) | 1.7 typ; 2.5 max | V |
| $I_{GT}$ ($V_D$ = 12 Vdc, $R_L$ = 30 Ω) | 6 typ; 15 max | mA |
| $V_{GT}$ ($V_D$ = 12 Vdc, $R_L$ = 30 Ω) | 0.9 typ; 2 max | V |
| $i_{HO}$ | 9 typ; 20 max | mA |
| dv/dt ($V_D$ = $V_{DROM}$, $T_C$ = 100°C) | 10 min; 200 max | V/μs |
| $t_{gt}$ ($V_D$ = $V_{DROM}$, $i_T$ = 30 A, $I_{GT}$ = 200 mA, $t_r$ = 0.1 μs) | 1.6 | μs |
| $t_q$ ($V_{DX}$ = $V_{DROM}$, $i_T$ = 18 A, $t_p$ = 50 μs, $I_{GT}$ = 200 mA, −di/dt = −30 A/μs, dv/dt = 20 V/μs, $T_C$ = 75°C) | 15 typ; 50 max | μs |
| $\theta_{J-C}$ | 1.5 max | °C/W |
| $\theta_{J-IS}$ | 1.7 max | °C/W |

CONDUCTION RATING CHART (CASE TEMPERATURE)

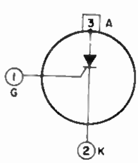



**10A, 100V**

## 40741

Si all-diffused type used for power switching and voltage regulator applications and for heating, lighting, and motor speed-control circuits. Outline No.37. See Mounting Hardware for desired mounting arrangement. This type is electrically identical with type 40737.

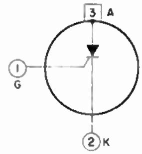



**10A, 100V**

## 40745

Si all-diffused type used for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits. Outline No.71. See Mounting Hardware for desired mounting arrangement. This type is electrically identical with type 40737.

## 40738 10A, 200V




Si all-diffused type used for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits. Outline No.36. For Conduction Rating Chart and Forward Gate Characteristics curves, refer to type 40737.

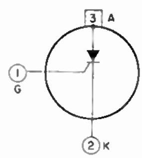
### MAXIMUM RATINGS

| | | |
|---|---|---|
| $V_{RSOM}$ | 200 | V |
| $V_{DSOM}$ | 250 | V |
| $V_{RROM}$ | 200 | V |
| $V_{DROM}$ | 200 | V |
| $I_{TSM}$ (1 cycle of sinusoidal principal voltage): | | |
| 50 Hz | 85 | A |
| 60 Hz | 100 | A |
| $I_{T(AV)}$ ($T_C$ = 85°C, conduction angle = 180°) | 6.3 | A |
| $I_{T(RMS)}$ ($T_C$ = 85°C, conduction angle = 180°) | 10 | A |
| di/dt ($V_{DM}$ = $v_{(BO)O}$, $I_{GT}$ = 200 mA, $t_r$ = 0.5 μs) | 200 | A/μs |
| $P_{GM}$ (10 μs max) | 40 | W |
| $P_{G(AV)}$ (10 ms max) | 0.5 | W |
| $T_{STG}$ | −65 to 150 | °C |
| $T_C$(opr) | −65 to 100 | °C |
| $T_S$ (10 s max) | 225 | °C |

### CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

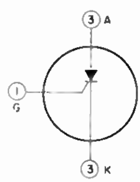
| | | |
|---|---|---|
| $v_{(BO)O}$ ($T_C$ = 100°C) | 200 | V |
| $I_{DOM}$ ($V_{DO}$ = $V_{DROM}$, $T_C$ = 100°C) | 0.2 typ; 3 max | mA |
| $I_{RROM}$ ($V_{RO}$ = $V_{RROM}$) | 0.1 typ; 3 max | mA |
| $v_T$ ($i_T$ = 100 A, $T_C$ = 25°C) | 1.7 typ; 2.5 max | V |
| $I_{GT}$ ($V_D$ = 12 Vdc, $R_L$ = 30 Ω) | 6 typ; 15 max | mA |
| $V_{GT}$ ($V_D$ = 12 Vdc, $R_L$ = 30 Ω) | 0.9 typ; 2 max | V |
| $i_{HO}$ | 9 typ; 20 max | mA |
| dv/dt ($V_D$ = $V_{DROM}$, $T_C$ = 100°C) | 10 typ; 200 max | V/μs |
| $t_{gt}$ ($V_D$ = $V_{DROM}$, $i_T$ = 30 A, $I_{GT}$ = 200 mA, $t_r$ = 0.1 μs) | 1.6 | μs |
| $t_q$ ($V_{DX}$ = $V_{DROM}$, $i_T$ = 18 A, $t_p$ = 50 μs, $I_{GT}$ = 200 mA, −di/dt = −30 A/μs, dv/dt = 20 V/μs, $T_C$ = 75°C) | 15 typ; 50 max | μs |
| $\theta_{J-C}$ | 1.5 max | °C/W |
| $\theta_{J-IS}$ | 1.7 max | °C/W |

## 40742 10A, 200V



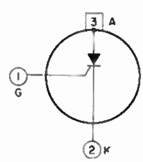

Si all-diffused type use for power switching and voltage regulator applications and for heating, lighting, and motor speed-control circuits. Outline No.37. See Mounting Hardware for desired mounting arrangement. This type is electrically identical with type 40738.

## 40746 10A, 200V




Si all-diffused type used for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits. Outline No.71. See Mounting Hardware for desired mounting arrangement. This type is electrically identical with type 40738.

## 40739 10A, 400V



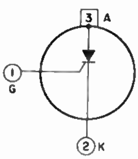

Si all-diffused type used for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits. Outline No.36. For Conduction Rating Chart and Forward Gate Characteristics curves, refer to type 40737.

## MAXIMUM RATINGS

| | | |
|---|---|---|
| $V_{RSOM}$ | 400 | V |
| $V_{DSOM}$ | 500 | V |
| $V_{RROM}$ | 400 | V |
| $V_{DROM}$ | 400 | V |
| $I_{TSM}$ (1 cycle of sinusoidal principal voltage): | | |
| 50 Hz | 85 | A |
| 60 Hz | 100 | A |
| $I_{T(AV)}$ ($T_C = 85°C$, conduction angle $= 180°$) | 6.3 | A |
| $I_{T(RMS)}$ ($T_C = 85°C$, conduction angle $= 180°$) | 10 | A |
| di/dt ($V_{DM} = v_{(BO)O}$, $I_{GT} = 200$ mA, $t_r = 0.5$ μs) | 200 | A/μs |
| $P_{GM}$ (10 μs max) | 40 | W |
| $P_{G(AV)}$ (10 ms max) | 0.5 | W |
| $T_{STG}$ | −65 to 150 | °C |
| $T_C$(opr) | −65 to 100 | °C |
| $T_S$ (10 s max) | 225 | °C |

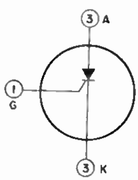
## CHARACTERISTICS (At maximum electrical ratings at $T_C = 25°C$)

| | | |
|---|---|---|
| $v_{(BO)O}$ ($T_C = 100°$) | 400 | V |
| $I_{DOM}$ ($V_{DO} = V_{DROM}$, $T_C = 100°C$) | 0.2 typ; 3 max | mA |
| $I_{RROM}$ ($V_{RO} = V_{RROM}$) | 0.1 typ; 3 max | mA |
| $v_T$ ($i_T = 100$ A, $T_C = 25°C$) | 1.7 typ; 2.5 max | V |
| $I_{GT}$ ($V_D = 12$ Vdc, $R_L = 30\ \Omega$) | 6 typ; 15 max | mA |
| $V_{GT}$ ($V_D = 12$ Vdc, $R_L = 30\ \Omega$) | 0.9 typ; 2 max | V |
| $i_{HO}$ | 9 typ; 20 max | mA |
| dv/dt ($V_D = V_{DROM}$, $T_C = 100°$) | 10 typ; 150 max | V/μs |
| $t_{gt}$ ($V_D = V_{DROM}$, $i_T = 30$ A, $I_{GT} = 200$ mA, $t_r = 0.1$ μs) | 1.6 | μs |
| $t_q$ ($V_{DX} = V_{DROM}$, $i_T = 18$ A, $t_p = 50$ μs, $I_{GT} = 200$ mA, $-$di/dt $= -30$ A/μs, dv/dt $= 20$ V/μs, $T_C = 75°C$) | 15 typ; 50 max | μs |
| $\theta_{J\text{-}C}$ | 1.5 max | °C/W |
| $\theta_{J\text{-}IS}$ | 1.7 max | °C/W |



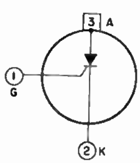

## 10A, 400V 40743

Si all-diffused type used for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits. Outline No.37. See Mounting Hardware for desired mounting arrangement. This type is electrically identical with type 40739.




## 10A, 400V 40747

Si all-diffused type used for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits. Outline No.71. See Mounting Hardware for desired mounting arrangement. This type is electrically identical with type 40739.




## 10A, 600V 40740

Si all-diffused type used for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits. Outline No.36. For Conduction Rating Chart and Forward Gate Characteristics curves, refer to type 40737.

## MAXIMUM RATINGS

| | | |
|---|---|---|
| $V_{RSOM}$ | 600 | V |
| $V_{DSOM}$ | 700 | V |
| $V_{RROM}$ | 600 | V |
| $V_{DROM}$ | 600 | V |
| $I_{TSM}$ (1 cycle of sinusoidal principal voltage): | | |
| 50 Hz | 85 | A |
| 60 Hz | 100 | A |

## MAXIMUM RATINGS (cont'd)

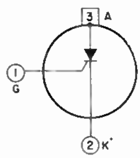
| | | |
|---|---|---|
| $I_{T(AV)}$ ($T_C$ = 85°C, conduction angle = 180°) | 6.3 | A |
| $I_{T(RMS)}$ ($T_C$ = 85°C, conduction angle = 180°) | 10 | A |
| di/dt ($V_{DM}$ = $v_{(BO)O}$, $I_{GT}$ = 200 mA, $t_r$ = 0.5 μs) | 200 | A/μs |
| $P_{GM}$ (10 μs max) | 40 | W |
| $P_{G(AV)}$ (10 ms max) | 0.5 | W |
| $T_{STG}$ | —65 to 150 | °C |
| $T_C$(opr) | —65 to 100 | °C |
| $T_S$ (10 s max) | 225 | °C |

## CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

| | | |
|---|---|---|
| $v_{(BO)O}$ ($T_C$ = 100°C) | 600 | V |
| $I_{DOM}$ ($V_{DO}$ = $V_{DROM}$, $T_C$ = 100°C) | 0.2 typ; 3 max | mA |
| $I_{RROM}$ ($V_{RO}$ = $V_{RROM}$) | 0.1 typ; 3 max | mA |
| $v_T$ ($i_T$ = 100 A, $T_C$ = 25°C) | 1.7 typ; 2.5 max | V |
| $I_{GT}$ ($V_D$ = 12 Vdc, $R_L$ = 30 Ω) | 6 typ; 15 max | mA |
| $V_{GT}$ ($V_D$ = 12 Vdc, $R_L$ = 30 Ω) | 0.9 typ; 2 max | V |
| $i_{HO}$ | 9 typ; 20 max | mA |
| dv/dt ($V_D$ = $V_{DROM}$, $T_C$ = 100°C) | 10 typ; 75 max | V/μs |
| $t_{gt}$ ($V_D$ = $V_{DROM}$, $i_T$ = 30 A, $I_{GT}$ = 200 mA, $t_r$ = 0.1 μs) | 1.6 | μs |
| $t_q$ ($V_{DX}$ = $V_{DROM}$, $i_T$ = 18 A, tp = 50 μs, $I_{GT}$ = 200 mA, —di/dt = —30 A/μs, dv/dt = 20 V/μs, $T_C$ = 75°C) | 15 typ; 50 max | μs |
| $\Theta_{J-C}$ | 1.5 max | °C/W |
| $\Theta_{J-IS}$ | 1.7 max | °C/W |

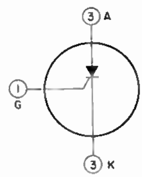
## 40744 — 10A, 600V

Si all-diffused type used for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits. Outline No.37. See Mounting Hardware for desired mounting arrangement. This type is electrically identical with type 40740.



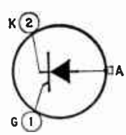

## 40748 — 10A, 600V

Si all-diffused type used for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits. Outline No.71. See Mounting Hardware for desired mounting arrangement. This type is electrically identical with type 40740.




## 2N3668–2N3670 — 12.5A, 100V—400V

Si all-diffused three-junction types for use in power-control and power-switching applications. JEDEC TO-3, Outline No.2. See Mounting Hardware for desired mounting arrangement.

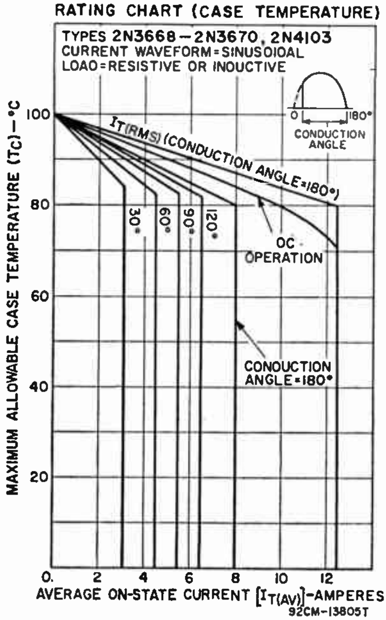


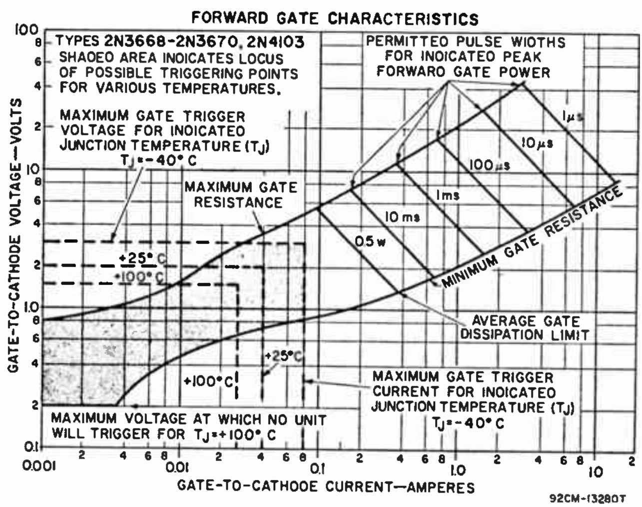

## MAXIMUM RATINGS (For sinusoidal ac supply voltage at f = 50 to 400 Hz with resistive or inductive load)

| | 2N3668 | 2N3669 | 2N3670 | |
|---|---|---|---|---|
| $V_{RSOM}$ | 150 | 330 | 660 | V |
| $V_{RROM}$ | 100 | 200 | 400 | V |
| $V_{DROM}$ | 600 | 600 | 600 | V |

## MAXIMUM RATINGS (cont'd)

| | | |
|---|---|---|
| $I_{T(AV)}$ (conduction angle = 180°, $T_C$ = 80°C) | 8 | A |
| $I_{T(RMS)}$ | 12.5 | A |
| $I_{TSM}$ (1 cycle of principle voltage) | 200 | A |
| Critical di/dt | 200 | A/μs |
| $[I_{TS(RMS)}]^2t$ (1 to 8.3 ms) | 165 | $A^2s$ |



**MAXIMUM RATINGS (cont'd)**

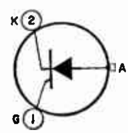
| | 2N3668 | 2N3669 | 2N3670 | |
|---|---|---|---|---|
| $P_{GM}$ (peak, forward, or reverse for 10 $\mu$s) | | 40 | | W |
| $P_{G(AV)}$ | | 0.5 | | W |
| $T_{stg}$ | | −40 to 125 | | °C |
| $T_C$ | | −40 to 100 | | °C |

**CHARACTERISTICS (At maximum electrical rating at $T_C$ = 25°C)**

| | 2N3668 | 2N3669 | 2N3670 | |
|---|---|---|---|---|
| $v_{F(BO)O}$ ($T_C$ = 100°C) | 100 min | 200 min | 400 min | V |
| | 0.2 typ | 0.25 typ | 0.3 typ | mA |
| $I_{DOM}$ ($T_C$ = 100°C, $V_{DO}$ = $v_{F(BO)O}$ min value | 2 max | 2.5 max | 3 max | mA |
| | 0.05 typ | 0.1 typ | 0.2 typ | mA |
| $I_{RROM}$ ($V_{RO}$ = $V_{RROM}$) | 1 max | 1.25 max | 1.5 max | mA |
| $v_T$ (on-state current = 25 A) | | 1.5 typ; 1.8 max | | V |
| $I_{GT}$ | | 1 min, 20 typ, 40 max | | mA(dc) |
| $V_{GT}$ | | 1.5 typ; 2 max | | V(dc) |
| $i_{HO}$ | | 0.5 to 50 | | mA |
| Critical dv/dt ($V_D$ = $v_{F(BO)O}$ min value, exponential rise, $T_C$ = 100°C) | | 10 min; 100 typ | | V/$\mu$s |
| $t_{gt}$ ($V_D$ = $v_{F(BO)O}$ min value, $i_T$ = 8 A, $I_{GT}$ = 200 mA, $t_r$ = 0.1 $\mu$s) | | 0.75 min; 1.25 typ | | $\mu$s |
| $t_q$ ($i_T$ = 8 A, 50 $\mu$s pulse width, $dv_D/dt$ = 20 V/$\mu$s, $di_R/dt$ = 30 A/$\mu$s, $I_{GT}$ = 200 mA, $T_C$ = 80°C) | | 20 typ; 50 max | | $\mu$s |
| $\theta_{J-C}$ | | 1.7 max | | °C/W |

# 2N4103

**12.5A, 700V**




Si all-diffused three-junction type for use in power-control and power-switching applications. See Mounting Hardware for desired mounting arrangement. JEDEC TO-3, Outline No.2. This type is identical with type 2N3668 except for the following items:

**MAXIMUM RATINGS (For sinusoidal ac supply voltage at f = 50 to 400 Hz with resistive or inductive load)**

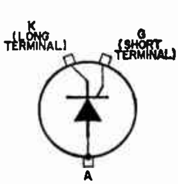
| | | |
|---|---|---|
| $V_{RSOM}$ | 700 | V |
| $V_{RROM}$ | 600 | V |
| $V_{DROM}$ | 700 | V |

**CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)**

| | | |
|---|---|---|
| $v_{F(BO)O}$ ($T_C$ = 100°C) | 600 min | V |
| $I_{DOM}$ ($V_{DO}$ = $v_{F(BO)O}$ min value, $T_C$ = 100°C) | 0.35 typ; 4 max | mA |
| $I_{RROM}$ ($V_{RO}$ = $V_{RROM}$) | 0.3 typ; 3 max | mA |

# 2N1842A–2N1850A

**16A, 600V**




Si all-diffused three-junction types for use in power-control and power-switching applications. JEDEC TO-48, Outline No.20. See Mounting Hardware for desired mounting arrangement.

**MAXIMUM RATINGS (For sinusoidal ac supply voltage at f = 50 to 400 Hz with resistive or inductive load)**

| | 2N1842A | 2N1843A | 2N1844A | 2N1845A | 2N1846A | 2N1847A | 2N1848A | 2N1849A | 2N1850A | |
|---|---|---|---|---|---|---|---|---|---|---|
| $V_{RSOM}$ | 35 | 75 | 150 | 225 | 300 | 350 | 400 | 500 | 600 | V |
| $V_{RROM}$ | 25 | 50 | 100 | 150 | 200 | 250 | 300 | 400 | 500 | V |
| $V_{DROM}$ | | | | | 600 | | | | | V |
| $I_{T(AV)}$ | | | | | 10 (conduction angle = 180°, $T_C$ = 80°C) | | | | | V |
| $I_{T(RMS)}$ | | | | | 16 | | | | | A |
| $I_{TSM}$ | | | | | 125 (1 cycle of voltage) | | | | | A |
| $P_{GM}$ | | | | | 5 | | | | | W |
| $P_{G(AV)}$ | | | | | 0.5 | | | | | W |

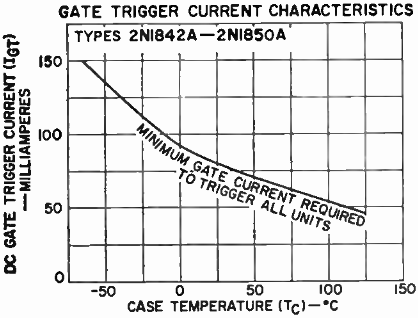
## MAXIMUM RATINGS (cont'd)

| | 2N1842A | 2N1843A | 2N1844A | 2N1845A | 2N1846A | 2N1847A | 2N1848A | 2N1849A | 2N1850A | |
|---|---|---|---|---|---|---|---|---|---|---|
| $I_{GTM}$ | 2 | | | | | | | | | A |
| $V_{GTM}$ | 10, 5 | | | | | | | | | V |
| $T_{stg}$ | −65 to 125 | | | | | | | | | °C |
| $T_C$ | −65 to 125 | | | | | | | | | °C |

## CHARACTERISTICS (At maximum electrical rating at $T_C$ = 125°C)

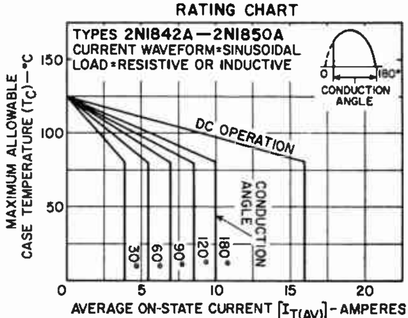
| | 2N1842A | 2N1843A | 2N1844A | 2N1845A | 2N1846A | 2N1847A | 2N1848A | 2N1849A | 2N1850A | |
|---|---|---|---|---|---|---|---|---|---|---|
| $v_{F(BO)O}$ (min) | 25 | 50 | 100 | 150 | 200 | 250 | 300 | 400 | 500 | V |
| $I_{DOM}$ (max) | 22.5 | 19 | 12.5 | 6.5 | 6 | 5.5 | 5 | 4 | 3 | mA |
| $I_{RROM}$ (max) | 22.5 | 19 | 12.5 | 6.5 | 6 | 5.5 | 5 | 4 | 3 | mA |
| $v_T$ | 1.2 ($T_C$ = 80°C) | | | | | | | | | V |
| $I_{GT}$ | 45 | | | | | | | | | mA |
| $V_{GT}$(max) | 3.5 ($T_C$ = −40°C) | | | | | | | | | V |
| $V_{GT}$(max) | 3.7 ($T_C$ = −65°C) | | | | | | | | | V |
| $V_{GT}$(min) | 0.25 | | | | | | | | | V |
| $V_{GT}$(min) | 0.3 ($T_C$ = 100°C) | | | | | | | | | V |
| $i_{HO}$ | 8 | | | | | | | | | mA |
| $\theta_{J-C}$ | 2 | | | | | | | | | °C/W |

GATE TRIGGER CURRENT CHARACTERISTICS

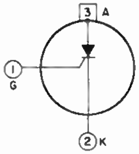



92CS-11906T2

RATING CHART




92CS-11905T3




## 20A, 100V

## 40749

Si all-diffused type used for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits. Outline No.36.

## MAXIMUM RATINGS

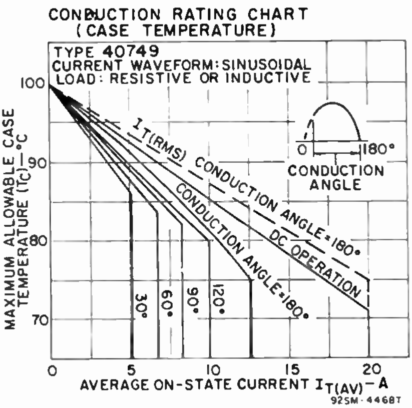
| | | |
|---|---|---|
| $V_{RSOM}$ | 100 | V |
| $V_{DSOM}$ | 150 | V |
| $V_{RROM}$ | 100 | V |
| $V_{DROM}$ | 100 | V |
| $I_{TSM}$ (1 cycle of sinusoidal principal voltage): | | |
| 50 Hz | 170 | A |
| 60 Hz | 200 | A |
| $I_{T(AV)}$ ($T_C$ = 75°C, conduction angle = 180°) | 12.5 | A |
| $I_{T(RMS)}$ ($T_C$ = 75°C, conduction angle = 180°) | 20 | A |
| di/dt ($V_{DM}$ = $v_{(BO)O}$, $I_{GT}$ = 200 mA, $t_r$ = 0.5 $\mu$s) | 200 | A/$\mu$s |
| $P_{GM}$ (10 $\mu$s max) | 40 | W |
| $P_{G(AV)}$ (10 ms max) | 0.5 | W |
| $T_{STG}$ | −65 to 150 | °C |
| $T_C$(opr) | −65 to 100 | °C |
| $T_S$ (10 s max) | 225 | °C |

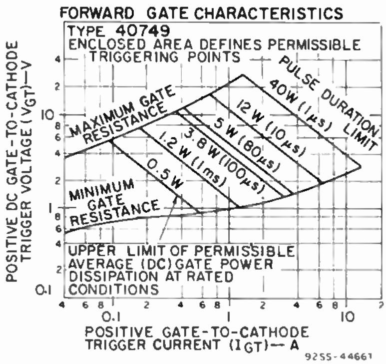
## CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

| | | |
|---|---|---|
| $v_{(BO)O}$ ($T_C$ = 100°C) | 100 min | V |
| $I_{DOM}$ ($V_{DO}$ = $V_{DROM}$, $T_C$ = 100°C) | 0.2 typ; 3 max | mA |
| $I_{RROM}$ ($V_{RO}$ = $V_{RROM}$) | 0.1 typ; 2 max | mA |
| $v_T$ ($i_T$ = 100 A, $T_C$ = 25°C) | 1.9 typ; 2.4 max | V |
| $I_{GT}$ ($V_D$ = 12 Vdc, $R_L$ = 30 Ω) | 8 typ; 15 max | mA |

## CHARACTERISTICS (cont'd)

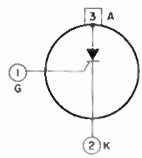
| | | |
|---|---|---|
| $V_{GT}$ ($V_D$ = 12 Vdc, $R_L$ = 30 Ω) | 1.1 typ; 2 max | V |
| $i_{HO}$ | 9 typ; 20 max | mA |
| dv/dt | 10 min; 100 max | V/μs |
| $t_{gt}$ ($V_D$ = $v_{(BO)O}$ min value, $i_T$ = 30 A, $I_{GT}$ = 200 mA, $t_r$ = 0.1 μs) | 2 | μs |
| $t_q$ ($V_{F(BO)O}$ min value, $i_T$ = 18 A, tp = 50 μs, $I_{GT}$ = 200 mA, −di/dt = −30 A/μs, dv/dt = 20 V/μs, $T_C$ = 75°C) | 20 typ; 40 max | μs |
| $\Theta_{J-C}$ | 1.2 max | °C/W |
| $\Theta_{J-HS}$ | 1.4 max | °C/W |




# 40752

**20A, 100V**




Si all-diffused type used for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits. Outline No.36. For Conduction Rating Chart and Forward Gate Characteristics curves, refer to type 40749.

## MAXIMUM RATINGS

| | | |
|---|---|---|
| $V_{RSOM}$ | 100 | V |
| $V_{DSOM}$ | 150 | V |
| $V_{RROM}$ | 100 | V |
| $V_{DROM}$ | 100 | V |
| $I_{TSM}$ (1 cycle of sinusoidal principal voltage): | | |
| 50 Hz | 170 | A |
| 60 Hz | 200 | A |
| $I_{T(AV)}$ ($T_C$ = 75°C, conduction angle = 180°) | 12.5 | A |
| $I_{T(RMS)}$ ($T_C$ = 75°C, conduction angle = 180°) | 20 | A |
| di/dt ($V_{DM}$ = $v_{(BO)O}$, $I_{GT}$ = 200 mA, $t_r$ = 0.5 μs) | 200 | A/μs |
| $P_{GM}$ (10 μs max) | 40 | W |
| $P_{G(AV)}$ (10 ms max) | 0.5 | W |
| $T_{STG}$ | −65 to 150 | °C |
| $T_C$(opr) | −65 to 100 | °C |
| $T_S$ (10 s max) | 225 | °C |

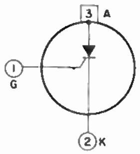
## CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

| | | |
|---|---|---|
| $v_{(BO)O}$ ($T_C$ = 100°C) | 600 | V |
| $I_{DOM}$ ($V_{DO}$ = $V_{DROM}$, $T_C$ = 100°C) | 0.2 typ; 3 max | mA |
| $I_{RROM}$ ($V_{RO}$ = $V_{RROM}$) | 0.1 typ; 2 max | mA |
| $v_T$ ($i_T$ = 100 A, $T_C$ = 25°C) | 1.9 typ; 2.4 max | V |
| $I_{GT}$ ($V_D$ = 12 Vdc, $R_L$ = 30 Ω) | 8 typ; 15 max | mA |
| $V_{GT}$ ($V_D$ = 12 Vdc, $R_L$ = 30 Ω) | 1.1 typ; 2 max | V |
| $i_{HO}$ | 9 typ; 20 max | mA |
| dv/dt | 10 min; 75 max | V/μs |

**CHARACTERISTICS (cont'd)**

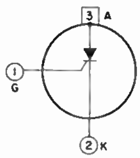
| | | |
|---|---|---|
| $t_{gt}$ ($V_D = V_{(BO)O}$ min value, $i_T = 30$ A, $I_{GT} = 200$ mA, $t_r = 0.1$ $\mu s$) | 2 | $\mu s$ |
| $t_q$ ($V_{F(BO)O}$ min value, $i_T = 18$ A, $t_p = 50$ $\mu s$, $I_{GT} = 200$ mA, $-di/dt = -30$ A/$\mu s$, $dv/dt = 20$ V/$\mu s$, $T_C = 75°C$) | 20 typ; 40 max | $\mu s$ |
| $\theta_{J-C}$ | 1.2 max | °C/W |
| $\theta_{J-IS}$ | 1.4 max | °C/W |

## 20A, 100V — 40753



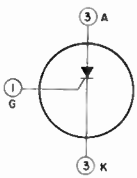

Si all-diffused type used for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits. Outline No.37. See Mounting Hardware for desired mounting arrangement. This type is electrically identical with type 40749.

## 20A, 100V — 40756



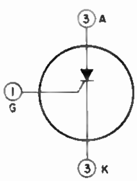

Si all-diffused type used for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits. Outline No.37. See Mounting Hardware for desired mounting arrangement. This type is electrically identical with type 40752

## 20A, 100V — 40757



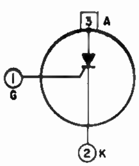

Si all-diffused type used for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits. Outline No.71. See Mounting Hardware for desired mounting arrangement. This type is electrically identical with type 40749.

## 20A, 100V — 40760




Si all-diffused type used for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits. Outline No.71. See Mounting Hardware for desired mounting arrangement. This type is electrically identical with type 40752.

## 20A, 200V — 40750




Si all-diffused type used for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits. Outline No.36. For Conduction Rating Chart and Forward Gate Characteristics curves, refer to type 40749.

## MAXIMUM RATINGS

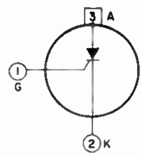
| | | |
|---|---|---|
| $V_{RSOM}$ | 100 | V |
| $V_{DSOM}$ | 150 | V |
| $V_{RROM}$ | 100 | V |
| $V_{DROM}$ | 100 | V |
| $I_{TSM}$ (1 cycle of sinusoidal principal voltage): | | |
| 50 Hz | 170 | A |
| 60 Hz | 200 | A |
| $I_{T(AV)}$ ($T_C$ = 75°C, conduction angle = 180°) | 12.5 | A |
| $I_{T(RMS)}$ ($T_C$ = 75°C, conduction angle = 180°) | 20 | A |
| di/dt ($V_{DM} = v_{(BO)O}$, $I_{GT}$ = 200 mA, $t_r$ = 0.5 μs) | 200 | A/μs |
| $P_{GM}$ (10 μs max) | 40 | W |
| $P_{G(AV)}$ (10 ms max) | 0.5 | W |
| $T_{STG}$ | −65 to 150 | °C |
| $T_C$(opr) | −65 to 100 | °C |
| $T_S$ (10 s max) | 225 | °C |

## CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

| | | |
|---|---|---|
| $v_{(BO)O}$ ($T_C$ = 100°C) | 200 | V |
| $I_{DOM}$ ($V_{DO} = V_{DROM}$, $T_C$ = 100°C) | 0.2 typ; 3 max | mA |
| $I_{RROM}$ ($V_{RO} = V_{RROM}$) | 0.1 typ; 2 max | mA |
| $v_T$ ($i_T$ = 100 A, $T_C$ = 25°C) | 1.9 typ; 2.4 max | V |
| $I_{GT}$ ($V_D$ = 12 Vdc, $R_L$ = 30 Ω) | 8 typ; 15 max | mA |
| $V_{GT}$ ($V_D$ = 12 Vdc, $R_L$ = 30 Ω) | 1.1 typ; 2 max | V |
| $i_{HO}$ | 9 typ; 20 max | mA |
| dv/dt | 10 min; 150 max | V/μs |
| $t_{gt}$ ($V_D = v_{(BO)O}$ min value, $i_T$ = 30 A, $I_{GT}$ = 200 mA, $t_r$ = 0.1 μs) | 2 | μs |
| $t_q$ ($V_{F(BO)O}$ min value, $i_T$ = 18 A, tp = 50 μs, $I_{GT}$ = 200 mA, −di/dt = −30 A/μs, dv/dt = 20 V/μs, $T_C$ = 75°C) | 20 typ; 40 max | μs |
| $\theta_{J-C}$ | 1.2 max | °C/W |
| $\theta_{J-HS}$ | 1.4 max | °C/W |

# 40754

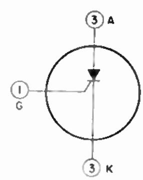
**20A, 200V**




Si all-diffused type used for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits. Outline No.37. See Mounting Hardware for desired mounting arrangement. This type is electrically identical with type 40750.

# 40758

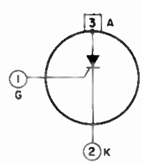
**20A, 200V**




Si all-diffused type used for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits. Outline No.71. See Mounting Hardware for desired mounting arrangement. This type is electrically identical with type 40750.

# 40751

**20A, 400V**




Si all-diffused type used for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits. Outline No.36. For Conduction Rating Chart and Forward Gate Characteristics curves, refer to type 40749.

## MAXIMUM RATINGS

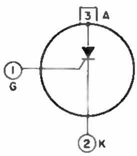
| | | |
|---|---|---|
| $V_{RSOM}$ | 100 | V |
| $V_{DSOM}$ | 150 | V |
| $V_{RROM}$ | 100 | V |
| $V_{DROM}$ | 100 | V |

## MAXIMUM RATINGS (cont'd)

| | | |
|---|---|---|
| $I_{TSM}$ (1 cycle of sinusoidal principal voltage): | | |
| 50 Hz | 170 | A |
| 60 Hz | 200 | A |
| $I_{T(AV)}$ ($T_C$ = 75°C, conduction angle = 180°) | 12.5 | A |
| $I_{T(RMS)}$ ($T_C$ = 75°C, conduction angle = 180°) | 20 | A |
| di/dt ($V_{DM}$ = $v_{(BO)O}$, $I_{GT}$ = 200 mA, $t_r$ = 0.5 μs) | 200 | A/μs |
| $P_{GM}$ (10 μs max) | 40 | W |
| $P_{G(AV)}$ (10 ms max) | 0.5 | W |
| $T_{STG}$ | —65 to 150 | °C |
| $T_C$(opr) | —65 to 100 | °C |
| $T_S$ (10 s max) | 225 | °C |

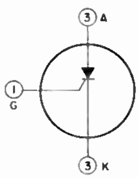
## CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

| | | |
|---|---|---|
| $v_{(BO)O}$ ($T_C$ = 100°C) | 400 | V |
| $I_{DOM}$ ($V_{DO}$ = $V_{DROM}$, $T_C$ = 100°C) | 0.2 typ; 3 max | mA |
| $I_{RROM}$ ($V_{RO}$ = $V_{RROM}$) | 0.1 typ; 2 max | mA |
| $v_T$ ($i_T$ = 100 A, $T_C$ = 25°C) | 1.9 typ; 2.4 max | V |
| $I_{GT}$ ($V_D$ = 12 Vdc, $R_L$ = 30 Ω) | 8 typ; 15 max | mA |
| $V_{GT}$ ($V_D$ = 12 Vdc, $R_L$ = 30 Ω) | 1.1 typ; 2 max | V |
| $i_{HO}$ | 9 typ; 20 max | mA |
| dv/dt | 10 min; 100 max | V/μs |
| $t_{gt}$ ($V_D$ = $v_{(BO)O}$ min value, $i_T$ = 30 A, $I_{GT}$ = 200 mA, $t_r$ = 0.1 μs) | 2 | μs |
| $t_q$ ($V_{F(BO)O}$ min value, $i_T$ = 18 A, tp = 50 μs, $I_{GT}$ = 200 mA, —di/dt = —30 A/μs, dv/dt = 20 V/μs, $T_C$ = 75°C) | 20 typ; 40 max | μs |
| $\theta_{J-C}$ | 1.2 max | °C/W |
| $\theta_{J-IS}$ | 1.4 max | °C/W |



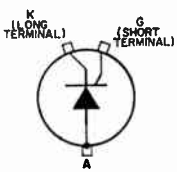

## 20A, 400V — 40755

Si all-diffused type used for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits. Outline No.37. See Mounting Hardware for desired mounting arrangement. This type is electrically identical with type 40751.




## 20A, 400V — 40759

Si all-diffused type used for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits. Outline No.71. See Mounting Hardware for desired mounting arrangement. This type is electrically identical with type 40751.




## 25A, 600V — 2N681–2N690

Si all-diffused three-junction types for use in power-control and power-switching applications. JEDEC TO-48, Outline No.20. See Mounting Hardware for desired mounting arrangement.

## MAXIMUM RATINGS (For sinusoidal ac supply voltage at f = 50 to 400 Hz with resistive or inductive load)

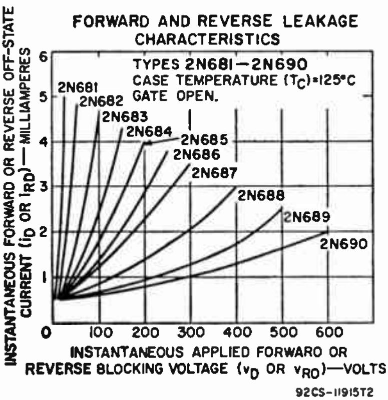
| | 2N681 | 2N682 | 2N683 | 2N684 | 2N685 | 2N686 | 2N687 | 2N688 | 2N689 | 2N690 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $V_{RSOM}$ | 35 | 75 | 150 | 225 | 300 | 350 | 400 | 500 | 600 | 720 | V |
| $V_{RROM}$ | 25 | 50 | 100 | 150 | 200 | 250 | 300 | 400 | 500 | 600 | V |

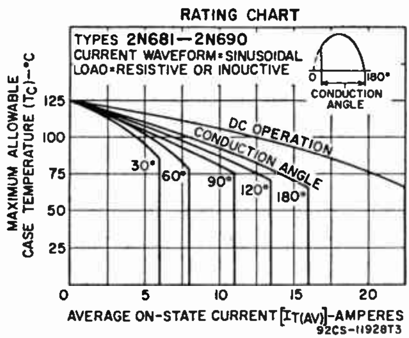
### MAXIMUM RATINGS (cont'd)

| | | |
|---|---|---|
| $V_{DROM}$ | 600 | V |
| $I_{T(AV)}$ | 16 (conduction angle = 180°, $T_C$ = 65°C) | A |
| $I_{T(RMS)}$ | 25 | A |
| $I_{TSM}$ | 150 (1 cycle applied voltage) | A |
| $P_{GM}$ | 5 | W |
| $P_{G(AV)}$ | 0.5 | W |
| $I_{GTM}$ | 2 | A |
| $V_{GTM}$ | 10, 5 | V |
| $T_{stg}$ | −65 to 150 | °C |
| $T_C$ | −65 to 125 | °C |

### CHARACTERISTICS (At maximum electrical rating at $T_C$ = 125°C)

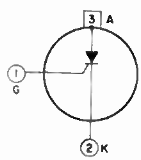
| | 2N681 | 2N682 | 2N683 | 2N684 | 2N685 | 2N686 | 2N687 | 2N688 | 2N689 | 2N690 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $v_{F(BO)O}$ (min) | 25 | 50 | 100 | 150 | 200 | 250 | 300 | 400 | 500 | 600 | V |
| $I_{DOM}$ (max) | 6.5 | 6.5 | 6.5 | 6.5 | 6 | 5.5 | 5 | 4 | 3 | 2.5 | mA |
| $I_{RROM}$ (max) | 6.5 | 6.5 | 6.5 | 6.5 | 6 | 5.5 | 5 | 4 | 3 | 2.5 | mA |
| $v_T$ (max) | 0.86 (on-state current = 25 A, $T_C$ = 65°C) | | | | | | | | | | V |
| $I_{GT}$ (max) | 25 | | | | | | | | | | mA |
| $V_{GT}$ (max) | 3 (−65 to 125°C) | | | | | | | | | | V |
| $V_{GT}$ (min) | 0.25 | | | | | | | | | | V |
| $i_{HO}$ | 15 | | | | | | | | | | mA |
| $\theta_{J-C}$ | 2 | | | | | | | | | | °C/W |




# 2N3650–2N3653

**35A, 100V—400V**




Si all-diffused types used for high-speed switching applications such as power inverters, switching regulators, and high-current pulse applications. JEDEC TO-48, Outline No.20. See Mounting Hardware for desired mounting arrangement.

### MAXIMUM RATINGS

| | 2N3650 | 2N3651 | 2N3652 | 2N3653 | |
|---|---|---|---|---|---|
| $V_{RSOM}$ | 150 | 300 | 400 | 500 | V |
| $V_{DSOM}$ | 150 | 300 | 400 | 500 | V |
| $V_{RROM}$ | 100 | 200 | 300 | 400 | V |
| $V_{DROM}$ | 100 | 200 | 300 | 400 | V |
| $I_{TSM}$ (1 cycle of principal voltage at 60 Hz) | 180 | | | | A |
| $I_{T(AV)}$ (conduction angle = 180°) | 25 | | | | A |
| $I_{T(RMS)}$ | 35 | | | | A |
| di/dt ($V_{DM}$ = $v_{(BO)O}$, $I_{GT}$ = 200 mA, $t_r$ = 0.1 μs) | 400 | | | | A/μs |
| $P_{GM}$ (10 μs max) | 40 | | | | W |

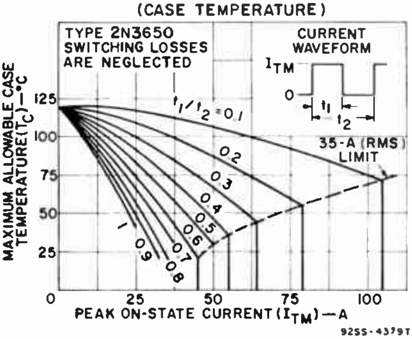
## MAXIMUM RATINGS (cont'd)

| | | |
|---|---|---|
| $P_{G(AV)}$ (10 ms max) | 1 | W |
| $T_{STG}$ | −65 to 150 | °C |
| $T_C$(opr) | −65 to 120 | °C |
| $T_S$ (10 s max) | 225 | °C |

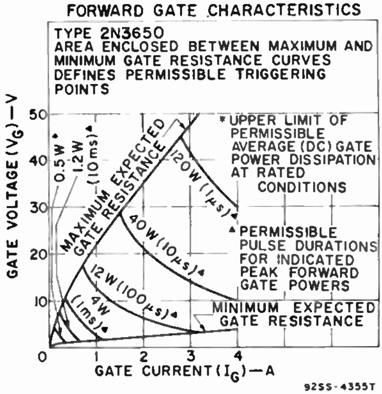
## CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

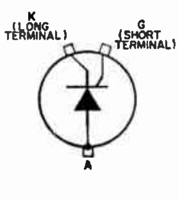
| | | | | | |
|---|---|---|---|---|---|
| $v_{(BO)O}$ ($T_C$ = 120°C) | 100 min | 200 min | 300 min | 400 min | V |
| $I_{DOM}$ ($V_{DO}$ = $V_{DROM}$, $T_C$ = 120°C) | 6 max | 6 max | 5.5 max | 4 max | mA |
| $I_{RROM}$ ($V_{RO}$ = $V_{DRROM}$, $T_C$ = 120°C) | 6 max | 6 max | 5.5 max | 4 max | mA |
| $v_T$ ($i_T$ = 25 A) | 2.05 max | | | | V |
| $I_{GT}$: | | | | | |
| $V_D$ = 6 Vdc, $R_L$ = 4 Ω | 80 typ; 180 max | | | | mA |
| $V_D$ = 6 Vdc, $R_L$ = 2 Ω, $T_C$ = − 65°C | 150 typ; 500 max | | | | mA |
| $V_{GT}$: | | | | | |
| $V_D$ = 6 Vdc, $R_L$ = 4 Ω | 1.5 typ; 3 max | | | | V |
| $V_D$ = $V_{DROM}$, $R_L$ = 200 Ω, $T_C$ = 120°C | 0.25 min | | | | V |
| $V_D$ = 6 Vdc, $R_L$ = 2 Ω, $T_C$ = −65°C | 2 typ; 4.5 max | | | | V |
| $i_{HO}$: | | | | | |
| $T_C$ = 25°C | 75 typ; 150 max | | | | mA |
| $T_C$ = −65°C | 150 typ; 350 max | | | | mA |
| Critical dv/dt ($V_{DO}$ = $V_{DROM}$, exponential rise, $T_C$ = 120°C) | 200 min | | | | V/μs |
| tq, Rectangular Pulse ($V_{DX}$ = $V_{DROM}$, $i_T$ = 10 A, tp = 50 μs, $I_{GT}$ = 200 mA at turn-on, — di/dt = 5 A/μs, dv/dt = 200 V/μs, $V_{RX}$ = 15 min, $V_{GK}$ = 0 at turn-off, $T_C$ = 120°C) | 11 typ; 15 max | | | | μs |
| tq, Half-Sinosoidal Waveform ($V_{DX}$ = $V_{DROM}$, $i_T$ = 100 A, tp = 1.5 μs, $I_{GT}$ = 200 mA, dv/dt = 200 V/μs, $V_{RX}$ = 30 Vmin, $V_{GK}$ = 0 at turn-off, $T_C$ = 115°C) | 12 typ; 15 max | | | | μs |
| $\theta_{J-C}$ | 1.7 max | | | | °C/W |

CONDUCTION RATING CHART (CASE TEMPERATURE)




FORWARD GATE CHARACTERISTICS




## 35A, 100V—600V

# 2N3870–2N3873

Si all-diffused three-junction types for use in power-control and power-switching applications. Outline No.36. For curve of forward gate characteristics, refer to type 2N3668.

## MAXIMUM RATINGS (For sinusoidal ac supply voltage at f = 50 to 400 Hz with resistive or inductive load)

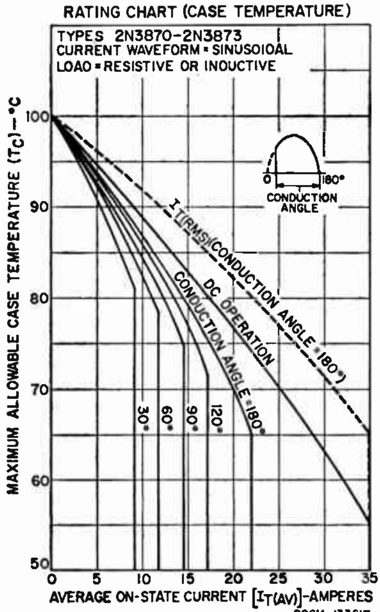
| | 2N3870 | 2N3871 | 2N3872 | 2N3873 | |
|---|---|---|---|---|---|
| $V_{RSOM}$ | 150 | 330 | 660 | 700 | V |
| $V_{RROM}$ | 100 | 200 | 400 | 600 | V |
| $V_{DROM}$ | 100 | 200 | 400 | 600 | V |
| $I_{T(AV)}$ (conduction angle = 180° $T_C$ = 65°C) | 22 | | | | A |
| $I_{T(RMS)}$ | 35 | | | | A |
| $I_{TSM}$ (1 cycle of principle voltage) | 350 | | | | A |
| Critical di/dt | 200 | | | | A/μs |
| $P_{GM}$ (peak, forward, or reverse for 10 μs) | 40 | | | | W |
| $P_{G(AV)}$ | 0.5 | | | | W |
| $T_{stg}$ | −40 to 125 | | | | °C |
| $T_C$ | −40 to 100 | | | | °C |

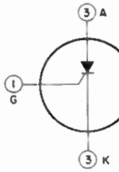
## CHARACTERISTICS (At maximum electrical rating at $T_C$ = 25°C)

| | 2N3870 | 2N3871 | 2N3872 | 2N3873 | |
|---|---|---|---|---|---|
| $v_{F(BO)O}$ ($T_C$ = 100°C) | 100 min | 200 min | 400 min | 600 min | V |
| $I_{DOM}$ ($V_D$ = $v_{F(BO)O}$ min value, $T_C$ = 100°C) | 0.2 typ | 0.25 typ | 0.3 typ | 0.35 typ | mA |
| | 2 max | 2.5 max | 3 max | 4 max | mA |
| $I_{RROM}$ ($V_{RD}$ = $v_{F(BO)O}$ min value, $T_C$ = 100°C) | 3 max | | | | mA |
| $v_T$ (on-state current = 100 A) | 1.7 typ; 2.1 max | | | | V |

| | 2N3870 | 2N3871 | 2N3872 | 2N3873 | |
|---|---|---|---|---|---|
| $v_T$ (initial) ($i_T$ = 300 A, t = 2 μs, $V_D$ = $v_{F(BO)O}$ min value, $I_{GT}$ = 200 mA) | 15 typ; 25 max | | | | V |
| $I_{GT}$ | 1 min, 25 typ, 40 max | | | | mA(dc) |
| $V_{GT}$ | 1.1 typ; 2 max | | | | V(dc) |
| $I_{HO}$ | 0.5 to 70 | | | | mA |
| Critical dv/dt ($V_D$ = $v_{F(BO)O}$ min value, exponential rise, $T_C$ = 100°C) | 10 min; 100 typ | | | | V(dc) |
| $t_{gt}$ ($V_D$ = $v_{F(BO)O}$ min value, $i_T$ = 30 A, $I_{GT}$ = 200 mA, $t_r$ = 0.1 μs) | 1.25 typ; 2 max | | | | μs |
| $t_q$ ($i_T$ = 18 A, 50 μs pulse width, $dv_D/dt$ = 20 V/μs, $di_R/dt$ = 30 A/μs, $I_{GT}$ = 200 mA, $T_C$ = 80°C) | 20 typ; 40 max | | | | μs |

RATING CHART (CASE TEMPERATURE)






35A, 100V— 600V

# 40680–40683

Si all-diffused types used for power switching applications and for use in heating, lighting and motor speed-control circuits. Outline No.71. See Mounting Hardware for desired mounting arrangement.

## MAXIMUM RATINGS (For sinusoidal ac supply voltage at f = 50 — 400 Hz with resistive or inductive load)

| | 40680 | 40681 | 40682 | 40683 | |
|---|---|---|---|---|---|
| $V_{RSOM}$* | 100 | 200 | 400 | 600 | V |
| $V_{DSOM}$* | 150 | 250 | 500 | 700 | V |
| $V_{RROM}$* | 100 | 200 | 400 | 600 | V |
| $V_{DROM}$* | 100 | 200 | 400 | 600 | V |
| $I_{TSM}$ (1 cycle principal voltage at 50 Hz) | 300 | | | | A |
| $I_{TSM}$ (1 cycle principal voltage at 60 Hz) | 350 | | | | A |
| $I_{T(RMS)}$ ($T_C$ = 60°C, conduction angle = 180°) | 35 | | | | A |
| $P_{GM}$▲ (10 $\mu$s max) | 40 | | | | W |
| $P_{G(AV)}$▲ | 0.5 | | | | W |
| di/dt▲ ($V_T$ = $V_{DROM}$, $I_{GT}$ = 200 mA, $t_r$ = 0.5 $\mu$s) | 200 | | | | A/$\mu$s |
| $T_{STG}$ | −65 to 150 | | | | °C |
| $T_C$(opr) | −65 to 100 | | | | °C |
| $T_S$ (10 s max) | 225 | | | | °C |

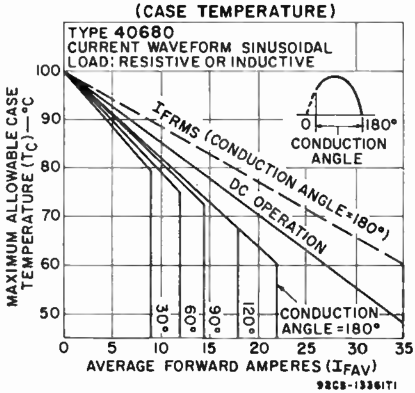
* These values do not apply if there is a positive gate signal. Gate must be open, terminated, or negatively biased.

▲ Any values of peak gate current or peak gate voltage which give the maximum gate power are permissible.

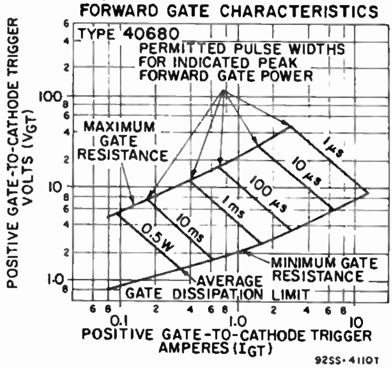
## CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

| | 40680 | 40681 | 40682 | 40683 | |
|---|---|---|---|---|---|
| $v_{F(BO)O}$ ($T_C$ = 100°C) | 100 min | 200 min | 400 min | 600 min | V |
| $I_{DOM}$ ($V_{DO}$ = $V_{DROM}$, $T_C$ = 100°C) | 0.2 typ; 2 max | 0.25 typ; 2.5 max | 0.3 typ; 3 max | 0.35 typ; 4 max | mA |
| $I_{RROM}$ ($V_{RO}$ = $V_{RROM}$, $T_C$ = 100°C) | 0.3 typ; 3 max | 0.4 typ; 3 max | 0.4 typ; 3 max | 0.5 typ; 3 max | mA |
| $v_T$ ($i_T$ = 100 A) | 1.7 typ; 2.1 max | | | | V |
| $I_{GT}$ ($V_D$ = 12 Vdc, $R_L$ = 30 Ω) | 1 to 40 | | | | mA |
| $V_{GT}$ ($V_D$ = 12 Vdc, $R_L$ = 30 Ω) | 1.1 typ; 2 max | | | 1 typ; 2 max | V |
| $i_{HO}$ | 20 typ; 70 max | | | | mA |
| dv/dt ($V_{DO}$ = $V_{F(BO)O}$, $T_C$ = 100°C) | 10 min; 100 typ | | | | V/$\mu$s |

CONDUCTION RATING CHART (CASE TEMPERATURE)



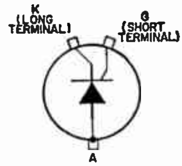

FORWARD GATE CHARACTERISTICS



**CHARACTERISTICS (cont'd)**

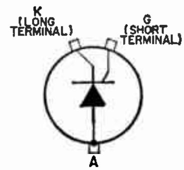
| | | |
|---|---|---|
| $t_{gt}$ ($V_D = V_{F(BO)O}$, $i_T$ = 30 A, $I_{GT}$ = 200 mA, $t_r$ = 0.1 μs) | 2 | μs |
| $t_q$ ($V_D = V_{F(BO)O}$, $i_T$ = 18 A, $t_p$ = 50 μs, dv/dt = −20 V/μs, di/dt = −30 A/μs, $I_{GT}$ = 200 mA, $T_C$ = 75°C) | 20 typ; 40 max | μs |
| $v_F$ Initial ($i_F$ = 300 A, t = 2 μs, $V_{FB} = v_{F(BO)O}$, $I_{GT}$ = 200 mA) | 15 typ; 25 max | V |
| Thermal Resistance, Junction-to-Isolated Stud | 1 max | °C/W |

## 2N3896–2N3899 35A, 100V—600V




Si all-diffused three-junction types for use in power-control and power-switching applications. Outline No.32. Types 2N3896, 2N3897, 2N3898, and 2N3899 are electrically identical with types 2N3870, 2N3871, 2N3872, and 2N3873, respectively.

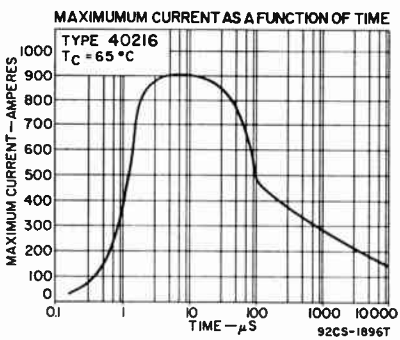
## 40216 35A, 600V




Si all-diffused three-junction type for use in radar pulse modulators, inverters, switching regulators, and other applications requiring a large ratio of peak to average current. JEDEC TO-48, Outline No.20. See **Mounting Hardware** for desired mounting arrangement.

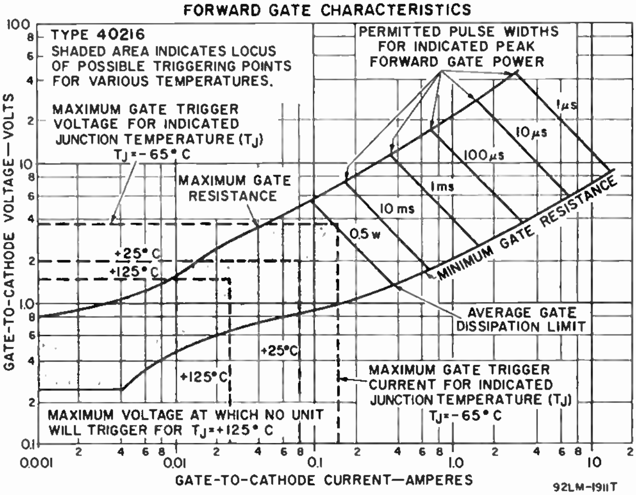
**MAXIMUM RATINGS**

| | | |
|---|---|---|
| $V_{RSOM}$ | 720 | V |
| $V_{RROM}$ | 600 | V |
| $V_{DROM}$ | 600 | V |
| $I_{T(RMS)}$ ($T_C$ = 65°C) | 35 | A |
| $I_{TRM}$ | 900 | A |
| $P_M$ ($T_C$ = 65°C) | 30 | W |
| $P_{GM}$ (peak, forward or reverse, for 10 μs) | 40 | W |
| $P_{G(AV)}$ | 0.5 | W |
| $T_{stg}$ | −65 to 150 | °C |
| $T_C$ | −65 to 125 | °C |

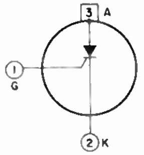


## CHARACTERISTICS (At maximum electrical rating at $T_C$ = 25°C)

| | | |
|---|---|---|
| $v_{F(BO)O}$ ($T_C$ = 125°C) | 600 min | V |
| $I_{DOM}$ ($T_C$ = 125°C) | 10 max | mA |
| $I_{RROM}$ ($T_C$ = 125°C) | 10 max | mA |
| $I_{GT}$ | 1 min, 25 typ, 80 max | mA(dc) |
| $V_{GT}$ | 1.1 typ; 2 max | V(dc) |
| $i_{HO}$ | 0.5 to 70 | mA |
| Critical dv/dt ($V_D$ = $v_{F(BO)O}$ min value, exponential rise, $T_C$ = 125°C) | 20 min; 50 typ | μs |
| $t_{gt}$ ($V_D$ = $v_{F(BO)O}$ min value, $i_T$ = 30 A, $I_{GT}$ = 200 mA, $t_r$ = 0.1 μs) | 1.25 | μs |
| $t_q$ ($i_T$ = 18 A, 50 μs pulse width, $dv_D/dt$ = 20 V/μs, $di_R/dt$ = 30 A/μs, $I_{GT}$ = 200 mA, $T_C$ = 80°C) | 15 to 40 | μs |
| $\theta_{J-C}$ | 2 max | °C/W |




## 35A, 600V — 40735




Si all-diffused type used for high-speed switching applications such as power inverters, switching, regulators, and high-current pulse applications. JEDEC TO-48, Outline No.20. See Mounting Hardware for desired mounting arrangement. This type is identical with type 2N3650 except for the following items:

## MAXIMUM RATINGS

| | | |
|---|---|---|
| $V_{RSOM}$ | 700 | V |
| $V_{DSOM}$ | 700 | V |
| $V_{RROM}$ | 600 | V |
| $V_{DROM}$ | 600 | V |

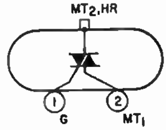
## CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)

| | | |
|---|---|---|
| $v_{(BO)O}$ ($T_C$ = 120°C) | 600 min | V |
| $I_{DOM}$ | 3 max | mA |

# 40504–40506

**1.7A—5A**

**200V—700V**

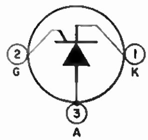



Si all-diffused three-junction types used in power-control and power-switching applications. JEDEC TO-66 (with heat radiator), Outline No.26. Types 40504, 40505, and 40506 are electrically identical with types 2N3228, 2N3525, and 2N4101, respectively.

# 2N3528 / 2N3529

**2N3528 2A, 200V**

**2N3529 2A, 400V**




Si all-diffused three-junction types for use in power-control and power-switching applications. JEDEC TO-8, Outline No.10. These types are identical with type 2N3228 except for the following items:

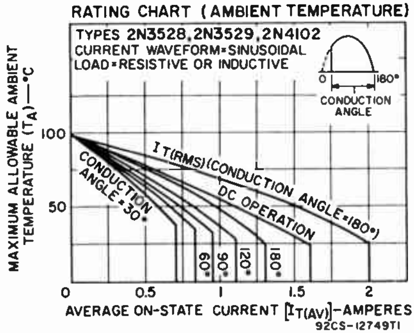
**MAXIMUM RATINGS (For sinusoidal ac supply voltage at f = 50 to 400 Hz with resistive or inductive load)**

| | 2N3528 | 2N3529 | |
|---|---|---|---|
| $V_{RSOM}$ | — | 660 | V |
| $V_{RROM}$ | — | 400 | V |
| $V_{DROM}$ | — | 600 | V |
| $I_{T(AV)}$ (conduction angle = 180°, $T_A$ = 25°C) | 1.3 | 1.3 | A |
| $I_{T(RMS)}$ ($T_A$ = 25°C) | 2 | 2 | A |

**CHARACTERISTICS (At maximum electrical ratings at $T_C$ = 25°C)**

| | 2N3528 | 2N3529 | |
|---|---|---|---|
| $V_{F(BO)O}$ ($T_C$ = 100°C) | — | 400 min | V |
| $I_{DOM}$ ($V_{DO} = V_{F(BO)O}$, $T_C$ = 100°C) | — | 0.2 typ; 3 max | mA |
| $I_{RROM}$ ($V_{RO} = V_{RSOM}$, $T_C$ = 100°C) | — | 0.1 typ; 1.5 max | mA |
| $\theta_{J-A}$ | 40 max | 40 max | °C/W |

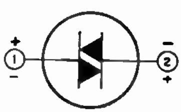
RATING CHART (AMBIENT TEMPERATURE)




## *Diacs*

# 1N5411

**DIAC**




Si all-diffused three-layer trigger diode type used for triac phase-control circuits for lamp dimming, universal-motor speed, and heat controls. JEDEC DO-26, Outline No.66.

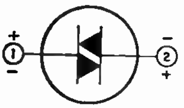
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Peak Pulse Current, Forward or Reverse ($t_p$ = 30 μs, df = 0.004) | | 2 | A |
| Device Dissipation ($T_C$ up to 75°C) | | 0.5 | W |
| Temperature Range: | | | |
| Operating (Junction) | $T_J$(opr) | −40 to 100 | °C |
| Storage | $T_{STG}$ | −40 to 150 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

## CHARACTERISTICS (At case temperature = 25°C)

| | | | |
|---|---|---|---|
| Breakover Voltage, Forward or Reverse | $V_{(BO)}$ | 29 to 35 | V |
| Breakover-Voltage Symmetry | $\lvert{}^{+}V_{(BO)}\rvert - \lvert{}^{-}V_{(BO)}\rvert$ | ±3 | V |
| Breakback Voltage Change, Forward or Reverse ($I_{BO}$ (forward or reverse) = 10 mA) | ΔV | 5 min | V |
| Peak Breakover Current | $I_{(BO)}$ | 50 max | μA |

## DIAC 40583




Si all-diffused three-layer trigger diode type used for triac phase-control circuits for lamp dimming, universal-motor speed, and heat controls. JEDEC DO-26, Outline No.66. This type is identical with type 1N5411 except for the following item:

## CHARACTERISTICS (At case temperature = 25°C)

| | | |
|---|---|---|
| Breakover Voltage, Forward or Reverse | $V_{(BO)}$ | 27 to 37 A |

# Technical Data for Rectifiers and Other Diodes

THIS section contains detailed technical data for all current RCA silicon rectifiers and other solid-state diodes. The data on the rectifiers is presented in an easy-to-read quick-reference chart to facilitate comparison and selection of individual types. The rectifiers are listed in the chart in order of ascending current ratings. The data on the diodes are presented in display format.

In selection of devices for use in new electronic equipment, a prospective user should refer to the appropriate section of the Selection Guide included earlier in the Manual. For the reader who requires data on specific types, a complete numerical-alphabetical-numerical index to all current RCA solid-state devices is provided immediately following the Circuits Section in the back of the Manual.

## Silicon Diffused-Junction Rectifiers

| | | | MAXIMUM RATINGS | | | | | | CHARAC-TERISTICS | |
|---|---|---|---|---|---|---|---|---|---|---|
| RCA TYPE | OUTLINE JEDEC | NO. | $I_{FAV}$ at $T_C$ A | °C | $i_{FM}$ (rep) A | (surge) A | $V_{RMS}$ V | $V_{RM}$ and $V_M$ (block) V | $V_{FM}$ V | $I_{RM}$ (dynamic) mA |
| 1N3754 | TO-1** | 41 | 0.125 | 65 | 1.3 | 30 | 35 | 100 | 1 | 0.3 |
| 1N3755 | TO-1** | 41 | 0.125 | 65 | 1.3 | 30 | 70 | 200 | 1 | 0.3 |
| 1N3756 | TO-1** | 41 | 0.125 | 65 | 1.3 | 30 | 140 | 400 | 1 | 0.3 |
| 40265 | TO-1** | 41 | 0.125 | 65 | 1.3 | 30 | 140 | 400 | 1 | 0.4 |
| 1N3563 | TO-1° | 40 | 0.3* | 75 | 4* | 35* | 700 | 1000 | 1.2 | 0.2 |
| 1N3196 | TO-1‡ | 39 | 0.4* | 75 | 5* | 35* | 560 | 800 | 1.2 | 0.2 |
| 1N3256 | TO-1° | 41 | Insulated version of 1N3196 | | | | | | | |
| 1N3193 | TO-1‡ | 39 | 0.5* | 75 | 6* | 35* | 140 | 200 | 1.2 | 0.2 |
| 1N3194 | TO-1‡ | 39 | 0.5* | 75 | 6* | 35* | 280 | 400 | 1.2 | 0.2 |
| 1N3195 | TO-1‡ | 39 | 0.5* | 75 | 6* | 35* | 420 | 600 | 1.2 | 0.2 |
| 1N3253 | TO-1° | 40 | Insulated version of 1N3193 | | | | | | | |
| 1N3254 | TO-1° | 40 | Insulated version of 1N3194 | | | | | | | |
| 1N3255 | TO-1° | 40 | Insulated version of 1N3195 | | | | | | | |
| 40808 | DO-26 | 40 | 0.5 | 25 | — | 32 | 420 | 600 | 1 | 0.005 |
| 40809 | DO-26 | 40 | 0.5 | 25 | — | 32 | 560 | 800 | 1 | 0.005 |
| 1N444B | DO-1 | 38 | 0.65 | 50 | 3.5 | 15 | 350 | 500 | 1.5 | 1.75● |
| 1N445B | DO-1 | 38 | 0.65 | 50 | 3.5 | 15 | 420 | 600 | 1.5 | 2● |
| 1N440B | DO-1 | 38 | 0.75 | 50 | 3.5 | 15 | 70 | 100 | 1.5 | 0.3● |
| 1N441B | DO-1 | 38 | 0.75 | 50 | 3.5 | 15 | 140 | 200 | 1.5 | 0.75● |
| 1N442B | DO-1 | 38 | 0.75 | 50 | 3.5 | 15 | 210 | 300 | 1.5 | 1● |

** Similar to TO-1 package with lead 3 omitted.
° Similar to TO-1 package with axial leads and insulated plastic sleeve over metal case.
‡ Similar to TO-1 package with axial leads. * With capacitive load. ● Static value in $\mu$A.

| RCA TYPE | OUTLINE JEDEC | OUTLINE NO. | MAXIMUM RATINGS $I_{FAV}$ A | at $T_C$ °C | $I_{FM}$ (rep) A | $I_{FM}$ (surge) A | $V_{RMS}$ V | $V_{RM}$ and $V_M$ (block) V | CHARACTERISTICS $V_{FM}$ V | $I_{RM}$ (dynamic) mA |
|---|---|---|---|---|---|---|---|---|---|---|
| 1N443B | DO-1 | 38 | 0.75 | 50 | 3.5 | 15 | 280 | 400 | 1.5 | 1.5● |
| 1N536 | DO-1 | 38 | 0.75 | 50 | — | 15 | 35 | 50 | 1.1 | 5● |
| 1N537 | DO-1 | 38 | 0.75 | 50 | — | 15 | 70 | 100 | 1.1 | 5● |
| 1N538 | DO-1 | 38 | 0.75 | 50 | — | 15 | 140 | 200 | 1.1 | 5● |
| 1N539 | DO-1 | 38 | 0.75 | 50 | — | 15 | 210 | 300 | 1.1 | 5● |
| 1N540 | DO-1 | 38 | 0.75 | 50 | — | 15 | 280 | 400 | 1.1 | 5● |
| 1N547 | DO-1 | 38 | 0.75 | 50 | — | 15 | 420 | 600 | 1.2 | 5● |
| 1N1095 | DO-1 | 38 | 0.75 | 50 | — | 15 | 350 | 500 | 1.2 | 5● |
| 1N1763A | DO-1 | 38 | 1 | 75 | 5 | 35 | 280 | 400 | 1.2 | 0.1 |
| 1N1764A | DO-1 | 38 | 1 | 75 | 5 | 35 | 350 | 500 | 1.2 | 0.1 |
| 1N2858A | DO-1 | 38 | 1 | 75 | 5 | 35 | 35 | 50 | 1.2 | 0.1 |
| 1N2859A | DO-1 | 38 | 1 | 75 | 5 | 35 | 70 | 100 | 1.2 | 0.1 |
| 1N2860A | DO-1 | 38 | 1 | 75 | 5 | 35 | 140 | 200 | 1.2 | 0.1 |
| 1N2861A | DO-1 | 38 | 1 | 75 | 5 | 35 | 210 | 300 | 1.2 | 0.1 |
| 1N2862A | DO-1 | 38 | 1 | 75 | 5 | 35 | 280 | 400 | 1.2 | 0.1 |
| 1N2863A | DO-1 | 38 | 1 | 75 | 5 | 35 | 350 | 500 | 1.2 | 0.1 |
| 1N2864A | DO-1 | 38 | 1 | 75 | 5 | 35 | 420 | 600 | 1.2 | 0.1 |
| 40642 | DO-26 | 40 | 1 | — | 6.5 | 70 | — | 700▲ | 2 | 10◎ |
| 40643 | DO-26 | 40 | 1 | — | 6 | 10 | — | 800‡ | 1.3 | 10◎ |
| 40644 | DO-26 | 40 | 1 | — | 0.3 | 20 | — | 700▲ | 1.3 | 10◎ |
| 40266 | DO-1 | 38 | 2* | 105 | 10 | 35 | 35 | 100 | 3 | 10† |
| 40267 | DO-1 | 38 | 2* | 105 | 10 | 35 | 70 | 200 | 3 | 10† |
| 1N1612■ | DO-4 | 42 | 5 | 135 | 15 | — | 35 | 50 | 1.5 | 1 |
| 1N1613■ | DO-4 | 42 | 5 | 135 | 15 | — | 70 | 100 | 1.5 | 1 |
| 1N1614■ | DO-4 | 42 | 5 | 135 | 15 | — | 140 | 200 | 1.5 | 1 |
| 1N1615■ | DO-4 | 42 | 5 | 135 | 15 | — | 280 | 400 | 1.5 | 1 |
| 1N1616■ | DO-4 | 42 | 5 | 135 | 15 | — | 420 | 600 | 1.5 | 1 |
| 1N1341B■ | DO-4 | 42 | 6 | 150 | 25 | 160 | 35 | 50 | 0.65 | 0.45 |
| 1N1342B■ | DO-4 | 42 | 6 | 150 | 25 | 160 | 70 | 100 | 0.65 | 0.45 |
| 1N1344B■ | DO-4 | 42 | 6 | 150 | 25 | 160 | 140 | 200 | 0.65 | 0.45 |
| 1N1345B■ | DO-4 | 42 | 6 | 150 | 25 | 160 | 212 | 300 | 0.65 | 0.45 |
| 1N1346B■ | DO-4 | 42 | 6 | 150 | 25 | 160 | 284 | 400 | 0.65 | 0.45 |
| 1N1347B■ | DO-4 | 42 | 6 | 150 | 25 | 160 | 355 | 500 | 0.65 | 0.45 |
| 1N1348B■ | DO-4 | 42 | 6 | 150 | 25 | 160 | 424 | 600 | 0.65 | 0.45 |
| 40108■ | DO-4 | 42 | 10 | 150 | 40 | 140 | — | 50 | 0.6 | 2 |
| 40109■ | DO-4 | 42 | 10 | 150 | 40 | 140 | — | 100 | 0.6 | 2 |
| 40110■ | DO-4 | 42 | 10 | 150 | 40 | 140 | — | 200 | 0.6 | 1.5 |
| 40111■ | DO-4 | 42 | 10 | 150 | 40 | 140 | — | 300 | 0.6 | 1.5 |
| 40112■ | DO-4 | 42 | 10 | 150 | 40 | 140 | — | 400 | 0.6 | 1 |
| 40113■ | DO-4 | 42 | 10 | 150 | 40 | 140 | — | 500 | 0.6 | 0.85 |
| 40114■ | DO-4 | 42 | 10 | 150 | 40 | 140 | — | 600 | 0.6 | 0.75 |
| 40115■ | DO-4 | 42 | 10 | 150 | 40 | 140 | — | 800 | 0.6 | 0.65 |
| 1N1199A■ | DO-4 | 42 | 12 | 150 | 50 | 240 | 35 | 50 | 0.55 | 3 |
| 1N1200A■ | DO-4 | 42 | 12 | 150 | 50 | 240 | 70 | 100 | 0.55 | 2.5 |
| 1N1202A■ | DO-4 | 42 | 12 | 150 | 50 | 240 | 140 | 200 | 0.55 | 2 |

● Static value in $\mu$A. ▲ $V_{RM}$ (block) = 550V. ‡ $V_{RM}$ (block) = 450V. Static value in $\mu$A.
◎ Static condition. * With capacitive load. † Value in $\mu$A.
■ Reverse-polarity version available.

# Silicon Diffused-Junction Rectifiers

| RCA TYPE | OUTLINE JEDEC | OUTLINE NO. | MAXIMUM RATINGS $I_{FAV}$ A | at $T_C$ °C | $i_{FM}$ (rep) A | $i_{FM}$ (surge) A | $V_{RMS}$ V | $V_{RM}$ and $V_M$ (block) V | CHARACTERISTICS $V_{FM}$ V | $I_{RM}$ (dynamic) mA |
|---|---|---|---|---|---|---|---|---|---|---|
| 1N1203A■ | DO-4 | 42 | 12 | 150 | 50 | 240 | 212 | 300 | 0.55 | 1.75 |
| 1N1204A■ | DO-4 | 42 | 12 | 150 | 50 | 240 | 284 | 400 | 0.55 | 1.5 |
| 1N1205A■ | DO-4 | 42 | 12 | 150 | 50 | 240 | 355 | 500 | 0.55 | 1.25 |
| 1N1206A■ | DO-4 | 42 | 12 | 150 | 50 | 240 | 424 | 600 | 0.55 | 1 |
| 40208■ | DO-5 | 43 | 18 | 150 | 72 | 250 | — | 50 | 0.65 | 3 |
| 40209■ | DO-5 | 43 | 18 | 150 | 72 | 250 | — | 100 | 0.65 | 3 |
| 40210■ | DO-5 | 43 | 18 | 150 | 72 | 250 | — | 200 | 0.65 | 2.5 |
| 40211■ | DO-5 | 43 | 18 | 150 | 72 | 250 | — | 300 | 0.65 | 2.5 |
| 40212■ | DO-5 | 43 | 18 | 150 | 72 | 250 | — | 400 | 0.65 | 2 |
| 40213■ | DO-5 | 43 | 18 | 150 | 72 | 250 | — | 500 | 0.65 | 1.75 |
| 40214■ | DO-5 | 43 | 18 | 150 | 72 | 250 | — | 600 | 0.65 | 1.5 |
| 1N248C■ | DO-5 | 43 | 20 | 150 | 90 | 350 | 39 | 55▲ | 0.6 | 3.8 |
| 1N249C■ | DO-5 | 43 | 20 | 150 | 90 | 350 | 77 | 110▲ | 0.6 | 3.6 |
| 1N250C■ | DO-5 | 43 | 20 | 150 | 90 | 350 | 154 | 220▲ | 0.6 | 3.4 |
| 1N1195A■ | DO-5 | 43 | 20 | 150 | 90 | 350 | 212 | 300 | 0.6 | 3.2 |
| 1N1196A■ | DO-5 | 43 | 20 | 150 | 90 | 350 | 284 | 400 | 0.6 | 2.5 |
| 1N1197A■ | DO-5 | 43 | 20 | 150 | 90 | 350 | 355 | 500 | 0.6 | 2.2 |
| 1N1198A■ | DO-5 | 43 | 20 | 150 | 90 | 350 | 424 | 600 | 0.6 | 1.5 |
| 1N1183A■ | DO-5 | 43 | 40 | 150 | 195 | 800 | 35 | 50 | 0.65 | 2.5 |
| 1N1184A■ | DO-5 | 43 | 40 | 150 | 195 | 800 | 70 | 100 | 0.65 | 2.5 |
| 1N1186A■ | DO-5 | 43 | 40 | 150 | 195 | 800 | 140 | 200 | 0.65 | 2.5 |
| 1N1187A■ | DO-5 | 43 | 40 | 150 | 195 | 800 | 212 | 300 | 0.65 | 2.5 |
| 1N1188A■ | DO-5 | 43 | 40 | 150 | 195 | 800 | 284 | 400 | 0.65 | 2.2 |
| 1N1189A■ | DO-5 | 43 | 40 | 150 | 195 | 800 | 355 | 500 | 0.65 | 2 |
| 1N1190A■ | DO-5 | 43 | 40 | 150 | 195 | 800 | 424 | 600 | 0.65 | 1.8 |

■ Reverse-polarity version available. ▲ $V_M$ (block) is 10% less.

# Silicon Diffused-Junction Stack Rectifiers

| RCA TYPE | OUTLINE NO. | MAXIMUM RATINGS $I_{FAV}$ at 100°C A | $i_{FM}$ (rep) A | $i_{FM}$ (surge) A | V $V_{RMS}$ | $V_{RM}$ (rep) and $V_M$ (block) V | $V_{RM}$‡ (non-rep) V | CHARACTERISTICS $V_{FM}$■ V | $I_{RM}$■ (dynamic) A | $C_S$ (max) pF |
|---|---|---|---|---|---|---|---|---|---|---|
| CR201 | 45a | 0.155 | 3 | 10 | 1345 | 1900 | 2280 | 1.8 | 0.1 | — |
| CR203 | 45b | 0.155 | 3 | 10 | 2240 | 3165 | 3800 | 3 | 0.1 | — |
| CR204 | 45c | 0.155 | 3 | 10 | 3395 | 4800 | 5760 | 3.6 | 0.1 | — |
| CR206 | 45d | 0.155 | 3 | 10 | 4475 | 6330 | 7600 | 6 | 0.1 | — |
| CR208 | 45e | 0.155 | 3 | 10 | 5655 | 8000 | 9600 | 6 | 0.1 | — |
| CR210 | 45f | 0.155 | 3 | 10 | 7070 | 10000 | 12000 | 7.2 | 0.1 | — |
| CR212 | 45g | 0.155 | 3 | 10 | 8485 | 12000 | 14400 | 9 | 0.1 | — |
| CR107 | 44g | 0.230 | 5 | 20 | 5370 | 7595 | 9115 | 7.2 | 0.3 | 105 |
| CR108 | 44h | 0.230 | 5 | 20 | 5820 | 8230 | 9875 | 7.8 | 0.3 | 100 |
| CR109 | 44i | 0.230 | 5 | 20 | 6710 | 9495 | 11395 | 9 | 0.3 | 90 |
| CR110 | 44j | 0.230 | 5 | 20 | 7160 | 10130 | 12155 | 9.6 | 0.3 | 80 |
| CR106 | 44f | 0.250 | 5 | 20 | 4475 | 6330 | 7600 | 6 | 0.3 | 125 |
| CR104 | 44d | 0.270 | 5 | 20 | 3130 | 4430 | 5315 | 4.2 | 0.3 | 175 |
| CR105 | 44e | 0.270 | 5 | 20 | 3580 | 5065 | 6080 | 4.8 | 0.3 | 160 |
| CR103 | 44c | 0.315 | 5 | 20 | 2240 | 3165 | 3800 | 3 | 0.3 | 250 |

■ At maximum rated operating conditions. ‡ For duration of 5 ms max; $T_C$ = 60 to 125°C.

# Silicon Diffused-Junction Stack Rectifiers (cont'd)

| RCA TYPE | OUTLINE NO. | MAXIMUM RATINGS: $I_{FAV}$ at 100°C A | $I_{FM}$ (rep) A | $I_{FM}$ (surge) A | V $V_{RMS}$ | $V_{RM}$ (rep) and $V_M$ (block) V | $V_{RM}$‡ (non-rep) V | CHARACTERISTICS: $V_{FM}$■ V | $I_{RM}$■ (dynamic) A | $C_S$ (max) pF |
|---|---|---|---|---|---|---|---|---|---|---|
| CR102 | 44b | 0.355 | 5 | 20 | 1790 | 2530 | 3035 | 2.4 | 0.3 | 320 |
| CR101 | 44a | 0.385 | 5 | 20 | 895 | 1265 | 1520 | 1.2 | 0.3 | 600 |
| CR301 | 46a | 2.5 | — | 250 | 1695 | 2400 | 2880 | — | 1.5 | ** |
| CR302 | 46b | 2.5 | — | 250 | 2545 | 3600 | 4320 | — | 1.5 | ** |
| CR303 | 46c | 2.5 | — | 250 | 3395 | 4800 | 5760 | — | 1.5 | ** |
| CR304 | 46d | 2.5 | — | 250 | 4240 | 6000 | 7200 | — | 1.5 | ** |
| CR305 | 46e | 2.5 | — | 250 | 5090 | 7200 | 8640 | — | 1.5 | ** |
| CR306 | 46f | 2.5 | — | 250 | 5935 | 8400 | 10080 | — | 1.5 | ** |
| CR307 | 46g | 2.5 | — | 250 | 6785 | 9600 | 11520 | — | 1.5 | ** |
| CR311 | 46h | 4.5 | — | 250 | 1695 | 2400 | 2880 | — | 1.5 | ** |
| CR312 | 46i | 4.5 | — | 250 | 2545 | 3600 | 4320 | — | 1.5 | ** |
| CR313 | 46j | 4.5 | — | 250 | 3395 | 4800 | 5760 | — | 1.5 | ** |
| CR314 | 46k | 4.5 | — | 250 | 4240 | 6000 | 7200 | — | 1.5 | ** |
| CR315 | 46l | 4.5 | — | 250 | 5090 | 7200 | 8640 | — | 1.5 | ** |
| CR316 | 46m | 4.5 | — | 250 | 5935 | 8400 | 10080 | — | 1.5 | ** |
| CR317 | 46n | 4.5 | — | 250 | 6785 | 9600 | 11520 | — | 1.5 | ** |
| CR321 | 46o | 6 | — | 400 | 1695 | 2400 | 2880 | — | 1.5 | ** |
| CR322 | 46p | 6 | — | 400 | 2545 | 3600 | 4320 | — | 1.5 | ** |
| CR323 | 46q | 6 | — | 400 | 3395 | 4800 | 5760 | — | 1.5 | ** |
| CR324 | 46r | 6 | — | 400 | 4240 | 6000 | 7200 | — | 1.5 | ** |
| CR325 | 46s | 6 | — | 400 | 5090 | 7200 | 8640 | — | 1.5 | ** |
| CR331 | 46t | 8.5 | — | 400 | 1695 | 2400 | 2880 | — | 1.5 | ** |
| CR332 | 46u | 8.5 | — | 400 | 2545 | 3600 | 4320 | — | 1.5 | ** |
| CR333 | 46v | 8.5 | — | 400 | 3395 | 4800 | 5760 | — | 1.5 | ** |
| CR334 | 46w | 8.5 | — | 400 | 4240 | 6000 | 7200 | — | 1.5 | ** |
| CR335 | 46x | 8.5 | — | 400 | 5090 | 7200 | 8640 | — | 1.5 | ** |
| CR341 | 46y | 11.5 | — | 850 | 1695 | 2400 | 2880 | — | 1.5 | ** |
| CR342 | 46z | 11.5 | — | 850 | 2545 | 3600 | 4320 | — | 1.5 | ** |
| CR343 | 46aa | 11.5 | — | 850 | 3395 | 4800 | 5760 | — | 1.5 | ** |
| CR344 | 46bb | 11.5 | — | 850 | 4240 | 6000 | 7200 | — | 1.5 | ** |
| CR351 | 46cc | 17.5 | — | 850 | 1695 | 2400 | 2880 | — | 1.5 | ** |
| CR352 | 46dd | 17.5 | — | 850 | 2545 | 3600 | 4320 | — | 1.5 | ** |
| CR353 | 46ee | 17.5 | — | 850 | 3395 | 4800 | 5760 | — | 1.5 | ** |
| CR354 | 46ff | 17.5 | — | 850 | 4240 | 6000 | 7200 | — | 1.5 | ** |

** $C_S$ typically 0.01 μF per cell.

# Silicon Plug-in Rectifiers

| RCA TYPE | OUTLINE NO. | AVERAGE DC OUTPUT A | AVERAGE DC OUTPUT V | RMS SUPPLY V |
|---|---|---|---|---|
| CR401† | 46a | 18 | 200 | 222 |
| CR402† | 46a | 18 | 400 | 444 |
| CR403† | 46c | 18 | 800 | 888 |
| CR501‡ | 46b | 24 | 300 | 222 |
| CR502‡ | 46b | 24 | 600 | 444 |
| CR404† | 46o | 34 | 200 | 222 |
| CR405† | 46o | 34 | 400 | 444 |
| CR406† | 46v | 34 | 800 | 888 |
| CR503‡ | 46p | 46 | 300 | 222 |
| CR504‡ | 46p | 46 | 600 | 444 |
| CR407† | 46y | 70 | 200 | 222 |
| CR408† | 46y | 70 | 400 | 444 |
| CR409† | 46aa | 70 | 800 | 888 |
| CR505‡ | 46z | 92 | 300 | 222 |
| CR506‡ | 46z | 92 | 600 | 441 |

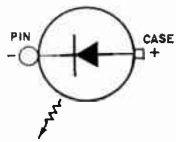
† Single-phase, full-wave types. ‡ Three-phase, full-wave types.

# Silicon Bridge Rectifiers

These high-voltage diffused-junction types are direct replacements for the mercury-vapor and gas rectifier tubes indicated. Data for the tube-type rectifiers are given in the **RCA Transmitting Tube Manual TT-5.**

| RCA TYPE | REPLACES TYPE(S) |
|---|---|
| CR273/8008 | 8008 |
| CR274/872A | 872, 872A |
| CR275/866A/3B28 | 866, 866A, 3B28 |

## 40598A EMITTING DIODE




GaAs **high-frequency** type used for continuous or pulse applications in military, industrial, and commercial equipment. **Outline** No.67.

### MAXIMUM RATINGS

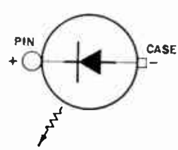
| | | | |
|---|---|---|---|
| Peak Forward Current | $I_{FM}$ | 1 | A |
| Average Forward Current: | | | |
| $T_C$ from —73 to 50°C | $I_{F(AV)}$ | 50 | mA |
| $T_C$ from 50 to 75°C | $I_{F(AV)}$ | See Rating Chart | |
| Peak Reverse Voltage | $V_{RM}$ | 2 | V |
| $T_C$ from —73 to 50°C | $P_{IN(AV)}$ | 90 | |
| $T_C$ from 50 to 75°C | $P_{IN(AV)}$ | See Rating Chart | |
| Temperature: | | | |
| Operating | $T_C$ | —73 to 75 | °C |
| Storage | $T_{STG}$ | —72 to 100 | °C |
| During Soldering (5 s) | | 130 | °C |

### CHARACTERISTICS (At case temperature = 27°C)

| | | | |
|---|---|---|---|
| DC Forward Voltage Drop ($I_F$ = 10 mA) | $V_F$ | 1.2 typ; 1.5 max | V |
| DC Forward Voltage Drop ($I_F$ = 50 mA) | $V_F$ | 1.4 typ; 1.8 max | V |
| Peak Reverse Current ($V_R$ = 2 V) | $I_{RM}$ | 10 max | µA |
| Continuous Service ($I_F$ = 50 mA): | | | |
| DC Forward Voltage | $V_F$ | 1.4 | V |
| Radiant Power Output* | $P_O$ | 1 min; 1.6 typ | mW |
| Radiant Power Output per Ampere | $P_O/A$ | 20 min; 32 typ | mW/A |
| Power Efficiency ($P_O/V_FI_F$) | $\eta$ | 1.1 min; 2.3 typ | % |
| Pulse Service: | | | |
| Peak Radiant Power Output ($I_F$ = 1 A, $t_p$ = 2 µs, df = 1%, pulse rep. rate = 500 p/s) | $P_{OM}$ | 24 | mW |
| Radiation Characteristics, Continuous or Pulse Service: | | | |
| Wavelength at Peak of Emitted Spectrum | $\lambda$ | 9100 to 9500 | °A |
| Line Width at Half-Power Points | | 500 | °A |
| Half-Angle Beam Spread: At Half-Power Point | $\alpha$ | 15 | degrees |
| At 20% Power Point | $\alpha$ | 30 | degrees |

* Radiant Power Output is derived by measuring the short-circuit current in a calibrated silicon photovoltaic cell positioned close to the emitter to collect the total infrared emission.

## 40736R EMITTING DIODE




Ge arsenide **high-efficiency** type used for continuous or pulse applications in a wide range of optical applications. **Outline** No. 72. See **Mounting Hardware** for desired mounting arrangement.

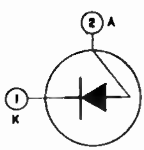
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Peak Forward Current | $I_{FM}$ | 1.5 | A |
| Average Forward Current | $I_{F(AV)}$ | 50 | mA |
| Average Forward Current ($T_C$ above 50°C) | $I_{F(AV)}$ | See Rating Chart | |
| Peak Reverse Voltage | $V_{RM}$ | 2 | V |
| Temperature Range: | | | |
| Operating | $T_C$ | −65 to 75 | °C |
| Storage | $T_{STG}$ | −65 to 100 | °C |
| Case and Stem-Soldering Temperature (5 s) | | 130 | °C |

### CHARACTERISTICS (At case temperature = 27°C)

| | | | |
|---|---|---|---|
| DC Forward Voltage Drop ($I_F$ = 10 mA) | $V_F$ | 1.2 typ; 1.5 max | V |
| DC Forward Voltage Drop ($I_F$ = 50 mA) | $V_F$ | 1.4 typ; 1.8 max | V |
| Peak Reverse Current ($V_R$ = 2 V) | $I_{RM}$ | 10 max | μA |
| **Continuous Service** ($I_F$ = 50 mA): | | | |
| DC Forward Voltage Drop | $V_F$ | 1.4 | V |
| Radiant Power Output‡ | $P_O$ | 1 min; 1.6 typ | mW |
| Radiant Power Output per Ampere | $P_O/A$ | 20 min; 32 typ | mW/A |
| Power Efficiency ($P_O/V_FI_F$) | $\eta$ | 1.1 min; 23 typ | % |
| **Pulse Service:** | | | |
| Peak Radiant Power Output ($I_F$ = 1 A, $t_p$ = 2 μs, df = 1%, pulse repetitive rate = 5000 p/s) | $P_{OM}$ | 24 | mW |
| **Radiation Characteristics (Continuous or Pulse Service):** | | | |
| Wavelength at Peak of Emitted Spectrum | $\lambda$ | 9100 to 9500 | Å |
| Line Width at Half-Power Points | | 500 | Å |
| Half-Angle Beam Spread: | | | |
| At half-power point | $\alpha$ | 15 | degrees |
| At 20% power point | $\alpha$ | 30 | degrees |

‡ Radiant Power Output is derived by measuring the short-circuit current in a calibrated silicon photovoltaic cell positioned close to the emitter to collect the infrared emission.




## COMPENSATING DIODE 1N2326

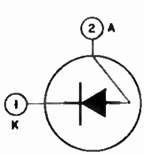
Ge alloy-junction type used in temperature- and voltage-compensation applications. Similar to JEDEC TO-1 (2-lead), Outline No.41.

### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Reverse Voltage | $V_{RM}$ | −1 | V |
| Peak Recurrent Current | $i_{FM}$(rep) | 200 | mA |
| DC Forward Current | $I_{FM}$ | 100 | mA |
| Temperature Range: | | | |
| Operating ($T_A$) and Storage ($T_{STG}$) | | −65 to 85 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

### CHARACTERISTICS

| | | *min* | *typ* | *max* | |
|---|---|---|---|---|---|
| DC Forward Voltage Drop: | | | | | |
| $I_{FAV}$ = 2 mA | $V_{FAV}$ | 120 | 135 | 150 | mV |
| $I_{FAV}$ = 100 mA | $V_{FAV}$ | 240 | 260 | 280 | mV |




## COMPENSATING DIODE 40428

Ge alloy-junction type used in temperature- and voltage-compensation applications. Similar to JEDEC TO-1 (2-lead), Outline No.41.

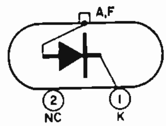
### MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Reverse Voltage | $V_{RM}$ | −0.5 | V |
| DC Forward Current | $I_{FM}$ | 100 | mA |
| Peak Forward Current | $i_F$(max) | 200 | mA |
| Temperature Range: | | | |
| Operating ($T_A$) and Storage ($T_{STG}$) | | −65 to 85 | °C |
| Lead-Soldering Temperature (10 s max) | $T_L$ | 255 | °C |

## CHARACTERISTICS

| DC Forward Voltage Drop: | | min | typ | max | |
|---|---|---|---|---|---|
| $T_C$ = 25°C | $V_{FAV}$ | 235 | 260 | 285 | mV |
| $T_A$ = 25°C | $V_{FAV}$ | 225 | 250 | 275 | mV |

# 1N4785 DAMPER DIODE




Ge diffused-junction type used in transistorized 114-degree, 18-kilovolt horizontal-deflection systems in television receivers with types 2N3730, 2N3731, and 2N3732. JEDEC TO-3, Outline No.2.

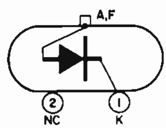
## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Peak Reverse Voltage | $v_{RM}$ | 320 | V |
| Continuous Reverse Voltage | $V_{RM}$ | 60 | V |
| Peak Forward Current | $i_{FM}$ | 10 | A |
| Average Forward Current | $I_{FM}$ | 7 | A |
| Temperature Range: | | | |
| Operating ($T_J$) and Storage ($T_{STG}$) | | −65 to 85 | °C |
| Pin-Soldering Temperature | $T_P$ | 230 | °C |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Peak Reverse Voltage ($I_R$ = 1 mA) | $v_{RM}$ | 320 min | V |
| Reverse Current, Static ($V_R$ = 10 V) | $I_R$ | 150 max | μA |
| Forward Voltage Drop, Static ($I_F$ = 7 A) | $V_F$ | 0.77 max | V |

# 40442 DAMPER DIODE




Ge diffused-junction type used in transistorized 114-degree, 18-kilovolt horizontal-deflection systems in television receivers with types 2N3730, 2N3731, 2N3732, 40439, and 40440 to make up a complete transistor/damper-diode complement. JEDEC TO-3, Outline No.2. This type is identical to type 1N4785 except for the following items:

## MAXIMUM RATINGS

| | | | |
|---|---|---|---|
| Peak Reverse Voltage | $v_{RM}$ | 200 | V |
| Continuous Reverse Voltage | $V_{RM}$ | 40 | V |

## CHARACTERISTICS

| | | | |
|---|---|---|---|
| Peak Reverse Voltage ($I_R$ = 1 mA) | $v_{RM}$ | 200 min | V |

# CHART OF DISCONTINUED TRANSISTORS

(Shown for reference only; see page 270 for symbol identification.)

## BIPOLAR TYPES

| RCA Type | Bas-‡ ing | Mate- rial | Out- line | MAXIMUM RATINGS $V_{CB}$ (volts) | $V_{EB}$ (volts) | $I_C$ (amperes) | $P_T$ (watts) | CHARACTER-ISTICS Min. $h_{FE}$ | $I_{CB}$ ($\mu$A) | Maximum Operating Tempera-ture (°C) | Can be replaced by RCA type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2N104 | 12 | Ge | 16 | —30 | — | —0.050 | 0.150 | 44 | —10 | 70 | — |
| 2N105 | 1 | Ge | * | —25 | — | —0.015 | 0.035 | 55 | —5 | 55 | 2N408 |
| 2N139 | 12 | Ge | 16 | —16 | — | —0.015 | 0.035 | 48 | —6 | 70 | — |
| 2N140 | 12 | Ge | 16 | —16 | — | —0.015 | 0.080 | 75 | —6 | 71 | — |
| 2N173 | 2 | Ge | 14 | —60 | —40 | —15 | 150 | 35 | —100 | 100 | — |
| 2N174 | 2 | Ge | 14 | —80 | —60 | —15 | 150 | 25 | —100 | 100 | — |
| 2N175 | 12 | Ge | 2 | —10 | — | —0.002 | 0.050 | — | —12 | 50 | — |
| 2N206 | 1 | Ge | 1 | —30 | — | —0.050 | 0.075 | 33 | —10 | 85 | 2N408 |
| 2N215 | 12 | Ge | 16 | —30 | — | —0.050 | 0.150 | 44 | —10 | 70 | — |
| 2N218 | 1 | Ge | 1 | —16 | — | —0.015 | 0.035 | 48 | —6 | 70 | — |
| 2N219 | 1 | Ge | 1 | —16 | — | —0.015 | 0.08 | 75 | —6 | 71 | — |
| 2N220 | 12 | Ge | 2 | —10 | — | —0.002 | 0.050 | — | —12 | 50 | — |
| 2N247 | 3 | Ge | 9 | —35 | — | —0.010 | 0.080 | 60 | —10 | 71 | 2N1180 |
| 2N269 | 1 | Ge | 1 | —25 | —12 | —0.100 | 0.120 | 24 | —5 | 85 | 2N404 |
| 2N270 | 12 | Ge | 9 | —25 | —12 | —0.150 | 0.250 | 50 | —16 | 85 | — |
| 2N277 | 2 | Ge | 14 | —40 | —20 | —15 | 150 | 35 | —4000 | 100 | — |
| 2N278 | 2 | Ge | 14 | —50 | —30 | —15 | 150 | 35 | —15000 | 100 | — |
| 2N301 | 4 | Ge | 2 | —40 | —10 | —3 | 11 | 70 | —100 | 91 | 2N2869/2N301 |
| 2N301A | 4 | Ge | 2 | —60 | —10 | —3 | 11 | 70 | —100 | 91 | 2N2870/2N301A |
| 2N307 | 4 | Ge | 2 | —35 | — | —1 | 10 | 20 | —1500 | 75 | 2N2869 |
| 2N331 | 1 | Ge | 11 | —30 | —12 | —0.200 | 0.200 | 50 | —16 | 71 | 2N1638 |
| 2N356 | 5 | Ge | * | 20 | 20 | 0.5 | 0.100 | 30 | 5 | 85 | 2N647 |
| 2N357 | 5 | Ge | * | 20 | 20 | 0.5 | 0.100 | 30 | 5 | 85 | 2N647 |
| 2N358 | 5 | Ge | * | 20 | 20 | 0.5 | 0.100 | 30 | 5 | 85 | 2N647 |
| 2N371 | 3 | Ge | 9 | —24 | —0.5 | —0.010 | 0.08 | 80 | —20 | 71 | — |
| 2N373 | 3 | Ge | 9 | —25 | —0.5 | —0.010 | 0.080 | 60 | —8 | 71 | 2N1638 |
| 2N374 | 3 | Ge | 9 | —25 | —0.5 | —0.010 | 0.080 | 60 | —8 | 71 | 2N1631 |
| 2N395 | 17 | Ge | 5 | —30 | —20 | —0.2 | 0.15 | 10 | —6 | 85 | — |
| 2N396 | 17 | Ge | 5 | — | — | — | — | 15 | —6 | — | — |
| 2N396A | 17 | Ge | 5 | —30 | —20 | —0.2 | 0.20 | 15 | —6 | 85 | — |
| 2N397 | 17 | Ge | 5 | —30 | —20 | —0.2 | 0.20 | 20 | —6 | 85 | — |
| 2N409 | 12 | Ge | 16 | —13 | — | —0.015 | 0.080 | 48 | —10 | 71 | — |
| 2N411 | 12 | Ge | 16 | —13 | — | —0.015 | 0.080 | 75 | —10 | 71 | — |
| 2N441 | 2 | Ge | 14 | —40 | —20 | —15 | 150 | 20 | —4000 | 100 | — |
| 2N442 | 2 | Ge | 14 | —50 | —30 | —15 | 150 | 20 | —4000 | 100 | — |
| 2N443 | 2 | Ge | 14 | —60 | —40 | —15 | 150 | 20 | —4000 | 100 | — |
| 2N456 | 4 | Ge | 25 | —40 | —20 | —5 | 50 | 52 | — | 95 | 2N2869 |
| 2N457 | 4 | Ge | 25 | —60 | —20 | —5 | 50 | 52 | — | 95 | 2N2869 |
| 2N497 | 6 | Si | 5 | 60 | 8 | — | 4 | 12 | 10 | 200 | — |
| 2N544 | 3 | Ge | 9 | —18 | —1 | —0.010 | 0.080 | 60 | —4 | 71 | 2N217 |

* 1 - emitter, 2 - base, 3 - collector.

‡ For terminal connections diagrams, see page 665.

# CHART OF DISCONTINUED TRANSISTORS (cont'd)

## BIPOLAR TYPES (cont'd)

| RCA Type | Bas-‡ ing | Mate-rial | Out-line | MAXIMUM RATINGS $V_{CB}$ (volts) | $V_{EB}$ (volts) | $I_C$ (amperes) | $P_T$ (watts) | CHARACTERISTICS Min. $h_{FE}$ | $I_{CB}$ ($\mu A$) | Maximum Operating Temperature (°C) | Can be replaced by RCA type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2N561 | 4 | Ge | 25 | —80 | —60 | —10 | 50 | 75 | — | 100 | 2N2869 |
| 2N578 | 1 | Ge | 11 | —20 | —12 | —0.400 | 0.120 | 10 | —5 | 71 | 2N412 |
| 2N579 | 1 | Ge | 11 | —20 | —12 | —0.400 | 0.120 | 20 | —5 | 71 | 2N412 |
| 2N580 | 1 | Ge | 11 | —20 | —12 | —0.400 | 0.120 | 30 | —5 | 71 | 2N412 |
| 2N581 | 10 | Ge | 5 | —18 | —10 | —0.100 | 0.150 | 20 | —10 | 100 | — |
| 2N582 | 10 | Ge | 5 | —25 | —12 | —0.100 | 0.150 | 20 | —5 | 100 | — |
| 2N583 | 1 | Ge | 1 | —18 | —10 | —0.100 | 0.120 | 20 | —10 | 85 | 2N412 |
| 2N584 | 1 | Ge | 1 | —25 | —12 | —0.100 | 0.120 | 40 | —5 | 85 | 2N408 |
| 2N586 | 12 | Ge | 9 | —45 | —12 | —0.250 | 0.250 | 35 | —16 | 85 | — |
| 2N640 | 3 | Ge | 9 | —34 | —1 | —0.010 | 0.080 | 50 | —5 | 71 | 2N1637 |
| 2N641 | 3 | Ge | 9 | —34 | —1 | —0.010 | 0.080 | 50 | —7 | 71 | 2N1638 |
| 2N642 | 3 | Ge | 9 | —34 | —1 | —0.010 | 0.080 | 50 | —7 | 71 | 2N1639 |
| 2N643 | 1 | Ge | 11 | —30 | —2 | —0.100 | 0.120 | 20 | —10 | 71 | — |
| 2N644 | 1 | Ge | 11 | —30 | —2 | —0.100 | 0.100 | 20 | —10 | 71 | — |
| 2N645 | 1 | Ge | 11 | —30 | —2 | —0.100 | 0.120 | 20 | —10 | 71 | — |
| 2N656 | 6 | Si | 5 | 60 | 8 | — | 4 | 30 | 10 | 200 | — |
| 2N696 | 6 | Si | 5 | 60 | 5 | —0.500 | 2 | 20 | 1 | 175 | — |
| 2N705 | 7 | Ge | 12 | —15 | —3.5 | —0.05 | 0.15 | 25 | —3 | 100 | — |
| 2N708 | 6 | Si | 12 | 40 | — | — | 0.36 | 15 | 0.025 | 200 | — |
| 2N710 | 7 | Ge | 12 | —15 | —2 | —0.05 | 0.15 | 25 | —3 | 100 | — |
| 2N711 | 7 | Ge | 12 | —12 | —1 | —0.1 | 0.15 | 20 | —3 | 100 | — |
| 2N794 | 7 | Ge | 12 | —13 | —1 | —0.100 | 0.150 | 30 | —3 | 85 | 2N1300 |
| 2N795 | 7 | Ge | 12 | —13 | —4 | —0.100 | 0.150 | 30 | —3 | 85 | 2N1301 |
| 2N796 | 7 | Ge | 12 | —13 | —4 | —0.100 | 0.150 | 50 | —3 | 85 | 2N1683 |
| 2N828 | 7 | Ge | 12 | —15 | —2.5 | —0.2 | 0.3 | 25 | —3 | 100 | — |
| 2N914 | 6 | Si | 12 | 40 | — | — | 0.36 | 10 | 0.025 | 200 | — |
| 2N955 | 6 | Ge | 12 | 12 | 2 | 0.1 | 0.15 | 30 | 5 | 100 | — |
| 2N955A | 6 | Ge | 12 | 12 | 2 | 0.15 | 0.15 | 30 | 5 | 100 | — |
| 2N960 | 7 | Ge | 12 | —15 | —2.5 | —0.1 | 0.3 | 20 | —3 | 100 | — |
| 2N961 | 7 | Ge | 12 | —12 | —2 | —0.1 | 0.3 | 20 | —3 | 100 | — |
| 2N962 | 7 | Ge | 12 | —12 | —1.25 | —0.1 | 0.3 | 20 | —3 | 100 | — |
| 2N963 | 7 | Ge | 12 | —12 | —1.25 | —0.1 | 0.3 | 20 | —5 | 100 | — |
| 2N964 | 7 | Ge | 12 | —15 | —2.5 | —0.1 | 0.3 | 40 | —3 | 100 | — |
| 2N965 | 7 | Ge | 12 | —12 | —2 | —0.1 | 0.3 | 40 | —3 | 100 | — |
| 2N966 | 7 | Ge | 12 | —12 | —1.25 | —0.1 | 0.3 | 40 | —3 | 100 | — |
| 2N967 | 7 | Ge | 12 | —12 | —1.25 | —0.1 | 0.3 | 40 | —5 | 100 | — |
| 2N1010 | 5 | Ge | 1 | 10 | — | 0.002 | 0.020 | — | 10 | 55 | — |
| 2N1014 | 4 | Ge | 25 | —100 | —60 | —10 | 50 | 75 | — | 100 | 2N2869 |
| 2N1067 | 8 | Si | 10 | 60 | 12 | 0.5 | 5 | 35 | 15 | 175 | 2N3053 |

‡ For terminal connections diagrams, see page 665.

# CHART OF DISCONTINUED TRANSISTORS (cont'd)

## BIPOLAR TYPES (cont'd)

| | | | | MAXIMUM RATINGS | | | | CHARACTERISTICS | | Maximum Operating Temperature | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RCA Type | Basing‡ | Material | Outline | $V_{CB}$ (volts) | $V_{EB}$ (volts) | $I_C$ (amperes) | $P_T$ (watts) | Min. $h_{FE}$ | $I_{CB}$ ($\mu A$) | (°C) | Can be replaced by RCA type |
| **2N1068** | 8 | Si | 10 | 60 | 12 | 1.5 | 10 | 38 | 15 | 175 | 2N3262 |
| **2N1069** | 9 | Si | 2 | 60 | 1.7 | 4 | 50 | 20 | 25 | 175 | 2N1489 |
| **2N1070** | 9 | Si | 2 | 60 | 9 | 4 | 50 | 20 | 25 | 175 | 2N1702 |
| **2N1090** | 26 | Ge | 5 | 25 | 20 | 0.400 | 0.120 | 20 | 8 | 85 | — |
| **2N1091** | 26 | Ge | 5 | 25 | 20 | 0.400 | 0.120 | 30 | 8 | 85 | — |
| **2N1092** | 6 | Si | 5 | 60 | 12 | 0.5 | 2 | 35 | 15 | 175 | — |
| **2N1099** | 2 | Ge | 14 | −80 | −40 | −15 | 150 | 35 | −4000 | 100 | — |
| **2N1100** | 2 | Ge | 14 | −100 | −80 | −15 | 150 | 25 | −4000 | 100 | — |
| **2N1165** | 2 | Ge | 5 | 25 | 25 | 0.4 | 0.12 | 20 | 10 | 71 | — |
| **2N1170** | 10 | Ge | 5 | 40 | 40 | 0.4 | 0.12 | 20 | 8 | 71 | — |
| **2N1213** | 7 | Ge | 5 | −25 | −1 | −0.100 | 0.075 | — | −3 | 85 | — |
| **2N1214** | 10 | Ge | 5 | −25 | −1 | −0.100 | 0.075 | — | −3 | 85 | — |
| **2N1215** | 10 | Ge | 5 | −25 | −1 | −0.100 | 0.075 | — | −3 | 85 | — |
| **2N1216** | 10 | Ge | 5 | −25 | −1 | −0.100 | 0.075 | — | −3 | 85 | — |
| **2N1319** | 10 | Ge | 5 | −20 | −20 | −0.4 | 0.12 | 15 | −6 | 71 | — |
| **2N1358** | 2 | Ge | 14 | −80 | −60 | −15 | 150 | 25 | −200 | 100 | — |
| **2N1384** | 10 | 14 | Ge | −30 | −1 | −0.5 | 0.24 | 20 | −8 | 85 | — |
| **2N1412** | 2 | Ge | 14 | −100 | −80 | −15 | 150 | 25 | −4000 | 100 | — |
| **2N1425** | 3 | Ge | 9 | −24 | −0.5 | −0.010 | 0.080 | 50 | −12 | 71 | 2N1638 |
| **2N1426** | 3 | Ge | 9 | −24 | −0.5 | −0.010 | 0.080 | 130 | −12 | 71 | 2N1638 |
| **2N1450** | 1 | Ge | 11 | −30 | −1 | −0.100 | 0.120 | 20 | −10 | 85 | 2N217 |
| **2N1511** | 11 | Si | 14 | 60 | 60 | 6 | 75 | 15 | 25 | 200 | 2N1487 |
| **2N1512** | 11 | Si | 14 | 100 | 100 | 6 | 75 | 15 | 25 | 200 | 2N1488 |
| **2N1513** | 11 | Si | 14 | 60 | 60 | 6 | 75 | 15 | 25 | 200 | 2N1489 |
| **2N1514** | 11 | Si | 14 | 100 | 100 | 6 | 75 | 15 | 25 | 200 | 2N1490 |
| **2N1525** | 12 | Ge | 16 | −24 | −0.5 | −0.010 | 0.080 | — | −16 | 71 | — |
| **2N1527** | 12 | Ge | 16 | −24 | −0.5 | −0.010 | 0.080 | — | −16 | 71 | — |
| **2N1633** | 12 | Ge | 16 | −34 | −0.5 | −0.010 | 0.080 | 75 | −16 | 85 | 2N1638 |
| **2N1634** | 1 | Ge | 1 | −34 | −0.5 | −0.010 | 0.080 | 75 | −16 | 85 | 2N1638 |
| **2N1635** | 12 | Ge | 16 | −34 | −0.5 | −0.010 | 0.080 | 75 | −16 | 85 | 2N1638 |
| **2N1636** | 1 | Ge | 1 | −34 | −0.5 | −0.010 | 0.080 | 75 | −16 | 85 | 2N1638 |
| **2N1708** | 6 | Si | 12 | 25 | 3 | 0.2 | 0.3 | 20 | 0.025 | 175 | — |
| **2N1768** | 23 | Si | 22 | 60 | 12 | 3 | 40 | 35 | 15 | 200 | 2N1485 |
| **2N1769** | 23 | Si | 22 | 100 | 12 | 3 | 40 | 35 | 15 | 200 | 2N1486 |
| **2N1853** | 10 | Ge | 5 | −18 | −2 | −0.100 | 0.150 | 30 | −4.2 | 85 | — |
| **2N1854** | 10 | Ge | 5 | −18 | −2 | −0.100 | 0.150 | 25 | −40 | 85 | — |
| **2N2205** | 6 | Si | 12 | 25 | — | 0.2 | 0.3 | 20 | 0.025 | 175 | — |
| **2N2206** | 6 | Si | 19 | 25 | 3 | 0.2 | 1 | 40 | 0.025 | 175 | — |
| **2N2273** | 7 | Ge | 12 | −25 | −1 | −0.1 | 0.1 | 20 | −10 | 100 | 2N1179 |
| **2N2339** | 23 | Si | 22 | 60 | 40 | 2.5 | 40 | 20 | 3000 | 200 | 2N1701 |

‡ For terminal connections diagrams, see page 665.

# CHART OF DISCONTINUED TRANSISTORS (cont'd)

## BIPOLAR TYPES (cont'd)

| RCA Type | Basing‡ | Material | Outline | MAXIMUM RATINGS $V_{CB}$ (volts) | $V_{EB}$ (volts) | $I_C$ (amperes) | $P_T$ (watts) | CHARACTERISTICS Min. $h_{FE}$ | $I_{CB}$ ($\mu$A) | Maximum Operating Temperature (°C) | Can be replaced by RCA type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2N2482 | 6 | Ge | 12 | 20 | 3 | 0.1 | 0.15 | 25 | 5 | 100 | — |
| 2N2873 | 13 | Ge | 1 | —35 | —0.1 | —0.010 | 0.115 | 40 | 12 | 100 | — |
| 2N2898 | 6 | Si | 19 | 120 | 7 | 1 | 1.8 | 40 | 0.002 | 200 | — |
| 2N2899 | 6 | Si | 19 | 140 | 7 | 1 | 1.8 | 60 | 0.01 | 200 | — |
| 2N2900 | 6 | Si | 19 | 60 | 7 | 1 | 1.8 | 50 | 0.05 | 200 | — |
| 2N2938 | 6 | Si | 21 | 25 | — | 0.5 | 0.3 | 25 | 0.025 | 175 | — |
| 2N3011 | 6 | Si | 12 | 30 | 5 | 0.0002 | 0.36 | 12 | — | 200 | — |
| 2N3230 | 25 | Si | 30 | 80 | 10 | 7 | 25 | 1000 | — | 200 | — |
| 2N3231 | 25 | Si | 30 | 100 | 10 | 7 | 25 | 1000 | — | 200 | — |
| 2N3241 | 8 | Si | 32 | 30 | 5 | 0.1 | 2 | 50 | 0.1 | 175 | 2N3241A |
| 2N3242 | 8 | Si | 32 | 30 | 5 | 0.2 | 2 | 75 | 0.01 | 175 | 2N3242A |
| 2N3435 | 6 | Si | 5 | 80 | 4 | 0.25 | 1 | 50 | 0.05 | 200 | — |
| 2N4081 | 18 | Si | 31 | 40 | 3 | — | 0.2 | 40 | 0.02 | 200 | — |
| 2N4296 | 9 | Si | 25 | 350 | 4 | 1 | 0.020 | 35 | 100 | 175 | — |
| 2N4297 | 9 | Si | 25 | 350 | 4 | 1 | 0.020 | 50 | 100 | 175 | — |
| 2N4298 | 9 | Si | 25 | 500 | 4 | 1 | 0.020 | 20 | 100 | 175 | — |
| 2N4299 | 9 | Si | 25 | 500 | 4 | 1 | 0.020 | 35 | 100 | 175 | — |
| 2N4395 | 9 | Si | 2 | 60 | 4 | 5 | 62.5 | 20 | 100 | 150 | — |
| 2N4396 | 9 | Si | 2 | 80 | 4 | 5 | 62.5 | 20 | 100 | 150 | — |
| 2N4397 | 18 | Si | 31 | 40 | 3 | — | 0.2 | 40 | 0.02 | 200 | — |
| 2N4934 | 27 | Si | 31 | 40 | 3 | — | 0.200 | 40 | 0.010 | 200 | — |
| 2N4935 | 27 | Si | 31 | 50 | 3 | — | 0.200 | 60 | 0.010 | 200 | — |
| 2N4936 | 27 | Si | 31 | 50 | 3 | — | 0.200 | 60 | 0.010 | 200 | — |
| 2N5017 | — | Si | 49 | — | 4 | 4.5 | 30 | — | — | 200 | — |
| 3746 | — | Ge | 17 | —34 | —0.5 | —0.20 | 0.080 | — | —16 | 85 | — |
| 3907/ 2N404 | 10 | Ge | 5 | —25 | —12 | —0.2 | 0.15 | 30 | —5 | 85 | — |
| 40217 | 6 | Si | 21 | 25 | 3 | — | 0.3 | 20 | 0.5 | 175 | — |
| 40218 | 6 | Si | 21 | 25 | 5 | 50 | 0.3 | 20 | 0.5 | 175 | — |
| 40219 | 6 | Si | 21 | 40 | — | — | 0.36 | 15 | 0.025 | 200 | — |
| 40220 | 6 | Si | 21 | 40 | 5 | 0.2 | 0.3 | 25 | 0.5 | 175 | — |
| 40221 | 6 | Si | 21 | 40 | — | — | 0.36 | 10 | 0.025 | 200 | — |
| 40222 | 6 | Si | 21 | 25 | — | 0.2 | 0.3 | 20 | 0.025 | 175 | — |
| 40253 | 1 | Ge | 1 | —25 | —2.5 | 0.500 | 0.125 | 50 | —14 | 90 | — |
| 40255 | 14 | Si | 5 | 450 | 7 | 1 | 10 | 30 | — | 200 | — |
| 40256 | 14 | Si | 5 | 300 | 7 | 1 | 10 | 30 | — | 200 | — |
| 40261 | 1 | Ge | 1 | —50 | —0.5 | —0.010 | 0.125 | — | —12 | 85 | — |
| 40262 | 1 | Ge | 1 | —50 | —0.5 | —0.010 | 0.125 | — | —12 | 85 | — |
| 40263 | 1 | Ge | 1 | —20 | —2.5 | —0.050 | 0.120 | — | —12 | 100 | — |
| 40264 | 24 | Si | 34 | 300 | 3 | 0.1 | 4 | 30 | 100 | 150 | — |

‡ For terminal connections diagrams, see page 665.

# CHART OF DISCONTINUED TRANSISTORS (cont'd)

## BIPOLAR TYPES (cont'd)

| RCA Type | Bas-‡ ing | Mate- rial | Out- line | MAXIMUM RATINGS $V_{CB}$ (volts) | $V_{EB}$ (volts) | $I_C$ (amperes) | $P_T$ (watts) | CHARACTERISTICS Min. $h_{FE}$ | $I_{CB}$ ($\mu$A) | Maximum Operating Temperature (°C) | Can be replaced by RCA type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 40269 | 10 | Ge | 5 | —25 | —12 | 0.1 | 0.15 | 50 | —5 | 85 | — |
| 40283 | 6 | Si | 19 | 60 | 5 | — | 0.4 | 10 | — | 200 | — |
| 40296 | 15 | Si | 28 | 30 | 2.5 | 0.040 | 0.200 | 30 | 0.01 | 200 | — |
| 40350 | 15 | Si | 31 | 35 | — | 0.025 | 0.18 | 40 | 1 | 175 | — |
| 40351 | 15 | Si | 31 | 35 | — | 0.025 | 0.18 | 40 | 1 | 175 | — |
| 40352 | 15 | Si | 31 | 35 | — | 0.025 | 0.18 | 27 | 1 | 175 | — |
| 40403 | 19 | Ge | 5 | −30 | −20 | −0.2 | 0.2 | 15 | −6 | 85 | — |
| 40404 | 6 | Si | 21 | 40 | 5 | 0.5 | 1 | 25 | 0.025 | 175 | — |
| 40422 | 9 | Si | 25 | 300 | 2 | 0.15 | 8 | 50 | 100 | 150 | — |
| 40423 | 9 | Si | 27 | 300 | 2 | 0.15 | 3.8 | 50 | 100 | 150 | — |
| 40424 | 9 | Si | 25 | 300 | 2 | 0.15 | 8 | 30 | 100 | 150 | — |
| 40425 | 9 | Si | 27 | 300 | 2 | 0.15 | 3.8 | 30 | 100 | 150 | — |
| 40426 | 9 | Si | 25 | 300 | 2 | 0.15 | 8 | 20 | 100 | 150 | — |
| 40427 | 9 | Si | 27 | 300 | 2 | 0.15 | 3.8 | 20 | 100 | 150 | — |
| 40444 | 9 | Si | 2 | 120 | 7 | 20 | 140 | 20 | — | 200 | — |
| 40450 | 20 | Si | 33 | 30 | 7.5 | — | 1 | 100 | 10 | 175 | — |
| 40451 | 20 | Si | 33 | 40 | 8 | — | 1 | 125 | 1 | 175 | — |
| 40452 | 20 | Si | 33 | 40 | 8 | 0.300 | 1 | 35 | 1 | 175 | — |
| 40453 | 20 | Si | 31 | — | 7.5 | 0.200 | 1 | 20 | 5 | 175 | — |
| 40454 | 20 | Si | 33 | — | 7.5 | 0.200 | 1 | 20 | 5 | 175 | — |
| 40455 | 20 | Si | 33 | — | 7 | 0.200 | 1 | 100 | 10 | 175 | — |
| 40456 | 20 | Si | 33 | — | 7 | 0.200 | 1 | 50 | 10 | 175 | — |
| 40457 | 6 | Si | 32 | — | 7 | 1 | 0.5 | 30 | 0.5 | 175 | — |
| 40459 | 20 | Si | 33 | 60 | 8 | 1 | 1 | 50 | 1 | 175 | — |
| 40464 | 9 | Si | 2 | 35 | 4 | 5 | 40 | 30 | 250 | 150 | — |
| 40465 | 9 | Si | 2 | 40 | 4 | 5 | 40 | 70 | 0.1 | 150 | — |
| 40466 | 9 | Si | 2 | 50 | 4 | 5 | 40 | 50 | 100 | 150 | — |
| 40469 | 18 | Si | 31 | 45 | 3 | 0.05 | 0.18 | 40 | 0.02 | 175 | — |
| 40470 | 18 | Si | 31 | 45 | 3 | 0.05 | 0.18 | 40 | 0.02 | 175 | — |
| 40471 | 18 | Si | 31 | 45 | 3 | 0.05 | 0.18 | 27 | 0.02 | 175 | — |
| 40472 | 27 | Si | 33 | 45 | 3 | 0.050 | 0.180 | 40 | 1 | 175 | — |
| 40473 | 27 | Si | 31 | 45 | 3 | 0.050 | 0.180 | 40 | 1 | 175 | — |
| 40474 | 27 | Si | 31 | 45 | 3 | 0.050 | 0.180 | 27 | 1 | 175 | — |
| 40475 | 27 | Si | 31 | 45 | 3 | 0.050 | 0.180 | 40 | 1 | 175 | — |
| 40476 | 27 | Si | 31 | 45 | 3 | 0.050 | 0.180 | 27 | 1 | 175 | — |

‡ For terminal connections diagrams, see page 665.

# CHART OF DISCONTINUED TRANSISTORS (cont'd)

## BIPOLAR TYPES (cont'd)

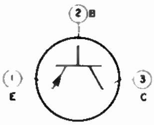
| RCA Type | Bas-‡ ing | Mate-rial | Out-line | MAXIMUM RATINGS $V_{CB}$ (volts) | $V_{EB}$ (volts) | $I_C$ (amperes) | $P_T$ (watts) | CHARACTERISTICS Min. $h_{FE}$ | $I_{CB}$ ($\mu$A) | Maximum Operating Temperature (°C) | Can be replaced by RCA type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 40477 | 27 | Si | 31 | 45 | 3 | 0.050 | 0.180 | 27 | 1 | 175 | — |
| 40478 | 27 | Si | 31 | 45 | 3 | 0.050 | 0.180 | 40 | 0.02 | 175 | — |
| 40479 | 27 | Si | 31 | 45 | 3 | 0.050 | 0.180 | 40 | 0.02 | 175 | — |
| 40480 | 27 | Si | 31 | 45 | 3 | 0.050 | 0.180 | 27 | 0.02 | 175 | — |
| 40481 | 27 | Si | 31 | 45 | 3 | 0.050 | 0.180 | 70 | 0.02 | 175 | — |
| 40482 | 27 | Si | 31 | 45 | 3 | 0.050 | 0.180 | 27 | 0.02 | 175 | — |
| 40487 | 1 | Ge | 1 | —50 | —1.5 | —0.010 | 0.080 | — | —12 | 85 | — |
| 40488 | 1 | Ge | 1 | —12 | —0.5 | —0.010 | 0.080 | — | —12 | 85 | — |
| 40489 | 1 | Ge | 1 | —50 | —0.5 | —0.010 | 0.080 | — | —12 | 85 | — |
| 40490 | 1 | Ge | 1 | —20 | —2.5 | —0.020 | 0.12 | — | —12 | 100 | — |
| 40500 | 6 | Si | 31 | 7.5 | 7.5 | 0.2 | 2 | 50 | 0.1 | 175 | — |
| 40501 | 20 | Si | 33 | 7.5 | 7.5 | 0.2 | 1 | 50 | 0.1 | 175 | — |
| 40517 | 15 | Si | 28 | 30 | 2.5 | 0.040 | 0.200 | 30 | 1 | 200 | — |
| 40518 | 15 | Si | 28 | 30 | 2.5 | 0.040 | 0.200 | 30 | 1 | 200 | — |
| 40546 | 9 | Si | 25 | — | — | 0.15 | 8 | 50 | 100 | 150 | — |
| 40547 | 9 | Si | 25 | — | — | 0.15 | 8 | 20 | 100 | 150 | — |

## MOS FIELD-EFFECT TYPES

| Type RCA | Bas-‡ ing | Mate-rial | Out-line | MAXIMUM RATINGS $I_D$ (mA) | $V_{DS}$ (volts) | $P_T$ (watts) | CHARACTERISTICS ture ($\mu$mhos) | $I_{DS}$(off) (pA) | $r_{DS}$(on) (ohms) | Maximum Operating Temperature (°C) | Can be replaced by RCA type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3N99 | 16 | Si | 28 | 15 | 32 | 0.15 | 1500 | 50 | 900 | 85 | — |
| 40460 | 16 | Si | 28 | 15 | 32 | 0.15 | 2000 | 50 | 800 | 85 | — |
| 40461 | 21 | Si | 28 | — | ±25 | 0.15 | 3500 | — | 90 | 125 | — |
| 3N98 | 21 | Si | 28 | — | 25 | 0.15 | 3500 | — | — | 125 | — |
| 40467 | 21 | Si | 31 | — | 0-20 | 0.1 | 7400 | — | — | 125 | — |
| 40468 | 22 | Si | 31 | 20 | 20 | 0.10 | 7500 | — | — | 125 | — |
| 40559 | 22 | Si | 31 | 50 | 0-20 | 0.40 | — | — | — | 175 | — |

‡ For terminal connections diagrams, see page 665.

# TERMINAL DIAGRAMS FOR DISCONTINUED TYPES

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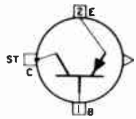


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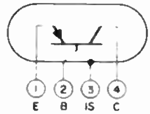


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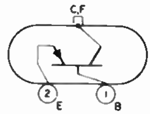


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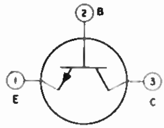


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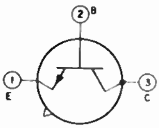


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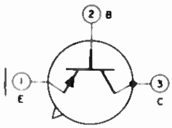


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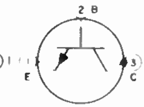


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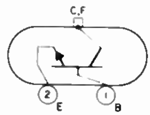


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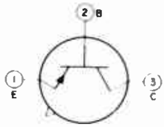


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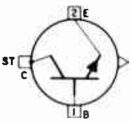


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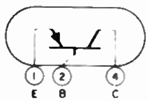


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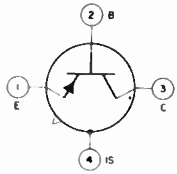


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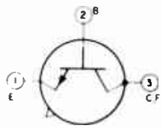


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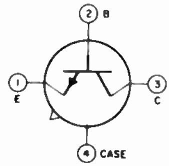


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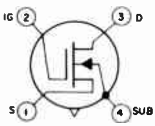


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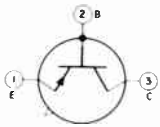


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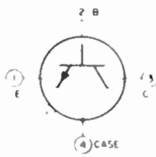


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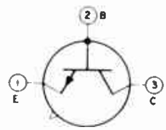


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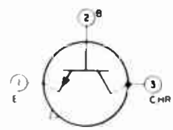


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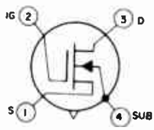


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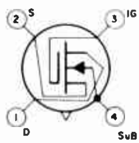


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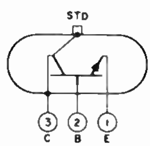


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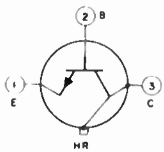


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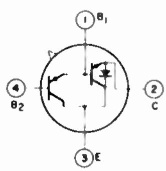


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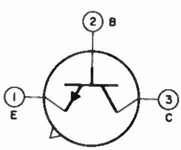


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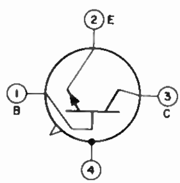
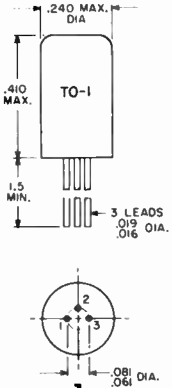



27

# Outlines

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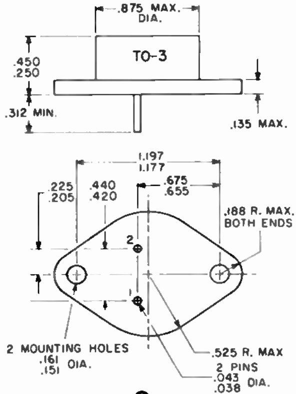


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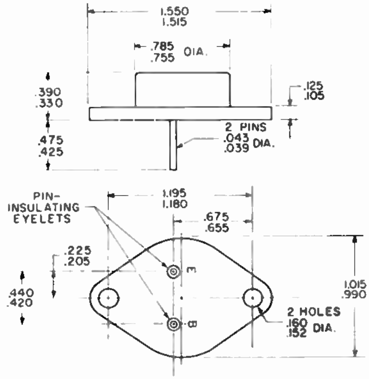


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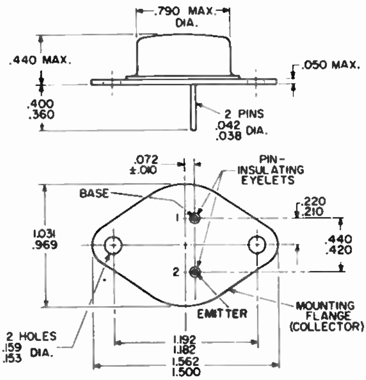


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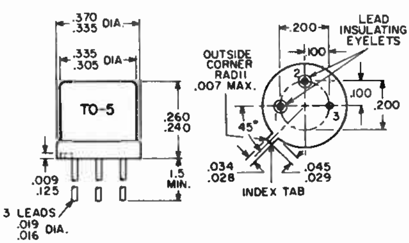


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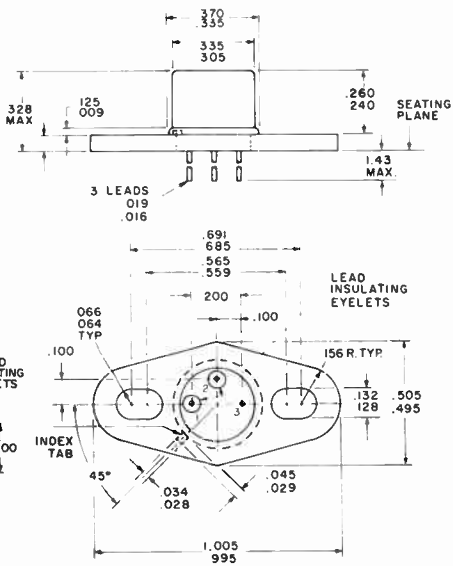


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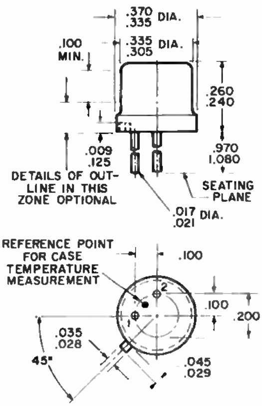


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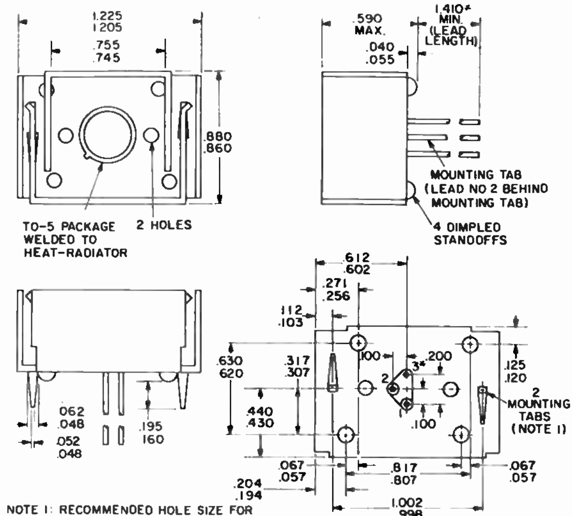
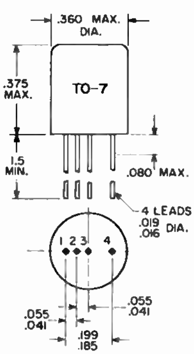



NOTE 1: RECOMMENDED HOLE SIZE FOR PRINTED-CIRCUIT BOARD IS 0.070 DIA.

* MODIFIED TO-5 TYPE IS A 2 LEAD PACKAGE HAVING LEAD LENGTHS OF 0.9 min. LENGTH.

8

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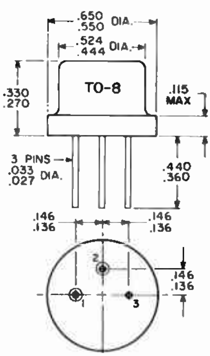


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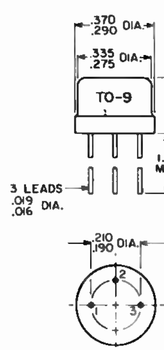


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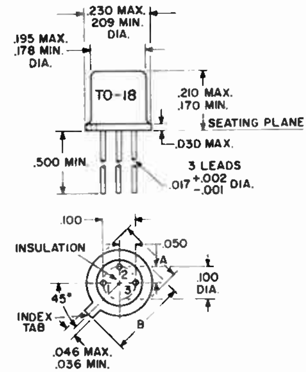


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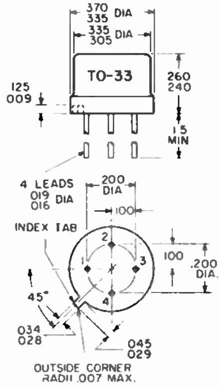


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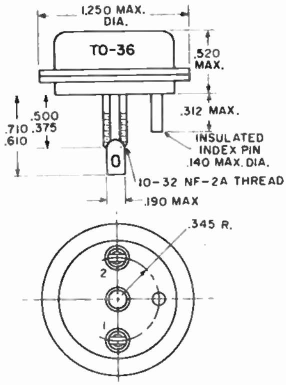


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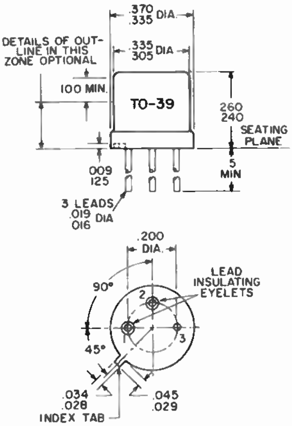


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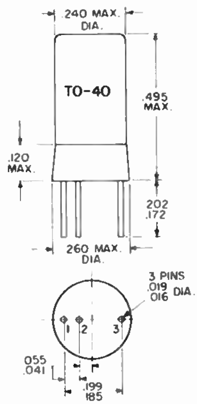


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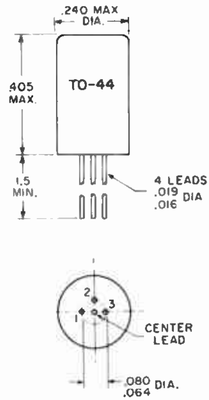


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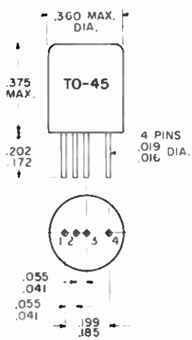


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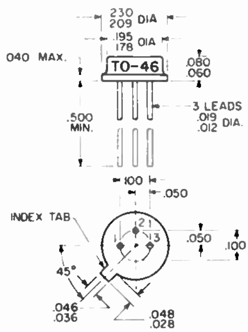


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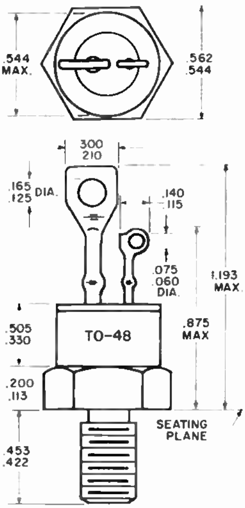
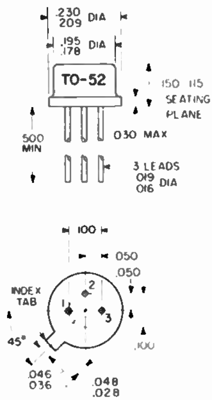
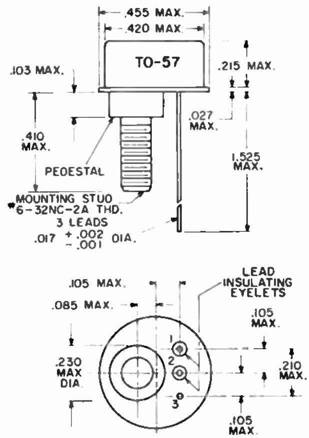

.544 MAX.
.562 .544
300 210
.165 .125 DIA.
.140 .115
.075 .060 DIA.
1.193 MAX.
.505 .330
TO-48
.875 MAX
.200 .113
SEATING PLANE
.453 .422

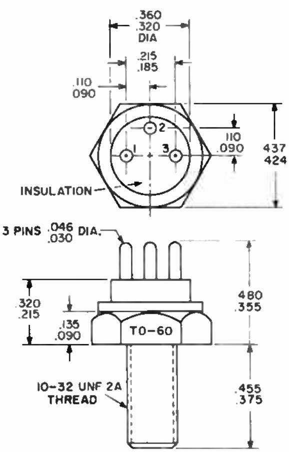
20


.230 .209 DIA
.195 .178 DIA
TO-52
.150 .115 SEATING PLANE
.500 MIN
.030 MAX
3 LEADS .019 .016 DIA
.100
.050
.050
INDEX TAB
45°
.100
.046 .036
.048 .028

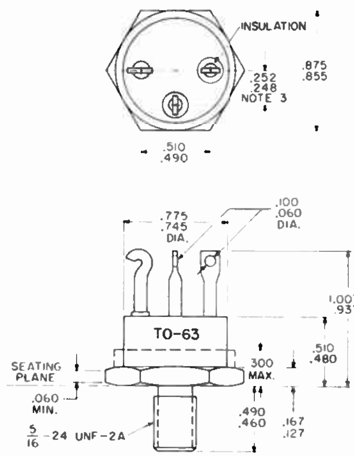
21


.455 MAX.
.420 MAX.
TO-57
.103 MAX.
.215 MAX.
.027 MAX.
.410 MAX.
1.525 MAX.
PEDESTAL
MOUNTING STUD 6-32NC-2A THD.
3 LEADS
.017 +.002 -.001 DIA.
.105 MAX.
.085 MAX.
LEAD INSULATING EYELETS
.105 MAX.
.230 MAX DIA.
.210 MAX.
.105 MAX.

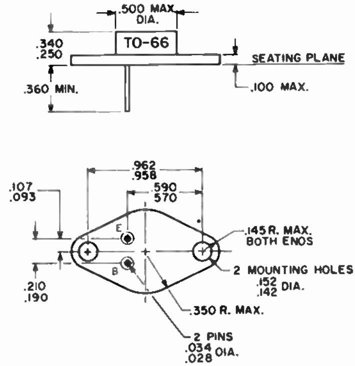
22


.360 .320 DIA
.215 .185
.110 .090
.110 .090
.437 .424
INSULATION
3 PINS .046 .030 DIA.
.320 .215
.135 .090
TO-60
.480 .355
10-32 UNF 2A THREAD
.455 .375

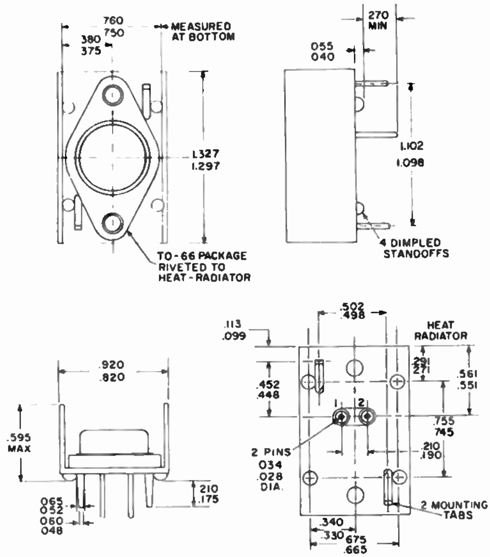
23


INSULATION
.875 .855
.252 .248 NOTE 3
.510 .490
.775 .745 DIA.
.100 .060 DIA.
1.007 .937
TO-63
.510 .480
SEATING PLANE
.300 MAX.
.060 MIN.
.490 .460
.167 .127
5/16 -24 UNF-2A

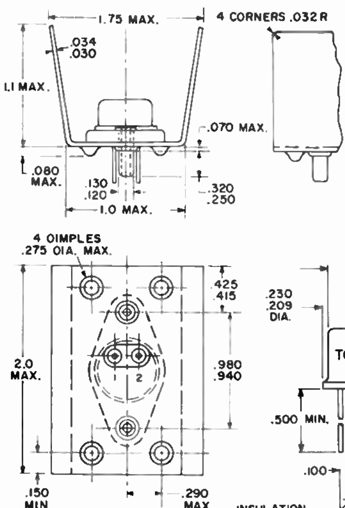
24


.500 MAX. DIA.
TO-66
.340
.250
SEATING PLANE
.360 MIN.
.100 MAX.
.962
.958
.590
.570
.107
.093
E
B
.145 R. MAX. BOTH ENDS
2 MOUNTING HOLES
.152
.142 DIA.
.210
.190
.350 R. MAX.
2 PINS
.034
.028 DIA.

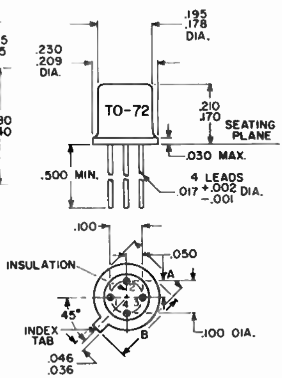
25


760
750
380
375
MEASURED AT BOTTOM
270 MIN
055
040
1.327
1.297
1.102
1.098
TO-66 PACKAGE RIVETED TO HEAT-RADIATOR
4 DIMPLED STANDOFFS
.920
.820
.595 MAX
065
052
060
048
210
.175
.502
.498
.113
.099
HEAT RADIATOR
.291
.271
.561
.551
.452
.448
.755
745
2 PINS
034
.028
DIA.
.210
.190
2 MOUNTING TABS
.340
.330
675
.665

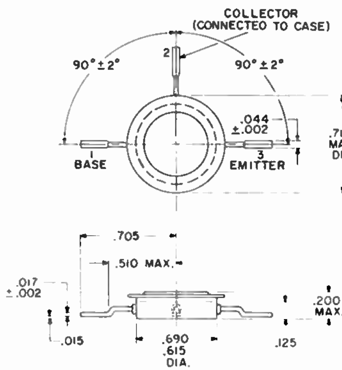
26


1.75 MAX.
4 CORNERS .032 R
.034
.030
1.1 MAX.
.070 MAX.
.080 MAX.
.130
.120
.320
.250
1.0 MAX.
4 DIMPLES .275 DIA. MAX.
.425
.415
2.0 MAX.
.980
.940
2
.150 MIN.
.290 MAX.

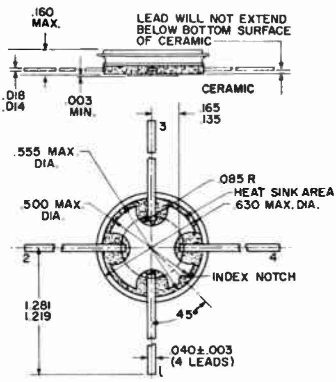
27


.195
.178
DIA.
.230
.209
DIA.
TO-72
.210
.170
SEATING PLANE
.030 MAX.
.500 MIN.
4 LEADS
.017 +.002 −.001 DIA.
.100
.050
INSULATION
A
45°
INDEX TAB
B
.100 DIA.
.046
.036

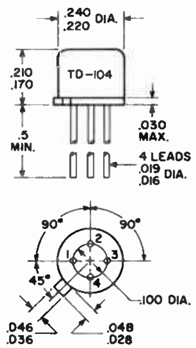
28


COLLECTOR (CONNECTED TO CASE)
2
90° ± 2°
90° ± 2°
.044
±.002
.710 MAX. DIA.
1
BASE
3
EMITTER
.705
.510 MAX.
.017
±.002
.200 MAX.
.015
.690
.615
DIA.
.125

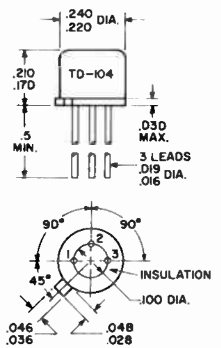
29



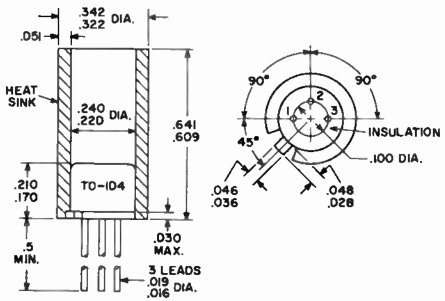

30



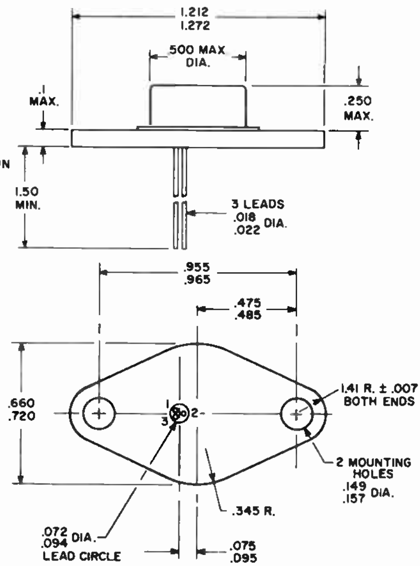

31



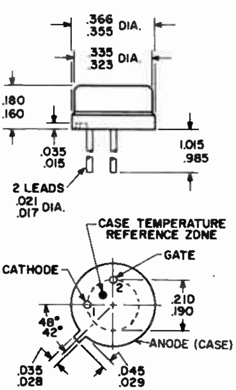

32



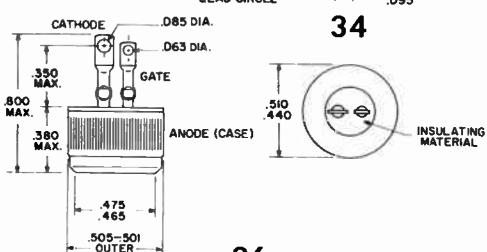

33



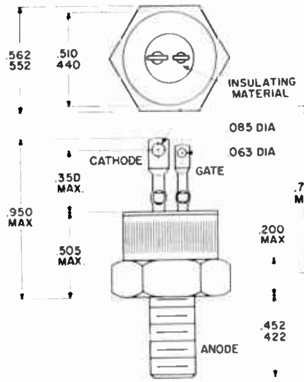

34



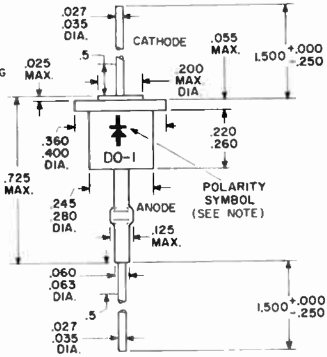

35



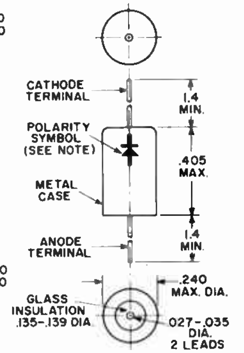

36



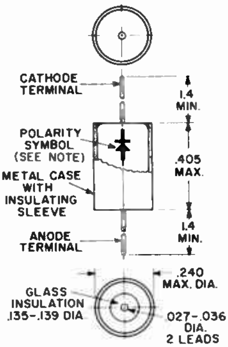

37



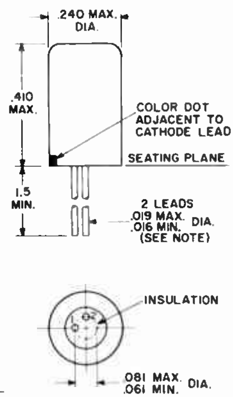

38



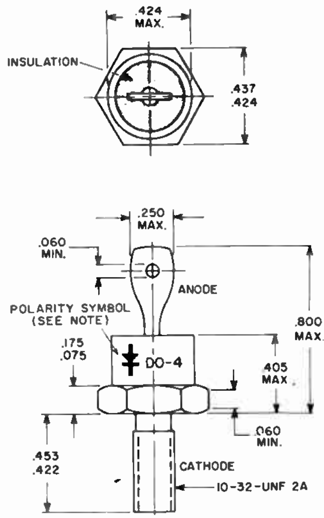

39



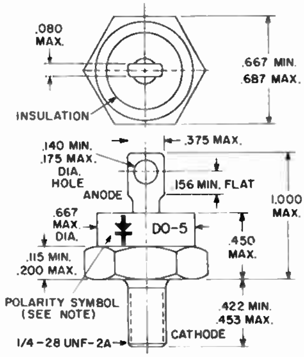

40



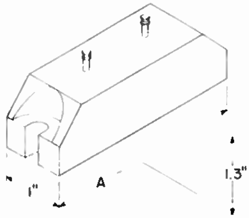

41




42



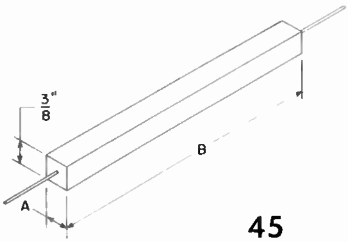

43




44

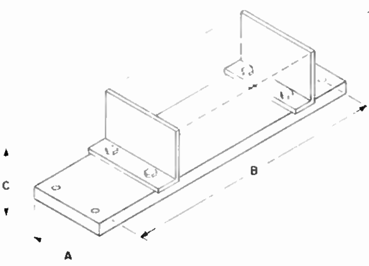
| Outline No. | "A" (Inches) |
|---|---|
| 44a | 2¾ |
| 44b | 2¾ |
| 44c | 2¾ |
| 44d | 3¼ |
| 44e | 3¼ |
| 44f | 4½ |
| 44g | 4½ |
| 44h | 4½ |
| 44i | 5½ |
| 44j | 5½ |

NOTE: ARROW INDICATES DIRECTION OF FORWARD CURRENT AS INDICATED BY DC AMMETER



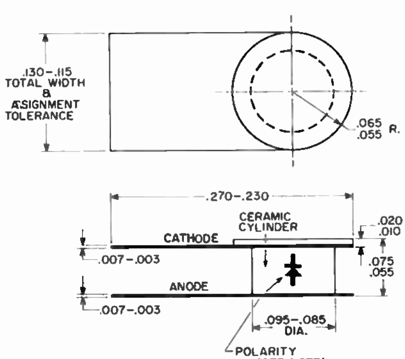

45

| Outline No. | "A" (Inches) | "B" |
|---|---|---|
| 45a | 3/4 | 2 |
| 45b | 5/16 | 3 1/2 |
| 45c | 5/16 | 4 1/2 |
| 45d | 3/4 | 3 1/2 |
| 45e | 3/4 | 3 1/2 |
| 45f | 3/4 | 4 1/2 |
| 45g | 3/4 | 4 1/2 |

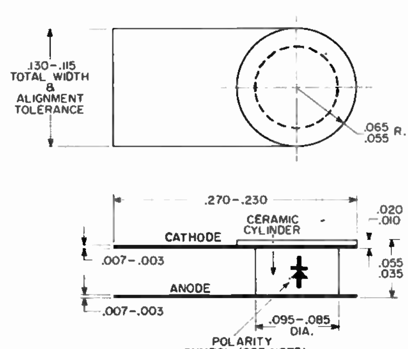



46

| Outline No. | "A" (Inches) | "B" | "C" | Outline No. | "A" (Inches) | "B" | "C" |
|---|---|---|---|---|---|---|---|
| 46a | 2 1/4 | 5 1/4 | 2 | 41q | 3 | 11 7/16 | 3 3/16 |
| 46b | 2 1/4 | 7 | 2 | 41r | 3 | 14 1/4 | 3 5/16 |
| 46c | 2 1/4 | 8 3/4 | 2 | 41s | 3 | 16 5/16 | 3 5/16 |
| 46d | 2 1/4 | 10 1/2 | 2 | 41t | 3 | 7 1/16 | 3 5/16 |
| 46e | 2 1/4 | 12 1/4 | 2 | 41u | 3 | 9 1/2 | 3 3/16 |
| 46f | 2 1/4 | 14 | 2 | 41v | 3 | 11 7/16 | 3 5/16 |
| 46g | 2 1/4 | 15 3/4 | 2 | 41w | 3 | 14 1/4 | 3 5/16 |
| 46h | 2 1/4 | 5 1/4 | 2 | 41x | 3 | 16 5/16 | 3 5/16 |
| 46i | 2 1/4 | 7 | 2 | 41y | 5 1/2 | 7 11/16 | 5 5/16 |
| 46j | 2 1/4 | 8 3/4 | 2 | 41z | 5 1/2 | 10 1/4 | 5 5/16 |
| 46k | 2 1/4 | 10 1/2 | 2 | 41aa | 5 1/2 | 12 13/16 | 5 5/16 |
| 46l | 2 1/4 | 12 1/4 | 2 | 41bb | 5 1/2 | 15 5/16 | 5 5/16 |
| 46m | 2 1/4 | 14 | 2 | 41cc | 5 1/2 | 7 11/16 | 5 5/16 |
| 46n | 2 1/4 | 15 3/4 | 2 | 41dd | 5 1/2 | 10 1/4 | 5 5/16 |
| 46o | 3 | 7 1/16 | 3 5/16 | 41ee | 5 1/2 | 12 13/16 | 5 5/16 |
| 46p | 3 | 9 1/2 | 3 3/16 | 41ff | 5 1/2 | 15 5/16 | 5 5/16 |

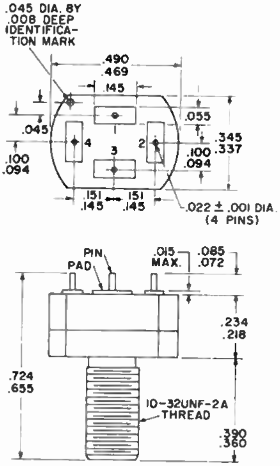



47

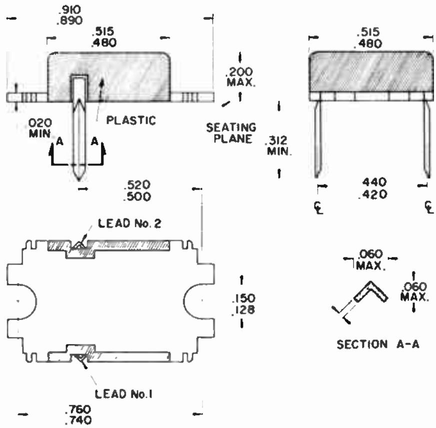



48

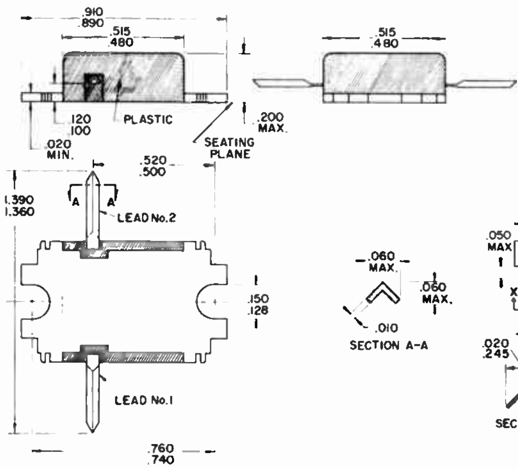
NOTE: ARROW INDICATES DIRECTION
OF FORWARD CURRENT AS
INDICATED BY DC AMMETER


.045 DIA. BY .008 DEEP IDENTIFICATION MARK
.490 .469
.145
.055
.045
.345 .337
.100 .094
.100 .094
.151 .145
.151 .145
.022 ± .001 DIA. (4 PINS)
PIN
PAD
.015 MAX.
.085 .072
.234 .218
.724 .655
10-32UNF-2A THREAD
.390 .360

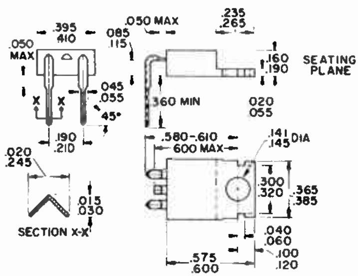
49


.910 .890
.515 .480
.200 MAX.
PLASTIC
.020 MIN
SEATING PLANE
.312 MIN.
.520 .500
LEAD No. 2
.150 .128
LEAD No. 1
.760 .740
.440 .420
.060 MAX.
.060 MAX.
SECTION A-A

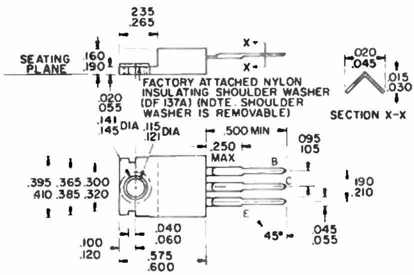
50


.910 .890
.515 .480
.120 .100
PLASTIC
.020 MIN.
SEATING PLANE
.200 MAX.
.520 .500
1.390 1.360
LEAD No. 2
.150 .128
LEAD No. 1
.760 .740
.060 MAX.
.060 MAX.
.010
SECTION A-A

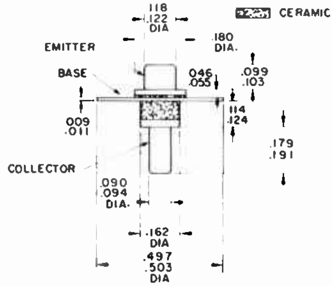
51


.050 MAX
.395 .410
.085 .115
.050 MAX
.235 .265
.160 .190
SEATING PLANE
.045 .055
.360 MIN
.020 .055
45°
.190 .210
.580-.610
.600 MAX
.141 .145 DIA
.020 .245
.300 .320
.365 .385
.015 .030
SECTION X-X
.040 .060
.100 .120
.575 .600

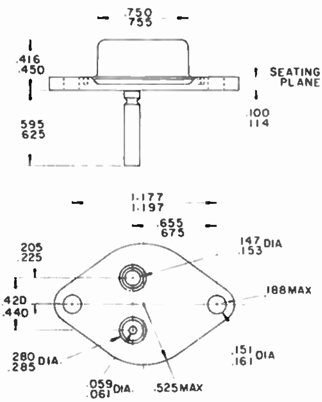
52



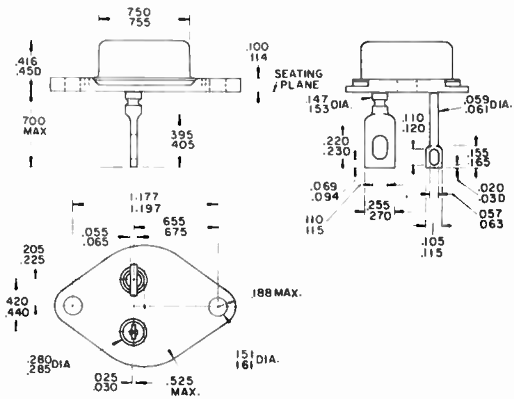

53



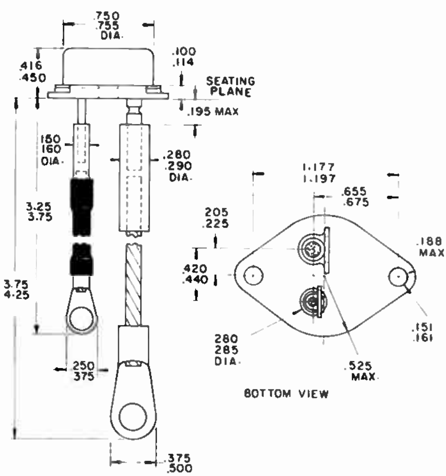

54



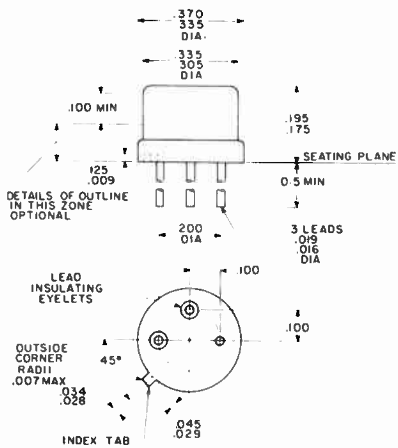

55



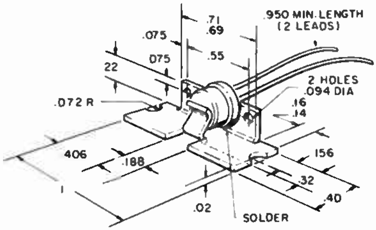

56



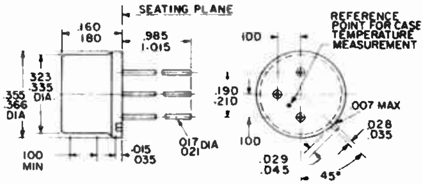

57



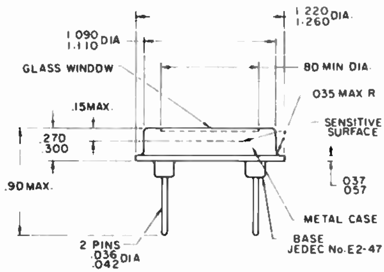

58



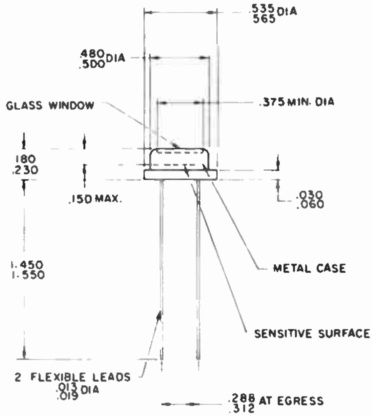

59



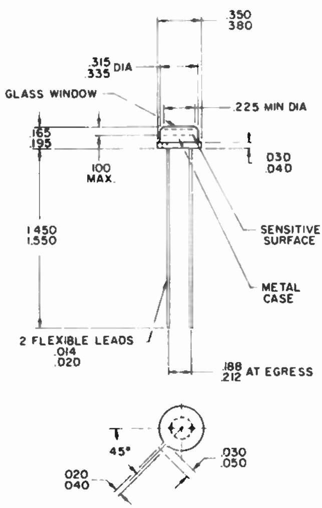

60



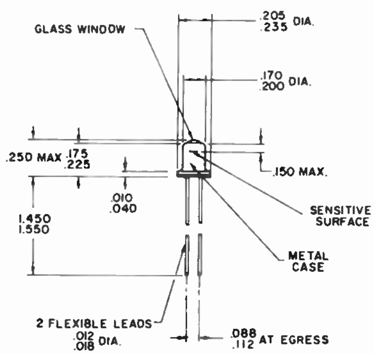

61



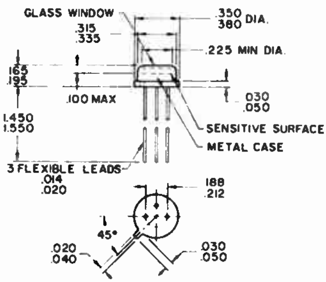

62



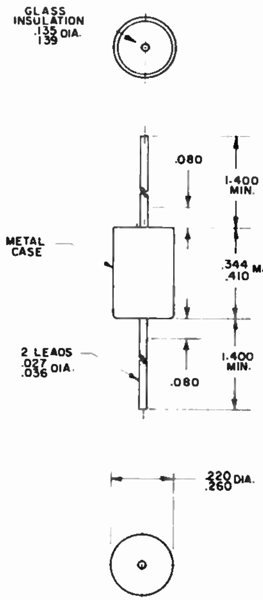

63



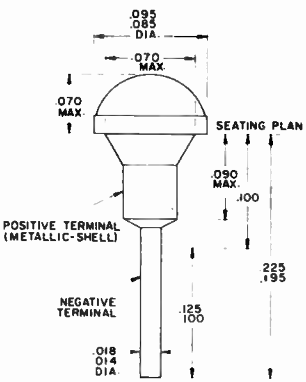

64


GLASS WINDOW
.350 .380 DIA.
.315 .335
.225 MIN DIA.
.165 .195
.100 MAX
.030 .050
1.450 1.550
SENSITIVE SURFACE
METAL CASE
3 FLEXIBLE LEADS
.014 .020
.188 .212
45°
.020 .040
.030 .050

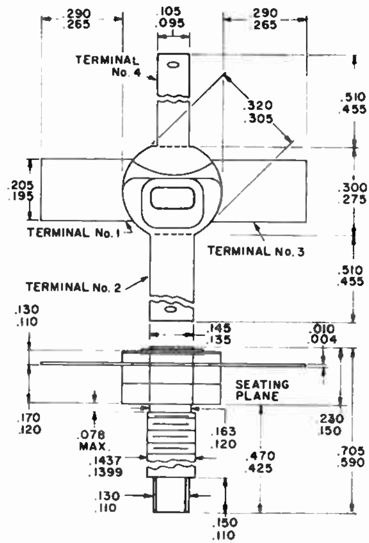
65


GLASS INSULATION
.135 .139 DIA.
.080
1.400 MIN.
METAL CASE
.344 .410 MAX.
2 LEADS
.027 .036 DIA.
.080
1.400 MIN.
.220 .260 DIA.

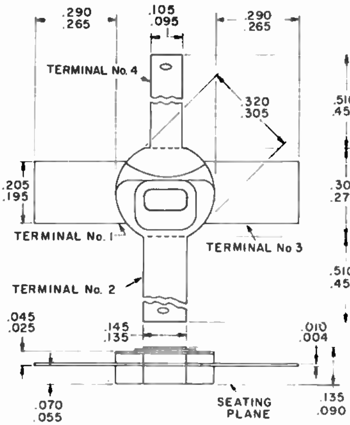
66


.095 .085 DIA.
.070 MAX.
.070 MAX.
SEATING PLAN
.090 MAX.
.100
POSITIVE TERMINAL (METALLIC-SHELL)
.225 .195
NEGATIVE TERMINAL
.125 .100
.018 .014 DIA.

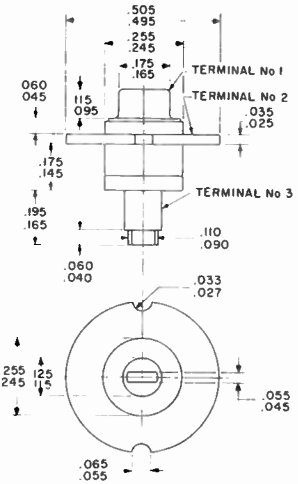
67


.290 .265
.105 .095
.290 .265
TERMINAL No. 4
.320 .305
.510 .455
.205 .195
.300 .275
TERMINAL No. 1
TERMINAL No. 3
.510 .455
TERMINAL No. 2
.130 .110
.145 .135
.010 .004
SEATING PLANE
.170 .120
.078 MAX.
.163 .120
.230 .150
.1437 .1399
.470 .425
.705 .590
.130 .110
.150 .110

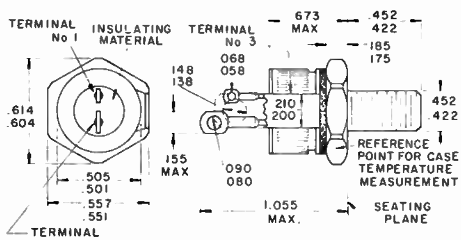
68


.290
.265
.105
.095
.290
.265
TERMINAL No. 4
.320
.305
.510
.455
.205
.195
.300
.275
TERMINAL No. 1
TERMINAL No 3
TERMINAL No. 2
.510
.455
.045
.025
.145
.135
.010
.004
.070
.055
SEATING PLANE
.135
.090

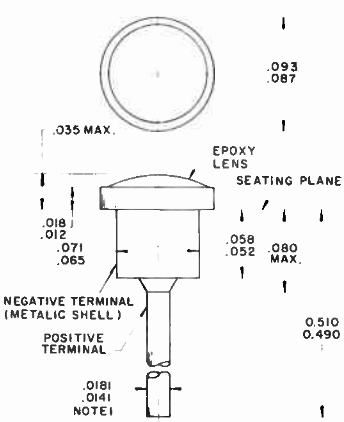
69


.505
.495
.255
.245
.175
.165
TERMINAL No 1
060
045
115
095
TERMINAL No 2
.035
.025
.175
.145
TERMINAL No 3
.195
.165
.110
.090
.060
.040
.033
.027
.255
.245
125
115
.055
.045
.065
.055

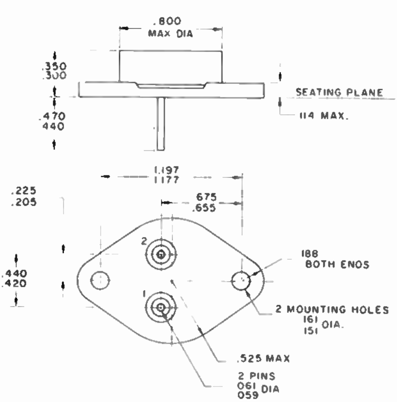
70


TERMINAL No 1
INSULATING MATERIAL
TERMINAL No 3
673 MAX
.452
.422
185
175
068
058
148
138
.614
.604
210
200
452
.422
155 MAX
REFERENCE POINT FOR CASE TEMPERATURE MEASUREMENT
.505
.501
090
080
.557
.551
1.055 MAX.
SEATING PLANE
TERMINAL No 2

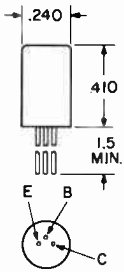
71


.093
.087
.035 MAX.
EPOXY LENS
SEATING PLANE
.018
.012
.071
.065
.058
.052
.080 MAX.
NEGATIVE TERMINAL (METALIC SHELL)
POSITIVE TERMINAL
0.510
0.490
.0181
.0141
NOTE 1

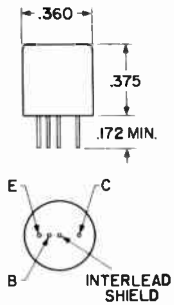
72


.800 MAX DIA
.350
.300
SEATING PLANE
.470
.440
114 MAX.
1.197
1.177
.225
.205
675
.655
188 BOTH ENDS
.440
.420
2 MOUNTING HOLES
161
151
DIA.
.525 MAX
2 PINS
061
059
DIA

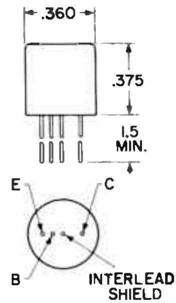
73


.240
.410
1.5
MIN.
E
B
C

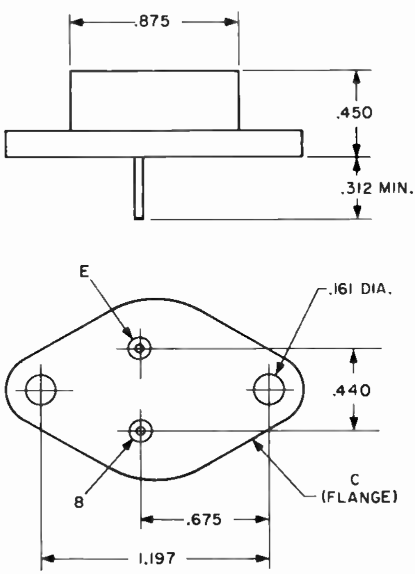
**A**


.360
.375
.172 MIN.
E
C
B
INTERLEAD
SHIELD

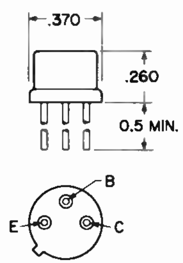
**B**


.360
.375
1.5
MIN.
E
C
B
INTERLEAD
SHIELD

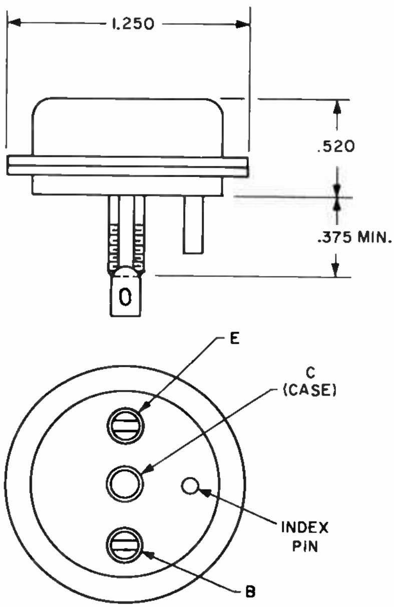
**C**


.875
.450
.312 MIN.
E
.161 DIA.
.440
8
C
(FLANGE)
.675
1.197

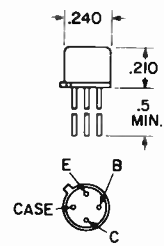
**D**


.370
.260
0.5 MIN.
B
E
C

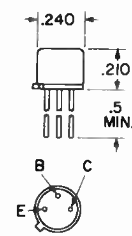
**E**


1.250
.520
.375 MIN.
E
C
(CASE)
INDEX
PIN
B

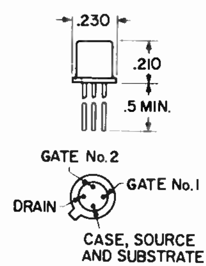
F


.240
.210
.5
MIN.
E
B
CASE
C

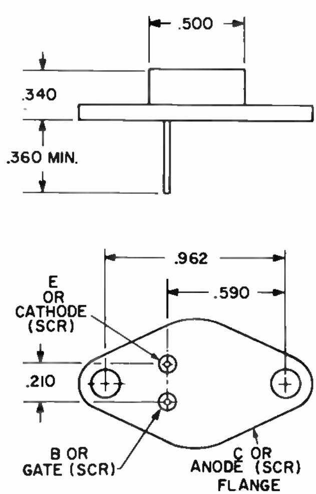
G


.240
.210
.5
MIN.
B
C
E

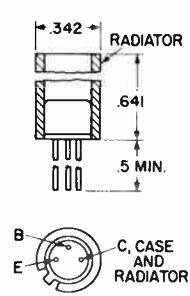
H


.230
.210
.5 MIN.
GATE No. 2
GATE No. 1
DRAIN
CASE, SOURCE
AND SUBSTRATE

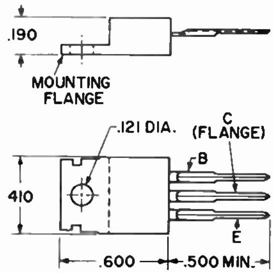
K


.500
.340
.360 MIN.
.962
.590
E
OR
CATHODE
(SCR)
.210
B OR
GATE (SCR)
C OR
ANODE (SCR)
FLANGE

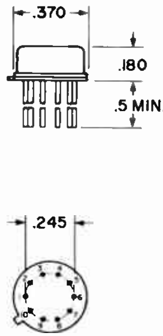
J


.342
RADIATOR
.641
.5 MIN.
B
E
C, CASE
AND
RADIATOR

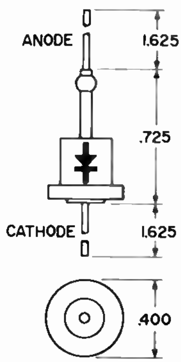
L


.190
MOUNTING FLANGE
.121 DIA.
C (FLANGE)
B
410
E
.600
.500 MIN.

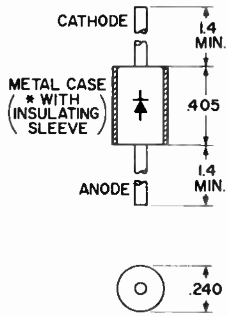
M


.370
.180
.5 MIN.
.245

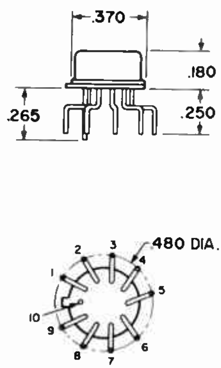
N


ANODE
1.625
.725
CATHODE
1.625
.400

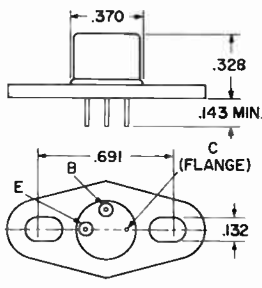
O


CATHODE
1.4 MIN.
METAL CASE
* WITH INSULATING SLEEVE
.405
ANODE
1.4 MIN.
.240

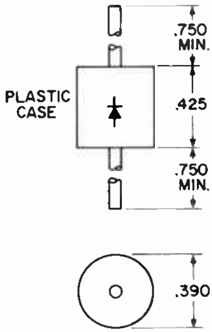
P


.370
.180
.265
.250
.480 DIA.
1
2
3
4
5
6
7
8
9
10

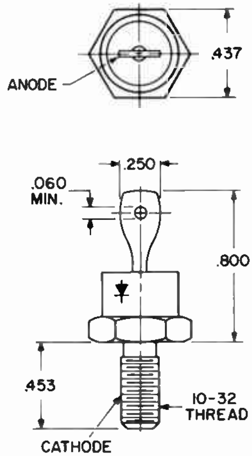
R


.370
.328
.143 MIN.
.691
C (FLANGE)
B
E
.132

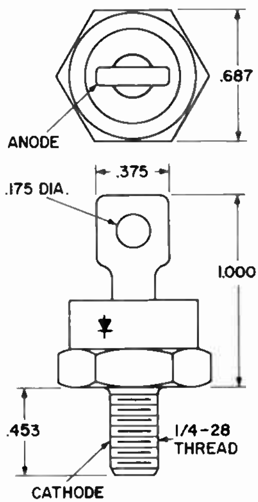
S


.750
MIN.
PLASTIC
CASE
.425
.750
MIN.
.390

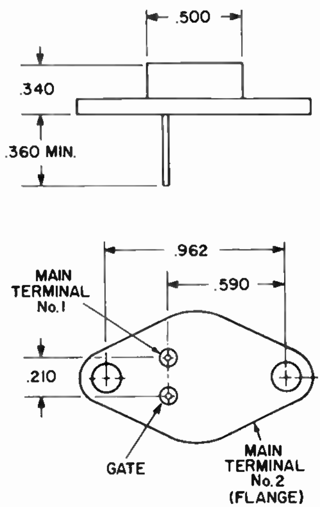
T


ANODE
.437
.250
.060
MIN.
.800
.453
10-32
THREAD
CATHODE

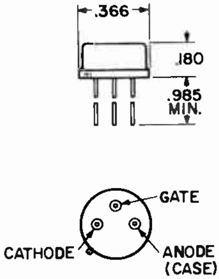
U


.687
ANODE
.375
.175 DIA.
1.000
.453
1/4-28
THREAD
CATHODE

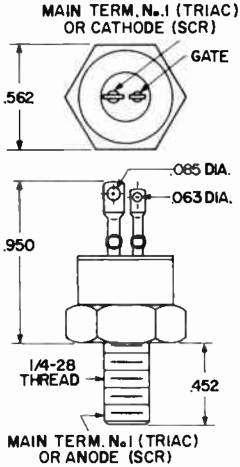
V


.500
.340
.360 MIN.
.962
.590
MAIN
TERMINAL
No.1
.210
GATE
MAIN
TERMINAL
No.2
(FLANGE)

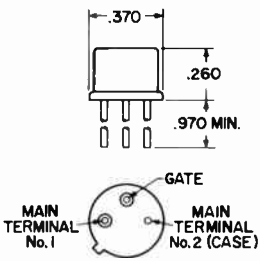
W


.366
.180
.985
MIN.
GATE
CATHODE
ANODE
(CASE)

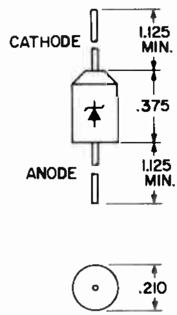
X


MAIN TERM. No.1 (TRIAC)
OR CATHODE (SCR)
GATE
.562
.085 DIA.
.063 DIA.
.950
1/4-28
THREAD
.452
MAIN TERM. No.1 (TRIAC)
OR ANODE (SCR)

Y


.370
.260
.970 MIN.
GATE
MAIN
TERMINAL
No. 1
MAIN
TERMINAL
No. 2 (CASE)

Z


CATHODE
1.125
MIN.
.375
ANODE
1.125
MIN.
.210

AA

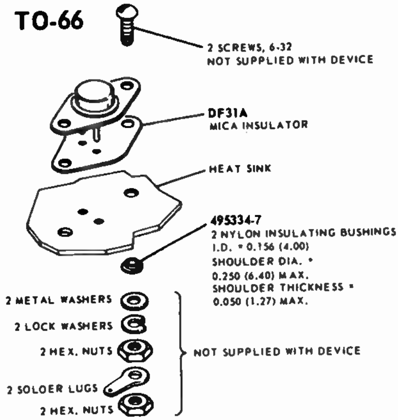
# Mounting Hardware

## HERMETIC PACKAGES

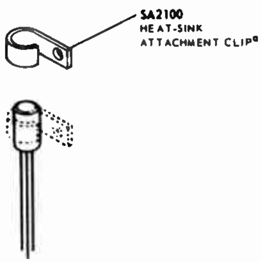
### TO-104

FOR MOUNTING HARDWARE INSTRUCTIONS SEE TO-1

### TO-66

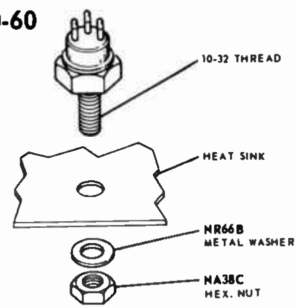


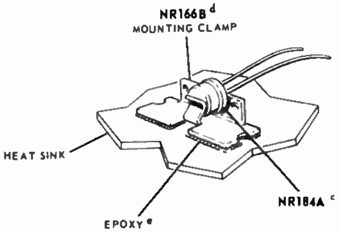

### TO-1




[a]Part is not supplied with device but is available from RCA or an authorized RCA distributor.

### TO-60

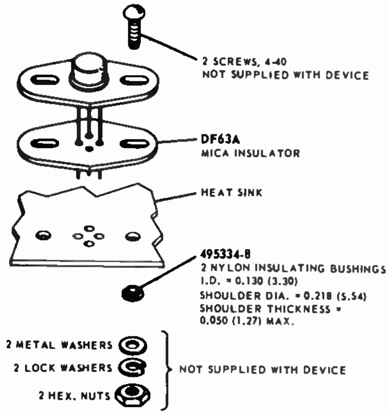




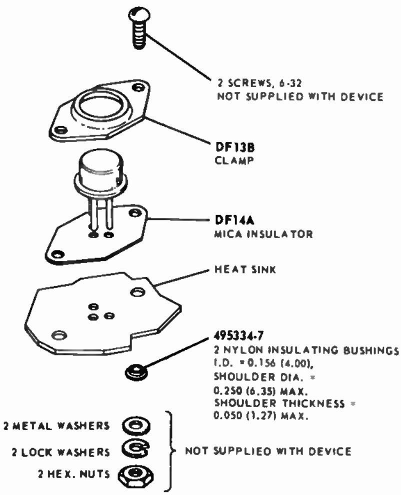

[c] Part is not supplied with device but is available from RCA (Part No. NR184A) and from Kester Solder Co., Newark, N.J. 07105, (Part No. KSFD-37500S) or equivalent.

[d] Part is not supplied with device but is available from RCA (Part No. NR166B) and from General Stamping Co., Inc., Denville, N.J. 07834 (Part No. 14-110)., or equivalent.

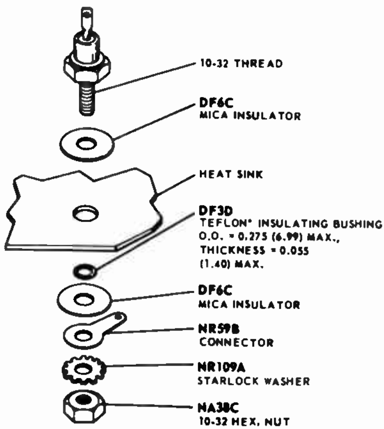
[e] An epoxy such as Hysol-Epoxy Patch Kit 6C, Hysol Corp., Olean, N.Y. 14761 or equivalent.




## TO-8

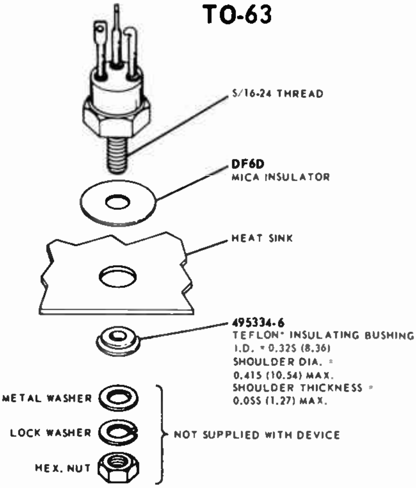



## DO-4



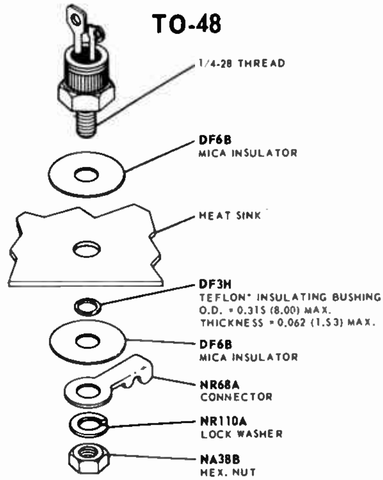

*REGISTERED TRADEMARK OF E.I. DUPONT DE NEMOURS & CO.

## TO-63



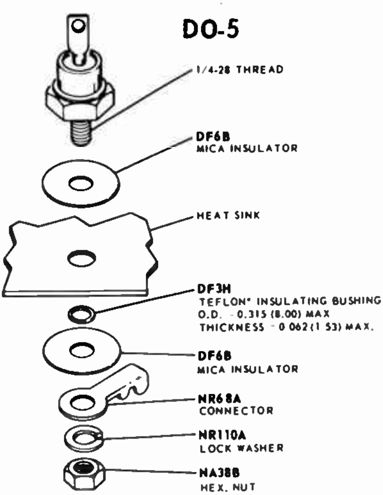

*REGISTERED TRADEMARK OF E.I. DUPONT DE NEMOURS & CO.

## TO-48



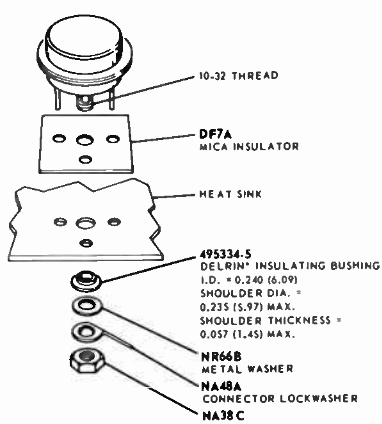

*REGISTERED TRADEMARK OF E.I. DUPONT DE NEMOURS & CO.

## DO-5



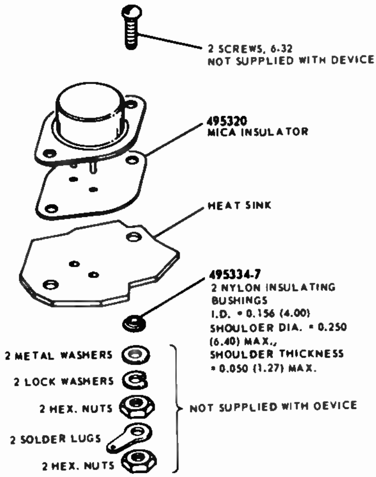

*REGISTERED TRADEMARK OF E.I. DUPONT DE NEMOURS & CO.

## TO-36

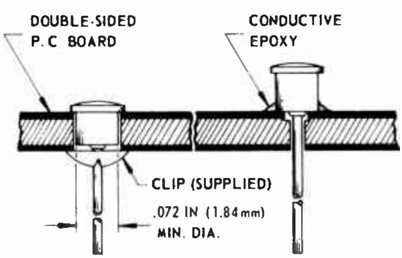


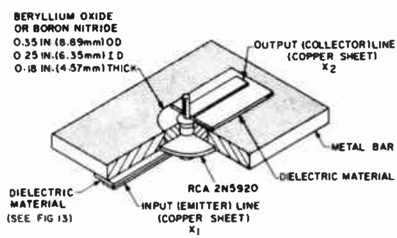

*REGISTERED TRADEMARK OF E.I. DUPONT DE NEMOURS & CO.

## TO-3




## FOR MOUNTING HARDWARE INSTRUCTIONS SEE DO-5

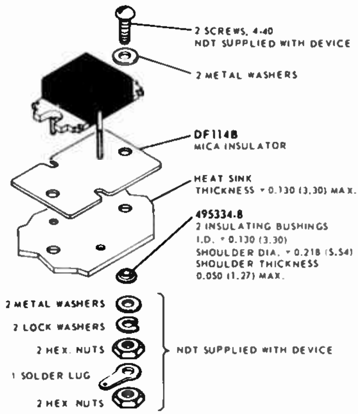


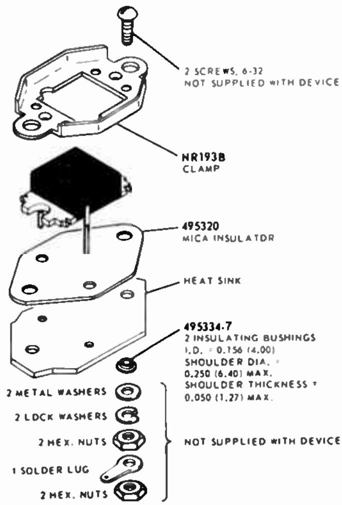




NOTE. FOR DIMENSIONS OF $X_1$ AND $X_2$ SEE FIG 1

# HIGH-POWER PLASTIC PACKAGES

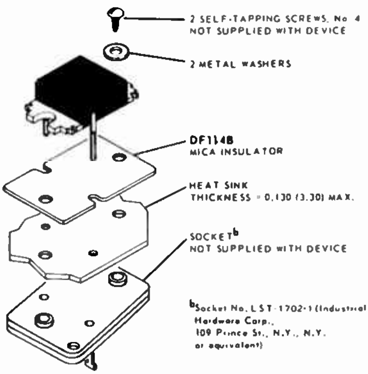
## CHASSIS MOUNTING



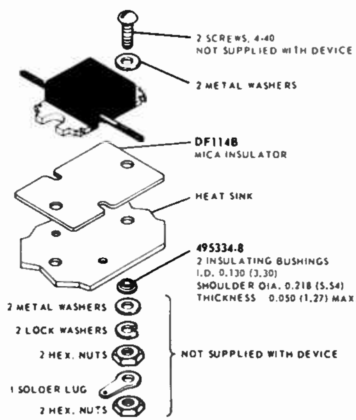




## SOCKET MOUNTING

Although supplied, the insulating bushings (495334-8) are not required when the transistor is socket mounted



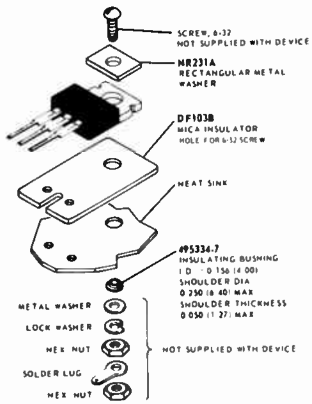

## PRINTED-CIRCUIT BOARD MOUNTING

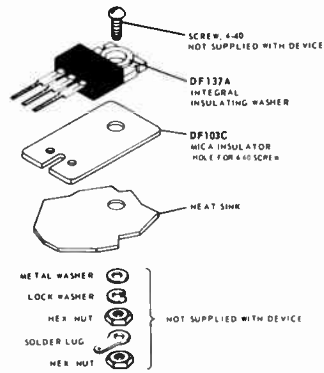


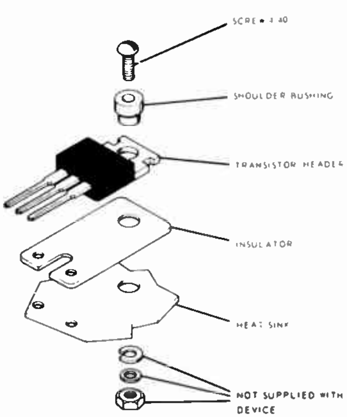

Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

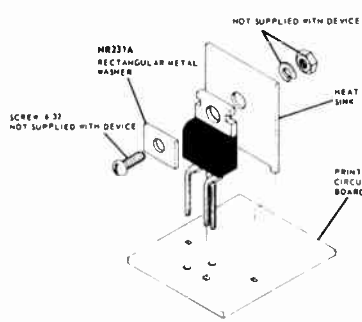
# VERSAWATT PACKAGES

## PRINTED-CIRCUIT BOARD MOUNTING



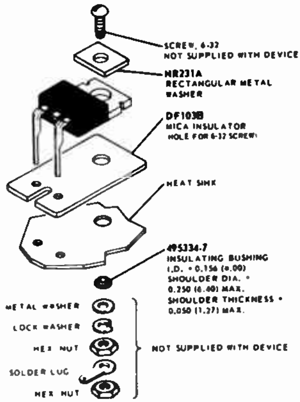




Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated

## CHASSIS MOUNTING



# Circuits

THE circuits in this section illustrate some of the more important applications of RCA solid-state devices; they are not necessarily examples of commercial practice. The brief description provided with each circuit explains the functional relationships of the various stages and points out the intended applications, the major performance characteristics, and significant design features of the over-all circuit. Detailed descriptive information on individual circuit stages (such as detectors, amplifiers, or oscillators) is given earlier in this Manual, as well as in many textbooks on semiconductor circuits.

Electrical specifications are given for circuit components to assist those interested in home construction. Layouts and mechanical details are omitted because they vary widely with the requirements of individual set builders and with the sizes and shapes of the components employed.

Performance of these circuits depends as much on the quality of the components selected and the care employed in layout and construction as on the circuits themselves. Good signal reproduction from receivers and amplifiers requires the use of good-quality speakers, transformers, chokes and input sources (microphones, phonograph pickups, etc.).

Coils for the receiver circuits can frequently be purchased at local parts dealers by specifying the characteristics required: for rf coils, the circuit position (antenna or interstage), tuning range desired, and tuning capacitances employed; for if coils or transformers, the intermediate frequency, circuit position (1st if, 2nd if, etc.), and, in some cases, the associated transistor types; for oscillator coils, the receiver tuning range, intermediate frequency, type of converter transistor, and type of winding (tapped or transformer-coupled).

The voltage ratings specified for capacitors are the minimum dc working voltages required. Paper, mica, or ceramic capacitors having higher voltage ratings than those specified may be used except insofar as the physical sizes of such capacitors may affect equipment layout. However, if electrolytic capacitors having substantially higher voltage ratings than those specified are used, they may not "form" completely at the operating voltage, with the result that the effective capacitances of such units may be below their rated value. The wattage ratings specified for resistors assume methods of construction that provide adequate ventilation; compact installations having poor ventilation may require resistors of higher wattage ratings.

Circuits which work at very high frequencies or which are required to handle very wide bandwidths demand more than ordinary skill and experience in construction. Placement of component parts is quite critical and may require considerable experimentation. All rf leads to components including bypass capacitors must be kept short and must be properly dressed to minimize undesirable coupling and capacitance effects. Correct circuit alignment and oscillator tracking may require the use of a cathode-ray oscilloscope, a high-impedance vacuum-tube voltmeter, and a signal generator capable of supplying a properly modulated signal at the appropriate frequencies. Unless the builder has had considerable experience with broad-band, high-frequency circuits, he should not undertake the construction of such circuits.

# List of Circuits

## MANUFACTURERS OF SPECIAL COMPONENTS AND MATERIALS
### REFERRED TO IN PARTS LISTS

AirDux, trade name of
Icore Electro-Plastics, Inc.
Subsidiary of Icore Industries
1050 Kifer Road
Sunnyvale, Calif.

Allen-Bradley Co.
1201 S. 2nd Street
Milwaukee, Wis.

Alpha Wire Corporation
180 Varick Street
New York, N. Y.

American Technical Ceramics (ATC)
Norden Lane
Huntington Station, N. Y.

Amphenol Connector Division
Amphenol-Borg Electronics Corp.
1830 South 54th Street
Chicago, Ill.

Arco Electronics, Inc.
Community Drive
Great Neck, N. Y.

Automatic Winding Division
General Instrument Co.
65 Governeur Street
Newark, N. J.

B and W, Inc.
Canal and Beaver Dam Road
Bristol, Pa.

Bud Radio, Inc.
4605 E. 355th Street
Willoughby, Ohio

Cambion, trade name of Cambridge
Thermionic Corp.

Cambridge Thermionic Corp. (CTC)
445 Concord Avenue
Cambridge, Mass.

Centralab
Division of Globe Union, Inc.
P.O. Box 591
Milwaukee, Wisc.

Cutler-Hammer, Inc.
4201 North 27th Street
Milwaukee, Wisc.

Erie Technological Products, Inc.
644 West 12th Street
Erie, Pa.

Ferroxcube Corp. of America
Old Kings Highway
Saugerties, N. Y.

Freed Transformer Co.
1718 Weirfield Street
Brooklyn, N. Y.

General Ceramics Corp.
Crows Mill Road
Keasby, N. J.

Hammarlund Manufacturing Co.
Hammarlund Drive
Mars Hill, N. C.

International Resistor Corp.
401 N. Broad Street
Philadelphia, Pa.

Johanson Mfg. Corp.
P.O. Box 329
Boonton, N. J.

Litz, trade name of
Alpha Wire Corp.
180 Varick Street
New York, N. Y.

Magnetic Metals Corp.
Hayes Avenue at 21st Street
Camden, N. J.

P. R. Mallory and Co., Inc.
3029 E. Washington Street
Indianapolis, Ind.

Mallory Controls Co.
Div. P. R. Mallory and Co., Inc.
Box 231
Frankfort, Ind.

Micro Switch
Division of Honeywell, Inc.
Freeport, Ill.

Microtran Co., Inc.
145 East Mineola Avenue
Valley Stream, N. Y.

Mid-West Coil and Transformer Co.
1642 North Halstead
Chicago, Ill.

James Millen Manufacturing Co.
150 Exchange Street
Malden, Mass.

J. W. Miller Co.
5917 South Main Street
Los Angeles, Calif.

## MANUFACTURERS (cont'd)

Nytronics, Inc.
550 Springfield Avenue
Berkeley Heights, N. J.

Potter and Brumfield
Division of American Machine and Foundry Co.
1200 East Broadway
Princeton, Ind.

Quality Components
Bridge and Railroad Streets
Saint Marys, Pa.

Radio Condenser Corp.
Division of TRW, Inc.
Davin and Copewood Street
Camden, N. J.

Simpson Electric Co.
5200 West Kinzie Street
Chicago, Ill.

F. W. Sickles Division
General Instrument Corp.
165 Front Street
Chicopee, Mass.

Sprague Electric Co.
481 Marshall St.
North Adams, Mass.

Stancor (Chicago-Stancor)
3501 West Addison Street
Chicago, Ill.

Thordarson-Meissner
7th and Bellmont
Mt. Carmel, Ill.

Triad
305 North Briant Street
Huntington, Ind.

Triwec Transformer Co.
3261 Milwaukee Avenue
Chicago, Ill.

Vibroplex Co., Inc.
833 Broadway
New York, N. Y.

Vitramon, Inc.
Box 544
Bridgeport, Conn.

Wakefield Engineering, Inc.
139 Foundry Street
Wakefield, Mass.

**NOTES:** Components and materials identified by RCA stock numbers may be obtained through authorized RCA distributors. In general, all components specified in the circuit parts lists can be purchased from local radio and electronic supply stores or mail-order houses. If the parts are not available from these sources, they may be obtained from the pertinent manufacturers listed above.

## 15-1 12-VOLT AUTOMOBILE RADIO RECEIVER

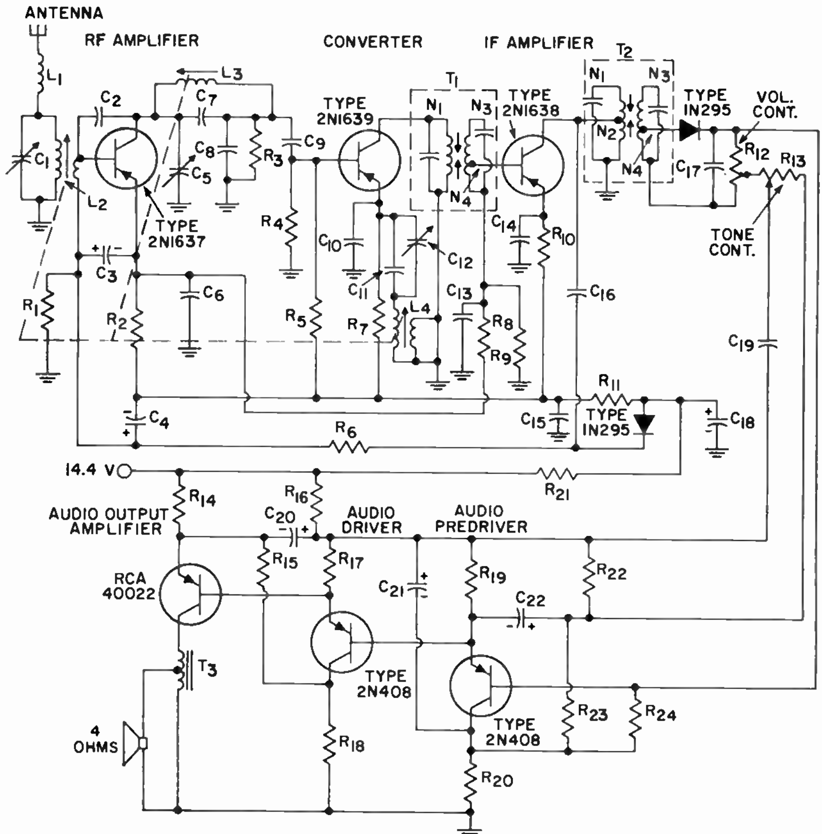
### Circuit Description

This 5-transistor superheterodyne radio receiver operates from the storage battery in automobiles that employ a 12-volt ignition system. The rf amplifier uses a high-gain 2N1637 transistor to provide the increased sensitivity and higher signal-to-noise ratio required in automobile radio receivers. The tuned rf amplifier selects and amplifies the amplitude-modulated rf signals from the desired broadcast station picked up by the automobile whip antenna. In the 2N1639 converter stage, the amplitude-modulated rf signal from the rf amplifier is mixed with a local-oscillator signal developed by the tuned circuit consisting of oscillator coil $L_4$ and capacitors $C_{11}$ and $C_{12}$ to provide a signal at the receiver intermediate frequency of 262.5 kHz (this value, rather than 455 kHz, is used in auto radios because the if amplifier provides greater gain and selectivity at the lower frequency).

The antenna circuit, rf amplifier, and converter are tuned together by means of mechanically ganged variable inductors $L_2$, $L_3$, and $L_4$ so that the local-oscillator frequency is always 262.5 kHz above the frequency to which the other circuits are tuned. Trimmer capacitors $C_1$, $C_5$, and $C_{12}$ are adjusted to provide the proper tracking relationship.

The 262.5-kHz signal from the converter stage is amplified by a single 2N1638 if amplifier and is then demodulated in the 1N295 second-detector circuit. The audio signal from

## 15-1 12-VOLT AUTOMOBILE RADIO RECEIVER (cont'd)




**NOTE: This circuit uses coils and transformers that are not available as stock items from any manufacturer. Home construction of this circuit should not be attempted unless the builder has had considerable experience in the winding of inductive components and has access to the special equipment required. The builder should also refer to the general considerations for construction of high-frequency and broadband circuits given on page 691.**

### Parts List

$C_1$ = trimmer capacitor, 5 to 80 pF, Arco No. 462 or equiv.
$C_2$ = 2 pF, silver mica
$C_3$ = 2.2 $\mu$F, electrolytic, 3 V
$C_4$ = 25 $\mu$F, electrolytic, 6 V
$C_5$, $C_{12}$ = trimmer capacitor, 110 to 580 pF, Arco No. 467 or equiv.
$C_6$, $C_9$, $C_{13}$, $C_{14}$, $C_{15}$, $C_{19}$ = 0.05 $\mu$F ceramic disc
$C_7$ = 200 pF, silver mica
$C_8$ = 0.005 $\mu$F, ceramic disc
$C_{10}$ = 0.0075 $\mu$F, ceramic disc
$C_{11}$ = 330 pF, silver mica
$C_{16}$ = 180 pF, silver mica
$C_{17}$ = 0.02 $\mu$F, ceramic disc
$C_{18}$ = 100 $\mu$F, electrolytic, 15 V
$C_{20}$ = 500 $\mu$F, electrolytic, 3 V
$C_{21}$ = 50 $\mu$F, electrolytic, 6 V
$C_{22}$ = 100 $\mu$F, electrolytic, 3 V
$L_1$ = rf choke, 5$\mu$H
$L_2$, $L_3$, $L_4$ = ganged tuning-coil assembly; manufactured by F. W. Sickles Co. and Radio Condenser Corp.
$L_2$ = antenna coil; primary = variable inductor, tunes with 110-pF capacitance from 535 to 1610 kHz, Q = 65 at 1610 kHz; secondary = 3½ turns
$L_3$ = rf coil, variable inductor, tunes with 600-pF capacitance from 535 to 1610 kHz, Q = 65 at 1610 kHz

## 15-1 12-VOLT AUTOMOBILE RADIO RECEIVER (cont'd)

### Parts List (cont'd)

$L_4$ = oscillator coil; primary = variable inductor, tunes with 470-pF capacitance from 797.5 to 1872.5 kHz, Q = 65 at 1872.5 kHz; secondary = 30 turns
$R_1$ = 82000 ohms, 0.5 watt
$R_2$ = 560 ohms, 0.5 watt
$R_3$ = 180 ohms, 0.5 watt
$R_4$ = 56000 ohms, 0.5 watt
$R_5$ = 5700 ohms, 0.5 watt
$R_6$ = 8200 ohms, 0.5 watt
$R_7$ = 1500 ohms, 0.5 watt
$R_8$ = 5600 ohms, 0.5 watt
$R_9$ = 0.1 megohm, 0.5 watt
$R_{10}$ = 470 ohms, 0.5 watt
$R_{11}$ = 100 ohms, 0.5 watt
$R_{12}$ = volume control, potentiometer, 2500 ohms, 0.5 watt, audio taper
$R_{13}$ = tone control, potentiometer, 1000 ohms, 0.5 watt, audio taper
$R_{14}$ = 3.3 ohms, 1 watt
$R_{15}$ = 82 ohms, 0.5 watt
$R_{16}$ = 68 ohms, 0.5 watt
$R_{17}$ = 120 ohms, 0.5 watt
$R_{18}$ = 220 ohms, 0.5 watt
$R_{19}$ = 1200 ohms, 0.5 watt
$R_{20}$ = 4700 ohms, 0.5 watt
$R_{21}$ = 680 ohms, 0.5 watt
$R_{22}$, $R_{24}$ = 3300 ohms, 0.5 watt
$R_{23}$ = 33000 ohms, 0.5 watt
$T_1$ = first if (262.5-kHz) transformer (includes 220-pF capacitor across each winding); primary unloaded Q = 47, primary loaded Q = 40.56; secondary unloaded Q = 47; secondary loaded Q = 39.4; input impedance = 68200 ohms; turns ratio of tapped secondary, $N_3/N_4$ = 18.25
$T_2$ = second if (262.5-kHz) transformer (includes 110-pF capacitor across each winding); primary unloaded Q = 47, primary loaded Q = 33.8; secondary unloaded Q = 47, secondary loaded Q = 23.5; turns ratio of tapped primary, $N_1/N_2$ = 4.28; turns ratio of tapped secondary $N_3/N_4$ = 10.2; input im-coupling = 0.85
$T_3$ = output transformer; transforms 22 ohms at 425 mA dc to 3.5 ohms; Thordarson-Meissner No. TR-168, or equiv.

### Circuit Description (cont'd)

the detector, which is developed across the volume-control potentiometer $R_{12}$, is coupled through the tone-control potentiometer $R_{13}$ to the audio-amplifier section of the receiver. In this section, the audio signal is amplified by two 2N408 voltage amplifiers (audio predriver and driver stages) and applied to the base circuit of the 40022 power amplifier stage which drives the speaker. Transformer $T_3$ matches the output impedance of the amplifier to the speaker voice coil.

A portion of the audio-frequency signal from the detector is coupled from the wiper arm of the tone control through a frequency-selective network to the audio amplifiers. The tone-control network by de-emphasis of low frequencies tends to equalize the amplitudes of low- and high-frequency audio signals.

## 15-2 HIGH-QUALITY FM TUNER FOR MULTIPLEX RECEIVER

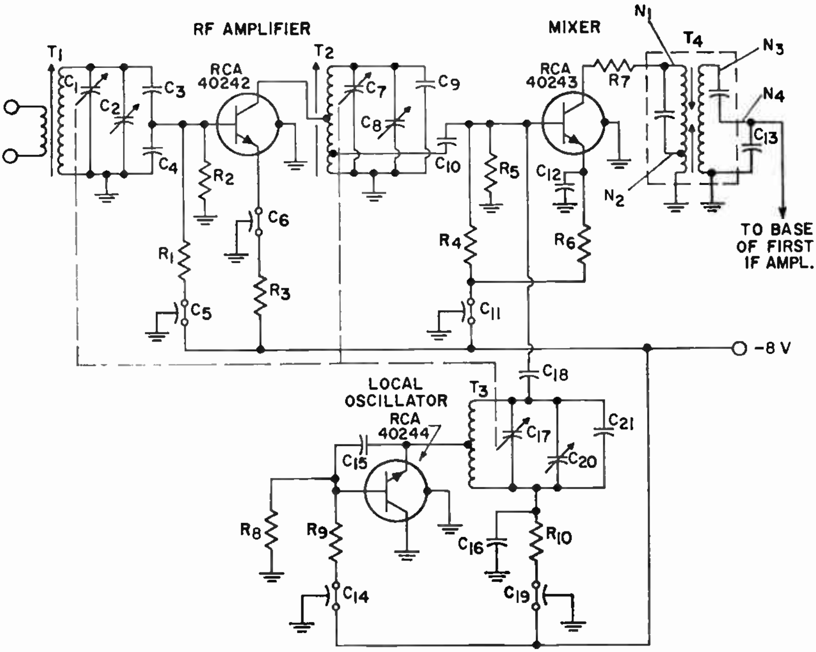
### Circuit Description

This high-quality FM tuner uses silicon n-p-n transistors that provide good receiver quieting and limiting performance because of their high usable gains and low noise levels (typical device noise is 3 dB at 100 MHz for a 300-ohm source impedance). These transistors provide excellent amplification in the FM band and are capable of sustained oscillation at frequencies up to 1100 MHz.

**RF section**—The rf-amplifier stage uses a 40242 transistor in a common-emitter circuit configuration to obtain the highest stable gain over the entire FM broadcast frequency range. This stage can provide an unneutralized gain of 15.4 dB. The operating point of the stage is chosen so that agc can be applied effectively.

The 40243 mixer transistor is also operated in a common-emitter configuration. An oscillator-signal injection voltage of approximately 90 millivolts is coupled across capacitor

## 15-2 HIGH-QUALITY FM TUNER (cont'd)




RF SECTION

**NOTE: This circuit uses coils and transformers that are not available as stock items from any manufacturer. Home construction of this circuit should not be attempted unless the builder has had considerable experience in the winding of inductive components and has access to the special equipment required. The builder should also refer to the general considerations for construction of high-frequency and broadband circuits given on page 691.**

### Parts List for RF Section

$C_1$, $C_7$, $C_{17}$ = ganged tuning capacitors, $C_1$, $C_7$ = 7.25 to 19 pF; $C_{17}$ = 6 to 21 pF

$C_2$, $C_8$ = trimmer capacitor (part of ganged tuning capacitor assembly), approximately 17 pF maximum.

$C_3$, $C_9$ = 5.6 pF, miniature ceramic

$C_4$ = 27 pF, ceramic disc

$C_5$, $C_6$, $C_{11}$, $C_{14}$, $C_{19}$ = feed-through capacitor, 1000 pF

$C_{10}$ = 2000 pF, ceramic disc, 1000 V

$C_{12}$ = 0.01 $\mu$F, ceramic disc

$C_{13}$, $C_{16}$ = 1000 pF, ceramic disc, 1000 V

$C_{15}$ = 3.3 pF, NPO ceramic

$C_{18}$ = 0.22 pF to 3.3 pF (value determines oscillator injection voltage and is dependent upon factors such as circuit layout and placement of components)

$C_{20}$ = tubular trimmer capacitor, 1.5 to 10 pF

$C_{21}$ = 12 pF, ceramic disc

$R_1$, $R_4$ = 3300 ohms, 0.5 watt

$R_2$, $R_5$ = 18000 ohms, 0.5 watt

$R_3$, $R_6$ = 330 ohms, 0.5 watt

$R_7$ = 100 ohms, 0.5 watt

$R_8$ = 8200 ohms, 0.5 watt

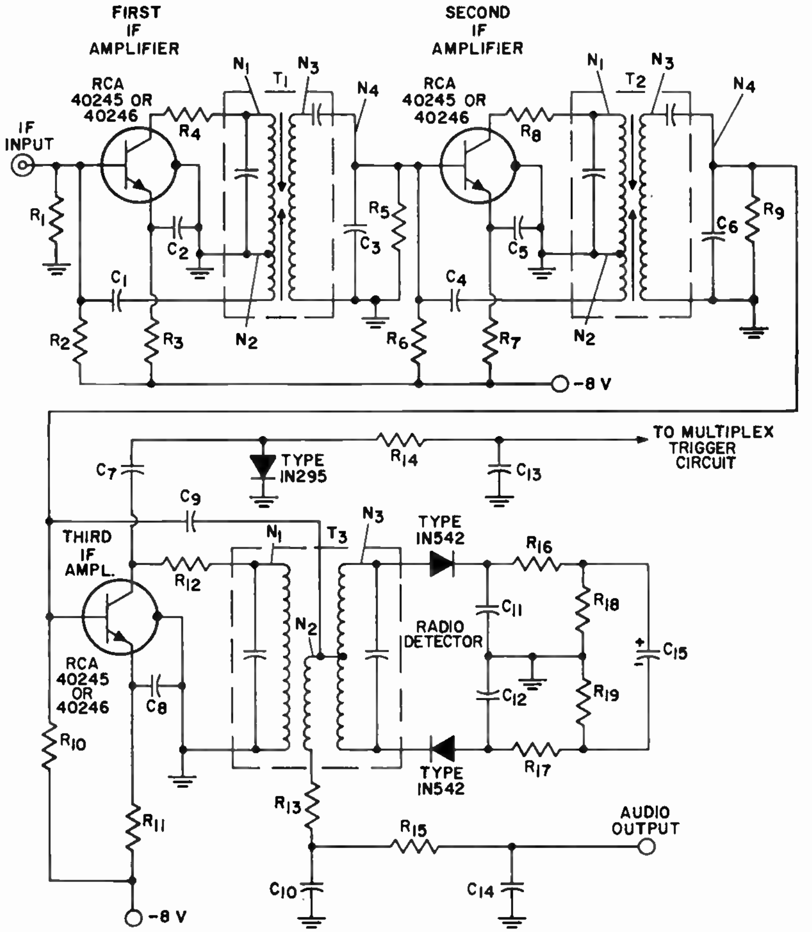
$R_9$ = 4700 ohms, 0.5 watt

$R_{10}$ = 1500 ohms, 0.5 watt

$T_1$ = FM antenna transformer; slug-tuned; slug, 0.250 inch long, 0.181 inch in diameter, Arnold Type 1RN9 or equiv.; secondary, 4 turns of No. 22 bare-tinned copper wire wound with 1 wire-diameter spacing between adjacent turns or 7/32-inch outer-diameter coil form, resonates with 27-pF capacitance at 100 MHz, impedance = 6100 ohms; primary, 2 turns of No. 30 Gripeze wire close wound below cold end of secondary and in same direction, impedance (includes shunting effect of rf amplifier biasing network) = 460 ohms.

$T_2$ = rf interstage coil; 4 turns of No. 18 bare-tinned copper wire wound with approximately 1/8-inch spacing between turns on 5/16-inch diameter coil form (coil form is removed after coil is wound); resonates with 27-pF capacitance at 100 MHz; impedance of full winding, 6100 ohms; input tap located so that impedance at tap = 590 ohms; output tap located so that impedance at input tap is 540 ohms with the transformer properly loaded.

## 15-2 HIGH-QUALITY FM TUNER (cont'd)




IF SECTION

NOTE: Type 1N542 diodes are a matched pair.

### Parts List for RF Section (cont'd)

$T_3$ = oscillator coil; 3½ turns of No. 18 bare-tinned copper wire wound with 3/32-inch spacing between turns on 7/32-inch-diameter coil form (coil form is removed after coil is wound), center tapped.

$T_4$ = first if (10.7-MHz) transformer, primary unloaded Q = 60, primary loaded Q = 60, ratio of full secondary to section below tap ($N_1/N_2$) = 7.27, secondary unloaded Q = 62.3, secondary loaded Q = 60, ratio of full secondary to section that corresponds to lower tuning capacitor ($N_3/N_4$, as determined by tapped capacitors) = 26.65, output impedance = 6070 ohms, per cent of critical coupling = 90

### Parts List for IF Section

$C_1$, $C_4$ = 4.7 pF, ceramic disc

$C_2$, $C_5$, $C_8$ = 0.01 $\mu$F, ceramic disc

$C_3$, $C_6$ = 1000 pF, ceramic disc, 1000 V

$C_7$ = 5 pF, ceramic disc

$C_9$ = 1.0 pF, ceramic disc

$C_{10}$, $C_{11}$, $C_{12}$ = 330 pF, ceramic

$C_{13}$ = 0.05 $\mu$F, ceramic disc

$C_{14}$ = 0.02 $\mu$F, ceramic disc

## 15-2 HIGH-QUALITY FM TUNER (cont'd)

### Parts List for IF Section (cont'd)

$C_{15}$ = 5 μF, electrolytic, 10 V.
$R_1$, $R_5$, $R_9$ = 12000 ohms, 0.5 watt
$R_2$, $R_6$, $R_{10}$ = 2700 ohms, 0.5 watt
$R_3$, $R_4$, $R_7$, $R_8$, $R_{11}$ = 220 ohms, 0.5 watt
$R_{12}$ = 470 ohms, 0.5 watt
$R_{13}$ = 68 ohms, 0.5 watt
$R_{14}$ = 22000 ohms, 0.5 watt
$R_{15}$ = 3900 ohms, 0.5 watt
$R_{16}$ = 1000 ohms, 0.5 watt
$R_{17}$ = 1500 ohms, 0.5 watt
$R_{18}$, $R_{19}$ = 6800 ohms, 0.5 watt
$T_1$ = second if (10.7-MHz) transformer, primary unloaded Q = 72.4, primary loaded Q = 60, ratio of full primary to section below tap ($N_1/N_2$) = 7.27, secondary unloaded Q = 62.3, secondary loaded Q = 60, ratio of full secondary to section that corresponds to lower tuning capacitor ($N_3/N_4$, as determined by tapped capacitors) = 26.65, output impedance = 6070 ohms, per cent of critical coupling = 90
$T_2$ = third if (10.7-MHz) transformer, primary unloaded Q = 49.7, primary loaded Q = 41.2, ratio of full primary to section below tap ($N_1/N_2$) = 7.27, secondary unloaded Q = 64.2, secondary loaded Q = 61.85, ratio of full secondary to section that corresponds to lower tuning capacitor ($N_3/N_4$, as determined by tapped capacitors) = 27.5 output impedance = 6070 ohms, per cent of critical coupling = 90
$T_3$ = ratio-detector transformer, primary unloaded Q (with tertiary winding $N_2$ returned to ground through a 68-ohm resistance) = 65, primary loaded Q = 28.5, primary-to-tertiary turns ratio ($N_1/N_2$) = 2.5, secondary unloaded Q = 65, secondary loaded Q = 24.75, output impedance = 6070 ohms, per cent of critical coupling = 90

### Circuit Description (cont'd)

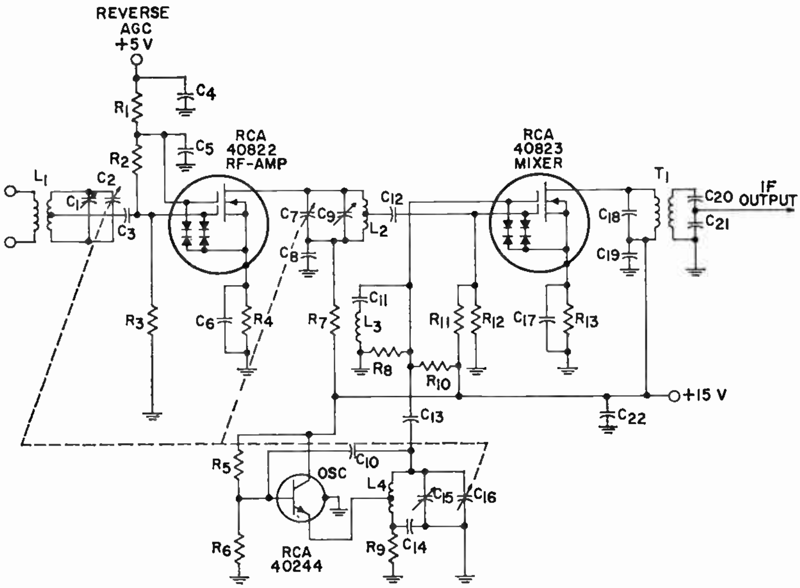
$C_{18}$ to the base of the mixer transistor from the oscillator resonant circuit $C_{17}$, $C_{20}$, $C_{21}$ and $T_4$. The 40244 oscillator stage is adjusted to provide a uniform injection voltage to the base of the mixer transistor over the entire FM oscillator-frequency range.

IF section—The three stage if-amplifier strip uses three 40245 or 40246 transistors in a common-emitter circuit configuration to provide 23.4 dB of stable gain per stage. The three double-tuned if transformers $T_1$, $T_2$, and $T_3$ provide a 6-dB bandwidth of 300 kHz, which is adequate for reproduction of stereo signals.

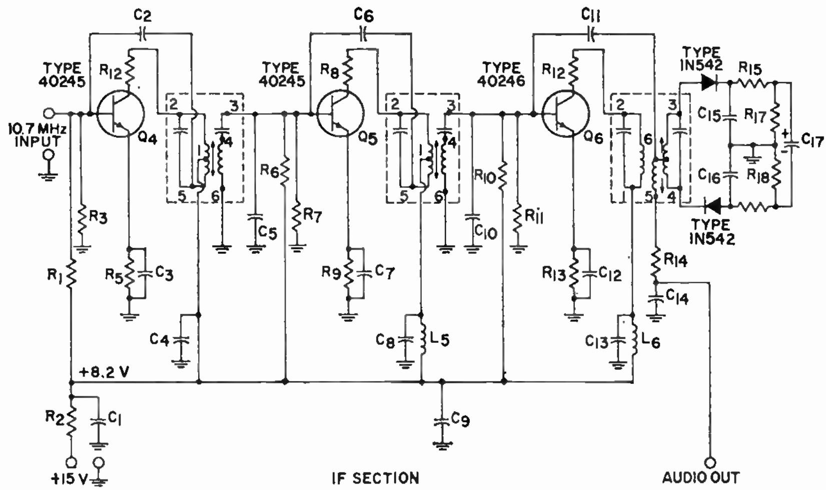
The 1N295 diode and associated components in the collector circuit of the third if amplifier develops a negative voltage proportional to the rf input signal. This voltage is used to drive a schmitt trigger stage associated with the noise immunity circuit of the FM stereo demodulator (refer to discussion of the demodulator, circuit 15-4). If desired, the negative voltage may also be applied to the base of the 40242 transistor in the rf amplifier as agc bias. As a result, the final 40246 if-amplifier transistor can go into full limiting before appreciable agc is developed. This arrangement provides a relatively wide agc bandwidth which is helpful in tuning to strong signals.

FM detection is accomplished by the ratio-detector circuit, which includes a matched pair of IN542 diodes and associated components. The detector transformer $T_3$ is designed to provide the wide peak-to-peak separation (450 kHz) required for good stereo multiplex operation. $R_{15}$ and $C_{14}$ in the detector output circuit form a standard FM de-emphasis network for high audio frequencies.

## *15-3* FM TUNER USING MOS-TRANSISTOR RF AMPLIFIER AND MIXER




RF SECTION




IF SECTION

**NOTE: Type 1N542 diodes are a matched pair.**

**NOTE: This circuit uses coils and transformers that are not available as stock items from any manufacturer. Home construction of this circuit should not be attempted unless the builder has had considerable experience in the winding of inductive components and has access to the special equipment required. The builder should also refer to the general considerations for construction of high-frequency and broadband circuits given on page 691.**

# 15-3 FM TUNER USING MOS-TRANSISTOR RF AMPLIFIER AND MIXER (cont'd)

## Parts List for RF Section

$C_1$, $C_9$, $C_{15}$ = Trimmer capacitor, 2 to 14 pF
$C_2$, $C_7$, $C_{16}$ = Ganged tuning capacitors, each section = 6 to 19.5 pF
$C_3$, $C_6$, $C_{14}$, $C_{17}$, $C_{22}$ = 2000 pF, ceramic
$C_4$, $C_5$ = 1000 pF, ceramic disc
$C_8$, $C_{19}$ = 0.01 $\mu$F, ceramic disc
$C_{10}$ = 3.3 pF, NPO ceramic
$C_{11}$ = 270 pF, ceramic disc
$C_{12}$ = 500 pF, ceramic disc
$C_{13}$ = 3 pF, NPO ceramic
$C_{18}$ = 68 pF, ceramic
$C_{20}$ = 50 pF, ceramic
$C_{21}$ = 1200 pF, ceramic
$L_1$ = antenna coil; 4 turns of No. 18 bare copper wire; inner diameter, 9/32 inch; winding length, 3/8 inch; nominal inductance, 0.86 $\mu$H; unloaded Q, 120; tapped approximately 1¼ turns from ground end; antenna link approximately 1 turn from ground end
$L_2$ = rf interstage coil; same as $L_1$ without antenna link
$L_3$ = rf choke, 1 $\mu$H
$L_4$ = oscillator coil; 3¼ turns of No. 18 bare copper wire; inner diameter, 9/32 inch; winding length, 5/16 inch; nominal inductance, 0.062 $\mu$H, unloaded Q, 120; tapped approximately 1 turn from low end
$R_1$, $R_{10}$ = 0.56 megohm, 0.5 watt
$R_2$ = 0.75 megohm, 0.5 watt
$R_3$ = 0.27 megohm, 0.5 watt
$R_4$, $R_{13}$ = 270 ohms, 0.5 watt
$R_5$ = 22000 ohms, 0.5 watt
$R_6$ = 56000 ohms, 0.5 watt
$R_7$ = 330 ohms, 0.5 watt
$R_8$, $R_{12}$ = 0.1 megohm, 0.5 watt
$R_9$ = 4700 ohms, 0.5 watt
$R_{11}$ = 1.6 megohms, 0.5 watt
$T_1$ = first if (10.7-MHz) transformer; double-tuned with 90 per cent of critical coupling; primary: 15 turns of No. 32 enamel wire, space wound at 60 turns per inch on 0.25-by-0.5-inch slug; secondary: 18 turns of No. 36 enamel wire, close wound on 0.25-by-0.25 inch slug; both coils wound on 9/32-inch coil form.

## Parts List for IF Section

$C_1$, $C_4$, $C_8$, $C_9$, $C_{13}$ = 0.02 $\mu$F, ceramic disc
$C_2$, $C_6$ = 4.7 pF, silver mica
$C_3$, $C_7$, $C_{12}$ = 0.01 $\mu$F, ceramic disc
$C_5$, $C_{10}$, $C_{14}$ = 0.001 $\mu$F, ceramic
$C_{11}$ = 1 pF, silver mica
$C_{15}$, $C_{16}$ = 330 pF, miniature ceramic
$C_{17}$ = 10 $\mu$F, electrolytic, 6V
$R_1$, $R_6$, $R_{10}$ = 12000 ohms, 0.5 watt
$R_2$ = 430 ohms, 0.5 watt
$R_3$, $R_7$, $R_{11}$ = 2700 ohms, 0.5 watt
$R_4$, $R_5$, $R_8$, $R_9$, $R_{13}$ = 220 ohms, 0.5 watt
$R_{12}$ = 330 ohms, 0.5 watt
$R_{14}$ = 68 ohms, 0.5 watt
$R_{15}$ = 1000 ohms, 0.5 watt
$R_{16}$ = 1500 ohms, 0.5 watt
$R_{17}$, $R_{18}$ = 6800 ohms, 0.5 watt
$T_1$, $T_2$ = if (10.7-MHz) transformer, double-tuned with 90 per cent of critical coupling, primary unloaded Q = 72.4, primary loaded Q = 60, ratio of full primary to section below tap ($N_1/N_2$) = 7.27, secondary unloaded Q = 62.3, secondary loaded Q = 60, ratio of full secondary to section that corresponds to lower tuning capacitor ($N_3/N_4$, as determined by tapped capacitors) = 26.65, output impedance = 6070 ohms
$T_3$ = ratio-detector transformer, double-tuned with 90 per cent of critical coupling, primary unloaded Q (with tertiary winding $N_2$ returned to ground through a 68-ohm resistance) = 65, primary loaded Q = 28.5 primary-to-tertiary turns ratio ($N_1/N_2$) 2.5, secondary unloaded Q = 65, secondary loaded Q = 24.75, output impedance = 6070 ohms

## Circuit Description

This FM tuner uses dual-gate-protected MOS field-effect transistors in the rf amplifier and mixer stages and a bipolar transistor in the local oscillator stage. The tuner operates from a dc supply of 15 volts.

The rf amplifier uses a 40822 dual-gate MOS transistor. This stage is designed to minimize the spurious

## 15-3 FM TUNER USING MOS-TRANSISTOR RF AMPLIFIER AND MIXER (cont'd)

**Circuit Description (cont'd)**

responses that occur in FM tuners when harmonics of unwanted incoming signals are mixed with harmonics of the local-oscillator signal to produce difference frequencies within the if pass band. Achievement of minimum spurious response requires that the signal input to the 40822 rf-amplifier transistor, applied to gate No. 1, be obtained from a tap as far down on the antenna coil $L_1$ as gain and noise considerations permit. This arrangement assures the smallest practical input voltage swing to the gate and, therefore, makes possible optimum use of the available dynamic range of the MOS transistor. In addition, the objective for low spurious response requires that the entire rf interstage coil $L_2$ be used as the load impedance for the 40822 MOS transistor. This coil, selected on the basis of the optimum compromise between gain and bandwidth requirements, presents a slight mismatch to the output of the 40822 transistor. Although the compromises in the input and output circuits of the rf amplifier result in a slight loading of the interstage coil $L_2$ and cause some degradation in the selectivity of the front end, these undesirable effects can be tolerated because the antenna coil $L_1$ is not loaded by the gate of the MOS transistor.

A dual-gate MOS transistor, such as the 40822, is ideally suited for use as an rf amplifier with automatic gain control. For maximum gain, the transistor is operated with a gate-No. 1 bias of −0.5 to 1 volt and a gate-No. 2 bias of 2 to 4 volts. In this tuner, the initial bias conditions required for the rf amplifier are established by a combination of the fixed bias developed across resistors $R_2$ and $R_3$ and the source bias developed across the source resistor $R_4$. Gain control is achieved by application of a negative-going agc voltage (i.e. reverse agc) to gate No. 2.

The output of the rf amplifier is applied to gate No. 1 of the 40823 dual-gate MOS transistor used in the mixer stage. The local-oscillator signal is injected at gate No. 2. The 1-microhenry inductor $L_3$ and the 270-picofarad capacitor $C_{11}$ form a series-resonant trap that bypasses any 10.7-MHz component that may appear at the local-oscillator input to the mixer.

The biasing arrangement for the mixer stage is particularly important. Both source (self) bias and fixed bias are used to establish the operating conditions required for the optimum combination of mixing and spurious-response rejection. On the basis of an empirical determination of the bias conditions necessary for this requirement, the 40823 mixer transistor operates with a gate-No. 2-to-source voltage of 0.6 volt and a gate-No. 1-to-source voltage of −0.75 volt.

The local-oscillator stage employs a 40244 bipolar transistor. This stage generates an extremely clean output waveform. The absence of harmonics in the oscillator signal is an important factor in good tuner design. The oscillator signal is coupled to gate No. 2 of the mixer transistor by means of the 3-picofarad capacitor $C_9$. This capacitor isolates the tuned circuit of the oscillator from the input circuit of the mixer and, in this way, minimizes the possibility of oscillator instabilities as a result of "pulling."

The 10.7-MHz if output from the mixer is coupled to the first if-amplifier stage by means of a double-tuned transformer $T_1$. The if amplifier employs two 40245 and one 40246 bipolar transistors, each operating in a neutralized common-

## 15-3 FM TUNER USING MOS-TRANSISTOR RF AMPLIFIER AND MIXER (cont'd)

### Circuit Description (cont'd)

emitter configuration at a collector current of 3.5 milliamperes. The over-all gain of the if amplifier is 88 dB. The frequency-modulated output of the if strip is demodulated by a ratio-detector circuit that uses a matched pair of 1N542 diodes. The operation of this if strip and ratio-detector circuit is very similar to the corresponding sections of the High-Quality FM Tuner shown in circuit 15-2.

## 15-4 FM STEREO MULTIPLEX DEMODULATOR

### Circuit Description

This FM stereo multiplex demodulator separates complex signals supplied by an FM tuner into right- and left-channel inputs for stereo audio output stages. The demodulator features a high input impedance, a noise immunity circuit, and automatic switching for stereophonic or monaural reception.

Operation of an FM tuner in the stereo mode may be unsatisfactory under weak-signal conditions because the signal-to-noise ratio is poorer for stereo reception than for monaural reception. In addition, if switching is permitted on weak signals the 19-kHz component of noise which is present between stations may cause undesired operation.

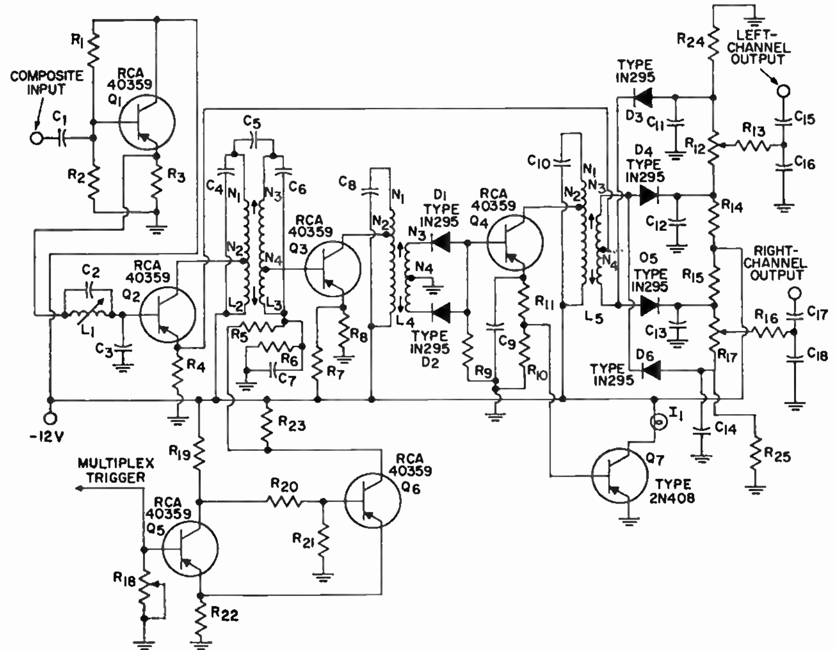
The demodulator incorporates circuits that sense the presence of adequately strong FM signals and provide automatic switching in the presence of 19-kHz pilot signal. It has a separation at 1 kHz of 36.5 dB, S.C.A. rejection of 59.4 dB, residual 38-kHz subcarrier rejection of 60 dB, insertion loss at 1 kHz of 2.5 dB, and total harmonic distortion at 1 kHz of 0.4 per cent. Six RCA-40359 transistors and one 2N408 transistor are used to provide the automatic switching and noise immunity. The demodulator is designed for operation with tuners, such as circuit 15-2, which provide an audio output of approximately 400 millivolts with 75-kHz deviation under strong signal conditions. If a tuner that provides less audio output is used, the gain in the sub-carrier amplifier can be increased by bypassing $R_8$. If a tuner of higher output is used, it may be necessary to use a voltage divider at the input.

The composite multiplex signal from the ratio detector of the FM tuner is applied to the base of transistor $Q_1$. Transistor $Q_1$ is an isolation stage which provides a high-impedance load for the ratio detector and a low-impedance source for the S.C.A. filter. The parallel resonant circuit $L_1C_2$ is tuned to 72 kHz to provide maximum S.C.A. rejection at low beat frequencies.

Transistor $Q_2$ is a 19-kHz amplifier which also serves to separate the pilot from the composite signal. $L_2$, $L_3$, and $C_6$ constitute a top-coupled double-tuned circuit which resonates at 19 kHz and thus passes only the 19-kHz portion of the composite signal to transistor $Q_3$. The remainder of the signal is taken from the emitter resistor $R_4$ and fed into the balanced demodulator at the secondary winding of $L_6$. Capacitor $C_3$ compensates for the degradation of the composite signal as it passes through the S.C.A. filter.

Transistors $Q_5$ and $Q_6$ comprise a

## 15-4 FM STEREO MULTIPLEX DEMODULATOR (cont'd)




**NOTE: This circuit uses coils and transformers that are not available as stock items from any manufacturer. Home construction of this circuit should not be attempted unless the builder has had considerable experience in the winding of inductive components and has access to the special equipment required. The builder should also refer to the general considerations for construction of high-frequency and broadband circuits given on page 691.**

### Parts List

$C_1$ = 0.33 $\mu$F
$C_2$ = 560 pF
$C_3$ = 300 pF (adjust for optimum separation)
$C_4$ = 1000 pF, part of $L_2$
$C_5$ = 10 pF
$C_6$ = 1000 pF, part of $L_3$
$C_7$, $C_9$, = 0.47 $\mu$F
$C_8$ = 1000 pF, part of $L_4$
$C_{10}$ = 390 pF, part of $L_5$
$C_{11}$, $C_{12}$, $C_{13}$, $C_{14}$ = 7500 pF, ± 5%
$C_{15}$, $C_{17}$ = 1.0 $\mu$F
$C_{16}$, $C_{18}$ = 0.02 $\mu$F
$I_1$ = stereo lamp, 14 mA at 10 V
$L_1$ = 10 mH, Q = 46 at 67 kHz
$L_2$ = 69 mH, Q = 93 at 19 kHz; $N_1/N_2$ = 5.66; (includes $C_4$)
$L_3$ = 69 mH, Q = 93 at 19 kHz, $N_1/N_2$ = 40.2; (includes $C_6$)
$L_4$ = 69 mH, Q = 88 at 19 kHz, $N_1/N_2$ = 5.24, $N_1/N_3$ = 5.21, $N_3/N_4$ = 2; (includes $C_8$)
$L_5$ = 41 mH, Q = 108 at 38 kHz, $N_1/N_2$ = 11.62, $N_1/N_3$ = 19.8, $N_3/N_4$ = 2; (includes $C_{10}$)
$R_1$ = 91,000 ohms, 0.5 watt
$R_2$ = 120,000 ohms, 0.5 watt
$R_3$ = 6800 ohms, 0.5 watt
$R_4$ = 1000 ohms, 0.5 watt
$R_5$ = 18,000 ohms, 0.5 watt
$R_6$, $R_{13}$, $R_{16}$, $R_{21}$ = 3300 ohms, 0.5 watt
$R_7$, $R_9$, $R_{14}$, $R_{15}$, $R_{23}$, $R_{24}$, $R_{25}$ = 10,000 ohms, 0.5 watt
$R_8$ = 510 ohms, 0.5 watt
$R_{10}$ = 220 ohms, 0.5 watt
$R_{11}$ = 1500 ohms, 0.5 watt
$R_{12}$, $R_{17}$ = potentiometer, 5000 ohms, 0.5 watt
$R_{18}$ = potentiometer, 10,000 ohms, 0.5 watt
$R_{19}$ = 8200 ohms, 0.5 watt
$R_{20}$ = 15,000 ohms, 0.5 watt
$R_{22}$ = 820 ohms, 0.5 watt

### Circuit Description (cont'd)

Schmitt trigger used as a noise-immunity circuit. A negative agc voltage obtained from the if amplifier of the tuner is applied to the base of $Q_5$. When no agc voltage is present, $Q_5$ is turned off, and $Q_6$ is turned on. In this state, which occurs under weak signal conditions, resistor $R_6$ is

## 15-4 FM STEREO MULTIPLEX DEMODULATOR (cont'd)

### Circuit Description (cont'd)

returned to a low-voltage point, and, therefore, transistor $Q_3$ is turned off. When a preset agc voltage is reached, $Q_6$ is turned off, $R_5$ is returned to the supply voltage through $R_{23}$, and $Q_3$ is turned on.

The multiplex output from the FM tuner drives the Schmitt trigger. The "on" trigger level can be adjusted by variation of $R_{18}$. The "off" trigger level is then determined by the hysteresis of the Schmitt-trigger circuit. Hysteresis is desirable because it prevents intermittent switching caused by slight signal variations in the vicinity of the trigger point. The hysteresis can be changed by adjustment of $R_{10}$.

Transistor $Q_3$ serves as a 19-kHz pilot amplifier and limiter when it is turned on by $Q_6$. When $Q_3$ is turned off, it acts as an open switch which stops the pilot signal. The emitter of $Q_3$ is reverse-biased by the current through $R_7$. Because this reverse bias exceeds the 19-kHz level at the base of $Q_3$, it prevents the 19-kHz pilot signal of a weak station from turning on $Q_3$ and thereby over-riding the noise-immunity circuit.

The output of the pilot amplifier $Q_3$ is fed to a balanced full-wave rectifier which consists of $D_1$, $D_2$, and the secondary winding of $L_4$. The output of the rectifier is unfiltered and develops both a dc component and a 38-kHz component. The dc component is used to bias transistor $Q_4$ on. The 38-kHz component is amplified by limiter-amplifier $Q_4$ and appears at the secondary winding of $L_5$. In the absence of a pilot signal, $Q_4$ is turned off because there is no 19-kHz output from $Q_3$ to be rectified.

The composite signal taken from the emitter resistor $R_4$ is added to the 38-kHz subcarrier in the secondary winding of $L_6$. When the subcarrier has the proper phase with respect to the composite signal, a 38-kHz amplitude-modulated signal is formed in which one side of the envelope contains right-channel information and the other side contains left-channel information.

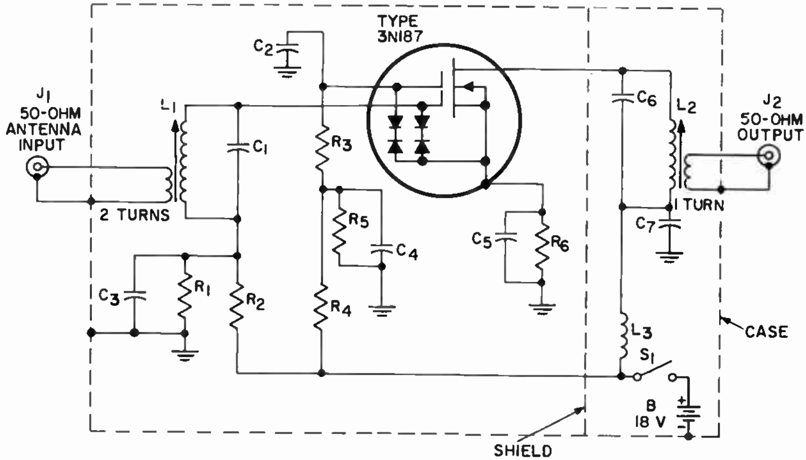
Diodes $D_3$ and $D_4$ form a balanced detector which permits one side of the envelope to pass. Resistor $R_{12}$ is adjusted for minimum 38-kHz residual signal at the output. When $Q_4$ is off and no subcarrier is present in the secondary winding of $L_6$, the left-plus-right portion of the composite signal is passed by the detector circuit, and the left-minus-right portion is filtered out. Diodes $D_5$ and $D_6$ form the balanced detector for the other channel. $R_{13}$, $C_{16}$, $R_{16}$, and $C_{18}$ form de-emphasis networks. $Q_7$ acts as a switch which lights a stereo indicator lamp when $Q_4$ is turned on.

## 15-5 PREAMPLIFIER FOR 6-, 10-, OR 15-METER AMATEUR-BAND RECEIVER

### Circuit Description

This inexpensive, easily constructed preamplifier circuit uses a 3N187 dual-gate-protected MOS transistor to provide more than 26 dB of gain ahead of a receiver operated in the 6-, 10-, or 15-meter amateur band. This additional gain, together with the low noise figure of

## 15-5 PREAMPLIFIER FOR 6-, 10-, OR 15-METER AMATEUR-BAND RECEIVER (cont'd)




**NOTE: See general considerations for construction of high-frequency and broadband circuits on page 691.**

### Parts List

B = Two RCA type VS323 batteries for transistor service; and one case, Bud-CU2103A or equivalent.
$C_1$ = 8 pF, mica or ceramic tubular
$C_2$, $C_3$, $C_4$, $C_5$, $C_7$ = 0.01 μF, ceramic
$C_6$ = 10 pF, mica or ceramic tubular
$J_1$, $J_2$ = Coaxial receptacle, Amphenol BNC type UG-1094 or equiv.
$L_1$, $L_2$ = 1.6 to 3.1 μH, adjustable, Miller 4404 or equiv.
$L_3$ = 22 μH, Miller 74F-225A1 or equiv.
$R_1$ = 27,000 ohms, 0.25 watt, 10%
$R_2$ = 150,000 ohms, 0.25 watt, 10%, carbon
$R_3$ = 1,800 ohms, 0.25 watt, 10%, carbon
$R_4$ = 100,000 ohms, 0.25 watt, 10%, carbon
$R_5$ = 33,000 ohms, 0.25 watt, 10%, carbon
$R_6$ = 270 ohms, 0.25 watt, 10%, carbon
$S_1$ = toggle switch, single-pole, single-throw

### Tuned-Circuit Components for 21 and 50 MHz

| Component | Value 21 MHz | Value 50 MHz |
|---|---|---|
| $C_1$ | 22 pF | 8 pF |
| $C_2$, $C_3$, $C_4$, $C_5$, $C_7$ | No Change | 1,000 pF, ceramic |
| $C_6$ | 22 pF | 10 pF |
| $L_1$ | No Change | 8 turns, No. 30 E wire on ¼-inch-diameter core (Miller 4500 or equiv.) Link: 2 turns, No. 30 E wire on ground end. |
| $L_2$ | No Change | Same as $L_1$ |
| $L_3$ | No Change | 6.8 μH (Miller 74F686AP or equiv.) |

## 15-5 PREAMPLIFIER FOR 6-, 10-, OR 15-METER AMATEUR-BAND RECEIVER (cont'd)

### Circuit Description (cont'd)

the preamplifier (less than 2.5 dB), substantially increases both the sensitivity and signal-to-noise ratio of the receiver. The circuit as shown is intended for use in the 10-meter (28-MHz) frequency band; the 3N187 MOS transistor, however, has excellent performance characteristics at frequencies well below the 10-meter band and up to 200 MHz. The preamplifier, therefore, can be readily adapted for use in other frequency bands with only a few changes in tuned-circuit components. A chart is provided to show the changes in tuned-circuit components required for operation in the 15-meter (21-MHz) and 6-meter (50-MHz) bands. The dc operating voltage for the preamplifier may be obtained from a battery supply, as shown in the circuit diagram, or from any other reasonably well-filtered dc supply voltage of 15 to 18 volts.

The dual-gate MOS transistor in the preamplifier is operated so that essentially it is electrically equivalent to two single-gate MOS transistors connected in cascode and enclosed in the same package. The advantage of the dual gate transistor is that it provides an inexpensive cascode circuit that offers maximum resistance to cross-modulation from nearby transmitters.

The rf input is link coupled from the antenna to the input tuned circuit formed by $L_1$ and $C_1$ and applied to gate No. 1 (pin 3) of the 3N187 transistor. This gate, which is equivalent to the gate (or base) of the grounded-source (or -emitter) section of a two-transistor cascode circuit, is forward-biased by the dc voltage at the junction of the voltage-divider resistors $R_1$ and $R_2$. The source resistor $R_3$ is large enough to assure that gate No. 1 is always negative with respect to the source. Gate No. 2 (pin 2), in accordance with cascode-circuit requirements, is returned to ac ground through capacitor $C_2$. The dc bias level for this gate, established by the voltage divider $R_4$ and $R_5$, represents a compromise between optimum gain and optimum cross-modulation resistance. The amplified rf signals developed in the drain circuit of the 3N187 transistor are link coupled from the tuned-circuit drain load impedance formed by $L_2$ and $C_6$, through coaxial connector $J_2$ to the input of the receiver.

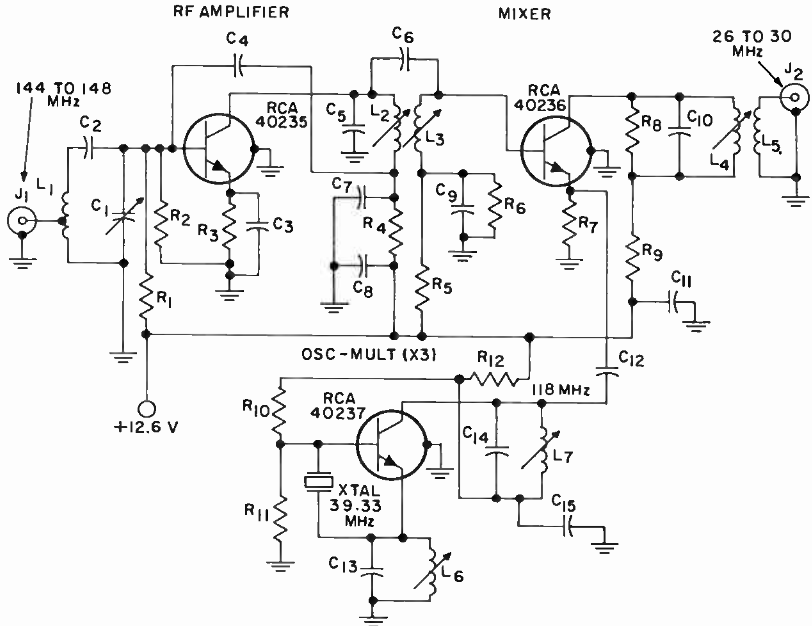
Tuning of the preamplifier is simplified because no special neutralization is required, even at frequencies as high as 155 MHz. Rough adjustments of coils $L_1$ and $L_2$ can be made by use of a grid-dip oscillator. The finishing adjustments are then made while listening to a weak station.

## 15-6 TWO-METER CONVERTER

### Circuit Description

This converter circuit can be used ahead of a 10-meter amateur-band radio receiver to provide amplification and the frequency conversion required to enable reception of signals in the 2-meter (144-to-148-MHz) amateur band. With minor circuit modification, the converter can also be used to adapt a 20-meter amateur-band receiver to receive 2-meter signals. The converter uses RCA 40235, 40236, and 40237 vhf transistors in common-emitter circuit configurations to provide the

## 15-6 TWO-METER CONVERTER (cont'd)




**NOTES: (1) See general considerations for the construction of high-frequency and broad-band circuits on page 691. (2) This circuit uses coils that are not standard commercial items; such coils must be wound by the circuit builder.**

### Parts List

$C_1$ = 0.5 to 5 pF, tubular trimmer, Erie 532-3R or equiv.
$C_2$ = 10 pF, ceramic tubular, Centralab TCZ-10 or equiv.
$C_3$, $C_9$, $C_{11}$ = 500 pF, silver button, Erie 662-003-501K or equiv.
$C_4$ = 4.7 pF, ceramic tubular, Centralab TCZ-4R7 or equiv.
$C_5$, $C_{12}$, $C_{14}$ = 3.3 pF, ceramic tubular Centralab TCZ-3R3 or equiv.
$C_6$ = 2.2 pF, ceramic tubular, Centralab TCZ-2R2 or equiv.
$C_7$ = 25 pF silver button, Erie 662-003-250 or equiv.
$C_8$, $C_{15}$ = 500 pF, ceramic disc, Centralab DD-501 or equiv.
$C_{10}$, $C_{13}$ = 30 pF, ceramic tubular, Centralab TCZ-30 or equiv.
$J_1$, $J_2$ = BNC-type coaxial jack
$L_1$ = 5 turns of No. 16 bare wire, ¼-inch diameter (spaced wire diameter), tap one turn up from bottom
$L_2$, $L_3$ = 4 turns of No. 26 enamelled wire, close wound on ¼-inch diameter ceramic slug-tuned form, Miller 4500 or equiv.
$L_4$ = 11 turns of No. 26 enamelled wire, close wound on ⅜-inch diameter phenolic slug-tuned form, Miller 21A000RBI or equiv.
$L_5$ = 3 turns of insulated wire, close-wound link
$L_6$ = 5 turns of No. 26 enamelled wire, close wound on ⅜-inch diameter phenolic slug-tuned form, Miller 21A000RBI or equiv.
$L_7$ = 7 turns of No. 26 enamelled wire, close wound on ¼-inch diameter ceramic slug-tuned form, Miller 4500 or equiv.
$R_1$ = 27,000 ohms, 0.5 watt
$R_2$ = 3,900 ohms, 0.5 watt
$R_3$, $R_7$ = 470 ohms, 0.5 watt
$R_4$, $R_9$ = 820 ohms, 0.5 watt
$R_5$ = 18,000 ohms, 0.5 watt
$R_6$ = 2,700 ohms, 0.5 watt
$R_8$ = 5,100 ohms, 0.5 watt
$R_{10}$ = 0.1 megohm, 0.5 watt
$R_{11}$ = 8,200 ohms, 0.5 watt
$R_{12}$ = 1,000 ohms, 0.5 watt
XTAL = 39.33 MHz, overtone crystal

### Circuit Description (cont'd)

required amplification and frequency-conversion functions with a noise figure (at 144 MHz) of less than 3 dB. The circuit operates from a 12.6-volt, 10-milliampere dc supply and, therefore, is ideally suited for

## 15-6 TWO-METER CONVERTER (cont'd)

### Circuit Description (cont'd)

mobile, as well as fixed-station, operations.

The 40235 transistor is used in a neutralized low-noise rf-amplifier stage. Capacitor $C_4$ couples the neutralizing feedback from collector circuit to base circuit required to ensure stable operation of this stage. Signals in the two-meter band are coupled from the antenna through the coaxial connector $J_1$ and the tuned input circuit formed by $L_1$, $C_1$ and $C_2$ to the base of the 40235 transistor. The variable capacitor $C_1$ is adjusted to tune the input circuit to select any desired signal in the 144-to-148-MHz frequency band. The selected signals are amplified by the 40235 transistor and coupled from the collector circuit of this transistor by tuning coils $L_2$ and $L_3$ and capacitor $C_6$ to the base of the 40236 transistor used in the mixer stage.

The 40237 transistor is operated in an overtone-crystal oscillator-multiplier stage to develop the local-oscillator signal for the converter. The crystal used in the base-to-emitter circuit of the oscillator-multiplier has a fundamental frequency of 39.33 MHz; the collector load circuit, formed by oscillator tuning coil $L_7$ and capacitor $C_{11}$, however, is tuned to select the third harmonic of the crystal fundamental. The oscillator-multiplier stage, therefore, develops a fixed-frequency 118-MHz local-oscillator signal that is coupled by capacitor $C_{12}$ to the emitter circuit of the 40236 mixer transistor.

In the mixer stage, the rf input signal from the antenna and the local-oscillator signal are heterodyned to derive the difference frequency used as the input to the 10-meter-band receiver. Output tuning coil $L_4$, capacitor $C_{10}$, and resistor $R_8$ forms a collector load circuit that is broadly tuned to select the difference-frequency signal developed in the mixer stage. This signal is transferred by the coupling link $L_5$ and the coaxial connector $J_2$ to the input of the 10-meter-band receiver.

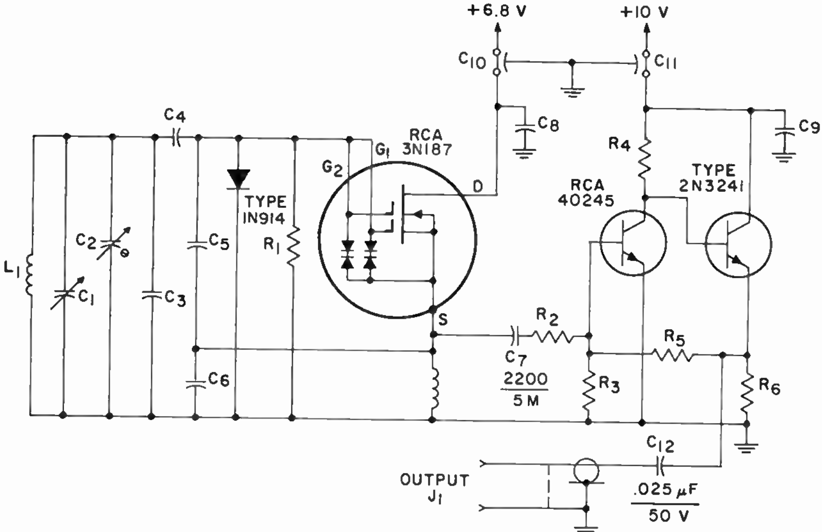
The 118-MHz local-oscillator frequency was selected so that the heterodyning action in the mixer provides a converter output of 26 to 30 MHz, depending upon the frequency of the selected rf input signal from the antenna. For example, a 144-MHz rf input signal results in a difference-frequency output of 144 MHz—118 MHz (or 26 MHz; a 148-MHz input frequency results in an output frequency of 148 MHz—118 MHz, or 30 MHz. The converter circuit, however, can be readily modified to provide a lower-frequency output. If it is desired to adapt a 20-meter-band receiver to receive 2-meter-band signals, it is necessary merely to use a crystal that has a fundamental frequency of 43.33 MHz and to double the number of turns in the output tuning coil $L_4$. No other changes are required.

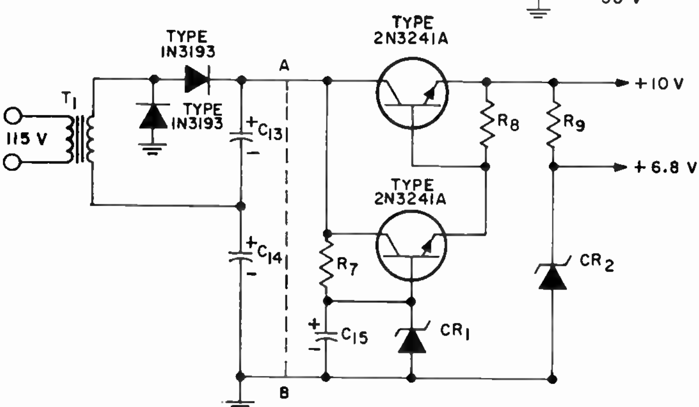
## 15-7 STABLE VARIABLE-FREQUENCY OSCILLATOR

### Circuit Description

This VFO circuit uses a 40823 dual-gate-protected MOS transistor in a highly stable variable-frequency oscillator stage and 40245 and 2N-3241A bipolar transistors in a two-stage isolation (output) amplifier to achieve exceptional frequency stability at low dc operating potentials. The MOS-transistor oscillator circuit is useful at any frequency up to and including the 144-MHz band. Tuned-circuit data are provided for the standard 3.5-to-4-MHz band, for the 5-to-5.5-MHz band for single-

## 15-7 STABLE VARIABLE-FREQUENCY OSCILLATOR (cont'd)




NOTES: (1) See general considerations for the construction of high-frequency and broadband circuits on page 691. (2) The coil $L_2$ is not a standard commercial item and, therefore, must be wound by the circuit builder.

### Parts List

$C_1$ = Double-bearing variable capacitor, Millen 23100 or 23050 (or equiv.) depending upon frequency range (see Tuned-Circuit Data)
$C_2$ = Air-type trimmer capacitor, 25 pF maximum, Hammarlund APC-25 or equiv.
$C_3$, $C_4$, $C_5$, $C_6$ = silver-mica capacitors (see Tuned-Circuit Data for values)
$C_7$ = 2200 pF, silver mica
$C_8$ = 0.05 pF, ceramic disc, 50 V.
$C_9$ = 0.1 pF, ceramic disc, 50 V.
$C_{10}$, $C_{11}$ = 1500 pF, feed-through
$C_{12}$ = 0.025 $\mu$F, ceramic disc, 50 V.
$C_{13}$ = 500 $\mu$F, electrolytic, 12 V.
$C_{14}$ = 500 $\mu$F, electrolytic, 12 V.
$C_{15}$ = 50 $\mu$F, electrolytic, 12 V.
$CR_1$ = Zener diode, 12-volt, 1-watt
$CR_2$ = ener diode, 6.8 volt, 1-watt
$J_1$ = Coaxial connector
$L_1$ = Variable inductor (see Tuned-Circuit Data for details)
$L_2$ = Miniature rf choke, 2.5 mH, iron core
$R_1$ = 22000 ohms, 0.5 watt
$R_2$ = 12000 to 47000 ohms, 0.5 watt; select value for 2-volt peak output level at input to transmitter
$R_3$ = 12000 ohms, 0.5 watt
$R_4$ = 820 ohms, 0.5 watt
$R_5$ = 47000 ohms, 0.5 watt
$R_6$ = 240 ohms, 0.5 watt
$R_7$ = 2200 ohms, 0.5 watt
$R_8$ = 220 ohms, 0.5 watt
$R_9$ = 180 ohms, 0.5 watt
$T_1$ = 6.3-volt, 1.2-ampere filament transformer

## 15-7 STABLE VARIABLE-FREQUENCY OSCILLATOR (cont'd)

### Tuned-Circuit Data

| | 3.5-4.0 MHz | 5.0-5.5 MHz | 8.0-9.0 MHz |
|---|---|---|---|
| $L_1$ | | | |
| No. of turns | 17* | 14¾* | 11½** |
| Wire size | 20 | 20 | 18 |
| Turns/inch | 16 | 16 | 8 |
| Diam., inches | 1 | 1 | 1 |
| $C_1$, p. | 100 | 50 | 50 |
| $C_2$, pf. | 25 | 25 | 25 |
| $C_3$, pf. | 100 | None | None |
| $C_4$, pf. | 390 | 390 | 270 |
| $C_5$, pf. | 680 | 680 | 560 |
| $C_6$, pf. | 680 | 680 | 560 |

* B & W 3015, AirDux 816T, or equiv.
** B & W 3014, AirDux 808T, or equiv.

### Circuit Description (cont'd)

sideband transmitters, and for the 8-to-9-MHz band for 50- and 144-MHz transmitters. (See chart on page 607.)

The oscillator stage is a Colpitts type. The variable capacitor $C_1$ is the tuning control for the circuit. With a Millen 10037 (or equivalent) "no sting" dial coupled to the shaft of this capacitor, the oscillator tuning range encompasses essentially the full dial area. Capacitor $C_2$ is the trimmer adjustment for the circuit. The effect of changes in transistor-element capacitances is reduced to a minimum by use of a three-capacitor ($C_4$, $C_5$, and $C_6$) voltage divider. The relatively large values of the capacitors $C_5$ and $C_6$, which are connected across the gate-to-source circuit of the MOS transistor, almost completely obviate the effect of the transistor capacitances. The rf choke $L_1$ provides the required low voltage (IR) drop for the source current of the MOS transistor.

The 1N914 silicon rectifier in the gate circuit of the oscillator stage is used to provide the rectified gate current for the MOS transistor. This rectifier makes possible a degree of automatic bias comparable to that obtainable with an electron tube and, in this way, contributes substantially to the frequency stability of the VFO circuit. The use of silver-mica types for all fixed-value capacitors in the oscillator stage assures a stable frequency-temperature characteristic.

The output of the oscillator stage is coupled from the source of the MOS transistor, through capacitor $C_7$ and resistor $R_1$, to the base of the 40245 bipolar transistor used in the input stage of the isolation amplifier. The output of the 40245 transistor, in turn, drives the 2N3241A emitter-follower output stage. The isolation amplifier is essentially a two-stage, direct-coupled, negative-feedback output circuit that greatly reduces the effect of a change in output conditions on oscillator performances and provides a convenient means (by a change in the value of resistor $R_1$) to vary the output voltage of the VFO circuit.

The dc operating potentials for the VFO circuit can be obtained directly from a 12-volt source. For operation from a 117-volt, 60-Hz ac source, a low-voltage dc supply, such as that shown in the circuit diagram, may be used to supply the required voltage. The 117-volt ac source voltage is stepped down to 6.3 volts ac by the power transformer $T_1$ and then converted to a dc voltage of 12 volts by the voltage-doubler circuit formed by the 1N3193 rectifier diodes and filter capacitors $C_{13}$ and $C_{14}$. The two 2N3241A bipolar transistors and the Zener diodes $CR_1$ and $CR_2$ connected between points A and B of the voltage-doubler circuit form an elec-

## 15-7 STABLE VARIABLE-FREQUENCY OSCILLATOR (cont'd)

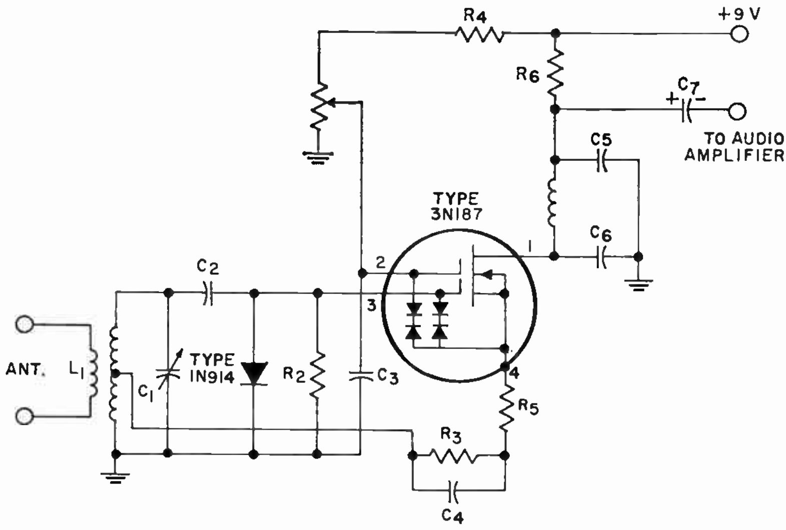
### Circuit Description (cont'd)

tronic voltage regulator that maintains constant dc output voltages with changes in the input ac voltage.

The voltage-regulator circuit is also used when the VFO is operated in a mobile system. For this type of operation, the power transformer $T_1$ and the voltage doubler are disconnected from the remainder of the circuit, and points A and B are connected to the positive and negative tertminals, respectively, of a 12-volt battery.

The VFO circuit is characterized by its exceptional frequency stability. A unit designed to operate in the 3.5-to-4-MHz frequency range exhibits a frequency drift of less than 30 Hz in 2 hours after a 30-second warm-up. A 5-to-5.5-MHz unit has a frequency drift of less than 50 Hz for the same period, and a 8-to-9-Mz unit has a frequency drift of only slightly more than 200 Hz.

## 15-8 REGENERATIVE DETECTOR




NOTES: (1) See general considerations for construction of high-frequency and broadband circuits on page 691. (2) This circuit uses coils that may not be available as standard commercial items; such coils must be wound by the circuit builder.

### Parts List

$C_1$ = tuning capacitor, 0 to 100 pF, E.F. Johnson No. R-149-5 or equiv.
$C_2$ = 47 pF, ceramic
$C_3$ = 0.05 $\mu$F, ceramic
$C_4$, $C_5$ = 0.01 $\mu$F, ceramic
$C_6$ = 0.001 $\mu$F, ceramic
$C_7$ = 0.1 $\mu$F, electrolytic, 15 V
$L_1$ = refer to coil-data chart
$L_2$ = refer to coil-data chart
$L_3$ = rf choke, 25 mH
$R_1$ = feedback control, potentiometer, 0.1 megohm, 0.5 watt
$R_2$, $R_3$ = 0.1 megohm, 0.5 watt
$R_4$ = 1800 ohms, 0.5 watt
$R_5$ = 150 ohms, 0.5 watt
$R_6$ = 4700 ohms, 0.5 watt

## 15-8 REGENERATIVE DETECTOR (cont'd)

### Coil Data for Different Frequency Bands

| | Inductance ($\mu$H) | Freq. Band (MHz) |
|---|---|---|
| $L_2$ | 110 | 1.5 to 4.0 |
| | 15 | 4.0 to 10.0 |
| | 2.6 | 10 to 25 |
| | 0.4 | 25 to 60 |
| $L_1$ | Number of windings is 25 per cent of the number of windings used for $L_2$ for each frequency band. | |

The coils are wound closely coupled on a common core. $L_1$ is wound near ground end of $L_2$. $L_2$ is tapped at approximately 25 per cent of total number of turns from the ground end.

### Circuit Description

This detector stage can be interconnected with the general-purpose audio amplifier, circuit 15-11, to form a simple CW or AM regenerative receiver. This receiver can extract the audio-signal information from an amplitude-modulated rf input signal as small as 0.5 microvolt. By selection of the proper values for the tuned-circuit components, the detector circuit can be adapted for operation over a wide range of frequencies A chart shows the recommended values of tuning inductance for various frequency bands in the range from 1.5 to 60 MHz. The detector stage employs a 3N187 dual-gate-protected MOS field-effect transistor and operates from a dc supply voltage of 9 volts.

An incoming amplitude-modulated rf signal developed across the antenna coil $L_1$ is inductively coupled into the detector input tuned circuit formed by the inductor $L_2$ and the variable capacitor $C_1$. The capacitor is adjusted to tune the detector to the desired signal frequency. The rf signal developed across the tuned circuit is applied to gate No. 1 of the 3N187 MOS transistor. The gate-No. 1-to-source circuit of the MOS transistor operates essentially as a gate-leak detector (analagous to an electron-tube grid-leak detector). The negative clamper formed by the IN914 diode, the capacitor $C_2$, and the gate-leak resistor $R_2$ bias the circuit so that only the positive peaks of the rf input signal result in current flow through the MOS transistor. The magnitude of these current pulses vary according to the audio modulating signal superimposed on the input rf carrier wave. These audio-signal variations are amplified in the source-to-drain circuit of the MOS transistor. The source-to-drain current of the transistor flows through a portion of the tuned-circuit inductor $L_2$. The rf components of this current are inductively coupled back to the tuned circuit by the autotransformer action of inductor $L_2$ in the proper phase to reinforce the signal developed at gate No. 1 of the transistor. This regenerative feedback permits repeated amplification of the incoming signal and, therefore, substantially increases the sensitivity of the detector circuit.

The amount of regenerative feedback coupled back to the input tuned circuit must be controllable because maximum regenerative amplification for AM operation occurs at a critical point just prior to that at which the detector oscillates and for CW operation occurs at a point just beyond that at which oscillation starts. The desired amount of feedback is obtained by adjustment of potentiometer $R_1$. This adjustment varies the bias applied to gate No. 2 to control the gain (i.e., transconductance) of the 3N187 transistor.

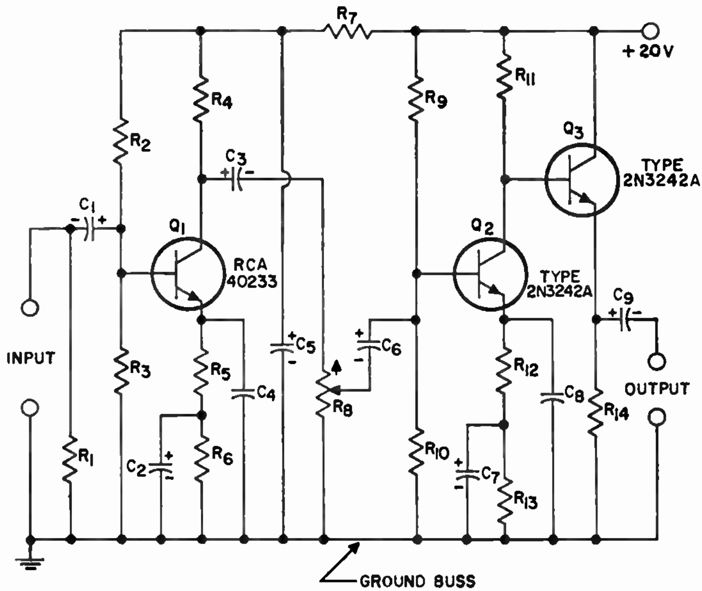
The rf choke $L_3$ and the bypass capacitors $C_4$ and $C_5$ form a low-pass network that filters out the rf components in the drain-circuit current so that the current through the detector load resistor $R_n$ consists almost entirely of audio-frequency components. The audio-signal voltage developed by this current is coupled by capacitor $C_7$ to the input of the audio amplifier.

## 15-9 MICROPHONE PREAMPLIFIER With High Dynamic Range

### Circuit Description

This three-stage preamplifier is designed for use with high-level microphones. It has an over-all voltage gain of 1500 to 2000 and can provide a maximum undistorted output voltage of 5 volts rms to a load impedance of 500 ohms or greater for a maximum undistorted input of 0.4 volt rms. The frequency response of the preamplifier is flat from 20 Hz to 30 kHz. The dc power requirements of the circuit are 20 volts at 30 milliamperes. This operating power can usually be obtained from the dc supply for the over-all audio-amplifier system.

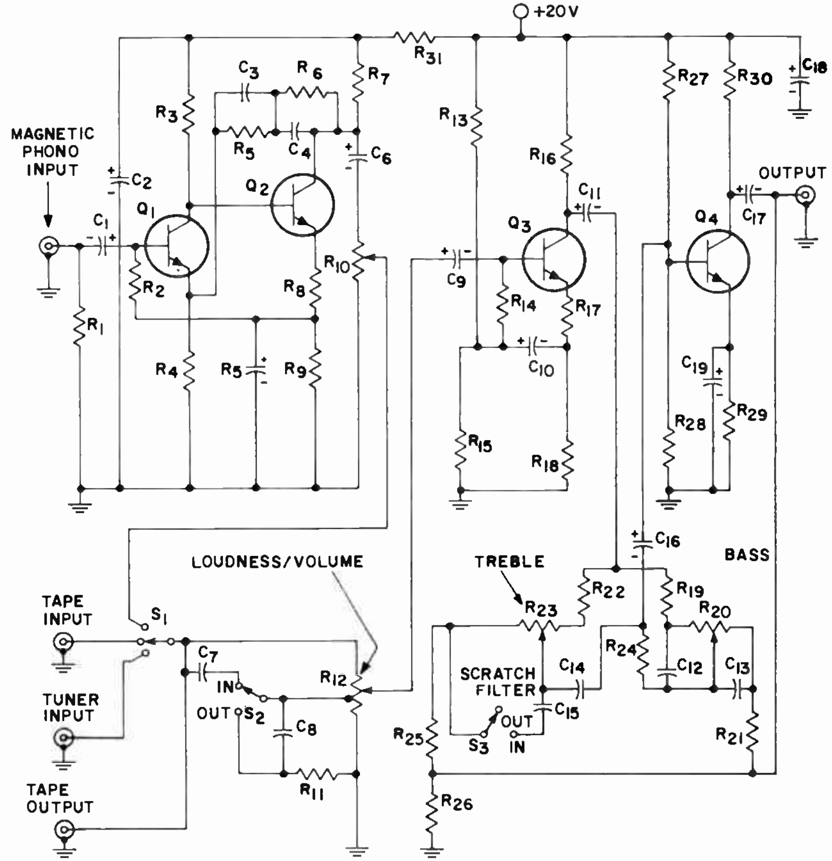
The preamplifier uses a low-noise 40233 in a class A input stage and two 2N3242A transistors in direct-coupled class A driver and emitter-follower output stages. The circuit operates equally well with either low-impedance or high-impedance microphones provided that the value of the input resistor $R_1$ is selected to match the microphone line impedance up to a maximum of 10,000 ohms.




### Parts List

$C_1$, $C_6$ = 15 µF, electrolytic, 6 V
$C_2$, $C_7$ = 300 µF, electrolytic, 6 V
$C_3$ = 10 µF, electrolytic, 15 V
$C_4$, $C_8$ = 0.05 µF, paper
$C_5$ = 250 µF, electrolytic, 25 V
$C_9$ = 50 µF, electrolytic, 15 V
$R_1$ = value required to match microphone line impedance (up to 10000 ohms), 10%, 0.5 watt
$R_2$, $R_9$ = 0.1 megohm, 10%, 0.5 watt
$R_3$, $R_{10}$ = 6200 ohms, 10%, 0.5 watt
$R_4$, $R_{11}$ = 10000 ohms, 10%, 0.5 watt
$R_5$, $R_{12}$ = 68 ohms, 10%, 0.5 watt
$R_6$, $R_{13}$ = 470 ohms, 10%, 0.5 watt
$R_7$ = 820 ohms, 10%, 0.5 watt
$R_8$ = potentiometer, 10000 ohms, 0.5 watt, audio taper
$R_{14}$ = 1000 ohms, 0.5 watt

## 15-10 HIGH-FIDELITY PREAMPLIFIER FOR PHONO, FM, OR TAPE PICKUP




### Parts List

$C_1$ = 2 $\mu$F, electrolytic, 6 V
$C_2$, $C_{17}$, $C_{18}$ = 25 $\mu$F, electrolytic, 25 V
$C_3$ = 0.0027 $\mu$F, paper, 200 V
$C_4$ = 0.01 $\mu$F, paper, 200 V
$C_5$ = 100 $\mu$F, electrolytic, 3 V
$C_6$ = 10 $\mu$F, electrolytic, 25 V
$C_7$ = 180 pF, mica, 500 V
$C_8$ = 0.033 $\mu$F, paper, 200 V
$C_9$ = 1 $\mu$F, electrolytic, 12 V
$C_{10}$, $C_{16}$ = 10 $\mu$F, electrolytic, 10 V
$C_{11}$ = 10 $\mu$F, electrolytic, 25 V
$C_{12}$, $C_{13}$ = 0.022 $\mu$F, paper, 200 V
$C_{14}$ = 0.0039 $\mu$F, paper, 200 V
$C_{15}$ = 0.0047 $\mu$F, paper, 200 V
$C_{19}$ = 100 $\mu$F, electrolytic, 6 V
$R_1$, $R_3$ = 68000 ohms, 10%, 0.5 watt
$R_2$ = 0.18 megohm, 10%, 0.5 watt
$R_4$ = 470 ohms, 10%, 0.5 watt
$R_5$ = 27000 ohms, 10%, 0.5 watt
$R_6$ = 0.47 megohm, 10%, 0.5 watt
$R_7$, $R_{19}$, $R_{21}$, $R_{24}$ = 10000 ohms, 10%, 0.5 watt
$R_8$ = 82 ohms, 10%, 0.5 watt
$R_9$ = 1800 ohms, 10%, 0.5 watt
$R_{10}$ = potentiometer, 0.1 megohm, 0.5 watt, audio taper
$R_{11}$ = 8200 ohms, 10%, 0.5 watt
$R_{12}$ = potentiometer, 0.25 megohm, 0.5 watt, audio taper with tap, Centralab F11-250K or equiv.
$R_{13}$ = 33000 ohms, 10%, 0.5 watt
$R_{14}$, $R_{28}$ = 18000 ohms, 10%, 0.5 watt

## 15-10 HIGH-FIDELITY PREAMPLIFIER (cont'd)

**Parts List (cont'd)**

$R_{15}$, $R_{31}$ = 4700 ohms, 10%, 0.5 watt
$R_{16}$ = 6800 ohms, 10%, 0.5 watt
$R_{17}$ = 68 ohms, 10%, 0.5 watt
$R_{18}$, $R_{22}$, $R_{25}$, $R_{29}$ = 1000 ohms, 10%, 0.5 watt
$R_{20}$, $R_{23}$ = potentiometer, 0.1 megohm, 0.5 watt, linear taper
$R_{26}$ = 47000 ohms, 10%, 0.5 watt
$R_{27}$ = 56000 ohms, 10%, 0.5 watt
$R_{30}$ = 2700 ohms, 10%, 0.5 watt
$S_1$ = switch, single-pole, 3-position, wafer
$S_2$ = switch, single-pole, double-throw, toggle
$S_3$ = switch, single-pole, single-throw, toggle

**Circuit Description**

This phonograph preamplifier can be used with an audio power amplifier, such as circuits 15-12 through 15-15, to provide an excellent high-fidelity system. The circuit is designed for use with a magnetic pickup that can supply an input signal of at least 5 millivolts. Provisions are also included in the preamplifier for tape and tuner inputs. For a 5-millivolt input signal, the preamplifier delivers an output of at least 1 volt. An input of 300 millivolts from a tuner or tape recorder is required to produce an output of 1 volt. The preamplifier requires a dc supply of 20 volts at 7.5 milliamperes.

The preamplifier uses a low-noise 40233 transistor $Q_1$ and a 2N3242A transistor $Q_2$ in a two-stage direct-coupled input circuit. A frequency-shaping network in the feedback circuit of transistor $Q_2$ provides frequency compensation when the preamplifier is used with a magnetic phonograph pickup. The output circuit of transistor $Q_2$ contains a level control $R_{10}$ that feeds the loudness control $R_{12}$ through the selector switch $S_1$. The loudness control, in turn, drives the tone-control circuits of the preamplifier. Tape, tuner, or phono inputs can be selected by means of the selector switch; an output connector in the arm of the selector switch permits tape recordings to be made without affecting volume or loudness.

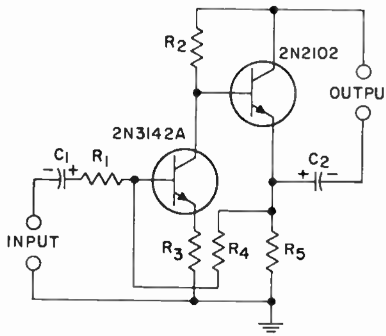
The treble and bass tone controls provide boost of 10 dB and cut of 15 dB for deep bass and high treble frequencies. Each control operates independently so that precise tone shaping is possible. When both controls are in the center position, the response is flat; the bass and treble frequencies are equally mixed.

Output distortion is low at all frequencies for any setting of either the bass or the treble tone control. The collector-to-base feedback in the 2N3242A transistors $Q_3$ and $Q_4$ works with the tone controls to provide the over-all tonal response of the preamplifier.

Included in the preamplifier is a loudness/volume control switch $S_2$. With the loudness control in, lower tones are enhanced at low output levels, and a more pleasing sound is produced. When the loudness control is switched out, the volume control attenuates all tones equally.

The scratch filter attenuates somewhat the frequencies at which scratch noise from scratched records is most prevalent.

## 15-11 GENERAL-PURPOSE AUDIO AMPLIFIER




### Parts List

$C_1$ = 10 microfarads, 6 volts, electrolytic
$C_2$ = 50 microfarads, 25 volts, electrolytic
$R_1$ = 1000 ohms, 0.5 watt
$R_2$ = 1200 ohms, 0.5 watt
$R_3$ = See chart, 0.5 watt
$R_4$ = See chart, 0.5 watt
$R_5$ = 270 ohms, 0.5 watt

All resistors have a tolerance of 10 per cent.

**Resistance Data for Different Voltage Gains and Input Impedances***

| Voltage Gain | Input Impedance (ohms) | $R_3$ (ohms) | $R_4$ (kilohms) |
|---|---|---|---|
| 166 | 2700 | 0 | 680 |
| 22 | 7300 | 39 | 470 |
| 17 | 9000 | 68 | 430 |
| 10 | 15000 | 100 | 390 |
| 3 | 55000 | 390 | 360 |
| 1 | 100000 | 1200 | 330 |

* Data obtained for an output of 1 volt rms into a 250-ohm line.

### Circuit Description

This two-stage amplifier is useful as a line driver for audio systems in which the power amplifier is located at a considerable distance from the signal source, as a driver for the line inputs of tape recorders, as an output stage for inexpensive radio receivers, and in many other general-purpose audio-amplifier applications. The amplifier has a frequency response that is flat from 20 to 20,000 Hz and can be used to drive any line that has an impedance of 250 ohms or greater. It operates from a dc supply of 12 volts and can supply a maximum undistorted output of 3-volts rms into a 250-ohm line.

The voltage gain and input impedance of the amplifier are determined by the values chosen for the emitter resistor ($R_3$) and feedback resistor ($R_4$) for the input stage. A chart shows values of these resistors for various voltage gains from unity to 166 and for input impedances from 2700 ohms to 55,000 ohms.

## 15-11 GENERAL-PURPOSE AUDIO AMPLIFIER (cont'd)

### Circuit Description (cont'd)

The amplifier employs a 2N3242A transistor $Q_1$ in a common-emitter input stage and a 2N2102 transistor $Q_2$ in an emitter-follower output stage. These stages are interconnected in a self-adjusting configuration that maintains the amplifier in a stable operating state regardless of variations in dc supply voltage and ambient temperature. This stability is achieved by use of a dc feedback applied from the output (emitter) of transistor $Q_2$ to the input (base) of transistor $Q_1$ through $R_1$.

If the emitter current of transistor $Q_1$ should increase, the base voltage of transistor $Q_2$ would also decrease because of the rise in the voltage drop across resistor $R_2$. This decrease in the base voltage of transistor $Q_2$ results in a corresponding reduction in the emitter current of this transistor. Consequently, the amount of positive dc voltage fed back from the emitter of transistor $Q_2$ to the base of transistor $Q_1$ is reduced. This reduction in voltage at the base of $Q_1$ causes a decrease in current through this transistor that compensates for the original increase, and the amplifier is stabilized. Use of an emitter-follower output stage makes possible the low output impedance of the amplifier.

## 15-12 12-WATT COMPLEMENTARY-SYMMETRY AUDIO POWER AMPLIFIER

### IHFM Music Power Rating, 15 W

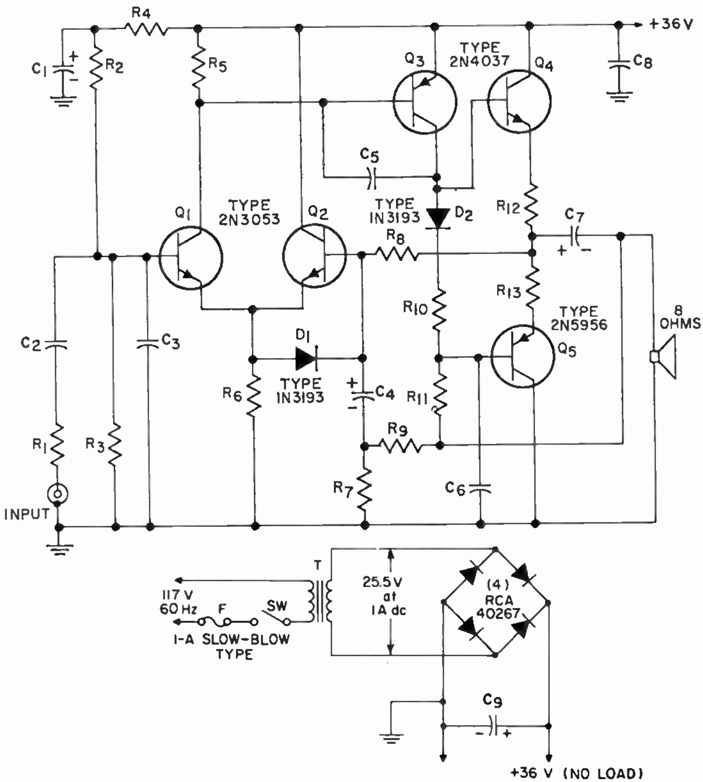
### Circuit Description

This three-stage audio power amplifier delivers 12 watts of rms power output to an 8-ohm load impedance for an input of 0.6 volt rms. Two such amplifiers can be used in a dual-channel (stereo) system to provide IHFM music power of 15 watts per channel or 30 watts total. The amplifier uses a direct-coupled complementary-symmetry output stage with conventional "bootstrap" drive to achieve excellent frequency-response characteristics and large amounts of negative feedback to assure low distortion. The amplifier operates from a dc power supply of 36 volts.

The input stage employs two 2N3053 n-p-n transistors in a differential-amplifier circuit configuration. This arrangement assures that the voltage at the mid-point of the output stage (i.e., positive side of capacitor $C_7$) is always one-half the power-supply voltage. As a result, the maximum range of output-voltage swing is allowed for all conditions of supply voltage. The feedback loop causes any voltage difference that develops between output and input to be amplified negatively (i.e., in opposite phase) and, in this way, assures that the output voltage closely tracks the input voltage.

The driver stage uses a 2N4037 silicon p-n-p transistor in a common-emitter circuit configuration. A 1N3193 compensating diode is used in this stage to provide thermal stability. This diode, which is thermally connected to the heat sink of the output transistors, is required to assure reliable operation of the output stage at ambient temperatures up to 55°C.

## 15-12 12-WATT COMPLEMENTARY-SYMMETRY AUDIO POWER AMPLIFIER (cont'd)




**NOTES: (1) Output transistors $Q_4$ and $Q_5$ and diode $D_1$ should be mounted on a common heat sink (Wakefield Type NC-403K or equiv.). Diode $D_1$ should be attached to the under side of the heat sink by use of small metal cable clamps. (2) Transistors $Q_1$ and $Q_2$ should be matched for base-to-emitter voltage within 0.04 volt and should be selected for a beta between 100 and 300 at 1 milliampere and 5 volts.**

### Parts List

$C_1$ = 10 $\mu$F, electrolytic, 50 V
$C_2$, $C_4$ = 5 $\mu$F, electrolytic, 25 V
$C_3$ = 150 pF, ceramic
$C_5$ = 75 pF, ceramic
$C_6$ = 470 pF, ceramic
$C_7$ = 1000 $\mu$F, electrolytic, 25 V
$C_8$ = 0.01 $\mu$F, ceramic
$C_9$ = 1000 $\mu$F, electrolytic, 50 V
$F_1$ = Fuse, 1 ampere, slow-blow type
$R_1$ = 1800 ohms, 0.5 watt
$R_2$ = 39000 ohms, 0.5 watt
$R_3$ = 47000 ohms, 0.5 watt
$R_4$ = 10000 ohms, 0.5 watt
$R_5$ = 330 ohms, 0.5 watt
$R_6$ = 2700 ohms, 0.5 watt
$R_7$ = 47 ohms, 0.5 watt
$R_8$ = 18000 ohms, 0.5 watt
$R_9$ = 1000 ohms, 0.5 watt
$R_{10}$ = 7.2 ohms, 0.5 watt
$R_{11}$ = 330 ohms, 2 watts
$R_{12}$, $R_{13}$ = 0.47 ohms, 1 watt
$S_1$ = On-off switch; single-pole, single-throw
$T_1$ = Power transformer; primary, 117 volts; secondary 25.5 volts at 1 ampere; Thordarson No. 23V118, Stancor No. TP4, Triad No. F-93X, or equiv.

### Circuit Description (cont'd)

The output stage employs a 2N5497 silicon n-p-n transistor and a 2N5956 silicon p-n-p transistor connected in complementary symmetry. The 470-picofarad capacitor $C_6$ connected from collector to base of the 2N5956 transistor reduces the high-frequency response of this type to approximately that of the 2N5497 plastic-package transistor. Both sections of the output stage, therefore, have essentially the same frequency-

## 15-12 12-WATT COMPLEMENTARY-SYMMETRY AUDIO POWER AMPLIFIER (cont'd)

### Circuit Description (cont'd)

response characteristics—a feature which simplifies the addition of negative feedback.

The resistor voltage divider ($R_7$ and $R_8$) connected across the speaker provides the proper amount of voltage for the loop feedback (from the amplifier output (speaker terminal) back to the base of transistor $Q_2$ in the differential-amplifier input stage).

The dc supply voltage required for the amplifier is supplied by a full-wave transformer-coupled bridge power supply that uses four RCA-40267 silicon rectifiers. A single supply can provide the dc operating power for both amplifiers in a dual-channel system. The 117-volt ac line voltage is stepped down to 25.5 volts by the power transformer $T_1$. The 40267 rectifier bridge and capacitor $C_9$ rectify and filter the voltage across the secondary of $T_1$ to provide a smooth dc output voltage approximately equal to the peak value of the stepped-down ac input voltage (i.e., $E_{dc} = 1.414 \times 25.5 = 36$ volts).

### Performance Characteristics

(Measured at a line voltage of 120 V, $T_A = 25°C$, and a frequency of 1 kHz, unless otherwise specified.)

| | |
|---|---|
| Power Output (8-ohm load): | |
| Music (at 5% THD, regulated supply) | 15 W |
| Dynamic (at 1% THD, regulated supply) | 13 W |
| Continuous (at 1% THD, unregulated supply) | 12 W |
| Sensitivity: | |
| For continuous power output rating | 600 mV |
| Hum and Noise: | |
| Below continuous power output: | |
| Input shorted | 90 dB |
| Input open | 70 dB |
| Input Resistance | 23 kΩ |
| Intermodulation Distortion 10 dB below continuous power output at 60 Hz and 7 kHz (4:1) | 0.6% |

## 15-13 HIGH-FIDELITY 25-WATT QUASI-COMPLEMENTARY-SYMMETRY AUDIO POWER AMPLIFIER

### IHFM Music Power Rating, 38 W

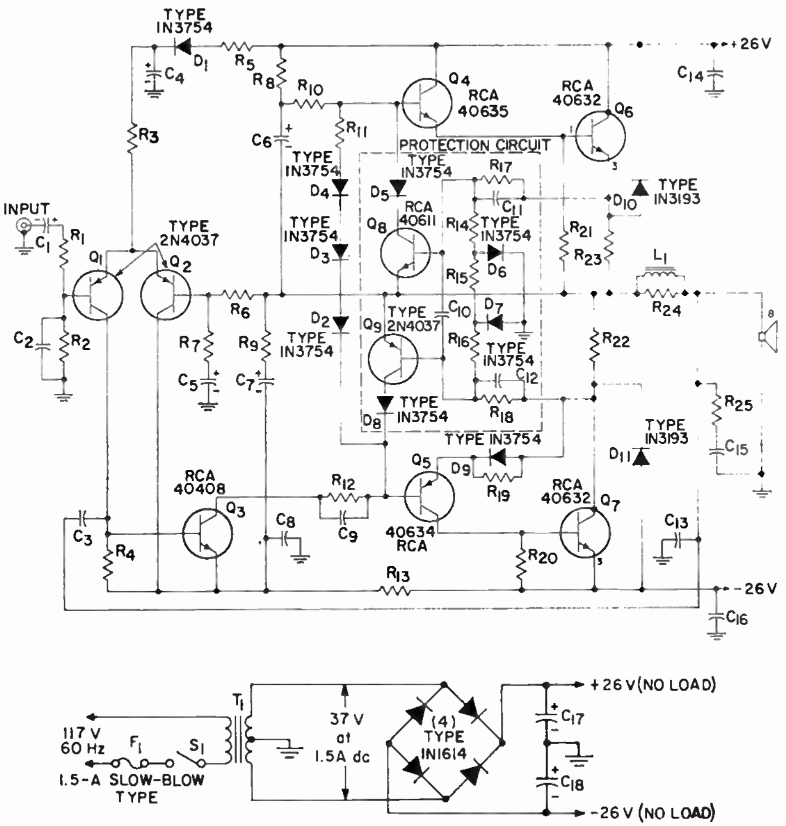
### Circuit Description

This high-fidelity amplifier provides 25 watts of rms power output (38 watts of IHFM music power output) for an input of 0.6 volt rms. The amplifier has a frequency response that it flat within 1 dB from 10 to 50,000 Hz. Total harmonic distortion at the full rated output of 25 watts is less than 1 per cent at 1000 Hz. The amplifier requires no driver or output transformer and has built-in safe-area limiting protection that prevents damage to the driver and output stages from high currents and excessive power dissipation.

The input stage uses two 2N4037 p-n-p transistors ($Q_1$ and $Q_2$) in a differential amplifier circuit. These transistors are matched for $V_{BE}$ characteristics to give a minimum offset voltage between their bases and, therefore, between input and output. The action of the feedback loop is to amplify negatively (i.e., in opposite phase) any voltage difference that develops between input and output, and, in this way, to cause the output voltage to follow the input voltage.

The predriver stage employs a 40408 n-p-n transistor ($Q_3$) in a

## 15-13 HIGH-FIDELITY 25-WATT QUASI-COMPLEMENTARY-SYMMETRY AUDIO POWER AMPLIFIER (cont'd)




**NOTES:** (1) Output transistors $Q_6$ and $Q_7$ and diodes $D_2$ through $D_4$ should be mounted on a common heat sink (Wakefield Type NC-403K or equiv.). Diodes should be attached to under side of heat sink by use of small metal cable clamps. (2) Transisotrs $Q_1$ and $Q_2$ should be matched for base-to-emitter voltage within 0.04 volt and should be selected for a beta between 100 and 300 at 1 milliampere and 5 volts.

### Parts List

$C_1$ = 5 μF, electrolytic, 12 V
$C_2$ = 180 pF, ceramic, 50 V
$C_3$ = 39 pF, ceramic, 50 V
$C_4$, $C_6$, $C_7$ = 50 μF, electrolytic, 50 V
$C_5$ = 50 μF, electrolytic, 12 V
$C_8$, $C_9$, $C_{15}$ = 0.02 μF, ceramic, 50 V
$C_{10}$, $C_{11}$, $C_{12}$, $C_{13}$, $C_{14}$, $C_{16}$ = 0.05 μF, ceramic, 50 V
$C_{17}$, $C_{18}$ = 2100 μF, electrolytic, 35 V
$F_1$ = fuse, 1.5-ampere, slow-blow
$L_1$ = 10 μH, Miller 4622 or equiv.
$R_1$, $R_8$ = 1800 ohms, 0.5 watt
$R_2$, $R_6$ = 18000 ohms, 0.5 watt
$R_3$ = 12000 ohms, 0.5 watt
$R_4$, $R_7$ = 680 ohms, 0.5 watt
$R_5$ = 180 ohms, 0.5 watt
$R_9$, $R_{12}$ = 270 ohms, 0.5 watt
$R_{10}$ = 2200 ohms, 0.5 watt
$R_{11}$ = 47 ohms, 0.5 watt
$R_{13}$, $R_{19}$, $R_{20}$, $R_{21}$ = 100 ohms, 0.5 watt
$R_{14}$, $R_{16}$ = 1000 ohms, 0.5 watt
$R_{15}$ = 4700 ohms, 0.5 watt
$R_{17}$, $R_{18}$ = 68 ohms, 0.5 watt
$R_{22}$, $R_{23}$ = 0.43 ohms, 5 watts
$R_{24}$, $R_{25}$ = 22 ohms, 0.5 watt
$S_1$ = ON-OFF switch, single-pole, single-throw
$T_1$ = power transformer; primary 117 volts; secondary, center-tapped, 37 volts at 1.5 amperes; Triwec Transformer Co. No. RCA-120 or equiv.

## 15-13 HIGH-FIDELITY 25-WATT QUASI-COMPLEMENTARY-SYMMETRY AUDIO POWER AMPLIFIER (cont'd)

### Circuit Description (cont'd)

common-emitter circuit. This circuit has a minimum loading effect on the input stage and provides the necessary voltage amplification for the entire amplifier. The subsequent stages provide the required current gain.

The driver stage uses a 40635 n-p-n transistor ($Q_4$) and a 40634 p-n-p transistor ($Q_5$) connected in complementary symmetry to develop push-pull drive for the output stage. Two 40632 silicon power transistors ($Q_6$ and $Q_7$) used in the output stage are connected in series with separate positive and negative supply voltages. The output is directly coupled to an 8-ohm speaker from the common point between the two transistors. Negative feedback of 35 dB is provided by $R_6$, $R_7$ and $C_5$. Feedback stabilization and proper frequency response are provided by the reactive elements $C_6$, $C_{15}$ and $L_1$.

Bias voltage for the complementary driver stages is provided by the forward voltage drop across the three 1N3754 diodes ($D_2$, $D_3$, and $D_4$) and resistor $R_{11}$. This voltage is necessary to maintain the output stages in class AB operation to avoid cross-over distortion. The 1N3754 diodes are connected thermally to the heat sink of the output transistors to provide the necessary thermal feedback to stabilize the quiescent current at its preset value at all case temperatures up to 100°C. Because of the high-temperature compensation provided by this thermal feedback network, the required stability in the output stages can be provided by small emitter resistors ($R_{22}$ and $R_{23}$) and losses are held to a minimum. (The $Q_5$-$Q_7$ pair operates like a large p-n-p transistor whose "emitter" is the collector of $Q_7$. Resistor $R_{22}$, therefore, is in the "effective emitter" of the pair.)

Safe-area limiting is provided by a current-limiting circuit whose principal components are the emitter resistors $R_{22}$ and $R_{23}$ and the 2N4037 p-n-p transistor $Q_9$ and 40611 n-p-n transistor $Q_8$ connected to them, respectively. If any condition exists which causes an excessive current to flow through either resistor, the resultant voltage developed across the resistor will turn on its corresponding protection transistor, removing the excessive base drive current from the appropriate driver transistor ($Q_4$ or $Q_5$). The value of current that is "excessive" depends on the output voltage. At an output voltage near ground (such as would be encountered with a short circuit) essentially the full voltage across the emitter resistor is applied across the base-emitter terminals of the protection transistor, which then turns on at a particular value of output current. When the output voltage is well above from ground, however, (as in the peaks in a normal operating situation) the emitter-to-ground voltage is applied to the network in the protection circuit and a voltage drop is developed across resistor $R_{17}$ or $R_{18}$. As a result, the full voltage across the emitter resistor is not applied to the protection transistor, and a larger output current that produces a larger voltage drop must occur before limiting takes place. Because the power dissipation of a transistor is the product of the voltage across it and the current through it, high currents may be tolerated at low values of voltage across the transistor (i.e., high values of output voltage, because the sum of output voltage and transistor voltage is equal to the supply voltage). Both the driver and output transistors, therefore, are protected from any excessive power dissipation, whether by a short circuit or with a normal load.

Further safe-area limiting is provided by the 1N3193 diodes $D_{10}$ and $D_{13}$ placed across the output transis-

## 15-13 HIGH-FIDELITY 25-WATT QUASI-COMPLEMENTARY-SYMMETRY AUDIO POWER AMPLIFIER (cont'd)

### Circuit Description (cont'd)

tors. These diodes guard against damage due to a highly inductive load by providing a path to return the energy from the inductor to the power supply when the load voltage and load current differ in sign. This energy must find a return path in any case. If the diodes are not present, the energy will flow through the output transistor in the reverse direction from normal current flow, and possibly cause breakdown.

The amplifier operates from a full-wave bridge power supply which provides symmetrical positive and negative dc outputs of 26 volts. This power supply may be used for both channels of a stereo system.

### Performance Characteristics

(Measured at a line voltage of 120V, an ambient temperature of 25°C, and a frequency of 1 kHz, unless otherwise specified.)

| | |
|---|---|
| Power Output (8-ohm load) | |
| Music (at 5% THD, regulated supply) | 38W |
| Dynamic (at 1% THD, regulated supply) | 33W |
| Continuous (at 1% THD, unregulated supply) | 25W |
| Sensitivity (For continuous power output rating): | 600 mV |
| Hum and Noise (below continuous power output): | |
| Input shorted | 80 dB |
| Input open | 75 dB |
| Input Resistance | 20,000 ohms |
| Intermodulation Distortion [10 dB below continuous power output at 60 Hz and 7 kHz (4:1)] | 0.1% |

## 15-14 HIGH-FIDELITY 40-WATT QUASI-COMPLEMENTARY-SYMMETRY AUDIO POWER AMPLIFIER IHFM Music Power Rating, 55 W

### Circuit Description

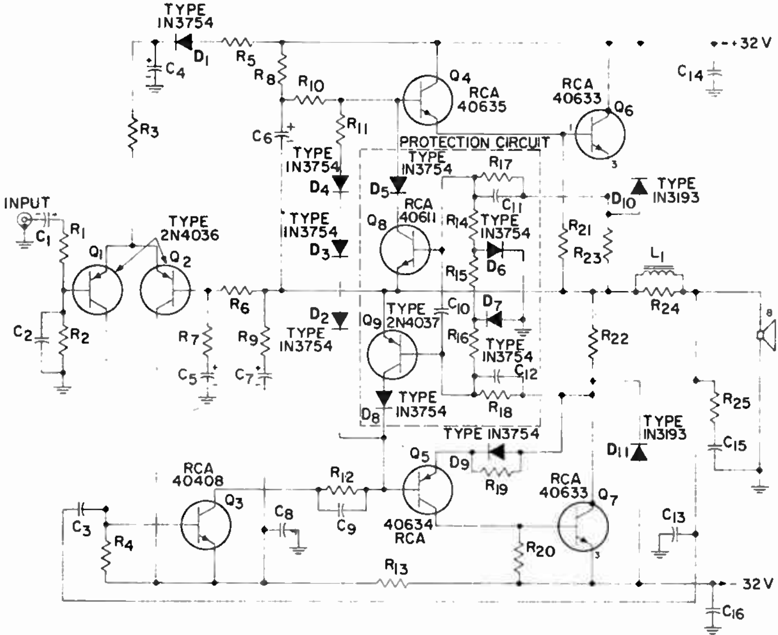
This high-fidelity audio power amplifier can deliver 40 watts of rms power output (55 watts of IHFM music power output) for an input of 0.6 volt rms. The frequency response of the amplifier is flat within 1 dB from 10 to 50,000 Hz. Total harmonic distortion at the full rated output of 40 watts is less than 1 per cent at 1000 Hz. Although component values, the transistor complement, and supply voltages differ, the circuit configuration of this amplifier is the same as that of the 25-watt amplifier in circuit 15-13, and the operation of the two amplifiers is identical. The 40-watt amplifier operates from symmetrical positive and negative dc voltages of 32 volts.

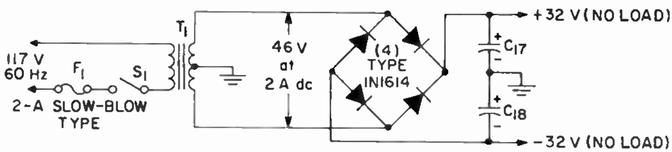
### Performance Characteristics

(Measured at a line voltage of 120V, an ambient temperature of 25°C, and a frequency of 1 kHz, unless otherwise specified.)

| | |
|---|---|
| Power Output (8-ohm load) | |
| Music (at 5% THD, regulated supply) | 55W |
| Dynamic (at 1% THD, regulated supply) | 50W |
| Continuous (at 1% THD, unregulated supply) | 40W |
| Sensitivity for continuous power output rating | 600 mV |
| Hum and Noise: | |
| Below continuous power output: | |
| Input shorted | 80 dB |
| Input open | 75 dB |
| Input Resistance | 20,000 ohms |
| Intermodulation Distortion [10 dB below continuous power output at 60 Hz and 7 kHz (4:1)] | 0.1% |

## 15-14 HIGH-FIDELITY 40-WATT QUASI-COMPLEMENTARY-SYMMETRY AUDIO POWER AMPLIFIER (cont'd)



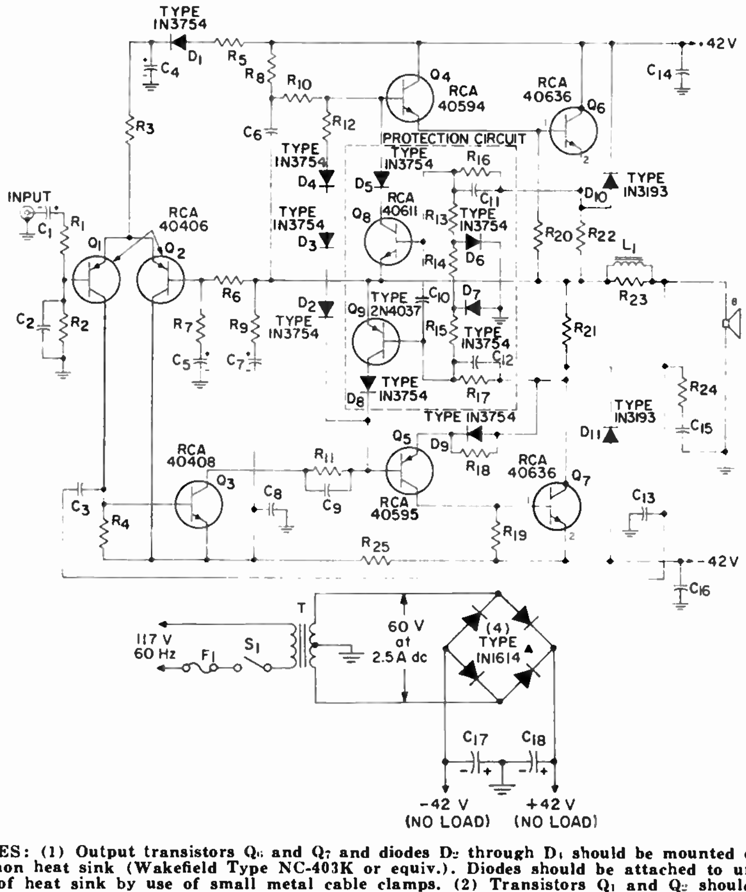

**NOTE:** (1) Output transistors $Q_6$ and $Q_7$ and diodes $D_2$ through $D_4$ should be mounted on a common heat sink (Wakefield Type NC403K or equiv.). Diodes should be attached to under side of heat sink by use of small metal cable clamps. (2) Transistors $Q_1$ and $Q_2$ should be matched for base-to-emitter voltage within 0.04 volt and should be selected for a beta between 100 and 300 at 1 millampere and 5 volts.

### Parts List

$C_1$ = 5 μF, electrolytic, 12 V
$C_2$ = 180 pF, ceramic, 50 V
$C_3$ = 39 pF, ceramic, 50 V
$C_4$, $C_6$, $C_7$ = 50 μF, electrolytic, 50 V
$C_5$ = 50 μF, electrolytic, 12 V
$C_8$, $C_9$, $C_{15}$ = 0.02 μF, ceramic, 50 V
$C_{10}$, $C_{11}$, $C_{12}$, $C_{13}$, $C_{14}$, $C_{16}$ = 0.05 μF, ceramic, 50 V
$C_{17}$, $C_{18}$ = 3500 μF, electrolytic, 50 V
$F_1$ = fuse, 2-ampere, slow-blow
$L_1$ = 10 μH, Miller 4622 or equiv.
$R_1$ = 1800 ohms, 0.5 watt
$R_2$, $R_8$ = 18000 ohms, 0.5 watt
$R_3$ = 15000 ohms, 0.5 watt
$R_4$ = 680 ohms, 0.5 watt
$R_5$ = 180 ohms, 0.5 watt
$R_7$ = 560 ohms, 0.5 watt
$R_8$ = 2200 ohms, 0.5 watt
$R_9$ = 270 ohms, 0.5 watt
$R_{10}$ = 2700 ohms, 0.5 watt
$R_{11}$ = 47 ohms, 0.5 watt
$R_{12}$ = 390 ohms, 0.5 watt
$R_{13}$, $R_{19}$, $R_{20}$, $R_{21}$ = 100 ohms, 0.5 watt
$R_{14}$, $R_{16}$ = 1000 ohms, 0.5 watt
$R_{15}$ = 4700 ohms, 0.5 watt
$R_{17}$, $R_{18}$ = 68 ohms, 0.5 watt
$R_{22}$, $R_{23}$ = 0.39 ohm, 5 watts
$R_{24}$, $R_{25}$ = 22 ohms, 0.5 watt
$S_1$ = ON-OFF switch, single-pole, single-throw
$T_1$ = power transformer; primary 117 volts; secondary, center-tapped, 46 volts at 2 amperes; Triwec Transformer Co. No. RCA-119 or equiv.

## 15-15 HIGH-FIDELITY 70-WATT QUASI-COMPLEMENTARY-SYMMETRY AUDIO POWER AMPLIFIER

### IHFM Music Power Rating, 100 W




NOTES: (1) Output transistors $Q_6$ and $Q_7$ and diodes $D_2$ through $D_4$ should be mounted on a common heat sink (Wakefield Type NC-403K or equiv.). Diodes should be attached to under side of heat sink by use of small metal cable clamps. (2) Transistors $Q_1$ and $Q_2$ should be matched for base-to-emitter voltage within 0.04 volt and should be selected for a beta between 100 and 300 at 1 milliampere and 5 volts.

### Parts List

$C_1$ = 5 µF, electrolytic 12 V
$C_2$ = 180 pF, ceramic, 50 V
$C_3$ = 39 pF, ceramic, 50 V
$C_4$, $C_6$, $C_7$ = 50 µF, electrolytic, 50 V
$C_5$ = 50 µF, electrolytic, 12 V
$C_8$, $C_9$, $C_{15}$ = 0.02 µF, ceramic, 50 V
$C_{10}$, $C_{11}$, $C_{12}$, $C_{13}$, $C_{14}$, $C_{16}$ = 0.05 µF, ceramic, 50 V
$C_{17}$, $C_{18}$ = 3500 µF, electrolytic, 50 V
$F_1$ = fuse, 3 ampere, slow-blow type
$L_1$ = 10 µH, Miller 4622 or equiv.
$R_1$ = 1800 ohms, 0.5 watt
$R_2$, $R_3$, $R_6$ = 18000 ohms, 0.5 watt
$R_4$ = 680 ohms, 0.5 watt
$R_5$ = 180 ohms, 0.5 watt
$R_7$, $R_{11}$ = 470 ohms, 0.5 watt
$R_8$ = 2700 ohms, 0.5 watt
$R_9$ = 270 ohms, 0.5 watt
$R_{10}$ = 3300 ohms, 0.5 watt
$R_{12}$ = 47 ohms, 0.5 watt
$R_{18}$, $R_{19}$, $R_{20}$, $R_{25}$ = 100 ohms, 0.5 watt
$R_{13}$, $R_{15}$ = 1000 ohms, 0.5 watt
$R_{14}$ = 4700 ohms, 0.5 watt
$R_{16}$, $R_{17}$ = 68 ohms, 0.5 watt
$R_{21}$, $R_{22}$ = 0.33 ohm, 5 watts
$R_{23}$, $R_{24}$ = 22 ohms, 0.5 watt
$S_1$ = ON-OFF switch, single-pole, single-throw
$T_1$ = power transformer; primary 117 volts; secondary, center-tapped, 60 volts at 2.5 amperes; Triwec Transformer Co. No. RCA 113 or equiv.

## 15-15 HIGH-FIDELITY 70-WATT QUASI-COMPLEMENTARY-SYMMETRY AUDIO POWER AMPLIFIER (cont'd)

### Circuit Description

This high-fidelity audio power amplifier provides 70 watts of rms power output (100 watts of IHFM music power output) for an input of 1 volt rms. The frequency response of the amplifier is flat within 1 dB from 5 to 25000 Hz. Total harmonic distortion at the full rated power output of 70 watts is less than 0.25 per cent at 1000 Hz. Although component values, the transistor complement, and supply voltages differ, the basic configuration and the operation of this amplifier are essentially identical to the 25-watt amplifier in circuit 15-13. The 70-watt amplifier operates from symmetrical positive and negative dc supply voltages of 42 volts.

### Performance Characteristics

(Measured at a line voltge of 120V, ambient temperature of 25°C, and a frequency of 1 kHz, unless otherwise specified)

| | |
|---|---|
| Power Output: | |
| Music (at 5% THD, regulated supply, 8-ohm load) | 100W |
| Dynamic (at 1% THD, regulated supply, 8-ohm load) | 88W |
| Continuous (at 1% THD, unregulated supply, 8-ohm load) | 70W |
| Sensitivity for continuous power output rating | |
| Hum and Noise (below continuous power output): | 85 dB |
| Input shorted | 80 dB |
| Input open | 20,000 ohms |
| Input Resistance | |
| Intermodulation Distortion [10 dB below continuous | 700 mV |
| power output at 60 Hz | |
| and 7 kHz (4:1)] | 0.1% |

## 15-16 SERVO AMPLIFIER

### Circuit Description

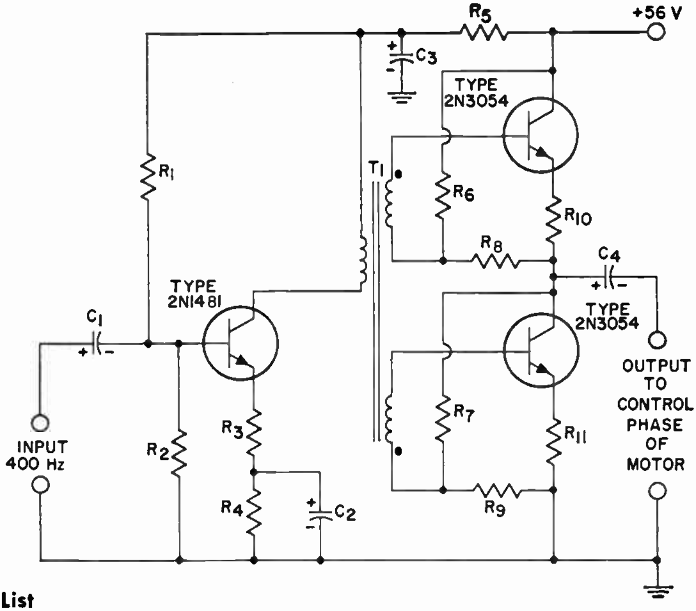
This servo amplifier can supply up to 6 watts of power to the drive motor of a servo system. The amplifier is driven by a 400-Hz ac signal and is operated from a dc supply voltage of 56 volts. A pair of 2N3054 silicon power transistors are used in a class AB, push-pull, single-ended output stage to develop the required output power.

A 2N1481 common-emitter input stage amplifies the 400-Hz input to the level required to drive the 2N3054 output transistors. The amplified 400-Hz signal at the collector of the 2N1481 transistor is coupled to the base of each 2N3054 output transistor by the transformer $T_1$. The secondary of $T_1$ is split to form two identical windings which are oriented so that the inputs to the output transistors are equal in amplitude and 180 degrees out of phase, as required for push-pull drive.

If the input to the upper output transistor were applied between the base and ground, this transistor would be operated as an emitter follower and could not provide voltage gain. The input, however, is applied between the base and the emitter so that, in effect, the upper transistor is operated as a common-emitter amplifier except that there is no phase reversal between input and output. Its gain, therefore, is equal to that of the lower output transistor, which is operated in a conventional common-emitter amplifier configuration. The positive half-cycle of the output signal developed by the upper transistor and the negative half-cycle developed by the lower transistor then have equal voltage swings. This output is coupled to the control-phase winding of the drive motor by the series output capacitor $C_1$.

## 15-16 SERVO AMPLIFIER (cont'd)

### Output, 6 W




**Parts List**

$C_1$ = 10 μF, electrolytic, 15 V
$C_2$ = 47 μF, electrolytic, 15 V
$C_3$ = 20 μF, electrolytic, 50 V
$C_4$ = 500 μF, electrolytic, 50 V

$R_1$ = 68000 ohms, 0.5 watt
$R_2$ = 5600 ohms, 0.5 watt
$R_3$ = 56 ohms, 0.5 watt
$R_4$ = 560 ohms, 0.5 watt
$R_5$ = 3300 ohms, 0.5 watt
$R_6$, $R_7$ = 18000 ohms, 0.5 watt
$R_8$, $R_9$ = 400 ohms, 0.5 watt
$R_{10}$ $R_{11}$ = 4 ohms, 1 watt

$T_1$ = driver transformer; core material 0.014-inch Magnetic Metals Corp. "Crystalligned" or equiv.; primary 1500 turns; secondary 450 turns, bifilar wound (each section 225 turns)

## 15-17 27-MHz, 5-WATT CITIZENS-BAND TRANSMITTER

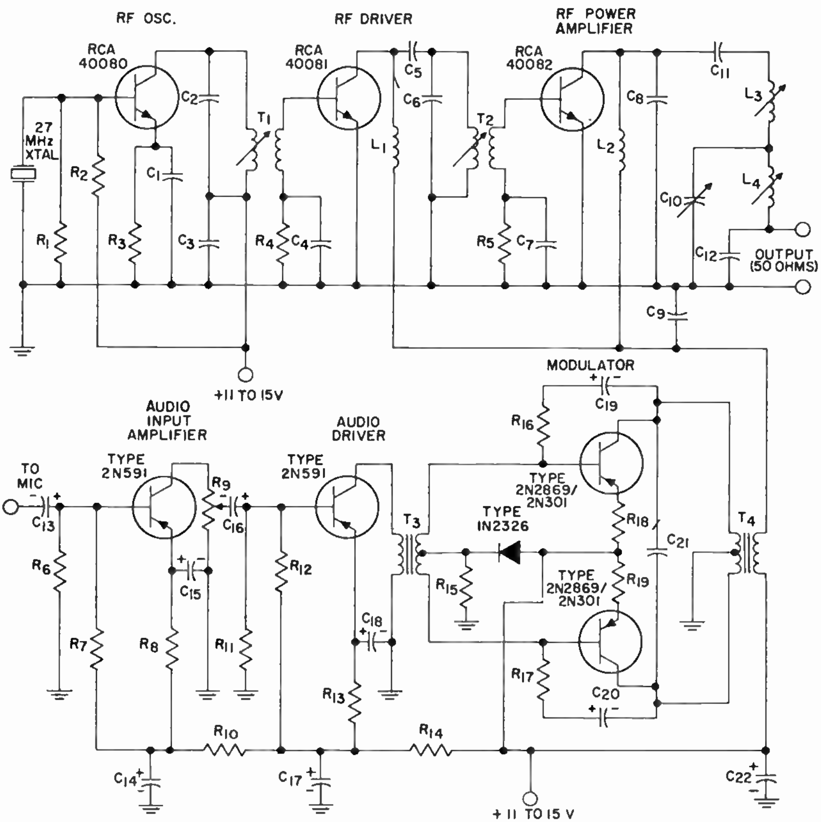
### Circuit Description

This transmitter operates directly from a 12-volt supply without the need for dc-to-dc converters, and is thus adaptable to mobile operations employing 12-volt systems. Its low power drain also makes it adaptable to portable use with small storage batteries.

The rf section of the transmitter, which consists of a 40080 crystal-controlled oscillator, a 40081 driver, and a 40082 power amplifier, develops 3.5 watts of rf power output at 27 MHz. Both the driver and the power amplifier are modulated to achieve 100-per-cent amplitude modulation.

The 40080 crystal-controlled oscillator stage is a Colpitts type of circuit that provides excellent frequency stability with respect to collector supply voltage and temperature (well within the 0.005-per-cent tolerance permitted by F.C.C.

## 15-17 27-MHz, 5-WATT CITIZENS-BAND TRANSMITTER (cont'd)




**NOTES: (1) See general considerations for construction of high-frequency and broadband circuits on page 691. (2) The 40082 transistor used in the rf power amplifier should be mounted on a good heat sink. (3) This circuit uses coils that are not standard commercial items; such coils must be wound by the circuit builder.**

### Parts List

$C_1$ = 75 pF, ceramic
$C_2$ = 30 pF, ceramic
$C_3$, $C_9$ = 0.01 $\mu$F, ceramic
$C_4$ = 0.001 $\mu$F, ceramic
$C_5$ = 47 pF, ceramic
$C_6$ = 51 pF, mica
$C_7$ = 0.002 $\mu$F, ceramic
$C_8$ = 24 pF, mica
$C_{10}$ = variable capacitor, 90 to 400 pF (ARCO 429, or equiv.)
$C_{11}$ = 100 pF, ceramic
$C_{12}$ = 220 pF, ceramic
$C_{13}$ = 5 $\mu$F, electrolytic
$C_{14}$, $C_{17}$ = 50 $\mu$F, electrolytic, 25 V
$C_{15}$, $C_{16}$, $C_{18}$ = 10 $\mu$F, electrolytic, 15 V
$C_{19}$, $C_{20}$ = 0.2 $\mu$F, electrolytic, 15 V
$C_{21}$ = 0.1 $\mu$F, ceramic
$C_{22}$ = 500 $\mu$F, electrolytic, 15 V
$L_1$, $L_2$ = rf choke, 15 $\mu$F, Miller 4624, or equiv.
$L_3$ = variable inductor (0.75 to 1.2 $\mu$H); 11 turns No. 22 wire wound on ¼-inch CTC coil form having a "green dot" core; Q = 120
$L_4$ = variable inductor (0.5 to 0.9 $\mu$H); 7 turns No. 22 wire wound on ¼-inch CTC coil form having a "green dot" core; Q = 140
$R_1$ = 510 ohms, 0.5 watt
$R_2$, $R_{12}$ = 5100 ohms, 0.5 watt
$R_3$ = 51 ohms, 0.5 watt
$R_4$ = 120 ohms, 0.5 watt
$R_5$ = 47 ohms, 0.5 watt
$R_6$ = 0.1 megohm, 0.5 watt
$R_7$ = 10000 ohms, 0.5 watt
$R_8$ = 2000 ohms, 0.5 watt
$R_9$ = potentiometer, 10000 ohms
$R_{10}$ = 3600 ohms, 0.5 watt
$R_{11}$ = 15000 ohms, 0.5 watt
$R_{13}$ = 1000 ohms, 0.5 watt
$R_{14}$ = 1200 ohms, 0.5 watt
$R_{15}$ = 240 ohms, 0.5 watt
$R_{16}$, $R_{17}$ = 2700 ohms, 0.5 watt
$R_{18}$, $R_{19}$ = 1.5 ohms, 0.5 watt
$T_1$ = rf transformer; primary 14 turns, secondary 3 turns of No. 22 wire wound on ¼-inch CTC coil form having a "green dot" core (CTC No. 1542-3 or equiv.); slug-tuned (0.75 to 1.2 $\mu$H); Q = 100
$T_2$ = rf transformer; primary 14 turns, secondary

## 15-17 27-MHz, 5-WATT CITIZENS-BAND TRANSMITTER (cont'd)

### Parts List (cont'd)

2-¾ turns of No. 22 wire wound on ¼-inch CTC coil form having a "green dot" core; slug-tuned (0.75 to 1.2 $\mu$H); Q = 100
$T_3$ = transformer; primary: 2500 ohms; secondary 200 ohms center-tapped; Microtran SMT 17-SB or equiv.
$T_4$ = transformer; primary: 100 ohms center-tapped; secondary: 30 ohms; Stancor TA-12 or equiv.
XTAL = 27-MHz transmitting crystal, standard third-overtone type.

### Circuit Description (cont'd)

regulations) and delivers a minimum rf power of 100 milliwatts to the input of the driver stage.

The 40081 driver stage uses a class C common-emitter configuration. The modulation input is applied to the collector circuit. This stage delivers a minimum of 400 milliwatts of modulated rf power to the power amplifier. A heat dissipator should be mounted on the case of the 40081. The 40082 power-amplifier stage also uses a class C common-emitter configuration and is modulated through the collector circuit. The double-$\pi$ network used as the output resonant circuit provides harmonic rejection of 50 dB, as required by F.C.C. regulations. The minimum rf power output supplied to the antenna from the power amplifier is 3 watts.

In the audio (modulator) section of the transmitter, two 2N591 class A amplifier stages are used to drive a class AB push-pull output stage using two 2N2869/2N301 transistors. This design provides maximum efficiency with low distortion. A 1N2326 compensating diode is used in the biasing network to provide thermal stability. The modulation transformer $T_4$ matches the collector-to-collector impedance of the modulator to that of the rf driver and power amplifier.

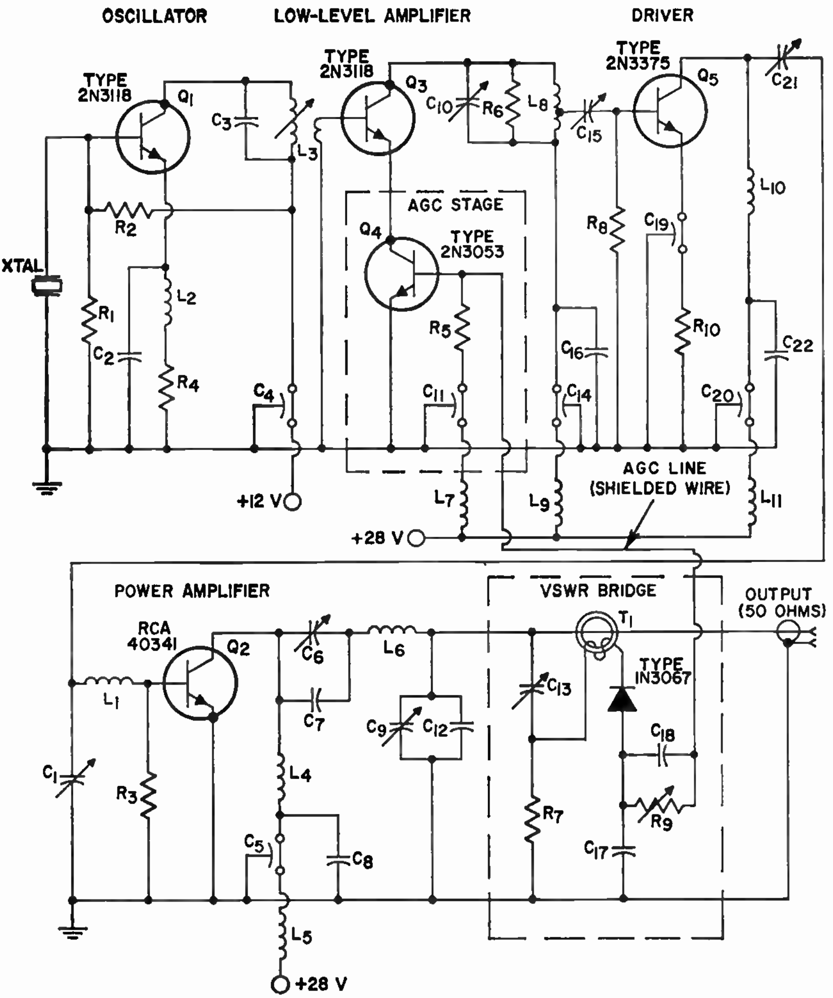
## 15-18 50-MHz, 40-WATT CW TRANSMITTER
With Load-Mismatch Protection

### Circuit Description

This cw transmitter uses a VSWR bridge circuit to maintain a steady-state dissipation in the output stage under all conditions of antenna mismatch. This technique makes it possible to realize the full power potential of the 40341 overlay transistor used in the output stage.

The 50-MHz crystal-controlled 2N3118 oscillator stage develops the low-level excitation signal for the transmitter. The 50-MHz output signal from the collector of the oscillator transistor is coupled by $L_3$ to the base of a second 2N3118 used in a predriver stage (low-level amplifier). This step-down transformer matches the collector impedance of the oscillator transistor to the low-impedance base circuit of the predriver transistor. The collector circuit of the predriver is tuned to provide maximum signal output at 50 MHz. This signal is coupled from a tap on inductor $L_8$ to the input (base) circuit of the driver stage,

## 15-18 50-MHz, 40-WATT CW TRANSMITTER (cont'd)




NOTES: (1) See general considerations for construction of high-frequency and broadband circuits on page 691. (2) This circuit uses coils that are not standard commercial items; such coils must be wound by the circuit builder.

### Parts List

$C_1$ = variable capacitor, 90 to 400 pF, Arco No. 429 or equiv.
$C_2$ = 51 pF, mica
$C_3$ = 30 pF, ceramic
$C_4$, $C_5$, $C_{11}$, $C_{14}$, $C_{19}$, $C_{20}$ = feedthrough capacitor, 1000 pF
$C_6$ = variable capacitor, 1.5 to 20 pF, Arco No. 402 or equiv.
$C_7$ = 36 pF, mica
$C_8$, $C_{16}$, $C_{22}$ = 0.02 $\mu$F, ceramic
$C_9$, $C_{10}$ = variable capacitor, 8 to 60 pF, Arco No. 404 or equiv.
$C_{12}$ = 91 pF, mica
$C_{13}$ = variable capacitor, 0.9 to 7 pF, Vitramon No. 400 or equiv.
$C_{15}$ = variable capacitor, 14 to 150 pF, Arco No. 426 or equiv.
$C_{17}$ = 1000 pF, ceramic
$C_{18}$ = 0.01 $\mu$F, ceramic
$C_{21}$ = variable capacitor, 32 to 250 pF, Vitramon No. 464 or equiv.
$L_1$ = 1 turn of No. 16 wire; inner diameter, 5/16 inch; length, 1/8 inch
$L_2$ = rf choke, 1 $\mu$H
$L_3$ = oscillator coil; primary, 7 turns; secondary, 1-3/4 turns; wound from

## 15-18 50-MHz, 40-WATT CW TRANSMITTER (cont'd)

### Parts List (cont'd)

No. 22 wire on CTC coil form having "white dot" core
$L_4$ = 5 turns of No. 16 wire; inner diameter, 5/16 inch; length, 1/2 inch
$L_5$, $L_7$, $L_9$, $L_{10}$, $L_{11}$ = rf choke, 7 μH
$L_6$ = 4 turns of B & W No. 3006 coil stock
$L_8$ = 6 turns of No. 16 wire; inner diameter, 3/8 inch; length, 3/4 inch
$R_1$, $R_6$ = 510 ohms, 0.5 watt
$R_2$ = 3900 ohms, 0.5 watt
$R_3$, $R_8$ = 2.2 ohms, wire-wound, 0.5 watt; International Resistor Corp. BWH type, or equiv.
$R_4$ = 51 ohms, 0.5 watt
$R_5$ = 24000 ohms, 0.5 watt
$R_7$ = 240 ohms, 0.5 watt
$R_9$ = agc control, potentiometer, 50000 ohms
$R_{10}$ = 5.6 ohms, 1 watt
$T_1$ = current transformer (toroid), Arnold No. A4-437-125-SF, or equiv.
XTAL = 50-MHz transmitting crystal

### Circuit Description (cont'd)

which uses a 2N3375 silicon power transistor to develop the power required to drive the output stage.

The 40341 overlay transistor used in the output stage develops 40 watts of power output at the transmitting frequency of 50 MHz. The driving power for the output stage is coupled from the collector of the driver transistor through a bandpass filter to the base of the output transistor. The filter networks in the collector circuit of the 40341 provide the required harmonic and spurious-frequency rejection. The 50-MHz output from these filter sections is coupled through a length of 50-ohm coaxial line to the antenna. Capacitors $C_6$, $C_9$, and $C_{13}$ are adjusted to provide optimum impedance match between the transmitter and the antenna.

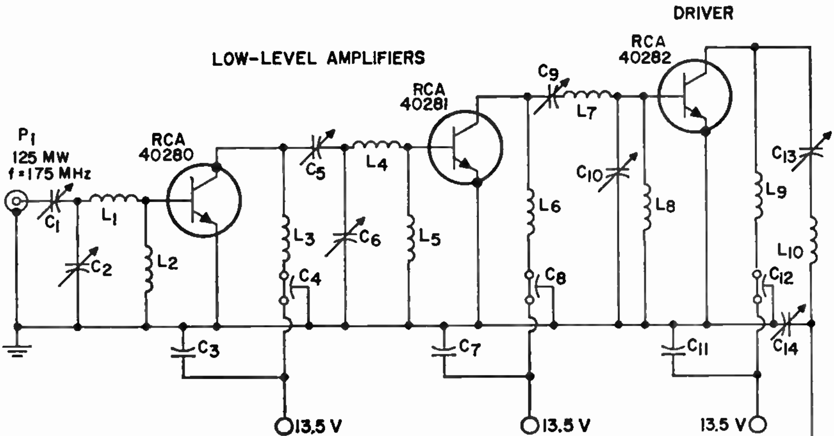
The output of the transmitter is sampled by a current transformer (toroid) $T_1$ loosely coupled about the output transmission line. This transformer is the sensor for a VSWR bridge detector used to prevent excessive dissipation in the output stage under conditions of antenna mismatch. If the antenna is disconnected or poorly matched to the transmitter, large standing waves of voltage and current occur on the output transmission line. A portion of this standing-wave energy is applied by $T_1$ to the 1N3067 diode in the bridge circuit. The rectified current from this diode charges capacitor $C_{18}$ to a dc voltage proportional to the amplitude of the standing waves. This voltage, which is essentially an agc bias, is applied to the base of the 2N3053 agc amplifier stage. The output of the agc stage biases the 2N3118 predriver stage so that its gain changes in inverse proportion to the amplitude of the standing wave on the output transmission line. Therefore, as the amplitude of the standing waves increases (tending to cause higher heat dissipation in the output transistor), the input drive to the output stage is reduced. This compensating effect maintains a steady-state dissipation in the output transistor regardless of mismatch conditions between the transmitter output circuit and the antenna.

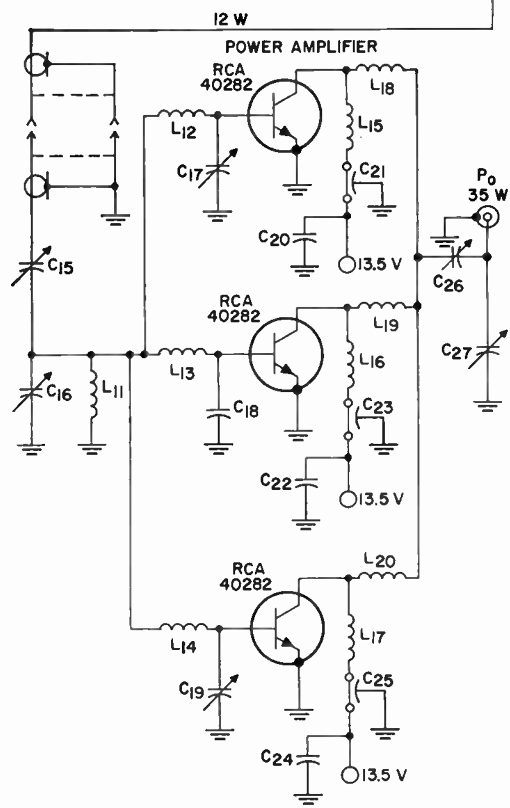
## 15-19 175-MHz, 35-WATT AMPLIFIER

### Circuit Description

This four-stage rf power amplifier operates from a dc supply of 13.5 volts and delivers 35 watts of power output at 175 MHz for an input of 125 milliwatts. The silicon overlay transistors used in the amplifier

## 15-19 175-MHz, 35-WATT AMPLIFIER (cont'd)




### Parts List

$C_1$ = variable capacitor, 3 to 35 pF, Arco No. 403, or equiv.

$C_2$, $C_6$, $C_{16}$, $C_{17}$, $C_{18}$, $C_{19}$, $C_{27}$ = variable capacitor, 8 to 60 pF, Arco No. 404, or equiv.

$C_3$, $C_7$, $C_{11}$ = 0.1 $\mu$F, ceramic disc

$C_4$, $C_8$, $C_{12}$, $C_{21}$, $C_{23}$, $C_{25}$ = feedthrough capacitor, 1500 pF

$C_5$, $C_{10}$, $C_{13}$, $C_{14}$, $C_{26}$ = variable capacitor, 7 to 100 pF, Arco No. 423, or equiv.

$C_9$ = variable capacitor, 14 to 150 pF, Arco No. 424 or equiv.

$C_{15}$ = variable capacitor, 1.5 to 20 pF, Arco No. 402 or equiv.

$C_{20}$, $C_{22}$, $C_{24}$ = 0.2 $\mu$F, ceramic disc

$L_1$ = 2 turns of No. 16 wire; inner diameter, 3/16 inch; length, 1/4 inch

$L_2$, $L_5$, $L_8$ = 450-ohm ferrite rf choke

$L_3$, $L_6$, $L_{11}$ = rf choke, 1.0 $\mu$H

$L_4$, $L_7$ = 3 turns of No. 16 wire; inner diameter, 3/16 inch; length, 1/4 inch

$L_9$ = 1-1/2 turns of No. 16 wire; inner diameter, 1/4 inch; length, 3/8 inch

$L_{10}$ = 2 turns of No. 16 wire; inner diameter, 1/4 inch; length, 5/16 inch

$L_{12}$, $L_{13}$, $L_{14}$ = 5 turns of No. 16 wire; inner diameter, 1/4 inch; length, 1/2 inch

$L_{15}$, $L_{16}$, $L_{17}$ = 2 turns of No. 18 wire; inner diameter, 1/8 inch; length, 1/8 inch

$L_{18}$, $L_{19}$, $L_{20}$ = 2 turns of No. 16 wire; inner diameter, 1/4 inch; length, 1/4 inch

**NOTES:** (1) See general considerations for construction of high-frequency and broadband circuits on page 691. (2) This circuit uses coils that are not standard commercial items; such coils must be wound by the circuit builder.

## 15-19 175-MHz, 35-WATT AMPLIFIER (cont'd)

### Circuit Description (cont'd)

supply maximum output power at this level of dc voltage for use in mobile systems.

The low-level portion of the amplifier consists of three unneutralized, class C, common-emitter rf amplifier stages interconnected by band-pass filters tuned to provide maximum transfer of energy at 175 MHz. The 40280 input stage develops 1 watt of power output when a 125-milliwatt 175-MHz signal is applied to the amplifier input terminal. This output is increased to 4 watts by the 40281 transistor used in the second stage. The 40282 driver transistor then develops 12 watts of driving power for the output stage.

When the low-level stages and the output stage are mounted on separate chassis, the output from the driver stage is coupled to the output stage through a low-loss coaxial line. The line is terminated by variable capacitors $C_{15}$ and $C_{16}$ and inductor $L_{11}$. The capacitors are adjusted to assure a good impedance match between the output of the driver and the input of the output stage at 175 MHz. The driving signal developed across inductor $L_{11}$ is applied to the tuned input networks of three parallel-connected 40282 transistors in the single-ended output stage. For an input of 12 watts, the three 40282 transistors deliver 35 watts of 175-MHz power to the output terminal of the amplifier. Capacitors $C_{26}$ and $C_{27}$ are adjusted to match the amplifier output to the load impedance at the operating frequency.

## 15-20 40-WATT PEAK-ENVELOPE-POWER AIRCRAFT-BAND AMPLIFIER FOR AM TRANSMITTERS

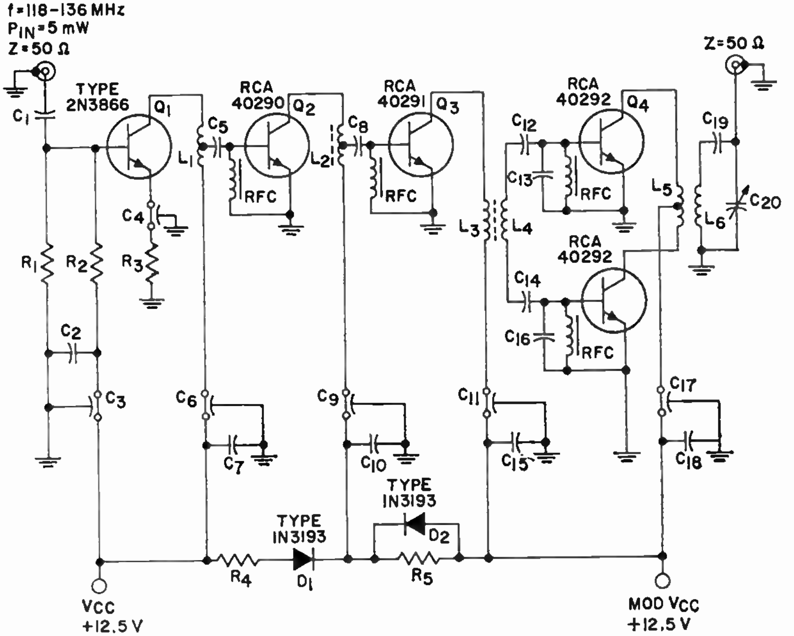
### Circuit Description

This broadband rf power amplifier is intended for use in amplitude-modulated (AM) transmitters operating in the aircraft communication band (118 to 136 MHz). The circuit is simple and easy to duplicate and requires a minimum of adjustments. The amplifier uses 2N3866 and 40290 transistors in a two-stage predriver, a 40291 in the driver stage, and two 40292 transistors in a push-pull output stage. These transistors, which are epitaxial silicon planar types of the "overlay" emitter-electrode construction, are intended for low-voltage, high-power operation in amplitude-modulated class C amplifiers.

In addition to standard breakdown-voltage ratings, the 40290, 40291, and 40292 transistors have rf breakdown-voltage characteristics which assure safe operation with high rf voltage on the collector. The 40292 transistors used in the final amplifier stage are 100-per-cent tested for load mismatch at a VSWR of 3:1. During this test, the transistor is fully modulated to simulate actual operation for added reliability.

The amplifier is capable of delivering peak envelope power of 40 watts at a modulation of 95 per cent with a collector voltage of 12.5 volts dc. Unmodulated drive of 5 milliwatts is required at the input. The over-all efficiency of the amplifier is 48 to 53 per cent, and the envelope distortion is less than 5 per cent for amplitude modulation of 95 per cent.

## 15-20 40-WATT PEAK-ENVELOPE-POWER AIRCRAFT-BAND AMPLIFIER FOR AM TRANSMITTERS (cont'd)




**NOTES:** (1) See general considerations for construction of high-frequency and broadband circuits on page 691. (2) This circuit uses coils that are not standard commercial items; such coils must be wound by the circuit builder.

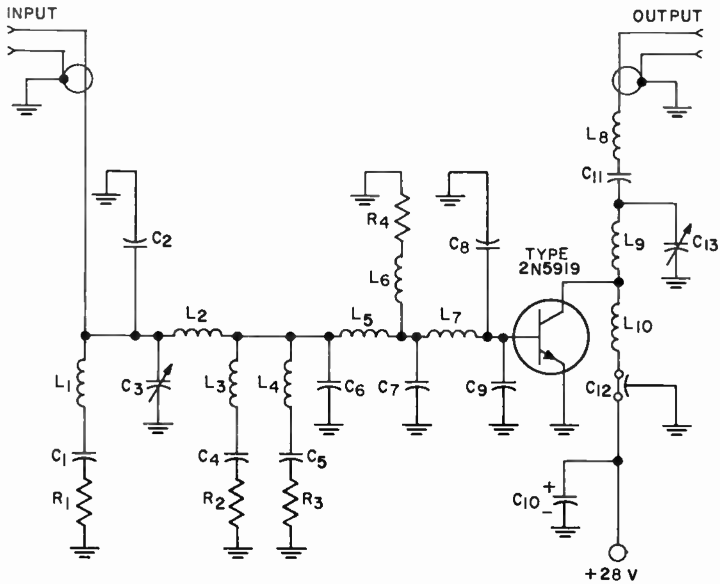
### Parts List

$C_1$ = 300 pF, silver mica
$C_2$ = 0.005 $\mu$F, ceramic
$C_3$, $C_4$, $C_6$, $C_9$, $C_{11}$, $C_{17}$ = Feedthrough capacitor, 1000 pF
$C_5$ = 50 pF, silver mica
$C_7$, $C_{10}$, $C_{15}$, $C_{18}$ = 0.5 $\mu$F, ceramic
$C_8$, $C_{12}$, $C_{14}$ = 82 pF, silver mica
$C_{13}$, $C_{16}$, $C_{19}$ = 150 pF, silver mica
$C_{20}$ = Variable capacitor, 8 to 60 pF, Arco No. 404 or equiv.
$L_1$ = 7 turns of No. 22 wire, 13/64 inch in diameter, 9/16 inch long, tapped at 1.5 turns
$L_2$ = 5.5 turns of No. 22 wire, 13/64 inch in diameter, closely wound on Cambion IRN-9 (or equiv.) core material, tapped at 2 turns
$L_3$ = 6 turns of No. 22 wire, 13/64 inch in diameter, interwind with $L_4$ on Cambion IRN-9 (or equiv.) core material
$L_4$ = 4 turns of No. 22 wire, 13/64 inch in diameter, interwind with $L_3$ on common core
$L_5$ = 5 turns of No. 22 wire, 13/64 inch in diameter, center-tapped; interwind with $L_6$
$L_6$ = Same as $L_5$; interwind with $L_5$
RFC = 1 turn of No. 28 wire, ferrite bead Ferroxcube No. 56-590-65/4B, or equiv.
$R_1$ = 470 ohms, 0.5 watt
$R_2$ = 1500 ohms, 0.5 watt
$R_3$ = 47 ohms, 0.5 watt
$R_4$ = 15 ohms, 0.5 watt
$R_5$ = 33 ohms, 0.5 watt

### Performance Characteristics

| | | |
|---|---|---|
| DC Supply Voltage | 12.5 | V |
| Peak Envelope Power | 40 | W |
| Modulation | 95 | % |
| Efficiency | 48-53 | % |
| Envelope Distortion for 95% AM | $<5$ | % |
| Second Harmonic | $>10$ | dB down |

## 15-21 16-WATT 225-TO-400-MHz POWER AMPLIFIER




NOTES: (1) See general considerations for construction of high-frequency and broadband circuits on page 691. (2) This circuit uses coils that are not standard commercial items; such coils must be wound by the circuit builder.

### Parts List

$C_1$ = Gimmick capacitor, 2.2 pF, Quality Components type 10% QC or equiv.
$C_2$ = 10 pF, silver mica
$C_3$ = Variable capacitor, 0.8 to 10 pF, Johanson No. 3957 or equiv.
$C_4$ = Gimmick capacitor, 1.0 pF, Quality Components type 10% QC or equiv.
$C_5$ = Gimmick capacitor, 1.5 pF, Quality Components type 10% QC or equiv.
$C_6$ = 36 pF, ATC-100 type or equiv.
$C_7$ = 51 pF, ATC-100 type or equiv.
$C_8$ = 68 pF, ATC-100 type or equiv.
$C_9$ = 47 pF, ATC-100 type or equiv.
$C_{10}$ = 1 $\mu$F, electrolytic, 50 V
$C_{11}$ = 12 pF, silver mica
$C_{12}$ = Feedthrough capacitor, 1000 pF, Allen-Bradley No. FA5C or equiv.
$C_{13}$ = Variable capacitor, 0.8 to 20 pF, Johanson No. 4802 or equiv.
$L_1$, $L_3$, $L_4$ = RF choke, 0.18 $\mu$H, Nytronics type P. #DD-0.18 or equiv.
$L_2$ = 1.5 turns*
$L_5$ = Copper strip, 5/8 inch long, 5/32 inch wide
$L_6$ = RF choke, 0.1 $\mu$H, Nytronics type P. #DD-0.10
$L_7$ = Transistor base lead, 0.5 inch long
$L_8$, $L_{10}$ = 3 turns*
$L_9$ = 2 turns*
$R_1$ = 100 ohms, 1 watt
$R_2$, $R_3$ = 100 ohms, 0.5 watt
$R_4$ = 5.1 ohms, carbon, 0.5 watt

* All coils are wound from No. 18 wire with an inner diameter of 5/32 inch and a pitch of 12 turns per inch.

### Circuit Description

This broadband power amplifier provides a constant power output of 16 watts with a gain variation of less than 1 dB over a bandwidth of 225 to 400 MHz for an input driving power of 3 to 4 watts. Two of these amplifiers can be connected in parallel to provide a constant power output of 25 watts over this frequency range. In a 225-to-400-MHz high-power transistor amplifier, a good transistor package is of particular

## 15-21 16-WATT 225-TO-400-MHz POWER AMPLIFIER (cont'd)

### Circuit Description (cont'd)

importance. Low parasitic inductances are essential because the real part of the transistor input impedance is inherently low.

The RCA-2N5919 transistor used in the broadband amplifier features a stripline package specifically designed for use in the 225-to-400-MHz frequency range. This transistor is operated in the Class C mode, as is usually the case in high-power rf amplifiers. If the amplifier is to be used in an amplitude-modulated system, the linearity requirements can be met by use of envelope correction, a slight forward bias, or both. The amplifier operates from a dc supply of 28 volts.

The broad flat response of the amplifier results from the fact that the circuit is designed for the best possible match across the band and that some of the power at the low end of the band is dissipated through dissipative RLC networks. The low input VSWR of the amplifier (maximum of 2 to 1 across the frequency band) verifies the effectiveness of this technique. A low input VSWR is necessary for protection of the driving stage in a cascade connection. A flat response reduces the dynamic range required in the output leveling system.

The collector efficiency of the amplifier has a minimum value of 63 per cent across the frequency band. The second harmonic of a 225-MHz signal is 12 dB down and that of a 400-MHz signal is 30 dB down from the fundamental. This harmonic rejection is excellent for an amplifier that is required to have a bandwidth that covers almost an octave.

## 15-22 "GRID-DIP" METER

For Measuring Resonant Frequencies from 3.5 to 100 MHz

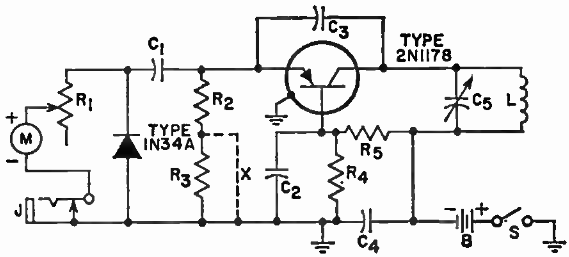
### Circuit Description

This circuit, which is essentially a transistor version of the electron-tube grip-dip meter, determines the frequency of resonant circuits quickly and accurately. Basically, it consists of a 2N1178 common-base rf oscillator stage that can be tuned over a wide frequency range. A 1N34A diode and a dc microammeter are used to show when rf power is being absorbed from the oscillator. The dc power for the oscillator is obtained from a 13.5-volt battery such as the RCA VS304.

Inductor L and capacitor $C_5$ form the oscillator resonant circuit. Feedback to sustain oscillations in the resonant circuit is coupled by capacitor $C_3$ from the collector to the emitter of the 2N1178. RF voltage in the emitter-to-base circuit is coupled by $C_1$ to the 1N34A diode, and the rectified output appears on the dc microammeter. When power is absorbed from the oscillator resonant circuit, rf feedback is reduced, and the reading on the microammeter decreases.

The coil used for inductor L is selected for the operating frequency desired. A frequency-tuning dial mounted on the same shaft with the variable capacitor $C_5$ indicates the operating frequency of the meter. For measurement of the frequency of a resonant circuit, a coil having

## 15-22 "GRID-DIP" METER (cont'd)




### Parts List

B = 13.5 volts, RCA VS304
$C_1$ = 33 pF, mica, 50 V
$C_2$ = 0.01 $\mu$F, paper, 50 V
$C_3$ = 5 pF, mica, 50 V
$C_4$ = 0.01 $\mu$F, paper, 50 V
$C_5$ = variable capacitor, 50 pF, Hammarlund type HF-50 or equivalent
J = phone jack, normally closed
L = plug-in coil
M = microammeter, 0 to 50 $\mu$A, Simpson model 1227 or equivalent
$R_1$ = variable resistor, 0-0.25 megohm, 0.5 watt
$R_2$ = 220 ohms, 0.5 watt
$R_3$ = 3,000 ohms, 0.5 watt
$R_4$ = 3,900 ohms, 0.5 watt
$R_5$ = 39,000 ohms, 0.5 watt
X = jumper, omit for measurements below 45 MHz

### Coil-Winding Data

| Coil | Freq. Range | Wire Size | No. of Turns |
|---|---|---|---|
| 1 | 3.4-6.9 MHz | #28, enamel | 48¼, close wound |
| 2 | 6.7-13.5 MHz | #24, enamel | 22, close wound |
| 3 | 13-27 MHz | #24, enamel | 9⅛, close wound |
| 4 | 25-47 MHz | #24, enamel | 4⅛, close wound |
| 5 | 46-78 MHz | #24, enamel | 1½, close wound |
| 6 | 74-97 MHz | #16, tinned | hairpin formed, 1⅞ inches long including pins, and ¼ inch wide |

**Coil forms are Amphenol type 24-5H or equivalent.**

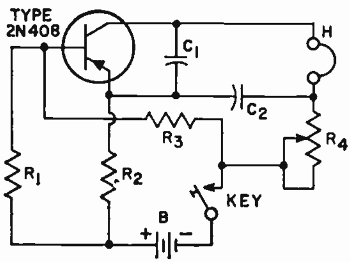
a suitable frequency range is inserted in the grid-dip meter, and the meter control knob is adjusted for a reading of about half-scale. The grid-dip meter is then tightly coupled to the unknown tuned circuit, and the tuning dial is rotated until a dip in the meter reading occurs. When transmitter tank circuits are measured, the transmitter plate supply must be turned off to eliminate danger of shock.

## 15-23 CODE-PRACTICE OSCILLATOR

### Circuit Description

This simple audio oscillator operates from a dc supply of 1.5 to 4.5 volts, depending on the amount of output desired. Magnetic headphones provide an audible indication of keying. When the key is closed, the 2N408 transistor supplies energy to the resonant circuit formed by capacitors $C_1$ and $C_2$ and the inductance of the headphones, and this circuit resonates to produce an audio tone in the headphones. Positive feedback to sustain oscillation is coupled from the resonant circuit through $C_1$ and $C_2$ to the emitter of the 2N408. $R_4$ is adjusted to obtain the desired level of sound from the headphones.

## 15-23 CODE-PRACTICE OSCILLATOR (cont'd)




### Parts List

B = 1.5-4.5 V (One to three series-connected RCA VS036 dry cells may be used, depending upon the volume level desired.)

$C_1$, $C_2$ = 0.1 $\mu$F, paper, 150 V

H = Headphone, 2000-ohm, magnetic

$R_1$ = 2200 ohms, 0.5 watt

$R_2$ = 27000 ohms, 0.5 watt

$R_3$ = 3000 ohms, 0.5 watt

$R_4$ = volume control potentiometer, 50000 ohms, 0.5 watt

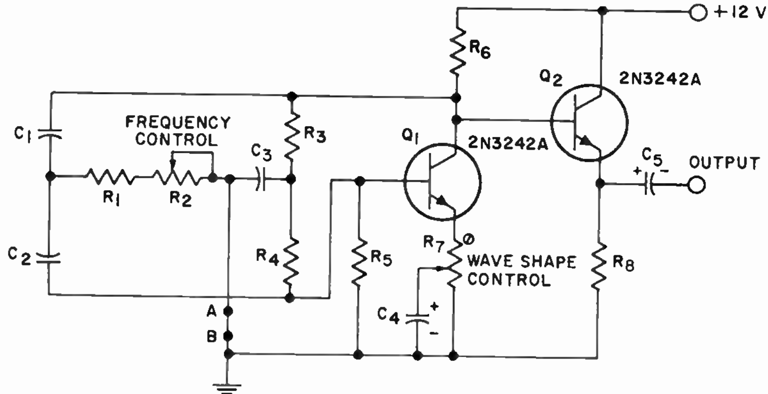
## 15-24 AUDIO OSCILLATOR

### Circuit Description

This basic audio-oscillator circuit may be used to provide a single-tone sine-wave output at any frequency to well above 100 kHz. (A chart of capacitance values is shown for different frequencies of operation.) The circuit is excellently suited for use in the testing of high-fidelity audio equipment and amateur radio transmitters; it can also be adapted for use as a code-practice oscillator. (A keyer can be inserted between points A and B.) The oscillator operates from a dc supply of 12 volts and supplies a relatively distortion-free output waveform to any circuit that has an input impedance of 3000 ohms or more.

The 2N3242A amplifier transistor $Q_1$, capacitors $C_1$, $C_2$, $C_3$, and $C_4$, and resistors $R_1$, $R_2$, and $R_3$ form a basic twin-T oscillator circuit. A portion of the signal developed at the collector of transistor $Q_1$ is applied to the twin-T network formed by $C_1$, $C_2$, $C_3$, $R_1$, $R_2$, $R_3$, and $R_4$. Potentiometer $R_2$ provides an adjustment of approximately ±10 per cent in the oscillator frequency. The output of this network is then coupled to the base of transistor $Q_1$ through capacitor $C_4$ to supply the positive feedback required to sustain oscillation. The oscillator-stage output from the collector of transistor $Q_1$ is applied to the base of the 2N3242A output transistor $Q_2$, which is operated in an emitter-follower circuit configuration. This stage amplifies the oscillator output to provide the sine-wave output signal. Potentiometer $R_7$ in the emitter circuit of transistor Q, is adjusted to obtain the desired output waveform.

## 15-24 AUDIO OSCILLATOR (cont'd)




### Parts List

$C_1$, $C_2$ = see chart for value, mica or paper
$C_3$ = twice the value of $C_1$, mica or paper
$C_4$ = 1 $\mu$F, electrolytic, 12 V
$C_5$ = 300 $\mu$F for frequencies below 2000 Hz or 5 $\mu$F for frequencies above 2000 Hz, electrolytic, 6 V
$C_6$ = 20 $\mu$F, electrolytic, 6 V
$R_1$ = 2700 ohms, 0.5 watt
$R_2$ = Frequency control, potentiometer, 5000 ohms, 0.5 watt
$R_3$, $R_4$ = 51000 ohms, 0.5 watt
$R_5$ = 22000 ohms, 0.5 watt
$R_6$ = 4700 ohms, 0.5 watt
$R_7$ = Wave-shape control, potentiometer, 250 ohms, 0.5 watt
$R_9$ = 820 ohms, 0.5 watt

### Capacitor Selection Chart for Different Operating Frequencies

| *Approx. Freq. (Hz)* | *Value of $C_1$ and $C_2$* |
|---|---|
| 100,000 | 50 pF |
| 50,000 | 100 pF |
| 10,000 | 500 pF |
| 5,000 | 1000 pF |
| 1,000 | 0.005 MF |
| 500 | 0.01 $\mu$F |
| 100 | 0.05 $\mu$F |
| 50 | 0.1 $\mu$F |
| 10 | 0.5 $\mu$F |
| 5 | 1 $\mu$F |

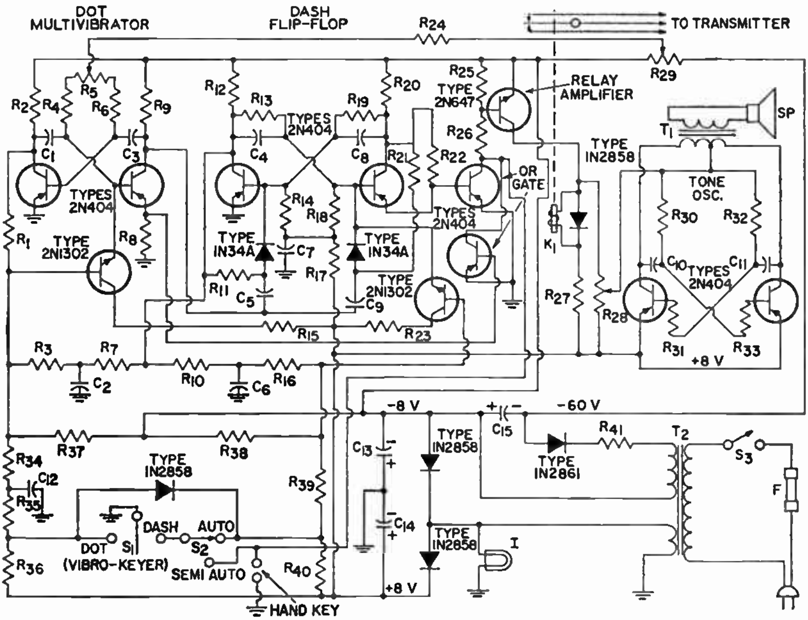
## 15-25 ELECTRONIC KEYER

### Circuit Description

This compact electronic keyer can be used for automatic keying of a cw transmitter at speeds up to 60 words per minute. Two multivibrator trigger circuits using 2N404 transistors automatically control the dot and dash transmissions. A "Vibro-Keyer", which is spring-loaded to the OFF position, selects the type of transmission desired. Unless the "Vibro-Keyer" is moved to either the DOT or the DASH position, both multivibrators are held inoperative by the biasing action of 2N1302 clamping circuits.

When the "Vibro-Keyer" $S_1$ is deflected to the DOT position, the first 2N1302 clamp transistor becomes inoperative, and the dot multivibrator is allowed to operate as a free-running circuit. Feedback circuits in the multivibrator assure continued operation, regardless of whether $S_1$ remains in the DOT position, long enough to develop the square-wave output that controls both the dura-

## 15-25 ELECTRONIC KEYER (cont'd)




### Parts List

$C_1$, $C_3$ = 1 $\mu$F, paper (or Mylar), 200 V
$C_2$ = 0.47 $\mu$F, ceramic, 25 V
$C_4$, $C_8$ = 560 pF, ceramic, 600 V
$C_5$, $C_9$ = 330 pF, ceramic, 600 V
$C_6$, $C_7$ = 0.01 $\mu$F, ceramic, 50 V
$C_{10}$, $C_{11}$ = 0.02 $\mu$F, ceramic, 50 V
$C_{12}$ = 0.1 $\mu$F, ceramic, 50 V
$C_{13}$, $C_{14}$ = 2000 $\mu$F, electrolytic, 15 V
$C_{15}$ = 16 $\mu$F, electrolytic, 150 V
F = fuse, 1 ampere
I = indicator lamp No. 47
K = dc relay; coil resistance =1350 ohms; Potter & Brumfield RS5D-V or equiv.
$R_1$ = 39000 ohms, 0.5 watt
$R_2$, $R_9$, $R_{12}$, $R_{20}$ = 3900 ohms, 0.5 watt
$R_3$, $R_{16}$ = 18000 ohms, 0.5 watt
$R_4$, $R_6$ = 51000 ohms, 0.5 watt
$R_5$, $R_{29}$ = potentiometer, 10000 ohms
$R_7$, $R_{10}$ = 22000 ohms, 0.5 watt
$R_8$, $R_{22}$ = 180 ohms, 0.5 watt
$R_{11}$, $R_{21}$ = 15000 ohms, 0.5 watt
$R_{13}$, $R_{19}$ = 33000 ohms, 0.5 watt
$R_{14}$, $R_{18}$, $R_{30}$, $R_{32}$ = 27000 ohms, 0.5 watt
$R_{15}$, $R_{23}$ = 270 ohms, 0.5 watt
$R_{17}$ = 68000 ohms, 0.5 watt
$R_{24}$ = 100000 ohms, 0.5 watt
$R_{25}$ = 68 ohms, 0.5 watt
$R_{26}$ = 560 ohms, 0.5 watt
$R_{27}$ = 620 ohms, 0.5 watt
$R_{28}$ = volume-control potentiometer, 50000 ohms
$R_{31}$, $R_{33}$ = 10000 ohms, 0.5 watt
$R_{34}$ = 6800 ohms, 0.5 watt
$R_{35}$ = 8200 ohms, 0.5 watt
$R_{36}$, $R_{39}$, $R_{40}$ = 15000 ohms, 0.5 watt
$R_{37}$, $R_{38}$ = 47000 ohms, 0.5 watt
$R_{41}$ = 10000 ohms, 1 watt
$S_1$ = Vibroplex keyer, or equiv.
$S_2$ = toggle switch, double-pole, double-throw
$S_3$ = toggle switch; single-pole, single-throw
$T_1$ = push-pull output transformer (14000 ohm to V.C.), Stancor No. A3496, or equiv.
$T_2$ = power transformer, Stancor PS8415, PS8421, or equiv.

### Circuit Description (cont'd)

tion of the dot and the space that follows it. When $S_1$ is set to the DASH position, both clamp transistors become inoperative. The dot multivibrator and the dash flip-flop then operate simultaneously. The dash flip-flop is triggered by the positive pulses from the dot multivibrator. The 1N34A steering diodes prevent triggering of the flip-flop by negative pulses. Because two positive pulses are required to produce

## 15-25 ELECTRONIC KEYER (cont'd)

### Circuit Description (cont'd)

one complete cycle of output from the flip-flop, the frequency of this circuit is one-half that of the dot multivibrator.

The square-wave outputs from the dot multivibrator and the dash flip-flop are coupled to two more 2N404 transistors used in an OR gate circuit. During the positive half-cycle of the square-wave inputs, the OR gate conducts to remove the cutoff bias from the 2N647 relay amplifier, which controls the operation of keying relay $K_1$. The relay is then energized, and its contacts close for the period required to key the transmitter for the selected type of transmission. One section of $K_1$ may be used to mute the receiver during key-down periods. Because the OR gate circuit is keyed successively by signals from the dot multivibrator and the dash flip-flop in the formation of a dash, the duration of a dash is three times that of a dot.

The keying speed of this electronic keyer is determined by the frequency of the dot multivibrator. This frequency is adjustable by means of potentiometer $R_{29}$, which varies the amplitude of the negative dc voltage. As the negative voltage at the armature of potentiometer $R_5$ is increased to a maximum value of 60 volts, the keying speed is increased to a maximum of 60 words per minute. Potentiometer $R_5$ controls the ratio of "on time" to "off time" of the dot multivibrator transistors, and thus determines the duration of both dot and dash transmissions and the minimum spacing between successive transmissions. The over-all keying speed is not affected by this adjustment.

The electronic keyer may also be operated as a semiautomatic key ("bug") when selecter switch $S_2$ is placed in the SEMIAUTO position. Dots are still produced automatically, but the automatic keying circuits are bypassed when $S_1$ is moved to the DASH position. The formation of dashes is then controlled manually. When $S_2$ is in the MAN position, a hand key (connected across the terminals marked HAND KEY) may be used for manual control of the keyer; the automatic keying circuits are then bypassed during the formation of both dots and dashes.

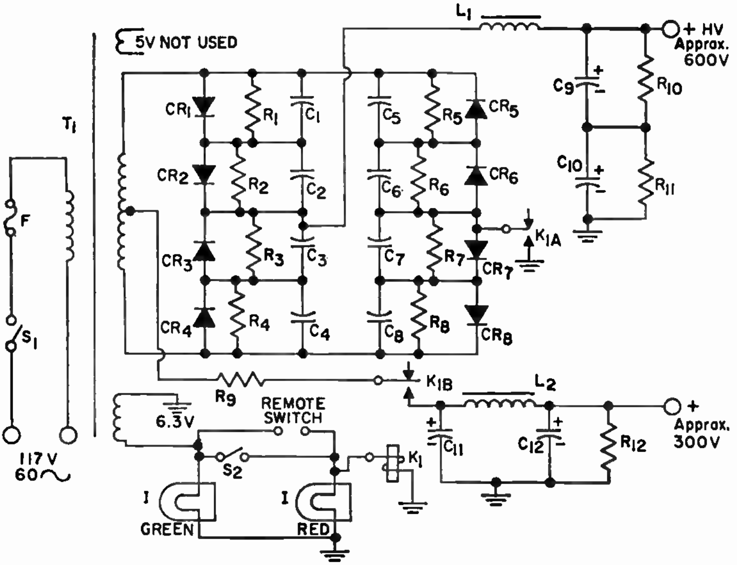
The keyer operates from a 117-volt, 60-Hz ac power input applied through a step-down power transformer $T_2$. The ac input voltage is converted to the negative dc voltage used to control keying speed by a 1N2861 half-wave rectifier circuit. Two other 2N2861 diodes are used in a voltage-doubler circuit that operates from the 6.3-volt secondary winding of transformer $T_2$ to produce the dc supply voltage for the various circuits in the keyer. A 2N404 tone oscillator, which is gated on by the relay-amplifier circuit, provides an audible indication of keying.

## 15-26 POWER SUPPLY FOR AMATEUR TRANSMITTER
### 600 Volts; 300 Volts; Total Current 330 Milliamperes (Intermittent Duty)

### Circuit Description

This power supply uses eight 1N2864 silicon diodes in series-connected pairs in a bridge-rectifier circuit to supply a 600-volt dc output from a 117-volt ac input. The second set of diode pairs ($CR_5$ through $CR_8$) is also used in a conventional full-wave rectifier circuit

## 15-26 POWER SUPPLY FOR AMATEUR TRANSMITTER (cont'd)




**Parts List**

$C_1$ $C_2$ $C_3$ $C_4$ $C_5$ $C_6$ $C_7$ $C_8$ = 0.001 μF, ceramic disc, 1000 V
$C_9$, $C_{10}$, $C_{11}$, $C_{12}$ = 40 μF, electrolytic, 450 V
$CR_1$ $CR_2$ $CR_3$ $CR_4$ $CR_5$ $CR_6$ $CR_7$ $CR_8$ = RCA-1N2864
F = fuse, 5 amperes
I = indicator lamp
$K_1$ = relay; Potter and Brumfield KA11AY or equiv.
$L_1$ = 2.8 henries, 300 mA; Stancor C-2334 or equiv.
$L_2$ = 4 henries, 175 mA; Stancor C-1410 or equiv.
$R_1$ $R_2$ $R_3$ $R_4$ $R_5$ $R_6$ $R_7$ $R_8$ = 0.47 megohm, 0.5 watt
$R_9$ = 47 ohms, 1 watt
$R_{10}$ $R_{11}$ = 15000 ohms, 10 watts
$R_{12}$ = 47000 ohms, 2 watts
$S_1$ $S_2$ = toggle switch, single-pole single-throw
T = power transformer; Stancor P-8166 or equiv.

**Circuit Description (cont'd)**

to supply a 300-volt dc output. Series-connected pairs of diodes are used to provide the rectification in this circuit because the peak-inverse-voltage rating of such combinations is twice that of a single diode.

The operation of the power supply is controlled by two switches. When the ON-OFF switch $S_1$ is closed, the 117-volt 60-c/s ac input power is applied across the primary of the step-up power transformer $T_1$. The power supply does not become operative, however, until switch $S_2$ is also closed. Relay $K_1$ is then energized, and the closed contacts of the relay complete the ground return paths for the power-supply circuits. Switch $S_2$ can be used as a STANDBY switch for the transmitter, or another switch may be connected in parallel with $S_2$ so that the standby-to-on function can be controlled from a remote location.

During the half-cycle of ac input for which the voltage across the secondary winding of $T_1$ is positive at the top end and negative at the bottom end, current flows from the bottom of the secondary through diodes $CR_7$ and $CR_8$ (which are oriented in the proper direction), out the $K_{1A}$ section of the relay contacts to ground, and then up through

## 15-26 POWER SUPPLY FOR AMATEUR TRANSMITTER (cont'd)

### Circuit Description (cont'd)

bleeder resistors $R_{10}$ and $R_{11}$ and the external load connected in shunt with the resistors to develop the 600-volt output. The return flow is completed through filter choke $L_1$, diodes $CR_1$ and $CR_2$, and the entire secondary winding. During the next half-cycle of the ac input, the polarity of the voltage across the secondary reverses, and the current flows through diodes $CR_5$ and $CR_6$, through the bleeder resistors and the external load circuit in the same direction as before, and then through diodes $CR_3$ and $CR_4$. Capacitors $C_9$ and $C_{10}$ and choke $L_1$ provide the filtering to smooth out the pulsations in the 600-volt dc output.

For the 300-volt dc output, only one-half the voltage across the secondary winding of $T_1$ is required. The $CR_5$-$CR_6$ and $CR_7$-$CR_8$ diode pairs are operated in a full-wave rectifier configuration to provide this output (diodes $CR_1$ through $CR_4$ are not included in the 300-volt circuit.) The current flow through the diode pairs is the same as described before, but the current is directed from the relay contacts up through bleeder resistor $R_{12}$ and the external load circuit. The return flow is through choke $L_2$ and the transformer center tap. Capacitors $C_{11}$ and $C_{12}$ and choke $L_2$ provide the filtering for the 300-volt dc output.

## 15-27 VOLTAGE REGULATOR, SERIES TYPE

### With Adjustable Output

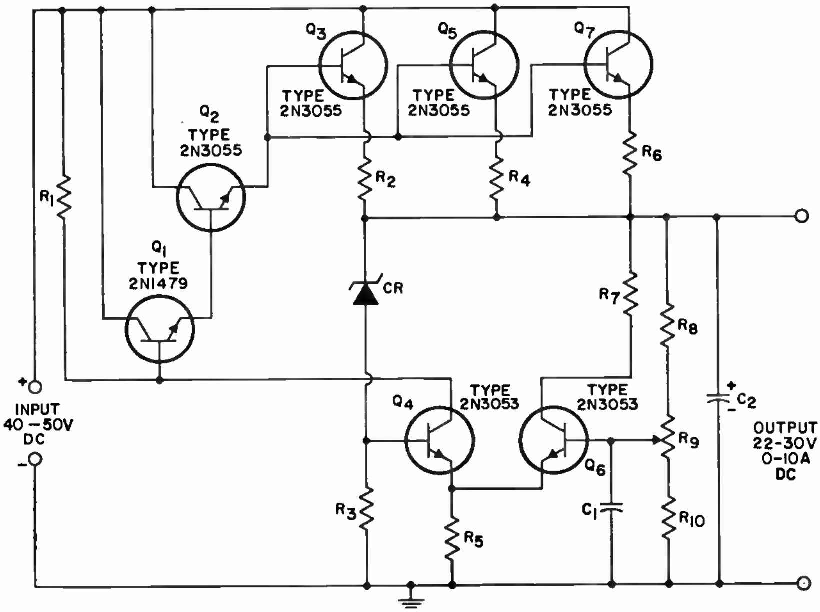
**Line Regulation within 1.0%** **Load Regulation within 0.5%**

### Circuit Description

In this series-type voltage regulator, regulation is accomplished by varying the current through three paralleled 2N3055 transistors connected in series with the load circuit. A reverse-bias-connected Zener diode provides the reference voltage for the circuit. The voltage drop across this diode remains constant at the reference potential of 12 volts over a wide range of current through the diode.

If the output voltage tends to rise for any reason, the total increase in voltage is distributed across bleeder resistors $R_8$, $R_9$, and $R_{10}$. If potentiometer $R_9$, the output-voltage adjustment, is set to the mid-point of its range, one-half the increase in output voltage is applied to the base of the 2N3053 transistor $Q_6$. This increased voltage is coupled (through the emitter-to-base junction of transistor $Q_6$) to the base of the 2N3053 transistor $Q_4$ by $R_5$, the common emitter resistor for the two transistors. The reference diode CR and its series resistor $R_3$ are connected in parallel with the bleeder resistors, and the increase in output voltage is also reflected across the diode-resistor network. However, because the voltage drop across CR remains constant, the full increase in voltage is developed across $R_3$ and thus is applied directly to the base of $Q_4$. Because the increase in voltage at the base is higher than that at the emitter, the collector current of the transistor $Q_4$ increases.

## 15-27 VOLTAGE REGULATOR, SERIES TYPE (cont'd)




**Parts List**

$C_1$ = 1 $\mu$F, paper, 25 V
$C_2$ = 100 $\mu$F, electrolytic, 50 V
CR = reference diode, 12 V, 1 watt
$R_1$ = 1200 ohms, 0.5 watt
$R_2$, $R_4$, $R_6$ = 0.1 ohm, 5 watts
$R_3$ = 2000 ohms, 0.5 watt
$R_5$ = 570 ohms, 0.5 watt
$R_7$ = 270 ohms, 0.5 watt
$R_8$ $R_{10}$ = 1000 ohms, 0.5 watt
$R_9$ = potentiometer, 1000 ohms, 0.5 watt

**Circuit Description (cont'd)**

As the collector current of $Q_4$ increases, the base voltage of the 2N1479 transistor $Q_1$ decreases by the amount of the increased drop across $R_1$. The resultant decrease in current through the 2N1479 transistor $Q_1$ causes a decrease in the emitter voltage of this transistor. The resultant decrease in current through transistor $Q_1$ causes a decrease in the emitter voltage and thus in the base voltage of the 2N3055 transistor $Q_2$. Similar action by $Q_2$ results in a negative-going voltage at the bases of transistors $Q_3$, $Q_5$, and $Q_7$. As a result, the current through these transistors, and through the load impedance in series with them, decreases. The decrease in load current tends to reduce the voltage developed across the load circuit to cancel the original tendency for an increase in the ouput voltage. Similarly, if the output voltage tends to decrease, the current through the three paralleled 2N3055 transistors and through the load circuit increases, so that the output voltage remains constant.

## 15-28 VOLTAGE REGULATOR, SHUNT TYPE

### Regulation 0.5%

### Circuit Description

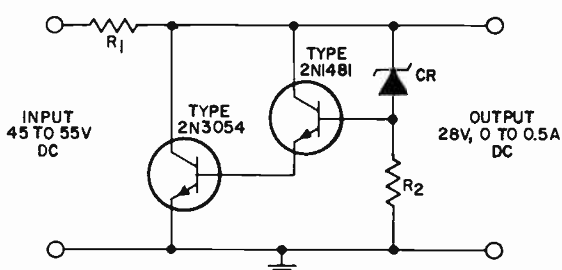
This simple two-transistor shunt-type voltage regulator can provide a constant (within 0.5 per cent) dc output of 28 volts for load currents up to 0.5 ampere and dc inputs from 45 to 55 volts. The two transistors operate as variable resistors to provide the output regulation. A 27-volt zener reference diode is used as the control, or sensing, element.

With a 28-volt output, the reverse-bias-connected reference diode, CR, operates in the breakdown-voltage region. In this region, the voltage drop across the diode remains constant (at the reference potential of 27 volts) over a wide range of reverse currents through the diode.

The output voltage tends to rise with an increase in either the applied voltage or the load-circuit impedance. The current through resistor $R_2$ and reference diode CR then increases. However, the voltage drop across CR remains constant at 27 volts, and the full increase in the output voltage is developed across $R_2$. This increased voltage across $R_2$ is directly coupled to the base of the 2N1481 transistor and increases the forward bias so that the 2N1481 conducts more heavily. The rise in the emitter current of the 2N1481 increases the forward bias on the 2N3054, and the current through this transistor also increases.

As the increased currents of the transistors flow through resistor $R_1$, which is in series with the load impedance, the voltage drop across $R_1$ becomes a larger proportion of the total applied voltage. In this way, any tendency for an increase in the output voltage is immediately reflected as an increased voltage drop across $R_1$ so that the output voltage delivered to the load circuit remains constant.

If the output voltage tends to decrease slightly, the voltage drop across reference diode CR still remains constant, and the full decrease occurs across $R_2$. As a result, the forward bias of both transistors decreases so that less current flows through $R_1$. The resultant decrease in the proportional amount of the applied voltage dropped across this resistor immediately cancels any tendency for a decrease in the output voltage, and the voltage applied to the load circuit again remains constant.




### Parts List

CR = reference diode, 27 V, 0.5 watt

$R_1$ = 28 ohms, 50 watts (includes source resistance of transformers, rectifiers, etc.)

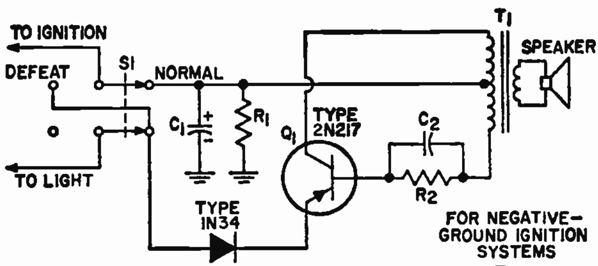
$R_2$ = 1000 ohms, 0.5 watt

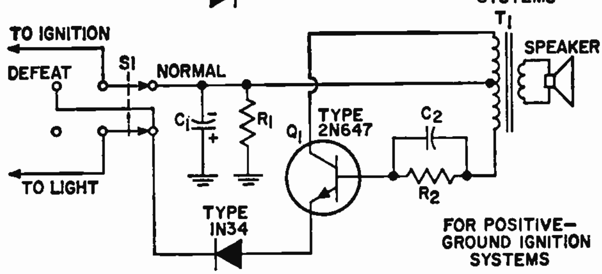
## 15-29 LIGHT MINDER FOR AUTOMOBILES

### Circuit Description

This light-minder circuit sounds an alarm if the lights of a car are left on when the ignition is turned off. The alarm stops when the lights are turned off. When the lights are intentionally left on, the alarm can be "defeated" so that no warning sounds. The alarm then sounds when the ignition switch is turned on as a reminder that the system has been "defeated" and the switch should be returned to its "normal" position.

The circuit is essentially an oscillator that obtains its supply voltage from two possible sources, the ignition system or the light system of the car. In the "normal" mode of operation, the ignition system is connected to the collector circuit of the 2N217 (or 2N647) transistor, and the light system is connected through the 1N34 diode to the 2N217 (or 2N647) emitter. When the ignition switch is on, the collector of the transistor is at the supply voltage. If, at the same time, the lights are on, the emitter of the transistor is also at the supply voltage. Because both the emitter and the collector are at the same voltage, the circuit does not oscillate and no alarm sounds. When the ignition is turned off, the collector is returned to ground through $R_1$ and $C_1$, but the emitter remains at the supply voltage and provides the necessary bias for the circuit to oscillate. Turning the lights out removes the supply voltage and stops the oscillation.




### Parts List

$C_1$ = 30 $\mu$F, electrolytic, 25 volts
$C_2$ = 0.22 $\mu$F, 25 volts
$R_1$ = 680 ohms, 0.5 watt
$R_2$ = 15000 ohms, 1 watt

$S_1$ = switch, double-pole, double-throw
Speaker = 1½-inch permanent-magnet type; voice-coil impedance, 3.2 ohms

$T_1$ = audio-output transformer; 400-ohm primary, 3.2-ohm secondary; Stancor No. TA-42 or equiv.

## 15-29 LIGHT MINDER FOR AUTOMOBILES (cont'd)

### Circuit Description (cont'd)

In the "defeat" mode of operation, the ignition system is connected through the 1N34 diode to the emitter of the transistor, and the light system is completely disconnected. The lights can then be turned on without the alarm sounding. When the ignition is turned on, it supplies the necessary voltage to the emitter of the transistor so that the circuit oscillates and causes the alarm to sound.

## 15-30 BATTERY CHARGERS
## For 6- and 12-Volt Automobile Batteries

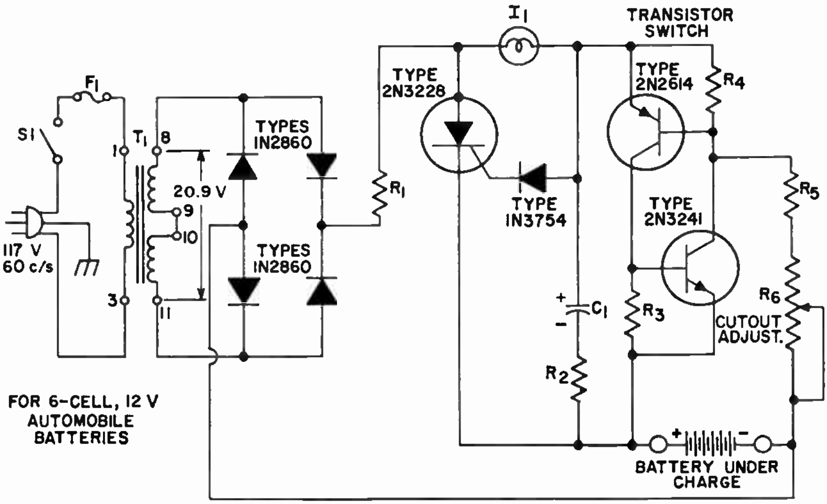
### Circuit Description

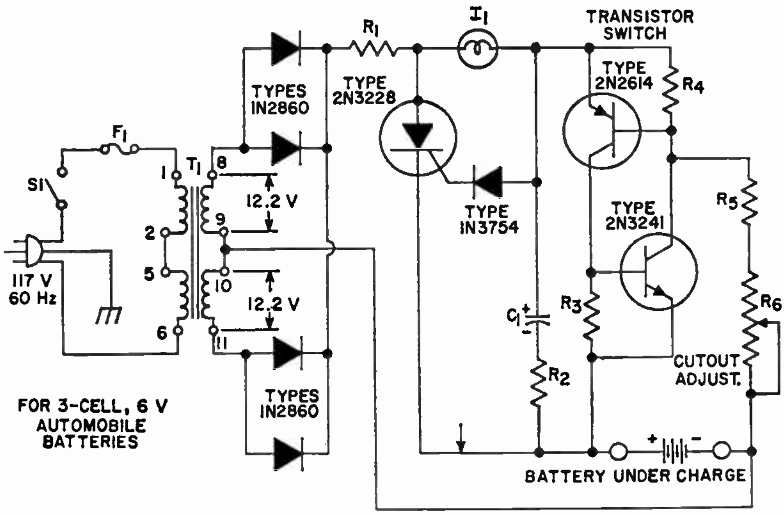
These battery chargers can be used to recharge run-down batteries in automobiles and other vehicles without removing them from their original mounting and without the need for constant attention. When the battery is fully charged, the charger circuits automatically switch from charging current to "trickle" charge, and an indicator lamp lights to provide a visual indication of this condition.

12-Volt Battery Charger—This circuit can be used to charge 6-cell, 12-volt lead storage batteries at a maximum charging rate of 2 amperes. When switch $S_1$ is closed, the rectified current produced by the four 1N2860 silicon diodes in the full-wave bridge rectifier charges capacitor $C_1$ through resistors $R_1$ and $R_2$ and the No. 1488 indicator lamp, $I_1$. As $C_1$ charges, the anode of the 1N3754 diode is rapidly raised to a positive voltage high enough so that the diode is allowed to conduct. Gate current is then supplied to the 2N3228 SCR to trigger it into conduction. The SCR and the battery under charge then form essentially the full load on the bridge rectifier, and a charging current flows through the battery that is proportional to the difference in potential between the battery voltage and the rectifier output. Resistor $R_1$ limits the current to a safe value to protect the 1N2860 rectifier diodes in the event that the load is a "dead" battery. The energy stored in $C_1$ assures that the SCR conducts and, thereby, that the charging current flows for practically the full 180 degrees of each successive half-cycle of input until the battery is fully charged. (The SCR is actually cut off near the end of each half-cycle but is retriggered shortly after the beginning of each succeeding half-cycle by the gate current applied through the 1N3754 diode as a result of the steady potential on $C_1$.)

When the battery is fully charged, the two-transistor regenerative switch is triggered into conduction (the triggering point is preset by means of potentiometer $R_6$). As a result of the regenerative action, the 2N2614 and 2N3241 transistors in the switch are rapidly driven to saturation and thus provide a low-impedance discharge path for $C_1$. The capacitor then discharges through these transistors and resistor $R_2$ to about 1 volt (the voltage drop across the transistors). This value is too low to sustain conduction of the 1N3754 diode, and the 2N3228 SCR is not triggered on the succeeding half-cycle of the input. The saturated transistor switch also provides a low-resistance path for the current to the No. 1488 indicator lamp, which glows to signal the

## 15-30 BATTERY CHARGERS (cont'd)




**NOTE:** Heat sinks are required for the 1N2860 rectifiers. A simple, effective method is to mount the rectifiers in fuse clips.

### Parts List

$C_1$ = 50 μF, electrolytic, 15 V
$F_1$ = fuse, 1-ampere, 3 AG
$I_1$ = pilot lamp, No. 1488 (14 V, 150 mA) for 12-volt system or No. 47 (6.3 V, 150 mA) for 6-volt system
$R_1$ = 5 ohms, 20 watts for 12-volt system or 2 ohms, 25 watts for 6-volt system
$R_2$ = 33 ohms, 0.5 watt
$R_3$ = 470 ohms, 0.5 watt
$R_4$ = 150 ohms, 0.5 watt
$R_5$ = 1800 ohms, 0.5 watt
$R_6$ = potentiometer, cutoff adjustment, 10000 ohms, 2 watts
$S_1$ = toggle switch, single-pole, single-throw, 3-ampere, 125-volt
$T_1$ = power transformer, Stancor No. RT-202, or equiv.

## 15-30 BATTERY CHARGERS (cont'd)

### Circuit Description (cont'd)

fully charged condition of the battery. The current in the lamp circuit ($R_1$, lamp, and transistor switch) provides a "trickle" charge of approximately 150 milliamperes to the battery.

6-Volt Battery Charger—This circuit can be used to charge 3-cell, 6-volt lead storage batteries at a maximum charging rate of 3.2 amperes. It is very similar to the 12-volt battery charger except for the rectifier configuration. In the 6-volt circuit, the four 1N2860 diodes are connected in a full-wave center-tapped rectifier circuit that provides the higher charging current of 3.2 amperes to the 6-volt battery. With the exception of the rectifier circuit, the indicator lamp, and the value used for $R_1$, the 6-volt charger is identical to the 12-volt charger and operates in the same way.

## 15-31 INTEGRAL-CYCLE TEMPERATURE CONTROLLER

### Circuit Description

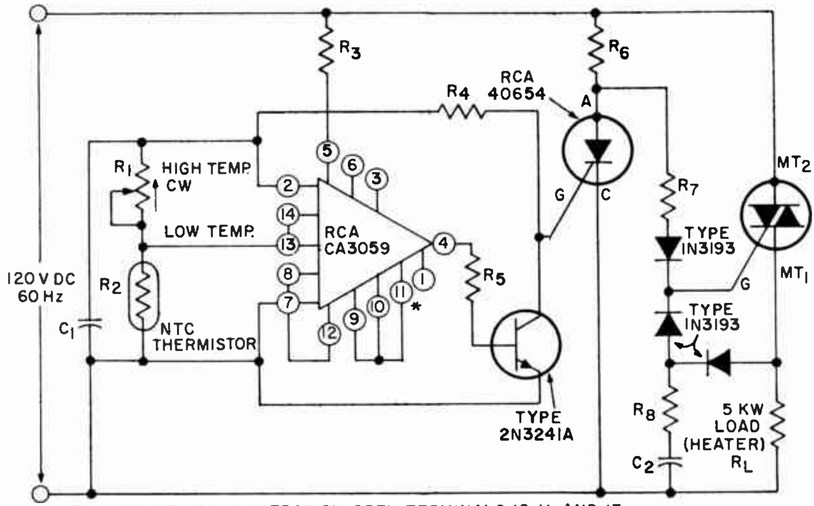
This temperature controller employs a CA3059 integrated-circuit zero-voltage switch, a 2N3241A transistor, a 40654 SCR, and a 2N5444 triac to control the ac power applied to an electric heating element. This circuit is completely devoid of half-cycling and hysteresis effects and includes a fail-safe feature (integral feature of the CA-3059) that causes power to be removed from the load (i.e., the triac is turned off) if the temperature sensor should be accidentally opened or shorted.

The sensor used with the controller is a negative-temperature-coefficient (NTC) thermistor, which is connected between terminals 7 and 13 of the CA3059. When the temperature being controlled is low, the resistance of the thermistor is high. For this condition, the CA3059 produces a positive-voltage output at terminal 4. The 2N3241A transistor inverts this voltage, and the 40654 SCR is not turned on. The 2N5444 triac is then triggered directly from the line on positive alternations of the ac voltage. When the triac is triggered, power is applied to the heating element ($R_L$), and capacitor $C_2$ is charged to the peak of the input ac voltage. When the ac line voltage swings negative, the capacitor discharges through the triac gate to trigger the triac. The diode-resistor-capacitor "slaving" network triggers the triac on negative alternations of the ac input after it has been triggered on positive alternations to provide only integral cycles of ac power to the load.

When the temperature being controlled rises to the desired level, the resistance of the thermistor decreases significantly, and a zero-voltage output is obtained at terminal 4 of the CA3059. The positive voltage that then appears at the collector of the 2N3241A transistor is applied to the gate of the 40654 SCR. The SCR then starts to conduct at the beginning of the positive alternation of the ac input voltage so that the trigger current is shunted away from the gate of the triac. The triac is then turned off. The cycle is repeated when the SCR is again turned off by the reversal of the polarity of the ac input voltage.

This circuit can be converted into

## 15-31 INTEGRAL-CYCLE TEMPERATURE CONTROLLER (cont'd)




* FOR PROPORTIONAL OPERATION OPEN TERMINALS 10, 11, AND 13, AND CONNECT POSITIVE RAMP VOLTAGE TO TERMINAL 13

### Parts List

$C_1$ = 100 µF, electrolytic 15 V
$C_2$ = 0.5 µF, 200 V
$R_1$ = Temperature-control potentiometer
$R_2$ = Negative-temperature-coefficient thermistor
$R_3$ = 5000 ohms, 5 watts
$R_4$ = 1500 ohms, 0.5 watt
$R_5$ = 10000 ohms, 0.5 watt
$R_6$ = 2200 ohms, 5 watts
$R_7$ = 1000 ohms, 0.5 watt
$R_8$ = 1000 ohms, 2 watts

### Circuit Description (cont'd)

a proportional integral-cycle temperature controller by application of a positive-going ramp voltage to terminal 9 of the CA3059 (with terminals 10 and 11 open). Detailed information on the operation and applications of the RCA-CA3059 integrated circuit is given in the RCA Linear Integrated Circuits Manual, Technical Series IC-42 or in the RCA Application Notes AN-4158 and AN-6268.

## 15-32 SHIFT REGISTER OR RING COUNTER

### Circuit Description

In this basic shift register, the successive outputs from the various stages are delayed (or shifted) from those of the preceding stages by a controlled time interval (i.e., the duration between input trigger pulses). These outputs are coupled through OR gates (not shown on circuit schematic) and may be used to program the timing sequence for

## 15-32 SHIFT REGISTER OR RING COUNTER (cont'd)

### Circuit Description (cont'd)

various digital switching operations. If point A′ on the circuit is connected to point A, the register becomes regenerative and may be used as a ring counter.

The dc supply voltages $E_1$ and $E_2$ are obtained from separate taps on a resistive voltage divider. With these voltages applied, the 2N1302 switching transistor is immediately triggered into conduction by the positive voltage applied to its base through $R_3$. One of the register stages must be triggered simultaneously to provide a complete path for the current through the switching transistor.

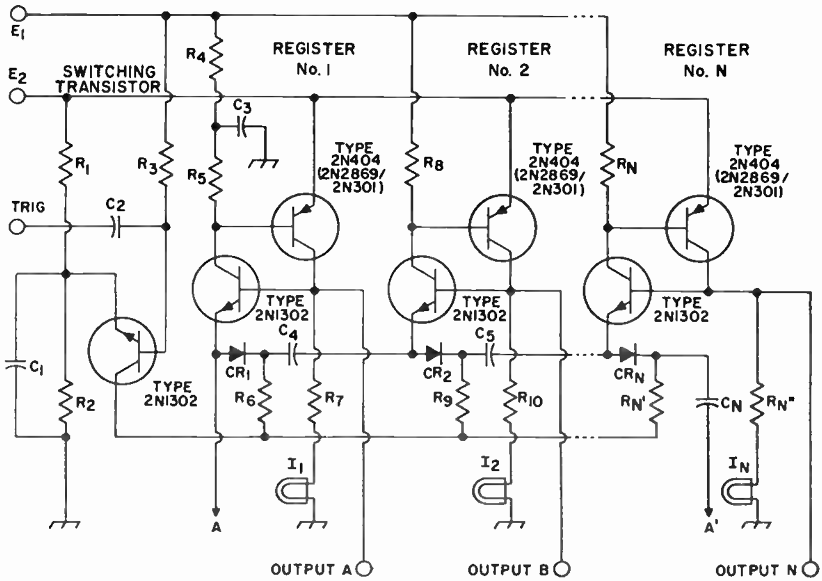
Each register stage is basically a two-transistor regenerative switch that employs an n-p-n triggering transistor and a p-n-p output transistor. For the $E_1$ and $E_2$ voltages used (see notes below circuit schematic), the n-p-n transistor is a 2N1302, and the p-n-p transistor is a 2N404 or a 2N2869/2N301 depending upon the level of output current desired. If either of the transistors in a register stage starts to conduct, both of them are quickly driven into saturation by the regenerative action of the stage. The relatively high current from the p-n-p transistor in the stage flows through the resistance that exists between the $E_1$ and $E_2$ taps on the power-supply voltage divider. The increased voltage drop across this resistance reduces the $E_2$ voltage to a value less than that required to trigger the other register stages, and these stages are held inoperative.

When power is initially applied to the circuit, $C_3$ and $R_4$ assure that the first register stage is triggered into conduction before current flows through any of the other register stages. When the power is first applied, the initial surge of current through $C_3$ and $R_4$ immediately triggers the 2N1302 transistor in the first stage into conduction. This transistor and the p-n-p output transistor are then quickly driven into saturation by the regenerative action of the stage. No other register stage is then allowed to conduct, and the lamp $I_1$ in the collector of the p-n-p transistor in the first stage lights to indicate that the output is being supplied by this stage. This condition is maintained until an input trigger pulse is applied. During this period, $C_4$ charges through diode $CR_1$, the 2N1302 transistor, and resistors $R_4$ and $R_5$ to the $E_1$ voltage less the sum of the voltages dropped across the other components in the charging path.

A negative trigger pulse is applied to the base of the 2N1302 switching transistor to initiate a register shift. A sufficiently large negative pulse will drive the switching transistor to cut off. All the register stages are then held inoperative for the duration of the trigger pulse. When the trigger pulse is removed, the switching transistor again conducts through one of the register stages. This time, however, no quick surge of current can flow through $C_3$ and $R_4$ to trigger the first register stage, because $C_3$ has fully charged to the $E_1$ voltage. Moreover, the charge on $C_4$ tends to reverse-bias diode $CR_1$, and thus impedes the flow of current through the first register stage. The charge on $C_4$, however, is series-aiding with the dc supply voltage in the second register stage. This series-aiding effect causes the second stage to be triggered into conduction before current can flow through any of the other stages. The biasing action of this stage then holds the other stages inoperative. The lamp $I_2$ then lights to indicate that the output is being supplied by the second stage.

When the next register shift is initiated by a negative trigger pulse, the charge on $C_6$ assures that the third register stage will be triggered

## 15-32 SHIFT REGISTER OR RING COUNTER (cont'd)




NOTES:
The shift register may use as many stages as desired and may be made regenerative by connecting points A and A′. In addition, the basic circuit can be adapted for operation at many different output-current levels. The circuit as shown is designed for an output-current level of 40 mA ($E_1$ = 12 V; $E_2$ = 9 V). Transistor types and component values shown in parentheses indicate the changes necessary for operation at an output-current level of 3 amperes ($E_1$ = 27 V; $E_2$ = 24 V). The voltages $E_1$ and $E_2$ should be obtained from a well-regulated dc power supply.

### Parts List

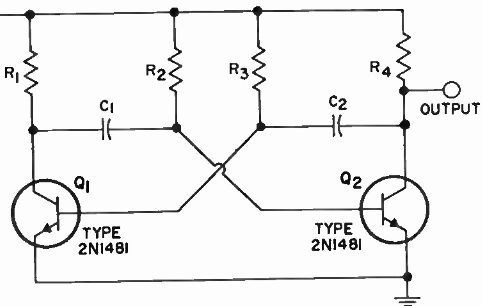
$C_1$ = 100 $\mu$F, electrolytic, 6 V
$C_2$, $C_4$, $C_5$, $C_N$ = 0.05 $\mu$F (or 0.1 $\mu$F), ceramic, 50 V
$C_3$ = 1 $\mu$F, (or 25 $\mu$F), electrolytic, 25 V
$CR_1$, $CR_2$, $CR_N$ = crystal diode 1N270 or equiv.
$I_1$, $I_2$, $I_N$ = indicator lamp No. 49; 2-volt, 60-mA (or No. 1488; 14-volt, 150-mA)
$R_1$ = 1000 ohms, 0.5 watt (or 680 ohms, 1 watt)
$R_2$ = 27 ohms, 0.5 watt (or 12 ohms, 1 watt)
$R_3$ = 1000 ohms, 0.5 watt
$R_4$ = 1000 ohms, 0.5 watt (or 330 ohms, 0.5 watt)
$R_5$, $R_8$, $R_N$ = 2200 ohms, 0.5 watt (or 680 ohms, 0.5 watt)
$R_6$, $R_9$, $R_N'$ = 560 ohms, 0.5 watt (or 180 ohms, 1 watt)
$R_7$, $R_{10}$, $R_N''$ = 150 ohms, 1 watt (or 82 ohms, 2 watts)

### Circuit Description (cont'd)

to supply the output. In this way, the operation of the register is shifted from one stage to the next each time a negative trigger pulse is applied. The register can be reset so that the operation starts with the first stage at any time by discharging capacitor $C_3$.

## 15-33 ASTABLE MULTIVIBRATOR (Frequency = 7000 Hz)

$$f = \frac{1}{(0.7C_1R_2) + (0.7C_2R_3)}$$




### Parts List

$C_1$, $C_2$ = 0.1 $\mu$F, paper, 25 V
$R_1$, $R_4$ = 60 ohms, 5 watts
$R_2$, $R_3$ = 1000 ohms, 0.5 watt

### Circuit Description

This astable (free-running) multivibrator develops a square-wave output that has a peak value equal to the dc supply voltage ($V_{CC}$ = 12 volts) and a minimum value equal to the collector saturation voltage of the transistors. The circuit is basically a two-stage nonsinusoidal oscillator in which one stage conducts at saturation while the other is cut off until a point is reached at which the stages reverse their conditions. The circuit employs two 2N1481 transistors operated in identical common-emitter amplifier stages with regenerative feedback resistance-capacitance coupled from the collector of each transistor to the base of the other transistor.

When power is initially applied to the circuit, the same amount of current tends to flow through each transistor. It is unlikely, however, that a perfect balance will be maintained, and if the current through transistor $Q_1$, for example, should increase slightly without an attendant increase in that through transistor $Q_2$, the multivibrator will oscillate to generate a square-wave output.

As the current through transistor $Q_1$ increases, the resultant decrease in collector voltage is immediately coupled to the base of transistor $Q_2$ by the discharge of capacitor $C_1$ through resistor $R_2$. This negative voltage at the base reduces the current through transistor $Q_2$, and its collector voltage rises. The charge of capacitor $C_2$ through resistor $R_3$ couples the increase in voltage at the collector of transistor $Q_2$ to the base of transistor $Q_1$, and further increases the flow of current through $Q_1$. The collector voltage of $Q_1$ decreases even more, and the base of $Q_2$ is driven more negative. As a result of this regenerative action, transistor $Q_1$ is driven to saturation almost instantaneously, and, just as quickly, transistor $Q_2$ is cut off. This condition is maintained as long as the discharge current of $C_1$ develops sufficient voltage across $R_2$ to hold $Q_2$ cut off. The time constant of $C_1$ and $R_2$, therefore, determines the time that $Q_2$ remains cut off (i.e., the duration of the positive half-cycle of the square-wave output). During this period, the voltage at the output terminal is the dc supply voltage (12 volts).

The discharge current from $C_1$ decreases exponentially, as determined by the time constant of the discharge path, and eventually becomes so small that the voltage developed across $R_2$ is insufficient to hold $Q_2$ cut off. The decrease in collector voltage that results when $Q_2$ conducts is coupled by $C_2$ and $R_3$ to the base of $Q_1$. The current through $Q_1$ then decreases, and the collector voltage of this transistor rises. The positive swing of the voltage at the collector of $Q_1$ is coupled

## 15-33 ASTABLE MULTIVIBRATOR (cont'd)

### Circuit Description (cont'd)

by $C_1$ and $R_2$ to the base of $Q_2$ to increase further the conduction of $Q_2$. The regenerative action of the multivibrator then quickly drives $Q_2$ to saturation and $Q_1$ to cutoff. The length of time that this condition is maintained is determined by the time constant of $C_2$ and $R_3$. During this period, which represents the negative half-cycle of the square-wave output, the voltage at the output terminal is the collector saturation potential of $Q_2$.

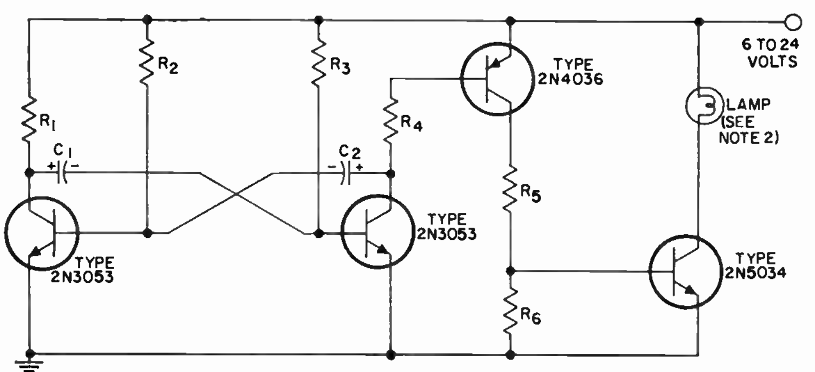
If desired, a square-wave output may also be obtained from the collector of transistor $Q_1$. This output will be equal in magnitude to that at the collector of transistor $Q_2$, but will be opposite in phase.

## 15-34 LIGHT FLASHER
## 100 Flashes Per Minute

### Circuit Description

In this circuit, a free-running, asymmetrical multivibrator is used to gate the operation of a two-stage amplifier. An incandescent lamp or other load may be connected in series with the collector of the output transistor, and each time the transistor conducts, voltage is applied across the bulb or alternate load. The input power may be any dc voltage from 6 to 24 volts.

The multivibrator uses a pair of 2N3053 transistors. The rectangular wave output developed at the col-




**NOTES: 1. Values of capacitors $C_1$ and $C_2$ may be changed to alter the flashing rate. 2. Bulbs and resistive loads up to 2.0 amperes may be used; however, if the flasher circuit is used to switch loads that have inductive components, diode protection must be provided for the 2N5034 output transistor.**

### Parts List

$C_1$ = 25 $\mu$F, electrolytic, 25 V
$C_2$ = 1 $\mu$F, electrolytic, 25 V
$R_1$ = 2000 ohms, 0.5 watt
$R_2$ = 0.1 megohm, 0.5 watt
$R_3$ = 24000 ohms, 0.5 watt
$R_4$ = 510 ohms, 2 watts
$R_5$ = 50 ohms, 10 watts
$R_6$ = 100 ohms, 0.5 watt

## 15-34 LIGHT FLASHER (cont'd)
### 100 Flashes Per Minute

**Circuit Description (cont'd)**

lector of the second transistor is resistively coupled to the base of the 2N4036 p-n-p transistor operated in a common-emitter amplifier stage.

The 2N4036 transistor is gated on and off by the rectangular-wave signal from the multivibrator. This stage in turn gates the operation of the 2N5034 n-p-n transistor used in the output stage. A lamp bulb or alternate load is connected from the positive side of the power supply to the collector of the output-stage transistor. The lamp, therefore, flashes at the frequency of the multivibrator. The frequency of operation, calculated by use of the equation given for circuit 15-33, is approximately 100 flashes per minute.

The repetition rate may be changed by altering the values of capacitors $C_1$ and $C_2$. The ON time changes proportionally with the value of $C_2$, and the OFF time changes proportionally with the value of $C_1$.

For operaton at dc supply voltages less than 24 volts, capacitor working voltages and resistor dissipation ratings may be reduced. Capacitor ratings may be reduced to the maximum supply voltage. The dissipation requirements of the resistors are proportional to the square of the supply voltage, e.g., for 12-volt operation, the dissipation rating for $R_5$ is required to be only 2.5 watts.

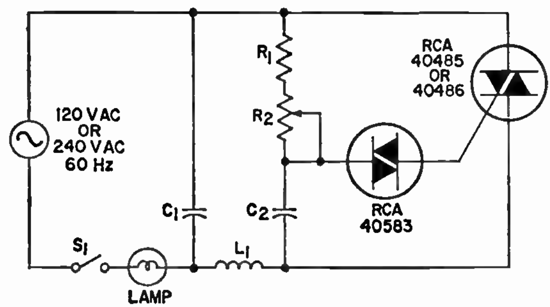
## 15-35 LIGHT DIMMERS

**Circuit Description**

These triac light-dimmer circuits are designed to provide full-wave control of the light intensity of incandescent lamps. Component values and triac types are shown for operation of the circuits from a 60-Hz ac source of 120 or 240 volts. For 120-volt operation, the 40485 triac is recommended; for 240-volt operation, the higher-power 40486 triac should be used. A 40583 trigger diode (diac), together with associated resistance-capacitance time-constant networks, is used to develop the gate current pulses that trigger the selected triac into coduction. In applications where space is premium, the triac and associated trigger diode may be replaced by the 40431 for 120-volt operation or the 40432 for 240-volt operation, because these devices combine the functions of both the triac and the diac in the same package.

In each light-dimmer circuit, the triac is connected in series with the lamp load. During the beginning of each half cycle of the input ac voltage, the triac is in the OFF state. As a result, the entire line voltage appears across the triac, and the lamp is not lighted. The entire line voltage, however, is also impressed across the resistance capacitance network connected in parallel with the triac, and this voltage charges the capacitor(s) in this network. When the voltage across the trigger capacitor, $C_2$ in circuit (a) or $C_3$ in circuit (b), rises to the breakover voltage $V_{BO}$ of the diac, and the diac conducts. The capacitor then discharges through the diac and the triac gate to trigger the triac. At

## 15-35 LIGHT DIMMERS (cont'd)




(a) Single-time-constant light-dimmer circuit.

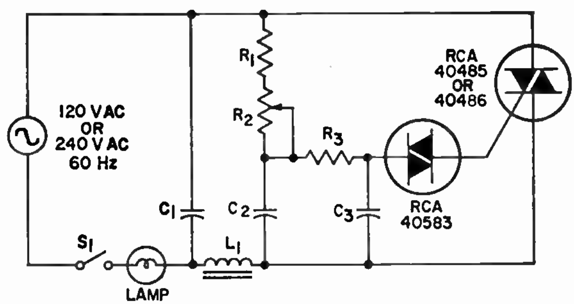
### Parts List

*120-Volt, 60-Hz Operation*

$C_1$, $C_2$ = 0.1 μF, 200 V
$L_1$ = 100 μH
$R_1$ = 3300 ohms, 0.5 watt
$R_2$ = light control, potentiometer, 0.25 megohm, 0.5 watt

*240-Volt, 50/60 Hz Operation*

$C_1$ = 0.1 μF, 400 V
$C_2$ = 0.05 μF, 400 V
$L_1$ = 200 μH
$R_1$ = 4700 ohms, 0.5 watt
$R_2$ = light control, potentiometer, 0.25 megohm, 1 watt




(b) Double-time-constant light-dimmer circuit.

### Parts List

*120-Volt, 60-Hz Operation*

$C_1$, $C_2$ = 0.1 μF, 200 V
$C_3$ = 0.1 μF, 100 V
$L_1$ = 100 μH
$R_1$ = 1000 ohms, 0.5 watt
$R_2$ = light control, potentiometer, 0.1 megohm, 0.5 watt

*240-Volt, 60-Hz Operation*

$C_1$ = 0.1 μF, 400 V
$C_2$ = 0.05 μF, 400 V
$C_3$ = 0.1 μF, 100 V
$L_1$ = 100 μH
$R_1$ = 7500 ohms, 2 watts
$R_2$ = light control, potentiometer, 0.2 megohm, 1 watt
$R_3$ = 7500 ohms, 2 watts

### Circuit Description (cont'd)

this point, the line voltage is transferred from the triac to the lamp load for the remainder of that half cycle of the input ac power. This sequence of events is repeated for each half cycle of either polarity.

The potentiometer $R_2$ is adjusted to control the brightness of the incandescent lamp. If the resistance of the potentiometer is decreased, the trigger capacitor charges more rapidly, and the breakover voltage of the diac is reached earlier in the cycle so that the power applied to

## 15-35 LIGHT DIMMERS (cont'd)

### Circuit Description (cont'd)

the lamp and thus the intensity of the light is increased. Conversely, if the resistance of the potentiometer is increased, triggering occurs later in the cycle, and the light intensity is decreased. The resistor $R_1$ in series with the potentiometer protects the potentiometer by limiting the current when he potentiometer is at the low-resistance end of its range.

Capacitor $C_1$ and inductor $L_1$ form an rfi suppression network. This network suppresses the high-frequency transients generated by the rapid ON-and-OFF switching of the triac so that these transients do not produce noise interference in nearby electrical equipment.

The two lamp-dimmer circuits differ in that circuit (a) employs a single-time-constant trigger network and circuit (b) uses a double-time-constant trigger circuit. As pointed out earlier in the section on Power Switching and Control, the use of the second time constant network reduces hysteresis effects and thereby extends the effective range of the light-control potentiometer. As applied to light dimmers, the term hysteresis refers to a difference in the control-potentiometer setting at which the lamp turns on and the setting at which the light is extinguished. The additional capacitor $C_2$ in circuit (b) reduces hysteresis by charging to a higher voltage than capacitor $C_3$. During gate triggering, $C_3$ discharges to form the gate current pulse. Capacitor $C_2$, however, has a longer discharge time constant and this capacitor restores some of the charge removed from $C_3$ by the gate current pulse.

It is important to realize that a triac in these circuits dissipates power at the rate of about one watt per ampere. Therefore, some means of heat removal must be provided to keep the device within its safe operating-temperature range. On a small light-control circuit such as one built into a lamp socket, the lead-in wire serves as an effective heat sink. Attachment of the triac case directly to one of the lead-in wires provides sufficient heat dissipation for operating currents up to 2 amperes (rms). On wall mounted controls operating up to 6 amperes, the combination of face plate and wall box serves as an effective heat sink. For higher-power controls, however, the ordinary face plate and wallbox do not provide sufficient heat-sink area. In this case, additional area may be obtained by use of a finned face plate that has a cover plate which stands out from the wall so air can circulate freely over the fins.

On wall-mounted controls, it is also important that the triac be electrically isolated from the face plate, but at the same time be in good thermal contact with it. Although the termal conductivity of most electrical insulators is relatively low when compared with metals, a low-thermal-resistance, electrically isolated bond of triac to face plate can be obtained if the thickness of the insulator is minimized, and the area for heat transfer through the insulator is maximized. Suitable insulating materials are fiber-glass tape, ceramic sheet, mica, and polyimide film.

# OTHER RCA TECHNICAL MANUALS

| | Price*† |
|---|---|
| RCA Linear Integrated Circuits (IC-42) | $2.50 |
| RCA COS/MOS Integrated Circuit Manual (CMS-270) | $2.50 |
| RCA Receiving-Tube Manual (RC-27) | $2.00 |
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