PRICE: 50 CENTS

75

2nd EDITION

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TRANSISTOR MANUAL

- CIRCUITS
- APPLICATIONS
- SPECIFICATIONS

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GENERAL ELECTRIC

GENERAL ELECTRIC TRANSISTOR MANUAL

2ND EDITION

CONTENTS

The Second Edition of the General Electric Transistor Manual has been greatly expanded. Seventeen General Electric Transistor Specifications have been added, including Silicon Transistors, and the Registered JETEC Transistor Type Tables have been brought up to date. The greatest increase in material will be found in the Transistor Applications Chapter and in the Circuit Diagrams. A complete new chapter on Power Supplies has been added along with several power supply diagrams.

This manual has been prepared to assist the service technician, hobbyist, experimenter, and ham in working with transistors. We have attempted to assemble the information necessary for an understandable working knowledge of the fundamentals and applications of transistors.

The information included covers such topics as Basic Theory, Construction Techniques used to obtain the various types of transistors available, Principles of Circuit Design, and Specifications, with outline drawings, of all transistors registered with JETEC. Complete explanations of the parameter symbols used are also given. Several Circuit Diagrams, varying from simple amplifiers to high fidelity amplifiers and radios have been included.

GENERAL ELECTRIC CO.
SEMICONDUCTOR PRODUCTS
1224 W. GENESEE ST.
SYRACUSE, N. Y.

BASIC SEMICONDUCTOR THEORY

The outer orbit of a germanium atom contains four electrons and a crystal of pure germanium takes the form of a diamond structure as shown in Figure 1.

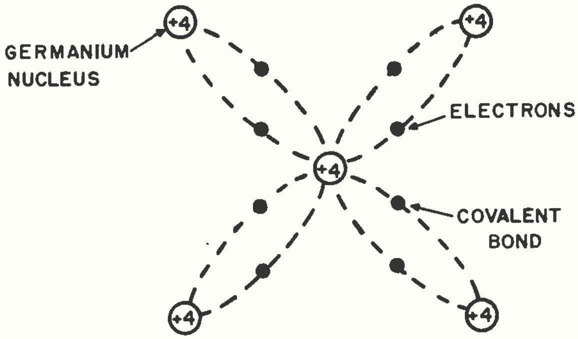


FIGURE 1

The four electrons of each atom form covalent bonds with the adjacent atoms and there are no free electrons. Absolutely pure germanium is therefore a poor conductor. If a voltage is applied to a piece of pure germanium, of the size used in transistors, only a few microamps of current will flow. This current is due to electrons which are broken away from their bonds by thermal agitation and this minute current increases exponentially with temperature.

If an atom with five electrons in the outer orbit such as Antimony or Arsenic is introduced into the crystal, a structure is formed as shown in Figure 2. The extra electrons are free to move and under the influence of an electrical field will move toward the positive voltage source. This atom of material other than germanium is called a doping agent and if it results in free electrons in the crystal, the crystal is known as "N" type germanium.

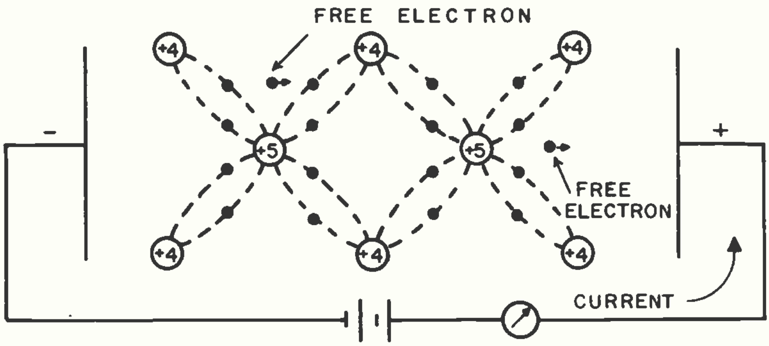


FIGURE 2

If a doping agent is used that only contains three electrons in the outer orbit such as Indium, Gallium or Aluminum, the crystal takes the form of Figure 3 where there is a deficiency of one electron and this deficiency is called a hole.

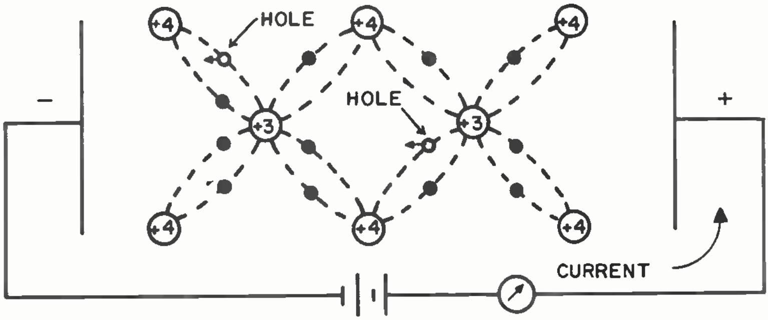


FIGURE 3

Under the influence of an electrical field, electrons will jump into this hole and the hole will appear to proceed towards the negative terminal. This crystal containing a deficiency of electrons is known as "P" type germanium. As far as the external circuit is concerned, it is impossible to differentiate between electron current and hole current. These two modes of conduction are quite distinct however, and are basic to transistor and rectifier theory. With an electrical field of 1 volt/cm in germanium, an electron will move at the rate of 3600 cm/sec whereas a hole will only move at 1700 cm/sec.

If a single crystal of germanium is so doped that it changes abruptly from "N" type to "P" type material and a positive voltage applied to the "P" region and a negative voltage to the "N" region, the situation is as shown in Figure 4a.

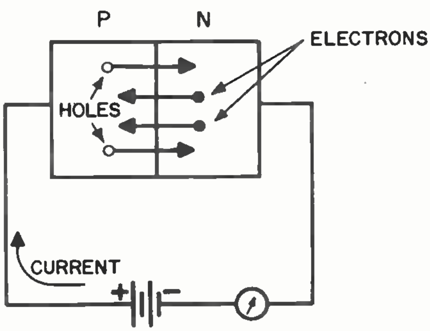


FIGURE 4A

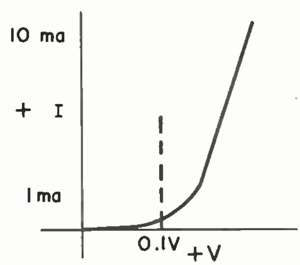


FIGURE 4B

The holes will move to the right across the junction and the electrons will move to the left with the resultant V-1 curve shown in Figure 4b. If the voltage is applied in the reverse direction, the holes and electrons will both move away from the junction as shown in Figure 5a until the electrical field produced by their displacement counteracts the applied electrical field. Under these conditions almost no current will flow in the external circuit and any current that does flow is caused by thermally generated electron hole pairs. The V-I characteristics of a reversed bias junction are shown in Figure 5b and it will be noted that the reverse leakage current is essentially independent of voltage up to the point where the junction actually breaks down.

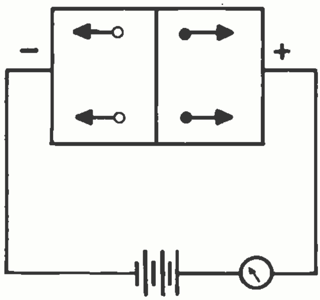


FIGURE 5A

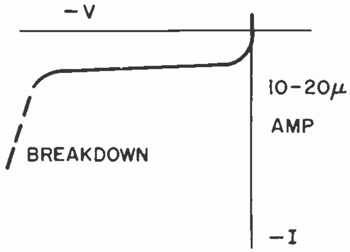


FIGURE 5B

An NPN transistor is formed by a crystal of germanium that is changed from "N" type to "P" type and back to "N" type as indicated in Figure 6.

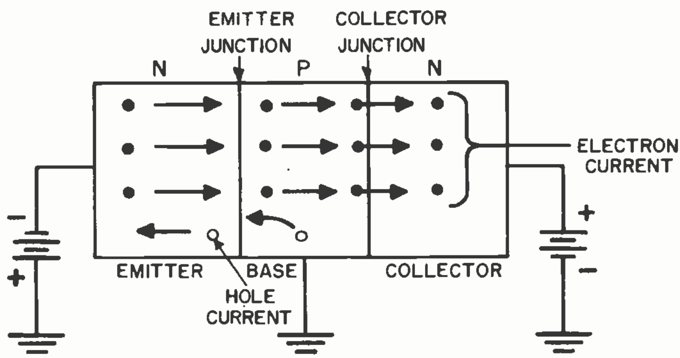


FIGURE 6

With the voltage applied as shown, one N-P junction is forward biased and this is called the emitter junction. The other junction is back biased and this is called the collector junction. The "P" type base region is relatively lightly doped in comparison with the "N" type emitter so that the majority of the current flowing from the emitter to base is electron current and very little of it is hole current. The majority of the electrons that are emitted into the base region diffuse across to the collector junction and pass on to the collector circuit. The ratio of the collector current to the emitter current is called alpha. It is desirable to have alpha as high as possible and this is done by light doping of the base region, using a thin base region on the order of 1 mil, and minimizing the unwanted impurities in germanium that might cause recombination of electrons before they traverse the base region. Alphas of 0.95 to 0.99 are common in commercial transistors. No current (except a small leakage current) will flow in the collector circuit unless current is introduced into the emitter. Since very little voltage (.1 to .5) is needed to cause appreciable current to flow into the emitter, the input power is very low. Almost all the emitter current will flow in the collector circuit where the voltage can be as high as 45 volts. Therefore, a relatively large amount of power can be controlled in an external load and the power gain of a transistor (power out/power in) in the circuit shown is over 1000.

The unijunction transistor's thyratron-like action depends on different principles. The silicon unijunction transistor was originally known as a double base diode. It is similar to the germanium version of the unijunction transistor but differs quantitatively in its characteristics.

The transistor shown in Figure 7 consists of an N type silicon bar with ohmic

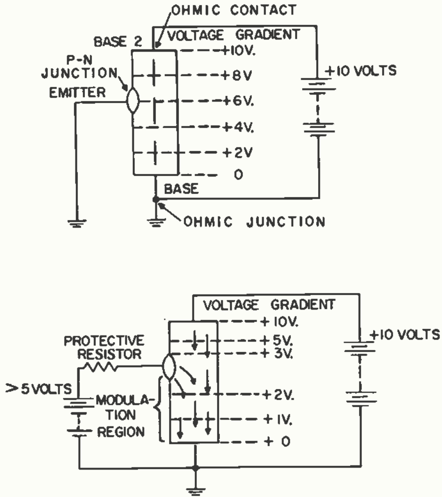


FIGURE 7

end connections. A p-n junction is formed along the bar, near the base 2 end. If the emitter is open or back-biased in the circuit of Figure 7, the bar behaves as a resistance and has a nearly uniform voltage gradient along its length. Because the junction is near base 2, the voltage opposite the emitter will be greater than half the supply voltage. Once the junction is forward biased, the emitter current flows lowering the resistivity of the bar between the emitter and base. Inherent regeneration results in a negative emitter to base 1 impedance. As the emitter current increases the conditions for regeneration eventually cease to exist and the emitter to base diode behaves in a conventional manner. The emitter characteristics in Figure 8 show the peak point (beginning of the negative resistance region) in the first quadrant indicating that a minimum of two or three microamperes of emitter current must flow before regeneration occurs. The valley point (end of negative resistance region) lies between five and twenty milliamperes.

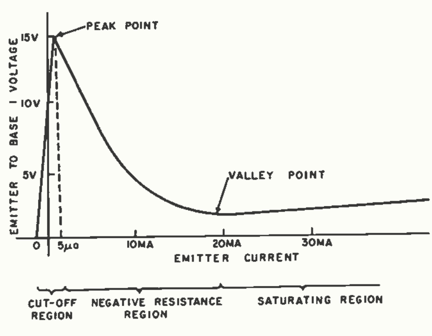


FIGURE 8

The most common type of junction transistor is the PNP diffused alloyed type. This transistor is made by taking a wafer of "N" type germanium, mounting it on a holder and pressing indium dots into each side. The assembly is then heated in a furnace until the indium melts and alloys with the germanium forming a "P" layer within the "N" type germanium. The complete assembly is shown by Figure 9.

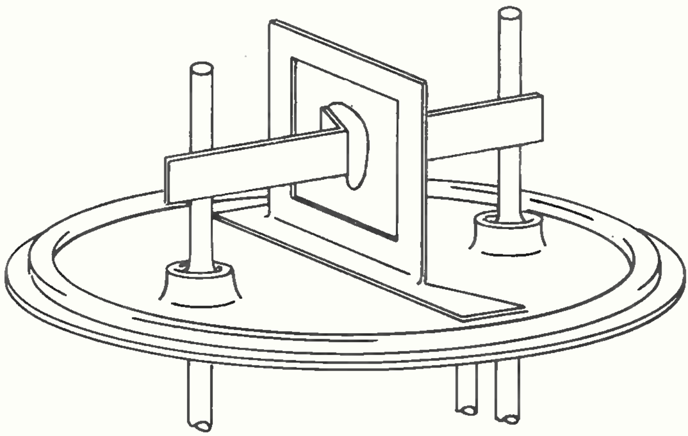


FIGURE 9

This type of transistor has good gain at audio frequencies and is suitable for medium power audio amplifiers since it is possible to pass currents of up to one-half ampere through the transistor. This structure is not as well suited for high frequency amplifiers since the large indium dots produce a high capacitance between collector and base making the unit inherently unstable at high frequencies.

The rate grown transistor is produced by an entirely different technique. A bar of germanium is grown from a bath of molten germanium so doped that the material will change from "P" type to "N" type depending on the temperature and rate of pulling. By suitable growing techniques, 10 to 15 thin "P" type layers are formed in a bar about the size of a cigar. This bar is then sawed up into pieces about 10 mils by 10 mils by 100 mils with the thin "P" layer in the center and long "N" regions on each side. About 7 to 10 thousand transistor bars can be cut from each ingot of germanium. The internal appearance of one of these transistors is shown in Figure 10. This transistor has a low collector capacitance and has excellent gain up to several megacycles. It is stable at high frequencies and is ideally suited for the radio frequency section of broadcast receivers. A rate grown transistor also makes an excellent unit for high speed gates and counting circuits.

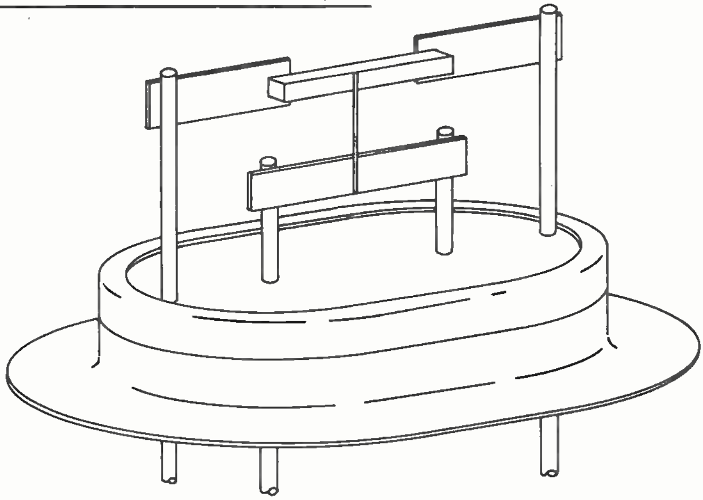


FIGURE 10

The meltback method of transistor construction starts off with a bar of germanium about 10 x 10 x 100 mils. The end of the bar is melted and allowed to refreeze very quickly. By suitable doping of the original material, the junction between the melted portion and the unmelted portion becomes a thin layer of "P" type material and the melted and unmelted portion of "N" type material remains "N" type material. This transistor is essentially a rate grown transistor, but the rate growing is done on an individual small bar rather than on the large germanium ingot. The appearance of a complete meltback triode is shown by Figure 11. This fabrication technique has the advantage of obtaining very close control over the base thickness and it is possible to obtain good performance at very high frequencies.

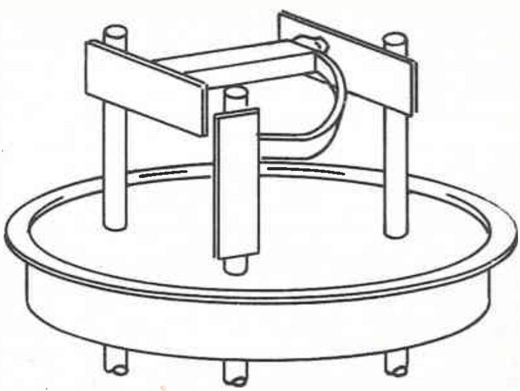


FIGURE 11

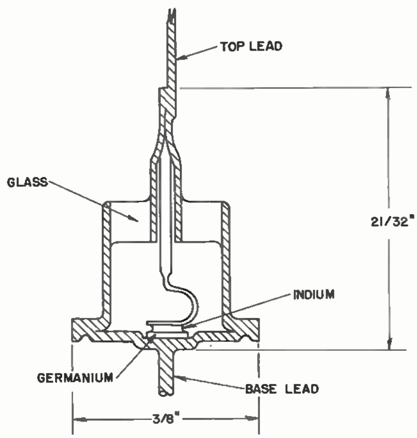
By the addition of an extra base connection to a triode, a tetrode is formed. If a current is passed through the base region from one base lead to the other, the active portion of the base region is electrically narrowed and high gain is possible up to 200 mc.

The diffused-meltback silicon transistor adds a step to the meltback process. As in the meltback process, a suitably doped silicon crystal is sawed into 4000 to 5000 bars. The end of each bar is then melted and refrozen causing a region of very low impurity concentration. The base region is then made by diffusing the internal impurities by subjecting the bar to high temperature for several hours. This technique of solid-state diffusion allows very fine control over the formation of the base region, and yields base regions as thin as 2 microns with relative ease. After leads have been attached and the device hermetically sealed, each unit is aged at high temperature for over 150 hours. This process makes excellent use of expensive silicon crystals and is capable of mass producing low cost silicon transistors with extreme reliability and stability. These transistors have alpha-cutoffs as high as 200 mc, high base to emitter breakdown voltage, low saturation resistance, and good Beta holdup.

RECTIFIER CONSTRUCTION

Germanium and Silicon rectifiers are two-element semiconductor devices constructed around the single P-N junction described in Figures 4A, 4B, 5A and 5B. Because of their inherently low forward resistance and high reverse resistance, these devices are widely used for converting alternating current to direct current, to block reverse currents in control circuits, and to increase the power gain of magnetic amplifiers through the effects of self-saturation.

Rectifiers are generally designed to handle power rather than small signals, and sizeable currents in addition to high voltages. These capabilities are attained through use of large cross-sectional area junctions and efficient means for dissipating heat losses, such as fins, heat sinks, etc.



SECTIONAL VIEW OF
IN91 SERIES OF GERMANIUM RECTIFIER

FIGURE 12

A section through a typical low power germanium rectifier is shown in Figure 12. The germanium pellet, which is soldered to the base disc, is approximately 1/16 inch square. Yet the junction of this germanium pellet with the indium alloy can rectify over 1/4 ampere at room temperature and block voltages in the reverse direction up to 300 volts peak. This latter rating is called the "Peak Inverse Voltage" of the cell. When this same cell is mounted on a 1-1/2 inch square fin as shown in Figure 13, its current carrying capabilities are increased to over 3/4 ampere at room temperature.

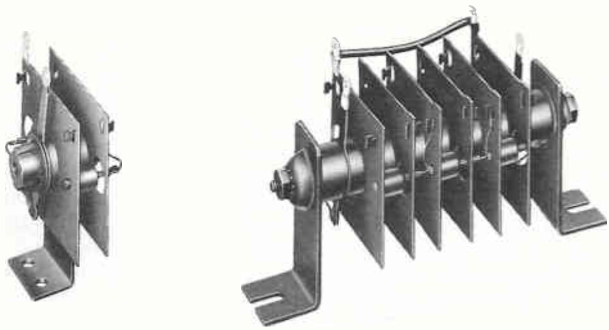


FIGURE 13

Germanium rectifiers of this type offer outstanding advantages over other types of rectifiers:

1. Low forward drop, unexcelled by any other type of rectifier with the same inverse voltage rating.
2. Reverse resistance so high as to be negligible for most applications.
3. No aging, and therefore indefinitely long life. Also, no filament to burn out.
4. No junction forming required . . . it is always ready to function after prolonged idleness.
5. Withstands corrosive atmospheres and fluids . . . the junction is protected by a welded hermetic seal.
6. Wide temperature range, from —65°C to as high as +85°C.
7. Ability to withstand shock and vibration . . . no moving parts, flimsy supports, or sensitive filament.

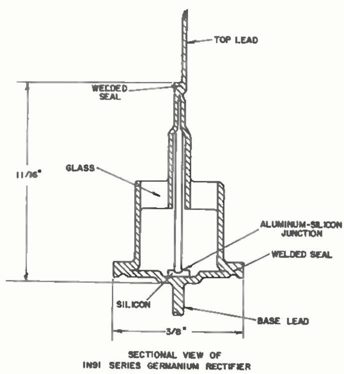


FIGURE 14

When ambient temperatures exceed 85°C, or when extremely low reverse currents are required, the silicon rectifier shown in cross-section in Figure 14 can be used. In outward appearance, the silicon rectifier looks identical to the germanium rectifier. However, instead of a germanium-indium junction inside, this cell employs the junction of a piece of aluminum wire alloyed into a wafer of the metal silicon. This device can operate in ambients up to 165°C and can handle currents up to 3/4 ampere at room temperature. Whereas its forward resistance is approximately 40% higher than a germanium device of the same rating, its reverse leakage current may be several hundred times less than a comparable germanium cell. It too can be mounted on a fin for higher current rating.

TRANSISTOR SPECIFICATIONS:

There are many properties of a transistor which can be specified, but this section will only deal with the more important specifications. A fundamental limitation to the use of transistors in circuits is BV_{CER}, the breakdown voltage in the grounded emitter connection. The grounded emitter breakdown voltage is a function of the resistance from the base to the emitter and it is necessary to specify this resistance shown as R in Figure 15.

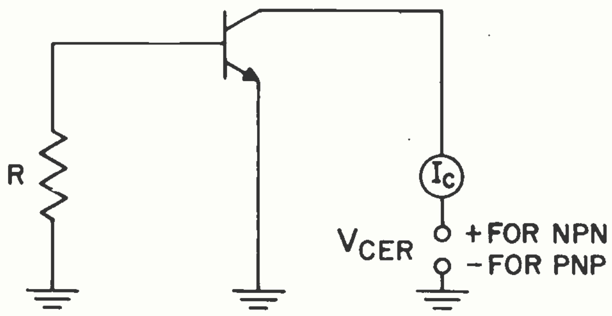
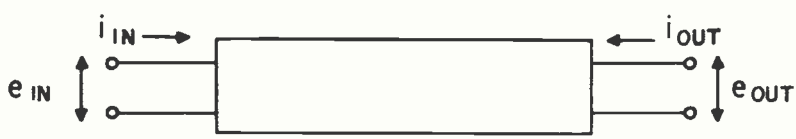


FIGURE 15

Since the breakdown voltage is not sharp, it is also necessary to specify a value of collector current at which breakdown will be considered to have taken place. For example, in PNP audio transistors the collector current is specified to be less than 600 μa with 25 volts applied and the resistance R equal to 10,000 ohms. With NPN transistors, the collector current should be less than 300 μa with 15 volts applied, and the base open-circuited.

The small signal parameters of transistors are usually specified in terms of the "h" or hybrid parameters. These parameters are defined for any network by the following equations:



$$e_{in} = h_i\, i_{in} + h_r\, e_{out}$$
$$i_{out} = h_f\, i_{in} + h_o\, e_{out}$$

where h_i = input impedance (ohms)
h_r = feedback voltage ratio (dimensionless)
h_f = forward current transfer ratio (dimensionless)
h_o = output conductance (mhos)

For transistors, a second subscript is added to designate which terminal of the transistor is grounded. For example, h_{fe} is the grounded emitter forward current transfer ratio.

The current transfer ratio is equal to the ratio of an a-c variation in collector current to an a-c variation in base current. This current gain can be specified either

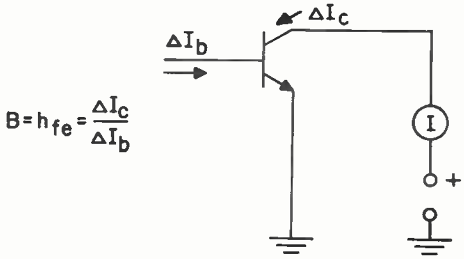


FIGURE 16

for small a-c values of base current or for large values of base current in which case it would be known as h_{FE}, the d-c current gain. The current gain is the most important property of a transistor in determining the gain of audio amplifiers.

The small signal "h" parameters of a transistor are a function of frequency and bias conditions. For a P-N-P alloy audio transistor, typical h parameters at 270 cps, and bias conditions of 5 volts (collector to emitter) and 1 ma collector current are:

Grounded Base		*Grounded Emitter*	
h_{ib}	30 ohms	h_{ie}	1500 ohms
h_{rb}	4×10^{-4}	h_{re}	2×10^{-2}
h_{fb}	-0.98	h_{fe}	50
h_{ob}	1×10^{-6} mhos	h_{oe}	50×10^{-6}

The h parameters at other bias conditions are shown by Figure 17.

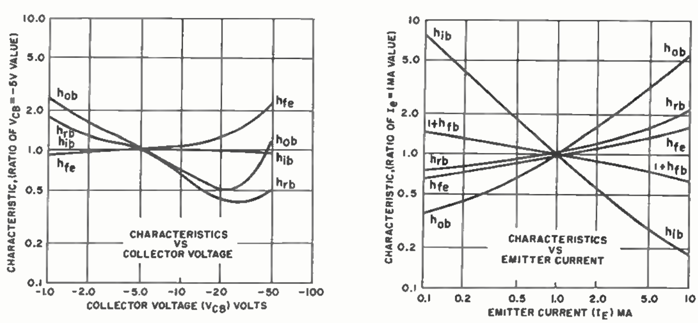


FIGURE 17

With transistors used as radio frequency amplifiers, it is necessary to specify a transformer coupled power gain as indicated in Figure 18. The power gain is the ratio of output power to input power under conditions where the input and output impedances are matched by means of the transformers. The input and output impedances must also be specified to select the proper transformer.

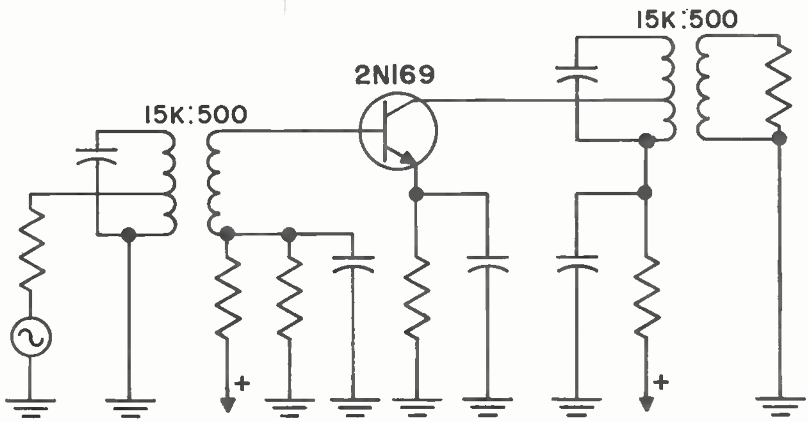


FIGURE 18

Another common transistor specification is the alpha cut-off frequency. This is the frequency at which the grounded base current gain has decreased to 0.7 of its low frequency value. For audio transistors, the alpha cut-off frequency is in the region of 1 mc. For transistors used in the rf section of radios, the alpha cut-off frequency should be 3 to 15 mcs. Other examples of transistor specifications are shown on the specification sheets starting on page 50.

BIASING:

The best method of biasing a transistor is shown in Figure 19.

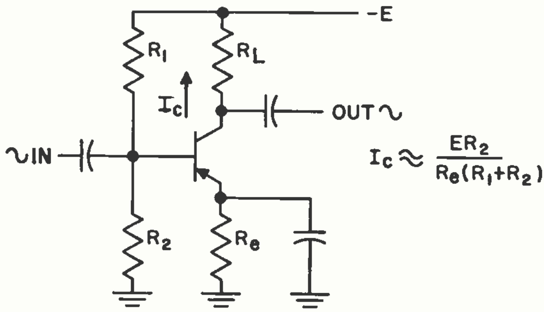


FIGURE 19

A voltage divider consisting of resistors R_1 and R_2 is connected to the base and the resistance R_e is placed in the emitter. Since the emitter junction is forward biased, the current that flows in the emitter circuit is essentially equal to the voltage at the base divided by R_e. To prevent degeneration of the a-c signal to be amplified, the emitter resistance is by-passed with a large capacitance. Good design practice is to make R_2 no larger than 5 to 10 times R_e. A typical value of R_e is 500-1000 ohms.

When the supply voltage is fairly high and wide variations in ambient temperature do not occur, it is possible to use the method of biasing as shown in Figure 20. In this circuit, the biasing is done with a resistance R_1 connected from the collector to base. The approximate formula for the collector to emitter voltage is shown in Figure 20, and is seen to depend on h_{fe}, the grounded emitter current gain.

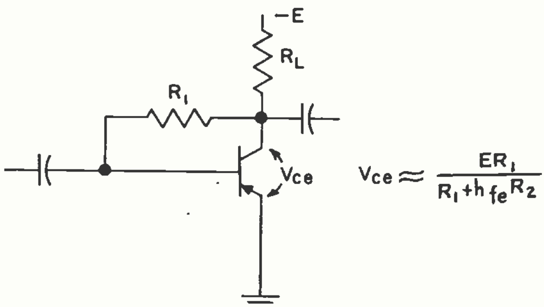


FIGURE 20

This method of biasing requires fairly tight production control over the current gain of the transistors to achieve interchangeability.

A method of biasing which is sometimes used is shown by Figure 21. The base is simply connected to the supply voltage through a large resistance which, in essence, supplies a fixed value of base current to the transistor. This method of biasing is

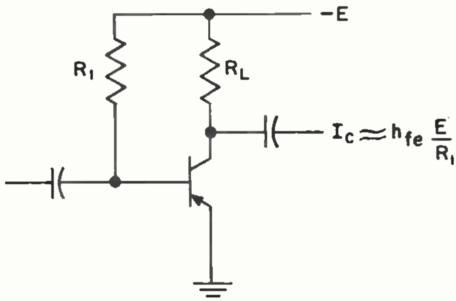


FIGURE 21

extremely dependent upon h_{fe} of the transistor and is not recommended except in circuits where the biasing resistance can be individually adjusted for optimum results

SINGLE STAGE AUDIO AMPLIFIER

Figure 22 shows a typical single stage audio amplifier using a 2N190 PNP transistor.

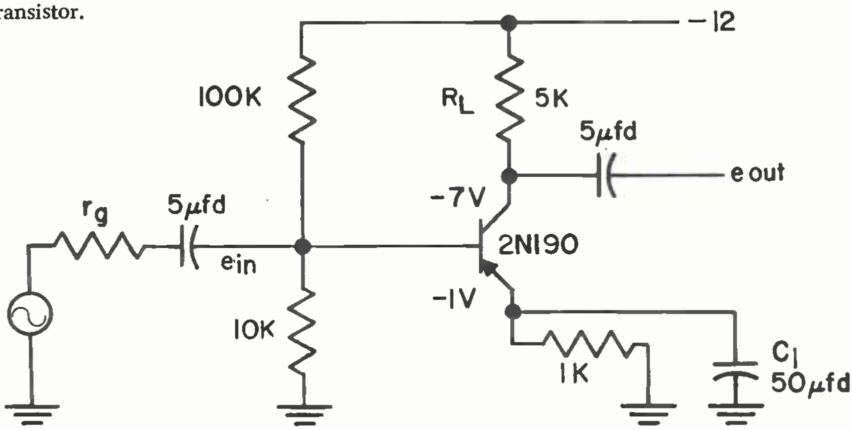


FIGURE 22

With the resistance values shown, the bias conditions on the transistor are 1 ma of collector current and six volts from collector to emitter. At frequencies at which C_1 provides good by-passing, the input resistance is given by the formula: $R_{in} = (1 + h_{fe})\, h_{ib}$. At 1 ma for a design center 2N190, the input resistance would be 37 $\times$ 30 or about 1100 ohms.

The a-c voltage gain $\frac{e_{out}}{e_{in}}$ is approximately equal to $\frac{R_L}{h_{ib}}$. For the circuit shown this would be $\frac{5000}{30}$ or approximately 167.

The frequency at which the voltage gain is down 3 db from the 1 Kc value depends on r_g. This frequency is given approximately by the formula:

$$\text{low } f_{3db} \approx \frac{1+h_{fe}}{6.28(r_g C_1)}$$

TWO STAGE R-C COUPLED AMPLIFIER

The circuit of a two stage R-C coupled amplifier is shown by Figure 23. The input impedance is the same as the single stage amplifier and would be approximately 1100 ohms.

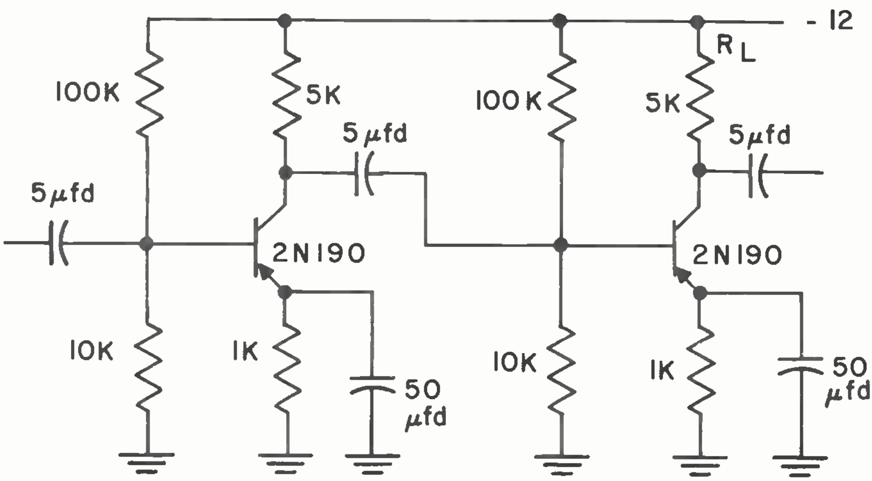


FIGURE 23

The load resistance for the first stage is now the input impedance of the second stage. The voltage gain is given approximately by the formula:

$$A_V \approx h_{fe} \frac{R_L}{h_{ib}}$$

More exact formulas for the performance of audio amplifiers may be found in the Reading List at the end of this manual.

CLASS B PUSH-PULL OUTPUT STAGES

In the majority of applications, the output power is specified so a design will usually begin at this point. The circuit of a typical push-pull Class B output stage is shown in Figure 24.

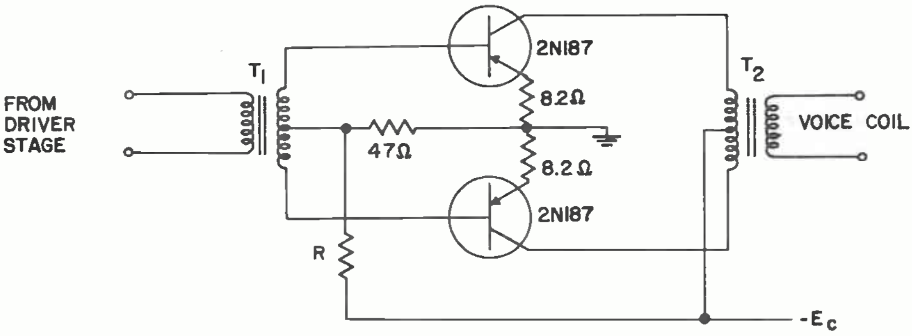


FIGURE 24

The voltage divider consisting of resistor, R and the 47 ohm resistor gives a slight forward bias on the transistors to prevent cross-over distortion. Usually about 1/10 of a volt is sufficient to prevent cross-over distortion and under these conditions, the no-signal total collector current is about 1.5 ma. The 8.2 ohm resistors in the emitter leads stabilize the transistors so they will not go into thermal runaway when the junction temperature rises to 60°C. Typical collector characteristics with a load line are shown below:

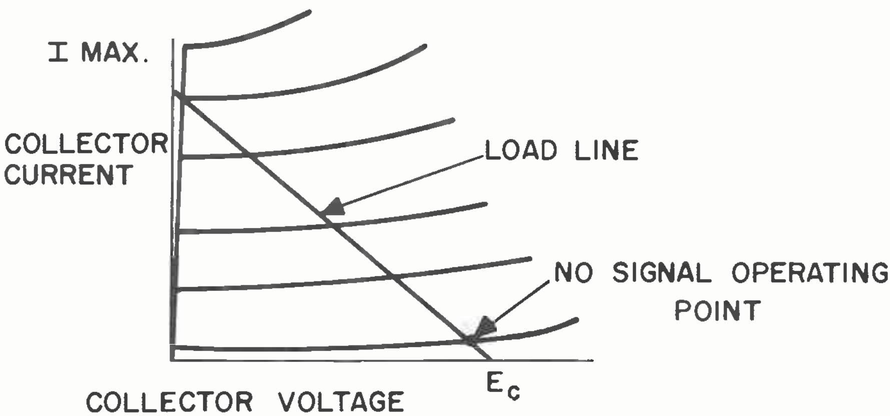


FIGURE 25

It can be shown that the maximum a-c output power without clipping using a push-pull stage is given by the formula:

$$P_{out} = \frac{I_{max} \quad E_c}{2}$$

Since the load resistance is equal to

$$R_L = \frac{E_c}{I_{max}}$$

and the collector to collector impedance is four times the load resistance per collector, the output power is given by the formula:

$$P_o = \frac{2 \quad E_c^2}{R_{c-c}} \qquad (1)$$

Thus, for a specified output power and supply voltage the collector to collector load resistance can be determined. For output powers in the order of 50 mw to 750 mw, the load impedance is so low that it is essentially a short circuit compared to the output impedance of the transistors. Thus, unlike small signal amplifiers, no attempt is made to match the output impedance of transistors in power output stages.

The power gain is given by the formula:

$$\text{Power Gain} = \frac{P_{out}}{P_{in}} = \frac{I_o^2}{I_{in}^2} \frac{R_L}{R_{in}}$$

Since $\frac{I_o}{I_{in}}$ is equal to the current gain, Beta, for small load resistance, the power gain formula can be written as:

$$P.\,G. = \beta^2 \frac{R_{c-c}}{R_{b-b}} \qquad (2)$$

where R_{c-c} = collector to collector load resistance.

R_{b-b} = base to base input resistance.

β = grounded emitter current gain.

Since the load resistance is determined by the required maximum undistorted output power, the power gain can be written in terms of the maximum output power by combining equations (1) and (2) to give:

$$P.\,G. = \frac{2\beta^2 E^2c}{R_{b-b}\,P_{out}} \qquad (3)$$

CLASS A OUTPUT STAGES

A Class A output stage is biased as shown on the collector characteristics below:

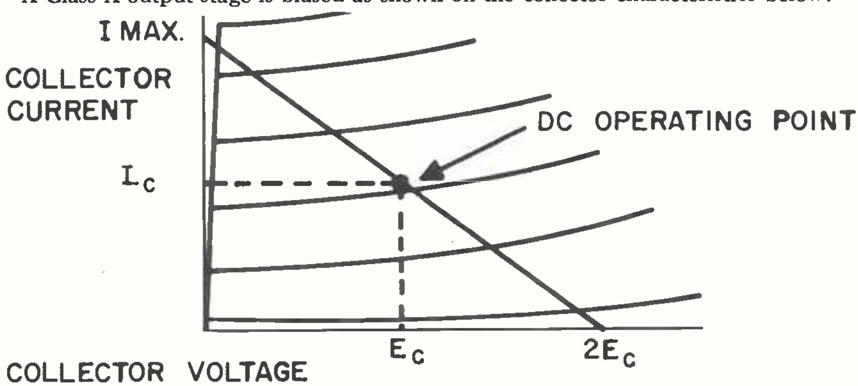


FIGURE 26

The operating point is chosen so that the output signal can swing equally in the positive and negative direction. The maximum output power without clipping is equal to:

$$P_{out} = \frac{E_c \quad I_c}{2}$$

The load resistance is then given by the formula:

$$R_L = \frac{E_c}{I_c}$$

Combining these two equations, the load resistance can be expressed in terms of the supply voltage and power output by the formula below:

$$R_L = \frac{E_c^2}{2\,P_o} \tag{4}$$

For output powers of 10 mw and above, the load resistance is very small compared to the transistor output impedance and the current gain of the transistor is essentially the short circuit current gain Beta. Thus for a Class A output stage the power gain is given by the formula:

$$P.\,G. = \frac{\beta^2 R_L}{R_{in}} = \frac{\beta^2 E_c^2}{2\,R_{in}\,P_o} \tag{5}$$

CLASS A DRIVER STAGES

For a required output power of 250 mw, the typical gain for a push-pull output stage would be in the order of 23 db. Thus the input power to the output stage would be about 1 to 2 mw. The load resistance of a Class A driver stage is then determined by the power that must be furnished to the output stage and this load resistance is given by equation (4). For output powers in the order of a few milliwatts, the load resistance is not negligible in comparison to the output impedance of the transistors, therefore, more exact equations must be used to determine the power gain of a Class A driver stage. From four terminal network theory, after making appropriate approximations, it can be shown that the voltage gain is given by the formula:

$$A_V = \frac{R_L}{h_{ib}} \tag{6}$$

where h_{ib} = grounded base input impedance.

The current gain is given by the formula:

$$A_I = \frac{\alpha}{1 - \alpha + R_L\,h_{ob}} \tag{7}$$

where h_{ob} = grounded base output conductance.

The power gain is the product of the current gain and the voltage gain, thus unlike the formula for high power output stages, there is no simple relationship between required output power and power gain for a Class A driver amplifier.

DESIGN CHARTS

Figures 27 through 35 are design charts for determination of transformer impedances and typical power gains for Class A driver stages, Class A output stages, and Class B push-pull stages. Their use can be best understood by working through a typical example. It will be assumed that it is desired to design a driver and push-pull amplifier capable of delivering a 250 mw with a 9 volt supply. Using Figure 27, for 250 mw of undistorted output power, the required collector to collector load resistance is 450 ohms. From Figure 29 using a typical 2N187, the power gain is 22.5 db. In numerical terms, a power gain of 22.5 db is 178. Therefore, the required input power to the driver stage would be:

$$P_{in} = \frac{250}{178}$$

or 1.4 mw. Assuming about 70% efficiency in the transformers, the required output power of the driver stage will be 2 mw. From Figure 31, for 2 mw of undistorted output power, the load resistance is slightly over 10,000 ohms so a 10,000 ohm transformer could be used. From Figure 34 assuming a 2N191 driver transistor, the power gain is 41 db. The typical power gain of the two stages using a 2N191 driver and

2N187's in the output would be 63.5 db. The secondary impedance of the driving transformer should be 2,000 ohms center tapped as shown on the specification sheet for the 2N186, 2N187 and 2N188. The secondary impedance of the output transformer should be selected to match the impedance of the load.

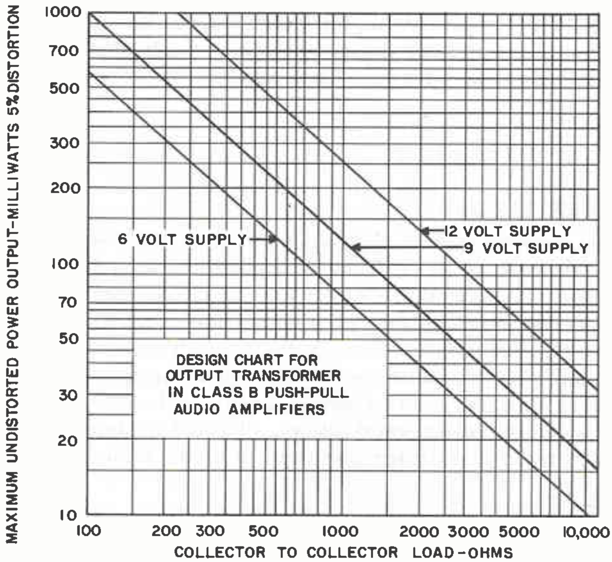


FIGURE 27

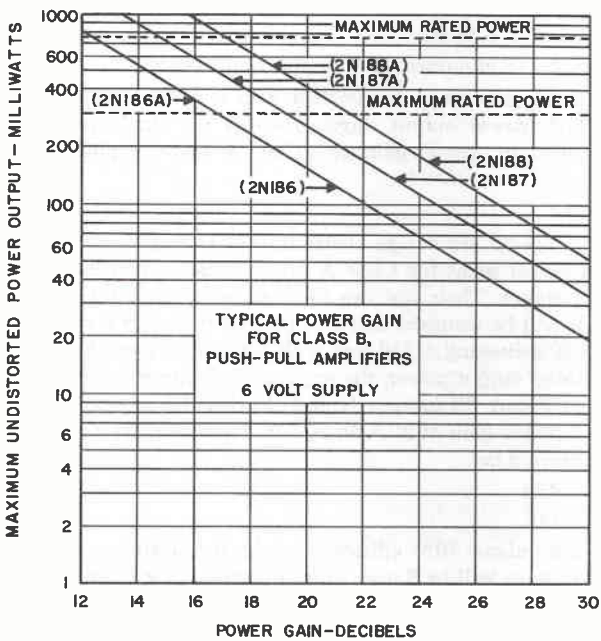


FIGURE 28

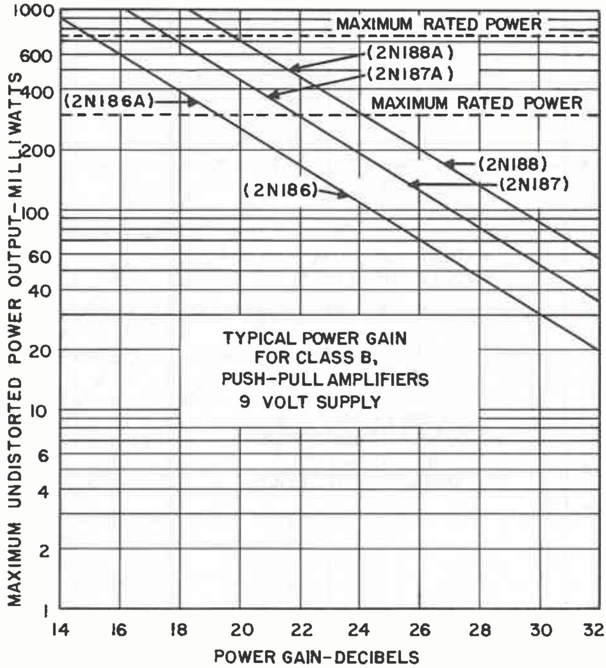


FIGURE 29

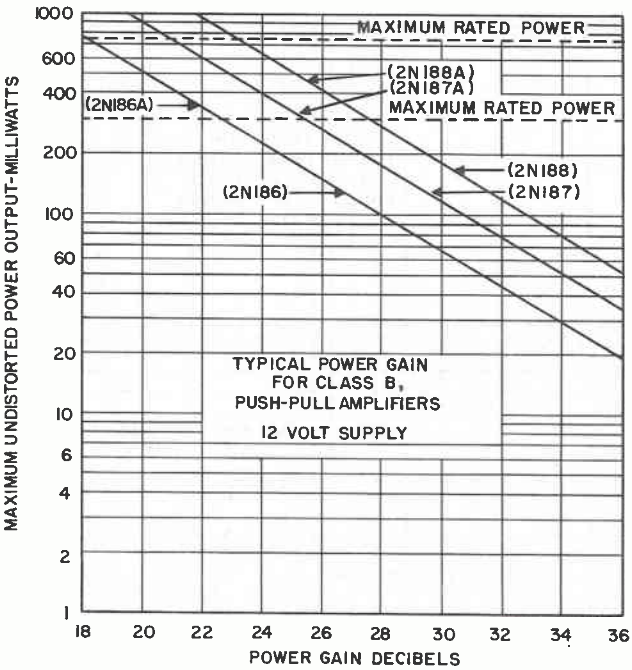


FIGURE 30

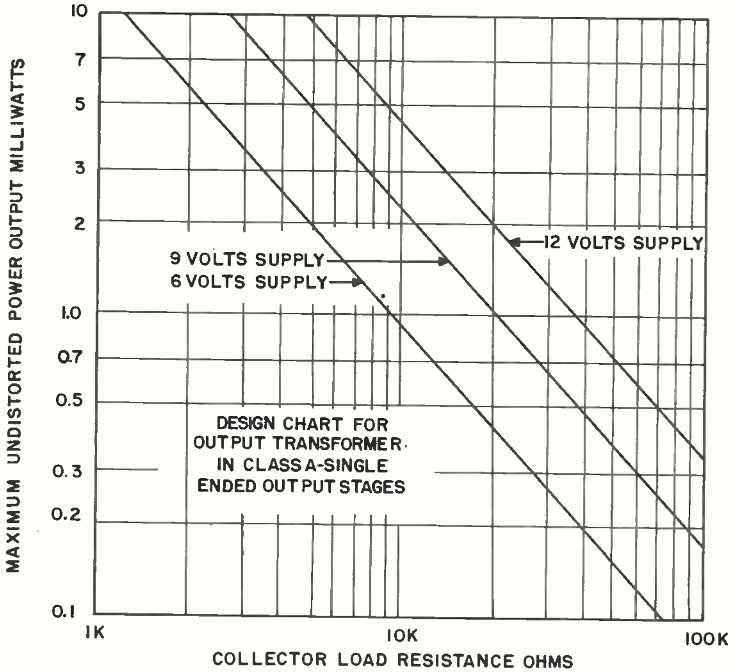


FIGURE 31

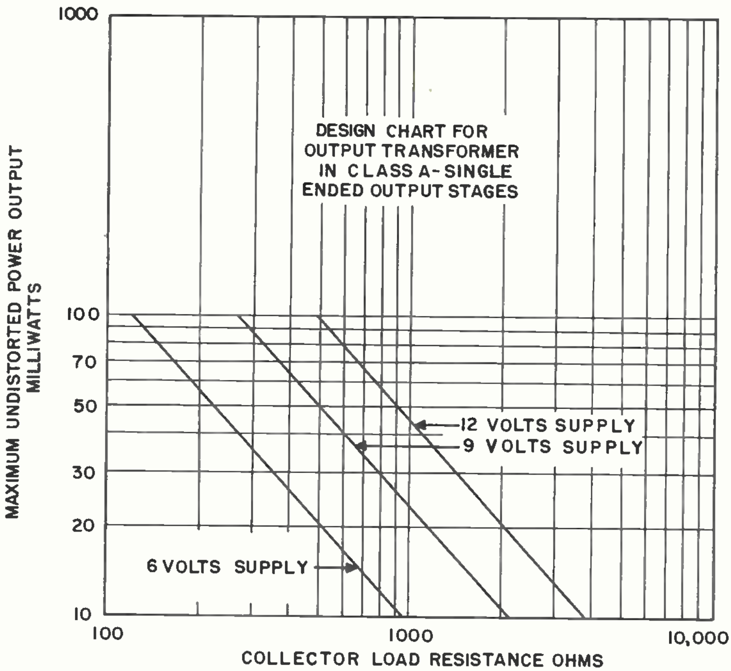


FIGURE 32

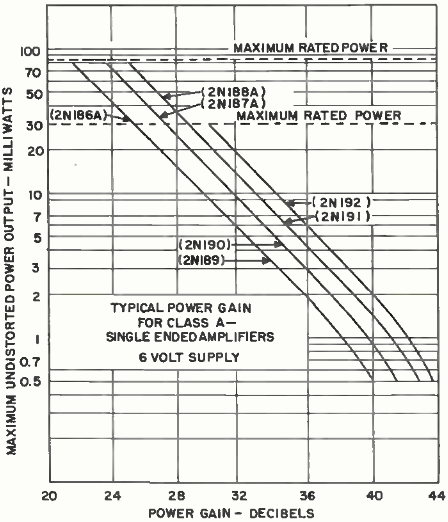


FIGURE 33

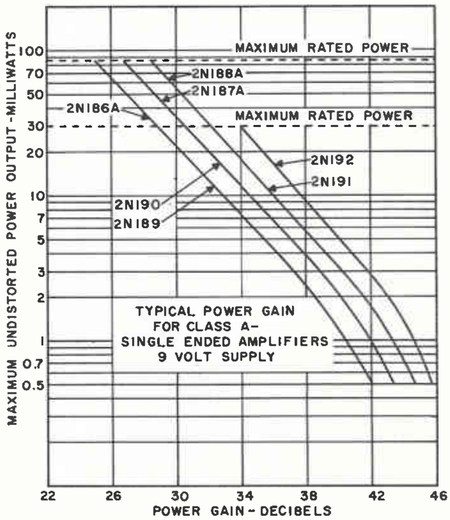


FIGURE 34

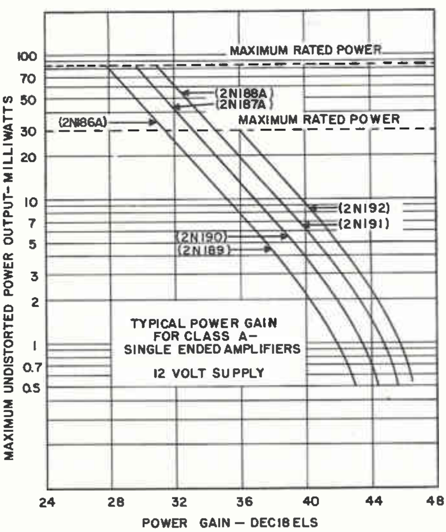


FIGURE 35

"HI-FI" CIRCUITS

Transistors are ideally suited for Hi-Fi amplifiers since there is no problem with hum pick-up from filaments as there is with tubes. Transistors are inherently low impedance devices, therefore matching the characteristics of magnetic pick-ups and loudspeakers.

To obtain the wide frequency response and low distortion needed in hi-fi equipment, negative feedback must be used around conventional transistor amplifiers.

PRE-AMPLIFIERS

By using an un-bypassed resistance in the emitter of the second stage of a two stage amplifier, a voltage is obtained which is proportional to the output current of the amplifier. If a resistance and a capacitor are connected to this resistor as shown in Figure 36, a signal is fed back to the input which is proportional to the output current.

If the feedback capacitor is made very large, the frequency response is essentially flat and the gain is determined only by the ratio of R_1 to R_2. If the capacitor is made small, the feedback current will depend upon the frequency being amplified and it is possible to obtain a boost of the low frequencies. With the values shown, the two

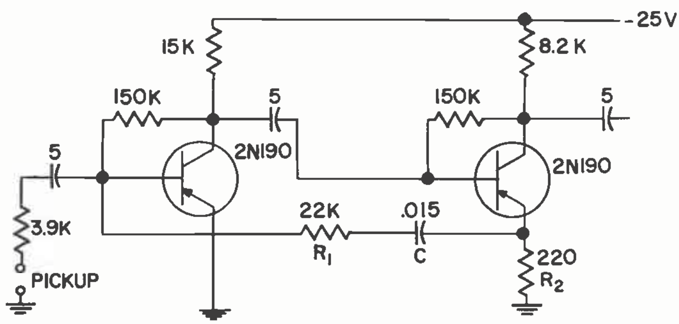


FIGURE 36

stage amplifier provides compensation for a General Electric Variable Reluctance Pick-up reproducing from records recorded to the RIAA Standards.

In vacuum tube pre-amplifiers, feedback voltage is usually obtained from the plate of the second stage and applied to a resistor in the cathode of the first stage. This method of feedback is not well suited for an all-transistor amplifier since voltage feedback tends to control the *voltage* applied to the next stage whereas it would be more desirable in transistor amplifiers to control the *current* into the next stage by feedback. If a transistor pre-amplifier is to be used with a vacuum tube amplifier, however, voltage feedback can be used successfully.

A very simple one transistor pre-amplifier for the General Electric Reluctance Pick-up is shown by Figure 37.

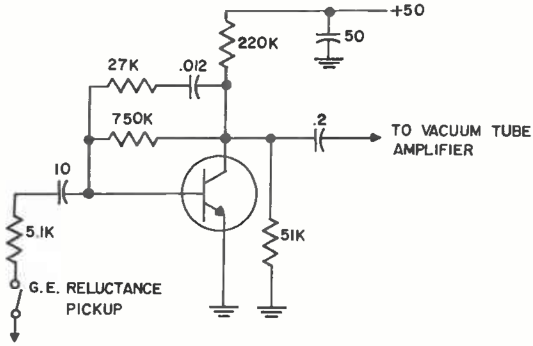


FIGURE 37

In this circuit, voltage feedback is used from collector to base to give the desired bass boost and the input resistor R_1 in combination with the inductance of the magnetic cartridge gives the proper high frequency roll-off. By using different values of R_1, correct compensation can be obtained for other pick-ups. The 50 volt supply can be obtained from a voltage divider across the B^+ supply of the tube amplifier.

TONE CONTROLS

Tone control circuits for transistor amplifiers are somewhat different than conventional vacuum tube tone controls since the impedance levels in transistor circuits are lower. A satisfactory bass and treble tone control for use between transistor stages is shown by Figure 38.*

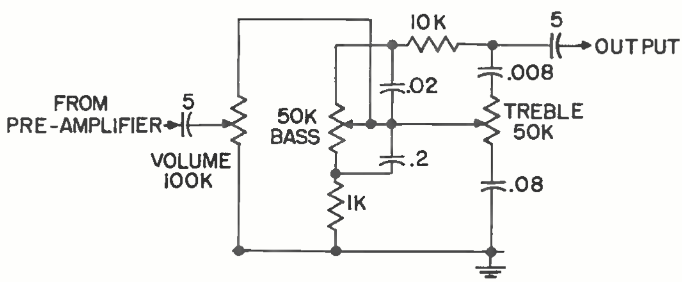


FIGURE 38

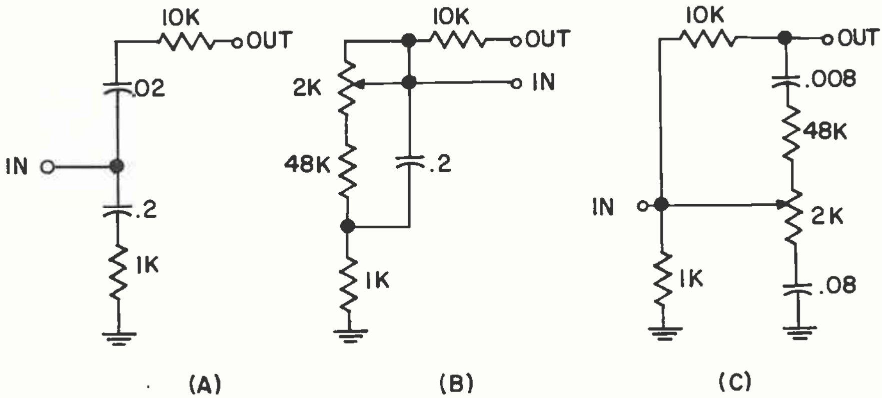
The action of the tone controls is easily understood if they are considered as current transfer networks rather than voltage transfer networks as in vacuum tube amplifiers. The output current from the preceding stage goes to the volume control where part of it is shunted to ground and the rest goes to the junction of the 0.02 μfd and 0.2 μfd capacitors and the center arms of the potentiometers. At 1000 cycles, the equivalent circuit of the tone controls is very simple, as shown in Figure 39(A). At this frequency, the current is divided so that 10/11ths of the current is shunted to ground

* "Transistor Electronics", Lo, Endres et al.

and 1/11th goes on to the next transistor. The low-frequency equivalent circuit for the "bass boost" condition is shown in Figure 39(B). With the movable arm of the potentiometer near the top, the 0.02 μfd capacitor is bypassed and more of the current is shunted into the 10,000 ohm resistor as the impedance of the 0.2 μfd capacitor rises at low frequencies.

The high-frequency equivalent circuit of the tone control is shown in Figure 39(C) for the "treble cut" condition. Depending on the potentiometer setting, most of the higher frequencies will be shunted to ground as compared to a 1000 cycle signal. With the potentiometer arm at the top, the higher frequency current would bypass the 10,000 ohm resistor and a treble boost would be achieved.

The performance of the tone controls is shown by Figure 40.



(A) A 1 KC EQUIVALENT CIRCUIT. (B) LOW-FREQUENCY EQUIVALENT CIRCUIT, AND (C) THE EQUIVALENT CIRCUIT AT HIGH FREQUENCIES.

FIGURE 39

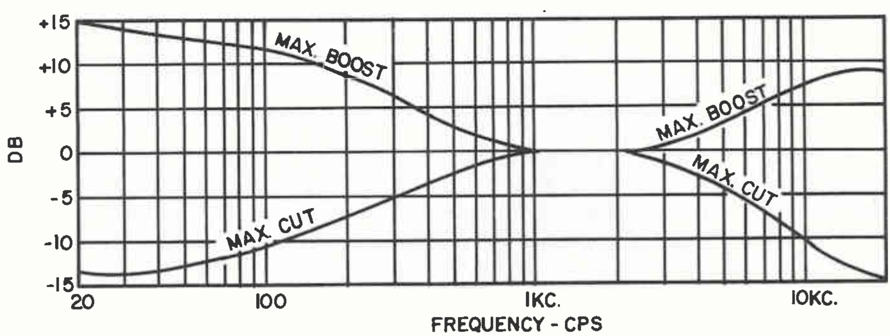


FIGURE 40

POWER OUTPUT STAGES

A great deal of effort has gone into developing transformerless push-pull amplifiers using vacuum tubes. Practical circuits, however, use many power tubes in parallel to provide the high currents necessary for direct driving of low impedance loudspeakers.

The advent of power transistors has given new impetus to the development of transformerless circuits since transistors are basically low voltage, high current devices. The emitter follower stage, in particular, offers the most interesting possibilities since it has low inherent distortion and low output impedance.

A very simple emitter follower output stage is shown in Figure 41. The loudspeaker is capacitively connected to a large enough emitter resistance so that essentially all the AC current flows into the load. It is obvious that with bias currents of one ampere,

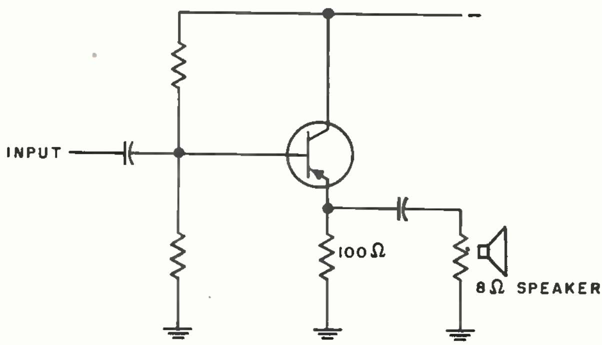


FIGURE 41

an emitter resistance of any practical value will be extremely wasteful of power. The resistor could be replaced by a choke, but a 1 henry choke capable of carrying one ampere of current is impractical in size.

By using another transistor to replace the 100 ohm resistor in Figure 41 it is possible to make a transformerless, self-phase inverting, push-pull amplifier. This basic circuit, called the followed emitter follower, is shown in Figure 42. By inserting a small resistor, on the order of one ohm, in the collector of T_1, a signal is generated propor-

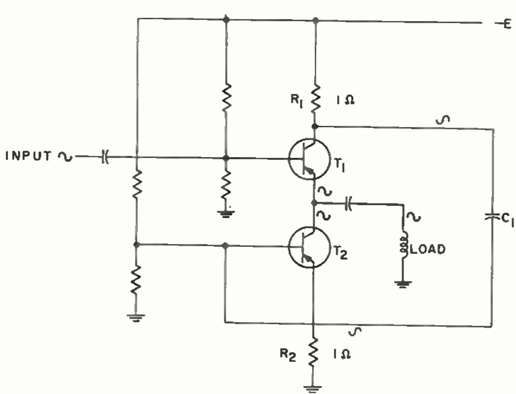


FIGURE 42

tional to the current flowing in T1. If a one ohm resistor is placed in the emitter of T2 and capacitor C1 connected as shown in Figure 42, the same voltage will appear across resistor R2 as appeared across R1. This means that the current flowing in T2 is an exact replica of the current flowing in T1 except it is 180° out-of-phase. These two currents add together and flow into the load so that each transistor only has to carry half of the required AC current. The current in T2 follows the current in T1 (hence the named followed emitter follower) and will change in accordance with the variations of input impedance with frequency that are experienced in loudspeakers.

The circuit Figure 42 has two disadvantages. The first disadvantage is that for adequate thermal stability, resistor R2 and hence R1 must be several ohms and therefore dissipate considerable power and needlessly increase the required supply voltage. A second disadvantage is that any hum appearing on the supply voltage is coupled almost without attenuation through capacitor C1 to the base of T2 and hence appears across the load. These difficulties can be overcome by using the circuit of Figure 43.

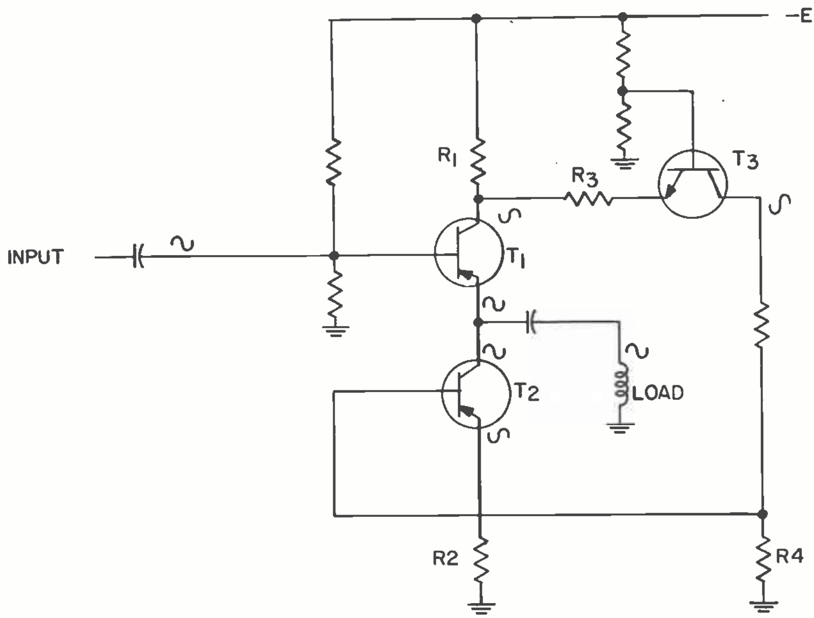


FIGURE 43

In this circuit, transistor T3 is in the common base configuration and acts to couple the A.C. signal across R1 to the base of T2 without change in phase. Any A.C. ripple will be applied both to the base and emitter of T3 and hence will not cause any net change in emitter current that would be coupled to T2. A major advantage of this additional transistor is that any change in DC voltage at the collector of T1 is amplified and appears at the base of T2 in such a manner as to return the current in the power transistors to the original value. The loop gain for DC voltage changes is unity and hence the stability of the entire circuit is equal to that of a grounded base transistor even though the transistors are in the grounded emitter configuration.

A practical version of this circuit is shown in Figure 44. Additional transistors are

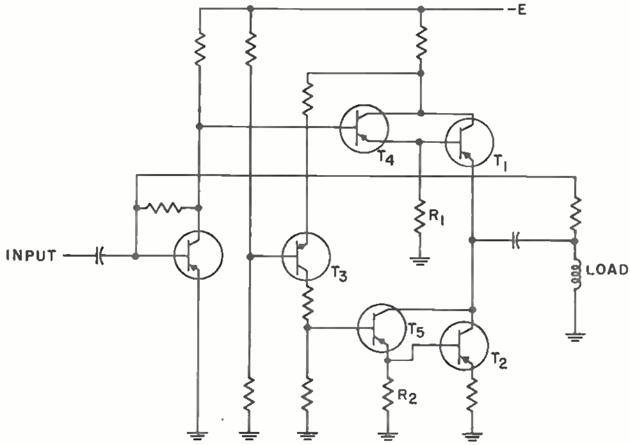


FIGURE 44

connected to the power transistors in the Darlington connection to increase the current gain. Resistors R1 and R2 are used to increase the bias current flowing in T4 and T5. This allows the power transistors to be driven to full output at high audio frequencies where the current gain of power transistors begins to decrease. Overall feedback is taken from the loudspeaker to the driver stage to further decrease the distortion. This amplifier is capable of 7 watt output power into an 8 ohm load at 1/2 percent distortion and the distortion at 1/2 power is .25 percent. The maximum output power is limited by the supply voltage which in this case was 30 volts. The AC impedance looking back from the load into the amplifier is only three-tenths of an ohm providing a damping factor of 25 for an 8 ohm speaker.

The frequency response is flat within ±0.1 db from 20 cps to 20 Kc. The complete schematic diagram of a transistor Hi-Fi amplifier is on pages 97 and 98.

IF AMPLIFIERS:

A typical circuit for a transistor IF amplifier is shown by Figure 45.

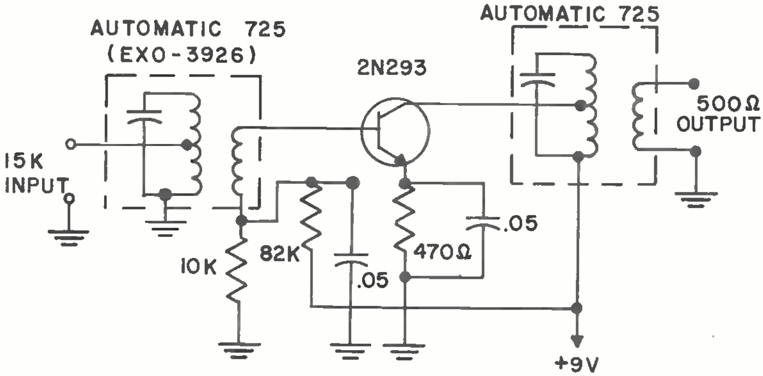
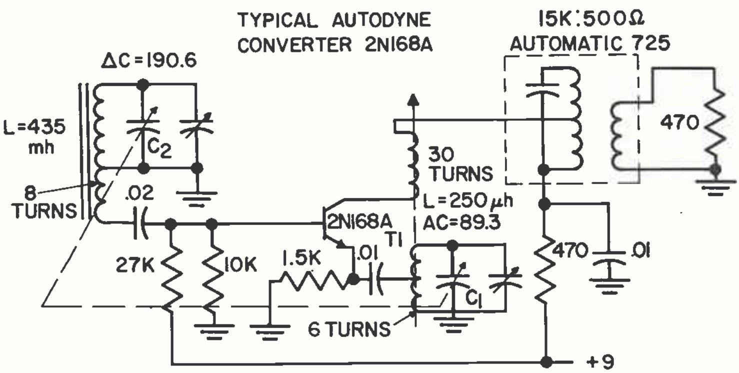


FIGURE 45

The collector current is determined by a voltage divider on the base and a large resistance in the emitter. The input and output are coupled by means of tuned IF transformers. The .05 capacitors are used to prevent degeneration by the resistance in the emitter. The collector of the transistor is connected to a tap on the output transformer to provide proper matching for the transistor and also to make the performance of the stage relatively independent of variations between transistors of the same type. With a rate-grown NPN transistor such as the 2N293, it is unnecessary to use neutralization to obtain a stable IF amplifier. With PNP alloy transistors, it is necessary to use neutralization to obtain a stable amplifier and the neutralization capacitor depends on the collector capacitance of the transistor. The gain of a transistor IF amplifier will decrease if the emitter current is decreased. This property of the transistor can be used to control the gain of the IF amplifier so that weak stations and strong stations will produce the same audio output from a radio. Typical circuits for changing the gain of an IF amplifier in accordance with the strength of the received signal are shown in the circuit section of the manual.

AUTODYNE CONVERTER CIRCUITS

The converter stage of a transistor radio is a combination of a local oscillator, mixer and IF amplifier. A typical circuit for this stage is shown by Figure 46.



ANTENNA-DELTA COIL#1-105A OR EQUIVALENT

OSCILLATOR COIL – E. STANWYCK CO.#1129 (MODIFIED) OR EQUIVALENT

CAPACITOR-RADIO CONDENSER#242 OR EQUIVALENT

I.F. TRANSFORMER-AUTOMATIC 725 (EXO-3926) OR EQUIVALENT

FIGURE 46

Transformer T_1 feeds back a signal from the collector to the emitter causing oscillations. Capacitor C_1 tunes the circuit so that it oscillates at a frequency 455 Kc higher than the incoming radio signal. This local oscillator signal is injected into the emitter of the transistor. The incoming signal is tuned by means of capacitor C_2 and after passing through an auto transformer to match the input impedance of the transistor, it is injected into the base. The two signals are mixed by the amplifier and the resultant beat frequency of 455 Kc is selected by the IF transformer and fed into the next stage. For optimum performance the collector current should be 0.6 to 0.8 ma and the local oscillator injection voltage at the emitter 0.15 to 0.25 volts.

REFLEX CIRCUITS

"A reflex amplifier is one which is used to amplify at two frequencies – usually intermediate and audio frequencies."*

The system consists of using an I.F. amplifier stage and after detection to return the audio portion to the same stage where it is then amplified again. Since in Figure 47,

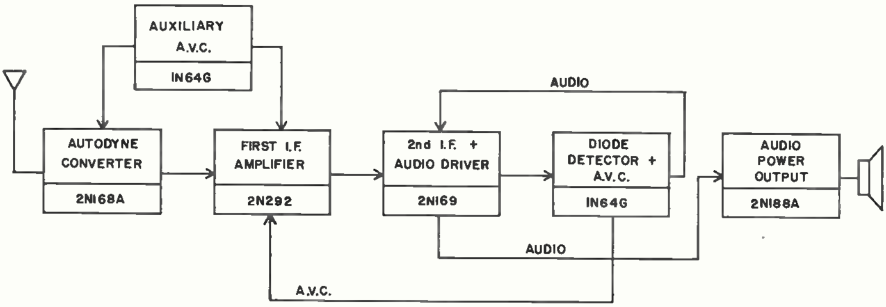


FIGURE 47

two signals of widely different frequencies are amplified, this does not constitute a *"regenerative effect"* and the input and output loads of these stages can be split audio – I.F. loads. In Figure 48, the I.F. signal (455 Kc/s) is fed through T2 to the detector circuit CR1, C3 and R5. The detected audio appears across the volume control R5 and is returned through C4 to the cold side of the secondary of T1.

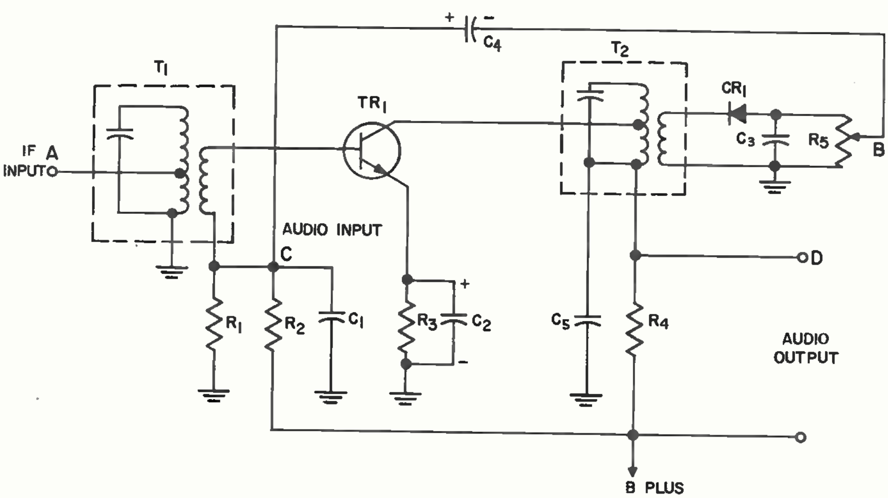


FIGURE 48

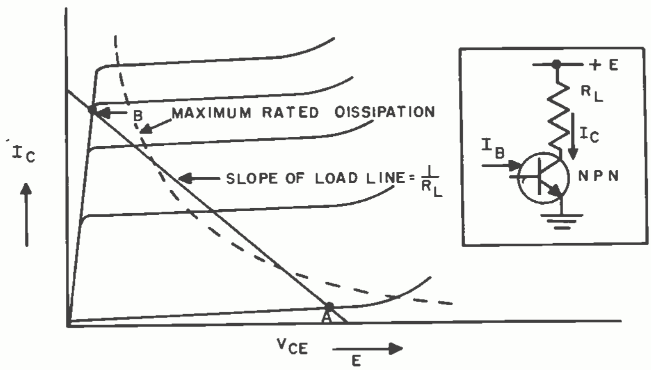
* F. Langford-Smith, Radiotron Designers Handbook, Australia, 1953, p. 1140

Since the secondary only consists of a few turns of wire, it is essentially a short circuit at audio frequencies. C1 bypasses the I.F. signal otherwise appearing across the parallel combination of R1 and R2. The emitter resistor R3 is bypassed for both audio and I.F. by the electrolytic condenser C2. After amplification, the audio signal appears across R4 from where it is then fed to the audio output stage. C5 bypasses R4 for I.F. frequencies and the primary of T2 is essentially a short circuit for the audio signal.

The advantage of "reflex" circuits is that one stage produces gain otherwise requiring two stages with the resulting savings in cost, space, and battery drain. The disadvantages of such circuits are that the design is considerably more difficult, although once a satisfactory receiver has been designed, no outstanding production difficulties should be encountered. Other disadvantages are a somewhat higher amount of playthrough (i.e. signal output with volume control at zero setting), and a minimum volume effect. The latter is the occurrence of minimum volume at a volume control setting slightly higher than zero. At this point, the signal is distorted due to the balancing out of the fundamentals from the normal signal and the out-of-phase play-through component. Schematics of complete radios using "reflex" I.F. stages are on pages 99 through 102.

TRANSISTOR SWITCHES

A switch is characterized by a high resistance when it is open and a low resistance when it is closed. Transistors can be used as switches. They offer the advantages of no moving or wearing parts and are easily actuated from various electrical inputs. Transistor collector characteristics as applied to a switching application is shown in Figure 49. The operating point A indicates the transistor's high resistance when $I_B = O$. $I_C = \frac{I_{CO}}{1-\alpha}$



COLLECTOR CHARACTERISTICS

FIGURE 49

when $I_B = O$. Since $I-\alpha$ is a small number, 1_C may be many times greater than I_{CO}. Shorting the base to the emitter results in a smaller I_C. If the base to emitter junction is reversed biased by more than .2v, I_C will approach I_{CO}. Reverse biasing achieves the highest resistance across an open transistor switch.

When the transistor switch is turned on, the voltage across it should be a minimum. At operating point B of Figure 49, the transistor is a low resistance. Alloy transistors such as the 2N188A have about one ohm resistance when switched on. Grown junction transistors, such as the 2N167 have approximately 80 ohms resistance which makes them less suitable for high power switching although they are well suited for high speed computer applications. In order that a low resistance be achieved, it is necessary that point B lie beyond the knee of the characteristic curves. The region beyond the knee is referred to as the saturation region. Enough base current must be supplied to ensure that this point is reached. It is also important that both the on and off operating points lie in the region below the maximum rated dissipation to avoid transistor destruction. It is permissible, however, to pass through the high dissipation region very rapidly since peak dissipations of about one watt can be tolerated for a few microseconds with a transistor rated at 150 mw. In calculating the I_B necessary to reach point B, it is necessary to know how h_{FE} varies with I_C. Curves such as Figure 50 are provided for switching transistors. Knowing h_{FE} from the curve gives

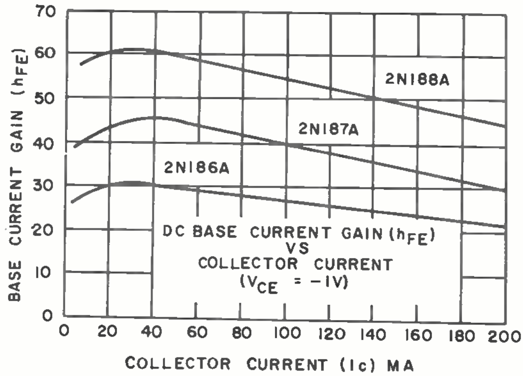
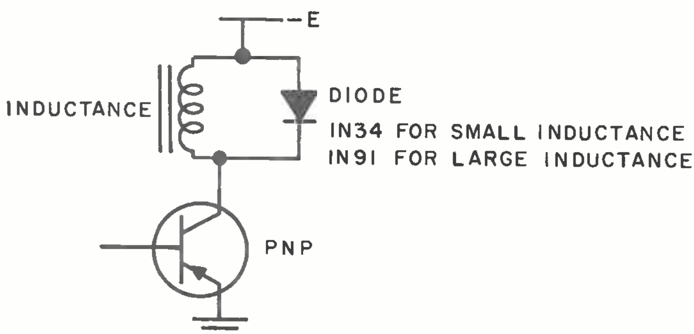


FIGURE 50

$I_{B\,min}$ since $I_{B\,min} = \frac{I_C}{h_{FE}}$. Generally I_B is made two or three times greater than $I_{B\,min}$ to allow for variations in h_{FE} with temperature or aging. The maximum rated collector voltage should never be exceeded since destructive heating can occur once a transistor breaks down. Inductive loads can generate injurious voltage transients. These can be avoided by connecting a diode across the inductance to absorb the transient as shown in Figure 51.

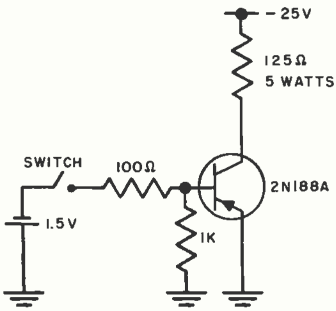


DIODE USED TO PROTECT TRANSISTOR FROM INDUCTIVE VOLTAGE TRANSIENTS.

FIGURE 51

Lighted incandescent lamps have about 10 times their off resistance. Consequently, I_B must be increased appreciably to avoid overheating the switching transistor when lighting a lamp.

A typical switching circuit is shown in Figure 52. The requirement is to switch a



TYPICAL VALUES

I_c = 80μA SWITCH OPEN

I_c = 0.2A SWITCH CLOSED

I_s = 10mA = CURRENT THROUGH SWITCH

V_{ce} = .19V SWITCH CLOSED

V_{be} = .48V SWITCH CLOSED

INPUT POWER = 15 MILLIWATTS

LOAD POWER = 5 WATTS

FIGURE 52

200 ma current in a 25 volts circuit, delivering 5 watts to the load resistor. The mechanical switch contacts are to carry a low current and be operated at a low voltage to minimize arcing. The circuit shown uses a 2N188A. The 1K resistor from the base to ground reduces the leakage current when the switch is open. Typical values are indicated in Figure 52.

PULSE CIRCUITS

Feedback makes circuits independent of variations within the feedback loop. Negative feedback is used to ensure undistorted output. Positive feedback stabilizes circuitry in a different manner. In positive feedback circuits the output has precise levels which are largely independent of component variations or input waveforms. Thus the output can be accurately predicted in spite of distortion of the input. It is this characteristic of positive feedback amplifiers that has made electronic computers feasible. Counters, flip-flops and multivibrators in computer and radar circuits are stabilized by the positive feedback inherent in their design.

By applying positive feedback in switching applications, it is possible to ensure that the transistor passes through the high dissipation region quickly even though the triggering input may be applied very slowly. A number of positive feedback circuits are possible. Figure 53 shows a conventional stabilized two stage amplifier with the

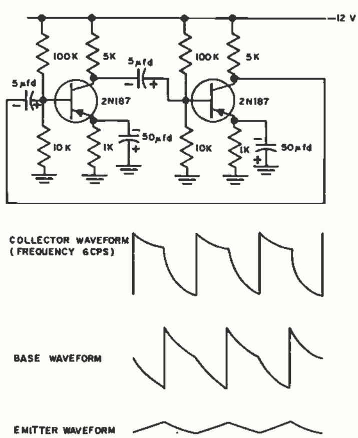


FIGURE 53

output connected to the input giving positive feedback. This circuit will oscillate producing essentially square waves at the collectors and sawteeth at the bases. A varia-

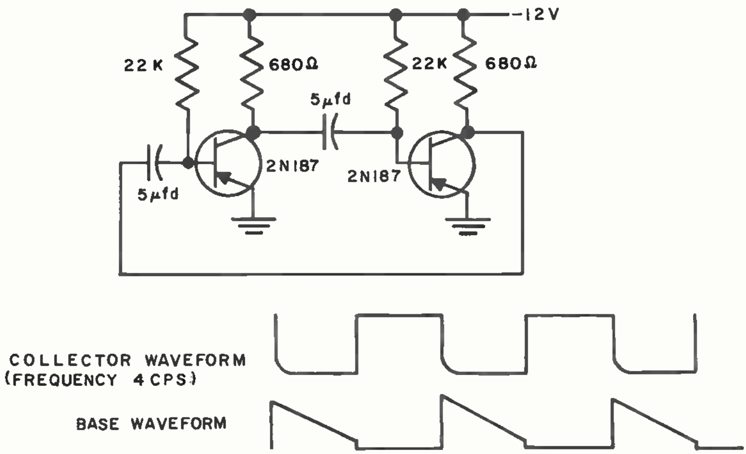


FIGURE 54

tion of this circuit is shown in Figure 54. The stabilizing components of Figure 53 are omitted here since they are not necessary unless transistor interchangeability and operation over a wide temperature range are necessary. To ensure that this circuit starts readily, the base resistors should limit I_B to a value such that the collector voltage does not drop below one volt since transistors have low gain in the saturation region. If positive feedback is applied to a D.C. amplifier, a bistable circuit results.

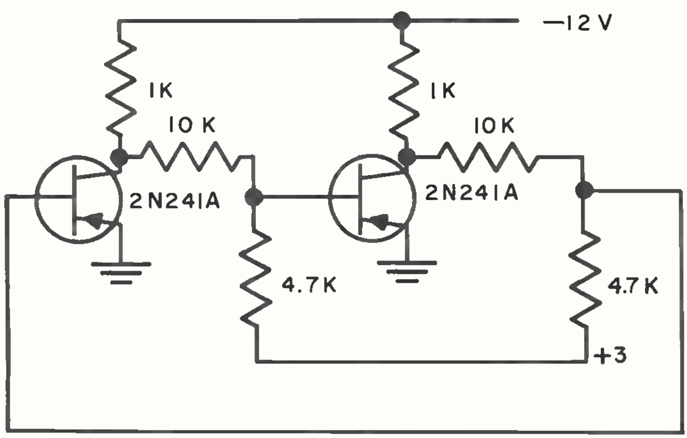


FIGURE 55

In Figure 55, only one transistor conducts at a time. If the transistor which is off has a resistor connected momentarily from its base to the collector supply to make it conduct the other transistor will immediately turn off. A variation of this circuit is

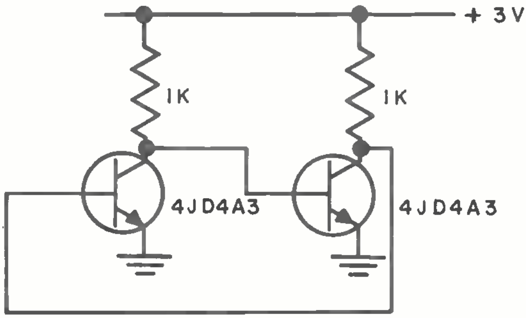


FIGURE 56

shown in Figure 56. Certain transistors, such as the G.E. germanium 4JD1A68 or the G.E. silicon 4JD4A3, are specially selected to work in this very simple circuit. Circuit operation can be easily understood if one transistor is assumed to be non-conducting. The other transistor will be at the operating point B of Figure 49 because both resistors in the circuit are equal. With typical values of collector current (about 2 ma), the collector voltage will be less than 100 millivolts. When this voltage is applied to the base of the non-conducting transistor as shown in the circuit, it is insufficient to cause an appreciable I_B, consequently, this transistor is truly non-conducting as was initially assumed. The base voltage on the conducting transistor is about .3 volts using germanium transistors, and .7 volts using silicon transistors. The few components used in the circuit are equal. With typical values of collector current (about 2 ma), the germanium circuits are stable up to about 40°C, silicon circuits are stable at 125°C.

In a transistor amplifier, the collector and emitter voltages are in phase so that collector to emitter feedback is positive. Figure 57 illustrates this form of feedback

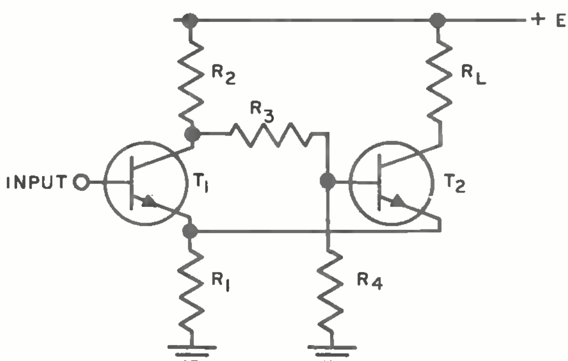


FIGURE 57

applied to transistor T1. It is impossible to connect the collector and emitter directly together without impedance matching. Transistor T2 can be considered an emitter follower which reduces the feedback impedance making it suitable to drive the emitter of the first transistor. This is the transistor analogue of the tube cathode-coupled flip-flop. Note that the collector of the second transistor doesn't contribute to circuit operation and consequently a load can be introduced there if desired. It turns out that this circuit lends itself to simple design and can be used in a number of applications.

SIMPLIFIED FLIP-FLOP DESIGN

The following is a simplified design procedure, which will quickly yield a working circuit that can be optimized by more complicated techniques if required. Referring to Figure 57, it is assumed that it is required to connect a load R_L across a voltage E. The design procedure makes 0.9E appear across R_L which is generally satisfactory, however, it is only necessary to increase the supply voltage by about 10% to get E volts across R_L.

1. Choose R_L and E.
2. Calculate I_{C2} $\qquad I_{C2} \approx \frac{0.9E}{R_L}$
3. Select a transistor rated for E volts and I_{C2} ma. If $I_{C2} < 10$ ma any good NPN or PNP transistor will do. For $I_{C2} > 10$ ma, the alloy junction transistors are best.
4. Select $R_1 \approx \frac{R_L}{10}$
5. Select $R_2 > R_L$ $\quad$ typically $R_2 = 2R_L$

   If the input to the base of T1 is applied very slowly, it may be possible to exceed the dissipation ratings of T1 unless $\frac{E^2}{4R_2}$ does not exceed the maximum permissible dissipation of T1.

   The dissipation considerations may limit the minimum value of R_2 that can be used. In calculating R_3 and R_4, I_{CO} will be neglected since it is generally small compared to the current being switched. This design will assure stable operation, but the switching characteristics will not be precisely determined. It is assumed that a transistor in saturation has approximately .5v from base to emitter and .2v from collector to emitter. The measured values given in Figure 52 justify this assumption.
6. Calculate V_{B2}, the base voltage on T2. V_{B2} is approximately the emitter voltage plus .5v. $V_E2 \approx R_1I_{C2}$ therefore $V_{B2} \approx R_1I_{C2} + .5$.
7. Determine h_{FE} at I_{C2} for T_2 using published data. Use the minimum value quoted. Call this h_{FE2}.
8. Calculate I_{B2}, the base current of T_2. $I_{B2} = \frac{I_{C2}}{h_{FE2}}$
9. Allow a current equal to I_{B2} through R_4 for good temperature stability; therefore,

   $$R_4 = \frac{V_{B2}}{I_{B2}} = \frac{(R_1I_{C2} + .5)}{I_{C2}}\ h_{FE2}$$

   or

   $$R_4 = \frac{R_L}{10}\ (h_{FE2}) \text{ if .5 is negligible compared to } R_1I_{C2}.$$
10. While T_1 is off, R_2 and R_3 in series must supply the current through R_4 plus the base current of T_2, i.e., 2 I_{B2}. Neglecting the .5 volt base to emitter voltage:

    $$R_2 + R_3 = \frac{R_L\ h_{FE2}}{2}$$
11. Since R_2 has been chosen earlier, R_3 can be determined. $R_3 = \frac{R_L\ h_{FE2}}{2} - R_2$
12. Check that $R_3 \geq R_4$ in order to assure stability when T_2 is off. If this condition is not met, decrease R_2 and repeat the calculations.

    If a variable high impedance current source is used to drive the base of T_1, a curve showing base voltage vs. base current can be drawn resembling that of Figure 58. The shape of this curve and the impedance connected to the base

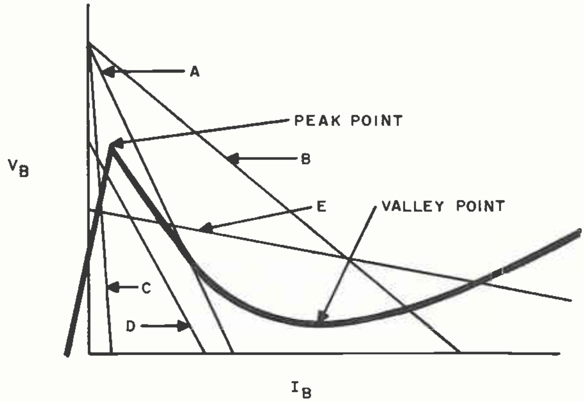


FIGURE 58

of T_1 determine whether the circuit is free-running, monstable or bistable. It is therefore important to determine the coordinates of the peak point and the valley point in order to obtain the desired mode of operation.

13. The peak point current (I_p) may be very small if T_2 has exactly the h_{FE2} used in the design. However, since the design used the minimum value of h_{FE2}, generally, the actual h_{FE2} will be greater. Calculate I'_{B2} as in 7 and 8 using the maximum h_{FE2}. This permits calculating
$$I_{C1} = \frac{5E}{11R_2} - \frac{I'_{B2}(R_2 + R_3)}{R_2}$$
where I_{C1} is the maximum T_1 collector current possible at the peak point. This gives I_p max. $= \frac{I_{C1}}{h_{FE1}}$ where h_{FE1} is h_{FE} for T_1 at a current I_{C1}. Therefore the actual I_p will lie between O and $\frac{I_{C1}}{h_{FE1}}$.

14. The peak point voltage (V_p) is reached when I_{C2} begins to decrease. If T_2 has the h_{FE2} used in the calculations, I_{C2} decreases as soon as T_1 starts to conduct. Since the emitter voltage of T_1 is known ($V_{E1} = V_{E2}$), the peak point voltage is approximately $V_p = \frac{E}{11}$.
If h_{FE2} is actually greater than the value used in the calculations, T_1 must conduct appreciably before I_{C2} drops. The upper limit for V_p is given by assuming that both I_{C2} and I_{C1} (from 13) flow through R_1 simultaneously. Then V_p max. $= R_1 (I_{C1} + I_{C2}) + .5$ where .5 volts is the base to emitter voltage. Therefore the actual V_p will lie between $\frac{E}{11}$ and $R_1 (I_{C1} + I_{C2}) + .5$.

15. The valley point voltage (Vv) is reached when T_2 just stops conducting, i.e. when $I_{C2} = O$. I_{CO} is neglected. An upper limit on Vv is the voltage across R_1 when T_1 saturates plus its emitter to base voltage.
$$V_v = R_1 I_{C1} + .5 = \frac{R_1 E}{R_1 + R_3} + .5$$
Since R_1 was chosen much smaller than R_L, V_p and Vv are simply related.
$$\frac{V_p}{V_v} \quad \frac{R_3}{R_L}.$$

16. The valley point current (I_v) is $I_v \approx \frac{I_{C1}}{h_{FE1}'}$ where h_{FE1}' is the current gain of T_1 for a collector current $I_{C1} = \frac{E}{R_1 + R_3}$.

Now that the coordinates of the peak and valley points are known, in order to get oscillations the input characteristics must be intersected in the negative resistance region only, by a load line such as A in Figure 58. A typical circuit is shown in Figure 59. R_1 and C determine the frequency of oscillation.

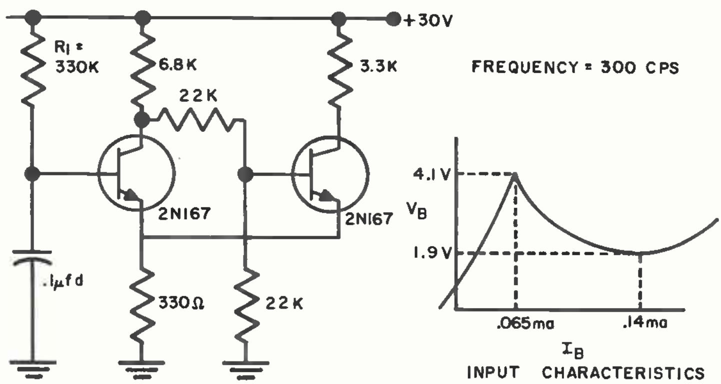


FIGURE 59

Load line B gives only one stable operating point with T_1 conducting continuously. A negative pulse to the base of T_1 will turn it off for an interval dependent on R_1C after which T_1 will again conduct. A typical circuit is shown in Figure 60.

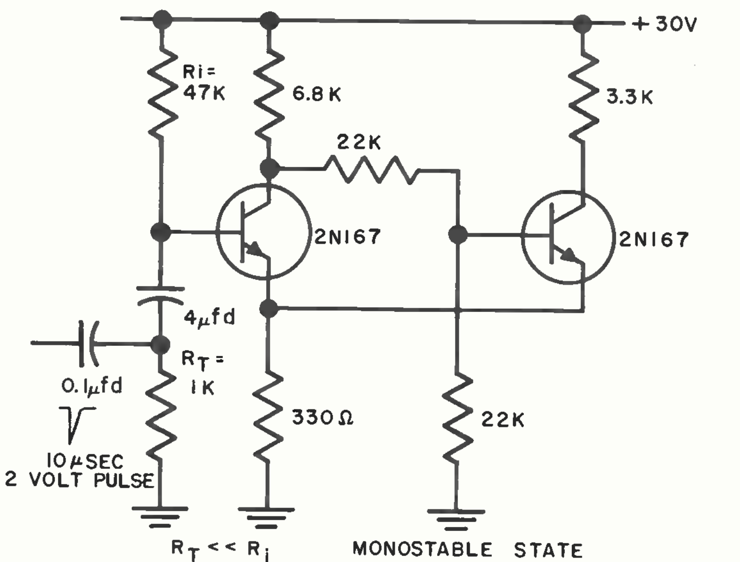


FIGURE 60

If R_1 is made so large that the peak point current cannot be reached, as indicated by load line C of Figure 58, only one stable position will exist with T_1 essentially off. A positive trigger will cause T_1 to conduct for a short interval. The same triggering scheme as shown for load line B applies. Finally, if R_1 is returned to a voltage between the peak point and valley point potentials, one of two conditions will apply. If R_1 is large, load line D will result giving similar performance to load line C. If R_1 is small as in load line E, two stable operating points will be obtained. In the latter case, a positive trigger will cause T_1 to conduct until a negative trigger arrives turning it off. The flip-flop will stay in either state indefinitely. The bistable circuit is as shown

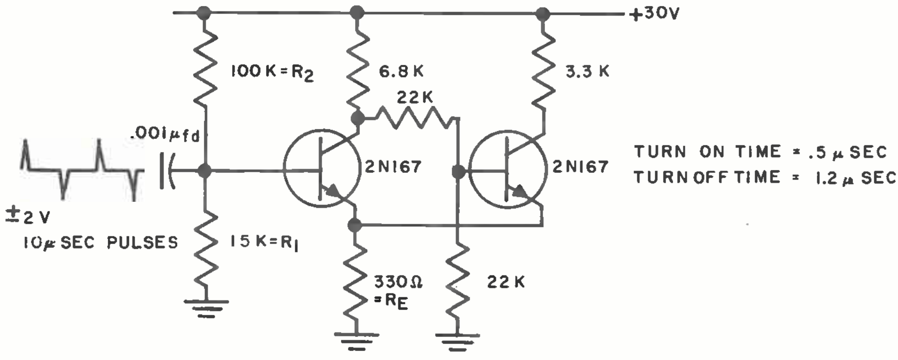


FIGURE 61

in Figure 61. Here, $R_1 = \frac{R_1 R_2}{R_1 + R_2}$ and the voltage it is returned to is $E \frac{R_1}{R_1 + R_2}$.

Since $R_L \simeq 10\ R_E$, then $R_2 \simeq 10R_1$, therefore $R_1 \simeq R_1$, and

$$E \frac{R_1}{R_1 + R_2} \simeq E \frac{R_1}{R_2}$$

This circuit can also be triggered by DC. The capacitor would be replaced by a resistor which would inject current into the base of T1. For precise triggering with small trigger signals, it is necessary to adjust R_1 and its' return voltage until the load line lies very nearly along the negative resistance part of the input characteristic. A potentiometer in the emitter of T_2 permits adjustment of the sensitivity. This is shown in Figure 62.

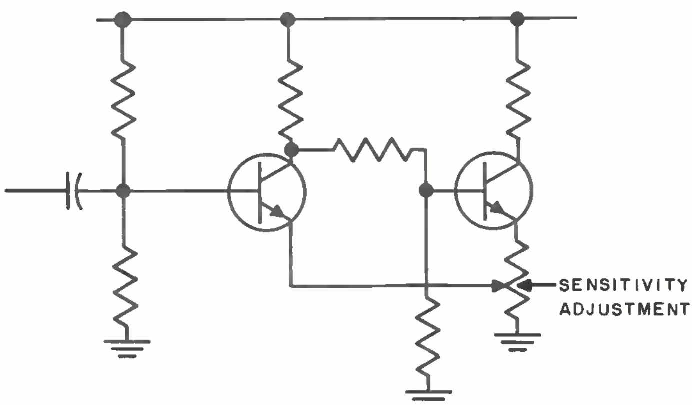


FIGURE 62

The Unijunction transistor (formerly known as the double base diode) has input characteristics similar to those of the circuit just described. This makes it possible with a single transistor to make free-running, monostable and bistable circuits. Its operation is described in the Semiconductor Theory portion of this manual.

A simple oscillator is shown in Figure 63. For typical transistors, if R lies between

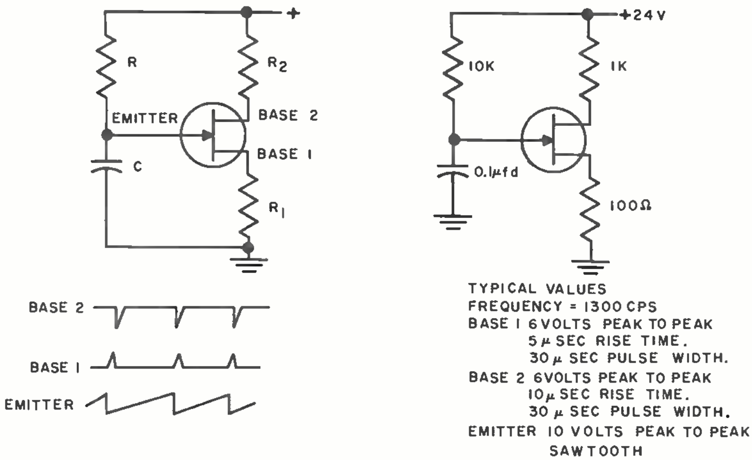


FIGURE 63

2,000 ohms and 1 megohm, oscillations are obtained as shown. For R < 2K, the transistor will stay on continuously. For R > 1 megohm, the transistor stays off continuously. The frequency is readily changed by varying R or C. This circuit can be readily adapted to a number of applications.

The oscillator can be synchronized to generate sub-harmonics with circuit waveforms resembling those of a blocking oscillator. Figure 64 shows such a circuit.

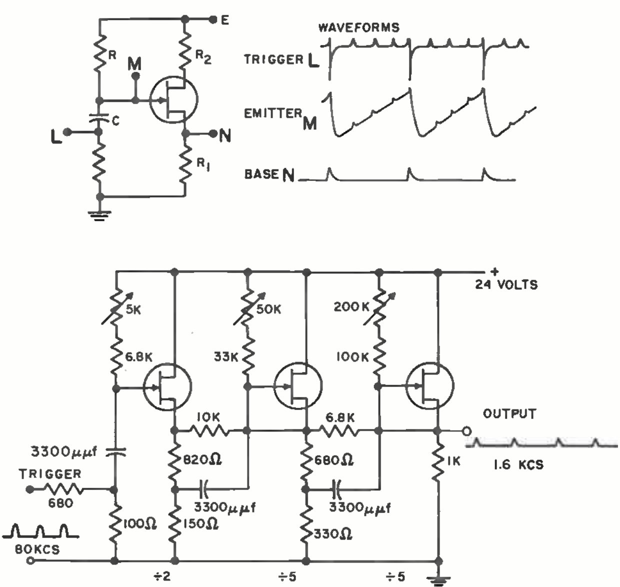


FIGURE 64

A moderate output audio oscillator is constructed by placing a 3 ohm loudspeaker in the base 1 circuit.

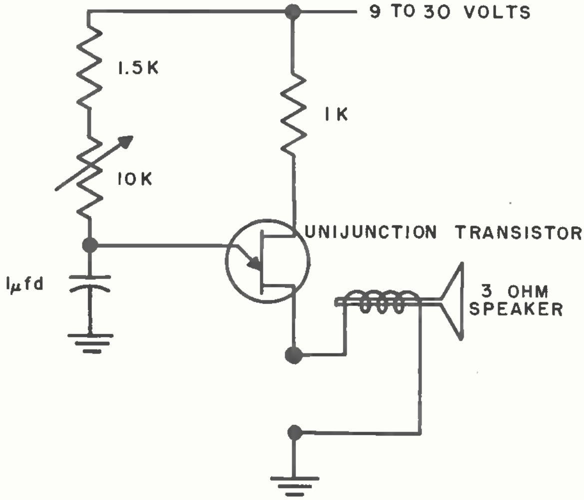


FIGURE 65

By increasing the value of R, the circuit can be used as a highly stable metronome.

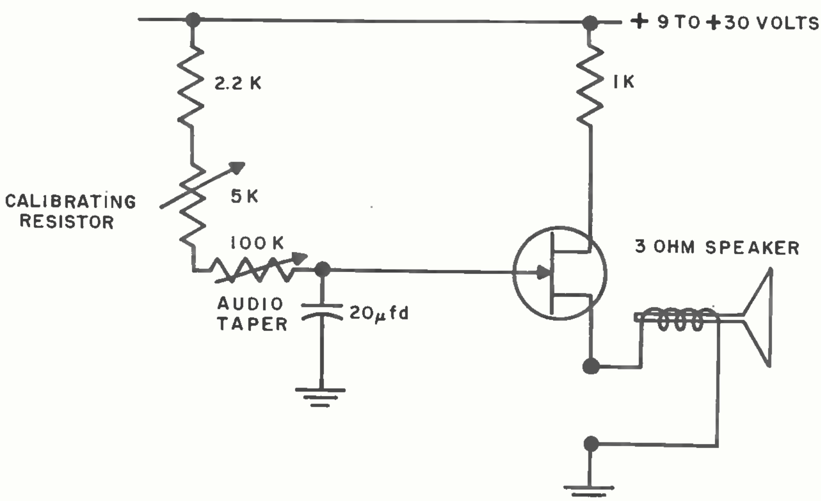
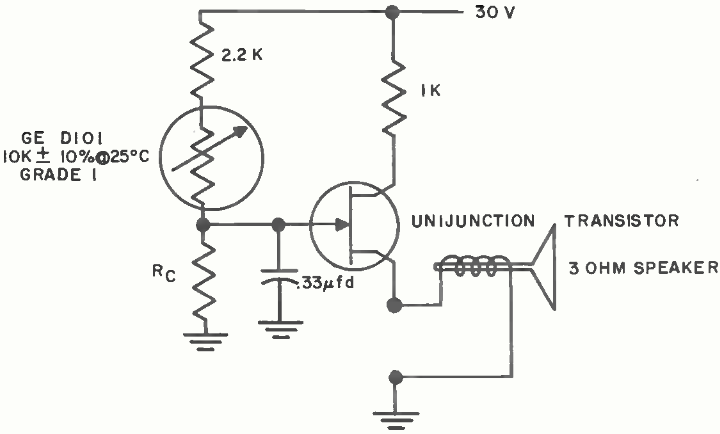


FIGURE 66

A temperature sensitive circuit useful as a thermostat or a fire alarm is achieved by using a thermistor as shown in Figure 67.

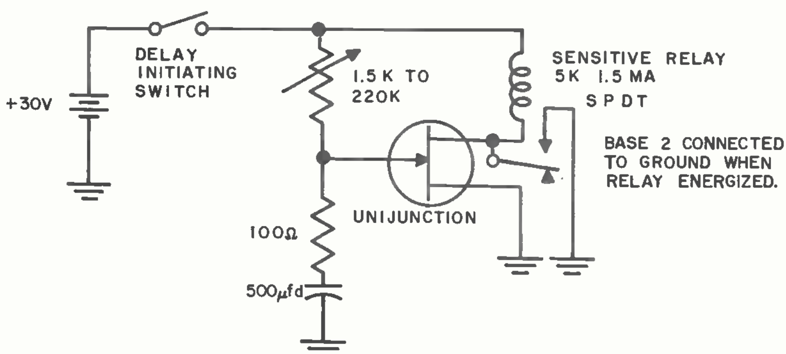


TYPICAL VALUES

R_C	ALARM TEMPERATURE
15 K	100°F
10 K	120°F
6.8 K	150°F
4.7 K	220°F

FIGURE 67

A variable time delay generator up to 3 or 4 minutes is easily achieved. The circuit of Figure 68 offers high accuracy and a short recovery time.



DELAY APPROX 1 SECOND FOR 1K OF VARIABLE RESISTOR

FIGURE 68

A precise timer can be made by adapting the delay circuit. A variation of the

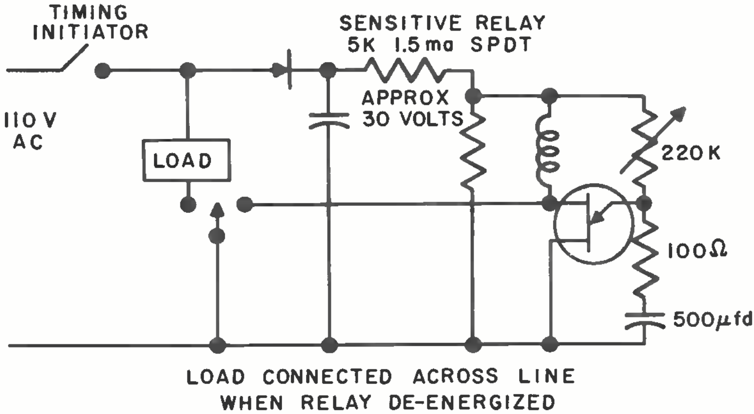


FIGURE 69

oscillator circuit generates rectangular waveforms. For oscillation R_1 should lie be-

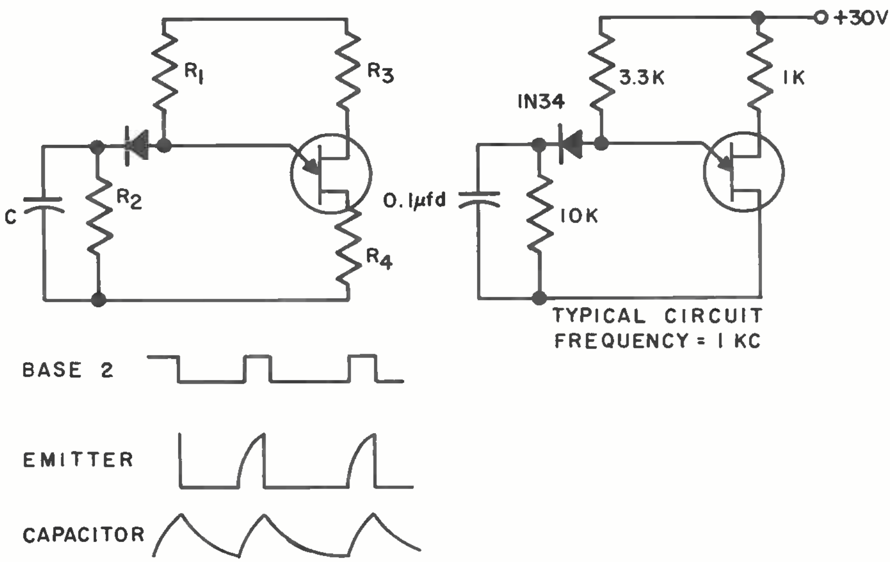


FIGURE 70

tween 2K and 1 megohm for typical transistors. R_2 must satisfy the equation $\frac{R_2}{R_1 + R_2}$ > stand-off ratio.

Another positive feedback configuration is made possible by using NPN and PNP transistors. Figure 71 shows a direct coupled NPN-PNP amplifier with positive feed-

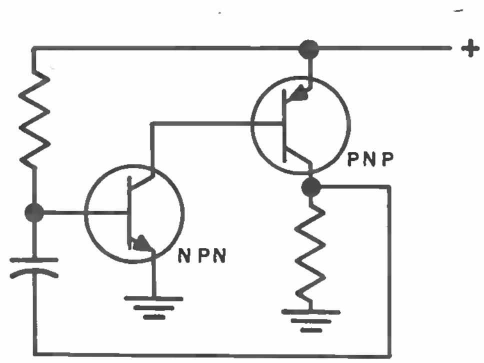


FIGURE 71

back. This circuit generates a sawtooth at the base of the NPN transistor.

A variation of this circuit has the amplifier input at the emitter of the NPN transistor and feedback is applied to its base. It is found that the collectors and bases of the transistors are interconnected. This is the well-known hook connection. Figure 72 shows the circuit and the input characteristics. This curve can be used as with the

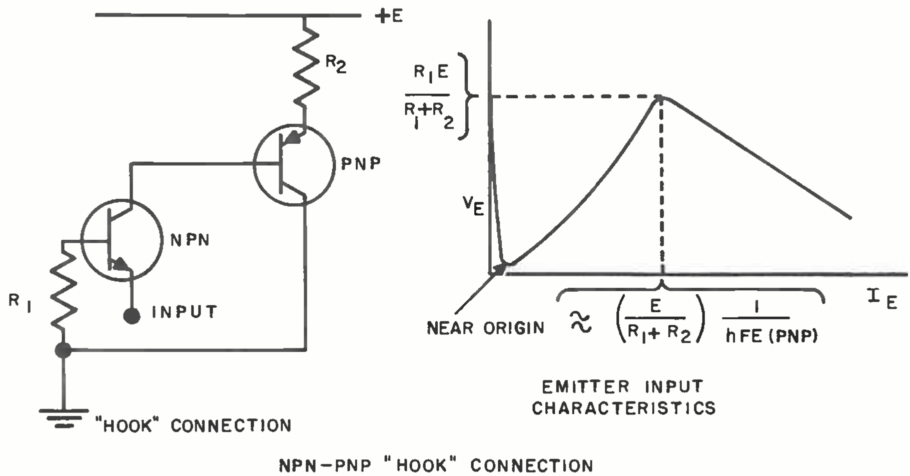
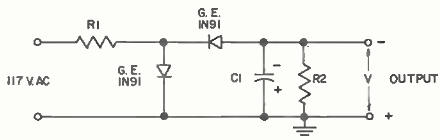


FIGURE 72

Unijunction Transistor and emitter coupled flip-flop to get free-running, monstable and bistable operation. One of the features of this circuit is that both transistors are on or off together minimizing the amount of standby power required.

Both silicon and germanium cells can be used in the types of power supplies illustrated in Figures 73, 74, 75, and 76. All four of these power supplies are designed for low ripple output and high reliability at minimum expense. However, they are limited to Class A types of load in which the average load current does not vary with the amplitude of the impressed signal. Class B loads require a stiffer voltage source than

PRE-AMP POWER SUPPLY

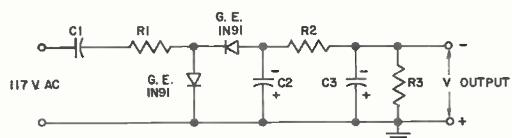


OUTPUT VOLTAGE V	OUTPUT CURRENT	R1	C1	R2*	APPROX. RIPPLE
12 VOLTS	1 MA.	43K, 1/2W	250 μf 15 VOLT ELECTROLYTIC	180K 1/2W	0.1%
12 VOLTS	2 MA.	22K, 1/2W	250μf 15 VOLT ELECTROLYTIC	100K 1/2W	0.1%
25 VOLTS	2 MA.	18K, 1/2W	250μf 15 VOLT ELECTROLYTIC	180K 1/2W	0.1%

*TO ADJUST VOLTAGE OUTPUT FOR OTHER OUTPUT CURRENTS, ADJUST R2.

FIGURE 73

GENERAL PURPOSE TRANSISTOR POWER SUPPLY

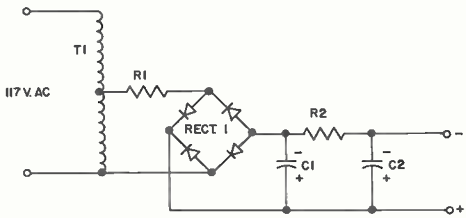


OUTPUT VOLTAGE V	OUTPUT CURRENT	R1	R2	R3*	C1 METALLIZED PAPER	C2	C3	APPROX. RIPPLE
12 VOLTS	100MA.	2Ω 1 WATT	100Ω 2W	2200Ω 1W	THREE 2-μf IN PARALLEL 200 V	250 μf 15 VOLT ELECTROLYTIC	250 μf 15 VOLT ELECTROLYTIC	0.5%
12 VOLTS	150MA	2Ω 1 WATT	100Ω 10W	2200Ω 1W	FOUR 2-μf IN PARALLEL 200V	250μf 15 VOLT ELECTROLYTIC	250μf 15 VOLT ELECTROLYTIC	0.5%
25 VOLTS	50 MA	2Ω 1 WATT	250Ω 2W	10,000Ω 1W	TWO 2-μf IN PARALLEL 200V	100μf 50 VOLT ELECTROLYTIC	250μf 25 VOLT ELECTROLYTIC	0.5%

* TO ADJUST VOLTAGE OUTPUT FOR OTHER OUTPUT CURRENTS, ADJUST R3.

FIGURE 74

POWER SUPPLY FOR HIGH POWER CLASS A TRANSISTOR AMPLIFIERS

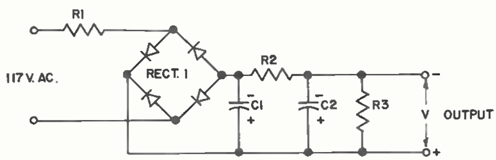


OUTPUT VOLTAGE V	OUTPUT CURRENT	R1	R2	C1	C2	RECT. 1	APPROX. RIPPLE
40 VOLTS	1 AMP.	3Ω 10 WATTS	20Ω 20 WATTS	300μf 150 VOLT ELECTROLYTIC	1000μf 50 VOLT ELECTROLYTIC	FOUR G.E. 1N158 OR FOUR G.E. 1N540	1%

T1 - U.T.C. R-43 AUTOTRANSFORMER OR EQUAL
2:1 WINDING RATIO

FIGURE 75

POWER SUPPLY FOR HIGH-POWER CLASS A TRANSISTOR AMPLIFIER



OUTPUT VOLTAGE V	OUTPUT CURRENT	R1	R2	C1	C2	R3*	RECT. 1	APPROX. RIPPLE
40 VOLTS	1 AMP	5Ω 20W	75Ω 100W	100μf 150 VOLTS ELECTROLYTIC	300μf 50 VOLTS ELECTROLYTIC	1000Ω 2 W	FOUR G.E. 1N158 OR FOUR G.E. 1N540	1%

* TO ADJUST VOLTAGE OUTPUT FOR OTHER OUTPUT CURRENTS, ADJUST R3.

FIGURE 76

the resistance-capacity combinations of the illustrated power supplies can provide. For Class B and other loads that require good voltage regulation, it is recommended that the line voltage be reduced through transformers rather than series resistance or capacitance, and that chokes be substituted for the series resistance in the filter elements. Alternately, a regulated power supply such as shown on page 95 can be used.

This circuit uses a step-down transformer and full-wave rectifier as a source of unregulated DC. A power transistor acts as a series regulator and mercury batteries are used for the voltage reference. The battery drain is very small so their life is essentially equal to the shelf life.

When a semiconductor rectifier feeds a capacity-input filter such as in Figures 73 through 76, it is necessary to limit the high charging current that flows into the input capacitor when the circuit is energized. Otherwise this surge of current may destroy the rectifier. Resistor R1 is used in Figures 73 through 76 to limit this charging current to safe values.

As shown, the four power supplies do not isolate the load circuit from the 117 volt AC line. In Figures 73 and 74, the load circuit may be grounded provided a polarized plug is used on the AC line cord to ensure that the grounded side of the AC line is always connected to the grounded side of the load. Figures 75 and 76 utilize what is called a single phase bridge rectifier circuit to achieve full wave rectification, and hence, lower ripple. Since ground cannot be carried through on a common line to the load in this type of circuit, it is necessary to insulate the load "ground" from accidental contact with true ground, or to insert an isolation transformer ahead of the power supply to isolate the two systems. Careful attention to these factors is of particular importance when supplying DC to high gain amplifiers to eliminate hum.

As illustrated, Figures 73 and 74 develop a negative output voltage with respect to ground as required when supplying P-N-P transistors with grounded emitters. To develop a positive voltage with respect to ground, it is only necessary to reverse the rectifiers and electrolytic capacitors in the circuit.

The power supply of Figure 75 uses an autotransformer to reduce the line voltage to one-half normal value before applying to the rectifiers. Provided the additional heat dissipation is not objectionable, Figure 76 provides a cheaper means of achieving the same objective by using resistor R2 to reduce the voltage to the desired value.

EXPLANATION OF PARAMETER SYMBOLS

SMALL SIGNAL & HIGH FREQUENCY PARAMETERS (at specified bias)

Symbols	Abbreviated Definitions
h_{ob}	Com. base — output admittance, input AC open-circuited
h_{ib}	Com. base — input impedance, output AC short-circuited
h_{rb}	Com. base — reverse voltage transfer ratio, input AC open-circuited
h_{fb}	Com. base } forward current transfer ratio, output AC short-circuited
h_{fe}	Com. emitter } forward current transfer ratio, output AC short-circuited
h_{fc}	Com. collector } forward current transfer ratio, output AC short-circuited
h_{oe}, h_{ie}	Examples of other corresponding com. emitter symbols
f_{ab}	Com. base } the frequency at which the magnitude of the small-signal short-circuit forward current transfer ratio is 0.707 of its low frequency value.
f_{ae}	Com. emitter } the frequency at which the magnitude of the small-signal short-circuit forward current transfer ratio is 0.707 of its low frequency value.
C_{ob}	Collector to base } Capacitance measured across the output terminals with the input AC open-circuited
C_{oe}	Collector to emitter } Capacitance measured across the output terminals with the input AC open-circuited
r'_b	Base spreading resistance
G_e	Com. emitter Power Gain (use G_b for com. base)
CG_e	Conversion gain
NF	Noise Figure

SWITCHING CHARACTERISTICS (at specified bias)

t_d	Ohmic delay time } These depend on both transistor and circuit parameters
t_r	Rise time } These depend on both transistor and circuit parameters
t_s	Storage time } These depend on both transistor and circuit parameters
t_f	Fall time } These depend on both transistor and circuit parameters
V_{CE} (SAT.)	Saturation voltage at specified I_C and I_B. This is defined only with the collector saturation region.
h_{FE}	Com. emitter — static value of short-circuit forward current transfer ratio, $h_{FE} = \frac{I_C}{I_B}$
h_{FE} (INV)	Inverted h_{FE} (emitter and collector leads switched)

DC MEASUREMENTS

I_C, I_E, I_B	DC currents into collector, emitter, or base terminal
V_{CB}, V_{EB}	Voltage collector to base, or emitter to base
V_{CE}	Voltage collector to emitter
V_{BE}	Voltage base to emitter
BV_{CBO}	Breakdown voltage, collector to base junction reverse biased, emitter open-circuited (value of I_C should be specified)
V_{CEO}	Voltage collector to emitter, at zero base current, with the collector junction reverse biased. Specify I_C.
BV_{CEO}	Breakdown voltage, collector to emitter, with base open-circuited. This may be a function of both "m" (the charge carrier multiplication factor) and the h_{fb} of the transistor. Specify I_C.
V_{CER}	Similar to V_{CEO} except a resistor of value "R" between base and emitter.
V_{CES}	Similar to V_{CEO} but base shorted to emitter.
V_{PT}	Punch-through voltage, collector to base voltage at which the collector space charge layer has widened until it contacts the emitter junction. At voltages above punch-through, $V_{PT} = V_{CB} - V_{EB}$
V_{CCB}	Supply voltage collector to base } NOTE — third subscript may be omitted if no confusion results.
V_{CCE}	Supply voltage collector to emitter } NOTE — third subscript may be omitted if no confusion results.
V_{BBE}	Supply voltage base to emitter } NOTE — third subscript may be omitted if no confusion results.
I_{CO}, I_{CBO}	Collector current when collector junction is reverse biased and emitter is DC open-circuited.
I_{EO}, I_{EBO}	Emitter current when emitter junction is reverse biased and collector is DC open-circuited.
I_{CEO}	Collector current with collector junction reverse biased and base open-circuited.
I_{CES}	Collector current with collector junction reverse biased and base shorted to emitter.
I_{ECS}	Emitter current with emitter junction reverse biased and base shorted to collector.

OTHER SYMBOLS USED

P_{CM}	Peak collector power dissipation for a specified time limit
P_{CAV}	Average maximum collector power dissipation
P_o	Power output
Z_i	Input impedance
Z_o	Output impedance
T_A	Operating Temperature
T_J	Junction Temperature
T_{STG}	Storage Temperature

NOTE: In devices with several electrodes of the same type, indicate electrode by number. Example: I_{B2}. In multiple unit devices, indicate device by number preceding electrode subscript. Example: I_{2C}. Where ambiguity might arise, separate complete electrode designations by hyphens or commas. Example: $V_{1C1\text{-}2C1}$ (Voltage between collector #1 of device #1 and collector #1 of device #2.)

NOTE: Reverse biased junction means biased for current flow in the high resistance direction.

2N43

Outline Drawing No. 8

The General Electric Type 2N43 Germanium Alloy Junction Transistor Triode is a PNP unit particularly recommended for high gain, low power applications. A hermetic enclosure is provided by use of glass-to-metal seals and welded seams.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS: (25°C)

Voltages		
Collector to Base	V_{CB}	—45 volts
Collector to Emitter	V_{CE}	—30 volts
Emitter to Base	V_{EB}	—5 volts
Collector Current	I_C	—300 ma
Power		
Total Transistor Dissipation	P_M	155 mw
Temperature		
Storage or Junction Temperature	T_{STG}–T_J	Max. +100 °C Min. —65 °C

ELECTRICAL CHARACTERISTICS: (25°C)

Small Signal Characteristics (V_{CB} or V_{CE} = —5 volts, I_E = 1 ma; f = 270 cps unless otherwise specified)		MIN.	MAX.	DESIGN CENTER	
Common base output admittance (input A-C open circuited)	h_{ob}	.1	1.5	.8	μmhos
Forward current transfer ratio (output A-C short circuited)	h_{fe}	30	66	42	
Common base input impedance (output A-C short circuited)	h_{ib}	25	35	29	ohms
Common base reverse voltage transfer ratio (input A-C open circuited)	h_{rb}	1	15	5×10^{-4}	
Common base output capacity (input A-C open circuited; f = 1 mc)	C_{ob}	20	60	40	μμf
Noise Figure (f = 1 Kc; BW = 1 cycle)	NF		20	6	db
Frequency cutoff (Common Base)	f_{ab}	.5	3.5	1.3	mc
D-C Characteristics					
Collector cutoff current (V_{CBO} = —45v)	I_{CO}		16	8	μamps
Emitter cutoff current (V_{EBO} = —5v)	I_{EO}		10	4	μamps
Common emitter static forward current transfer ratio (V_{CE} = —1 volt, I_C = 20 ma)	h_{FE}	34		53	
Common emitter static forward current transfer ratio (V_{CE} = —1 volt, I_C = 100 ma)	h_{FE}	30		48	
Collector to emitter voltage (10 K ohms resistor base to emitter, I_C = 0.6 ma)	V_{CER}	—25			volts
Punch-through voltage	V_{PT}	—30			volts
Thermal Characteristics					
Junction temperature rise/unit collector or emitter dissipation (in free air)				0.33	°C/mw
Junction temperature rise/unit collector or emitter dissipation (infinite heat sink)				0.2	°C/mw

2N43A

Outline Drawing No. 8

The 2N43A is a commercial version of the military type 2N43A per MIL-T-19500, and is tested to the same electrical, mechanical and degradation tests.

4JD1A17

Outline Drawing No. 8

The General Electric Type 4JD1A17 Germanium Alloy Junction Transistor Triode is a PNP unit particularly recommended for high gain, low power applications. A hermetic enclosure is provided by use of glass-to-metal seals and welded seams.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS: (25°C)

Voltages		
Collector to Base	V_{CB}	—45 volts
Collector to Emitter	V_{CE}	—30 volts
Emitter to Base	V_{EB}	—5 volts
Collector Current	I_C	—300 ma
Total Transistor Dissipation	P_M	155 mw
Storage or Junction Temperature	T_{STG}–T_J	Max. 100 °C Min. —65 °C

ELECTRICAL CHARACTERISTICS: (25 °C)

		MIN.	MAX.	DESIGN CENTER	
Small Signal Characteristics					
(VCB or VCE = —5 volts, IE = 1 ma; f = 270 cps unless otherwise specified)					
Common base output admittance (input A-C open circuited)	h_{ob}	0.1	1.5	0.8	μmhos
Forward current transfer ratio (output A-C short circuited)	h_{fe}	20	66	39	
Common base input impedance (output A-C short circuited)	h_{ib}	25	38	30	ohms
Common base reverse voltage transfer ratio (input A-C open circuited)	h_{rb}	1.0	15	5×10^{-4}	
Common base output capacity (input A-C open circuited; f = 1 mc)	C_{ob}	20	60	40	μμf
Noise Figure (f = 1 Kc; BW = 1 cycle)	NF		15	6	db
Frequency cutoff (Common Base)	f_{ab}	0.5	3.5	1.1	mc
D-C Characteristics					
Collector cutoff current (V_{CBO} = —45v)	I_{CO}		16	8	μamps
Emitter cutoff current (V_{EBO} = —5v)	I_{EO}		10	4	μamps
Common emitter static forward current transfer ratio (V_{CE} = —1 volt, I_C = 20 ma)	h_{FE}	25		43	
Common emitter static forward current transfer ratio (V_{CE} =—1 volt, I_C = 100 ma)	h_{FE}	23		37	
Collector to emitter voltage (10 K ohms resistor base to emitter, I_C = 0.6 ma)	V_{CER}	—25			volts
Punch-through voltage	V_{PT}	—30			volts
Thermal Characteristics					
Junction temperature rise/unit collector or emitter dissipation (in free air)				0.33	°C/mw
Junction temperature rise/unit collector or emitter dissipation (infinite heat sink)				0.2	°C/mw

2N44

Outline Drawing No. 8

The General Electric Type 2N44 Germanium Alloy Junction Transistor Triode is a PNP unit particularly recommended for medium gain, low power applications. A hermetic enclosure is provided by use of glass-to-metal seals and welded seams.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS: (25°C)

Voltages		
Collector to Base	V_{CB}	—45 volts
Collector to Emitter	V_{CE}	—30 volts
Emitter to Base	V_{EB}	—5 volts
Collector Current	I_C	300 ma
Total Transistor Dissipation	P_M	155 mw
Storage or Junction Temperature	T_{STG}–T_J	Max. +100 °C Min. —65 °C

ELECTRICAL CHARACTERISTICS: (25°C)

		MIN.	MAX.	DESIGN CENTER	
Small Signal Characteristics					
(VCB or VCE = —5 volts, IE = 1 ma; f = 270 cps unless otherwise specified)					
Common base output admittance (input A-C open circuited)	h_{ob}	0.1	1.5	0.9	μmhos
Forward current transfer ratio (output A-C short circuited)	h_{fe}			25	
Common base input impedance (output A-C short circuited)	h_{ib}	27	38	31	ohms
Common base reverse voltage transfer ratio (input A-C open circuited)	h_{rb}	1.0	13	4×10^{-4}	
Common base output capacity (input A-C open circuited; f = 1 mc)	C_{ob}	20	60	40	μμf
Noise Figure (f = 1 Kc; BW = 1 cycle)	NF		15	6	db
Frequency cutoff (Common Base)	f_{ab}	0.5	3.0	1.0	mc

D-C Characteristics

Collector cutoff current (V_{CBO} = —45v)	I_{CO}		16	8	µamps
Emitter cutoff current (V_{EBO} = —5v)	I_{EO}		10	4	µamps
Common emitter static forward current transfer ratio (V_{CE} = —1 volt, I_C = 20 ma)	h_{FE}	18	43	31	
Common emitter static forward current transfer ratio (V_{CE} = —1 volt, I_C = 100 ma)	h_{FE}	13		25	
Collector to emitter voltage (10 K ohms resistor base to emitter, I_C = 0.6 ma)	V_{CER}	—25			volts
Punch-through voltage	V_{PT}	—30			volts

Thermal Characteristics

Junction temperature rise/unit collector or emitter dissipation (in free air)				0.33	°C/mw
Junction temperature rise/unit collector or emitter dissipation (infinite heat sink)				0.2	°C/mw

2N45

Outline Drawing No. 8

The General Electric Type 2N45 Germanium Alloy Junction Transistor Triode is a PNP unit particularly recommended for low gain, low power applications. A hermetic enclosure is provided by use of glass-to-metal seals and welded seams.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS: (25°C)

Voltages		
Collector to Base	V_{CB}	—45 volts
Collector to Emitter	V_{CE}	—30 volts
Emitter to Base	V_{EB}	—5 volts
Collector Current	I_C	300 ma
Total Transistor Dissipation	P_M	155 mw
Storage or Junction Temperature	T_{STG}–T_J	Max. +100 °C Min. —65 °C

ELECTRICAL CHARACTERISTICS: (25 °C)

Small Signal Characteristics (V_{CB} or V_{CE} = —5 volts, I_E = 1 ma; f = 270 cps unless otherwise specified)		MIN.	MAX.	DESIGN CENTER	
Common base output admittance (input A-C open circuited)	h_{ob}	0.1	1.6	1.1	µmhos
Forward current transfer ratio (output A-C short circuited)	h_{fe}			15	
Common base input impedance (output A-C short circuited)	h_{ib}	27	38	31	ohms
Common base reverse voltage transfer ratio (input A-C open circuited)	h_{rb}	1	10	4×10^{-4}	
Common base output capacity (input A-C open circuited; f = 1 mc)	C_{ob}	20	60	40	µµf
Noise Figure (f = 1 Kc; BW = 1 cycle)	NF		15	6	db
Frequency cutoff (Common Base)	f_{ab}	0.5	2.5	0.9	mc
D-C Characteristics					
Collector cutoff Current (V_{CBO} = —45v)	I_{CO}		16	8	µamps
Emitter cutoff current (V_{EBO} = —5v)	I_{EO}		10	4	µamps
Common emitter static forward current transfer ratio (V_{CE} = —1 volt, I_C = 20 ma)	h_{FE}	11	31	20	
Common emitter static forward current transfer ratio (V_{CE} = —1 volt, I_C = 100 ma)	h_{FE}			15	
Collector to emitter voltage (10 K ohms resistor base to emitter, I_C = 0.6 ma)	V_{CER}	—25			volts
Punch-through voltage	V_{PT}	—30			volts
Thermal Characteristics					
Junction temperature rise/unit collector or emitter dissipation (in free air)				0.33	°C/mw
Junction temperature rise/unit collector or emitter dissipation (infinite heat sink)				0.2	°C/mw

2N78

Outline Drwg. No. 14

The General Electric 2N78 is a grown junction NPN high frequency transistor intended for high gain RF and IF amplifier service and general purpose applications. The G.E. rate-growing process used in the manufacture of the 2N78 provides the uniform and stable characteristics required for mobile and industrial service.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS:

Collector to Emitter Voltage (base open), V_{CEO}	15 volts
Collector to Base Voltage (emitter open), V_{CBO}	15 volts
Collector Current, I_C	20 ma
Emitter Current, I_E	—20 ma
Collector Dissipation (25°C)*, P_{CM}	65 mw
Storage Temperature, T_{STG}	85 °C

ELECTRICAL CHARACTERISTICS: (25°C)

	DESIGN CENTER	LIMITS MAX.	LIMITS MIN.	
Low Frequency Characteristics (Common Base) ($V_{CB} = 5$ V, $I_E = -1$ ma, f = 270 cps)				
Input Impedance (output short circuit), h_{ib}	55	35	75	ohms
Voltage Feedback Ratio (input short circuit), h_{rb}	2×10^{-4}	$.8 \times 10^{-4}$	10×10^{-4}	
Current Amplification (output short circuit), h_{fb}	.983 ($\beta = 50$)	.952 ($\beta = 20$)		
Output Admittance (input open circuit), h_{ob}	.2	.1	.7	µmhos
Noise Figure ($V_{CB} = 1.5$ V, $I_E = -0.5$ ma, f = 1 KC	12		20	db
High Frequency Characteristics (Common Base) ($V_{CB} = 5$ V, $I_E = -1$ ma)				
Alpha Cutoff Frequency, f_{ab}	6	3.7		mc
Output Capacity (f = 2 mc), C_{ob}	4	1	6	µµf
Cutoff Characteristics				
Collector Cutoff Current ($V_{CB} = 15$ V), I_{CO}	1	6		µa
Collector Cutoff Current ($V_{CB} = 5$ V), I_{CO}		2		µa

*Derate 1.1 mw/°C increase in ambient temperature.

2N107

Outline Drwg. No. 8

The General Electric type 2N107 is a diffused junction PNP transistor particularly suggested for students, experimenters, hobbyists, and hams. It is available only from franchised General Electric distributors. The 2N107 is hermetically sealed and will dissipate 50 milliwatts in 25°C free air.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS:

Collector Voltage (referred to base), V_{CB}	—12 volts
Collector Current, I_C	—10 ma
Emitter Current, I_E	10 ma
Junction Temperature, T_J	60 °C

ELECTRICAL CHARACTERISTICS: (25°C)

(Common Base, $T_J = 30$°C, f = 270 cps
$V_{CB} = -5$v, $I_E = 1$ ma)

Collector Voltage, V_{CB}	—5.0 volts
Emitter Current, I_E	1.0 ma
Output Admittance (input open circuit), h_{ob}	1.0 µmhos
Current Amplification (output short circuit), h_{fb}	—.95
Input Impedance (output short circuit), h_{ib}	32 ohms
Voltage Feedback Ratio (input open circuit), h_{rb}	3×10^{-4}
Collector Cutoff Current, I_{CO}	10 µa
Output Capacitance, C_{ob}	40 µµf
Frequency Cutoff, f_{ab}	0.6 mc
Common Emitter, ($V_{CE} = -1$v, $I_E = 1$ ma)	
Base Current Gain, h_{fe}	20

2N123

Outline Drwg. No. 8

The General Electric type 2N123 is a PNP alloy junction high frequency switching transistor intended for military, industrial and data processing applications where high reliability at the maximum ratings is of prime importance.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS:

Collector to Emitter Voltage (base open), V_{CEO}	—15 volts
Collector to Base Voltage (emitter open), V_{CBO}	—20 volts
Emitter to Base Voltage (collector open), V_{EBO}	—10 volts
Collector Current, I_C	—125 ma
Peak Collector Current (10 µs max.), I_{CM}	—500 ma
Emitter Current, I_E	125 ma
Collector Dissipation (25°C)*, P_{CAV}	100 mw
Peak Collector Dissipation (10 µs max.; 25°C)**, P_{CM}	500 mw
Total Transistor Dissipation (25°C)***, P_{AV}	150 mw
Storage Temperature, T_{STG}	—55 to 85 °C

ELECTRICAL CHARACTERISTICS: (25°C)

Switching Characteristics (Common Emitter)	DESIGN CENTER	LIMITS MIN.	LIMITS MAX.	
D.C. Base Current Gain ($V_{CE} - 1$ v; $I_C = 10$ ma) I_C/I_B	50	30	150	
Saturation Voltage ($I_B = .5$ ma; $I_C = 10$ ma), V_{CE}	.15		0.2	volts
Pulse Response Time ($I_C = 10$ ma)				
Delay & Rise Time, t_r	.9			µsec
Storage Time, t_s	.5			µsec
Fall Time, t_f	.5			µsec

Cutoff Characteristics				
Collector Cutoff Current ($V_{CB} = -20v$), I_{CO}	2		6	μa
Emitter Cutoff Current ($V_{EB} = -10v$), I_{EO}	2		6	μa
Collector to Emitter (Base open, $I_C = -0.6$ ma), V_{CE}	25	15		volts
High Frequency Characteristics (Common Base) ($V_{CB} = -5v$; $I_E = 1$ ma)				
Alpha Cutoff Frequency, f_{ab}	8	5		mc
Collector Capacitance (f = 1 mc), C_{ob}	15			$\mu\mu f$
Voltage Feedback Ratio (f = 1 mc), h_{rb}	8×10^{-3}			
Base Spreading Resistance, r'_b	80			ohms
Low Frequency Characteristics (Common Base) ($V_{CB} = -5v$; $I_E = 1$ ma; f = 270 cps)				
Input Impedance, h_{ib}	28			ohms
Voltage Feedback Ratio, h_{rb}	8×10^{-4}			
Current Amplification, h_{fb}	.980	.970		
Output Admittance, h_{ob}	.9			μmbos

Derate for increase in ambient temperature:
*1.67 mw/°C, **8 mw/°C, ***2.5 mw/°C

2N135, 2N136, 2N137

Outline Drwg. No. 8

The General Electric types 2N135, 2N136 and 2N137 are PNP alloy junction germanium transistors intended for RF and IF service in broadcast receivers. Special control of manufacturing processes provides a narrow spread of characteristics, resulting in uniformly high power gain at radio frequencies. These types are obsolete and available for replacement only.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS: (25°C)	**2N135**	**2N136**	**2N137**	
Collector Voltage:				
Common Base (emitter open), V_{CBO}	−20	−20	−10	volts
Common Emitter ($R_{be} = 100$ ohms), V_{CER}*	−20	−20	−10	volts
Common Emitter ($R_{be} = 1$ megohm), V_{CER}*	−12	−12	− 6	volts
Collector Current, I_C	−50	−50	−50	ma
Emitter Current, I_E	50	50	50	ma
Collector Dissipation**, P_{CM}	100	100	100	mw
Storage Temperature, T_{STG}	85	85	85	°C
ELECTRICAL CHARACTERISTICS: Design Center Values (Common Base, 25°C, $V_{CB} = 5v$, $I_E = 1$ ma)				
Voltage Feed back Ratio (input open circuit, f = 1 mc), h_{rb}	7×10^{-3}	7×10^{-3}	7×10^{-3}	
Output Capacitance (f = 1 mc), C_{ob}	14	14	14	$\mu\mu f$

2N164A

Outline Drawing No. 31

The 2N164A is a rate grown NPN germanium transistor intended for mixer/oscillator and IF amplifier applications in radio receivers. Special manufacturing techniques provide a low value and a narrow spread in collector capacity so that neutralization in many circuits is not required. The 2N164A has a frequency cutoff control to insure proper operation as an oscillator or autodyne mixer. For IF amplifier service the range in power gain is controlled to 3 db. The 2N164A is housed in a glass and metal enclosure which has been designed to be the optimum size in both height and diameter for use in printed circuit boards. The lead arrangement is on a 100 mil grid with .141 in. between leads, which allows direct insertion in the printed circuit boards. An indexing tab is provided on the header for easy location and automatic insertion purposes. The 2N164A may be dip soldered on printed circuit boards if normal precautions are made for solder bridging and provided the boards are not immersed in the solder bath for more than 15 seconds.

CONVERTER TRANSISTOR SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS:		
Voltages		
Collector to Emitter (Base Open)	V_{CEO}	15 volts
Collector to Base (Emitter Open)	V_{CBO}	15 volts
Collector Current	I_C	−20 ma
Power		
Collector Dissipation at 25°C*	P_{CM}	65 mw
Temperature Range		
Operating and Storage	T_A-T_{STG}	−55 to 85 °C

ELECTRICAL CHARACTERISTICS: (25°C)**

Converter Service		
Maximum Ratings		
Collector Supply Voltage	V_{CC}	12 volts
Design Center Characteristics		
Input Impedance (I_E = 1 ma; V_{CE} = 5v; f = 455 KC)	Z_i	350 ohms
Output Impedance (I_E = 1 ma; V_{CE} = 5v; f = 455 KC)	Z_o	15 K ohms
Voltage Feedback Ratio (I_E = 1 ma; V_{CB} = 5v; f = 1 mc)	h_{rb}	5×10^{-3}
Collector to Base Capacitance (I_E = 1 ma; V_{CB} = 5v; f = 1mc)	C_{ob}	2.4 $\mu\mu$f
Frequency Cutoff (I_E = 1 ma; V_{CB} = 5v)	f_{ab}	8 mc
Minimum Frequency Cutoff (I_E = 1 ma; V_{CB} = 5v)	f_{ab}	5 mc min
Base Current Gain (I_B = 20 μa; V_{CE} = 1v)	h_{FE}	40
Minimum Base Current Gain	h_{FE}	23
Maximum Base Current Gain	h_{FE}	135
Conversion Gain	CG_e	25 db
IF Amplifier Performance (See Circuits Pages 68, 69)		
Collector Supply Voltage	V_{CC}	5 volts
Collector Current	I_C	1 ma
Input Frequency	f	455 KC
Available Power Gain	G_e	39 db
Minimum Power Gain in typical IF test circuit (see circuits Pages 68, 69)	G_e	28 db min
Power Gain Range of Variation in typical IF Circuit		3 db
Cutoff Characteristics		
Collector Cutoff Current (V_{CB} = 5v)	I_{CO}	.5 μa
Collector Cutoff Current (V_{CB} = 15v)	I_{CO}	5 μa max

*Derate 1.1 mw/°C increase in ambient temperature over 25°C.
**All values are typical unless indicated as a min. or max.

2N165

Outline Drawing No. 31

The General Electric Type 2N165 is a rate-grown NPN transistor intended for IF amplifier applications in broadcast radio receivers. The collector capacity is controlled to a uniformly low value so that neutralization in most circuits is not required. Power gain at 455 KC in a typical receiver circuit is restricted to a 3 db spread. The uniformity provided by the controls of collector capacity and power gain allows easy and economical incorporation of this type into receiver circuits. The 2N165 is housed in a glass and metal enclosure which has been designed to be the optimum size in both height and diameter for use in printed circuit boards. The lead arrangement is on a 100 mil grid with .141 in. between leads, which allows direct insertion in the printed circuit boards.

IF TRANSISTOR SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS:

Voltages		
Collector to Emitter (Base Open)	V_{CEO}	15 volts
Collector to Base (Emitter Open)	V_{CBO}	15 volts
Collector Current	I_C	−20 ma
Power		
Collector Dissipation at 25°C*	P_{CM}	65 mw
Temperature Range		
Operating and Storage	T_A-T_{STG}	−55 to 85 °C

ELECTRICAL CHARACTERISTICS: (25°C)**

IF Amplifier Service		
Maximum Ratings		
Collector Supply Voltage	V_{CC}	12 volts
Design Center Characteristics		
(I_E = 1 ma; V_{CE} = 5v; f = 455 KC except as noted)		
Input Impedance	Z_i	500 ohms
Output Impedance	Z_o	15 K ohms
Voltage Feedback Ratio (V_{CB} = 5v; f = 1 mc)	h_{rb}	10×10^{-3}
Collector to Base Capacitance (V_{CB} = 5v; f = 1 mc)	C_{ob}	2.4 $\mu\mu$f
Frequency Cutoff (V_{CB} = 5v)	f_{ab}	5 mc
Base Current Gain (I_B = 20 μa; V_{CE} = 1v)	h_{FE}	72
Minimum Base Current Gain	h_{FE}	36
Maximum Base Current Gain	h_{FE}	220
IF Amplifier Performance (See Circuits Pages 68, 69)		
Collector Supply Voltage	V_{CC}	5 volts
Collector Current	I_C	1 ma
Input Frequency	f	455 KC
Available Power Gain	G_e	36 db
Minimum Power Gain in typical IF circuit (see circuits Pages 68, 69)	G_e	25 db min
Power Gain Range of Variation in Typical IF Circuit	G_e	3 db
Cutoff Characteristics		
Collector Cutoff Current (V_{CB} = 5v)	I_{CO}	.5 μa
Collector Cutoff Current (V_{CB} = 15v)	I_{CO}	5 μa max

*Derate 1.1 mw/°C increase in ambient temperature.
**All values are typical unless indicated as a min. or max.

2N166

Outline Drawing No. 31

The 2N166 is a rate grown NPN germanium transistor intended for use in high frequency circuits by amateurs, hobbyists, and experimenters. The 2N166 can be used in any of the many published circuits where a low voltage, high frequency transistor is necessary, such as for regenerative receivers, high frequency oscillators, etc. If you desire to use the 2N166 NPN transistor in a circuit showing a PNP type transistor, it is only necessary to change the connections to the power supply.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS:

Voltages		
Collector to Emitter	V_{CE}	6 volts
Collector Current	I_C	20 ma
Power		
Collector Dissipation @ 25°C*	P_{CM}	25 mw
Temperature Range		
Operating and Storage	T_A-T_{STG}	−55 to 50 °C

ELECTRICAL CHARACTERISTICS: (25°C)**

High Frequency Characteristics		
(I_E = 1 ma; V_{CE} = 5v; f = 455 KC except as noted)		
Input Impedance (Common Emitter)	Z_i	800 ohms
Output Impedance (Common Emitter)	Z_o	15 K ohms
Collector to Base Capacitance (f = 1 mc)	C_{ob}	3 μμf
Frequency Cutoff (V_{CB} = 5V)	f_{ab}	5 mc
Power Gain (Common Emitter)	G_e	24 db
Low Frequency Characteristics		
(I_E = 1 ma; V_{CE} = 5v; f = 270 cps)		
Input Impedance	h_{ib}	55 ohms
Voltage Feedback Ratio	h_{rb}	4×10^{-4}
Current Gain	h_{fb}	.97
Output Admittance	h_{ob}	$.3 \times 10^{-6}$ μmhos
Common Emitter Base Current Gain	h_{fe}	32
Cutoff Characteristics		
Collector Cutoff Current (V_{CB} = 5v)	I_{CO}	5 μa max

*Derate 1 mw/°C increase in ambient temperature.
**All values are typical unless indicated as a min. or max.

2N167

Outline Drwg. No. 14

The General Electric type 2N167 is an NPN high frequency, high speed switching transistor intended for industrial and military applications where reliability is of prime importance.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS:

Collector to Emitter Voltage (base open), V_{CEO}	30 volts
Collector to Base Voltage (emitter open), V_{CBO}	30 volts
Emitter to Base Voltage (collector open), V_{EBO}	5 volts
Collector Current, I_C	75 ma
Emitter Current, I_E	−75 ma
Collector Dissipation (25°C)*, P_{CM}	65 mw
Transistor Dissipation (25°C)**, P_M	75 mw
Storage Temperature, T_{STG}	85 °C

ELECTRICAL CHARACTERISTICS: (25°C)	DESIGN CENTER	LIMITS MIN.	LIMITS MAX.	
Switching Characteristics (Common Emitter)				
D-C Base Current Gain (V_{CE} = 1 v; I_C = 8 ma), I_C/I_B	25	17		
Saturation Voltage (I_B = .8 ma; I_C = 8 ma), V_{CE}	0.35			volts
Pulse Response Time (I_c = 8 ma)				
Delay & Rise Time, t_r	.6			μsec
Storage Time, t_s	.6			μsec
Fall Time, t_f	.4			μsec
Cutoff Characteristics				
Collector Cutoff Current (V_{CB} = 15 v), I_{CO}	.8		1.5	μa
Emitter Cutoff Current (V_{EB} = 5 v), I_{EO}	1.0		15	μa
Collector to Emitter Voltage (Base open, I_C = 0.3 ma), V_{CE}		30		volts
High Frequency Characteristics (Common Base) (V_{CB} = 5v; I_E = 1 ma)				
Alpha Cutoff Frequency, f_{ab}	8	5		mc
Collector Capacity (f = 1 mc), C_{ob}	4		8	μμf
Low Frequency Characteristics (Common Base) (V_{CB} = 5v; I_E = −1 ma; f = 270 cps)				
Input Impedance, h_{ib}	40			ohms
Voltage Feedback Ratio, h_{rb}	1.5×10^{-4}			
Base Current Amplification, h_{fb}	.975	.952		
Output Admittance, h_{ob}	.2			μmho

*Derate 1.1 mw/°C increase in ambient temperature.
**Derate 1.25 mw/°C increase in ambient temperature.

2N168A

Outline Drwg. No. 14

The 2N168A is a rate grown NPN germanium transistor intended for mixer/oscillator and IF amplifier applications in radio receivers. Special manufacturing techniques provide a low value and a narrow spread in collector capacity so that neutralization in many circuits is not required. The 2N168A has a frequency cutoff control to provide proper operation as an oscillator or autodyne mixer. For IF amplifier service the range in power gain in controlled to 3 db.

CONVERTER TRANSISTOR SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS:	
Voltage	
Collector to Emitter (base open), V_{CEO}	15 volts
Collector to Base (emitter open), V_{CBO}	15 volts
Current	
Collector, I_C	−20 ma
Power	
Collector Dissipation at 25°C*, P_{CM}	65 mw
Temperature Range	
Operating and Storage, T_A, T_{STG}	−55 to 85 °C
TYPICAL ELECTRICAL CHARACTERISTICS:	
Converter Service	
Maximum Ratings	
Collector Supply Voltage, V_{CC}	12 volts
Design Center Characteristics	
Input Impedance ($I_E = 1$ ma; $V_{CE} = 5$v; f = 455 KC), Z_i	350 ohms
Output Impedance ($I_E = 1$ ma; $V_{CE} = 5$v; f = 455 KC), Z_o	15 K ohms
Voltage Feedback Ratio ($I_B = 1$ ma; $V_{CB} = 5$v; f = 1 mc), h_{rb}	5×10^{-8}
Collector to Base Capacitance ($I_E = 1$ ma; $V_{CB} = 5$v; f = 1 mc), C_{ob}	2.4 $\mu\mu$f
Frequency Cutoff ($I_E = 1$ ma; $V_{CB} = 5$v), f_{ab}	8 mc
Min. Frequency Cutoff ($I_B = 1$ ma; $V_{CB} = 5$v), f_{ab}	5 mc min
Base Current Gain ($I_B = 20_{ma}$; $V_{CE} = 1$v), h_{FE}	40
Minimum Base Current Gain, h_{FE}	23
Maximum Base Current Gain, h_{FE}	135
Conversion Gain, CG_e	25 db
IF Amplifier Performance	
Collector Supply Voltage, V_{CC}	5 volts
Collector Current, I_E	1 ma
Input Frequency, f	455 KC
Available Power Gain, G_e	39 db
Minimum Power Gain in typical IF circuit, G_e	28 db min
Power Gain Range of Variation in typical IF circuit, G_e	3 db
Cutoff Characteristics	
Collector Cutoff Current ($V_{CB} = 5$v), I_{CO}	.5 μa
Collector Cutoff Current ($V_{CB} = 15$v), I_{CO}	5 μa max

*Derate 1.1 mw/°C increase in ambient temperature over 25°C.

2N169A, 2N169

Outline Drwg. No. 14

The 2N169A and 2N169 are rate grown NPN germanium transistors intended for use as IF amplifiers in broadcast radio receivers. The collector capacity is controlled to a low value so that neutralization in most circuits is not required. The power gain at 455 KC is maintained at a 3 db spread for the 2N169A. The 2N169A is a special high voltage unit intended for second IF amplifier service where large voltage signals are encountered. The 2N169 is also intended for low gain IF amplifier and power detector applications.

IF TRANSISTOR SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS:	**2N169A**	**2N169**	
Voltage			
Collector to Emitter (base open), V_{CEO}	25	15	volts
Collector to Base (emitter open), V_{CBO}	25	15	volts
Current			
Collector, I_C	−20	−20	ma
Power			
Collector Dissipation at 25°C*, P_{CM}	55	55	mw
Temperature Range			
Operating and Storage, T_A, T_{STG}	−55 to 75	−55 to 75	°C
TYPICAL ELECTRICAL CHARACTERISTICS:			
IF Amplifier Service			
Maximum Ratings			
Collector Supply Voltage, V_{CC}	12	12	volts
Design Center Characteristics			
($I_E = 1$ ma; $V_{CB} = 5$v; f = 455 KC except as noted)			
Input Impedance, Z_i	500	500	ohms
Output Impedance, Z_o	15	15	K ohms
Voltage Feedback Ratio ($V_{CB} = 5$v; f = 1 mc), h_{rb}	10×10^{-8}	10×10^{-8}	
Collector to Base Capacitance ($V_{CB} = 5$v; f = 1 mc), C_{ob}	2.4	2.4	$\mu\mu$f
Frequency Cutoff ($V_{CB} = 5$v), f_{ab}	5	5	mc

Base Current Gain (I_B = 20ma; V_{CE} = 1 v), h_{FE}	72	72	
Minimum Base Current Gain, h_{EE}	36	36	
Maximum Base Current Gain, h_{EE}	220	220	
IF Amplifier Performance			
Collector Supply Voltage, V_{CC}	5	5	volts
Collector Current, I_E	1	1	ma
Input Frequency, f	455	455	KC
Available Power Gain, G_e	36	36	db
Minimum Power Gain in typical IF circuit, G_e	25	25	db min
Power Gain Range of Variation in typical IF circuit, G_e	3	3	db
Cutoff Characteristics			
Collector Cutoff Current (V_{CB} = 5v), I_{CO}	.5	.5	μa
Collector Cutoff Current (V_{CB} = 15v), I_{CO}	5	5	μa max

*Derate 1.1 mw/°C increase in ambient temperature.

2N170

Outline Drwg. No. 14

The 2N170 is a rate grown NPN germanium transistor intended for use in high frequency circuits by amateurs, hobbyists, and experimenters. The 2N170 can be used in any of the many published circuits where a low voltage, high frequency transistor is necessary such as for regenerative receivers, high frequency oscillators, etc. If you desire to use the 2N170 NPN transistor in a circuit showing a PNP type transistor, it is only necessary to change the connections to the power supply.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS:	
Voltage	
Collector to Emitter, V_{CE}	6 volts
Current	
Collector, I_C	20 ma
Power	
Collector Dissipation @ 25°C*, P_{CM}	25 mw
Temperature Range	
Operating and Storage, T_A, T_{STG}	—55 to 50 °C
TYPICAL ELECTRICAL CHARACTERISTICS:	
High Frequency Characteristics	
(I_E = 1 ma; V_{CE} = 5v; f = 455 KC except as noted)	
Input Impedance (Common Emitter), Z_i	800 ohms
Output Impedance (Common Emitter), Z_o	15 Kohms
Collector to Base Capacitance (f = 1 mc), C_{ob}	2.4 $\mu\mu$f
Frequency Cutoff (V_{CB} = 5V), f_{ab}	4 mc
Power Gain (Common Emitter), G_e	22 db
Low Frequency Characteristics	
(I_E = 1 ma; V_{CE} = 5v; f = 270 cps)	
Input Impedance, h_{ib}	55 ohms
Voltage Feedback Ratio, h_{rb}	4×10^{-4}
Current Gain, h_{fb}	.95
Output Admittance, h_{ob}	$.5 \times 10^{-6}$ μmhos
Common Emitter Base Current Gain, h_{fe}	20
Cutoff Characteristics	
Collector Cutoff Current (V_{CB} = 5v), I_{CO}	5 μa max

*Derate 1 mw/°C increase in ambient temperature.

2N186, 2N187, 2N188

Outline Drwg. No. 8

The 2N186, 2N187, and 2N188 are medium power PNP transistors, intended for use as audio output amplifiers in radio receivers and quality sound systems. By unique process controls the current gain is maintained at an essentially constant value for collector currents from 1 ma to 200 ma. This linearity of current gain provides low distortion in Class B circuits, and permits use of any two transistors from a particular type without matching.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS:	
Voltages	
Collector to Base (emitter open), V_{CBO}	—25 volts
Collector to Emitter (R_{EB} = 1 K ohm), V_{CER}	—25 volts
Emitter to Base (collector open), V_{EBO}	— 5 volts
Collector Current, I_C	200 ma
Power	
Collector Dissipation (25°C)*, P_{CM}	75 mw

Temperature
Operating Range, T_A . . . . —55 to 60 °C
Storage Range, T_{STG} . . . . —55 to 85 °C

TYPICAL ELECTRICAL CHARACTERISTICS: (25°C)

Class B Audio Amplifier Operation	2N186	2N187	2N188	
(Values for two transistors. Note that matching is not required to hold distortion to less than 5% for any two transistors from a type)				
Maximum Class B Ratings (Common Emitter)				
Collector Supply Voltage, V_{CC}	—12	—12	—12	volts
Power Output (Distortion less than 5%), P_o	300	300	300	mw
Design Center Characteristics				
Input Impedance large signal base to base ($\Delta I_E = 150$ ma), h_{ie}	1200	2000	2600	ohms
Base Current Gain ($V_{CE} = -1$ v; $I_c = 150$ ma), h_{FE}	24	36	54	
Collector Capacity ($V_{CB} = -5$ v; $I_E = 1$ ma; f = 1 mc), C_{ob}	35	35	35	$\mu\mu$f
Frequency Cutoff ($V_{CB} = -5$ v; $I_E = 1$ ma), f_{ab}	.8	1.0	1.2	mc
Class B Circuit Performance (Common Emitter)				
Collector Voltage, V_{CC}	—12	—12	—12	volts
Minimum Power Gain at 100 mw power output, G_e	28	30	32	min db
Cutoff Characteristics				
Maximum Collector Cutoff Current ($V_{CB} = -25$ v), I_{CO}	16	16	16	max μa
Maximum Emitter Cutoff Current ($V_{EB} = -5$ v), I_{EO}	10	10	10	max μa

*Derate 1.25 mw/°C increase in ambient temperature within range 25°C to 60°C.

2N186A, 2N187A 2N188A

Outline Drwg. No. 8

The 2N186A, 2N187A, and 2N188A are medium power PNP transistors intended for use as audio output amplifiers in radio receivers and quality sound systems. By unique process controls the current gain is maintained at an essentially constant value for collector currents from 1 ma to 200 ma. This linearity of current gain provides low distortion in both Class A and Class B circuits, and permits the use of any two transistors from a particular type without matching in Class B Circuits.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS:

Voltages
Collector to Base (emitter open), V_{CBO} . . . . —25 volts
Collector to Emitter ($R_{EB} = 1$ K ohm), V_{CER} . . . . —25 volts
Emitter to Base (collector open), V_{EBO} . . . . — 5 volts

Collector Current, I_C . . . . 200 ma

Power
Collector Dissipation (25°C)*, P_{CM} . . . . 180 mw

Temperature
Operating Range, T_A . . . . —55 to 60 °C
Storage Range, T_{STG} . . . . —55 to 85 °C

TYPICAL ELECTRICAL CHARACTERISTICS: (25°C)

Class B Audio Amplifier Operation	2N186A	2N187A	2N188A	
(Values for two transistors. Note that matching is not required to hold distortion to less than 5% for any two transistors from a type)				
Maximum Class B Ratings (Common Emitter)				
Collector Supply Voltage, V_{CC}	—12	—12	—12	volts
Power Output (Distortion less than 5%), P_o	750	750	750	mw
Design Center Characteristics				
Input Impedance large signal base to base ($\Delta I_E = 150$ ma), h_{ie}		2000	2600	ohms
Base Current Gain ($V_{CE} = -1$ v; $I_C = 150$ ma), h_{FE}	24	36	54	
Collector Capacity ($V_{CB} = 5$ v; $I_E = 1$ ma; f = 1 mc), C_{ob}	35	35	35	$\mu\mu$f
Frequency Cutoff ($V_{CB} = -5$ v; $I_E = 1$ ma), f_{ab}	.8	1.0	1.2	mc
Class B Circuit Performance (Common Emitter)				
Collector Voltage, V_{CC}	—12	—12	—12	volts
Minimum Power Gain at 100 mw power output, G_e	28	30	32	min db
Class A Audio Amplifier Operation (Common Emitter) ($V_{CC} = 12$v; $I_E = 10$ ma)				
Power Gain at 50 mw power output, G_e	30	32	34	db
Cutoff Characteristics				
Maximum Collector Cutoff Current ($V_{CB} = -25$ v), I_{CO}	16	16	16	max μa
Maximum Emitter Cutoff Current ($V_{EB} = -5$ v), I_{EO}	10	10	10	max μa

*Derate 3 mw/°C increase in ambient temperature within range 25°C to 60°C.

2N189, 2N190, 2N191, 2N192

Outline Drwg. No. 8

The 2N189, 2N190, 2N191, and 2N192 are alloy junction PNP transistors intended for driver service in transistorized audio amplifiers. By control of transistor characteristics during manufacture, a specific power gain is provided for each type. Special processing techniques and the use of hermetic seals provides stability of these characteristics throughout life.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS:

Voltages	
Collector to Emitter (R_{EB} = 1 K ohm), V_{CER}	—25 volts
Collector Current, I_C	50 ma
Power	
Collector Dissipation (25°C)*, P_{CM}	75 mw
Temperature	
Operating Range, T_A	—55 to 60 °C
Storage Range, T_{STG}	—55 to 85 °C

TYPICAL ELECTRICAL CHARACTERISTICS: (25°C)

Audio Driver Class A Operation	**2N189**	**2N190**	**2N191**	**2N192**	
(Values for one transistor driving a transformer coupled output stage)					
Maximum Class A Ratings (Common Emitter)					
Collector Supply Voltage, Vcc	12	12	12	12	volts
Design Center Characteristics					
Input Impedance base to emitter (I_E = 1 ma), h_{ie}	1000	1400	1800	2200	ohms
Base Current Gain (V_{CE} = —5 v; I_E = 1 ma), h_{fe}	24	36	54	75	
Collector Capacity (V_{CB} = —5 v; I_E = 1 ma), C_{ob}	35	35	35	35	μμf
Frequency Cutoff (V_{CB} = —5 v; I_E = 1 ma), f_{ab}	.8	1.0	1.2	1.5	mc
Noise Figure (V_{CB} = —5 v; I_E = 1 ma; f = 1 KC; BW = 1 cycle), NF	15	15	15	15	db
Audio Circuit Performance (Common Emitter)					
Collector Supply Voltage, Vcc	12	12	12	12	volts
Emitter Current, I_E	1	1	1	1	ma
Minimum Power Gain at 1 mw power output, G_e	37	39	41	43	min db
Small Signal Characteristics (Common Base)					
(V_{CB} = 5v; I_E = 1 ma; f = 270 cps)					
Input Impedance, h_{ib}	29	29	29	29	ohms
Voltage Feedback Ratio, h_{rb}	4×10^{-4}	4×10^{-4}	4×10^{-4}	4×10^{-4}	
Current Amplification, h_{fb}	.96	.973	.98	.987	
Output Admittance, h_{ob}	1.0	.8	.6	.5	μmhos
Cutoff Characteristics					
Maximum Collector Cutoff Current (V_{CB} = 25 v), I_{CO}	16	16	16	16	max μa

*Derate 1.25 mw/°C increase in ambient temperature within range 25°C to 60°C.

2N241, 2N141A

Outline Drwg. No. 8

The 2N241, and 2N241A are medium power PNP transistors intended for use as audio output amplifiers in radio receivers and quality sound systems. By special process controls the current gain is maintained at an essentially constant value for collector currents from 1 ma to 200 ma. This linearity of current gain insures low distortion in both Class A and Class B circuits, and permits the use of any two transistors from a particular type without matching in Class B Circuits.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS:

Voltages	
Collector to Base (emitter open), V_{CBO}	—25 volts
Collector to Emitter (R_{EB} = 1 K ohm), V_{CER}	—25 volts
Emitter to Base (collector open), V_{EBO}	— 5 volts
Collector Current, I_C	200 ma

Power	**2N241**	**2N241A**
Collector Dissipation (25°C)*, P_{CM}	100	180 mw
Temperature		
Operating Range, T_A	—55 to 60 °C	—55 to 60 °C
Storage Range, T_{STG}	—55 to 85 °C	—55 to 85 °C

TYPICAL ELECTRICAL CHARACTERISTICS: (25°C)

Class B Audio Amplifier Operation			
(Values for two transistors. Note that matching is not required to hold distortion to less than 5% for any two transistors from a type)			
Maximum Class B Ratings (Common Emitter)			
Collector Supply Voltage, Vcc	—12	—12	volts
Power Output (Distortion less than 5%), P_{oe}	300	750	mw

Design Center Characteristics			
Input Impedance large signal base to base (ΔI_E = 150 ma), h_{ie}	4000	4000	ohms
Base Current Gain (V_{CB} = –1 v; I_c = 150 ma) h_{FE}	73	73	
Collector Capacity (V_{CB} = –5 v; I_E = 1 ma; f = 1 mc), C_{ob}	35	35	$\mu\mu$f
Frequency Cut off (V_{CE} = –5 v; I_E = 1 ma), f_{ab}	1.3	1.3	mc
Class B Circuit Performance (Common Emitter)			
Collector Voltage, V_{CC}	–12	–12	volts
Minimum Power Gain at 100 mw power output, G_e	34	34	min db
Class A Audio Amplifier Operation (Common Emitter)			
(V_{cc} = –12v; I_E = 10 ma)			
Power Gain at 50 mw power output, G_e		35	db
Cutoff Characteristics			
Maximum Collector Cutoff Current (V_{CB} = –25 v), I_{CO}	16	16	max μa
Maximum Emitter Cutoff Current (V_{EB} = –5 v), I_{EO}	10	10	max μa

*Derate 3 mw/°C increase in ambient temperature within range 25°C to 60°C.

2N265

Outline Drwg. No. 8

The 2N265 is an alloy junction PNP transistor intended for driver service in transistorized audio amplifiers. By control of transistor characteristics during manufacture, a specific power gain is provided for each type. Special processing techniques and the use of hermetic seals provides stability of these characteristics throughout life.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS:	
Voltages	
Collector to Emitter (R_{EB} = 1 K ohm), V_{CER}	–25 volts
Collector Current, I_C	50 ma
Power	
Collector Dissipation (25°C)*, P_{CM}	75 mw
Temperature	
Operating Range, T_A	–55 to 60 °C
Storage Range, T_{STG}	–55 to 85 °C
TYPICAL ELECTRICAL CHARACTERISTICS: (25°C)	
Audio Driver Class A Operation	
(Values for one transistor driving a transformer coupled output stage)	
Maximum Class A Ratings (Common Emitter)	
Collector Supply Voltage, V_{CC}	12 volts
Design Center Characteristics	
Input Impedance base to emitter (I_E = 1 ma), h_{ie}	4000 ohms
Base Current Gain (V_{CB} = –5 v; I_E = 1 ma), h_{fe}	110
Collector Capacity (V_{CB} = –5 v; I_E = 1 ma), C_{ob}	35 $\mu\mu$f
Frequency Cutoff (V_{CB} = –5 v; I_E = 1 ma), f_{ab}	1.5 mc
Noise Figure (V_{CB} = –5 v; I_E = I ma; f = 1 KC; BW = 1 cycle), NF	15 db
Audio Circuit Performance (Common Emitter)	
Collector Supply Voltage, V_{CC}	12 volts
Emitter Current, I_E	1 ma
Minimum Power Gain at 1 mw power output, G_e	45 min db
Small Signal Characteristics (Common Base)	
(V_{CB} = –5v; I_E = 1 ma; f = 270 cps)	
Input Impedance, h_{ib}	29 ohms
Voltage Feedback Ratio, h_{rb}	4×10^{-4}
Current Amplification, h_{fb}	.991
Output Admittance, h_{ob}	.5 μmhos
Cutoff Characteristics	
Maximum Collector Cutoff Current (V_{CB} = 25 v), I_{CO}	16 max μa

*Derate 1.25 mw/°C increase in ambient temperature within range 25°C to 60°C.

2N292, 2N293

Outline Drwg. No. 14

Types 2N292 and 2N293 are rate grown NPN germanium transistors intended for amplifier applications in radio receivers. Special manufacturing techniques provide a low value and a narrow spread in collector capacity so that neutralization in many circuits is not required. The type 2N293 is intended for receiver circuits where high gain is needed. In IF amplifier service the range in power gain is controlled to 3 db.

IF TRANSISTOR SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS	2N292	2N293	
Voltage			
Collector to Emitter (base open), V_{CEO}	15	15	volts
Collector to Base (emitter open), V_{CBO}	15	15	volts
Current			
Collector, I_C	–20	–20	ma
Power			
Collector Dissipation at 25°C*, P_{CM}	65	65	mw

Temperature Range			
Operating and Storage, T_A, T_{STG}	—55 to 85	—55 to 85	°C
ELECTRICAL CHARACTERISTICS**			
IF Amplifier Service			
Maximum Ratings			
Collector Supply Voltage, V_{CC}	12	12	volts
Design Center Characteristics			
Input Impedance (I_E = 1 ma; V_{CE} = 5v; f = 455 KC), Z_i	500	350	ohms
Output Impedance (I_E = 1 ma; V_{CE} = 5v; f = 455 KC), Z_o	15	15	K ohms
Voltage Feedback Ratio (I_E = 1 ma; V_{CB} = 5v; f = mc), h_{rb}	10×10^{-3}	5×10^{-3}	
Collector to Base Capacitance (I_E = 1 ma; V_{CB} = 5v; f = 1 mc), C_{ob}	2.4	2.4	$\mu\mu$f
Frequency Cutoff (I_E = 1 ma; V_{CB} = 5v), f_{ab}	5	8	mc
Base Current Gain (I_B = 20 ma; V_{CE} = 1v), h_{FE}	25	25	
Min. Base Current Gain, h_{FE}	6	6	
Max. Base Current Gain, h_{FE}	44	55	
IF Amplifier Performance			
Collector Supply Voltage, V_{CC}	5	5	volts
Collector Current, I_E	1	1	ma
Input Frequency, f	455	455	KC
Available Power Gain, G_e	36	30	db
Min. Power Gain in Typical IF Test Circuit, G_e	25	28	db min
Power Gain Range of Variation in Typical IF Circuit	3	3	db
Cutoff Characteristics			
Collector Cutoff Current (V_{CB} = 5v), Ico	.5	.5	μa
Collector Cutoff Current (V_{CB} = 15v), Ico	.5	.5	μa max

*Derate 1.1 mw/°C increase in ambient temperature over 25°C.
**All values are typical unless indicated as a min or max.

2N313, 2N314

Outline Drawing No. 31

The General Electric Types 2N313 and 2N314 transistors are rate grown NPN germanium devices intended for IF amplifier applications in radio receivers. Special manufacturing techniques provide a low value and a narrow spread in collector capacity so that neutralization in many circuits is not required. The Type 2N314 is intended for receiver circuits where high gain is needed in IF amplifier service, the range in power gain is controlled to 3 db. The Types 2N313 and 2N314 are housed in a glass and metal enclosure which has been designed to be the optimum size in both height and diameter for use in printed circuit boards. The lead arrangement is on a 100 mil grid with .141 in. between leads, which allows direct insertion in the printed circuit boards. An indexing tab is provided on the header for easy location and automatic insertion purposes. The 2N313 and 2N314 may be dip soldered on printed circuit boards if normal precautions are made for solder bridging and provided the boards are not immersed in the solder bath for more than 15 seconds.

IF TRANSISTOR SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS:

Voltages		
Collector to Emitter (Base Open)	V_{CEO}	15 volts
Collector to Base (Emitter Open)	V_{CBO}	15 volts
Collector Current	I_C	–20 ma
Power		
Collector Dissipation at 25°C*	P_{CM}	65 mw
Temperature Range		
Operating and Storage	T_A-T_{STG}	–55 to 85 °C

ELECTRICAL CHARACTERISTICS: (25°C)**

IF Amplifier Service		**2N313**	**2N314**	
Maximum Ratings				
Collector Supply Voltage	V_{CC}	12	12	volts
Design Center Characteristics				
Input Impedance (I_E = 1 ma; V_{CE} = 5v; f = 455 KC)	Z_i	500	350	ohms
Output Impedance (I_E = 1 ma; V_{CE} = 5v; f = 455 KC)	Z_o	15K	15K	ohms
Voltage Feedback Ratio (I_E = 1 ma; V_{CB} = 5v; f = 1 mc)	h_{rb}	10×10^{-3}	5×10^{-3}	
Collector to Base Capacitance (I_E = 1 ma, V_{CB} = 5v; f = 1 mc)	C_{ob}	2.4	2.4	$\mu\mu$f
Frequency Cutoff (I_E = 1 ma; V_{CB} = 5v)	f_{ab}	5	8	mc
Base Current Gain (I_B = 20 μa; V_{CE} = 1v)	h_{FE}	25	25	
Minimum Base Current Gain	h_{FE}	6	6	
Maximum Base Current Gain	h_{FE}	44	55	
IF Amplifier Performance				
Collector Supply Voltage	V_{CC}	5	5	volts
Collector Current	I_C	1	1	ma
Input Frequency	f	455	455	KC
Available Power Gain	G_e	36	39	db

Minimum Power Gain in Typical IF Test Circuit (See Circuits Pages 68, 69)	G_e	25	28	db min
Power Gain Range of Variation in Typical IF Circuit	G_e	3	3	db
Cutoff Characteristics				
Collector Cutoff Current ($V_{CB} = 5v$)	Ico	.5	.5	μa
Collector Cutoff Current ($V_{CB} = 15v$)	Ico	5	5	μa max

*Derate 1.1 mw/°C increase in ambient temperature over 25°C.
**All values are typical unless indicated as a min. or max.

2N319, 2N320, 2N321

Outline Drawing No. 29

The 2N319, 2N320, and 2N321 are miniaturized versions of the 2N186A series of G-E transistors. Like the prototype versions, the 2N319, 2N320, and 2N321 are medium power PNP transistors intended for use as audio output amplifiers in radio receivers and quality sound systems. By unique process controls the current gain is maintained at an essentially constant value for collector currents from 1 ma to 200 ma. This linearity of current gain provides low distortion in both Class A and Class B circuits, and permits the use of any two transistors from a particular type without matching in Class B Circuits.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS:

Voltages		
Collector to Emitter	V_{CE}	20 volts
Collector to Base	V_{CB}	30 volts
Emitter to Base	V_{EB}	3 volts
Collector Current	I_C	200 ma
Power		
Collector Dissipation	P_{CM}	200 mw
Temperature		
Operating and Storage Range	T_A-T_{STG}	−65 to 100 °C

TYPICAL ELECTRICAL CHARACTERISTICS: (25°C)

		2N319	2N320	2N321	
D.C. Characteristics					
Base Current Gain ($I_C = 20$ ma; $V_{CE} = -1v$)	h_{FE}	33	48	80	
Base Current Gain ($I_C = 100$ ma; $V_{CE} = -1v$)	h_{FE}	30	44	70	
Collector to Emitter Voltage ($R_{EB} = 10$ K) ($I_C = .6$ ma)	V_{CER}	20	20	20	volts
Collector Cutoff Current (V_{EB^2} —25v)	Ico	8	8	8	μa
Maximum Collector Cutoff Current ($V_{CB} = -25v$)	Ico	16	16	16	μa
Emitter Cutoff Current ($V_{EB} = 3v$)	I_{EO}	2	2	2	μa
Small Signal Characteristics (Common Base) ($V_{CB} = -5v$; $I_E = 1$ ma; $3 = 270$)					
Frequency Cutoff	f_{ab}	2.5	2.9	3.3	mc
Collector Capacity (f = 1 mc)	C_{ob}	24	24	24	μμf
Noise Figure	NF	6	6	6	db
Input Impedance	h_{ib}	30	30	30	ohms
Thermal Characteristics					
Thermal Resistance					
Without Heat Sink (Junction to Air)		.33	.33	.33	°C/mw
With Heat Sink (Junction to Case)		.2	.2	.2	°C/mw
Performance Data (Common Emitter)					
Class A Power Gain ($V_{CC} = -9v$)	G_e	30	31	32	db
Power Output	P_o	50	50	50	mw
Class B Power Gain ($V_{CC} = -9v$)	G_e	27	29	31	db
Power Output	P_o	100	100	100	mw

2N322, 2N323, 2N324

Outline Drawing No. 29

The 2N322, 2N323, 2N324 are alloy junction PNP transistors intended for driver service in audio amplifiers. They are miniaturized versions of the 2N190 series of G.E. transistors. By control of transistor characteristics during manufacture, a specific power gain is provided for each type. Special processing techniques and the use of hermetic seals provides stability of these characteristics throughout life.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS:

Voltages		
Collector to Emitter	V_{CE}	−16 volts
Collector to Base	V_{CB}	−16 volts
Collector Current	I_C	50 ma

Power					
Collector Dissipation	P_{CM}				75 mw
Temperature					
Operating and Storage Range	T_A-T_{STG}				−65 to +85 °C

TYPICAL ELECTRICAL CHARACTERISTICS: (25°C)

D.C. Characteristics		**2N322**	**2N323**	**2N324**	
Base Current Gain (I_C = 20 ma; V_{CE} = 1v)	h_{FE}	48	80	95	
Collector to Emitter Voltage (R_{EB} = 10 K, I_C = .6 ma)	V_{CE}	16	16	16	volts
Collector Cutoff Current	I_{CO}	10	10	10	μa
Max. Collector Cutoff Current	I_{CO}	16	16	16	μa
Small Signal Characteristics					
Frequency Cutoff (V_{CB} = −5v; I = 1 ma)	f_{ab}	29	33	34	
Collector Capacity (V_{CB} = −5v; I = 1 ma)	C_{ob}	24	24	24	μμf
Noise Figure (V_{CB} = −5v; I = 1 ma)	NF	10	10	10	db
Input Impedance (V_{CE} = −5v; I_E = 1 ma)	h_{ie}	2200	2600	3300	ohms
Current Gain (V_{CE} = −5v; I_E = 1 ma)	h_{fe}	70	84	112	
Thermal Characteristics					
Thermal Resistance Junction to Air		.33	.33	.33	°C/mw
Performance Data Common Emitter					
Power Gain Driver (V_{CC} = 9v)	G_e	39	41	43	db
Power Output	P_o	1	1	1	mw

2N430

Outline Drawing No. 30

The General Electric Type 2N430 transistor is a silicon triode intended for low level switching applications. This unit is characterized by low collector saturation resistance and fast transient response. The 2N430 is a diffused junction device manufactured by the General Electric diffused meltback process. The transistors are hermetically sealed in a welded case. The case dimensions and lead configuration are suitable for insertion in printed boards by automatic assembly equipment.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS: (25°C)

Voltages		
Collector to Base (Emitter Open)	BV_{CBO}	10 volts
Collector to Emitter (Base Open)	BV_{CEO}	10 volts
Emitter to Base (Collector Open)	BV_{EBO}	3 volts
Collector Current	I_C	30 ma
Power		
Collector Dissipation (25°C)*	P_{CM}	150 mw
Collector Dissipation (150°C)	P_{CM}	25 mw
Temperature Range		
Operating	T_A	−65 to 150 °C
Storage	T_{STG}	200 °C

ELECTRICAL CHARACTERISTICS: (25°C)

Design Center Characteristics		**MIN.**	**NOM.**	**MAX.**	
Collector to Base Capacitance (V_{CB}=5v, I_E=−1 ma, f=1 mc)	C_{ob}		14		μμf
Input Impedance (V_{CB}=5v, I_E=−1 ma, f=1000 cps)	h_{ib}		55		ohms
Frequency Cutoff (V_{CB}=5v, I_E=−2 ma)	f_{ab}		25		mc
Switching Circuit Application**					
Collector Saturation Voltage (I_B=0.2 ma, I_C=2.5 ma)	V_{CE}(Sat.)			0.175	volts
Base to Emitter Voltage (I_B=0.2 ma, I_C=2.5 ma)	V_{BE}	0.673	0.693	0.713	volts
Emitter Floating Potential (V_{CB}=4.5v, Resistance Emitter to base 10^{-6} ohms)	V_{BE}			0.2	volts
Collector Current (T=75°C, V_{BE}=.35 volts forward, V_{CB} = 1.5 volts)	t_f			100	μamps
Collector Current (T=25°C, I_E=0, V_{CB}=5 volts)	I_C			0.25	μamps
Transient Response***					
Rise Time	I_{CO}			1.3	μsec
Storage Time	t_r			0.3	μsec
Fall Time	t_s			0.4	μsec

*Derate 1 mw/°C increase in ambient temperature.
**See Typical "On"-"Off" Circuit.
***As measured in the following circuit:

2N431, 2N432

Outline Drawing No. 30

The General Electric Types 2N431 and 2N432 transistors are silicon triodes intended for amplifier application in the audio and radio frequency range. The 2N431 and 2N432 are diffused junction devices manufactured by the General Electric diffused meltback process. The transistors are hermetically sealed in a welded case. The case dimensions and lead configuration are suitable for insertion in printed boards by automatic assembly equipment.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS: (25°C)

Voltages		
Collector to Base (Emitter Open)	BV_{CBO}	30 volts
Collector to Emitter (Base Open)	BV_{CEO}	15 volts
Emitter to Base (Collector Open)	BV_{EBO}	5 volts
Collector Current	I_C	30 ma
Power		
Collector Dissipation (25°C)*	P_{CM}	150 mw
Collector Dissipation (150°C)	P_{CM}	25 mw
Temperature Range		
Operating	T_A	−65 to 150 °C
Storage	T_{STG}	200 °C

ELECTRICAL CHARACTERISTICS: (25°C)

		2N431			2N432			
		MIN.	NOM.	MAX.	MIN.	NOM.	MAX.	
Small Signal Hybrid Parameters (Common Base) ($I_E = -1$ ma, $V_{CB} = 5v$, f = 1000~)								
Input Impedance	h_{ib}		58			55		ohms
Reverse Voltage Transfer Ratio	h_{rb}		3×10^{-4}			3.3×10^{-4}		
Current Transfer Ratio	h_{fb}		0.940			0.970		
Output Impedance	h_{ob}		.55			.45		μmho
Current Transfer Ratio— Common Emitter (I_E −2 ma, $V_{CB} = 5v$)	h_{fe}	9	15	30	20	35	55	
High Frequency Parameters								
Collector to base Capacitance ($I_E = -1$ ma, $V_{CB} = 5v$, f = 1 mc)	C_{ob}		16			14		$\mu\mu$f
Frequency Cutoff — Common Base ($I_E = -2$ ma, $V_{CB} = 5v$)	f_{ab}		23			25		mc
DC Characteristics								
Collector Current ($I_E = 0$, $V_{CB} = 5v$, T = 25 °C)	I_{CO}			2			2	μamps.
Collector Current ($I_E = 0$, $V_{CB} = 5v$, T = 150 °C)	I_{CO}			50			50	μamps.
Saturation Voltage ($I_B = 1$ ma, $I_C = 5$ ma)	V_{CB}(Sat.)		0.25			0.25		volts

*Derate 1 mw/°C increase in ambient temperature.

2N433, 2N434

Outline Drawing No. 30

The General Electric Types 2N433 and 2N434 transistors are silicon triodes intended for amplifier application in the audio and radio frequency range. The 2N433 and 2N434 are diffused junction devices manufactured by the General Electric diffused meltback process. The transistors are hermetically sealed in a welded case. The case dimensions and lead configuration are suitable for insertion in printed boards by automatic assembly equipment.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS: (25°C)

Voltages		
Collector to Base (Emitter Open)	BV_{CBO}	30 volts
Collector to Emitter (Base Open)	BV_{CEO}	15 volts
Emitter to Base (Collector Open)	BV_{EBO}	5 volts
Collector Current	I_C	30 ma
Power		
Collector Dissipation (25°C)*	P_{CM}	150 mw
Collector Dissipation (150°C)	P_{CM}	25 mw
Temperature Range		
Operating	T_A	−65 to 150 °C
Storage	T_{STG}	200 °C

ELECTRICAL CHARACTERISTICS: (25°C)

		2N433			2N434			
		MIN.	NOM.	MAX.	MIN.	NOM.	MAX.	
Small Signal Hybrid Parameters (Common Base) ($I_E = -1$ ma, $V_{CB} = 5v$, f = 1000~)								
Input Impedance	h_{ib}		52			52		ohms
Reverse Voltage Transfer Ratio	h_{rb}		3×10^{-4}			4.7×10^{-4}		
Current Transfer Ratio	h_{fb}		0.983			0.991		
Output Impedance	h_{ob}		.35			.25		μmho
Current Transfer Ratio—Common Emitter (I_E —2 ma, $V_{CB} = 5v$)	h_{fe}	45	60	100	80	110		
High Frequency Parameters								
Collector to base Capacitance ($I_E = -1$ ma, $V_{CB} = 5v$, f = 1 mc)	C_{ob}		13			12		μμf
Frequency Cutoff — Common Base ($I_E = -2$ ma, $V_{CB} = 5v$)	f_{ab}		28			30		mc
DC Characteristics								
Collector Current ($I_E = 0$, $V_{CB} = 5v$, T = 25 °C)	I_{CO}			2			2	μamps.
Collector Current ($I_E = 0$, $V_{CB} = 5v$, T = 150 °C)	I_{CO}			50			50	μamps.
Saturation Voltage ($I_B = 1$ ma, $I_C = 5$ ma)	V_{CE}(Sat.)		0.25			0.25		volts

*Derate 1 mw/°C increase in ambient temperature.

4JD1B3, 4JD1B4

Outline Drawing No. 8

These General Electric symmetrical switching transistors are alloy junction PNP types designed for computer circuits where high current gain is required at collector currents up to 500 ma. They are unique in that the current gain is symmetrical, i.e., the current gain in the inverse direction is controlled to the same minimum level as the current gain in the forward direction. They use the time proven General Electric all-welded metal case, with the internal structure capable of sustaining severe shock and vibration.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS: (25°C)

Voltages			
Collector to Base	V_{CB}	—45	volts
Collector to Emitter	V_{CE}	—30	volts
Emitter to Base	V_{EB}	—45	volts
Collector Current	I_C	1000	ma
Emitter Current	I_E	1000	ma
Base Current	I_B	—1000	ma
Power			
Total Transistor Power Dissipation 25°C	P_M	200	mw
Temperature Range			
Storage or Junction	T_{STG} or T_J	—55 to 85	°C

ELECTRICAL CHARACTERISTICS: (25°C)

		4JD1B3	4JD1B4	
Switching Characteristics				
Base Current Gain* (I_C = —200 ma; V_{CE} = —.3v)	h_{FE}	15	20	min
Base Input Voltage* (I_C = —200 ma; V_{CE} = —.3v)	V_{BE}	—.5	—.5	max
Pulse Response Time*				
(I_C = —200 ma) (Note 1)				
4JD1B3 (I_{B1} = 13.3 ma; I_{B2} = 13.3 ma)				
4JD1B4 (I_{B1} = 10 ma; I_{B2} = 10 ma)				
Delay Time	t_d	0.6	0.6	μs typ.
Rise Time	t_r	6.0	8.0	μs typ.
Storage Time	t_s	2.0	2.0	μs typ.
Fall Time	t_f	2.5	3.5	μs typ.
Small Signal Characteristics				
(V_{CB} = —5v; I_E = 1 ma)				
Frequency Cutoff	f_{ab}	.8	.8	mc typ.
Output Capacity	C_{ob}	45	45	μfd typ.
Cutoff Characteristics				
Collector Cutoff Current (V_{CB} = —30v; I_E = 0)	I_{CO}	20	20	μa max
Emitter Cutoff Current (V_{EB} = —30v; I_C = 0)	I_{EO}	20	20	μa max
Voltage Collector to Emitter (10k ohm resistance, base to emitter, I_C = 0.6 ma.)	BV_{CER}	—30	—30	volts min
Collector to Emitter Punchthru Voltage ($V_{BE} \leqq$ Iv; $I_C \leqq$ 20 μa)	V_{PT}	—30	—30	volts min
Collector to Base Voltage (I_C = 50 μa; I_E = 0)	BV_{CBO}	—45	—45	volts min
Emitter to Base Voltage (I_E = 50 μa; I_C = 0)	BV_{EBO}	—45	—45	volts min
Thermal Characteristics				
Long Term Storage or Junction Temperature (Note 2)	T_J	65	65	°C
Junction to Free Air Thermal Resistance typical		.2	.2	°C/mw
Junction to Free Air Thermal Resistance max.		.3	.3	°C/mw

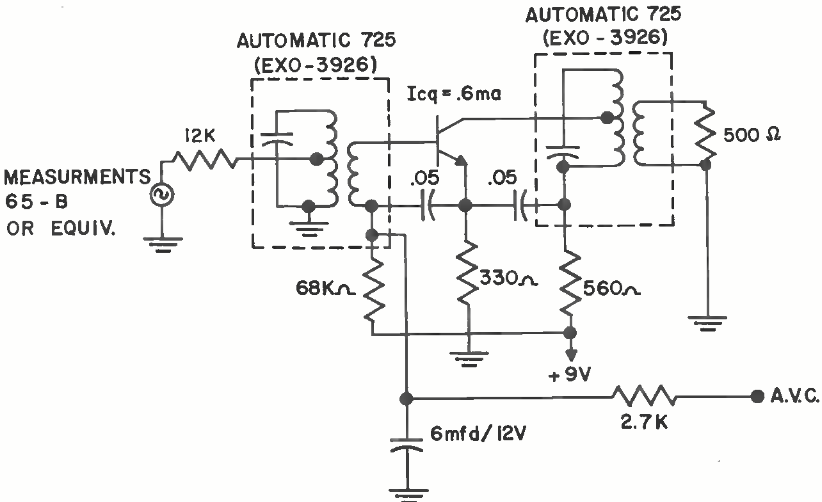
*This is a symmetrical parameter controlled for switching service. Control means that the max. or min. limit specified will be met when the emitter and collector leads are reversed in the test circuit. Control does not necessarily mean that the inverse characteristic is equal to the forward characteristic.

ADDITIONAL TYPES

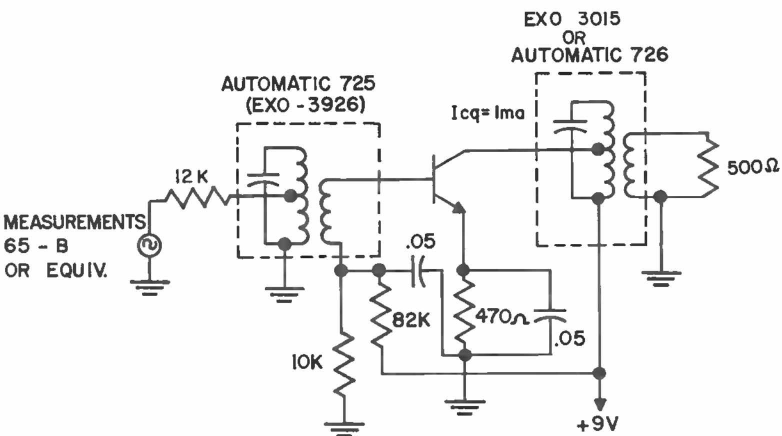
UNIJUNCTION TRANSISTOR **GERMANIUM TETRODES**

Specifications on these types are available by request.

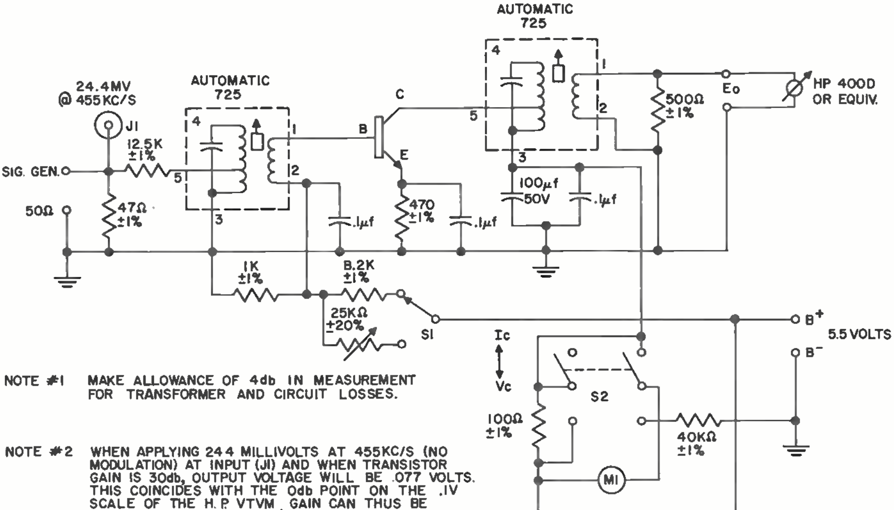
TYPICAL 1ST I. F. AMPL.



TYPICAL 2ND I. F. AMPL.



TYPICAL I F TEST CIRCUIT

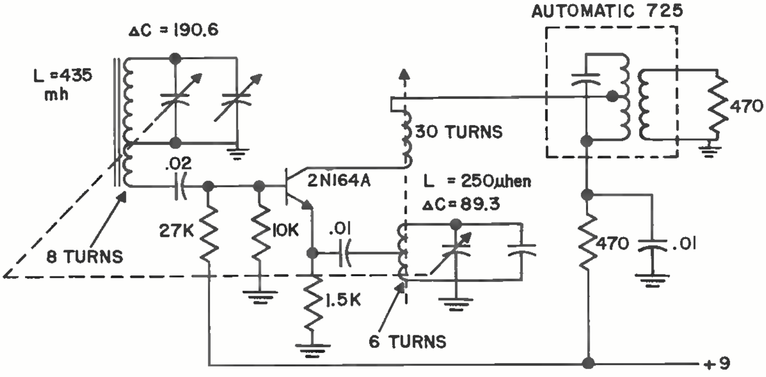


NOTE #1 MAKE ALLOWANCE OF 4db IN MEASUREMENT FOR TRANSFORMER AND CIRCUIT LOSSES.

NOTE #2 WHEN APPLYING 24.4 MILLIVOLTS AT 455KC/S (NO MODULATION) AT INPUT (J1) AND WHEN TRANSISTOR GAIN IS 30db, OUTPUT VOLTAGE WILL BE .077 VOLTS. THIS COINCIDES WITH THE 0db POINT ON THE .1V SCALE OF THE H. P. VTVM. GAIN CAN THUS BE MEASURED DIRECTLY IN db'S.

0–500μa (Ri=300Ω)
VOLTMETER READING 20 VOLTS FULL SCALE
AMMETER READING 2Ma FULL SCALE

TYPICAL AUTODYNE CONVERTER
2N164A



ANTENNA - DELTA COIL # 1 - 105A OR EQUIVALENT

OSCILLATOR COIL - E. STANWYCK CO. # 1129 (MODIFIED) OR EQUIVALENT

CAPACITOR - RADIO CONDENSER # 242 OR EQUIVALENT

I. F. TRANSFORMER - AUTOMATIC 725 (EXO-3926) OR EQUIVALENT

REGISTERED JETEC TRANSISTOR TYPES

For explanation of symbols, ratings and mfg. symbols see page 75.

RETMA No.	Type	Mfr.	Use	Dwg. No.	MAX. RATINGS: P_c mw @ 25°C	BV_{CE}	I_c ma	T_J°C	TYPICAL VALUES: h_{fe}	f_{ab} mc	G_e db	P_o mw — Class A	B	Closest GE
2N22	Pt	WE	SW	1	120	−100	−20	55	1.9α					
2N23	Pt	WE	SW	2	80	−50	−40	55	1.9α					
2N24	Pt	WE	AF	1	120	−30	−25	50	2.2α					
2N25	Pt	WE	AF	1	200	−50	−30	60	2.5α					
2N26	Pt	WE	SW	2	90	−30	−40	55						
2N27	NPN	WE	AF	1	50	35	100	85	100	1				
2N28	NPN	WE	AF	1	50	30	100	85	100	.5				
2N29	NPN	WE	AF	1	50	35	30	85	100	1				
2N30	Pt	GE	Obsolete	3	100	30	7	40	2.2α	2	17			old G11
2N31	Pt	GE	Obsolete	3	100	30	7	40	2.2α	2				old G11A
2N32	Pt	RCA		5	50	−40	−8	40	2.2α	2.7	21			
2N33	Pt	RCA	RF	5	30	−8.5	−7	40		50Mc	Osc.			
2N34	PNP	RCA	AF	6	50	−25	−8	50	40	.6	40			2N190
2N35	NPN	RCA	IF	6	50	25	8	50	40	.8	40		125	2N169A
2N36	PNP	CBS	AF	4	50	−20	−8	50	45		40			2N191
2N37	PNP	CBS	AF	4	50	−20	−8	50	30		36			2N190
2N38	PNP	CBS	AF	4	50	−20	−8	50	15		32			2N189
2N38A	PNP	CBS	AF	4	50	−20	−8	50	18		32			2N189
2N41	PNP	RCA		7	50	−25	−15	50	40		40			2N190
2N43	PNP	GE	AF	8	155	−45*	−300	100	42	1.3	40	40		2N43
2N43A	PNP	GE	AF	8	155	−45*	−300	100	42	1.3	40	40		2N43A
2N44	PNP	GE	AF	8	155	−45*	−300	100	25	1	39	40		2N44
2N45	PNP	GE	AF	8	155	−45*	−300	100	15	.9	38	40		2N45
2N46	PNP	RCA		7	see 2N41									2N190
2N47	PNP	Phil	AF	13	50	−35	−20	65	38	8	40			2N190 25V
2N48	PNP	Phil	AF	13	50	−35	−20	65	32	8	40			2N189 25V
2N49	PNP	Phil	AF	13	50	−35	−20	65	38	8	40			2N190 25V
2N50	Pt	Cle		1	50	−15	−1	50	2α	3	20			
2N51	Pt	Cle	SW	1	100	−50	−8	50			20			
2N52	Pt	Cle	RF	1	120	−50	−8	50			20			
2N53	Pt	Cle	RF	1	100	−50	−8	50	2α	5	20			
2N54	PNP	W	AF	9	200	−45	−10	60	32	.5	40			2N190 25V
2N55	PNP	W	AF	9	200	−45	−10	60	20	.5	39			2N190 25V
2N56	PNP	W	AF	9	200	−45	−10	60	12	.5	38			2N189 25V
2N57	PNP	W	PWR	12	20W	−60	−.8A		60		14	5W		
2N62	PNP	Phil	Obsolete		50	−35	−20		40					
2N63	PNP	Ray	AF	10	100	−22	−10	85	22	6	39	40		2N107
2N64	PNP	Ray	AF	10	100	−15	−10	85	45	8	41	40		2N191
2N65	PNP	Ray	AF	10	100	−12	−10	85	90	1.2	42	40		2N192

2N68	PNP	Syl	PWR	11	2W/4W	−25	−1.5A	70	40	.4	23	600	5W	
2N71	PNP	W	PWR	21	1W	−50	−250	60		.25	25	400		
2N72	Pt	RCA	Obsolete		50	−40	−20	55		2.5				
2N73	PNP	W	AF SW	9	200	−50					low level			
2N74	PNP	W	AF SW	9	200	−50					high level			
2N75	PNP	W	AF SW	9	200	−50					very low level			
2N76	PNP	GE	AF	8	50	−20	−10	60	20	1	38			2N190
2N77	PNP	RCA	AF	19	35	−25	−15	50	55	.7	44	50		2N191
2N78	NPN	GE	RF	14	75	15	20	85	50	4	22			2N169 or 2N168A
2N79	PNP	RCA	AF	20	35	−30	−50		46	.7	44	50		2N191
2N80	PNP	CBS	AF	4	50	−25	−8	Hi	80					2N192
2N81	PNP	GE	AF	8	50	−20	−15	100	30					use 2N189
2N82	PNP	CBS	AF	15	35	−20	−15	Hi	30					
2N94	NPN	Syl	RF Sw	10	30	20	50	75	30	3	38			{2N169A (and
2N94A	NPN	Syl	RF Sw	10	30	20	50	75	40	6	38			{2N123 PNP)
2N95	NPN	Syl	Pwr	11	2.5W/4W	25	1.5A	70	40	.4	23	600	5W	
2N97	NPN	GP	IF	10	50	30	10	75	13	1	20			2N169 15V
2N97A	NPN	GP	IF	10	50	40	10	85	13	1	20			2N169A 25V
2N98	NPN	GP	IF	10	50	40	10	75	38	2.5	22			2N169A 25V
2N98A	NPN	GP	IF	10	50	40	10	85	38	2.5	22			2N169A 25V
2N99	NPN	GP	IF	10	50	40	10	75	38	3.5	22			2N169A 25V
2N100	NPN	GP	IF	10	25	25	5	50	100	5	23			2N170 6V
2N101	PNP	Syl	Pwr	28	1W	−25	−1.5A	70			23	600		
2N102	NPN	Syl	Pwr	28	1W	25	1.5A	70			23	600	5W	
2N103	NPN	GP	Genl IF	10	50	35	10	75	5	.75	15			2N170 6V
2N104	PNP	RCA	AF	20	70	−30	−50	70	44	.7	41			2N190 25V
2N105	PNP	RCA	AF	23	35	−25	−15	50	55	.75	42			2N191
2N106	PNP	Ray	AF	10	100	−6	−10	85	45	.8	36	40		2N189
2N107	PNP	GE	AF	8	50	−6	−10	60	20	1	38			2N107
2N108	PNP	CBS	AF Out	16	50	−20	−15						35	
2N109	PNP	RCA	AF Out	20	50	−12	−35	50	70		33	75	150	2N188-2N192
2N111	PNP	Ray	IF	10	100	−6	−5	85	40	3	30			2N135
2N112	PNP	Ray	RF	10	100	−6	−5	85	40	5	32			2N136-2N135
2N113	PNP	Ray	RF	10	100	−6	−5	85	45	10	33			2N137
2N114	PNP	Ray	RF Sw	10	100	−6	−5	85	65	20				2N137 or 2N123
2N117	NPN	TI	Si (=903)	10	150	30	25	150	12	4				2N431-15V
2N118	NPN	TI	Si (=904)	10	150	30	25	150	24	5				2N432-15V
2N123	PNP	GE	RF Sw	8	100	−20	−125	85	50	8				2N123
2N124	NPN	TI	RF Sw	10	50	10	8	75	18	3				2N168
2N125	NPN	TI	RF Sw	10	50	10	8	75	32	5				2N167
2N126	NPN	TI	RF Sw	10	50	10	8	75	60	5				2N167
2N127	NPN	TI	RF Sw	10	50	10	8	75	130	5				2N167
2N128	PNP	Phil	SB Osc	13	30	−4.5	−5	85	35	60				
2N129	PNP	Phil	SB Osc	13	30	−4.5	−5	85	20	40				
2N135	PNP	GE	IF	8	100	−12	−50	85	20	4.5	29			2N135
2N136	PNP	GE	RF	8	100	−12	−50	85	40	6.5	31			2N136
2N137	PNP	GE	RF	8	100	−6	−50	85	60	10	33			2N137
2N138	PNP	Ray	AF Out		50	−12	−20	40	140		30		50	2N192
2N138A	PNP	Ray	AF Out		50	−45	−100	85	10		29	25	100	2N187 25V
2N139	PNP	RCA	IF	20	35	−16	−15	70	48	4.7	29			2N136-2N135
2N140	PNP	RCA	Osc	20	35	−16	−15	70	45	7	28			2N136

RETMA No.	Type	Mfr.	Use	Dwg. No.	MAX. RATINGS: P_C mw @ 25°C	BV_{CB}	I_C ma	T_J°C	TYPICAL VALUES: h_{fe}	f_{ab} mc	G_e db	P_o mw — Class A	B	Closest GE
2N141	PNP	Syl	Pwr	26	1.5W/4W	−30	−.8A	65	40	.4	26	600	5W	
2N142	NPN	Syl	Pwr	26	1.5W/4W	30	.8A	65	40	.4	26	600	5W	
2N143	PNP	Syl	Pwr	26	1W/4W	−30	−.8A	65	40	.4	26	600	5W	
2N144	NPN	Syl	Pwr	26	1W/4W	30	.8	65	40	.4	26	600	5W	
2N145	NPN	TI	IF	10	65	20	5	75			33 max			2N169 or 2N292
2N146	NPN	TI	IF	10	65	20	5	75			36 max			2N169 or 2N292
2N147	NPN	TI	Osc	10	65	20	5	75			39 max			2N168A or 2N293
2N148	NPN	TI	lo IF	10	65	16	5	75			35 max			2N169 or 2N292
2N148A	NPN	TI	lo IF	10	65	32	5	75			35 max			2N169A
2N149	NPN	TI	lo IF	10	65	16	5	75			38 max			2N169 or 2N292
2N149A	NPN	TI	lo IF	10	65	32	5	75			38 max			2N169A
2N150	NPN	TI	lo IF	10	65	16	5	75			41 max			2N169 or 2N292
2N150A	NPN	TI	lo IF	10	65	32	5	75			41 max			2N169A
2N155	PNP	CBS	Pwr	27	1.5W/5W	−30	−3A	85	48	.3	33	2W	9W	
2N156	PNP	CBS	Pwr	22	1.5W/5W	−30	−3A	85	40	.3	36	2W	9W	
2N158	PNP	CBS	Pwr	22	1.5W/5W	−60	−3A	85	40	.3	40	2W	17W	
2N159	Pt	Sprague	Sw		80	−50	−10			2				
2N160	NPN	GP	Si IF	10	150	40	25	150	14	4	34			2N431-15V
2N160A	NPN	GP	Si IF	10	150	40	25	150	14	4	34			2N431-15V
2N161	NPN	GP	Si RF	10	150	40	25	150	28	5	37			2N432-15V
2N161A	NPN	GP	Si RF	10	150	40	25	150	28	5	37			2N432-15V
2N162	NPN	GP	Si RF	10	150	40	25	150	38	8	38			2N432-15V
2N162A	NPN	GP	Si RF	10	150	40	25	150	38	8	38			2N432-15V
2N163	NPN	GP	Si RF	10	150	40	25	150	50	6	40			2N433-15V
2N163A	NPN	GP	Si RF	10	150	40	25	150	50	6	40			2N433-15V
2N164A	NPN	GE	Osc		65	15	20	85	40	8	39 max			2N168A
2N165	NPN	GE	IF		65	15	20	85	72	5	36 max			2N169
2N166	NPN	GE	Hobb		25	6	20	50	32	5	24			2N170
2N167	NPN	GE	Sw	14	65	30	75	85	36	8				2N167
2N168	NPN	GE	RF	14	55	15	20	75	20	6	39 max			use 2N293
2N168A	NPN	GE	Osc	14	65	15	20	85	40	8	39 max			2N168A
2N169	NPN	GE	IF	14	55	15	20	75	40	4	35 max			2N169
2N169A	NPN	GE	IF	14	55	25	20	75	30	5	35 max			2N169A
2N170	NPN	GE	RF	14	55	6	20	50	20	4	27			2N170
2N172	NPN	TI	IF	10	65	16	5	75			28			2N168A
2N173	PNP	Dlc	Pwr	18	40W	−60	−7A	90	100	.6		8	20W	
2N174	PNP	Dlc	Pwr	18	40W	−80	−7A	90	45	.2		20	80W	
2N175	PNP	RCA	AF	20	20	−10	−2	50	65	.8	43			2N192
2N176	PNP	Motor	Pwr	27		−12	−600	80			25	3W		
2N178	PNP	Motor	Pwr	27	10W	−12	−600	80	30		29	3W		
2N179	PNP	Motor	Pwr			−20	−60	88			32	300		
2N180	PNP	CBS	AF Out	4	150	−30	−25	75	60	.7	37	3W	300	2N188
2N181	PNP	CBS	AF Out	25	250	−30	−38	75	60	.7	34	110	600	2N188A 25V
2N182	NPN	CBS	IF	4	100	25	10	75	25	3.5				2N167
2N183	NPN	CBS	Sw	4	100	25	10	75	40	7.5				2N167

2N184	NPN	CBS	Sw	4	100	25	10	75	60	12				2N167
2N185	PNP	TI	AF	10	150	-20	-150	50	55		40.5	2	250	2N188A
2N186	PNP	GE	AF Out	8	75	-25	-200	60	24	.8	28		300	2N186
2N186A	PNP	GE	AF Out	8	180	-25	-200	60	24	.8	28		750	2N186A
2N187	PNP	GE	AF Out	8	75	-25	-200	60	36	1	30		300	2N187
2N187A	PNP	GE	AF Out	8	180	-25	-200	60	36	1	30		750	2N187A
2N188	PNP	GE	AF Out	8	75	-25	-200	60	54	1.2	32		300	2N188
2N188A	PNP	GE	AF Out	8	180	-25	-200	60	54	1.2	32		750	2N188A
2N189	PNP	GE	AF	8	75	-25	-50	60	24	.8	37	1		2N189
2N190	PNP	GE	AF	8	75	-25	-50	60	36	1	39	1		2N190
2N191	PNP	GE	AF	8	75	-25	-50	60	54	1.2	41	1		2N191
2N192	PNP	GE	AF	8	75	-25	-50	60	75	1.5	43	1		2N192
2N193	NPN	Syl	Osc		50	15		75	6	3				2N167
2N194	NPN	Syl	Osc	10	50	15	50	75	7.5	3.5	15			2N169
2N206	PNP	RCA	AF	19	75	-30	-50	85	47	.8	46			2N191
2N207	PNP	Phil	AF		50	-12	-20	65	100	2				
2N211	NPN	Syl	Osc		50	10	50	75	30	3.5				2N293
2N212	NPN	Syl	Osc	10	50	10	50	75	15	6	22			2N293
2N213	NPN	Syl	AF		50	25	100	75	150		42			2N169A
2N214	NPN	Syl	AF Out	10	125	25	75	70	70	.8	29		200	2N188 (PNP)
2N215	PNP	RCA	AF	19	50	-30	-50	70	44	.7	41			2N191
2N216	NPN	Syl	IF	10	50	15	50	75	15	3	26			2N169
2N217	PNP	RCA	AF	19	50	-25	-70	50	70		33		160	2N192
2N218	PNP	RCA	IF	19	35	-16	-15	70	48	4.7	30			2N135
2N219	PNP	RCA	Osc	19	35	-16	-15	70	45	7	27			2N136
2N220	PNP	RCA	AF	19	20	-10	-2	50	65	.8	43			2N192
2N223	PNP	Phil	AF		100	-18	-60	65	50	.6	37	1		2N192
2N224	PNP	Phil	AF Out		100	-25	-150	65	75	.5	36		300	2N241A
2N225	PNP	Phil	AF Out		100	-25	-150	65	75	.5	36		300	2N241A
2N226	PNP	Phil	AF Out		100	-25	-150	65	55	.4	30		300	2N188A
2N227	PNP	Phil	AF Out		100	-25	-150	65	55	.4	30		300	2N188A
2N228	NPN	Syl	AF Out	10	50	25		75	70	.8	26		100	2N169
2N229	NPN	Syl	AF	10	50	12	40	75	25	1.6				2N169
2N230	PNP	Mall	Pwr	27	15W	-30	-2A	85	83	.014 (β)				
2N235	PNP	Bendix	Pwr		25W	-40	-3A	90			33	2W		
2N235A	PNP	Bendix	Pwr		25W	-40	-3A	90			33	2W		
2N237	PNP	NAC	AF		150	-45	-20	55	70	1	44			2N192 25V
2N238	PNP	TI	AF	10	50	-20		60			42m			2N191
2N240	PNP	Phil	SB Sw		10	-6	-15		16					
2N241	PNP	GE	AF Out	8	100	-25	-200	60	60	1.2	34		300	2N241
2N241A	PNP	GE	AF Out	8	180	-25	-200	60	60	1.2	34		750	2N241A
2N242	PNP	Syl	Pwr	27		-45	-2A	100	40	5Kc (β)	30	2.5W		
2N247	PNP	RCA	Drift RF	24	35	-35	-10	85	60	30	(37 @ 1.5Mc)			
2N249	PNP	TI	AF Out	17	350	-25	-200	60	45		31	50	500	2N188A
2N250	PNP	TI	Pwr	27	12W	-30	-2A	80	50	6 Kc	34	6W		
2N251	PNP	TI	Pwr	27	12W	-60	-2A	80	50	6 Kc	34	6W		
2N253	NPN	TI	IF	10	65	12	5	75			30			2N293
2N254	NPN	TI	IF	10	65	20	5	75			34			2N293
2N255	PNP	CBS	Pwr	27	1.5W/6.25W	-15	-3A	85	40	.2	23	1W	5W	
2N256	PNP	CBS	Pwr	27	1.5W/6.25W	-30	-3A	85	40	.2	26	2W	10W	
2N257	PNP	Cle	Pwr	27	2W/25W	-20		85	50	7 Kc (β)	30	1W		

RETMA No.	Type	Mfr.	Use	Dwg. No.	MAX. RATINGS: P_C mw @ 25°C	BV_{CB}	I_C ma	T_J°C	TYPICAL VALUES: h_{fe}	f_{ab} mc	G_e db	P_o mw — Class A	B	Closest GE
2N260	PNP	Cle	Si	4	200	−10	−50	150	16	1.8	38			2N431 (NPN)
2N260A	PNP	Cle	Si	4	200	−30	−50	150	16	1.8	38			2N431-15V (NPN)
2N261	PNP	Cle	Si	4	200	−75	−50	150	10	1.8	36			
2N262	PNP	Cle	Si RF	4	200	−10	−50	150	20	6	40			2N432-(NPN)
2N262A	PNP	Cle	Si RF	4	200	−30	−50	150	20	6	40			2N432-15V (NPN)
2N265	PNP	GE	AF	8	75	−25	−50	60	110	1.5	45			2N265
2N267	PNP	RCA	RF Drift		Same as 2N247 except for flex. leads									
2N268	PNP	Cle	Pwr		2W/25W	−30			7	6 Kc (β)	28			
2N269	PNP	RCA	Sw		35	−20	−100	70	35	4				2N123
2N270	PNP	RCA	AF Out		150	−25	−150	50	70		32		500	2N320
2N277	PNP	Dlco	Pwr		55W	−40	−12A	95	60	.5	34	16W	30W	
2N278	PNP	Dlco	Pwr		55W	−50	−12A	95	60	.5	34	16W	30W	
2N290	PNP	Dlco	Pwr		55W	−70	−12A	95	50	.4	25	20W	85W	
2N292	NPN	GE	IF	14	55	15	20	75	80	6	35 max			2N292
2N293	NPN	GE	RF	14	55	15	20	75	35	4	39 max			2N293
2N297	PNP	Cle	Pwr		15W	−60	−5A	85	35	6Kc				
2N301	PNP	RCA	Pwr		12W	−40	−2A	85	70		30	2.7W		
2N301A	PNP	RCA	Pwr		12W	−60	−2A	85	70		30	2.7W		
2N306	NPN	Syl	AF		50	−12		75	30	.75				2N292
2N307	PNP	Syl	AF Out			−35	−1A	75	25	4				
2N311	PNP	Motor	Sw		75	−15		85	50					2N123
2N312	NPN	Motor	Sw		75	+15		85	50					2N167
2N313	NPN	GE	IF	31	65	15	20	85	25	5	36 max			2N292
2N314	NPN	GE	IF	31	65	15	20	85	25	8	39 max			2N293
2N315	PNP	GT	Sw		100	−15	−200	85	20	5				2N186
2N316	PNP	GT	Sw		100	−10	−200	85	30	12				2N187A
2N317	PNP	GT	Sw		100	−6	−200	85	30	20				2N188A
2N318	PNP	GT	Photo		50	−12	−20		100	.75				
2N319	PNP	GE	AF Out	29	200	−20	−200	85	36	3	30		750	2N187A
2N320	PNP	GE	AF Out	29	200	−20	−200	85	54	3	32		750	2N188A
2N321	PNP	GE	AF Out	29	200	−20	−200	85	73	3	35		750	2N241A
2N322	PNP	GE	AF	29	75	−16	−50	85	36	3	39			2N190
2N323	PNP	GE	AF	29	75	−16	−50	85	54	3	41			2N191
2N324	PNP	GE	AF	29	75	−16	−50	85	75	3	43			2N192
2N325	PNP	Syl	Pwr		12W	−35	−2A	85	40	.2				
2N326	NPN	Syl	Pwr		7W	+35	+2A	85	40	.2				
2N344	PNP	Phil	RF (= SB101)		20	−5	−5	85	22	50				
2N345	PNP	Phil	RF (= SB102)		20	−5	−5	85	60	50				
2N346	PNP	Phil	RF (= SB103)		20	−5	−5	85	15	75				
2N378	PNP	TS	Sw		15W	−20	−3A	85	35	7Kc (β)				
2N379	PNP	TS	Sw		15W	−40	−3A	85	30	7Kc (β)				
2N380	PNP	TS	Sw		15W	−30	−3A	85	60	7Kc (β)				
2N430	NPN	GE	Si Sw	30	150	10	30	150		25				2N430
2N431	NPN	GE	Si Sw	30	150	15	30	150	15	23				2N431
2N432	NPN	GE	Si RF	30	150	15	30	150	35	25				2N432
2N433	NPN	GE	Si RF	30	150	15	30	150	60	28				2N433
2N434	NPN	GE	Si RF	30	150	15	30	150	110	30				2N434

TYPES AND USES:

Si—Silicon High Temperature Transistors (all others germanium)
Pt—Point contact types
AF—Audio Frequency Amplifier—Driver
AF Out—High current AF Output
Pwr—Power output 1 watt or more
RF—Radio Frequency Amplifier
Osc—High gain High frequency RF oscillator
IF—Intermediate Frequency Amplifier
lo IF—Low IF (262 Kc) Amplifier
Sw—High current High frequency switch
AF Sw—Low frequency switch

RATINGS:

P_c=*Maximum collector dissipation* at 25°C (76°F) ambient room temperature. Secondary designations are ratings with connection to an appropriate heat sink.

BV_{CE}=*Minimum collector-to-emitter breakdown voltage*. GE transistors measured with Base-to-emitter resistance as follows:
10K for AF and AF Out PNP
1 Meg for RF, IF, and Osc PNP
Open circuit for NPN

*BV_{CB}=45 Minimum collector-to-base breakdown voltage (for grounded base applications).

I_C=*Maximum collector current*. (Negative for PNP, Positive for NPN.)

T_J=Maximum centigrade *junction temperature*. P_C must be derated linearly to O mw dissipation at this temperature.

h_{fe}=Small signal base to collector *current-gain*, or Beta (except for Pt Contact types where emitter to collector gain, alpha α, is given).

f_{ab}=*Alpha cut-off-frequency*. Frequency at which the emitter to collector current gain, or alpha, is down to $1\sqrt{2}$ or .707 of its low frequency audio value. For some power transistors, the Beta or base-to-collector current-gain cutoff—frequency is given as noted.

G_e=Grounded-emitter *Power Gain*.
AF, AF Out, and Pwr Gain measured at 1 Kc.
RF, IF, and Osc Gains at 455 Kc.
(Sw Gain is dependent on circuit and wave-shape.)
(All measured at typical power output level for given transistor type.)

P_o=Maximum *Power Output* at 5% harmonic distortion, in mw except where noted as watts. Class A single-ended, Class B Push Pull.

MANUFACTURERS:

CBS—CBS-Hytron.
Cle—Clevite Transistor Products.
Dlc—Delco Radio Div., General Motors Corp.
GE—General Electric Company.
GP—Germanium Products Corp.
Mall—P. R. Mallory and Company, Inc.
Mar—Marvelco, National Aircraft Corp.
Motor—Motorola, Inc.
Phil—Philco.
Ray—Raytheon Manufacturing Company.
RCA—RCA.
Sprague—Sprague Electronics Company.
Syl—Sylvania Electric Products Company.
TI—Texas Instruments, Inc.
TS—Tung-Sol.
W—Westinghouse Electric Corp.
WE—Western Electric Company.

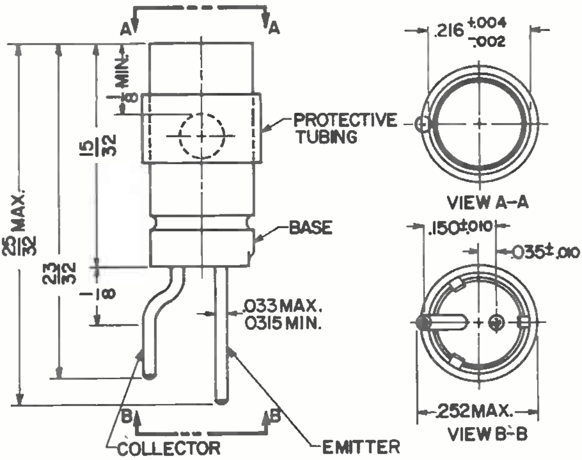
NOTE:

Closest GE types are given only as a general guide and are based on available published electrical specifications. However, General Electric Company makes no representation as to the accuracy and completeness of such information.

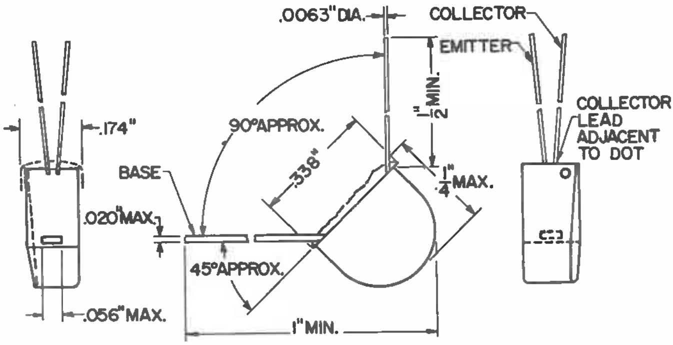
Where the maximum voltage rating of the GE unit is not equal to or greater than the given transistor, the GE rating is also given. Note that physical dimensions vary considerably among manufacturers and may be the limiting factor in some replacement applications.

Since manufacturing techniques are not identical, the General Electric Company makes no claim, nor does it warrant, that its transistors are exact equivalents or replacements for the types referred to.

OUTLINE DRAWINGS



1



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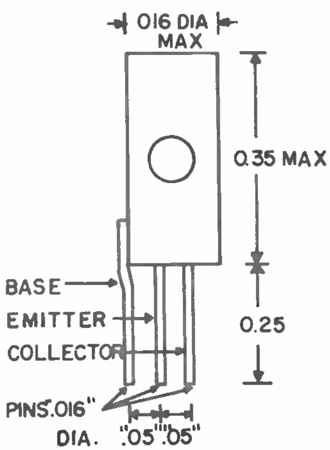

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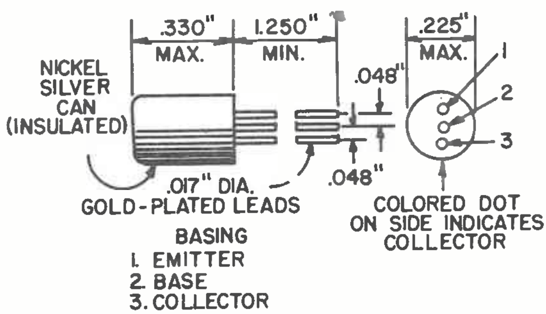

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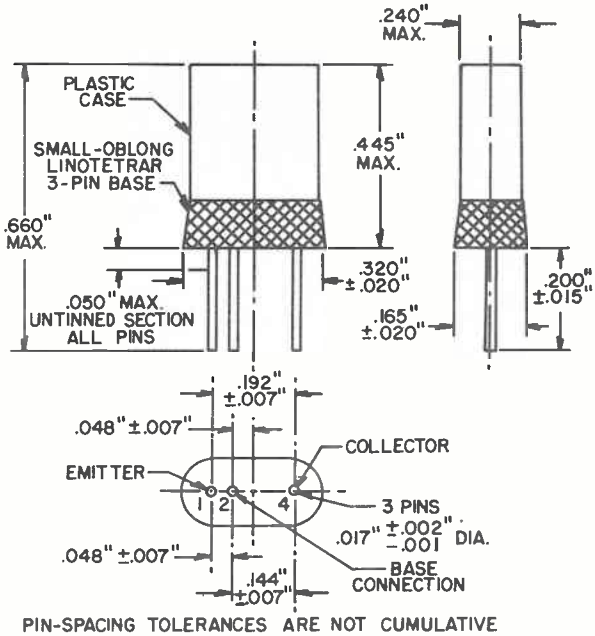
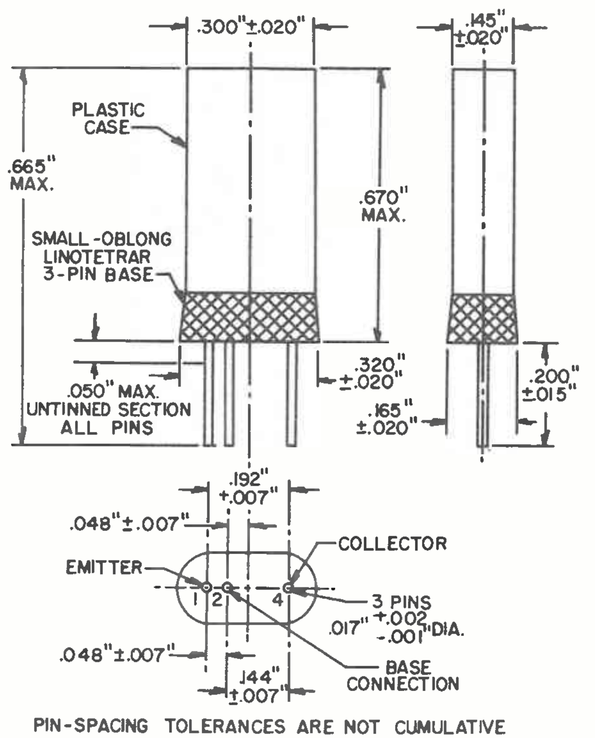
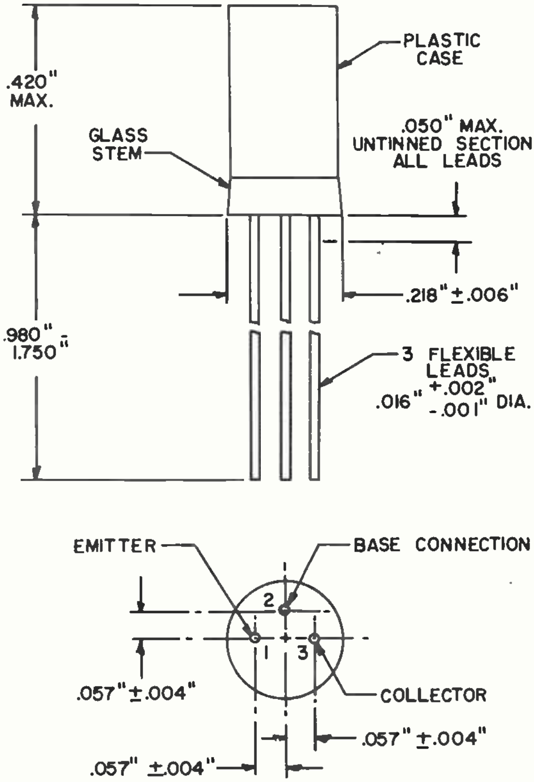

.240"
MAX.
PLASTIC
CASE
SMALL-OBLONG
LINOTETRAR
3-PIN BASE
.445"
MAX.
.660"
MAX.
.320"
±.020"
.200"
±.015"
.050" MAX.
UNTINNED SECTION
ALL PINS
.165"
±.020"
.192"
±.007"
.048" ±.007"
COLLECTOR
EMITTER
1
2
4
3 PINS
.017" +.002" -.001 DIA.
.048" ±.007"
BASE
CONNECTION
.144"
±.007"
PIN-SPACING TOLERANCES ARE NOT CUMULATIVE

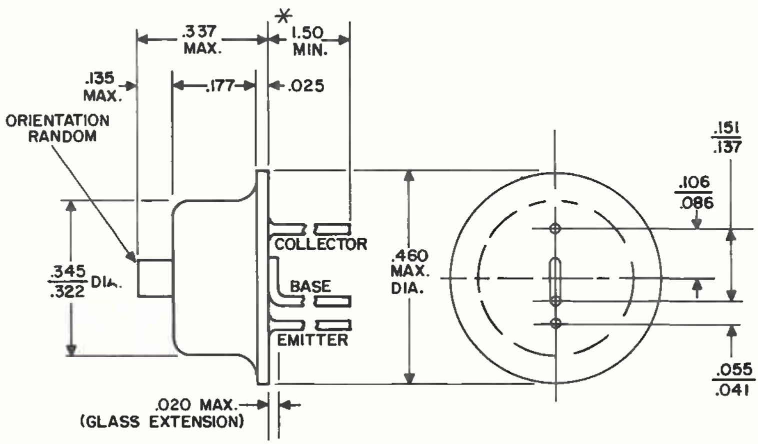
5


.300"±.020"
.145"
±.020"
PLASTIC
CASE
.665"
MAX.
.670"
MAX.
SMALL-OBLONG
LINOTETRAR
3-PIN BASE
.050" MAX.
UNTINNED SECTION
ALL PINS
.320"
±.020"
.200"
±.015"
.165"
±.020"
.192"
+.007"
.048" ±.007"
COLLECTOR
EMITTER
1
2
4
3 PINS
.017" +.002 -.001" DIA.
.048" ±.007"
BASE
CONNECTION
.144"
±.007"
PIN-SPACING TOLERANCES ARE NOT CUMULATIVE

6

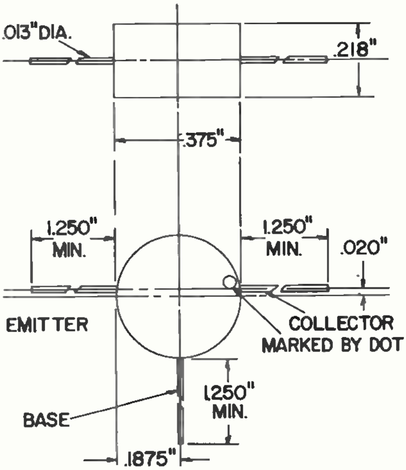


7

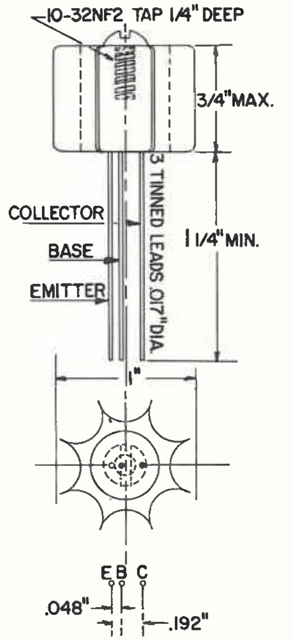


8

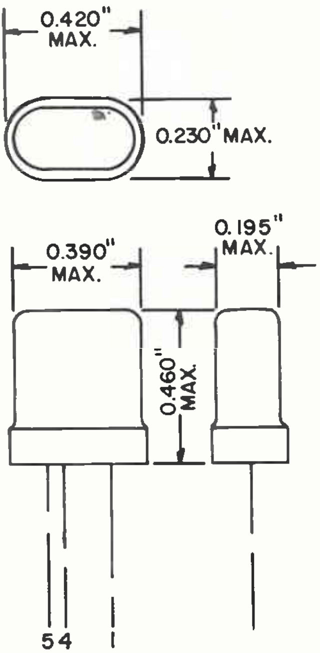
* CUT TO 0.200" FOR USE IN SOCKETS.
LEADS TINNED DIA. .018
MOUNTING POSITION - ANY
WEIGHT: .05 OZ.
BASE CONNECTED TO TRANSISTOR SHELL.
DIMENSIONS IN INCHES.



9

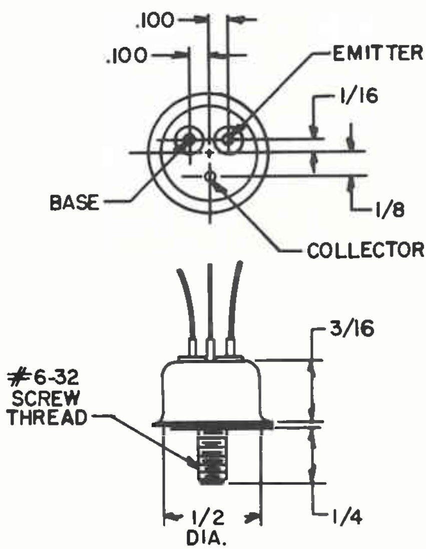


11

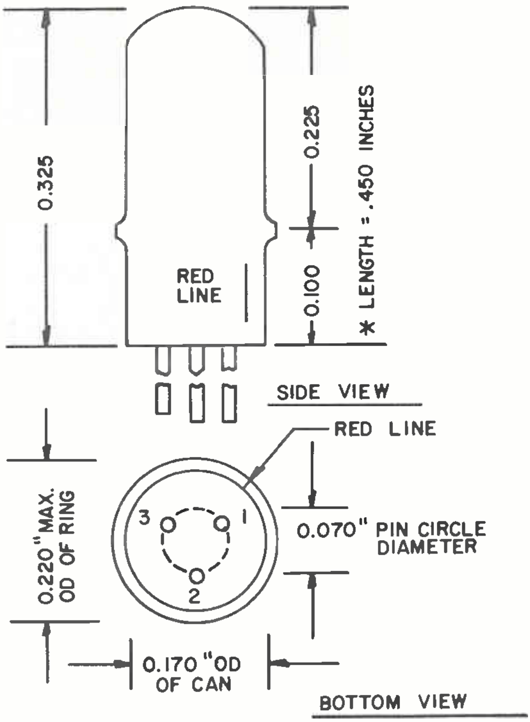


(0.016" TINNED FLEXIBLE LEADS.
LENGTH: 1.5"MIN.
SPACING: LEADS 1-4 0.144"
CENTER TO CENTER;
OTHER LEADS 0.048"
CENTER TO CENTER)

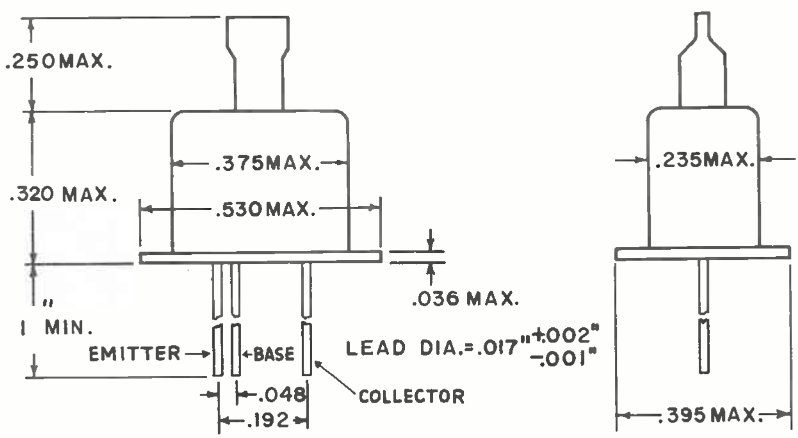
10



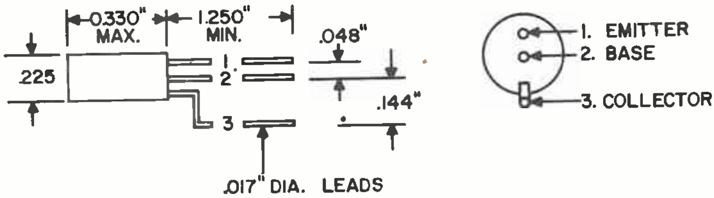
12


0.325
0.225
0.100
* LENGTH = .450 INCHES
RED LINE
SIDE VIEW
RED LINE
3
1
2
0.220" MAX. OD OF RING
0.070" PIN CIRCLE DIAMETER
0.170" OD OF CAN
BOTTOM VIEW

13

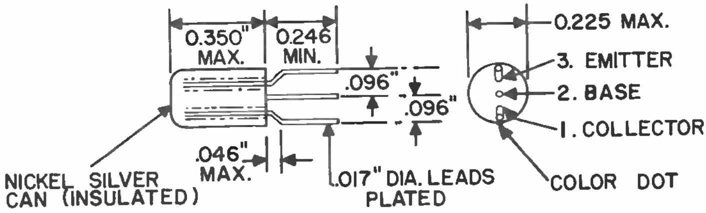

.250 MAX.
.375 MAX.
.320 MAX.
.530 MAX.
.036 MAX.
1" MIN.
EMITTER
BASE
LEAD DIA.=.017" +.002" -.001"
.048
COLLECTOR
.192
.235 MAX.
.395 MAX.

14



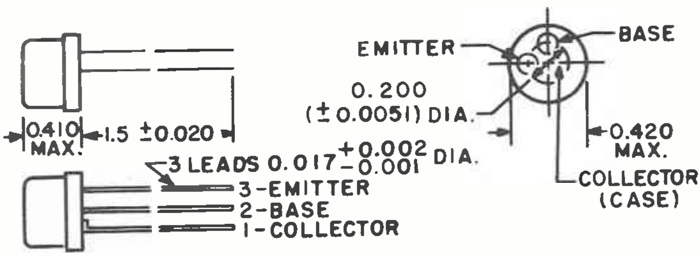
0.330" MAX.
1.250" MIN.
.048"
.225
1
2
3
.144"
.017" DIA. LEADS
1. EMITTER
2. BASE
3. COLLECTOR

15



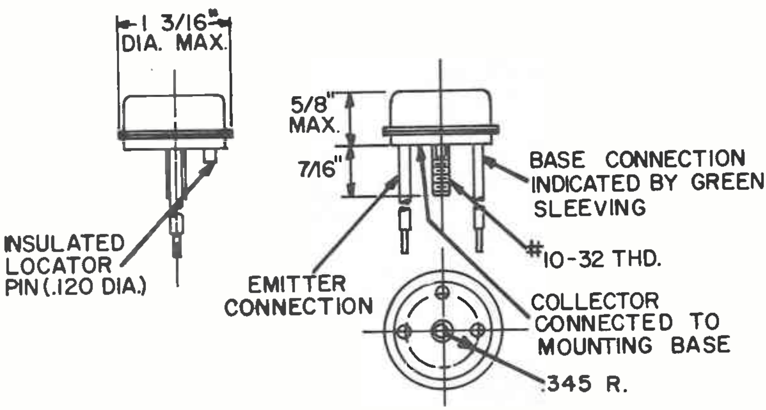
0.350" MAX.
0.246 MIN.
.096"
.096"
.046" MAX.
NICKEL SILVER CAN (INSULATED)
.017" DIA. LEADS PLATED
0.225 MAX.
3. EMITTER
2. BASE
1. COLLECTOR
COLOR DOT

16



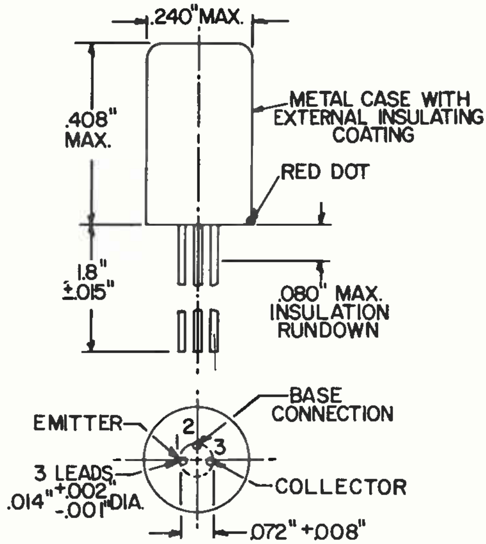
0.410 MAX.
1.5 ±0.020
3 LEADS 0.017 +0.002 −0.001 DIA.
3-EMITTER
2-BASE
1-COLLECTOR
EMITTER
BASE
0.200 (±0.0051) DIA.
0.420 MAX.
COLLECTOR (CASE)

17

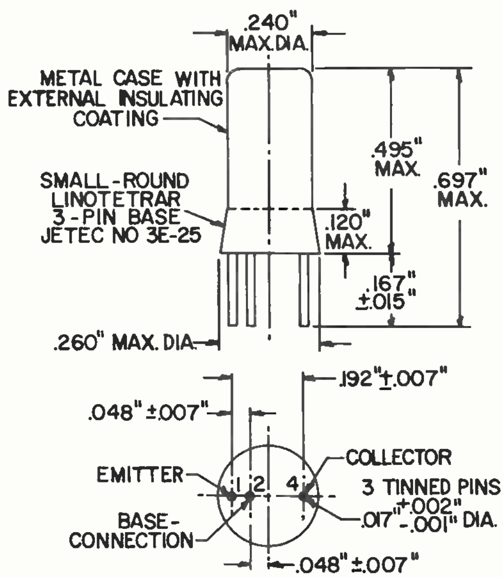


1 3/16" DIA. MAX.
INSULATED LOCATOR PIN (.120 DIA.)
5/8" MAX.
7/16"
BASE CONNECTION INDICATED BY GREEN SLEEVING
#10-32 THD.
EMITTER CONNECTION
COLLECTOR CONNECTED TO MOUNTING BASE
.345 R.

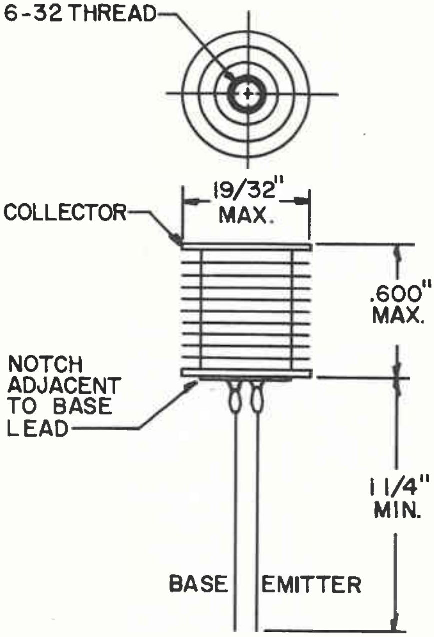
18


.240" MAX.
.408" MAX.
METAL CASE WITH EXTERNAL INSULATING COATING
RED DOT
1.8" ±.015"
.080" MAX. INSULATION RUNDOWN
EMITTER
BASE CONNECTION
3 LEADS .014" +.002" -.001" DIA.
COLLECTOR
.072" ±.008"

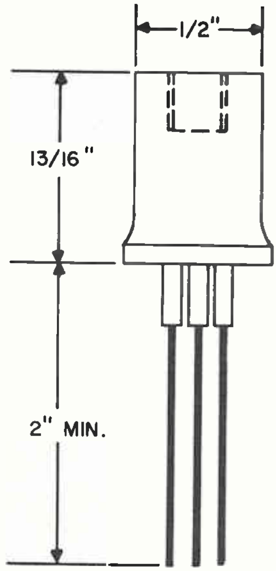
19


.240" MAX. DIA.
METAL CASE WITH EXTERNAL INSULATING COATING
.495" MAX.
.697" MAX.
SMALL-ROUND LINOTETRAR 3-PIN BASE JETEC NO 3E-25
.120" MAX.
.167" ±.015"
.260" MAX. DIA.
.192" ±.007"
.048" ±.007"
EMITTER
COLLECTOR
3 TINNED PINS .017" +.002" -.001" DIA.
BASE-CONNECTION
.048" ±.007"

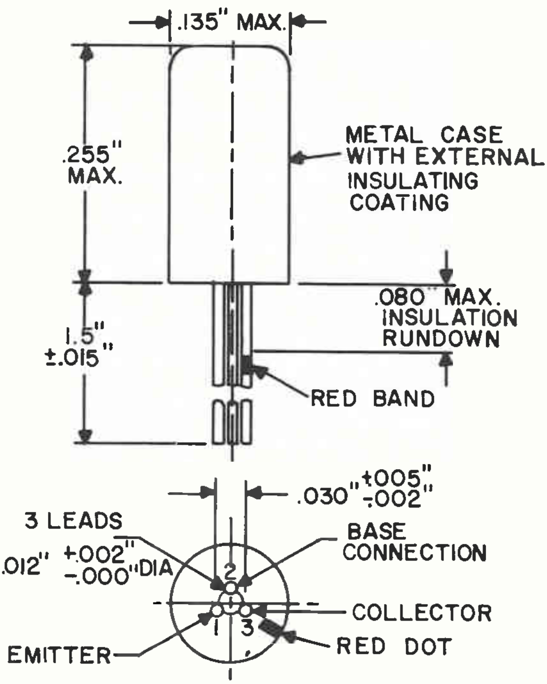
20


6-32 THREAD
19/32"
MAX.
COLLECTOR
.600"
MAX.
NOTCH
ADJACENT
TO BASE
LEAD
1 1/4"
MIN.
BASE
EMITTER

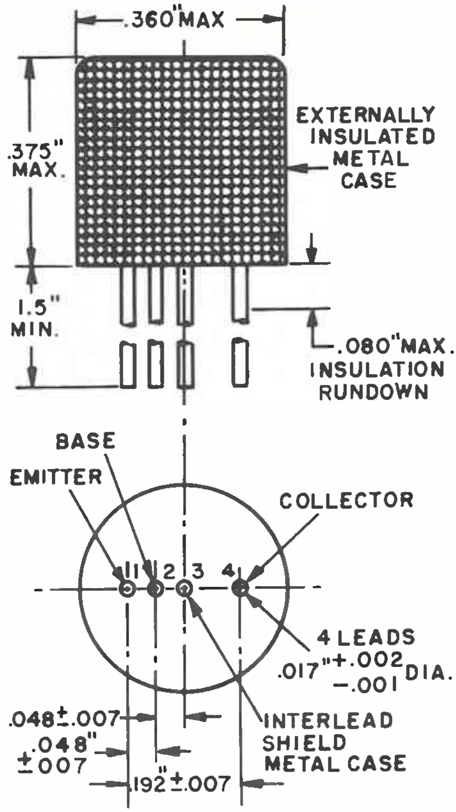
21


1/2"
13/16"
2" MIN.

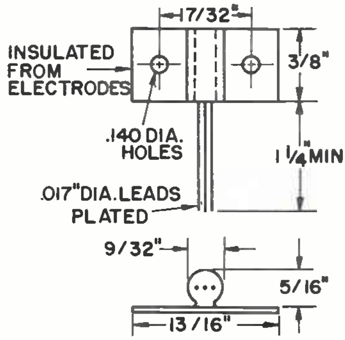
22


.135" MAX.
.255"
MAX.
METAL CASE
WITH EXTERNAL
INSULATING
COATING
.080" MAX.
INSULATION
RUNDOWN
1.5"
±.015"
RED BAND
.030" +.005" -.002"
3 LEADS
.012" +.002" -.000" DIA
BASE
CONNECTION
COLLECTOR
RED DOT
EMITTER
2
1
3

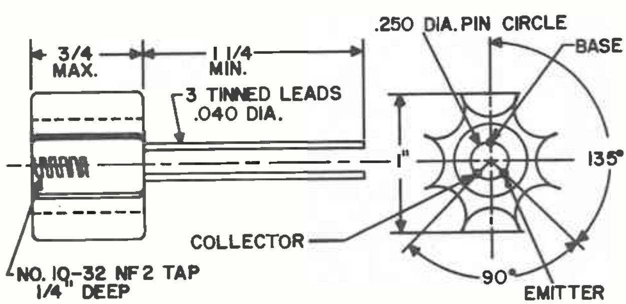
23


.360" MAX
.375" MAX.
EXTERNALLY INSULATED METAL CASE
1.5" MIN.
.080" MAX. INSULATION RUNDOWN
BASE
EMITTER
COLLECTOR
1 2 3 4
4 LEADS .017" +.002 −.001 DIA.
.048±.007
.048" ±.007
.192"±.007
INTERLEAD SHIELD METAL CASE

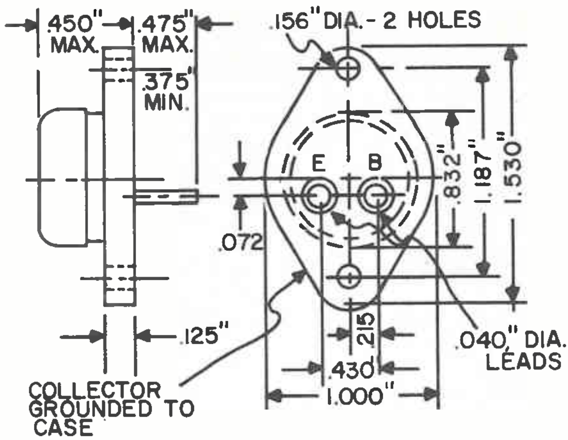
24


17/32"
INSULATED FROM ELECTRODES
3/8"
.140 DIA. HOLES
1 1/4" MIN.
.017" DIA. LEADS PLATED
9/32"
5/16"
13/16"

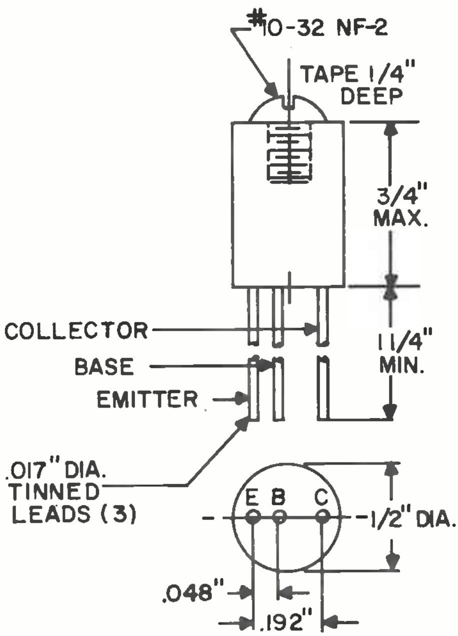
25


3/4 MAX.
1 1/4 MIN.
3 TINNED LEADS .040 DIA.
.250 DIA. PIN CIRCLE
BASE
1"
135°
COLLECTOR
NO. 10-32 NF2 TAP 1/4" DEEP
90°
EMITTER

26



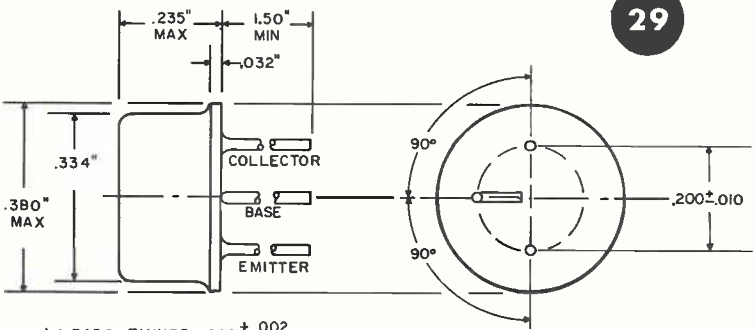
27



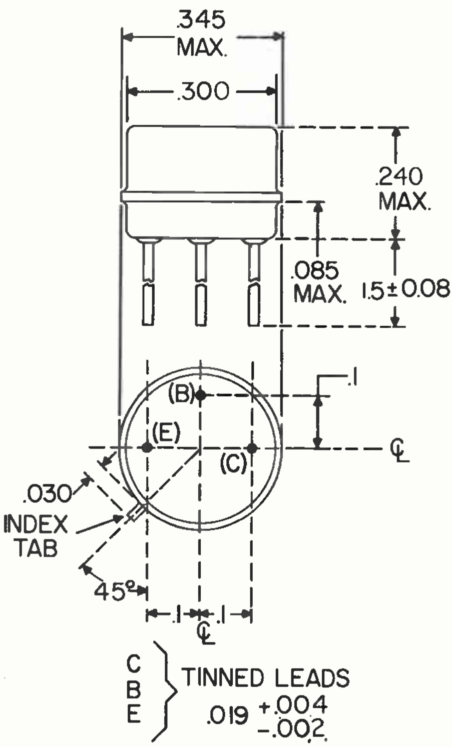
COLLECTOR CONNECTED TO SHELL

28

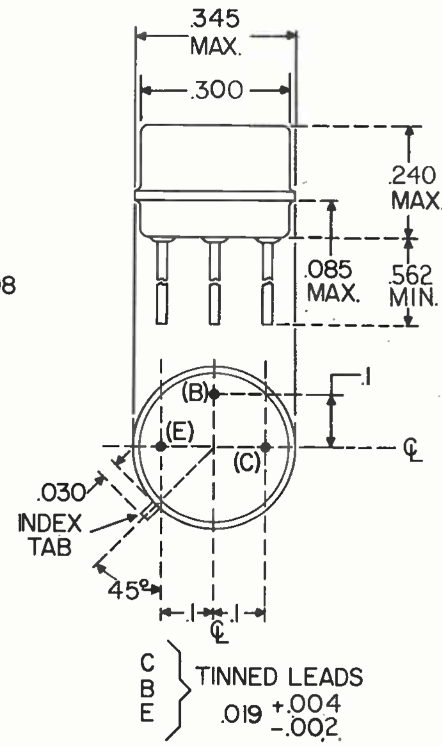
29



1. LEADS TINNED .019 +.002 −.001
2. MOUNTING POSITION — ANY
3. WEIGHT .05 OZ.
4. BASE CONNECTED TO TRANSISTOR SHELL
5. DIMENSIONS IN INCHES



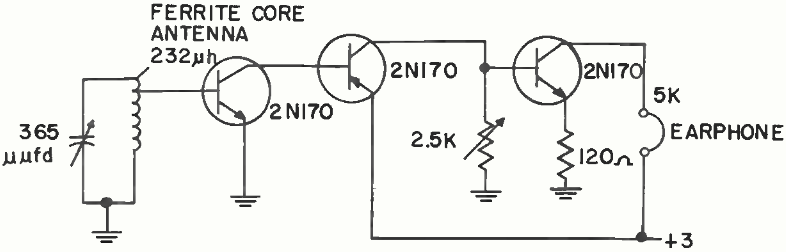
30



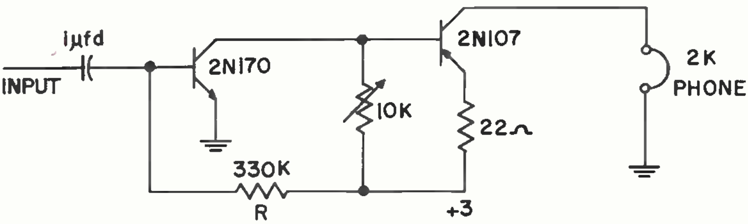
31

CIRCUIT DIAGRAMS

These circuit diagrams are included for illustration of typical transistor applications and are not intended as constructional information. For this reason, wattage ratings of resistors and voltage ratings of capacitors are not necessarily given. Similarly, shielding techniques and alignment methods which may be necessary in some circuit layouts are not indicated.
The description and illustration of the circuits contained herein does not convey to the purchaser of transistors any license under patent rights of General Electric Company. Although reasonable care has been taken in their preparation to insure their technical correctness, no responsibility is assumed by General Electric Company for any consequences of their use.

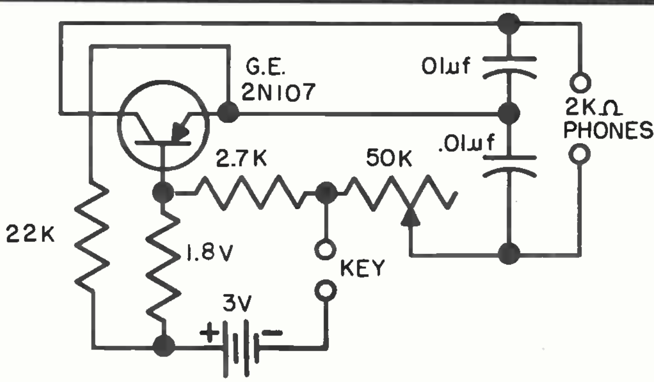


DIRECT COUPLED VEST POCKET RADIO

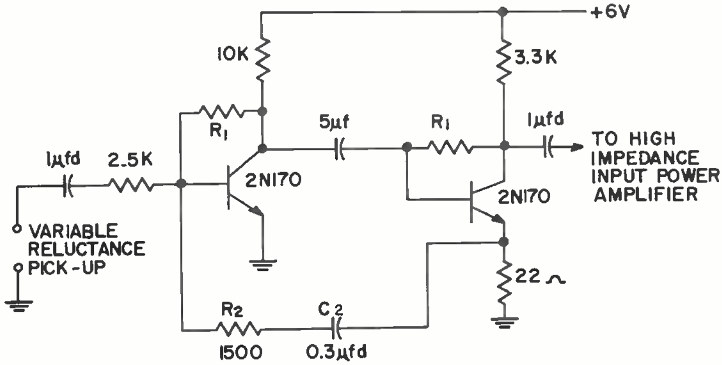


R SHOULD BE ADJUSTED FOR OPTIMUM RESULTS

DIRECT COUPLED "BATTERY SAVER" AMPLIFIER



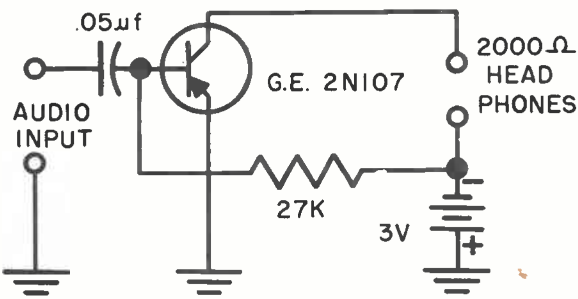
CODE PRACTICE OSCILLATOR



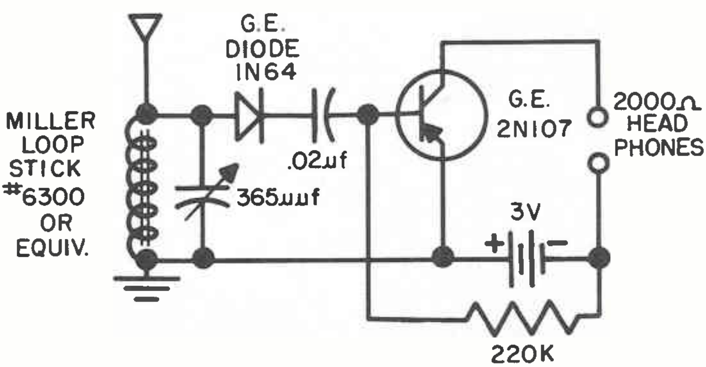
R1 (100K-500K) SHOULD BE CHOSEN TO MAKE COLLECTOR VOLTAGE 2.5 TO 3.5 VOLTS

CHANGING C2 AND R2 WILL VARY COMPENSATION CURVE. VALUES SHOWN GIVE APPROXIMATE COMPENSATION FOR R. I. A. A. RECORDING CHARACTERISTICS

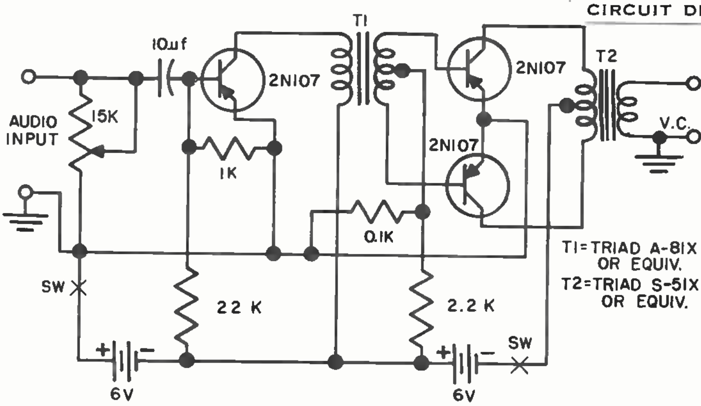
VARIABLE RELUCTANCE COMPENSATED PRE-AMPLIFIER



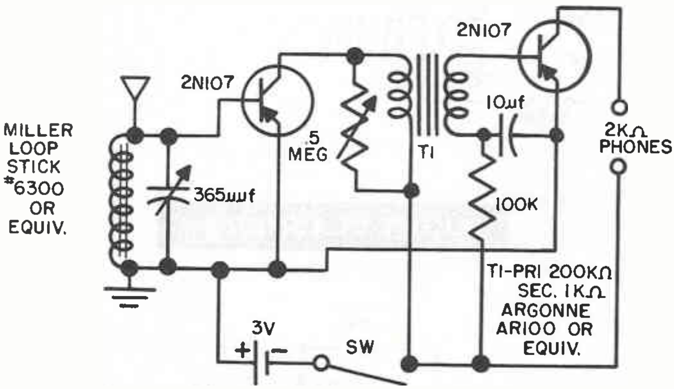
SIMPLE AUDIO AMPLIFIER



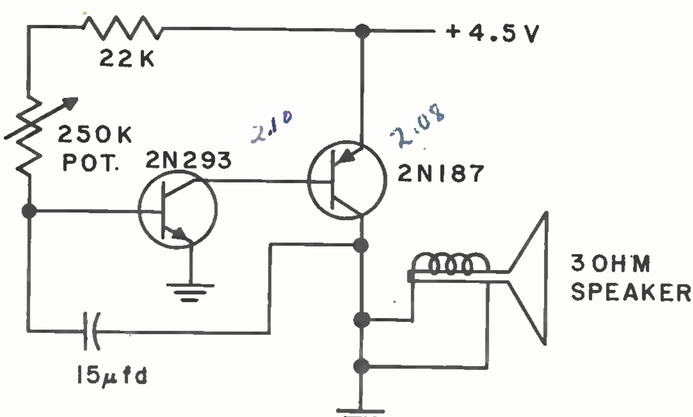
SIMPLE RADIO RECEIVER



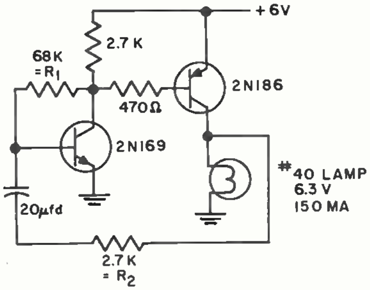
LOUDSPEAKER AUDIO AMPLIFIER



TWO TRANSISTOR RADIO RECEIVER

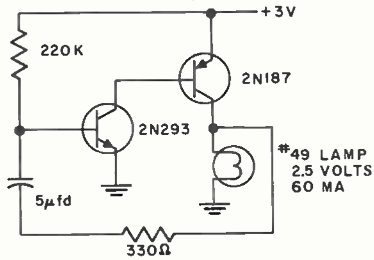


METRONOME



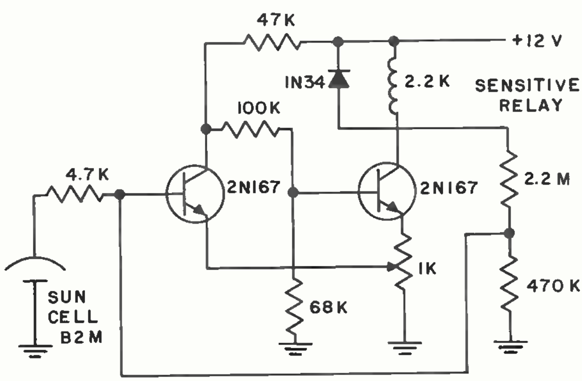
TYPICAL PERFORMANCE

- 60 FLASHES PER MINUTE
- LAMP ON 20% OF PERIOD
- FLASH RATE VARIED WITH R_1
- LAMP ON TIME VARIED WITH R_2
- IF LAMP STAYS ON REVERSE 2N169 IN SOCKET



- PERFORMANCE SIMILAR TO ABOVE EXCEPT THAT DESIGNED FOR SMALLER LAMP

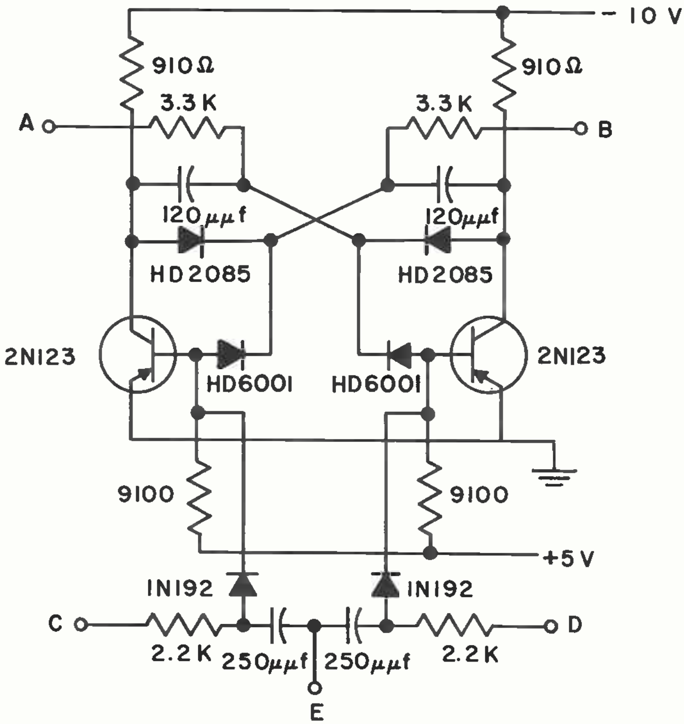
LIGHT FLASHERS

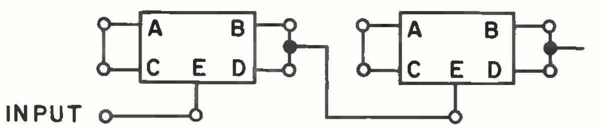


THE RELAY IS ENERGIZED WHEN A 100 WATT LAMP IS PLACED 5" FROM THE SUN CELL. THE VOLTAGE NEEDED AT THE SUN CELL TO OPERATE THE RELAY VARIES WITH TEMPERATURE AS FOLLOWS:

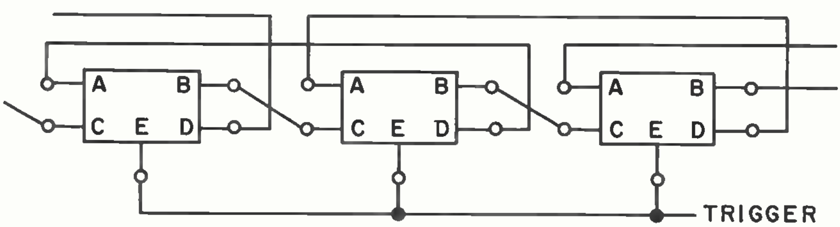
TEMPERATURE	VOLTAGE AT INPUT TO FLIP-FLOP	
	RELAY ENERGIZES	RELAY OPENS
23°C	0.14	0.17
40°C	0.09	0.13
60°C	0.04	0.09

SUN CELL TRIGGERED RELAY



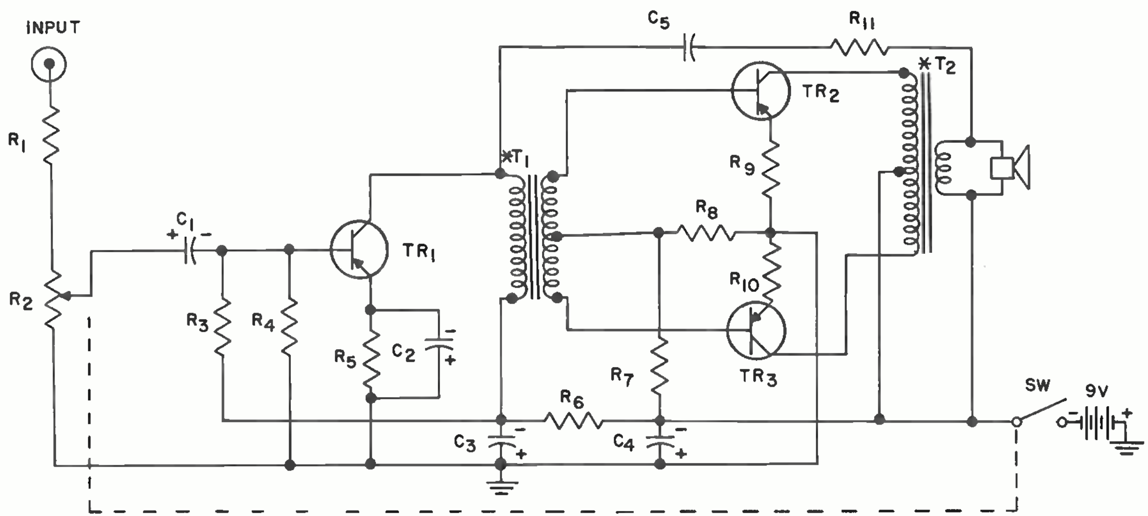


INTERCONNECTION AS COUNTER



INTERCONNECTION AS SHIFT REGISTER

500 KC COUNTER-SHIFT REGISTER FLIP-FLOP



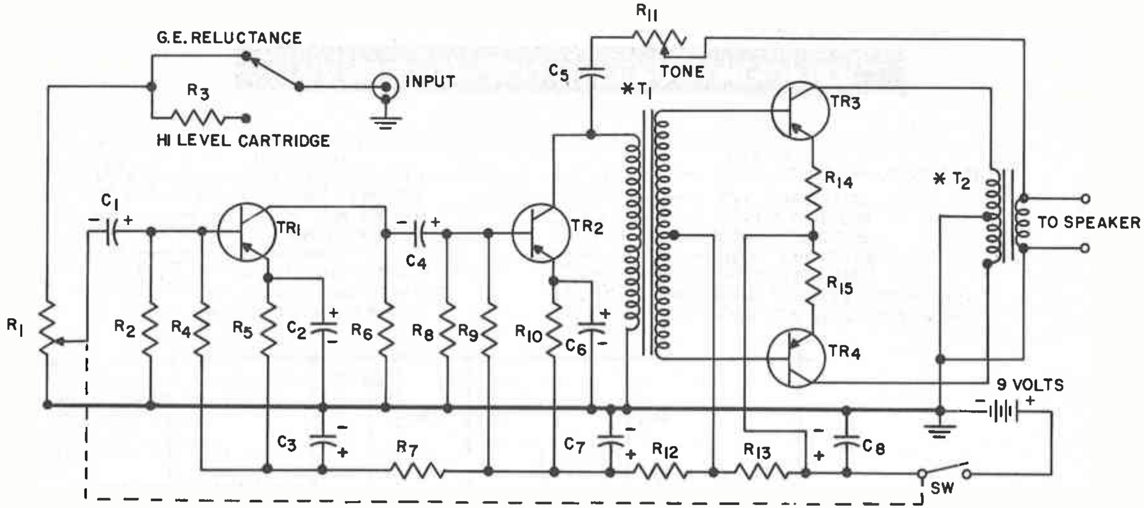
R_1,	220,000 OHM
R_2,	VOLUME CONTROL 10,000 OHM 1/2 W AUDIO TAPER
R_3,	68,000 OHM
R_4,	10,000 OHM
R_5,	470 OHM
R_6,	220 OHM
R_7,	1800 OHM
R_8,	33 OHM
R_9, R_{10},	8.2 OHM
R_{11}.	4.7K OHM

C_1	6μfd, 12V
C_2	100μfd, 3V
C_3, C_4,	50μfd, 12V
C_5,	.02μfd
TR_1,	G.E. 2N192 OR 2N265
TR_2, TR_3,	G.E. 2N241A
* T_1	6KΩ/5KΩ CT
* T_2	500Ω CT/ V.C.

MAXIMUM POWER OUTPUT : .35 WATTS
MAXIMUM POWER OUT AT 10% HARMONIC DISTORTION : .25 WATTS
SENSITIVITY FOR 50 MILLIWATTS REFERENCE POWER OUTPUT : .2 VOLTS
FOR USE WITH MAGNETIC CARTRIDGE OMIT R1, IN THIS CONDITION SENSITIVITY : 5 MILLIVOLTS

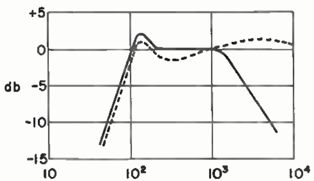
* FOR FURTHER INFORMATION SEE PAGES 109,110

THREE TRANSISTOR PHONO AMPLIFIER



FREQUENCY RESPONSE
OF FOUR TRANSISTOR AMPLIFIER

MAXIMUM BASS POSITION ————
MAXIMUM TREBLE POSITION ----------



AMPLIFIER LOADED WITH 3.2 Ω VOICE COIL SPEAKER RESONANCE @ 130 CPS

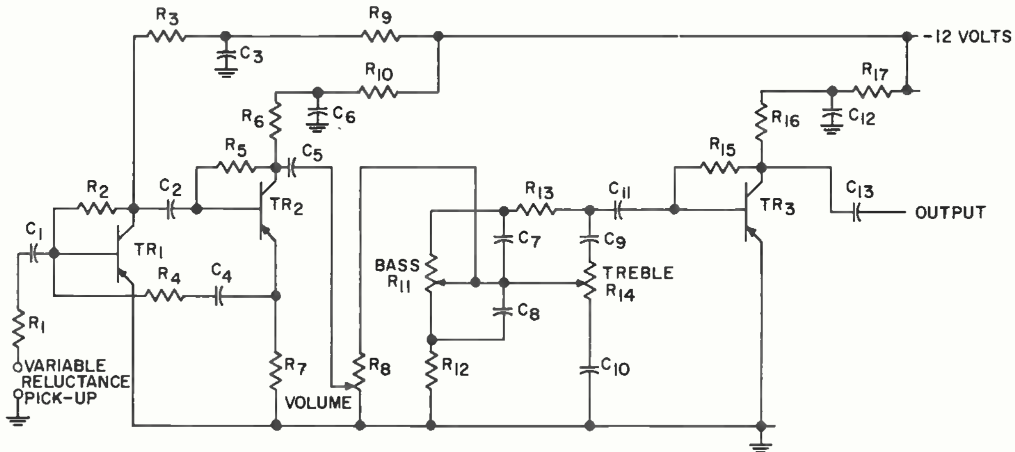
R_1,—5000 OHM VOLUMN CONTROL 1/2 W AUDIO TAPER
R_2,———150,000 OHM
R_3,———470,000 OHM
R_4,———10,000 OHM
R_6, R_9,—4700 OHM
R_7,———1000 OHM
R_8,———33,000 OHM
R_{11},———25,000 OHM
R_{12},———220 OHM
R_5, R_{10},—470 OHM

R_{13},—————47 OHM
R_{14}, R_{15},———8.2 OHM
C_1, C_3, C_7, C_8,—50μfd, 12V
C_2, C_6,———50μfd, 3V
C_4,—————15μfd, 12V
C_5,—————.02μfd
TR_1, TR_2,—G.E. 2N191 OR 2N323
TR_3, TR_4,—G.E. 2N188A OR 2N320
$*T_1$,—————4K/2.6K CT.
$*T_2$,—————200Ω C.T./V.C.

* FOR FURTHER INFORMATION SEE PAGES 109,110

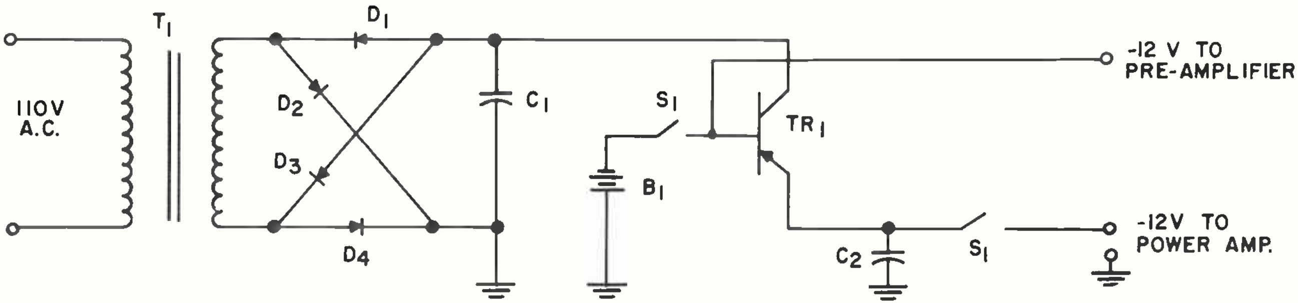
MAXIMUM POWER OUTPUT : .75 WATTS
MAXIMUM POWER OUT AT 10% HARMONIC DISTORTION : .45 WATTS
DISTORTION AT 100 MILLIWATTS
AT 100 C/S : 5%
AT 1000 C/S : 2%
AT 5000 C/S : 5%
SENSITIVITY FOR 50 MILLIWATTS REFERENCE POWER OUTPUT : CRYSTAL CARTRIDGE : 150 MV.
MAGNETIC PICK UP : 2 MV.

FOUR TRANSISTOR PHONO AMPLIFIER



R_1,	3900 OHM, 1/2 W. RES.	C_1, C_2, C_5, C_{11}, C_{13}	5μfd., 12 V. ELEC. CAPACITOR
R_2, R_5, R_{15}	220,000 OHM, 1/2 W. RES.	C_3, C_6, C_{12},	50μfd., 25V. ELEC. CAPACITOR
R_3, R_6, R_{16}	18,000 OHM, 1/2 W. RES.	C_4,	.05μfd., CAPACITOR
R_4,	4700 OHM,	C_7,	.02μfd., CAPACITOR
R_7,	220, OHM, 1/2 W. RES.	C_8,	.2μfd., CAPACITOR
R_8,	100,000 OHM, 2W. POT.	C_9,	.01μfd., CAPACITOR
R_9, R_{10}, R_{12}, R_{17}	1000 OHM, 1/2 W. RES.	C_{10},	.1μfd., CAPACITOR
R_{11}, R_{14}	50,000 OHM, 2W LINEAR TAPER POT.	TR_1, TR_2, TR_3	"P-N-P" JUNCTION TRANSISTOR (G.E. 2N190)
R_{13}	10,000 OHM, 1/2W. RES.		

TRANSISTORIZED HI-FI PREAMPLIFIER



TR_1 - POWER TRANSISTOR (MOUNT ON HEAT SINK) C.B.S. 2N256, 2N156 OR EQUIVALENT.

S_1 - D. P. S.T.

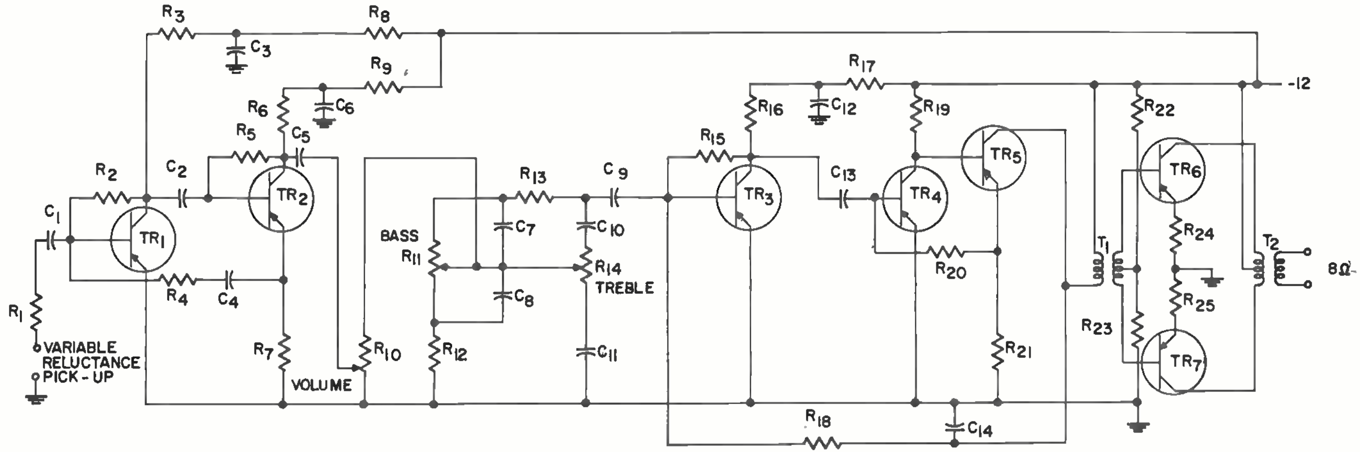
T_1 - STANCOR P-6469 117VAC TO 25.2 OR EQUIVALENT

D_1, D_2, D_3, D_4 - GENERAL ELECTRIC IN91 GERMANIUM RECTIFIERS

C_1, C_2 - 50 μfd, 50 VOLT

B_1 - 3, 4 VOLT MERCURY CELLS IN SERIES, MALLORY TR-233R OR EQUIVALENT

HI-FI AMPLIFIER REGULATED POWER SUPPLY



R_1 — 3900 OHMS
R_2, R_5, R_{15} — 220,000 OHMS
R_3, R_6, R_{16}, R_{19} — 18,000 OHMS
R_4, R_{22} — 4700 OHMS
R_7 — 220 OHMS
R_8, R_9, R_{12}, R_{17} — 1000 OHMS
R_{10} — 100,000 OHMS

R_{11}, R_{14} — 50,000 OHMS
R_{13} — 10,000 OHMS
R_{18} — 5,000,000 OHMS
R_{20} — 160,000 OHMS
R_{21} — 500 OHMS
R_{22} — 4700 OHMS
R_{23} — 30 OHMS

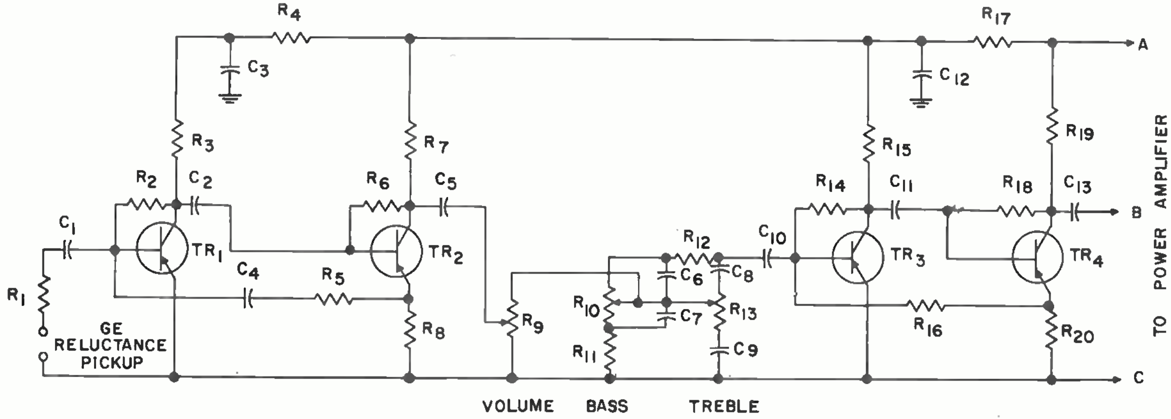
R_{24}, R_{25} — 8.2 OHMS
$C_1, C_2, C_5, C_9, C_{13}$ — 5 μf
C_3, C_6, C_{12} — 50 μf
C_4 — .05 μf
C_7 — .02 μf
C_8 — .2 μf

C_{10} — .008 μf
C_{11} — .08 μf
C_{14} — .0047 μf
$TR_1, TR_2, TR_3, TR_4, TR_5$ — P-N-P JUNCTION TRANSISTOR GE. 2N190 OR 2N322
TR_6, TR_7, 2N188A OR 2N320

T_1 NEW ENGLAND #2130 OR ARGONNE #AR500 5K:3K C.T.

T_2 NEW ENGLAND #2131 OR ARGONNE #AR501 125CT:8

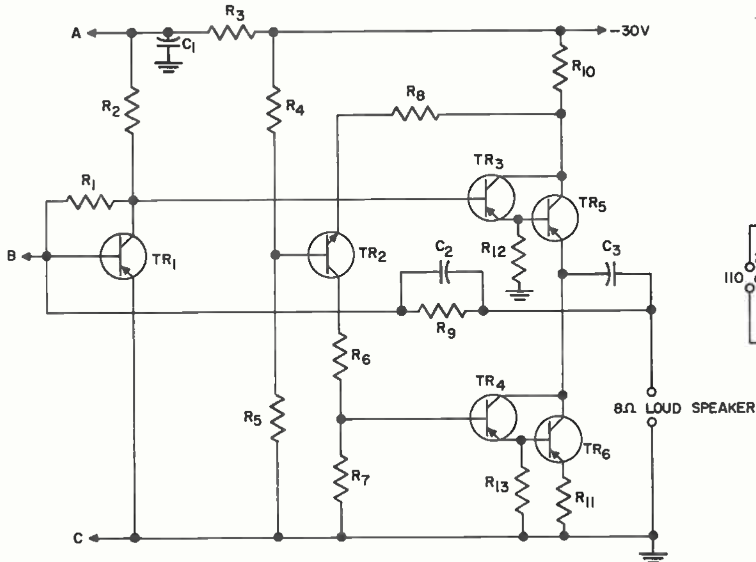
TRANSISTORIZED HI-FI AMPLIFIER

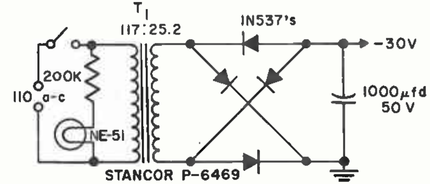


R_1	2700 OHM
R_2, R_6, R_{14}, R_{18}	150,000 OHM
R_3, R_{15}	15,000 OHM
R_4	2200 OHM
R_5	22,000 OHM
R_7	8200 OHM
R_8	220 OHM
R_9	VOLUME CONTROL 100,000 OHM 1/2 W AUDIO TAPER
R_{10}, R_{13}	50,000 OHM, LINEAR TAPER POT
R_{11}	1000 OHM
R_{12}, R_{19}	10,000 OHM
R_{16}	6800 OHM
R_{17}	1800 OHM
R_{20}	100 OHM
C_1, C_2, C_5, C_{10}, C_{11}, C_{13}	5 μfd
C_3, C_{12}	50 μfd
C_4	.015 μfd
C_6	.02 μfd
C_7	.2 μfd
C_8	.01 μfd
C_9	.1 μfd
TR_1, TR_2, TR_3, TR_4	GE 2N190

PRE-AMP AND DRIVER

POWER AMPLIFIER

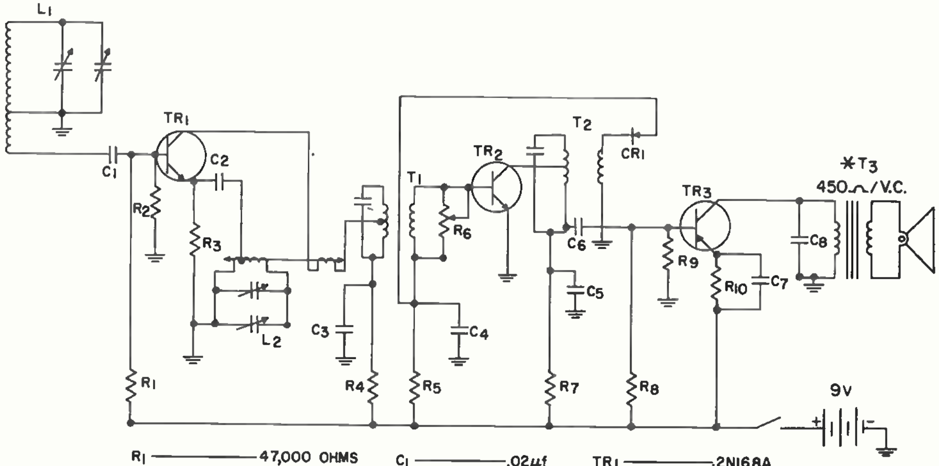




POWER SUPPLY

R_1	180,000 OHM	C_1	50μfd
R_2	4300 OHM	C_2	.001μfd
R_3	680 OHM	C_3	1000μfd
R_4	470 OHM	TR_1	G.E. 2N186A
R_5	15,000 OHM	TR_2	G.E. 2N169A
R_6	5600 OHM	TR_3, TR_4	G.E. 2N188A
R_7, R_{12}	1000 OHM	TR_5, TR_6	DELCO 2N174
R_8, R_{13}	220 OHM		
R_9	10,000 OHM		
R_{10}, R_{11}	1 OHM		

POWER AMPLIFIER



R1	47,000 OHMS
R2	10,000 OHMS
R3	1500 OHMS
R4	270 OHMS
R5	33,000 OHMS
R6	2,000 OHMS
R7	15,000 OHMS
R8	1000 OHMS
R9	4700 OHMS
R10	100 OHMS

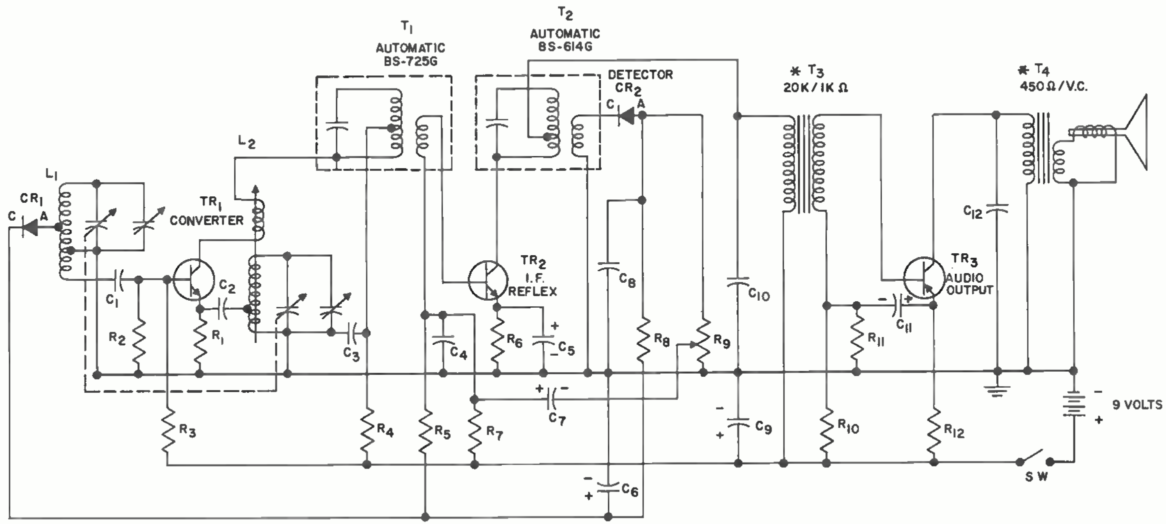
C1	.02 μf
C2	.01 μf
C3	.01 μf
C4	.01 μf
C5	.002 μf
C6	5 μf
C7	50 μf
C8	.05 μF

TR1	2N168A
TR2	2N169
TR3	2N241A
T1, T2,	AUTOMATIC 725

NOMINAL SENSITIVITY: 2.0 MILLIVOLTS/METER
(MEASURED WITH 5 MILLIWATTS REFERENCE POWER OUTPUT)
MAXIMUM POWER OUTPUT: 75 MILLIWATTS
SELECTIVITY AT -6 db: 10 KC/S
SELECTIVITY AT -60 db: 120 KC/S
TOTAL BATTERY DRAIN: 19 MILLIAMPS

*FOR FURTHER INFORMATION SEE PAGES 109, 110

THREE TRANSISTOR REFLEX RECEIVER



R1, —— 1500 OHM
R2, R5, R8, —— 10,000 OHM
R3, —— 47,000 OHM
R4, —— 270 OHM
R6, —— 330 OHM
R7, —— 330,000 OHM
R9, —— VOLUME CONTROL
10,000 OHM 1/2W AUDIO TAPER
R10, —— 1000 OHM
R11, —— 4700 OHM
R12 —— 100 OHM

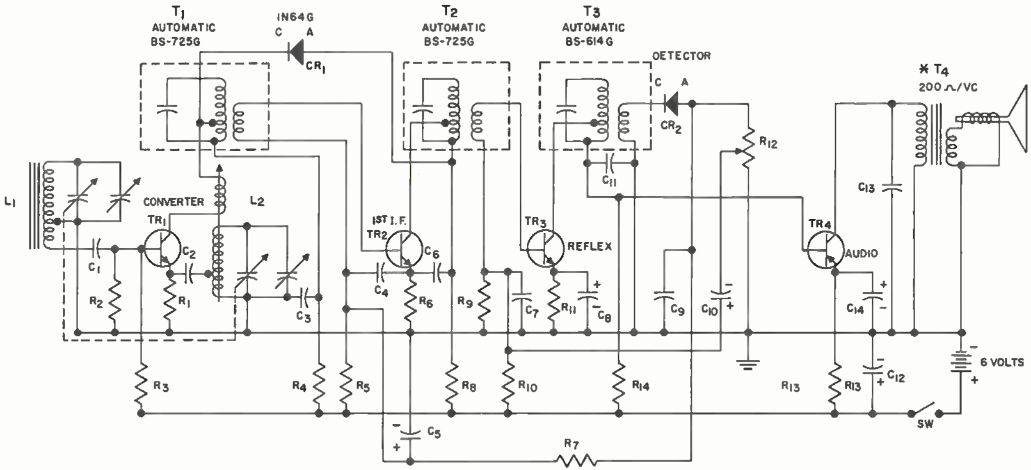
C1, C4, C8, —— .02 μfd
C2, C3, —— .01 μfd
C5, C11, —— 50 μfd, 3V
C6, —— 15 μfd, 12V
C7, —— 6 μfd, 6V
C9, —— 50 μfd, 12V
C10, —— .002 μfd,
C12, —— 0.1 μfd
TR1, —— G.E. 2N168A OR 2N164A CONVERTER
TR2, —— G.E. 2N168A OR 2N164A REFLEX
TR3, —— G.E. 2N241A OR 2N321 AUDIO

L1, —— 435 μh ± 10%
L2, —— 250 μh ± 10%
CR1, CR2, —— 1N64G
ΔC1 —— 190.6 }
ΔC2 —— 89.3 } R/C MODEL 242

NOMINAL SENSITIVITY: 600 MICROVOLTS/METER
(MEASURED WITH 5 MILLIWATTS REFERENCE POWER OUTPUT)
MAXIMUM POWER OUTPUT: 75 MILLIWATTS
SELECTIVITY AT -6db : 10 KC/S
SELECTIVITY AT -60db : 120 KC/S
TOTAL BATTERY DRAIN : 17.5 MILLIAMPS

* FOR FURTHER INFORMATION SEE PAGES 109, 110

THREE TRANSISTOR REFLEX RECEIVER



R1, —— 1500 OHM
R2, R9, —— 10,000 OHM
R3, —— 15,000 OHM
R4, —— 270 OHM
R5, —— 56,000 OHM
R6, —— 330 OHM
R7, —— 3300 OHM
R8, —— 1800 OHM
R10, —— 68,000 OHM
R11, —— 470 OHM
R12, —— VOLUME CONTROL
10,000 OHM ½ W AUDIO TAPER
R13, —— 39 OHM
R14, —— 1000 OHM

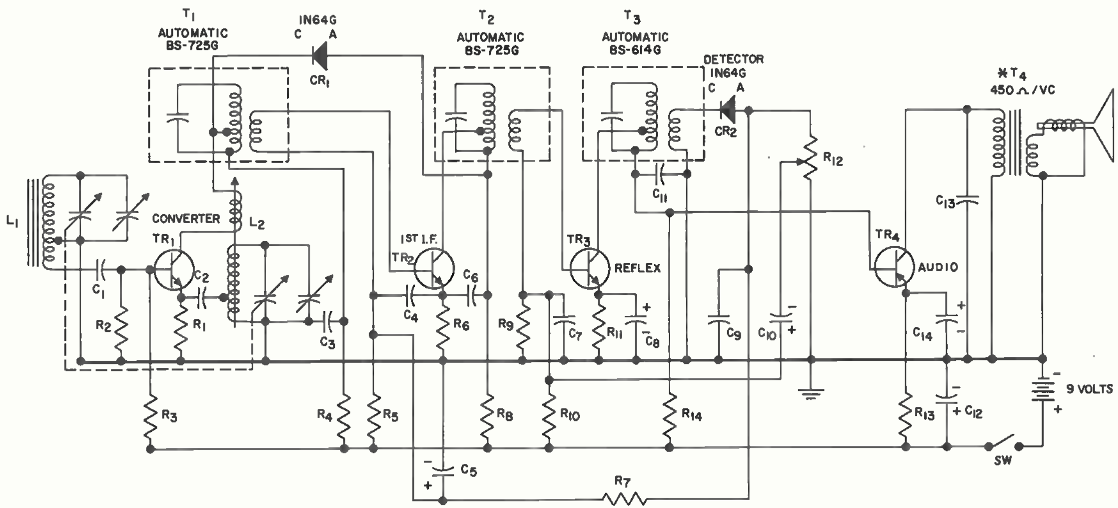
C1, C11, —— .02 μfd
C2, C3, C7, —— .01 μfd
C4, C6, C9, —— .05 μfd
C5, —— 15 μfd, 12 V
C8, —— 50 μfd, 3 V
C10, —— 6 μfd, 12 V
C12, —— 50 μfd, 12 V
C13, —— 0.1 μfd
C14, —— 100 μfd, 12 V
TR1 —— 2N168A OR 2N164A CONVERTER
TR2 —— 2N292 OR 2N313 1ST. I.F.
TR3 —— 2N169 OR 2N165 REFLEX
TR4 —— 2N241A OR 2N321 AUDIO

L1, —— 435 μh ± 10%
L2, —— 250 μh ± 10%
CR1, CR2, —— IN64G
ΔC —— 190.6 } R/C MODEL 242
ΔC —— 89.3 }

NOMINAL SENSITIVITY: 150 MICROVOLTS/METER
(MEASURED WITH 5 MILLIWATTS REFERENCE POWER OUTPUT)
MAXIMUM POWER OUTPUT: 75 MILLIWATTS
SELECTIVITY AT -6db : 8.0 KC/S
SELECTIVITY AT -60db : 65.0 KC/S
TOTAL BATTERY DRAIN : 25.0 MILLIAMPS

* FOR FURTHER INFORMATION SEE PAGES 109, 110

6 VOLT FOUR TRANSISTOR REFLEX RECEIVER



R_1, R_{14} — 1500 OHM
R_2, R_9 — 10,000 OHM
R_3 — 27,000 OHM
R_4, R_{11} — 470 OHM
R_5 — 120,000 OHM
R_6 — 330 OHM
R_7 — 3300 OHM
R_8 — 1800 OHM
R_{10} — 91,000 OHM
R_{12} — VOLUME CONTROL 10,000 OHM AUDIO TAPER
R_{13} — 100 OHM

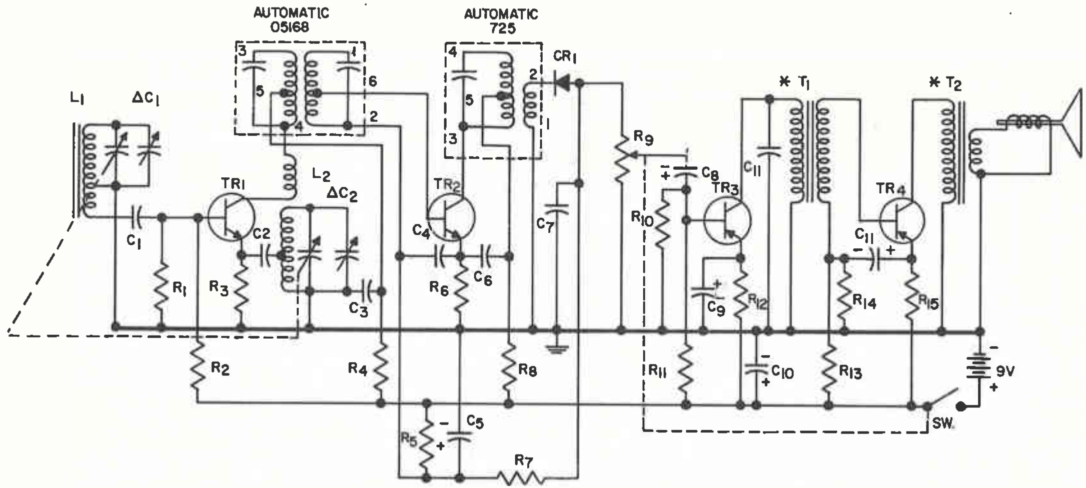
C_1, C_{11} — .02 μfd
C_2, C_3, C_7 — .01 μfd
C_4, C_6, C_9, C_{13} — .05 μfd
C_5 — 15 μfd, 12V
C_8 — 50 μfd, 3V
C_{10} — 6 μfd, 12V
C_{12} — 50 μfd, 12V
C_{14} — 100 μfd, 12V
TR_1 — 2N168A OR 2N164A CONVERTER
TR_2 — 2N292 OR 2N313 1ST. I.F.
TR_3 — 2N169 OR 2N165 REFLEX
TR_4 — 2N188A OR 2N320 AUDIO

L_1 — 435 μh ± 10%
L_2 — 250 μh ± 10%
CR_1, CR_2 — IN64G
ΔC_1 — 190.6 }
ΔC_2 — 89.3 } R/C MODEL 242

NOMINAL SENSITIVITY: 200 MICROVOLTS/METER
(MEASURED WITH 5 MILLIWATTS REFERENCE POWER OUTPUT)
MAXIMUM POWER OUTPUT: 75 MILLIWATTS
SELECTIVITY AT -6db : 8.0 KC/S
SELECTIVITY AT -60db : 60.0 KC/S
TOTAL BATTERY DRAIN : 17.0 MILLIAMPS

* FOR FURTHER INFORMATION SEE PAGES 109,110

9 VOLT FOUR TRANSISTOR REFLEX RECEIVER



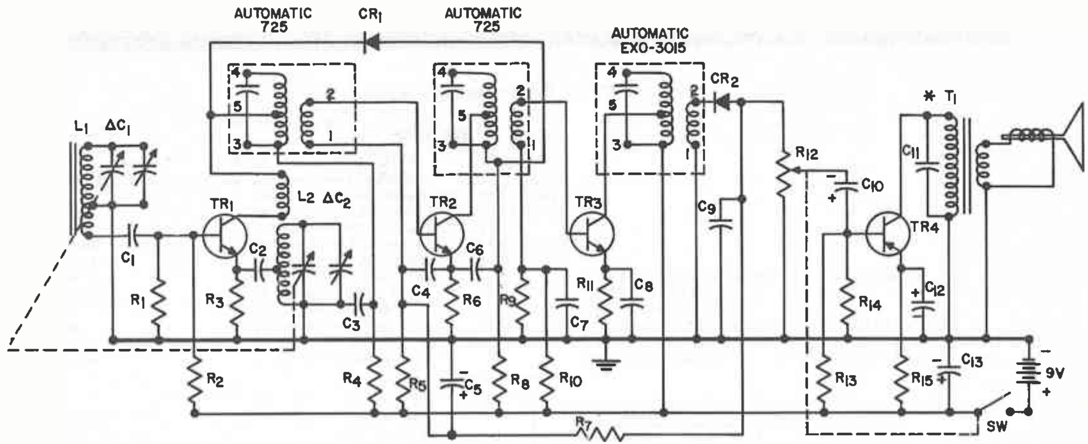
R_1, R_{11}, — 10,000 OHM
R_2, — 27,000 OHM
R_3, — 1500 OHM
R_4, R_8, — 470 OHM
R_5, — 120,000 OHM
R_6, — 330 OHM
R_7, — 12,000 OHM
R_{10}, — 47,000 OHM
R_{12}, R_{13}, — 1000 OHM
R_{14}, — 5600 OHM
R_{15}, — 68 OHM
R_9, — VOLUME CONTROL 10,000 Ω 1/2W AUDIO TAPER
* L_1, — 435 μh ±10%
* L_2, — 250 μh ±10%

C_1, C_4, C_6, — .05μfd
C_2, C_3, — .01μfd
C_5, — 15μfd, 12V
C_7, C_{11}, — .02μfd,
C_8, — 6μfd, 12V
C_9, C_{10}, C_{12}, — 50μfd, 12V
CR_1, — DR117, IN64G, OR CK706A
TR_1 — G.E. 2N168A OR 2N164A CONVERTER
TR_2 — G.E. 2N293 OR 2N314 I.F.
TR_3 — G.E. 2N192 OR 2N324 DRIVER
TR_4 — G.E. 2N241A OR 2N321 AUDIO
* T_1 — 20KΩ/600Ω
* T_2 — 500 Ω/V.C.
* ΔC_1, — 190.6 } R/C MODEL 242
* ΔC_2, — 89 3 }

NOMINAL SENSITIVITY : 300 MICROVOLTS / METER
(MEASURED WITH 5 MILLIWATTS REFERENCE POWER OUTPUT)
MAXIMUM POWER OUTPUT : 75 MILLIWATTS
SELECTIVITY AT -6 db : 8.0 KC/S
SELECTIVITY AT -60db : 65.0 KC/S
TOTAL BATTERY DRAIN : 18.0 MILLIAMPS

* FOR FURTHER INFORMATION SEE PAGES 109,110·

FOUR TRANSISTOR SUPERHETERODYNE BROADCAST RECEIVER



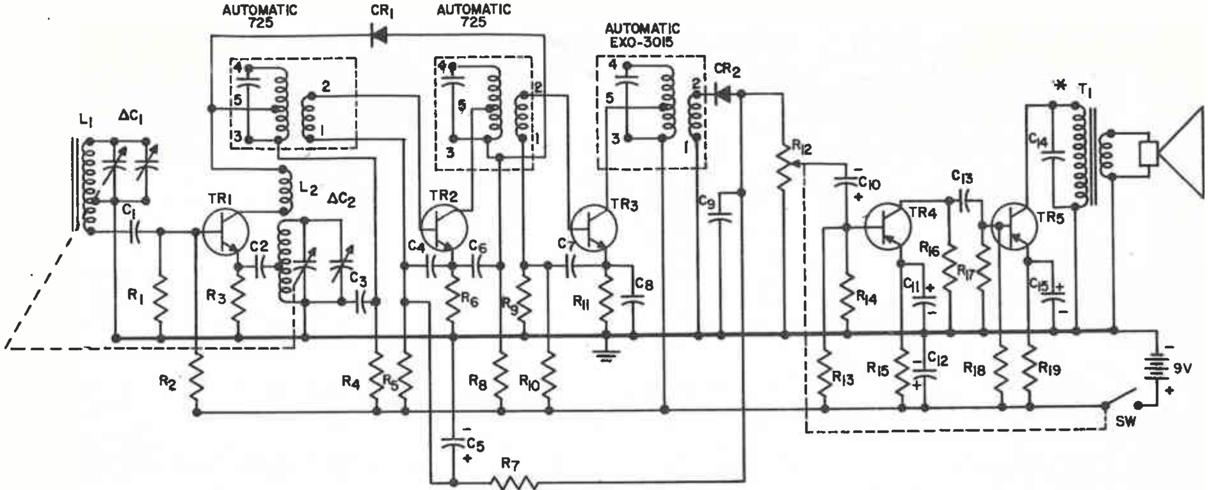
R_1, R_7, R_9,—10,000 OHM
R_{12},—VOLUME CONTROL 10,000 OHM 1/2W AUDIO TAPER
R_2,—27,000 OHM
R_3,—1500 OHM
R_4, R_{11},—470 OHM
R_5,—39,000 OHM
R_6,—330 OHM
R_8,—1800 OHM
R_{10},—68,000 OHM
R_{13},—1000 OHM
* R_{14},—5600 OHM
* R_{15},—68 OHM
* T_1,—500Ω/V.C.
* ΔC_1,—190.6 } R/C MODEL 242
* ΔC_2,—89.3 }

C_1.—.02μfd
C_2, C_3,—.01μfd
C_4, C_6, C_7, C_8, C_9,—.05μfd
C_5,—15μfd, 12V
C_{10},—6μfd, 12V
C_{11},—.1μfd
C_{12},—100μfd, 12V
C_{13},—50μfd, 12V
TR_1,—G.E. 2N168A OR 2N164A CONVERTER
TR_2, TR_3,—G.E. 2N293 OR 2N314 1ST & 2ND I.F.
TR_4,—G.E. 2N241A OR 2N321 AUDIO
* L_1,—435μh, ±10%
* L_2,—250μh, ±10%
CR_1, CR_2,—DR117, IN64G, OR CK706A

NOMINAL SENSITIVITY : 500 MICROVOLTS / METER
(MEASURED WITH 5 MILLIWATTS REFERENCE POWER OUTPUT)
MAXIMUM POWER OUTPUT : 75 MILLIWATTS
SELECTIVITY AT -6db : 8.0 KC/S
SELECTIVITY AT -60db : 65.0 KC/S
TOTAL BATTERY DRAIN : 20.0 MILLIAMPS.

* FOR FURTHER INFORMATION SEE PAGES 109,110

FOUR TRANSISTOR SUPERHETERODYNE BROADCAST RECEIVER



R1, R9, — 10,000 OHM
R2, — 27,000 OHM
R3, — 1500 OHM
R4, R11, R15, — 470 OHM
R5, — 68,000 OHM
R6, — 330 OHM
R7, — 2700 OHM
R8, R16, — 3300 OHM
R10, — 82,000 OHM
R12, — VOLUME CONTROL 10,000 OHM 1/2W AUDIO TAPER
R13, — 4700 OHM
R14, — 56,000 OHM
R17, — 5600 OHM
R18, — 1000 OHM
R19, — 68 OHM

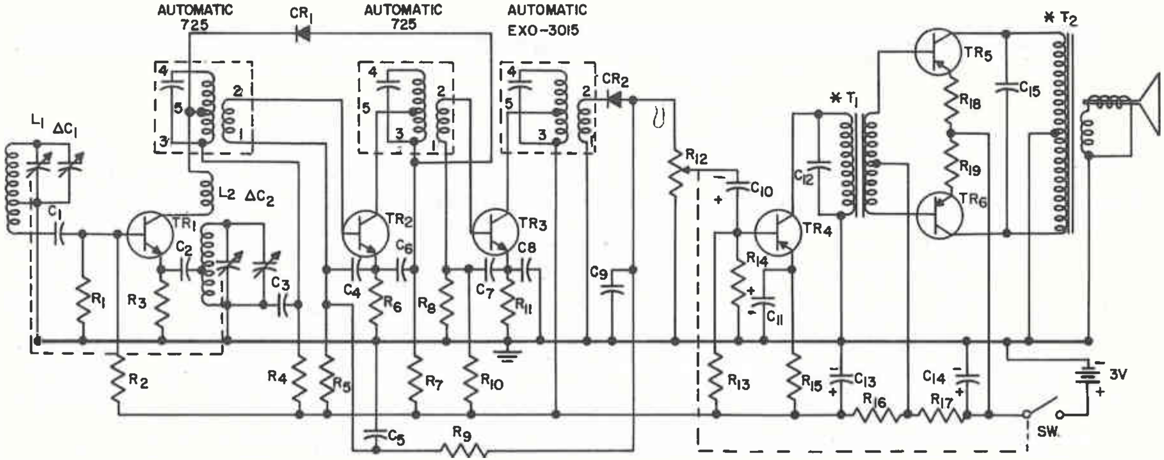
C1, — .02 µfd
C2, C3, — .01 µfd
C4, C6, C7, C8, C9, C14, — .05 µfd
C5, — 15 µfd, 12V
C10, C13, — 6 µfd
C11, C15, — 100 µfd, 12V
C12, — 50 µfd, 12V
TR1, — G.E. 2N168A OR 2N164A CONVERTER
TR2, — G.E. 2N293 OR 2N314 1ST. I.F.
TR3, — G.E. 2N169 OR 2N165 2ND. I.F.
TR4, — G.E. 2N265 DRIVER
TR5, — G.E. 2N188A OR 2N320 OUTPUT
* T1, — 500 Ω/VC
L1, — 435 µh ± 10%
L2, — 250 µh ± 10%
CR1, CR2, — DR117, IN64G OR CK706A

ΔC1, — 190.6 } R/C MODEL 242
ΔC2, — 89.3

NOMINAL SENSITIVITY : 150 MICROVOLTS/ METER
(MEASURED WITH 5 MILLIWATTS REFERENCE POWER OUTPUT)
MAXIMUM POWER OUTPUT : 75 MILLIWATTS.
SELECTIVITY AT -6db : 8.0 KC/S.
SELECTIVITY AT -60db: 65.0 KC/ S.
TOTAL BATTERY DRAIN: 18.0 MILLIAMPS.

*FOR FURTHER INFORMATION SEE PAGES 109, 110

FIVE TRANSISTOR SUPERHETERODYNE BROADCAST RECEIVER



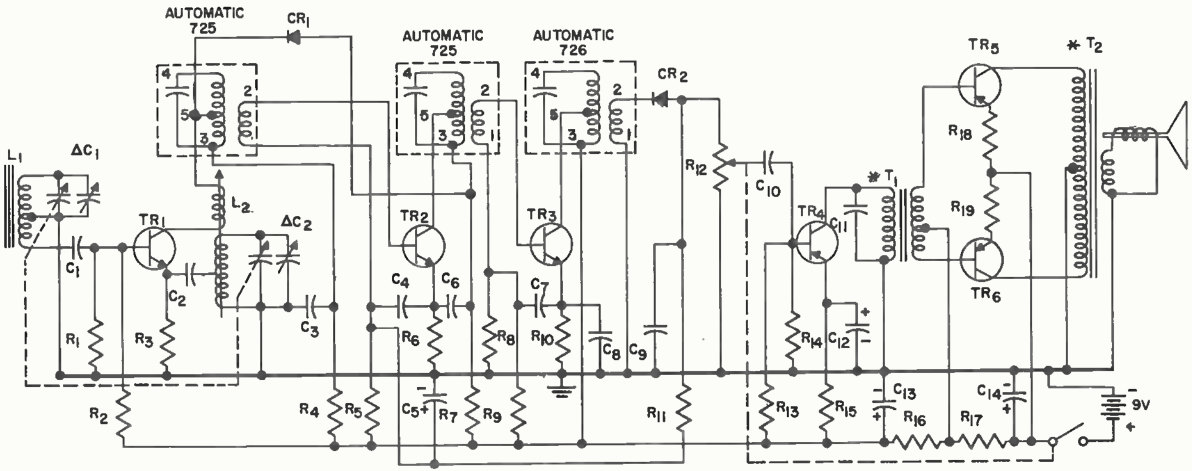
R1, R8, ——— 10,000 OHM
R2, ——— 33,000 OHM
R3, R11, ——— 470 OHM
R4, ——— 270 OHM
R5, ——— 12,000 OHM
R6, ——— 330 OHM
R7, ——— 1500 OHM
R9, ——— 2700 OHM
R10, ——— 18,000 OHM
R13, ——— 4700 OHM
R14, ——— 15,000 OHM
R15, ——— 390 OHM
R16, ——— 100 OHM
R17, ——— 39 OHM
R18, R19, ——— 5.0 OHM
R12, — VOLUME CONTROL 10,000 OHM 1/2 W AUDIO TAPER

C1, ——— .02 μfd
C2, C3, ——— .01 μfd
C4, C6, C7, C8, C9, — .05 μfd
C5, C10, ——— 6 μfd, 6V
C11, C13, C14, — 50 μfd, 6V
C15, ——— 0.1 μfd
TR1 ——— G.E. 2N168A OR 2N164A CONVERTER
TR2 ——— G.E. 2N293 OR 2N314 1ST I. F.
TR3 ——— G.E. 2N169 OR 2N165 2ND I. F.
TR4 ——— G.E. 2N192 OR 2N324 DRIVER
TR5, TR6, — G.E. 2N188 AUDIO
* T1 ——— 2600/2600 Ω CT.
* T2 ——— 300 Ω CT/V.C.
* L1, ——— 435 μh ± 10%
* L2, ——— 250 μh ± 10%
CR1, CR2, — DR117, IN64G, OR CK706A
* ΔC1, ——— 190.6 } R/C MODEL 242
* ΔC2, ——— 89.3 }

NOMINAL SENSITIVITY: 250 MICROVOLTS / METER
(MEASURED WITH 5 MW REFERENCE POWER OUTPUT)
MAXIMUM POWER OUTPUT: 100 MILLIWATTS.
SELECTIVITY AT -6db : 8.0 KC/S
SELECTIVITY AT -60db : 65.0 KC/S
ZERO SIGNAL BATTERY DRAIN : 7.0 MILLIAMPS.

* FOR FURTHER INFORMATION SEE PAGES 109, 110

THREE VOLT BROADCAST RECEIVER
CAN BE POWERED BY SUN OR FLASHLIGHT BATTERIES



R1, R8, —— 10,000 OHM
R2, —— 27,000 OHM
R3, —— 1500 OHM
R4, R10, R15, — 470 OHM
R5, —— 68,000 OHM
R6, —— 330 OHM
R7, —— 3300 OHM
R9, —— 82,000 OHM
R11, —— 2700 OHM
R12, —— VOLUME CONTROL 10,000 OHM 1/2W AUDIO TAPER
R13, —— 4700 OHM
R14, —— 56,000 OHM
R16, —— 220 OHM
R17, —— 33 OHM

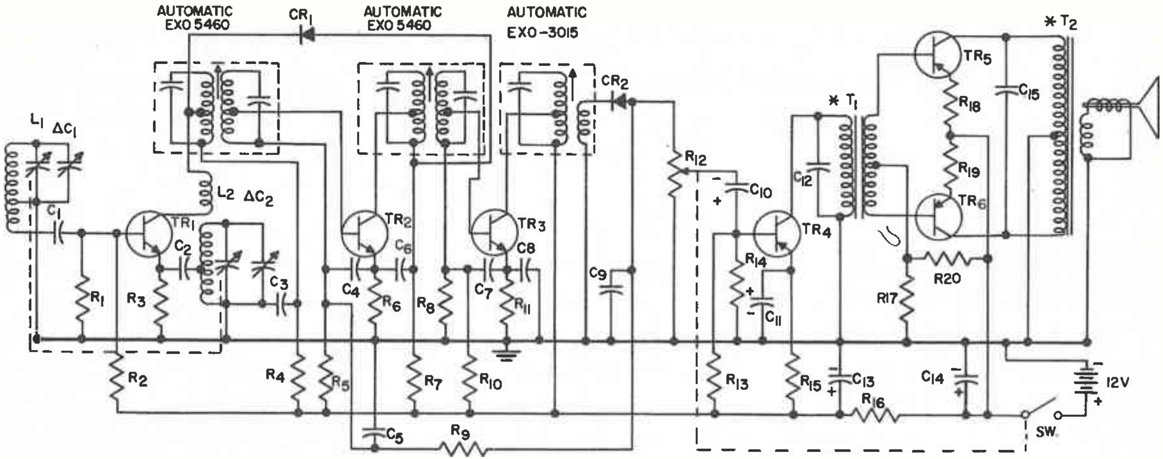
R18, R19, —— 8.2 OHM
C1, —— 0.2 μfd
C2, C3, —— .01 μfd
C4, C6, C7, C8, — .05 μfd
C5, C10, —— 6 μfd, 12V
C9, —— .05 μfd
C11, —— .003 μfd
C12, C13, C14, — 50 μfd, 12V
TR1, —— G.E. 2N168A OR 2N164A CONVERTER
TR2, —— G.E. 2N293 OR 2N314 1ST. I.F.
TR3, —— G.E. 2N169 OR 2N165 2ND. I.F.
TR4, —— G.E. 2N192 OR 2N324 DRIVER
TR5, TR6, — G.E. 2N188A OR 2N320 AUDIO
* T1, —— 5,000 / 2600Ω CT
* T2, —— 250Ω CT/V.C.

* L1 —— 435 μh ±10%
* L2 —— 250 μh ±10%
CR1, CR2, — DR117, 1N64G, OR CK706A
* ΔC1, — 190.6 } R/C MODEL 242
* ΔC2 — 89.3 }

NOMINAL SENSITIVITY = 200 MICROVOLTS / METER
(MEASURED WITH 50 MILLIWATTS REFERENCE POWER OUTPUT)
MAXIMUM POWER OUTPUT .6 WATTS.
SELECTIVITY AT -6db : 8.0 KC/S
SELECTIVITY AT -60db : 60.0 KC/S
ZERO SIGNAL BATTERY DRAIN 7.0 MILLIAMPS.

* FOR FURTHER INFORMATION SEE PAGES 109,110

SIX TRANSISTOR SUPERHETERODYNE BROADCAST RECEIVER



R_1, R_{11}, ——— 6800 OHM
R_2, ——— 33,000 OHM
R_3, ——— 1500 OHM
R_4, R_{10}, R_{15}, — 470 OHM
R_5, ——— 100,000 OHM
R_6, ——— 330 OHM
R_7, R_{13}, ——— 4700 OHM
R_8, ——— 2200 OHM
R_9, ——— 27,000 OHM
R_{12}, ——— VOLUME CONTROL
10,000 OHM 1/2W AUDIO TAPER
R_{14}, ——— 15,000 OHM
R_{16}, ——— 220 OHM
R_{17}, ——— 2700 OHM
R_{18}, R_{19}, ——— 10 OHM
R_{20}, ——— 33 OHM

C_1, ——— .02 μfd
C_2, C_3, ——— .01 μfd
C_4, C_6, C_7, C_8, — .1 μfd
C_5, ——— 6 μfd, 12V
C_9, ——— .05 μfd
C_{10}, ——— 6 μfd, 6V
C_{11}, ——— .003 μfd
C_{12}, C_{13}, C_{14}, — 50 μfd, 12V
TR_1, ——— G.E. 2N168A OR 2N164A CONVERTER
TR_2, ——— G.E. 2N168 1ST. I.F.
TR_3, ——— G.E. 2N169 OR 2N165 2ND. I.F.
TR_4, ——— G.E. 2N192 OR 2N324 DRIVE
TR_5, TR_6, ——— G.E. 2N188A OR 2N320 AUDIO 1&2
* T_1, ——— 2000/2600 CT.
* T_2, ——— 200Ω CT/VC

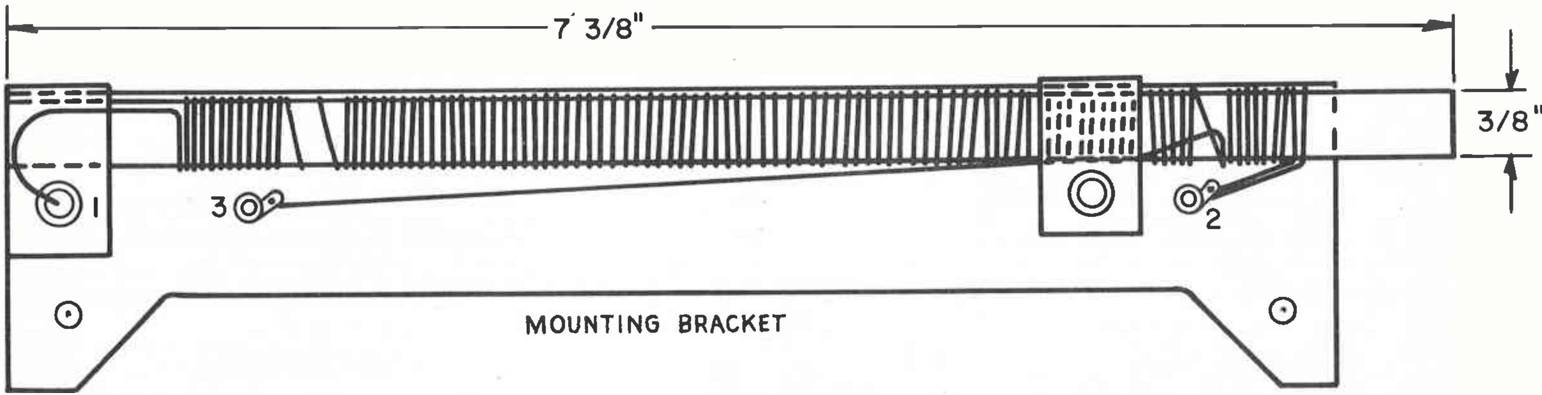
L_1, ——— 435 μh ± 10%
L_2, ——— 250 μh ± 10%
ΔC_1, — 190.6 } R/C MODEL
ΔC_2, — 89.3 }

NOMINAL SENSITIVITY: 150 MICROVOLTS/METER (MEASURED WITH 50 MILLIWATTS REFERENCE POWER OUTPUT)
MAXIMUM POWER OUTPUT: 1 WATT
SELECTIVITY AT -6db: 8.0 KC/S
SELECTIVITY AT -60db: 38.0 KC/S
ZERO SIGNAL BATTERY DRAIN: 10 MILLIAMPS

* FOR FURTHER INFORMATION SEE PAGES 109, 110

SIX TRANSISTOR, 1 WATT RECEIVER

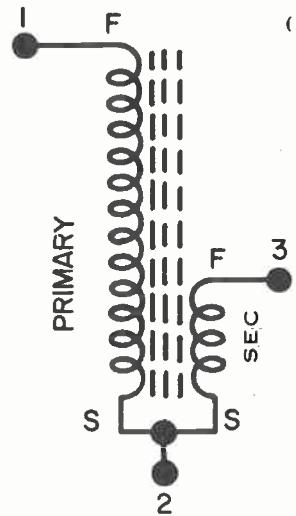
FERRITE ROD ANTENNA



(ACTUAL SIZE)

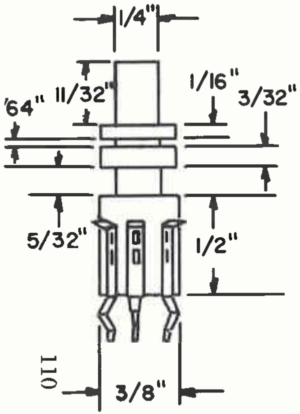
SPECIFICATIONS:

1. Core Material To Be Ferramic Q or Approved Equivalent
2. Winding Direction Clockwise When Viewed From Start Of Prim.
3. Secondary 6 Turns bifilar wound
4. Distributed Capacity To Be 5 mmfd Maximum
5. Primary Inductance 435 μhenries approximately
6. Unloaded Q of Primary 200 Min. When Measured At 790 KC/S
7. Ferrite Rod, Winding And Assembly Shall Be Wax Impregnated
8. Assembly Shall Be Flash Dipped

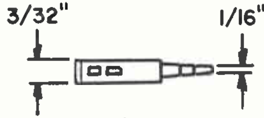


OSCILLATOR COIL

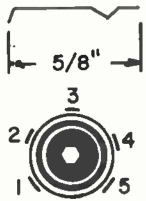
ED STANWYCK COIL COMPANY #1265 OR EQUIVALENT

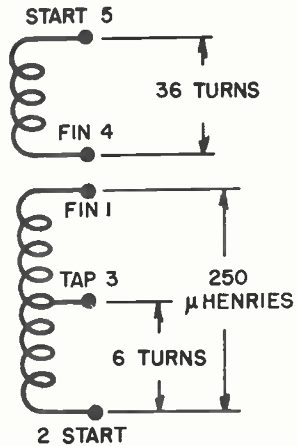


COIL DIMENSIONS



LUG DETAIL





INDEX DETAIL

SPECIFICATIONS:

1. Wire To Be #5/44 Heavy Easysol Bonded
2. Inductance of Primary To Be 250 μh Nom.
3. Core Adjustment Range ±10%
4. Distributed Capacity To Be 7 mmfd Maximum
5. Q at 790 KC/S To Be 100 ±10%
6. Primary To Be Tapped At 6 Turns
7. Secondary Winding To Be 36 Turns ± 1 Turn
8. Coil To Be Wax Impregnated & Flash Dipped
9. Coil Form To Be Cosmolite Or Appr. Equiv.
10. Collar To Be Cemented Securely To Form
11. All Materials To Be Acid Free

VARIABLE CONDENSER

RADIO CONDENSER COMPANY. MODEL 242 OR EQUIVALENT

Δ $C_{RF} = 190.6$ $C_{min.} = 7.6$

Δ $C_{OSC} = 89.3$ $C_{min.} = 6.8$

TRANSFORMERS

The audio transformers used in these designs were wound on laminations of 1⅝" by 1⅜" and a ½" stack size, and having an electrical efficiency of about 80%. Smaller or less efficient transformers will degrade the electrical fidelity of the circuits.

TRANSISTOR RADIOS

WITH ORIGINAL TRANSISTOR COMPLEMENTS*

(Closest GE Replacement Transistors Shown on second line of each listing)

MANUFACTURER & MODEL	V BATT	OSC	CONVERTER	IF	IF	DET	AF	AF	POWER	
Bulova 260	9V		2N172	2N146	2N146		310		2N185 (2)	
Bulova 270C	9V		CK766 GE 2N136	2N112A 2N135		1N295 1N64	2N132 2N192		2N138A 2N241A	
Bulova 270/277	9V		2N112 GE 2N136	2N112 2N135		CK706A 1N64	2N132 2N192		2N138 (2) 2N192 (2)	
CBS TR 250	21V/12V		GE 2N136	2N135	2N135	4JD1A26			2N44	
CBS TR 260	9V		2N172 GE 2N169	2N146 2N169	2N146 2N169	1N60 1N64	310 2N192		2N189 (2) or 352 2N189 (2) or 352	Note 2 Note 1
Dewald K 701 & 702	9V		2N112 GE 2N136	2N112 2N135	2N112 2N135	1N295 1N64	2N109 2N192		2N109 (2) 2N188 (2)	
Dumont 1210	9V		2N168A GE 2N168A	2N168 2N293	2N168 2N293	Diode 1N64	CK882 2N192		CK888 (2) 2N188 (2)	Note 3
Emerson 842	4V		830 GE 2N169	2N146 2N169	2N146 2N169	Diode 1N64	310 2N192		353 (2) 2N188 (2)	Note 2 Note 1
Emerson 844 and 847	9V		2N172 GE 2N169	2N146 2N169	2N146 2N169	1N195 1N64	2N109 2N192		2N185 (2) 2N188A (2)	
Emerson 855	9V		2N172 GE 2N169	2N146 2N169	2N146 2N169	1N195 1N64	2N109 2N192		2N109 (2) 2N188 (2)	Note 2
Firestone 4-C-34	9V	2N211 GE 2N135	2N212 2N293	2N94 2N169	2N94 2N169	1N64 1N64	2N35 2N169		2N214 (NPN) (2) 2N188 (PNP) (2)	
GE 675 Ebony, 676 Ivory	13½V		Early Prod 2N136	2N137	2N135	2N78			2N44	Note 4
677 Red, 678 Aqua	13½V		Late Prod 2N135	2N135	2N135	1N64	2N169		2N44	Note 5
GE 710	6V		GE 2N168A	2N292	2N169	1N64	Reflex		2N188A	
GE P715, Beige, P716 Black	3V		GE 2N168A	2N169	2N169	1N64	2N192		2N241 (2)	
GE P720 Ginger, P721 Champagne	6V		GE 2N168A	2N293	2N169	1N64	2N191		2N188A (2)	
GE 725	6V		GE 2N168A	2N293	2N169	1N64	2N192		2N188A (2)	
Hallicrafters TR 88 El Diablo	6V		2N112 GE 2N136	2N112 or 2N135	2N139 2N135	None None	2N109 or 310 2N192		2N109 (2) or 352 (2) 2N188 (2)	
Motorola 76T1	9V		2N140 GE 2N136	2N139 2N135	2N139 2N135	1N60 1N64	2N109 2N192	2N109 2N192	2N109 (2) 2N188 (2)	
Motorola 56 T1	9V		2N172 GE 2N169	2N146 2N169	2N146 2N169	R35 2N191			354 2N188	Note 2 Note 1
Motorola 6X31	6V		GE 2N168A	2N293	2N292	Diode	2N189 or 2N190;		2N186 or 2N187	
Motorola 6X32	6V		GE 2N168A	2N293	2N169	Diode	2N191 or 2N192;		2N188 or 2N241	

(Closest GE Replacement Transistors Shown on second line of each listing)

MANUFACTURER & MODEL	V BATT	OSC	CONVERTER	IF	IF	DET	AF	AF	POWER	
RCA 7BT-9J	9V		235 GE 2N168A	234 2N169	234 2N169	1N295 1N64	2N109 2N192		2N109 (2) 2N188 (2)	
RCA 7BT-10K	9V		235 GE 2N168A	234 2N169	234 2N169	1N60 1N64	2N109 2N192	2N109 2N192	2N109 (2) 2N188 (2)	
Raytheon T-100	9V		2N112/B GE 2N136	2N112 2N135		1N60 1N64	2N132		2N138 2N192	
Raytheon T-150	9V		2N112 GE 2N136	2N112 2N135	2N112 2N135	1N295 1N64	2N132 2N192		2N138 (2) 2N192 (2)	
Raytheon T-2500	6V	CK760 GE 2N135	CK760 2N136	CK760 2N135		1N60 1N64	2N133 2N192	2N130 2N191	2N138 (2) 2N192 (2)	
Raytheon 8 T P 1		CK760 GE 2N136	CK759 2N135	CK760 2N135	CK760 2N135	CK721 2N191	CK721 2N191		CK721 (2) 2N188 (2)	
Raytheon FM101A	6V	2N113/14 GE 2N136	2N112/13 2N135	2N112 2N135	2N112 2N135	2N112 2N135	CK721/22 2N191		CK721/22 (2) 2N188	
Regency TRL	22½V		223 GE 2N169	222 2N169	222 2N169	1N69 1N64			210 2N188	Note 1
Regency TR-5	9V		2N172 GE 2N169	2N145 2N169	2N145 2N169	1N60 1N64			353 (2) 2N188 (2)	
Sentinel 369P and CR 729AA and BA	4V		2N172 GE 2N169	2N146 2N169	2N146 2N169	1N295 1N64	310 2N191		2N185 (2) or 353 (2) 2N188A (2)	
Sonic TR 600 Capri	9V		GE 2N168A	2N292	2N169	1N64	2N190		2N187 (2)	
Traveler	13½V		GE 2N136	2N135	2N135	4JD1A26			2N187A	
Westinghouse 7	9V		2N172 GE 2N169	2N146 2N169	2N146 2N169	880 2N169	310 2N192		2N185 (2) 2N188A (2)	Note 2
Westinghouse H610PS, H611PS, and H612PS	9V		2N252 GE 2N169	2N253 2N293	2N254 2N293	1N295 1N64	2N238 2N191		351 2N188	
Westinghouse H602P7	9V		2N172 GE 2N169	2N146 2N169	2N146 2N169	1N87 1N64	2N217 2N192	2N217 2N192	2N217 (2) 2N188 (2)	
Zenith 500	6V		2N94 GE 2N169	2N94 2N169A	2N94 2N169A	1N295 1N64	2N35 2N169A		2N35 (2) 2N169A	Note 1
Zenith 800	12V		GE 2N168A	2N168	2N169A	1N295	2N190		2N188A (2)	Note 3

*This list includes transistor production radios for which information is currently available. *It is primarily for information and is intended only as a general guide for replacements.*

The radio battery should be replaced with a fresh unit before checking transistors. If necessary to replace transistors, some selection may be necessary in order to obtain optimum performance since transistors of various manufacturers are made by slightly different processes and are not precisely interchangeable.

NOTES:

1. Remove any neutralization loops around IF circuits before operating with GE NPN transistors.
2. In some radios where the 2N146 is shown in both IF stages, one 2N145 and one 2N147 may be found instead in these stages.
3. The 2N293 may be used to replace the 2N168 in IF stages.
4. The 2N169 may be used to replace the 2N78 in AF stages.
5. The 2N186A may be used to replace the 2N44 in AF output stages.

READING LIST

The following list of semiconductor references gives texts of both elementary and advanced character. Obviously, the list is not inclusive, but it will guide the reader to other references.

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(McGraw-Hill)

Garner, L., *Transistor Circuit Handbook*
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(Gernsback)

SEMICONDUCTOR PRODUCTS DEPARTMENT

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ECG-241

PRINTED IN U.S.A.