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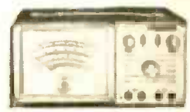

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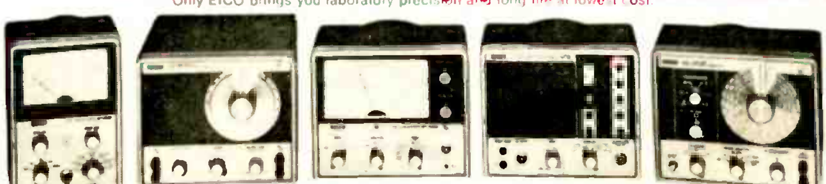

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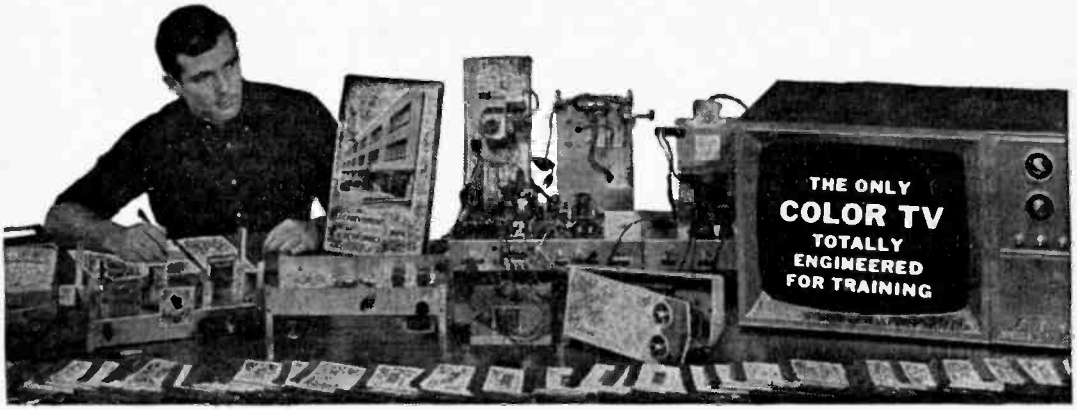

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UNDERSTANDING ELECTRONICS

FUNDAMENTALS are, by definition, essential to the understanding of any subject. Electricity is no exception. This article will build up your knowledge storehouse and serve to refresh your memory in areas that were forgotten or poorly understood.

The Lingo. Unless we state before hand exactly what we mean by *volt, ampere, watt, ohm*, etc., we could never be sure we are talking about the same thing. If each state in the Union had a different definition for the volt, 1.5 volts in Maine might just barely cause a #47 pilot lamp to glow red. and 1.5 volts in California might be too much—the lamp's filament could even be vaporized. Hence. electrical definitions determine the electrical standards that are used throughout the world today.

Volt. The volt is the unit of pressure or difference of potential, the practical unit of electromotive force (EMF). One volt is that potential which will maintain a current of one ampere through one ohm of resistance. Voltage is measured with a voltmeter, an instrument that is always connected across (in parallel with) a line or at that point in a circuit where the potential exists.

Ampere. The ampere is the practical unit of current. If one volt is impressed on a circuit with one ohm of resistance, one ampere of current will flow. When one ampere of current is flowing, 6,280,000,000,000,000.000 electrons are moving past a given point in a circuit each second. Current is measured with an ammeter; ammeters are always connected in series with one side of the line and the load.

Ohm. Resistance to current flow in an electrical circuit can be compared to resistance offered to water flow in pipes. The unit of resistance is the ohm. If a circuit has one volt impressed on it, and an ammeter indicates that one ampere of current is flowing, the circuit has a resistance of one ohm.

A length of #14 copper wire (.064 in. dia.) 400 feet long, has a resistance of 1 ohm, but 400 feet of #27 wire (.014 in. dia.) has a resistance of over 20 ohms. The smaller the diameter of wire, the greater its resistance per foot. Wire that is forced to carry current in excess of its rated capacity becomes hot. Heat not only presents a fire hazard but also increases the wire's resistance. Long lengths of wire offer increased resistance to current flow, just as a long pipe line offers increased resistance to water flow, and it is often necessary to increase wire diameter of long lines which are to carry much current, over that which would otherwise be used.

(Continued on page 8)

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While current-carrying wire is usually selected for low resistance, some types of materials are used electrically because of their high resistance. For example, an alloy of nickel and chrome, *Nichrome*, has a very high ohmic resistance and is used in heating elements of toasters, irons, room heaters, and other appliances. Since Nichrome has a high resistance per foot, a shorter length of it can be used to make up a heating element, and because it has high tensile strength, it can become very hot and still retain its form.

Resistors of many kinds are used in electrical circuits to control current flow and to "drop" voltage. These are usually made of high-resistance wire or of carbon, another high-resistance material. A set of simple formulas expresses the relationship of volts, amperes, and ohms in an electrical circuit. These formulas comprise *Ohm's Law*. In the formulas, I stands for current in amperes; E, for volts; and R, for resistance in ohms. Suppose that 110 volts is impressed on a circuit and we have a 20-ohm resistor in the circuit: how much current will flow through the circuit? Using the second formula, the answer is found to be 5.5 amperes. When any two units are known, the third can always be found using one of the formulas of Ohm's Law.

Watt. The watt is the unit of electrical power. Multiplying volts by amperes gives watts. Many household appliances are rated in watts; electric meters record the number of watt-hours used. A kilowatt is 1000 watts, and 1000 watts used for 1 hour is 1 kilowatt hour. 746 watts equals one horse power.

Watt value can be obtained by multiplication, as stated, in DC circuits, and in alternating current (AC) circuits also—if there is no inductance in the AC circuit. Any device that has wound coils (such as induction motors, chokes, relays) introduces inductance into circuit, however, and when a circuit is inductive, volts times amperes will not give true watts. Incandescent lamps, heaters and other pure resistance devices, are not inductive to any appreciable extent, and in these instances Ohm's Law may be used.

In fluorescent lamp units, a transformer and a choke—both wound units and highly inductive—are used as part of the ballast control unit. As a result, current lags behind voltage in fluorescent lamps, gets out of step with it, that is, in the rise and fall from zero to maximum value during an alternating cycle and multiplication of volts times amperes will not give true watt value. Therefore, a wattmeter—which has two terminals internally connected to a current coil and placed in the circuit in series with one side of the line, and two other terminals connected across the line, and is designed to record the true watts of an AC circuit—is used to measure true watts regardless of the power factor of a circuit.

Watts in both DC and non-inductive AC circuits can also be calculated by using the formula $I^2 \times R$, the current squared, times the resistance. A circuit with a difference of potential of 110 volts and with 4 amperes flowing in it will have, according to Ohm's Law, a resistance of 27.5 ohms. Four amperes squared equals 16, multiplied by 27.5 ohms, gives 440 watts (110 volts times 4 amperes also gives 440 watts).

Suppose now that we have a transmission line supplying a DC motor which draws 40 amperes of current. The length of each wire in the two-wire line is such that it has a resistance of .3 ohms (.6 ohms for the two wires). Forty squared equals 1600; 1600 x .6 = 960 watts lost merely transmitting the current. Therefore, in all cases, the two wires of a transmission line are selected for as low a resistance as possible. Their cross-sectional area is always as large as practical, not only for this reason, but also because overloading them would result in a rise in temperature, increasing resistance and also, therefore, the $I^2 \times R$ loss.

Power. Electrical energy can be delivered by either one of two types of currents, direct current (DC) and alternating current (AC). For certain applications, one type is better adapted to a job than the other, while in other applications only one type can be used. Direct current flows only in one direction; the terminals of its supply line will have a positive and negative polarity. Direct current is always in step with voltage, so volts times amperes will always equal true watts.

Alternating current, on the other hand, alternates, or reverses its direction, in both voltage and current. In one cycle, starting from a zero value, AC goes to a maximum in one direction, returns to and passes zero, goes to a maximum in the opposite direction, and then returns again to zero. For a 60-cycle frequency (most common in the U. S.) there are 60 complete cycles per second.

DC Generators. One method of producing DC is with a rotating machine, called a dynamo, which has a stationary field with a winding or windings, and a rotating centerpiece called the armature. The principle of its operation is based on the fact that if conductors are rotated in a magnetic field an E.M.F. will be induced in them. The field structure of the dynamo supplies the magnetism; its armature, the conductors. As the conductors pass alternate north and south poles of the field structure, an alternating voltage is supplied to the armature conductors and this is rectified to DC by connections to the dynamo's many-segment copper commutator. The load is supplied through the pick-up brushes that bear on the commutator segments. The armature is connected directly

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to the field winding in a shunt-connected motor so that the weak voltage first induced there will be increased. This results in a stronger flux in the magnetic field and, in turn, higher induced voltage in the armature, resulting ultimately in the dynamo delivering full-rated voltage at the brushes. A dynamo (DC generator) must be driven by some other supplier of energy, such as a motor, engine, waterwheel, or turbine. The voltage generated by it will depend on several factors including its speed of rotation, the make-up of its armature winding and the strength of its field.

Some DC generators have a series winding on their field in addition to the normally used shunt winding. They are called compound-wound generators. As additional current is drawn by the load, this series winding, which also carries load current, increases strength of the field, resulting in increased voltage. Thus additional current requirements generate greater voltage, offsetting the tendency for voltage to drop under load.

Any shunt- or compound-wound DC motor can act as a DC generator if driven, since essentially motor and generator are the same. The motor must be driven, however, in such a direction that the generated voltage will be supplied to the fields according to their original, residual polarity.

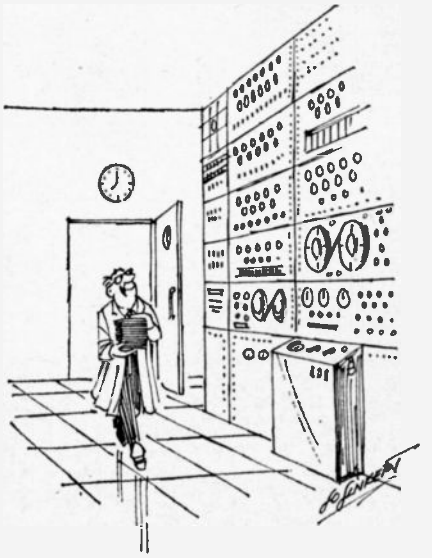
Batteries. Combination of electro-chemical cells (called batteries) produce the purest form of DC. They may be either of the dry or wet type and they are further divided into primary and secondary batteries. Cells connected in series give a voltage equal to the sum of the voltage of the individual cells. Connected in parallel, the voltage of the group remains that of one cell, but current can be drawn from it equal to the sum of the current available from each of the cells. It is also possible to connect cells in series-parallel, thus increasing both voltage and current availability.

Battery Types. In the dry cell (a primary type) a zinc outer casing forms the negative terminal and a solid carbon element in the center, the positive. A paste of active materials—usually granulated carbon, manganese dioxide, zinc chloride and ammonium chloride (salamoniac), or a combination of other chemicals—is packed around the carbon element in a blotting paper cylinder. The principle is that if two dissimilar elements are placed in an electrolyte (the active materials), a potential EMF will be developed between them. The development of an EMF is also dependent on the electrolytic solution's attacking one of the two dissimilar materials (the zinc), setting up a chemical action. A cell, therefore, converts chemical energy directly into electrical energy. Primary cells are only useful for intermittent work, such as the ringing of doorbells, or the operation of flash lights, portable radios and similar applications which are normally open circuit.

A simple primary wet cell is shown in our illustration. Other wet cells include the Daniell, Fuller, Edison Lelande, bichromate or chromic acid cell, and the gravity cell. These are all of the wet variety. The gravity cell is the most widely used in the U.S. for closed circuit work, such as in burglar alarms and telegraphs.

Secondary batteries are of the storage type and are used where a comparatively low-voltage but high-current DC source is required, as in automobiles. They may have three to six individual cells connected in series to get the necessary voltage, each cell delivering about 2 volts, when charged. A storage cell has two groups of lead plates separated by an insulating material. Each group is fused to a terminal strap or yoke within the cell and so arranged that the plates of each group are meshed with those of the other group. The assembled plates are placed in a hard rubber box or case, sealed at the top with tar, and provided with a terminal for each group of plates (positive and negative in polarity).

The most common method of manufacture of today's lead-acid cells, as they are called, is the grid forming of lead plates with a paste of active materials, usually red lead, litharge and sulphuric acid, with lamp black added for the negative plate, which is pressed into the openings. The electrolyte of dilute sulphuric acid is poured into the cell and a source of DC is connected to its terminals to charge it. In the charging process, electrical energy is changed to chemical energy and stored in that form. ■



"Good morning! It's sock-it-to-me time!"

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Quick-Mount Flush Speaker

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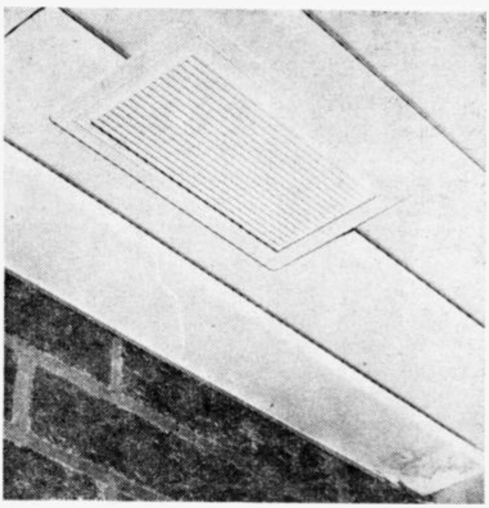


Magitran Poly-Planar G51P Speaker

Switched-on Saser Beam

The Saser Beam antenna line, says Mosley Electronics, cuts through CB interference like a laser cuts through steel. Model DMS-3D is a deluxe 12-element Saser Beam, a combination of two MS-3D beams stacked, and features the sturdy construction of a beam plus the choice of polarization usually found only in the quad design. Each of the six horizontal and six vertical elements has two high "Q" coils, so

(Continued on page 107)

Working with ELECTRONIC CIRCUITS

FOR BEST RESULTS, certain specialized techniques, tools and hardware are required when working with electronic circuits. Some of the tools and hardware to be discussed are not absolutely essential; however, they do make the job easier or the equipment better.

One of the most important techniques involved in electronic circuitry is soldering. All connections must be soldered, and soldered properly for optimum, trouble-free results. Finding an intermittent short or loose connection in a piece of electronic equipment is a hard, time-consuming job, and most are due to poor soldered joints.

Soldering. Most technicians use a soldering gun, or, in the case of printed circuit work, a very small pencil iron. The soldering gun tip is fairly small, heats rapidly, and stays hot only while the trigger is pressed. This prevents excessive heating and oxidation of the tip. Tips are available in various sizes and shapes and are readily replaceable.

A soldering gun works on a transformer principle, with the AC line being connected to the primary. The secondary consists of a very few turns of very heavy wire, with the copper tip being connected across this secondary. Due to the very few turns involved (compared to the primary), there is a very low voltage, but very high current in this secondary. This high current flowing through the tip causes it to get hot. The high current flows through the secondary, causing it to get warm. For this reason, soldering guns are rated for cycling use (i.e., two minutes off for each minute on, etc.).

Small soldering irons, often referred to as pencil irons, are usually of low wattage, and are used where delicate work is required. Screw-in tips for this type of iron are available in various forms, including specialized tips for de-soldering printed circuit components. Even with regular spade or diamond tips, they are extremely handy in working with transistor circuits or where space is limited.

Regular irons come in different sizes, both physically and electrically. Irons designed for general use usually have tips (spade or diamond-

(Continued on page 103)

INTRODUCING

101

Electronic Projects

FOR UNDER $10

If you've taken time to thumb through 101 ELECTRONIC PROJECTS for under $10, you've no doubt noticed that this is a different kind of magazine. It's actually an experimenter's desk reference, with modern, up-to-date circuits using readily obtainable components. Worth noting, too, is that none of the circuits was picked out of thin air. Instead, each one was requested by the readers of ELEMENTARY ELECTRONICS or SCIENCE EXPERIMENTER. If a circuit isn't here, it's because you didn't write to tell us about it or because there weren't enough reader requests to justify its inclusion.

We've expended considerable effort to make certain you can build the projects and get them working. With few exceptions, no industrial-type components are specified. And in almost all, the solid-state devices are readily available at your local distributor or from major electronics mail-order houses. In one or two circuits an industrial-type component must be used, but in this case we tell you where to get it.

Construction details are provided where necessary. If there are no instructions, you can build the circuit in any manner and in any cabinet. When metal cabinets must be used we tell you so; the same thing goes for heat sinks. When nothing is said about a heat sink you don't need one, even for power transistors. When a heat sink is needed we specify one.

To make things as easy as possible, symbols in the schematics have two parallel lines, while others have a straight and curved line. Those with a curved line have a "+" symbol over the straight line. Two straight lines mean a non-polarized capacitor (not an electrolytic) and you can install it without regard to any markings; there is no polarity. Capacitors indicated by a curved line are polarized and must be wired according to the polarity shown. The curved line is a warning that polarity must be double-checked, since the project will probably not work if capacitor connections are reversed.

Some capacitor voltage ratings might seem excessive, such as a 500-V disk specified for a 9-V circuit. In all instances we have specified the lowest-cost capacitor. A 500-V disc would cost less, than, say, a 10-V miniature capacitor. Since electrolytic capacitors often represent the biggest expenditure for a project, we suggest you use the cheapest ones you can get whenever possible. When a capacitor value is critical we specify a silver mica type. The minimum silver mica voltage rating you can easily obtain is 100 V so use this rating for lowest cost. To be on the safe side, never use a capacitor with a voltage rating lower than that specified.

Potentiometers can be any taper unless a specific taper is specified. When batteries are specified do not use a smaller size than recommended. Current requirements for a project are taken into account for the battery type suggested in the Parts List.

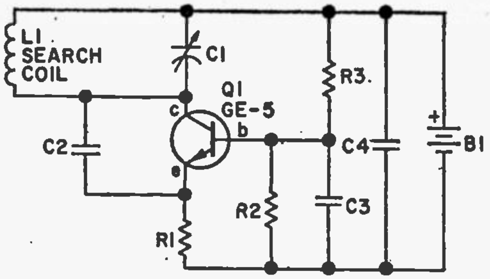
We have tried to ensure that every circuit will work with the specified transistors, but there is a normal variation in transistor characteristics that might affect performance. For example, a 2N3391 transistor has a possible gain range of 250 to 500, a 2:1 difference. If the unit you obtain has a gain of 500, the base bias becomes critical and the specified bias resistor might not work in your project. If you have an amplifier that distorts at high levels, or an oscillator that won't start, try changing the base bias resistor. It's usually the one connected from the collector power source to the base. Vary it approximately 20% in value, either higher or lower, then trim the resistance for optimum performance.

We'd like to hear from you concerning your favorite projects and circuits, and any other thoughts you might have on 101 ELECTRONIC PROJECTS.

Julian M. Sienkiewicz

JULIAN M. SIENKIEWICZ
Editor in Chief

1 Treasure Locator



You won't find Long John Silver's buried treasure but you will have lots of fun finding bottle caps and uneaten sandwiches at the beach; maybe even some quarters and dimes.

This treasure locator keeps costs down by using a transistor radio as the detector. The unit is assembled on a perf-board, with rigid component mounting a must. It is strapped to a broom handle close to the bottom where the search head is mounted. A transistor radio is mounted near the top of the handle.

With the radio tuned to a "weak station," Capacitor C1 is adjusted so the locator oscillator "beats" against the received signal, producing a whistle in the receiver. When the search head passes over buried metal, the metal changes the inductance of L1, thereby changing the locator oscillator's frequency and changing the "beat tone" in the radio.

The search coil consists of 18 turns of #22 enameled wire *scramble wound* (which means don't be neat) on a 4-in. diameter form, which can be a cardboard tube or a wood puck or even plastic—anything but metal. After the coil is wound and checked for proper operation, saturate the coil with *coil dope* or G.E.'s *RTV* adhesive (do not use *Silastic* or any other similar product but *RTV*.) If a single loop of the coil is not firmly cemented the unit will be unstable.

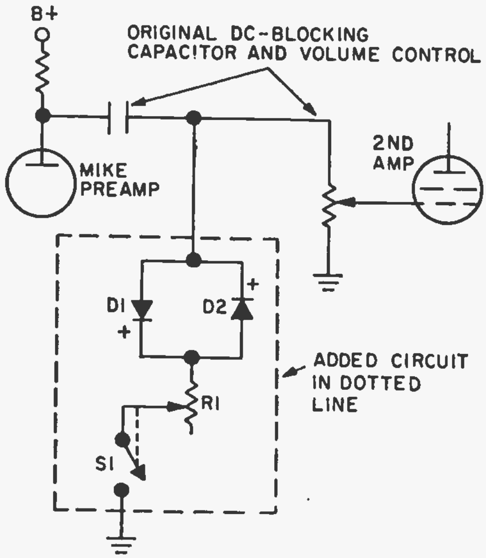
PARTS LIST FOR TREASURE LOCATOR

B1—9-VDC transistor battery
C1—280-pF trimmer or variable capacitor
C2—100-pF, 100-V silver mica capacitor
C3—0.05-uF, 25-V disc capacitor
C4—5-uF, 12-V electrolytic capacitor
L1—Search coil consisting of 18 turns of #22 enamel wire scramble wound on 4-in. diameter form
Q1—GE-5 npn transistor
R1—680-ohm, ½-watt resistor
R2—10,000-ohm, ½-watt resistor
R3—47,000-ohm, ½-watt resistor

2 Fuzz for a Buck

Want fuzz for the *Now* sound, but haven't got the loot for a fuzzbox? Try this one until Mom slips you some extra "bread".

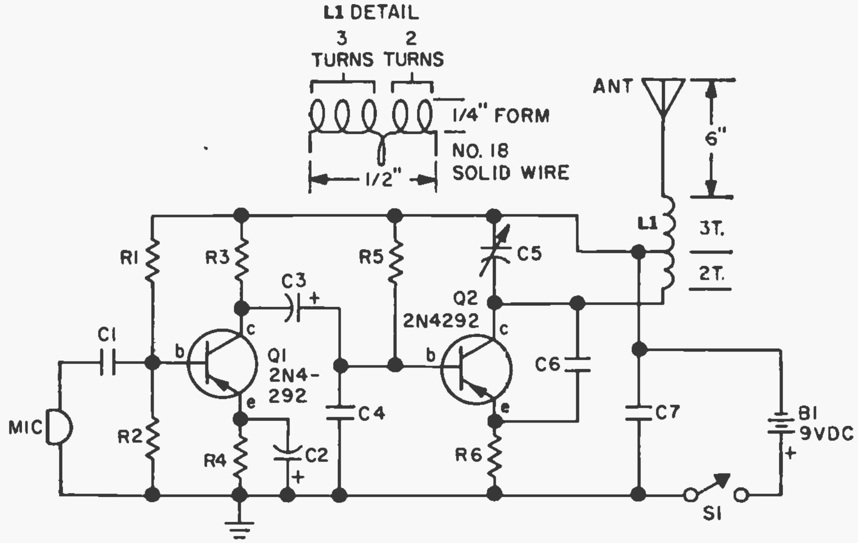
Install the two diodes and potentiometer across the guitar amplifier's volume control. The diodes clip the normal sound, producing the fuzz effect. R1 sets the degree of fuzz. It's not as much as you would get from a professional fuzzbox, but fuzz it is. One restriction is that an audio signal at the plate of the amplifier before the fuzz must be at least 1-volt RMS—generally true in most amplifiers.



PARTS LIST FOR FUZZ FOR A BUCK

D1, D2—1N60 diode
R1/S1—10,000-ohm miniature potentiometer with spst switch

3 FM Wireless Mike



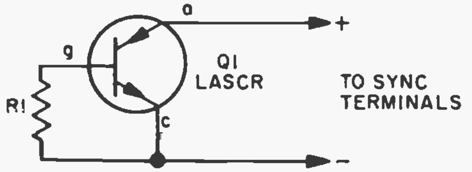
PARTS LIST FOR FM WIRELESS MIKE

B1—9-V battery, Type 2U6
C1—0.05-uF, 3-VDC capacitor
C2—20-uF, 3-VDC electrolytic capacitor
C3—5-uF, 12-VDC electrolytic capacitor
C4—47-pF, 25-VDC capacitor
C5—5-30 pF trimmer capacitor
C6—6.8-pF ceramic capacitor
C7—0.01-uF, 10-VDC capacitor
L1—See pictorial detail
MIC—Crystal or ceramic microphone element
Q1, Q2—2N4292 pnp transistor
R1—47,000-ohm, ½-watt resistor
R2—33,000-ohm, ½-watt resistor
R3—1500-ohm, ½-watt resistor
R4—3300-ohm, ½-watt resistor
R5—100,000-ohm, ½-watt resistor
R6—470-ohm, ½-watt resistor
S1—Spst switch

Just speak or play into the microphone and you'll broadcast to an FM receiver at distances up to 50 feet (maybe 100 feet if the wind is right). Use standard RF wiring precautions and make coil L1 exactly as shown. Best speech clarity is obtained by using a crystal or ceramic mike. For music reproduction, substitute a dynamic mike element.

The unit can be assembled on a perfboard using push-in terminals for tie points. The case must be metal to prevent hand capacitance from continuously changing the output frequency. Pass the 6-in. solid wire antenna through the metal case using a ¼-in. hole and a matching rubber grommet for an insulator.

4 Remote Flash



PARTS LIST FOR REMOTE FLASH

Q1—300-V light-activated silicon-controlled rectifier (LASCR)
R1—47,000-ohm, ½-watt resistor

Even if you spend $18 or $20 for a super-duper professional remote flash tripper, you'll get little more than this two-component circuit. Price is important if the results are equal.

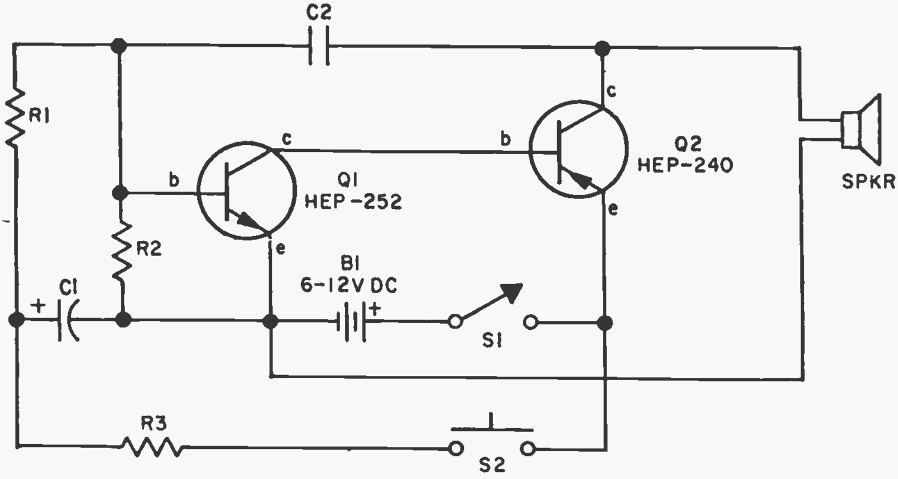
Transistor Q1 is a light-activated silicon-controlled rectifier (LASCR). The gate is tripped by light entering a small lens built into the top cap.

To operate, provide a 6-in. length of stiff wire for the anode and cathode connections and terminate the wires in a polarized power plug that matches the sync terminals on your electronic flashgun (strobelight). Make certain the anode lead connects to the *positive* sync terminal.

When using the device, bend the connecting wires so the LASCR lens faces the main flash. This will fire the remote unit.

No reset switch is needed. Voltage at the flash's sync terminals falls below the LASCR's holding voltage when the flash is fired, thereby turning off the LASCR.

5 Electronic Siren



A real screamer! Use a public-address type horn under the hood of your car and you'll punch a hole in the tightest traffic jam. (Be certain, of course, that you hold a position that entitles you to a siren.)

Press push-button switch S2 and the siren starts up, shifting to a higher frequency. Release it and the tone slides down until you send it up again by punching S2.

Adjustment of overall tone quality is made by changing C2's value. If the siren pulsates before the pushbutton switch is pressed, Q1 is too "leaky". Try a different transistor.

PARTS LIST FOR ELECTRONIC SIREN

B1—6-V or 12-V battery
C1—30-uF, 15-VDC electrolytic capacitor
C2—0.02-uF, 75-VDC capacitor
Q1—Motorola HEP-252 npn transistor
Q2—Motorola HEP-240 pnp transistor
R1, R2—56,000-ohm, ½-watt resistor
R3—27,000-ohm, ½-watt resistor
S1—Spst switch
S2—N.O. pushbutton switch
SPKR—8-ohm speaker or PA horn

6 Budget Lamp Dimmer

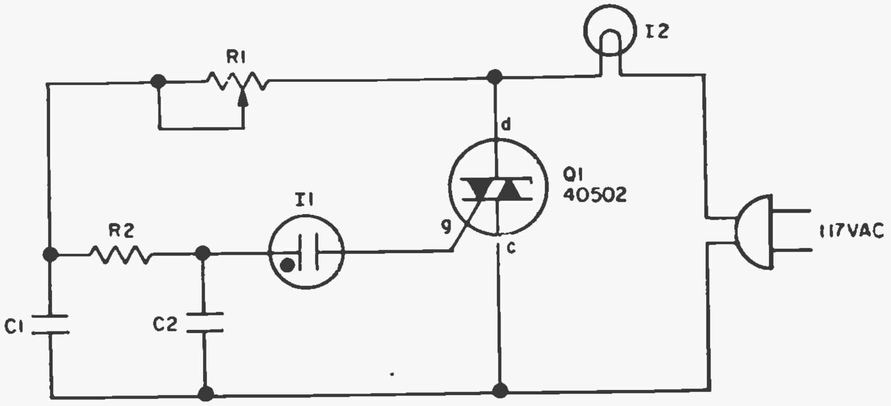
With miniature components and extreme care you can build a low power lamp dimmer right into a socket. Without a heat sink, Triac Q1 handles up to a 400-watt lamp.

Instead of a relatively expensive trigger diode, an ordinary neon lamp of the NE-83 or NE-2 variety can be used. (An NE-83 is treated for dark operation and will provide more consistent operation.)

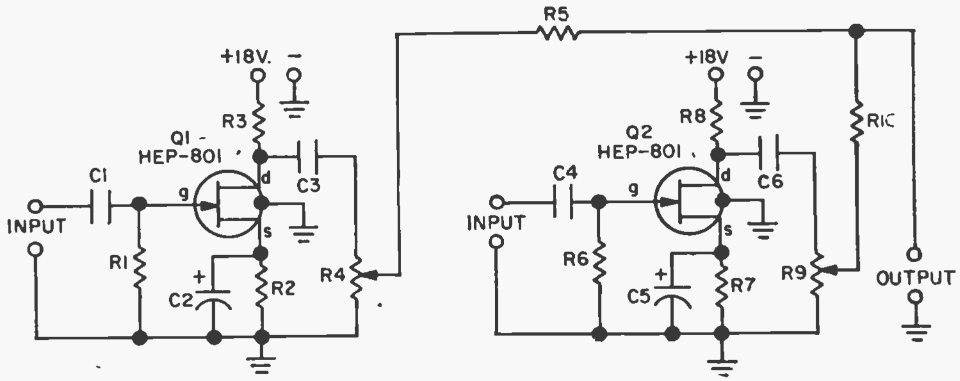
PARTS LIST FOR BUDGET LAMP DIMMER

C1, C2—0.068-uF, 200-VDC capacitor
I1—NE-83 or NE-2 neon lamp
I2—External lamp not to exceed 400 watts
Q1—RCA 40502 Triac
R1—50,000-ohm, 2-watt potentiometer
R2—15,000-ohm, ½-watt resistor

Because the neon does not trip the gate until it conducts, the lamp turns on at medium brilliance. The lamp can then be backed off to a soft glow. Because the neon drops out when the applied voltage falls below the neon holding voltage of approximately 40V the lamp cannot be adjusted as low as it can with a diode trigger.



7 Super Mike Mixer



For serious recording of anything other than speech and sound effects, two mikes are always better than one. Our super mike mixer does its mixing after amplification so the amplifiers compensate for the mixer loss first, thereby improving the signal-to-noise ratio as compared with simple mixers that mix first and amplify after the mixer.

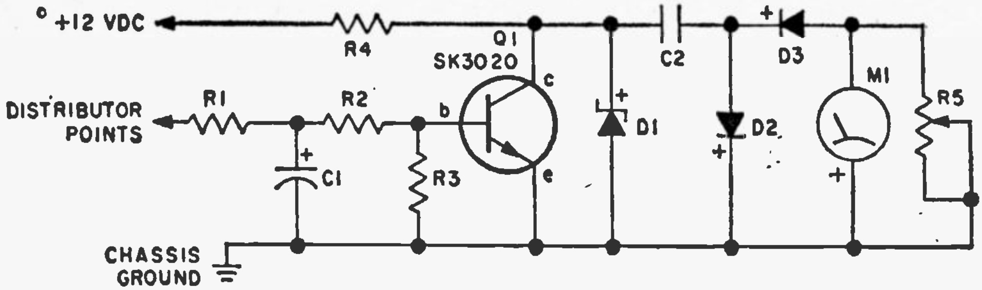
Using FET semiconductors with their *high input* impedance, this basic mixer can be used with high impedance crystal and ceramic microphones. It does not attenuate low frequency response whatsoever through low impedance loading of the microphone. The mixer's response is 10 to 20,000 Hertz.

Two mixers can be built into the same cabinet for stereo use. Even with two independent (stereo) mixers, current drain is on the order of a few milliamperes and two series-connected transistor radio-type batteries can be used.

PARTS LIST FOR SUPER MIKE MIXER

C1, C4—0.05-uF, 10-VDC capacitor
C2, C5—25-uF, 6-VDC electrolytic capacitor
C3, C6—0.1-uF, 25-VDC capacitor
Q1, Q2—Motorola HEP-801 FET transistor
R1, R6—2-megohm, ½-watt resistor
R2, R7—6800-ohm, ½-watt resistor
R3, R8—560-ohm, ½-watt resistor
R4, R9—500,000-ohm, audio taper potentiometer
R5, R10—100,000-ohm, ½-watt resistor

8 Auto Tachometer



PARTS LIST FOR AUTO TACHOMETER
C1—1-uF, 100-VDC electrolytic capacitor
C2—0.47-uF, 15-VDC capacitor
D1—9.1-V, 250-mW Zener diode
D2, D3—100-mA, 50-PIV silicon rectifier
M1—0-1 mA DC meter
Q1—SK3020 npn transistor (RCA)
R1—200-ohm, ½-watt resistor
R2—220-ohm, ½-watt resistor
R3—1500-ohm, ½-watt resistor
R4—330-ohm, ½-watt resistor
R5—1000-ohm potentiometer

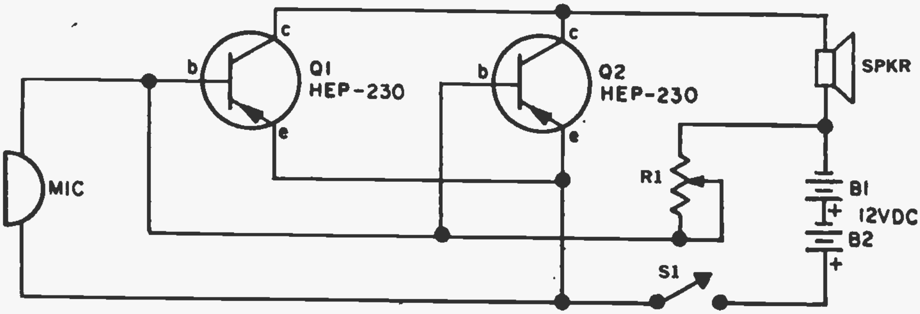
You can adjust a car engine to specified idle and choke rpm with this one-transistor tachometer.

Wiring is not critical and the unit can be assembled in a plastic box or metal cabinet. Zener diode D1 is any 250-milliwatt unit rated as close to 9 V as possible.

The unit can be used only on cars with a negative ground. The power lead connects to a positive 12-V point in the car's wiring, the ground lead connects to the car chassis. The distributor lead connects to the lead between the distributor and ignition coil. Do not connect it to a solid-state ignition system.

The meter scale is linear, with full scale representing approximately 10,000 rpm. Calibrate the tach against a commercial tach (at your local garage?) by noting the commercial tach's reading and adjusting R5 till your tach reads the same.

9 Power Megaphone



Just about any power transistor can be used in this megaphone. It's suitable for boats, playing fields, etc. Transistors Q1 and Q2 are the 2N301 type, generally available in "five-for-$1" experimenter kits.

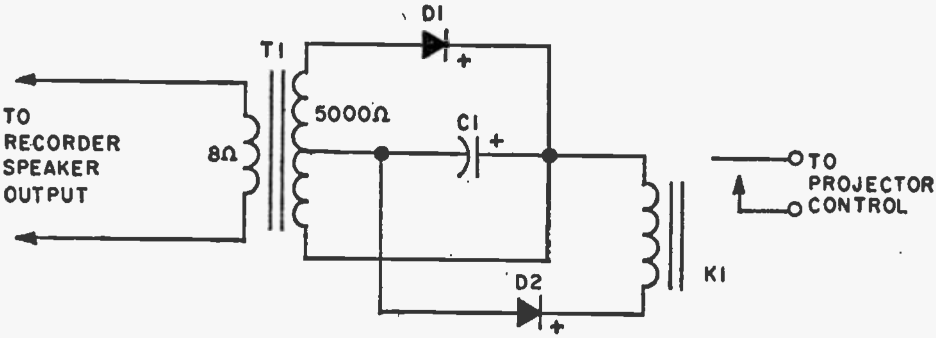
Transistors Q1 and Q2 are parallel-connected to handle the required power and speaker matching. The microphone is a carbon type such as a telephone handset. If a regular carbon mike is used, the push-to-talk (PTT) switch can be connected in place of S1 to provide PTT operation. There's no

warm-up or "capacitor charge" time. Batteries B1 and B2 are 6 V lantern types. The unit should be built in a metal case which can also serve as a transistor heat sink. Use insulators coated with silicon heat-sink grease between each transistor and the case.
Potentiometer R1 is adjusted for maximum sound output consistent with lowest distortion.

PARTS LIST FOR POWER MEGAPHONE

B1, B2—6-V lantern battery
M1—Carbon microphone
Q1, Q2—HEP-230/232 pnp transistor (Motorola)
R1—5000-ohm. potentiometer
S1—Spst switch
SPKR—4-ohm speaker or horn

10 Slide Programmer



Soundless slide shows are dull, dull, dull! But a stereo recorder can automate the whole show so slides change automatically in step with the commentary.
Record your commentary on the left track. At the instant you want slides to change, record a one-second noise or tone burst on the right track. Connect the programmer between the recorder's right speaker output and the projector's remote control cable. Make a test run to determine the right-track volume setting to make noise or tone bursts activate relay K1. No fancy tone generators needed here. Just give a hearty Bronx cheer into the mike of the left channel only!
Then start the tape from the beginning. The audience will hear your comemtary or spectacular music-and-sound reproduction through a speaker connected to the recorder's left channel, while the signal on the right channel automatically changes the slides.

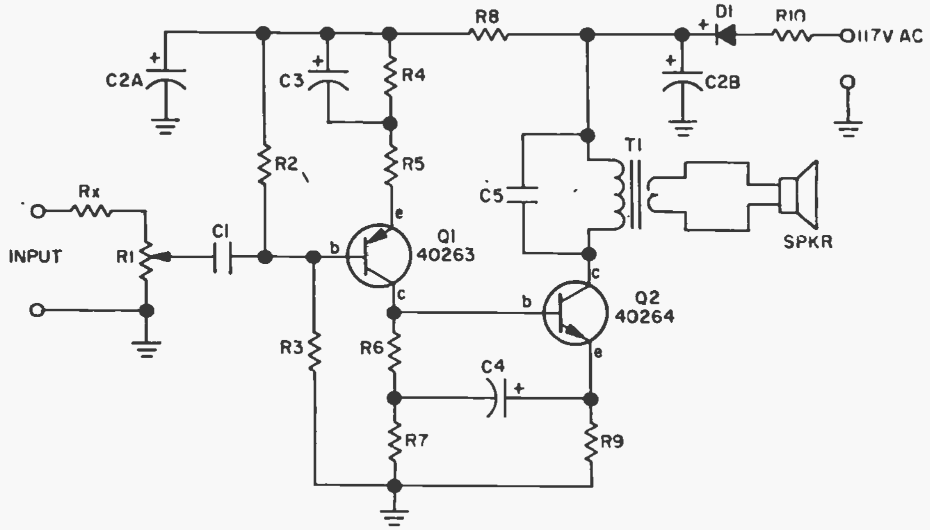
PARTS LIST FOR SLIDE PROGRAMMER

C1—25-uF, 50-VDC electrolytic capacitor
D1, D2—500-mA, 100-PIV silicon diode
K1—2500-ohm coil plate-type relay
T1—5000-ohm CT audio output transformer

11 Line-Powered Phono Amp

Old tube phonographs are easily updated with this transistorized line-powered amplifier. It offers one-watt output—somewhat greater than is usually provided by phono amps.
No power transformer is needed since transistors Q1 and Q2 are designed to work directly from a high voltage power source. Full output is obtained from phono pickups providing at least 0.5 V output. If a "low impedance" ceramic pickup is used, eliminate resistor Rx since the input impedance will be approximately correct. If a "standard" high impedance ceramic pickup is used, install a resistor of 300K-500K ohms for RX.
Tone control circuits, if desired, should be installed ahead of volume control R1.

Since one side of the AC line provides the ground connection, for maximum safety make certain no wire or part connected to "ground" is exposed on the phonograph. Sound quality is mainly determined by the size and characteristics of the speaker. Optimum sound balance can be obtained by slight changes in the value of C5. A higher value attenuates the highs while a lower value increases the highs.



PARTS LIST FOR LINE-POWERED PHONO AMPLIFIER	
C1—0.01-uF, 200-VDC capacitor	R4—1000-ohm, ½-watt resistor
C2—80/80-uF, 150-VDC electrolytic capacitor	R5—68-ohm, ½-watt resistor
C3, C4—25-uF, 6-VDC capacitor	R6—470-ohm, ½-watt resistor
C5—0.01-uF, 400-VDC capacitor	R7—820-ohm, ½-watt resistor
D1—750-mA, 250-PIV silicon rectifier	R9—120-ohm, ½-watt resistor
Q1—40263 pup transistor	R10—250-ohm, ½-watt resistor
Q2—40264 npn transistor	Rx—See Text
R1—2-megohm audio taper potentiometer	T1—2500-ohm pri., 4-ohm sec, audio output transformer
R2, R8—18,000-ohm, ½-watt resistor	SPKR—4-ohm PM speaker, 8-12-in. dia.
R3—33,000-ohm, ½-watt resistor	Misc.—Heat sink for Q2

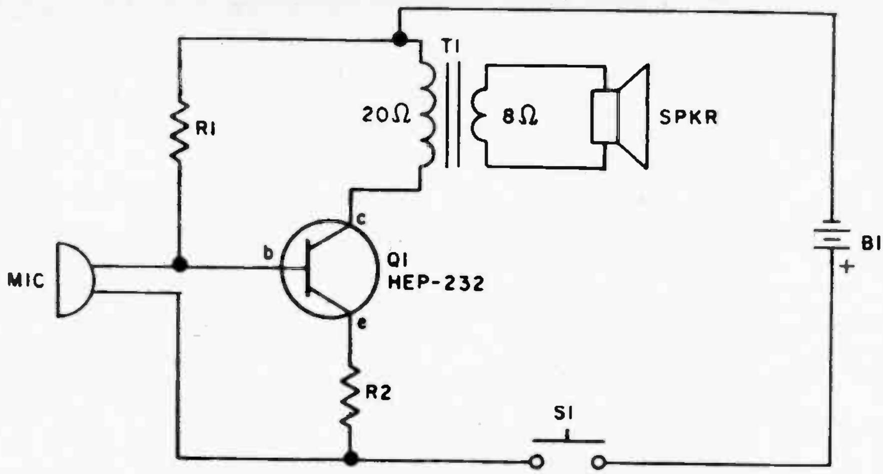
12 Loudhailer

Though the design is simple and easy to build, this one-transistor loudhailer puts out a powerhouse shout. The circuit, except for the mike, can be mounted in a metal cabinet with a paging horn or trumpet speaker mounted on top.

Transistor Q1 must be provided with a heat sink, which may be the cabinet itself. Take care, however, that Q1's case—the collector—is insulated from the cabinet with hardware provided in a power transistor

PARTS LIST FOR LOUDHAILER

- B1—6-VDC battery, lantern type or four "D" alkaline cells in series
- MIC—Carbon microphone
- Q1—Motorola HEP-232 pnp transistor
- R1—270-ohm, ½-watt resistor
- R2—1-ohm, 4-watt resistor
- SPKR—8-ohm impedance, horn-type speaker
- S1—Normally-open pushbutton switch
- T1—8 to 20-ohm impedance, 5-watt audio output transformer



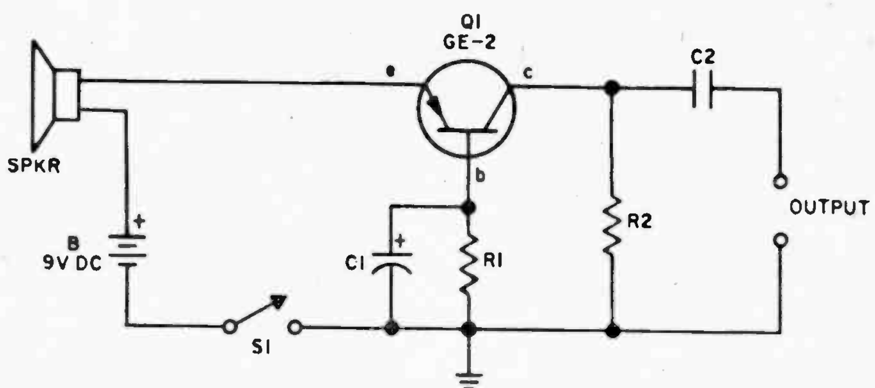
mounting kit.

The microphone can be a surplus carbon type or telephone transmitter element.

The entire unit can be assembled inside a speaker-trumpet if care is taken to acoustically isolate the microphone from the speaker to prevent howling feedback.

Note carefully that transformer T1 must be rated for at least 5 watts. Do not use a miniature transistor transformer.

13 Speaker-Mike Preamp



A speaker can often serve as a microphone in intercoms, "one-way telephones" or as an emergency microphone. All the speaker needs is amplification to raise "voice power" output to normal mike level.

A small speaker-mike preamp can easily be thrown together with junk box parts and just about any general purpose transistor with a beta of 30 to about 150. While an pnp transistor is shown, an npn type can be substituted if the battery and C1's polarity are reversed. No other changes are needed.

Q1 is a common base amplifier providing a low impedance input to match a low impedance speaker of 3.2, 4, 6-8, or 16 ohms. The collector output is medium impedance and the .47 uf capacitor at C2 allows the preamp to work into loads of 7000 ohms or higher.

PARTS LIST FOR SPEAKER-MIKE PREAMP

B1—9-V battery
C1—6-uF, 25-VDC electrolytic capacitor
C2—0.47-uF, 10-VDC capacitor
Q1—GE-2 pnp transistor
R1—270,000-ohm, ½-watt resistor
R2—27,000-ohm, ½-watt resistor
S1—Spst switch
SPKR—Any PM speaker, 4-10-ohms

14 VU Meter with Boost

PARTS LIST FOR VU METER WITH BOOST

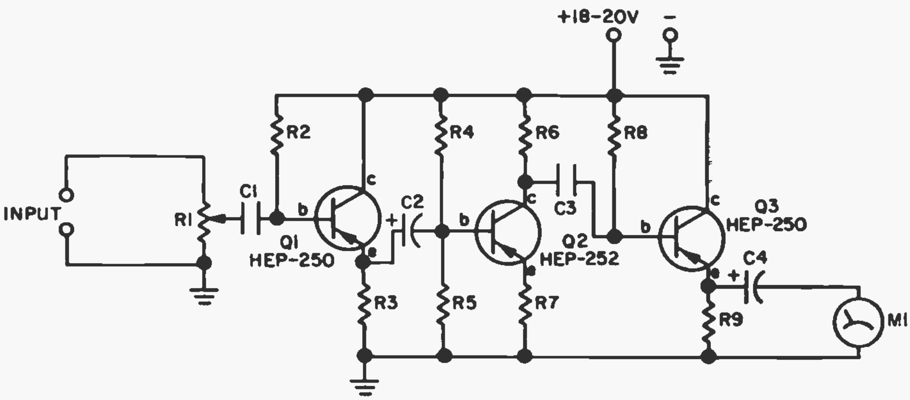
C1, C3—0.1-uF, 25-V capacitor
C2—10-uF, 15-V electrolytic capacitor
C4—30-uF, 15-V electrolytic capacitor
M1—VU meter
Q1, Q3—Motorola HEP-250 pnp transistor
Q2—Motorola HEP-252 pnp transistor
R1—1-megohm, audio taper potentiometer
R2, R8—470,000-ohm, ½-watt resistor
R3, R9—4700-ohm, ½-watt resistor
R4—120,000-ohm, ½-watt resistor
R5, R6—10,000-ohm, ½-watt resistor
R7—1500-ohm, ½-watt resistor

You can ride gain on audio signals, just as the pros do, with an amplified VU (Volume Unit) meter.

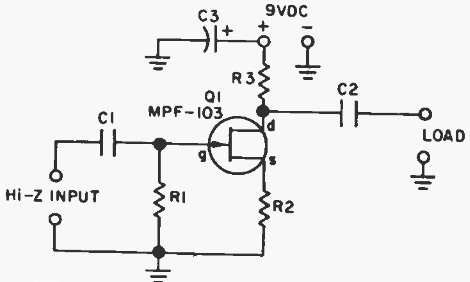
The circuit shown can produce VU readings almost down to microphone levels. Input level (sensitivity) control R1 allows the meter to be used, too, with high level audio signals.

Transistor Q1 is an emitter follower that presents a high impedance to the input terminals (through R1). Q2 is a voltage amplifier and Q3 is an emitter follower to match Q2's medium collector impedance to the relatively low meter impedance. Meter M1 can be any VU meter; an inexpensive miniature or a professional model. It's powered by two series-connected 2U6 type 9V batteries.

The amplified meter can also serve as a test instrument. Its high sensitivity can trace audio signals from the output of a magnetic pickup to an amplifier's power output or speaker terminals. It can also be used to plot the effects of tone control and equalizer circuits.



15 Mike Power



PARTS LIST FOR MIKE POWER

C1, C2—0.05-uF, 25-VDC capacitor
C3—100-uF, 15-VDC electrolytic capacitor
Q1—Motorola MPF-103 FET transistor
R1—2-megohm, ½-watt resistor
R2—3300-ohm, ½-watt resistor
R3—10,000-ohm, ½-watt resistor

Approximately 10 dB of extra microphone amplification for CB and ham transmitters, tape recorders and PA amplifiers is provided by the field effect transistor. Since an FET's input is many megohms, the amplifier's input impedance is determined by gate resistor R1, which is 2 megohms. It's a suitable load for high impedance crystal and ceramic microphones.

The amplifier is "flat" from 20 to 20,000 Hz. Low frequency response can be attenuated for communications use by reducing the value of C2 to one half.

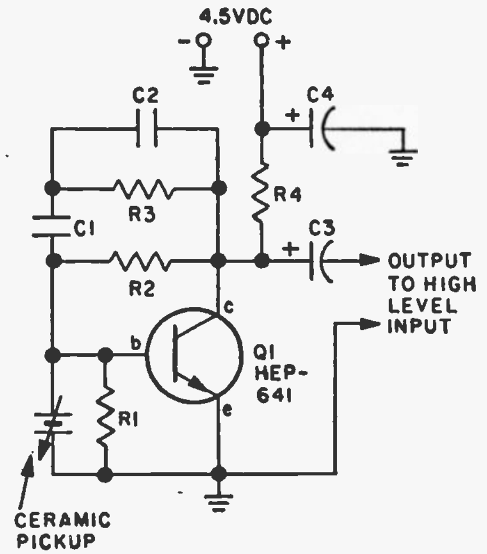
Power supply by-pass capacitor C4 must be used regardless of whether the voltage supply is a rectifier or battery. If C4 is not used there might br severe low frequency attenuation, sharply reduced gain or instability.

The amplifier's output can be connected to any load of 50,000 ohms or greater, which includes just about every piece of equipment except those specifically designed for low impedance microphones.

16 Ceramic Pickup Preamp

PARTS LIST FOR CERAMIC PICKUP PREAMP

- C1—0.01-uF, 10-VDC capacitor
- C2—3300-pF, 100-VDC capacitor
- C3—0.05-uF for tube amp; 10-uF, 10-VDC electrolytic capacitor for transistor amp
- C4—30-uF, 6-VDC capacitor
- Q1—Motorola HEP-641 npn transistor
- R1—10,000-ohm, ½-watt resistor
- R2—220,000-ohm, ½-watt resistor
- R3—33,000-ohm, ½-watt resistor
- R4—4700-ohm, ½-watt resistor



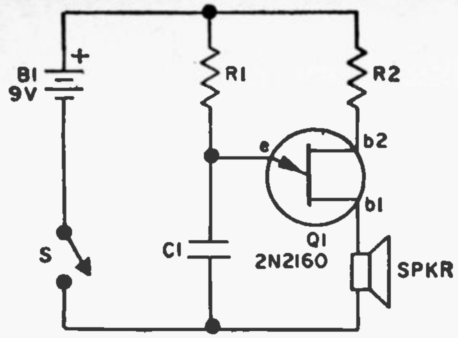
Because of record equalization and the characteristics of a ceramic pickup, its sound, when fed to a "flat" amplifier, can be lacking in lows. Some sort of equalization is needed when feeding the pickup to, say, a PA or tape recorder auxiliary amplifier.

This one-transistor preamp provides proper equalization for modern ceramic pickups and amplification to allow direct connection to all high level inputs on amplifiers or tape recorders. Equalization is accomplished through low impedance loading of the pickup by R1 and Q1's input impedance, and the C1/C2/R3 equalizer. Changes in equalization are obtained by adjustment of the C1/C2/R3 network. Do not change R2 for equalization, but it can be varied for a bias adjustment to accommodate other transistor types.

17 Mike Beeper

You can always feed an audio generator into a mike input to check an AF system, but how do you check the mike? Saying "woof, woof, *hello, test*" gets mighty tiring. Instead, clamp the Mike Beeper to the front of the mike with a rubber band and you'll send continuous tone *through the mike*. It lets you take your time checking the mike, connecting cable, jacks, amplifiers, etc.

The beeper can be built in a small plastic case—nothing is critical. The speaker may be just about size from one to three inches.



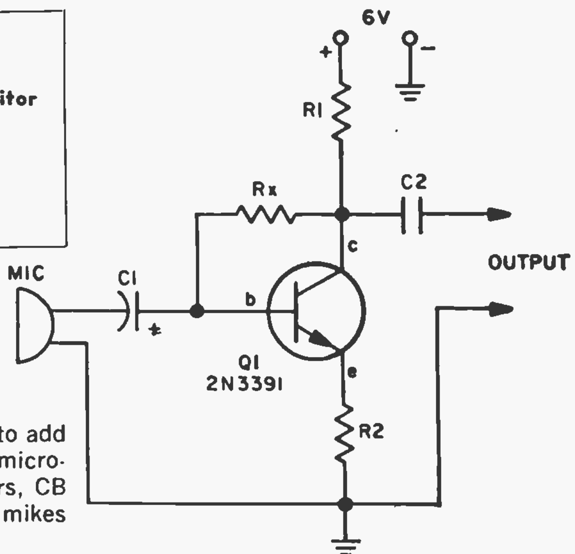
PARTS LIST FOR MIKE BEEPER

B1—Type 216 9-V battery
C1—0.1-uF, 10-VDC capacitor
Q1—2N2160 unijunction transistor
R1—10,000-ohm, ½-watt resistor
R2—47-ohm, ½-watt resistor
S1—Spst switch
Spkr—3.2 or 8-ohm miniature speaker

18 Low-Impedance Mike Preamp

PARTS LIST FOR LOW-IMPEDANCE MIKE PREAMP

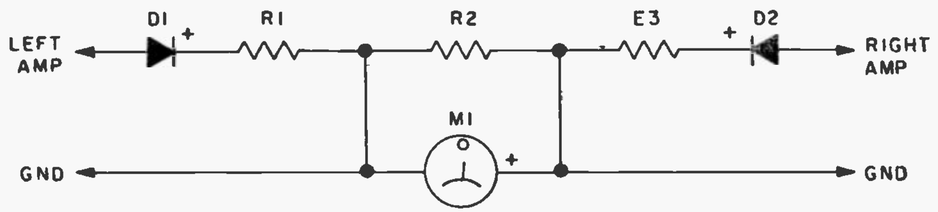
C1—10-uF, 15-VDC electrolytic capacitor
C2—0.47-uF capacitor
Q1—2N3391 npn transistor
R1—10,000-ohm, ½-watt resistor
R2—15-ohm, ½-watt resistor
RX—See text



Just a handful of parts is all it takes to add up to 30 db gain for low-impedance microphone inputs found on tape recorders, CB rigs, etc. The circuit is suitable for mikes in the 50- to 1000-ohm range.

Because transistor Q1 is a high-gain type it is very sensitive to slight changes in base bias. Hence, bias resistor Rx must be tailored for each transistor. Temporarily connect a 2 megohm potentiometer in place of Rx and adjust the pot until the collector to ground voltage is 3V. Measure the pot's resistance and substitute a fixed resistor(s) within 10% of the measured value.

19 Stereo Balancer



It looks ridiculously simple, but this instrument will give you precise volume and tone control balance between left and right stereo amplifiers.

For maximum convenience, the meter is a zero-center type. Resistors should be at least five percent and the diodes a matched pair. Note that the lead for each side that goes directly to the meter is connected, preferably, to the ground or common speaker terminal (one for each channel).

Optimum stereo level and phase balance occurs for matched speakers when the meter indicates "0". If the meter indicates either side of zero, the levels are not matched or the wires are incorrectly phased. Check in-correct phasing by making certain the meter leads are connected to the amplifier ground terminals.

An ordinary 0-1 mA DC meter can be substituted. You adjust for zero reading, but keep in mind that the meter pointer can be driven in the reverse direction off-scale. Use only as much amplifier power as necessary for a visible meter indication.

PARTS LIST FOR STEREO BALANCER

D1, D2—1N60 diode
M1—1-0-1 mA DC meter, zero center
R1, R3—560-ohm, ½-watt resistor, 5%
R2—1000-ohm, ½-watt resistor, 5%

20 CB Modulation Meter

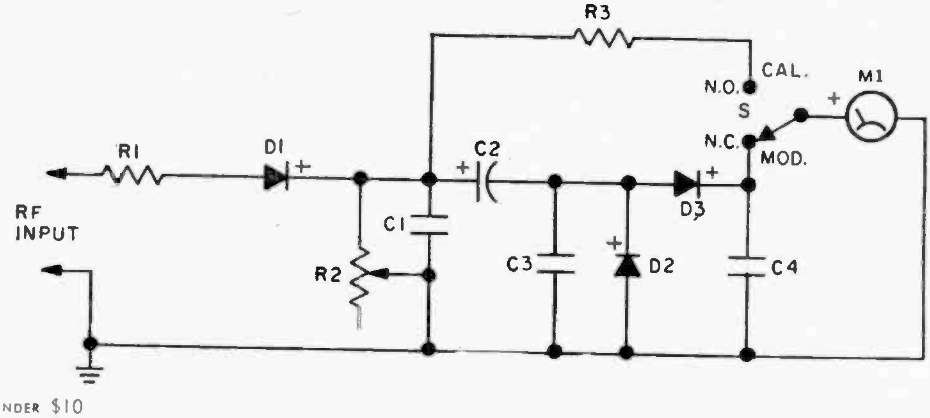
PARTS LIST FOR CB MODULATION METER

C1—500-pF, 100-VDC capacitor
C2—10-uF, 10-VDC electrolytic capacitor
C3—200-pF, 100-VDC capacitor
C4—300-pF, 100-VDC capacitor
D1, D2, D3—1N60 diode
M1—0-1 mA DC high-speed meter
R1—560-ohm, ½-watt resistor
R2—1000-ohm potentiometer
R3—910-ohm, ½-watt resistor, 5%
S1—Spdt spring-return switch

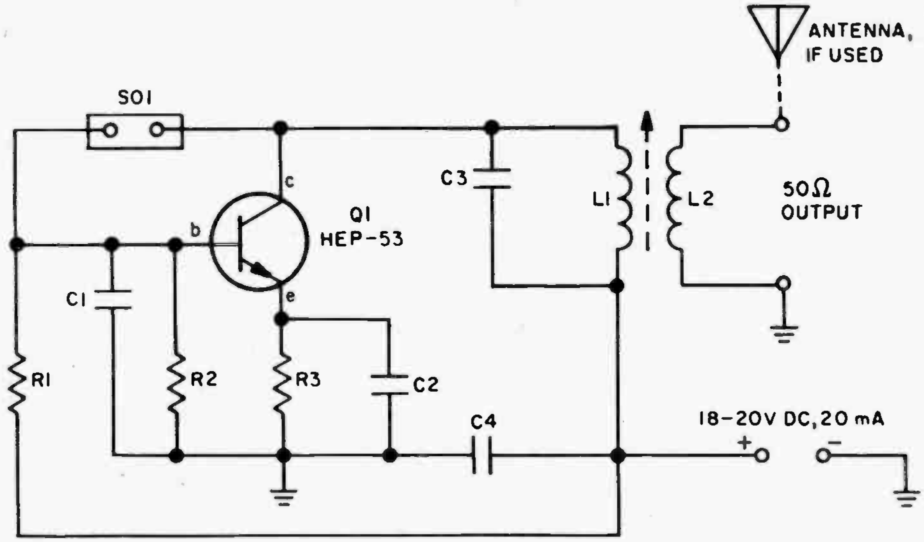
You can measure CB audio modulation percentage with the accuracy of the local broadcast station—'cause you'll be using the same type system.

In building the circuit, keep R1, D1 and R2's leads as short as possible. Meter M1 must be a high-speed model, such as the Alco P-1000 series. Connect the meter across the transceiver's RF output with a coaxial T-connector in the transmission line. As you key the transmitter, set switch S1 to *calibrate* and adjust R2 for a full scale reading. Accuracy will be within 10%.

Better accuracy is assured if R2's adjustment and meter calibrating point is compared against a scope modulation pattern. Don't compare this meter against commercial CB modulation meters. On a tone signal, this one is less accurate, but on speech modulation, the commercial models are not as accurate as a circuit of this type.



21 Multipurpose CB Oscillator



Utilizing 27 MHz overtone crystals, this low power oscillator provides precise frequency markers for CB transceiver dial calibration or for general receiver alignment. It can also serve as the transmitter for a 27 MHz radio-control circuit for remote camera tripping, models and other devices.

Coils L1 and L2 are wound on a J. W. Miller 4400-3 coil form having a 20-50 MHz powdered iron slug. Attach the end of a piece of No. 22 enameled wire to the coil terminal nearest the mounting screw and wind 15 close-spaced turns. Push the bottom terminal against the coil and solder the coil's free end to the bottom terminal. Then wind coil L2, which consists of 2 turns of No. 18 enameled wire, over the bottom end of L1. Twist L2's wires together to secure L2. Finally, cover the entire coil with coil dope and allow to dry overnight.

Plug in an overtone crystal at socket SO1 and adjust the coil's slug for maximum output as indicated on a field strength meter or a receiver's S-meter. The crystal frequency can be slightly shifted by small misalignment of the coil slug.

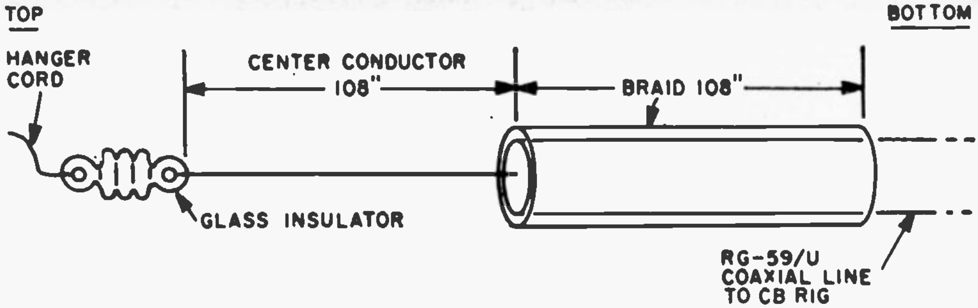
PARTS LIST FOR MULTIPURPOSE CB OSCILLATOR

C1—30-pF, 75-VDC disc capacitor
C2, C4—0.01-uF, 75-VDC disc capacitor
C3—22-pF, 100-VDC silver mica capacitor
L1—15 turns #22 enamel wire close-wound on 3/8-in. powdered iron slug form (J.W. Miller 4400-3)
L2—2 turns #18 enamel wire over cold end of L1
Q1—Motorola HEP-53 npn transistor
R1—10,000-ohm, 1/2-watt resistor
R2—680-ohm, 1/2-watt resistor
R3—180-ohm, 1/2-watt resistor
SO1—Crystal socket to match Xtal pins

22 Portable CB Antenna

A large antenna always beats the small one, so why use a dinky loaded whip for portable work? Make your own coaxial antenna from a length of RG-59U coaxial cable.

Cut away the outher insulation for 108 inches and fold the shield braid back along the cable. Attach a glass or ceramic insulator to the end of the center conductor and hang the antenna from a tree, roof, pole or window. Attach the lower end of the cable to your transceiver. Keep away from metal poles and buildings.



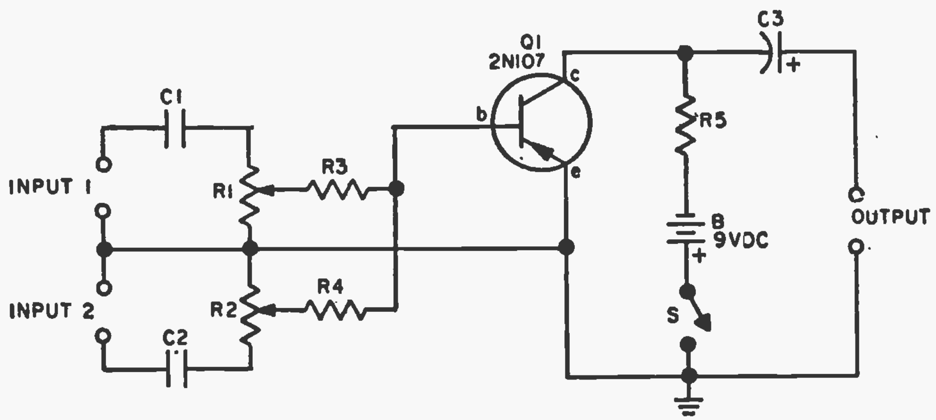
23 Junk Box Mike Mixer

Using components often found in an experimenter's junk box, this two-channel mike mixer handles high impedance or dynamic microphones. Level controls R1 and R2 should not be run wide open with hi-Z mikes since the input impedance then becomes the value of R3 and R4, or 100,000 ohms. If a hi-Z mike is loaded by less than 1 megohm, the low frequency response of the mike is attenuated.

Transistor Q1 can be almost any general purpose type such as the 2N107 or 2N217. However, the better the transistor, the better the signal-to-noise ratio. Top quality high-gain transistors should not be used since relatively high leakage current of experimenter-grade transistors provides the base bias current. Transistors with low leakage might produce high distortion because of low "internal" base bias.

PARTS LIST FOR JUNK BOX MIKE MIXER

- B1—9-V battery
- C1, C2—0.1-uF, 6-VDC capacitor
- C3—10-uF, 15-VDC electrolytic capacitor
- Q1—Pnp general purpose transistor, 2N107, 2N109, 2N217, etc.
- R1, R2—2-megohm audio taper potentiometer
- R3, R4—100,000-ohm, ½-watt resistor
- R5—15,000-ohm, ½-watt resistor
- S1—Spst switch

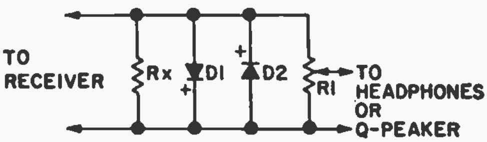


24 Headphone Limiter

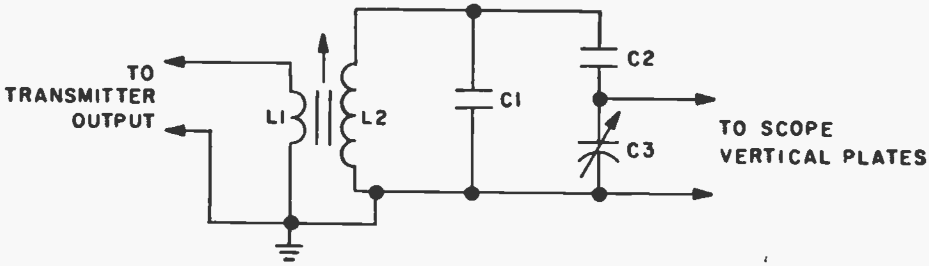
Most receivers don't provide automatic volume control on code reception. Thus a CW signal that blows your headphones off one moment might lie buried on the threshold of hearing the next. The Headphone Limiter chops those S9-100 signals down to size until they equalize with weaker signals, giving relatively constant headphone volume. Because the clipping action produces some distortion, the limiter should feed a headphone Q-peaker (described in another circuit). The value of Rx should match the existing speaker impedance and power. In most cases this will be equal to 4 times at 2-5 watts.

PARTS LIST FOR HEADPHONE LIMITER

- D1, D2—1N60 diode
- R1—5000-ohm audio taper potentiometer
- Rx—See text



25 CB Scope Booster



PARTS LIST FOR CB SCOPE BOOSTER

- C1, C2—5pF silver mica capacitor
- C3—45-pF trimmer capacitor
- L1—3 turns #22 solid, plastic-insulated wire, adjacent to ground end of L2
- L2—4 turns #18 enameled wire, centered on form
- 1—3/8-in. RF slug-tuned coil form (Lafayette 34E89135 or equiv.)

Critical inspection of a transmitter signal and accurate measurement of modulation is possible only with an oscilloscope. Unfortunately, a CB transmitter's RF output is so low the scope pattern is barely discernible —unless you use this booster. Since a scope's vertical plate connections operate at a high input impedance, it requires that a CB transmitter's output be fed to a parallel resonant circuit to step up to high RF voltage. The circuit shown will just about fill a 5-in. scope from edge to edge with virtually no loss at the transmitter.

First, wind L2 on the center of a 3/8-in. slug-tuned form. Then wind L1 adjacent to the ground end of L2. Connect L1 across the transmitter output with the CB antenna system also connected.

Adjust L1's slug for minimum standing-wave ratio (SWR). If the coil is correctly made, there should be no change in the antenna system's SWR. Adjust C3 for the desired scope trace height; it may be necessary to reset L1 each time C3 is adjusted.

Note that you must use your scope's vertical *plate* connection. The RF signal can't travel through the vertical amplifier unless your scope happens to cost a kilobuck or more.

26 CB Xmission Line Monitor

This monitor "steals" an insignificant amount of power, yet keeps constant watch on a CB rig's RF output. If a failing tube starts to drop the output, the line monitor immediaely lets you know it.

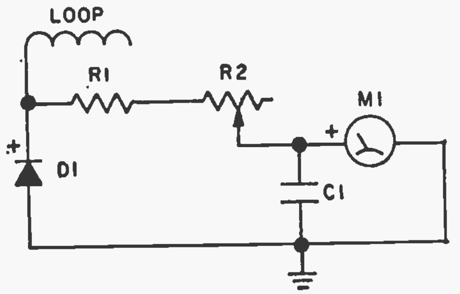
The device can be built in a separate metal cabinet or customized into the transceiver's cabinet.

Wiring between D1, R1, R2, and C1 must be as short as possible. The loop consists of four or five turns of insulated, solid hook-up wire wrapped around an exposed part of the output coax cable. Remove a part of the shield at that point; near RF output jack, for example. An alternate pickup is about 6 in. of wire slipped under the coax shield. If the shield is broken, solder a heavy copper wire to join the broken ends to avoid messing up your antenna transmission line.

Vary the number of turns in the loop to secure approximately half-scale meter indication. Potentiometer R1 serves as a coarse sensitivity control.

PARTS LIST FOR CB TRANSMISSION LINE MONITOR

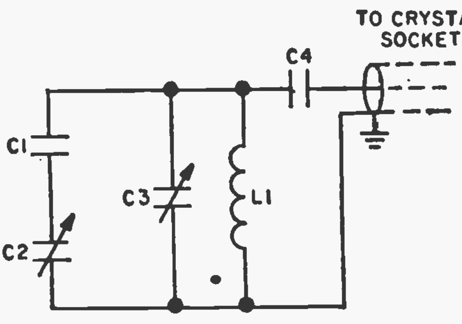
C1—0.001-uF, 100-VDC disc capacitor
D1—1N60 diode
M1—0-1 mA DC meter
R1—1500-ohm, ½-watt resistor
R2—10,000-ohm potentiometer



27 CB Tuning Adapter

PARTS LIST FOR CB TUNING ADAPTER

C1—10-pF silver mica capacitor
C2—17.5-pF trimmer capacitor
C3—30-pF variable capacitor
C4—47-pF, 100-VDC disc capacitor
L1—Coil, 5 turns #16 enameled wire wound on 1-in. dia. form. Spaced 1 in. end to end



A crystal-controlled CB rig with overtone crystals and an IF of 1300 to 1500 kHz can be converted to full 23-channel tuning with this adapter. It works on circuits where the crystal connects from oscillator grid to ground.

Use a 1-in. wood dowel for L1's form. Wind the coil as tightly as possible and stretch it to a length of 1 inch. Connection is made to the transceiver with the shortest possible length of RG-58A/U coaxial cable. The shield connects to the transceiver's chassis and to the bottom end of L1.

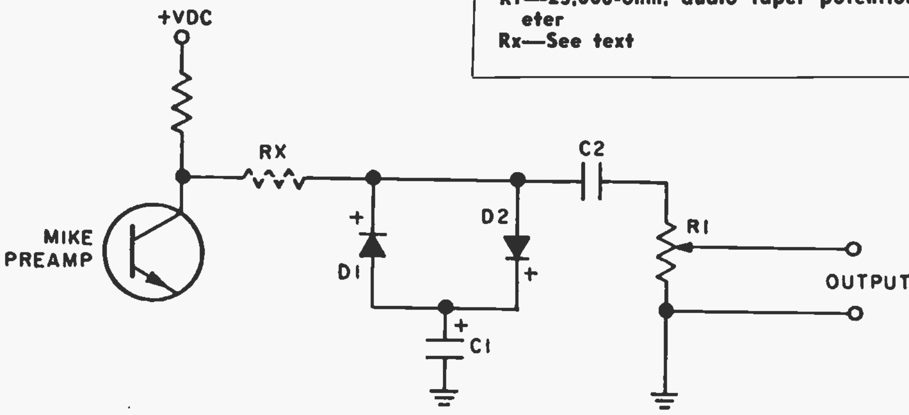
Set C3 so its plates are fully closed, then adjust C2 until channel 1 is received. Depending on the IF frequency, C3 might tune slightly more or less than the full band. If so, change C1's value very slightly to obtain only 23-channel coverage with C3. Making C1 smaller narrows the tuning range.

28 Speech Clipper

An effective speech clipper for transmitters and PA systems can be made from only two diodes and a capacitor.

Connect the diodes to the collector of the microphone preamplifier, the stage with at least a 1V peak-to-peak audio output voltage. The diodes clip at approximately .2V, allowing overall amplifier gain to be increased without speech peaks producing overmodulation or excess peak power output.

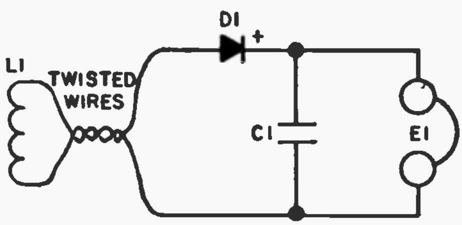
Capacitor C1's voltage rating must be at least equal to the DC supply voltage at the preamp collector. If the preamp uses a negative supply, reverse C1's polarity. The output level to the rest of the amplifier is determined by R1. If the diodes cause distortion in the preamplifier, add resistor Rx, as shown. Use the necessary value between 1000 and 10,000 ohms.



PARTS LIST FOR SPEECH CLIPPER

C1—100-uF electrolytic capacitor (see text)
C2—0.1-uF capacitor
D1, D2—1N60 diode
R1—25,000-ohm, audio taper potentiometer
Rx—See text

29 Modulation Monitor



PARTS LIST FOR MODULATION MONITOR

C1—100-pF disc capacitor
D1—1N60 diode
E1—Magnetic headphone, 2000 ohms or better
L1—Coil, 3 turns on 1½-in. dia. form, use any thin gauge wire

This simple modulation monitor for AM ham transmitters requires no connection to the transmitter. Just position the loop near the final tank or antenna matching coil until the signal is heard in the headphones.

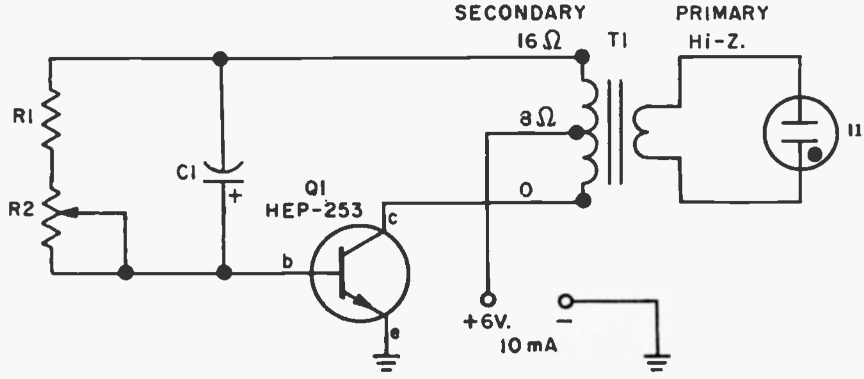
30 Mini-Drain Pilot Lamp

PARTS LIST FOR MINI-DRAIN PILOT LAMP

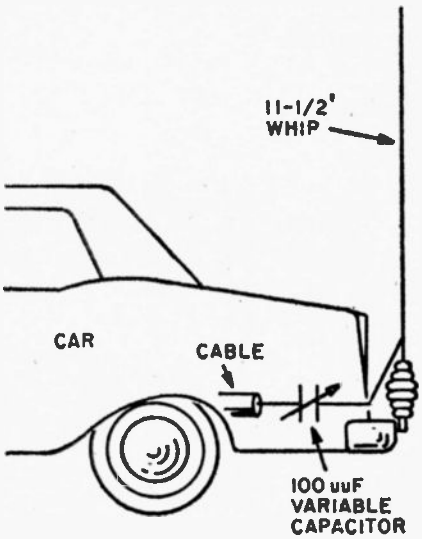
C1—3-uF, 25-VDC capacitor
I1—NE-2 neon lamp
Q1—Motorola HEP-253 pnp transistor
R1—100,000-ohm, ½-watt resistor
R2—250,000-ohm, potentiometer
T1—Miniature center-tapped transistor audio transformer; primary 4000-ohm to 8-16-ohm secondary

Need a pilot light for portable equipment that won't burn up batteries in minutes? Then try high frequency for the answer. Here's how it works: Q1 serves as a blocking oscillator with the frequency determined by R1-R2 and C1. The collector Q1 connects to T1's common (O) terminal, the power source to the 8-ohm terminal and R1-C1 to the 16-ohm terminal. Note that in this circuit the usual primary and secondary transformer windings are shown in reverse position. It's because the transformer is being used backwards. The neon lamp connects to the high-impedance winding of T1. If the primary is center-tapped, ignore the tap.

As Q1 oscillates at AF frequency, voltage from Q1's collector to the power supply is stepped up many times and becomes a high-voltage low-current source for the neon lamp. Adjust R2 so the frequency is high enough to keep the lamp constantly lit. If you want a warning device, potentiometer R2 can be adjusted so the neon lamp blinks on and off at a rapid rate.



31 Extended CB Antenna



The average 108-in. CB bumper or fender-mounted whip is nowhere near the desired 52 chms impedance. An improved transmission line match and lower angle of radiation (and more gain) are obtained by using an 11½-ft. extended whip. The extended whip, however, isn't resonant on the CB band and must be electrically shortened. It's done by connecting a small variable capacitor between the bottom of the antenna and the coax cable center conductor. Adjust the capacitor for lowest SWR reading.

32 Light Flasher

If a light blinks and winks someone will stop and look—and that's the purpose behind this attention-grabber.

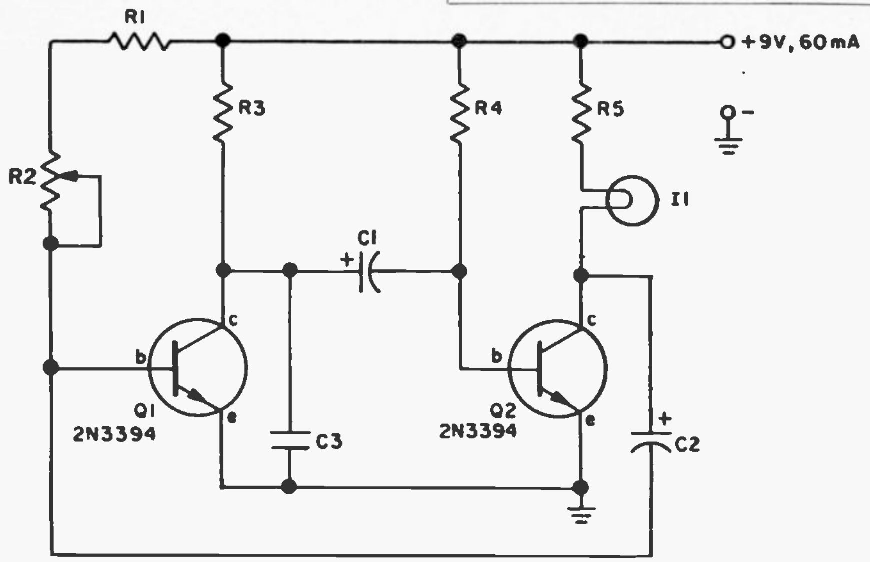
When power is first applied, current flows through Q2 and lamp L1 lignts. Then, feedback through capacitor C2 causes Q1 to conduct. As C1 discharges through Q2's base, Q2 is turned off, thereby extinguishing the lamp. When C1's voltage equalizes, Q2 turns on again and the cycle is repeated

. . . flip-flop, flip-flop. Potentiometer R2 determines the flip-flop rate, hence, the blink rate.

"Junk box" pnp transistors (instead of npn types) can be substituted if polarity is reversed at the battery, C1 and C2.

PARTS LIST FOR LIGHT FLASHER

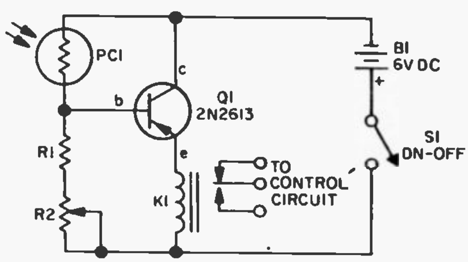
C1—10-uF, 15-VDC electrolytic capacitor
C2—30-uF, 15-VDC electrolytic capacitor
C3—0.2-uF, 25-VDC capacitor
I1—No. 49 panel lamp
Q1, Q2—2N3394 npn transistor
R1—4700-ohm, 1/2-watt resistor
R2—1-megohm potentiometer
R3, R4—10,000-ohm, 1/2-watt resistor
R5—120-ohm, 1/2-watt resistor



33 Control by Light

PARTS LIST FOR CONTROL BY LIGHT

B1—6-V battery
K1—1000-ohm, 2-3 mA sensitive relay
PC1—RCA 4425 photocell
Q1—2N2613 pnp transistor
R1—120-ohm, 1/2-watt resistor
R2—5000-ohm potentiometer
S1—Spst switch



With only a handful of low-cost components this photo relay turns a light on or off according general room illuminaion.

Q1 can be any general purpose pnp transistor of the 2N109 or 2N217 variety, though greater sensitivity is obtained with the 2N2613 type. Relay K1 is a high-sensitivity type like the Sigmas used by model radio control hobbyists.

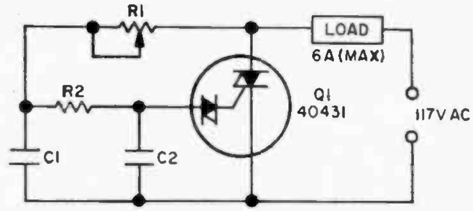
Potentiometer R2, part of a voltage divider consisting of photocell PC1, R1 and R2, is set so that with normal illumination falling on PC1 the base bias current (through PC1) is just below the value needed to generate the collector-emitter current required to activate relay K1. When additional light falls on PC1, photocell resistance decreases, thereby increasing the base bias, which causes greater collector current to flow and the relay closes.

This circuit can be controlled by sunlight so K1 drops out at dusk to turn on a night light. Or use a flashlight to trip K1 for "killing" TV commercials by shorting the TV speaker connections.

34 Motor Speed Control

PARTS LIST FOR MOTOR SPEED CONTROL

C1, C2—0.1-uF, 200-VDC capacitor
G1—RCA 40431 Triac-Diac
R1—100,000-ohm linear taper potentiometer
R2—10,000-ohm, 1-watt resistor



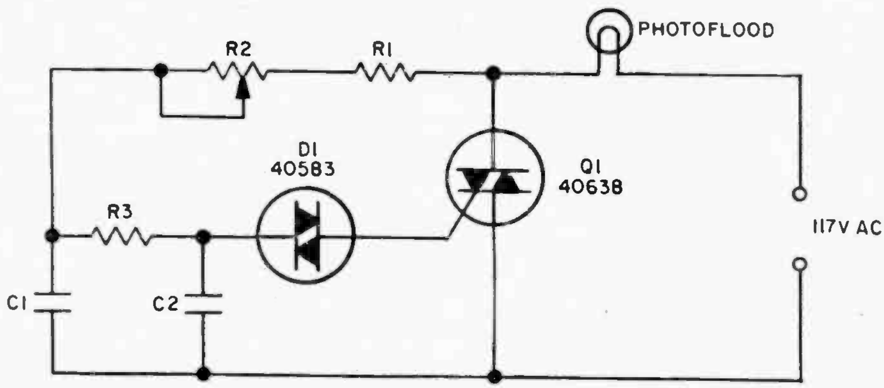
Old universal appliance motors and shaded-pole induction motors salvaged from inexpensive turntables can be easily converted to slow-speed hobby drills, chemical stirrers, vari-speed turntables movable display drives, etc. It's done with a full-wave Triac speed controller.

Unlike other speed controllers, which require an external trigger device, Q1 combines both the Triac and Diac trigger diode in the same case.

The motor used for the load must be limited to 6 amperes maximum (or 740 watts). Triac Q1 must be provided with a heat sink, which can be the metal cabinet. Build up a marble-size mound of epoxy on the cabinet and insert Q1's case into the epoxy. When the epoxy hardens the Triac's heat is dissipated to the cabinet. Make certain Q1's case is not shorted to the cabinet and is insulated by the epoxy.

With the component values shown on the parts list, the Triac controls motor speed from full *off* to full *on*.

35 Photoflood Dimmer



All the flexibility of a professional photo studio's variable lighting can be yours with this 500-watt lamp dimmer.

Triac Q1 is supplied with a heat sink which must, in turn, be connected to a larger heat sink. The entire unit is assembled in a metal cabinet with Q1's heat sink epoxy-cemented to the cabinet for heat dissipation.

Fusing must be employed. Otherwise, the surge current when 500-watt photo lamps burn out will instantly destroy Q1. Connect an 8AG (fast-action) 5-ampere fuse in series with the lamp or any other fuse of equal action, or faster. In this circuit 3 AG fuses cannot be used.

Potentiometer R2 will adjust the lamp's intensity from full *off* to essentially 100% full *on*.

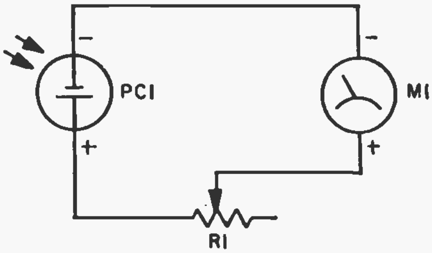
PARTS LIST FOR PHOTOFLOOD DIMMER

C1, C2—0.01-uF, 300-VDC capacitor
D1—RCA 40583 Diac
Q1—RCA 40638 Triac
R1—1000-ohm, ½-watt resistor
R2—100,000-ohm linear taper potentiometer
R3—15,000-ohm, ½-watt resistor

36 Enlarger Meter

PARTS LIST FOR ENLARGER METER

M1—100, 250, or 500-mA DC meter
PC1—Solar cell (Radio Shack 27-1710)
R1—5000-ohm potentiometer linear taper



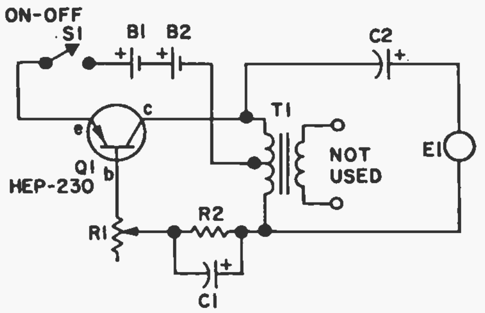
Every print a good print! That's what you get with the Enlarger Meter.

Meter M1 can be just about anything up to 0·1 DC mA. But ii you prefer low light levels and long exposures, install a sensitive meter of 500 uA or less.

When light from the enlarger falls on the solar cell (PC1), a voltage is generated that is in porportion to the amount of light. Sensitivity control R1 allows the user to set the meter indication to a convenient value.

To use the meter, first make a good normal print in your normal manner from a No. 2 or No. 3 negative. Then, do not disturb the enlarger setting, but integrate the light by placing a diffusing disc or opal glass under the lens. Place the solar cell on the easel and adjust R1 for a convenient meter reading, say, full scale. The meter is now calibrated. When using it, focus the enlarger, use the diffuser, and adjust the lens diaphragm until you get the reference meter reading. Then use the exposure time previously found for the calibration print. Suggested reading: Ilford annual of Photography, obtainable from any photo store. Also, check Kodak publications available at the same place.

37 Fish Caller



PARTS LIST FOR FISH CALLER

B1, B2—1.5-V AAA battery
C1, C2—50-uF, 25-VDC electrolytic capacitor
E1—Crystal earphone
Q1—Motorola HEP-230 pnp transistor
R1—2500-ohm potentiometer
R2—27,000-ohm, ¼-watt resistor
S1—Spst switch, part of R1
T1—Subminiature transistor output transformer: 500-ohm center tapped primary to 3.2-ohm secondary

Click-click might not sound like much to you but to a fish it's the dinner bell. That's the lure of this electronic circuit. Shove the whole works in a watertight container, lower it over the side, and wait for the fish to hit the hooks.

For proper operation T1 must be subminiature type about half as large as your thumb. E1 must be a crystal headphone (supplied with some transistor radios).

38 Light Comparator

The Light Comparator will check or adjust two light sources for equal intensity. The metering circuit is a balanced bridge consisting of R2, R3, Q1, and Q2. With solar

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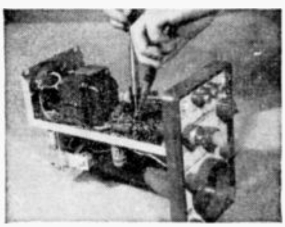
Construction of Oscilloscope.



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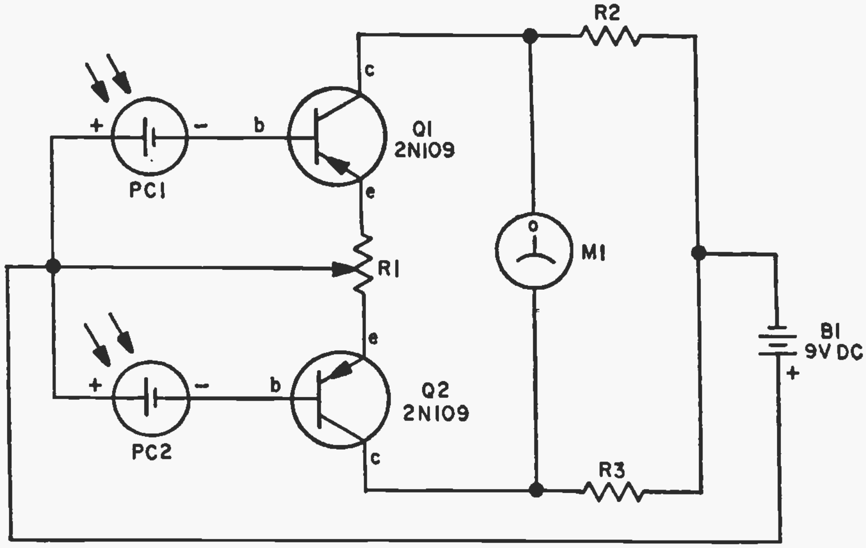
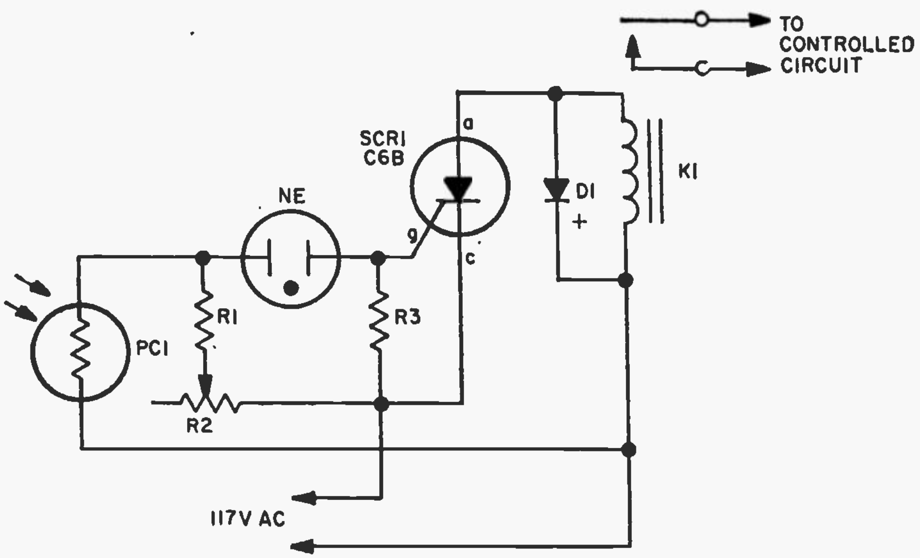
☐ Check here if interested in Classroom Training cells PC1 and PC2 exposed to the same light source, balance control R1 is adjusted for zero indication on the meter. In operation, unequal light falling on the cells changes the base bias of the transistors. This upsets the collector currents, causing the meter to indicate.

PARTS LIST FOR LIGHT COMPARATOR

B1—9-V battery
M1—1-0-1 mA DC meter, zero center
PC1, PC2—Solar cell
Q1, Q2—2N109 pnp transistor
R1—5000-ohm potentiometer
R2, R3—1000-ohm, ½-watt resistor



39 Light-Controlled Switch



A flashlight beam stabs out—the irritating TV commercial for underarm deodorant vanishes. Moments later, when the program returns, the flashlight beam stabs out again. The sound snaps back on. Between the flashlight and TV speaker circuit is the light-controlled switch.

When a beam of light strikes the photocell, the voltage across neon lamp NE-1 rises sharply. When conduction voltage is reached NE-1 turns on and fires the SCR. K1 is an impulse relay whose contacts stay in position even after coil current is removed. So the first impulse opens K1's contacts, the second impulse closes them, etc. To prevent ambient light from tripping the photocell, it should be recessed at least an inch inside a metal or cardboard tube.

PARTS LIST FOR LIGHT-CONTROLLED SWITCH

D1—200-PIV silicon diode
K1—Guardian IR-610L-A115 latching relay
NE—NE-83 neon lamp
PC1—Clairex CL505 for high light level; CL704 or CL705 for low light level
R1—22,000-ohm, ½-watt resistor
R2—1-megohm potentiometer
R3—100-ohm, ½-watt resistor
SCR1—GEC6B silicon-controlled rectifier

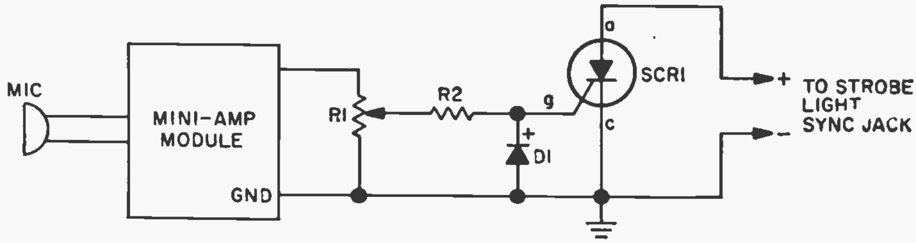
40 Stop Motion

PARTS LIST FOR STOP MOTION

D1—Motorola HEP-154 50-PIV silicon rectifier
MIC—Ceramic microphone
R1—5000-ohm potentiometer
R2—2700-ohm, ½-watt resistor
SCR1—GE C5G silicon-controlled rectifier

You, too, can take strobe-flash pictures the instant a pin pricks a balloon, a hammer breaks a lamp bulb or a bullet leaves a gun. You'll need a mini-amp—one of those transistor amplifier modules of 1-watt rating or less. *It must have an output transformer.* Don't use an "OTL" (no transformer) amplifier. The amplifier is terminated with a resistor on its highest output impedance, preferably 16 ohms. Make certain the connections to the strobe flash sync terminals are correctly polarized.

Darken the room lights, open the camera shutter and break a lamp bulb with a hammer. The sound of the hammer striking the lamp will trigger the flash, and the picture will have been taken at that instant.



41 Hot Crystal Radio

That old favorite, the crystal radio, becomes more than just a weak voice buried in the headphone when it's amplified with a "junk box" amplifier.

Transistor Q1 can be just about any general purpose pnp germanium type such as the 2N107, 2N109, etc. The SK3003 specified gives a little extra gain.

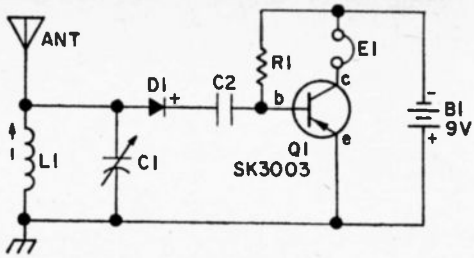
L1 is any ferrite antenna coil for the broadcast band, while E1 must be a magnetic headset for maximum output level. To align the receiver, set C1's dial to the known frequency of a strong local station and adjust L1's slug until you hear the station in the phones.

For reception of weaker signals the receiver should be connected to an earth ground such as the cold water pipe. The longer the antenna, the better the reception. Try 20 feet or more.

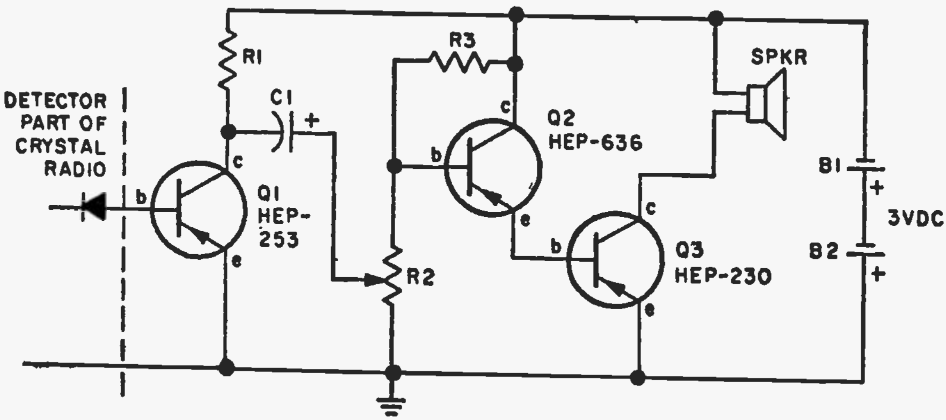
To feed the radio's output into an amplifier and speaker, replace the headphone with a 1000-ohm ½-watt resistor. Connect a .1 mfd, 25VDC capacitor from Q1's collector to the amplifier input. Then be sure to connect radio's ground to the amplifier ground.

PARTS LIST FOR HOT CRYSTAL RADIO

B1—9-V battery
C1—365-pF tuning capacitor
C2—0.2-uF, 10-VDC capacitor
D1—1N60 diode
E1—1000-3000-ohm impedance magnetic earphone
L1—Ferrite antenna coil
Q1—SK3003 pnp transistor
R1—100,000-ohm, ½-watt resistor



42 Crystal Radio Amplifier



Even with junk box parts, this three-stage OTL (Output Transformerless) amplifier will produce table-radio volume from a simple crystal detector.

Note the unusual connection for volume control R2. This arrangement is used because the end-to-end resistance of R2 is part of R3's base bias divider. The only critical connection is between Q1's base and the detector diode in the crystal radio. Transistor Q1's base must connect to the detector's anode, as shown. If the diode is presently wired in the crystal radio so that the output is taken from the cathode end (marked "T"), reverse the diode's polarity. It will have no effect on the radio's operation.

Any general-purpose transistors equivalent to those specified can be used.

PARTS LIST FOR CRYSTAL RADIO AMPLIFIER

B1, B2—1.5-V D battery
C1—6-uF, 6-VDC electrolytic capacitor
Q1—Motorola HEP-253 pnp transistor
Q2—Motorola HEP-636 pnp transistor
Q3—Motorola HEP-230 pnp transistor
R1—10,000-ohm, ½-watt resistor
R2—10,000-ohm potentiometer
R3—100,000-ohm, ½-watt resistor
SPKR—3.2-ohm speaker

43 Broadcast Band Booster

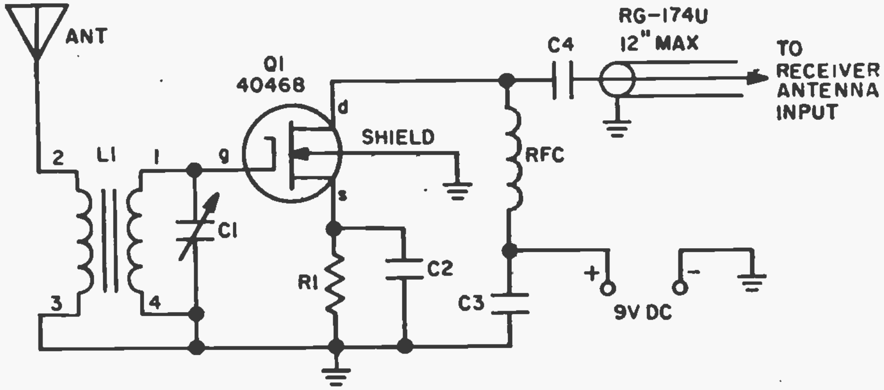
Signals you never knew existed can be dug out from under the "dead" spaces of your BC radio dial with this one-evening project. The high input impedance of the FET (field effect transistor) does not load down the antenna coil, hence, an overall circuit gain of some 3 to 5 S-units.

L1 is connected using the terminal arrangement given in the instructions provided with the coil. Capacitor C1 is any 365 uuf tuning capacitor; one salvaged from an old radio or one of the low-cost miniatures. The RF choke (RFC) must be no larger than 1 mH or the unit will break into oscillation across most of the BC band. Connection from the booster can be through a plug and jack, but the connecting cable, made of RG-174U coaxial cable, must be no longer than 12 inches or severe signal attenuation will result.

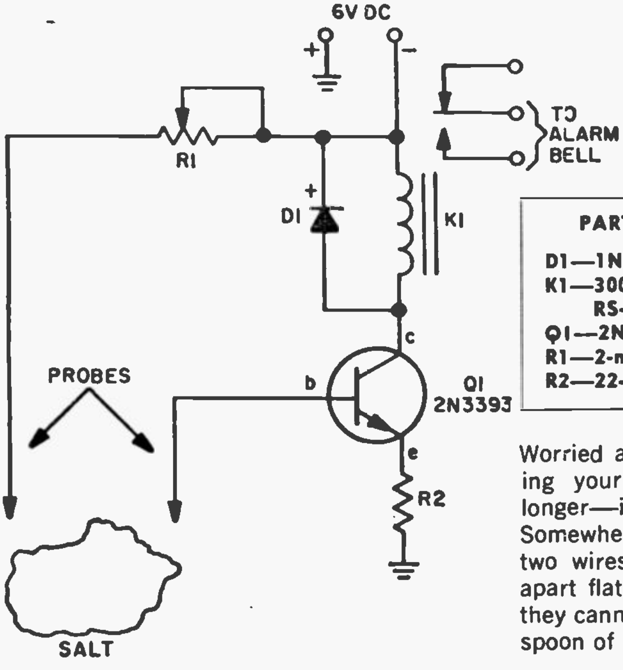
The high gain of the booster can cause oscillation if the output cable gets near the antenna. For best results, assemble the booster in a metal cabinet and ground the cabinet to a cold water pipe. If the BC receiver is the AC/DC type, connect a .05 uf, 400 VDC capacitor between the output cable shield and the receiver's ground.

PARTS LIST FOR BC BAND BOOSTER

C1—365-pF tuning capacitor
C2, C3—0.05-uF, 25-VDC capacitor
C4—100-pF, 100-VDC disc capacitor
L1—Broadcast band antenna coil (J.W. Miller A-5495A)
Q1—RCA 40468 FET transistor
R1—1000-ohm, ½-watt resistor, 10%
RFC—1-mH RF choke



44 Flood Alarm



PARTS LIST FOR FLOOD ALARM

D1—1N60 diode
K1—300-ohm, 6-VDC relay (P&B type RS-5D-6)
Q1—2N3393 npn transistor
R1—2-megohm potentiometer
R2—22-ohm, ½-watt resistor

Worried about water in the basement ruining your electronic equipment? Fear no longer—if you use a flood alarm.

Somewhere near the water pipes, position two wires spaced approximately one inch apart flat on the floor. Secure the wires so they cannot be moved. Place about one teaspoon of salt between the wires. If the floor is cement, mount wires and salt on a sheet of plastic because the salt can affect the cement.

When water comes in contact with the salt, current flows between the wires, completing Q1's base bias circuit. Collector current in Q1 will cause K1 to close, whose contacts ring an alarm bell. To set up the circuit, apply water to a test mound of salt and adjust R1 until K1 closes.

45 Direct-Coupled Radio

PARTS LIST FOR DIRECT-COUPLED RADIO

- **B1, B2—1.5-V battery**
- **C1—365-pF variable capacitor**
- **E1—2500-5000 ohm earphone**
- **L1—Tapped ferrite antenna coil**
- **Q1, Q3—Motorola HEP-641 npn transistor**
- **Q2—Motorola HEP-253 pnp transistor**
- **R1—5000-ohm potentiometer**
- **R2—100-ohm, ½-watt resistor**

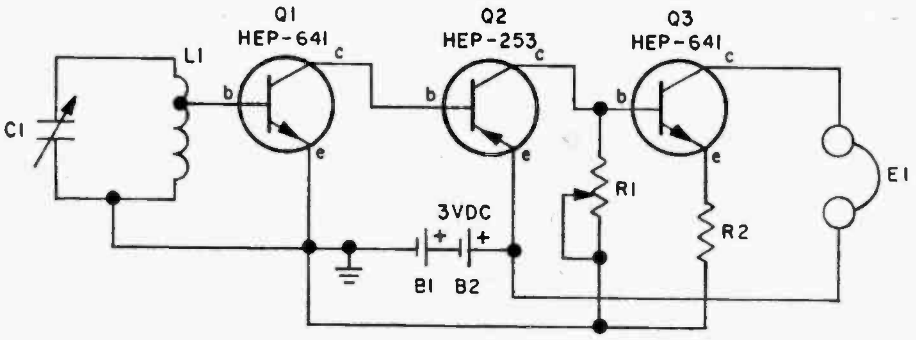
A shirt-pocket project, this direct-coupled radio uses transistor Q1 as a diode detector and first audio amplifier. Detection is across the base-emitter junction which operates as a diode. Normal base-emitter capacitance provides RF filtering. L1 can be a tapped (transistor type) ferrite antenna coil. Tuning capacitor C1 is a miniature *poly*-type variable.

Earphone E can be magnetic or crystal as long as its impedance is in the 2500- to 5000-ohm range.

Control R1 is adjusted for best earphone sound—or least distortion consistent with maximum volume.

During construction, carefully note that npn and pnp transistors are used. Don't intermix them since reverse polarity voltage can destroy a transistor.

Batteries B1 and B2 are the penlight (AAA) type—good for many hours of service.



46 Metronome Timer

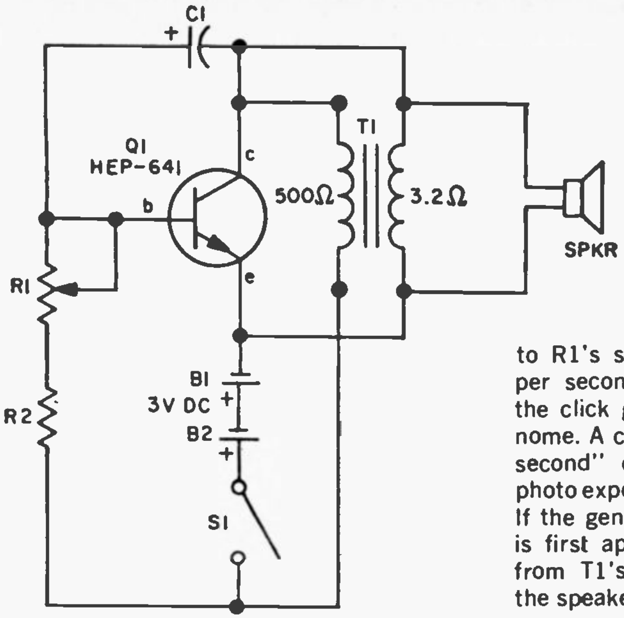
PARTS LIST FOR METRONOME TIMER

- **B1, B2—1.5-V D battery**
- **C1—10-uF, 6-VDC electrolytic capacitor**
- **Q1—Motorola HEP-641 npn transistor**
- **R1—1-megohm potentiometer**
- **R2—7500-ohm, ½-watt resistor**
- **S1—Spst switch**
- **SPKR—3.2-ohm, 2½-in. dia. speaker**
- **T1—50 to 3.2 ohm miniature audio transistor transformer**

Providing equally spaced clicks from 3 to 300 per minute, this click generator is either an electronic metronome or an interval timer, say, for photo enlarging.

Transistor Q1 functions as an amplifier, but positive feedback from T1's secondary to Q1's base causes the circuit to regenerate. This produces a steady stream of clicks in the speaker. The rate of oscillation, or number of clicks per minute, is determined by R1's setting.

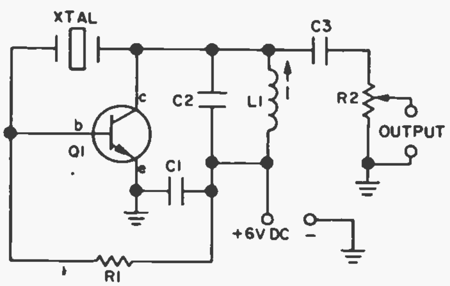
With a little time and patience, a dial affixed



to R1's shaft can be calibrated in "beats per second" by comparing the output of the click generator with a standard metronome. A calibration point for "one click per second" can be marked on the dial for photo exposure control.

If the generator does not click when power is first applied, interchange the two leads from T1's secondary. Do not interchange the speaker leads!

47 Simple IF Signal Generator



PARTS LIST FOR SIMPLE IF SIGNAL GENERATOR

C1—0.05-uF, 25-VDC capacitor
C2—50-pF silver mica capacitor
C3—15-pF silver mica capacitor
L1—3.4-5.8 mH RF coil (J.W. Miller 21A473RB1)
Q1—GE-5 npn transistor
R1—330,000-ohm, ½-watt resistor
R2—5000-ohm, potentiometer
XTL—455-kHz crystal

Using a 455-kHz crystal, this generator provides a signal for testing and aligning radio IF circuits. The unit is built on a perfboard or some other rigid mounting to achieve good circuit stability. A metal cabinet reduces radiation so the signal fed to the receiver will be primarily determined by level control R2.

To align the completed circuit, adjust L1's slug for maximum S-meter reading in a receiver or connect R2 to an oscilloscope and adjust L1 for maximum output.

Turn the power supply on and off several times to make certain the oscillator starts consistently. If the oscillator fails to start every time, adjust L1's slug *slightly* until you obtain immediate and consistent starting each time the power is applied.

48 Radio Pager

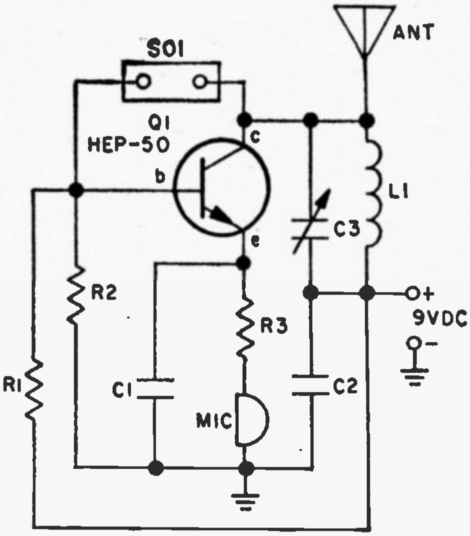
Small enough to fit into a cigarette pack, this pocket pager produces a low-output signal on the Citizen's Band (27 MHz) suitable for paging inside a building. The signal is strong enough to be heard on a standard transceiver, but not enough to cause receiver overload.

If only one crystal frequency is needed, socket SO1 can be eliminated and an overtone type crystal soldered directly into the circuit. Salvage crystals from junked units.

The whip antenna is a standard walkie-talkie three-section replacement type. The carbon microphone can be a telephone transmitter. You may want to use the portable CB antenna described in circuit 22 on page 26 or Extended CB Antenna in circuit 31 on page 31.

To tune; receive the signal on an S-meter-equipped receiver and adjust trimmer C3 for maximum output. Key the transmitter a few times to check crystal activity. If starting is intermittent, slightly alter C3's adjustment until operation is consistent.

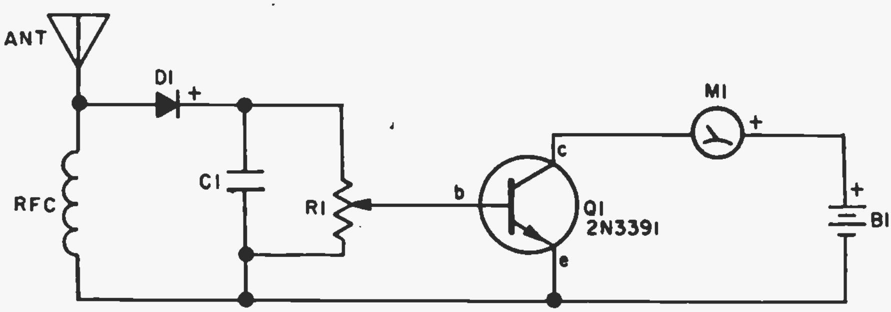
The power supply can be a standard 9V (2U6 type) battery.



PARTS LIST FOR RADIO PAGER

C1, C2—0.001-uF, 100-VDC disc capacitor
C3—50-pF trimmer capacitor
L1—10 turns #16 enameled wire wound on 3/8-in. form, spaced 1 in. end to end
MIC—Carbon microphone element
Q1—Motorola HEP-50 npn transistor
R1—47,000-ohm, 1/2-watt resistor
R2—10,000-ohm, 1/2-watt resistor
R3—330-ohm, 1/2-watt resistor
SO1—Crystal socket

49 Supersensitive FSM



PARTS LIST FOR SUPERSENSITIVE FSM

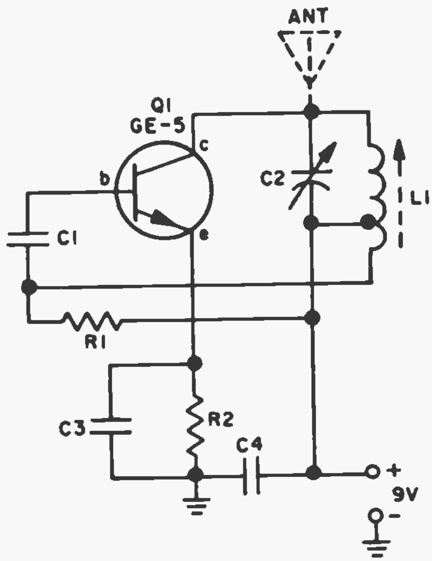
B1—1.5-V battery
C1—0.001-uF, 100-VDC capacitor
D1—1N60 diode
M1—0-1 mA DC meter
Q1—2N3391 npn transistor
R1—50,000-ohm potentiometer
RFC—2.5-mH choke

A kilowatt transmitter may pin the needle of regular FSMs (field strength meters), but you need high sensitivity to get readings from low-power oscillators, flea power transmitters and CB walkie-talkies. This simple, amplified FSM has a sensitivity of 150 to 300 times that of ordinary models. It indicates full scale when other meters can't budge off the pin.

Dependable frequency range is approximately 3 to 30 MHz. A metal enclosure is recommended, with a stiff wire antenna about 6 in. long. For compactness, RFC should be a miniature 2.5-mH choke.

To operate the unit, sensitivity control R1 is adjusted for ⅓ to ¾-scale reading. Avoid working too close to the top of the scale, since it can saturate transistor Q1, producing full-scale readings at all times. Back off on R1 as you make transmitter adjustments to keep the needle at approximately half scale. Any high-gain npn small-signal transistor can be substituted for Q1.

50 BFO for Transistor Radio



Placed near a multiband transistor portable, this BFO allows reception of CW and SSB signals in addition to the normal reception.

The BFO is a Hartley oscillator tunable across the broadcast band. Oscillator harmonics extend to the higher shortwave frequencies where they "beat" against CW and SSB stations. It provides standard BFO tone reception of CW signals and reasonably good reception on moderate to strong SSB signals.

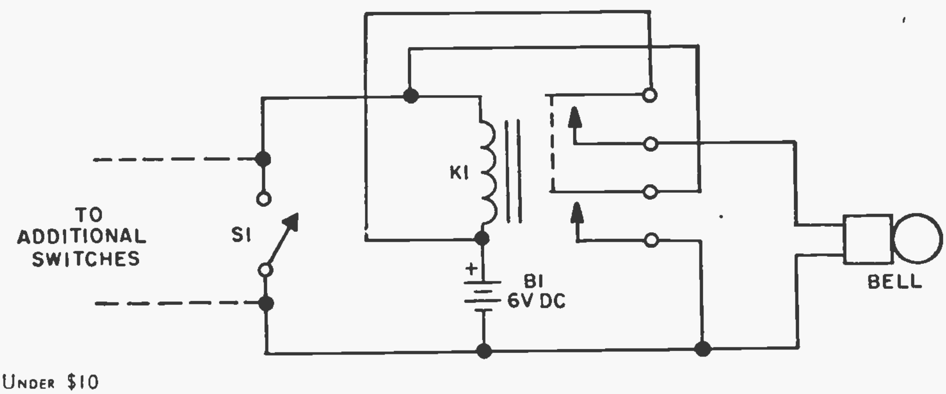
Once C2 is adjusted to the proper beat frequency, the BFO is positioned near the transistor radio for optimum reception. No antenna is needed if the unit is assembled in a plastic cabinet.

The BFO can also be used as a radio-type code practice oscillator with a range of approxmately 20 feet. Connect a 10-ft. antenna on a nearby BC radio. To send Morse code, insert a key in series with one battery lead.

PARTS LIST FOR BFO FOR TRANSISTOR RADIO

C1, C3, C4—0.05uF, 25-VDC capacitor
C2—360-pF variable capacitor
L1—Tapped BC antenna coil
Q1—GE-5 transistor
R1—2200-ohm, ½-watt resistor
R2—68-ohm, ½-watt resistor

51 Latching Burglar Alarm



PARTS LIST FOR LATCHING BURGLAR ALARM

B1—6-V lantern battery
BELL—6-VDC alarm bell
K1—6-VDC dpst relay
S1—Spst n.o. switch

Open a fancy commercial burglar alarm and all you'll find inside is this ordinary relay latching circuit.

The input terminals are connected to parallel-wired normally open (N.O.) magnetic switches, or wire-type security switches stretched across a window that close a ball contact circuit when the wire is pushed or pulled.

When a security switch closes the series battery circuit, relay K1 pulls in. One set of contacts close the alarm bell circuit, while the second set "latches" the battery circuit. Even if the security switches are opened, the alarm remains on. To disable the alarm, or for reset, install a concealed switch in series with one battery lead.

52 3-Way Tone Generator

Add a terminal or two and an ordinary CPO (code practice oscillator) becomes a three-way threat, serving as a CPO, tone enerator or intruder alarm.

The circuit is a Harley oscillator whose tone is determined by R2's value. Just about any wiring or layout will work, but transformer T1 must be the type used in table radios. A miniature transistor transformer might not oscillate, or if it does, will produce only "clean" high tones, with no raucous or low frequency tones.

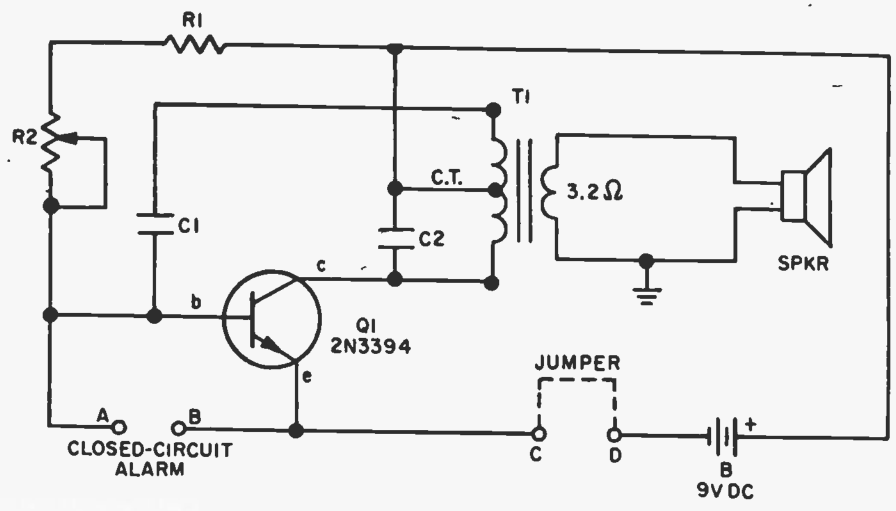
For CPO operation connect a hand key across points C and D. For a "make" intruder alarm, connect one or more normally open magnetic switches across points C and D. For a "break" intruder alarm connect a jumper across C and D and connect a series wire circuit across A and B, which disables the oscillator though power is applied. An intruder breaking the series circuit, or a normally closed magnetic switch, causes the alarm to sound off.

For use as a signal generator, connect C and D and attach a shielded test signal lead directly across the speaker terminals.

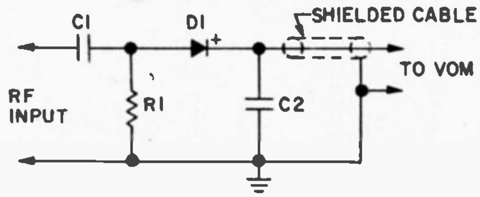
Service Note: If the unit fails to oscillate, generally due to transistor differences, change C2's value slightly.

PARTS LIST FOR THREE-WAY TONE GENERATOR

B1—9-V battery
C1, C2—0.02-uF, 25-VDC capacitor
Q1—2N3394 npn transistor
R1—10,000-ohm, 1/2-watt resistor
R2—250,000-ohm potentiometer
SPKR—3.2-ohm speaker
T1—Output transformer: 5000-ohm, center-tapped primary to 3.2-ohm secondary (must not be miniature transistor type)



53 RF Probe for VOM



PARTS LIST FOR RF PROBE FOR VOM

C1—500-pF, 400-VDC capacitor
C2—0.001-uF, disc capacitor
D1—1N60 diode
R1—15,000-ohm, ½-watt resistor

Assemble this accessory in a metal can, add a shielded cable and you'll make relative measurements of RF voltages to 200 MHz on a 20,000 ohms-per-volt multimeter. R voltage must not exceed approximately 30V, the breakdown rating of the 1N60 diode.

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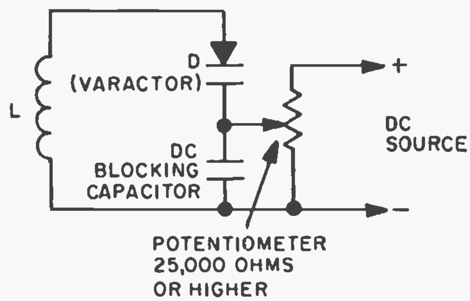
54 Electronic Tuning

We can't assign specific values because each case is different. But here's how to use varactors for electronic tuning. The varactor is a diode whose capacitance between anode and cathode is determined by an applied voltage. If a varactor is substituted for a tuning capacitor in an LC resonant circuit, the tuned frequency is determined by the applied voltage.

L1 and D1 form an LC parallel resonant circuit. The DC blocking capacitor, which prevents the power supply from shorting to ground, must equal zero impedance at the tuned frequency; its reactance should be at least 20 times the maximum value of D1. In effect, the blocking capacitor is a short to an AC signal and the external circuit "sees" only L1 and D1.

The appropriate diode can be selected from catalogs which list the voltage capacity ratio for different varactors. No Parts List offered for this project because of its special application to a particular tuner and design consideration.



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55 Appliance Tester

PARTS LIST FOR APPLIANCE TESTER

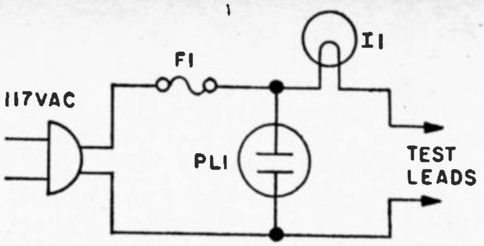
F1—Fuse to match load
I1—50-watt lamp
PL1—AC receptacle

A simple circuit consisting of a 50 watt lamp, fuse and power outlet is all that's needed to check out appliances such as toasters and electric coffee pots.

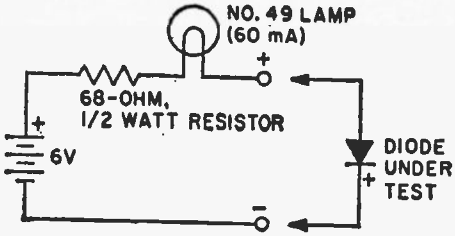
To check for opens, first plug the tester into a live outlet. Next, connect the test leads to the appliance's power cord; if the lamp lights the circuit is good (not open). Because the appliance is in series with the lamp the lamp may not light to full brilliance. You are only interested in whether the lamp lights at all—not the level of brilliance.

If you suspect there is a short from the appliance's motor or heating coil to the appliance frame which can cause a shock hazard, connect one test lead to the appliance frame and connect the other test lead first to one prong of the appliance's plug and then to the other prong. If the lamp lights

with either connection there is a short to the frame. If the lamp fails to light at all, the appliance frame is safe.
After the repair is made try out the appliance by using the fused power outlet, PL1. This way, if the appliance is still defective it will blow fuse F1 rather than a fuse in the basement.



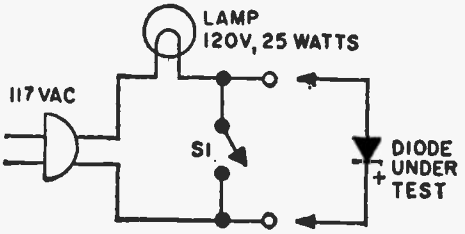
56 Low Voltage Diode Tester



Low voltage signal diodes are easily tested with this "go/no-go" checker. The only restriction is that a diode under test be rated to handle at least 60 mA. Diodes such as the IN34 cannot be checked since test current is too high.
If the diode is good, the lamp will light in one direction, and remain dark when the diode is reversed. If the lamp stays on when the diode is reversed, the diode is shorted. If the lamp stays dark when the diode is reversed, the diode is open.
To test diodes rated under 60 mA, a lower current lamp must be substituted in the checker.

57 Silicon Rectifier Tester

This simple GO/No-GO tester spots defective rectifier diodes before they are connected into a circuit. It is intended only for silicon rectifiers rated higher than 200 mA and indicates open and shorted conditions.
The lamp must be as specified: 120 V at 25 watts. Do not use a larger lamp or the diode might be destroyed.
Close switch S1 to check the lamp by turning it on. Connect the diode both ways, opening S1 for the test. One way the lamp should go on; reversing the diode should cause the lamp to extinguish. If the lamp stays on in both directions, the diode is shorted. If the lamp stays out in both directions the diode is open.

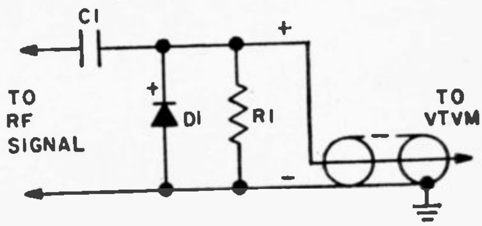


58 RF Probe

PARTS LIST FOR RF PROBE

C1—50-pF disc capacitor
D1—1N60 diode
R1—20-megohm, ½-watt resistor

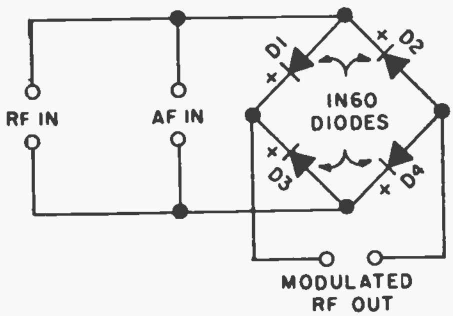
Three components are all that's needed to make a VTVM measure RF voltage up to 200 MHz (depending on the diode used). The probe should be built in a metal can with shielded wire for the connecting lead to the VTVM. Connect the shielded wire to the metal can and solder if possible. The diode rectifies the RF voltage, while the capacity of the shielded cable provides filtering. The output of the probe is positive, with the VTVM indicating the peak value of the RF waveform. To determine the RMS value, multiply the VTVM reading by 0.707. The maximum RF voltage that can be applied is limited by the diode. A 1N60 is limited to 20V peak RF voltage. For higher voltage-handling capacity, substitute a higher voltage small signal detector diode.



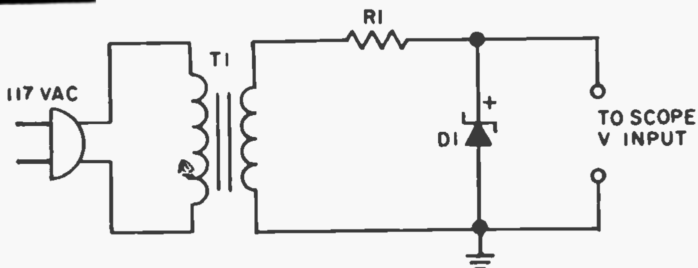
59 Signal Generator Modulator

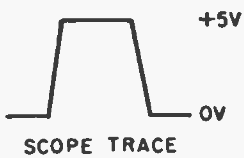
Most RF signal generators have built-in 400 Hz modulation. This four-diode circuit allows you to modulate the signal with other audio-frequency tones.

Using an unmodulated RF output from the generator, set the audio generator's output level to approximately 1/10 that of the RF generator. The signal appearing at the modulated RF output terminals will be modulated approximately 30 percent by the audio (AF) signal.



60 Budget Scope Calibrator





You can make accurate voltage measurements with your oscilloscope if you calibrate the vertical input with a Scope Calibrator.

When the top of zener diode D1 goes negative it conducts and voltage across the diode is essentially zero. When the voltage at the top of the zener goes positive, it builds until it reaches 5 V. At that point the diode conducts, dropping diode voltage to zero. The result is a square wave which varies from zero to +5 V, as shown. The scope's vertical input is connected across the diode and the vertical attenuator control is adjusted so the square wave exactly fills one vertical division. This provides a calibration of 5 V peak-to-peak per division. The scope's vertical attenuator then provides multiples of the calibration such as .5 V/div., 50 V/div., etc. Since calibrator output varies from zero volts it may be necessary to adjust the vertical centering when the scope's DC input is used.

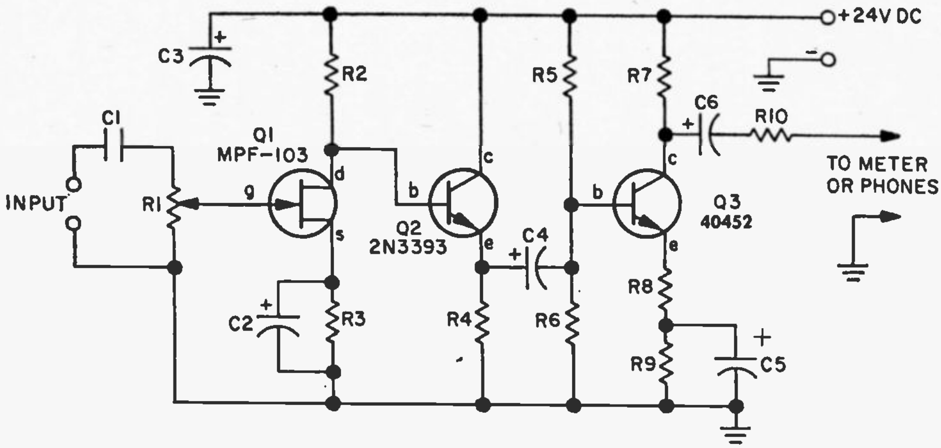
PARTS LIST FOR BUDGET SCOPE CALIBRATOR

D1—5-V, 1/4-watt Zener diode
R1—270-ohm, 1/2-watt resistor
T1—117 to 6.3 VAC filament transformer

61 Audio Sniffer

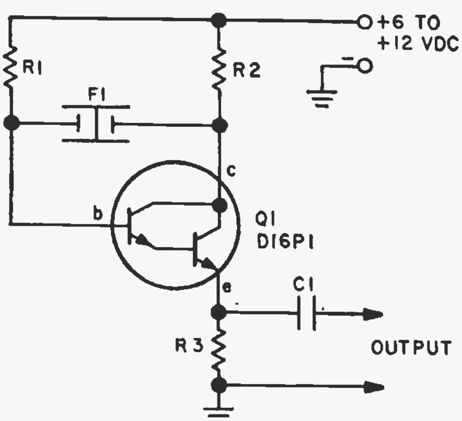
PARTS LIST FOR AUDIO SNIFFER

C1—.01-uF, 400-VDC capacitor	R1—2-megohm potentiometer
C2—100-uF, 6-VDC electrolytic capacitor	R2—33,000-ohm, ½-watt resistor
C3—250-uF, 50-VDC electrolytic capacitor	R3, R7—2200-ohm, ½-watt resistor
C4, C6—10-uF, 25-VDC electrolytic capacitor	R4, R 10—4700-ohm, ½-watt resistor
C5—200-uF, 6-VDC capacitor	R5—68,000-ohm, ½-watt resistor
Q1—Motorola MPF-103 FET transistor	R6—22,000-ohm, ½-watt resistor
Q2—2N3393 npn transistor	R8—18-ohm, ½-watt resistor
Q3—40452 npn transistor	R9—1000-ohm, ½-watt resistor



Got servicing problems on audio equipment? Then sniff them out quickly with an audio signal tracer. The sniffer has enough gain to fill headphones with a thundering roar on the output from a microphone or magnetic pickup. Substitute a VU meter for the headphones and you can make relative level measurements starting at the pickup through the power amplifier. See plans for VU meter with Boost (Circuit 14) on page 22.

62 Precision Freq. Oscillator



If you need a precise, frequency-controlled signal source for remote triggering of a telephone "snooper" or other selective device, you might try an electromechanical resonator. The frequency of resonator F1 in the transitter unit should match the frequency of reed relays in the receiving unit. A switch would allow several different resonator frequencies in the transmitter. A small amplifier with a speaker connects to the output of the *Darlington amplifier* (Q1). In operation, the resonator passes only the *tuned* frequency as positive feedback, causing the amplifier to oscillate at the resonant frequency.

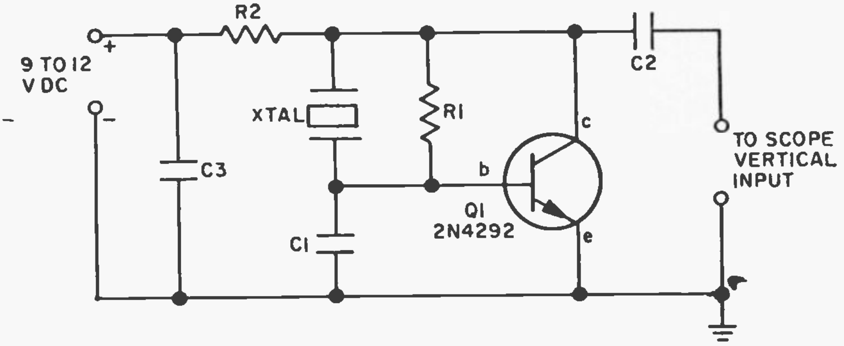
PARTS LIST FOR PRECISION FREQUENCY OSCILLATOR	
C1—0.2-uF, 10-VDC capacitor	Q1—GE D16P1 Darlington amplifier
F1—Twintron resonator (H.B. Engineering Corp., 1101 Ripley St., Silver Spring, Md. 20910)	R1—4.7-megohm, 1/2-watt resistor
	R2—2000-ohm, 1/2-watt resistor
	R3—560-ohm, 1/2-watt resistor

63 Scope Calibrator

Operating on exactly 100 kHz, the Scope Calibrator provides a reference for calibrating the variable time base oscillator of general purpose scopes. If the scope is set, for example, so one cycle of the signal fills exactly 10 graticule divisions, each division represents 1 MHz, or 1 microsecond. If the scope is adjusted for 10 cycles on 10 graticule divisions, or 1 cycle per division, each division represents 100 kHz or 10 microseconds. Now if the scope's time base oscillator is sufficiently stable so it doesn't drift too far off, you can make precise measurements of an unknown pulse width, length and frequency.

PARTS LIST FOR SCOPE CALIBRATOR

- C1, C3—0.01-uF, 25-VDC capacitor
- C2—0.002-uF, 25-VDC capacitor
- Q1—2N4292 npn transistor
- R1—100,000-ohm, 1/2-watt resistor
- R2—1000-ohm, 1/2-watt resistor
- Xtal—100-kHz crystal



64 Signal Injector

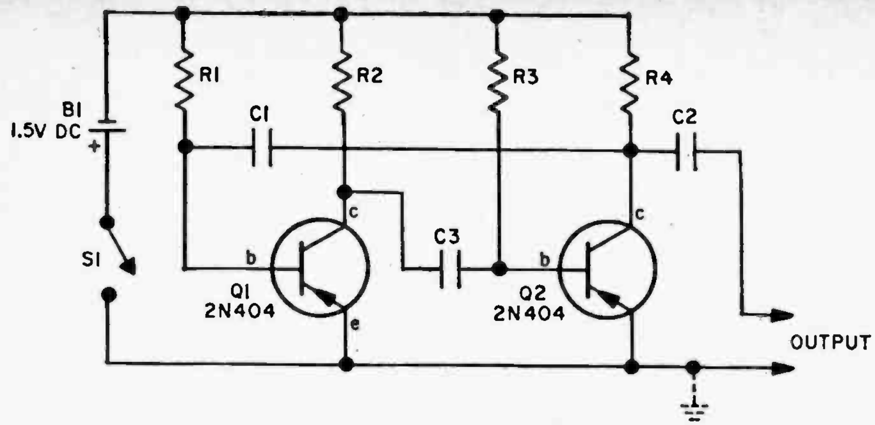
Producing harmonically rich 1-kHz pulses, this multivibrator generates an output signal from 1 KHz to almost 14 MHz. It's useful for servicing audio and RF receiving equipment.

The device is a *signal injector;* you work back from the speaker. At the point where you no longer hear a signal in the speaker you have localized the difficulty.

A precaution: signal level is quite high and it could destroy an RF transistor. So when working on low-level amplifiers or IF circuits, and the connection is to a transistor base, make an inductive hookup. Insulate the test probe with a layer of tape and rest it against the base connection. There's no problem with tube circuits.

PARTS LIST FOR SIGNAL INJECTOR

- B1—1.5-V or AAA battery
- C1, C2, C3—0.01-uF, 500-VDC disc capacitor
- Q1, Q2—2N404 pnp transistor
- R1, R3—100,000-ohm, 1/2-watt resistor
- R2, R4—10,000-ohm, 1/2-watt resistor
- S1—Spst switch



65 FM Alignment Oscillator

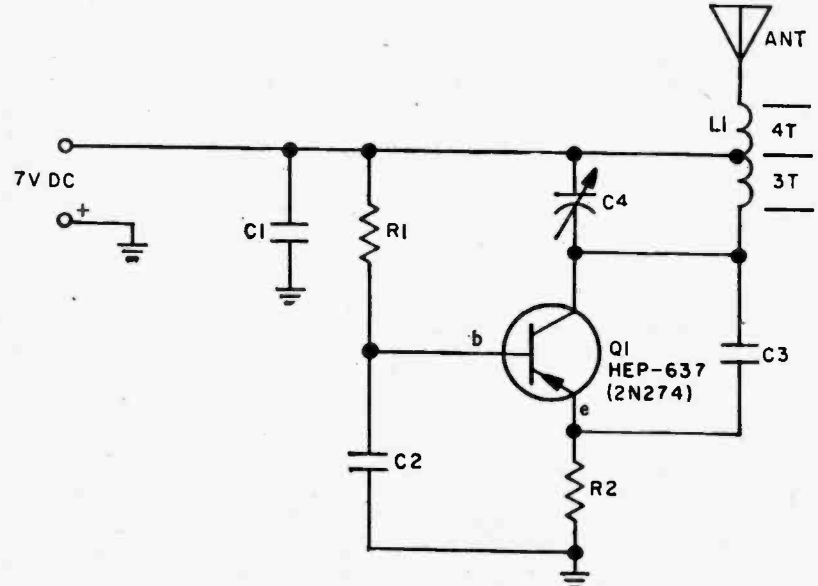
We don't suggest that you start aligning your stereo FM receiver, but some budget-priced and early-model FM mono receivers can be aligned or peaked with the FM Alignment Oscillator. Using a 7V mercury battery, the oscillator provides a radiated signal within 10 feet of the receiver. It's strong enough for alignment purposes, but won't overload the front end.

Coil L1 must be made with extra care. The 4-turn section is tight-wound, no spacing between turns. The 3-turn section is spaced —after winding—to a length of ⅜-in. from the tap to the end of the coil. The tap is made by scraping off some enamel, tinning the bare area, then soldering a solid bare wire to the tap.

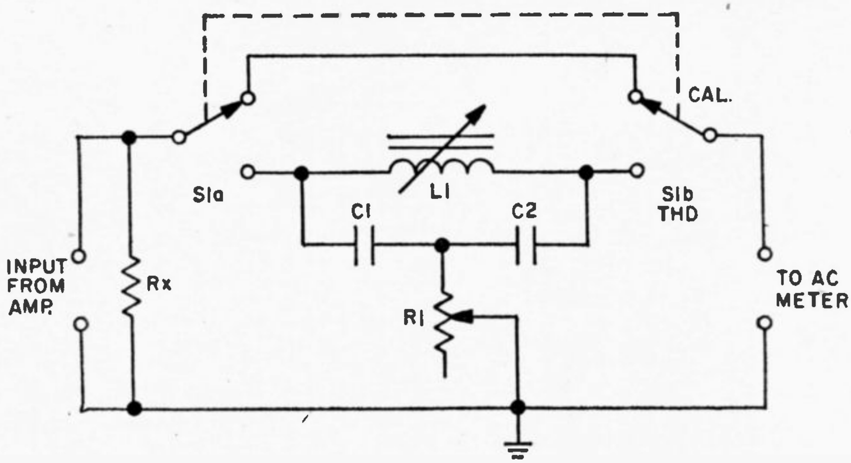
Frequency is preset by adjusting capacitor C4.

PARTS LIST FOR FM ALIGNMENT OSCILLATOR

C1, C2—500-pF, 100-VDC capacitor
C3—5-pF silver mica capacitor
C4—2.7-30 pF trimmer capacitor
L1—See text
Q1—Motorola HEP-637 pnp transistor
R1—100,000-ohm, ½-watt resistor
R2—470-ohm, ½-watt resistor



66 Distortion Meter



This 1-kHz distortion meter is extremely accurate and is handy for measuring the distortion of power amplifiers.

Resistor Rx is the load resistor for the amplifier; 4, 8 or 16 ohms at the appropriate power rating. The AC meter can be an AC-VTVM or a 20,000 ohms volt VOM. Adjust the amplifier for the desired power output, set switch S1 to the calibrate position and note the meter reading. Set S1 to the THD (Total Harmonic Distortion) position and adjust both coil L and resistor R for the *minimum* meter reading.

The percent harmonic distortion is equal to the *minimum* reading divided by the *calibrate* reading x 100.

The circuit works by filtering out the 1-kHz fundamental signal with the L1/C1/C2/R1 T-notch filter. What's left is the harmonic content.

PARTS LIST FOR DISTORTION METER

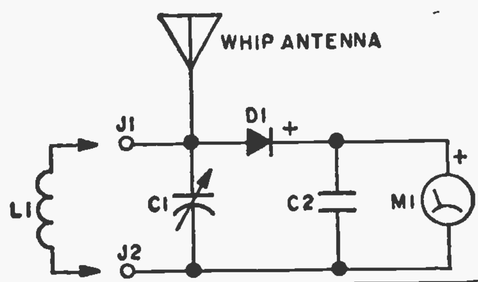
C1, C2—0.01-uF, 100-VDC capacitor, 5%
L1—UTC VC-15 variable inductor
R1—250,000-ohm potentiometer
Rx—Amplifier load resistor (see text)
S1—Dpdt switch

67 Tunable FSM

High sensitivity without amplification is obtained when an FSM (field strength meter) is tuned to its operating frequency. With a *poly*-type miniature capacitor for C1, the FSM can be built in a pocket-size cabinet.

Tuning range is from 1.5 to 144 MHz, depending on the choice of coil L1. The coil can use phone tip jacks for a plug-in connection for band changing. Consult any coil table for L1's winding data since coil construction depends on the type of wire and frequency.

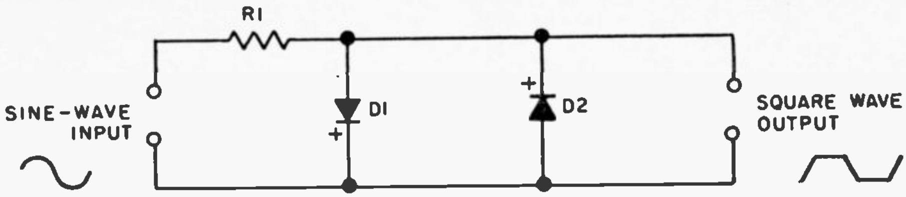
Even greater sensitivity is obtained if a more sensitive meter is used. A 50-uA meter, M1, provides maximum sensitivity combined with reasonably rugged construction.



PARTS LIST FOR TUNABLE FSM

C1—365-pF variable capacitor
C2—.005-uF, 100-VDC capacitor
D1—1N60 diode
J1, J2—Phone tip jack
J1—Coil (see text)
M1—0-1 mA DC meter

68 Sine Wave Squarer



Two reverse-parallel diodes of the germanium type provide an emergency square wave generator. Since a germanium diode has an approximate 0.2 V breakover, any sine wave applied to the diodes will be clipped at 0.2 V. It provides a 0.4 peak-to-peak square wave. It's not perfect since the "rise" of the original sine-wave is still present, as shown in the waveform.

To prevent loading and possible distortion of the sine wave input a 1000-ohm resistor should be connected between the squarer and the generator.

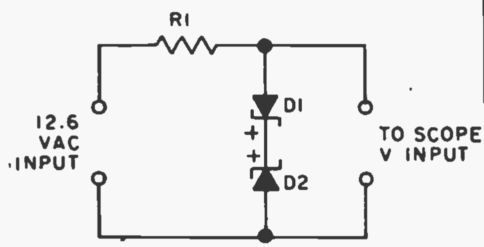
PARTS LIST FOR SINE WAVE SQUARER

D1, D2—Germanium diode, see text
R1—1000-ohm, ½-watt resistor

69 Scope Calibrator

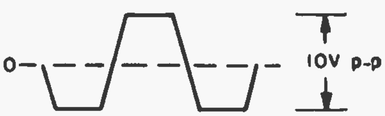
Back-to-back zener diodes provide a scope calibrator with a zero reference output. Whether the calibration voltage is fed to a scope's AC or DC input, the baseline will not have to be readjusted.

When the top of D1 goes positive D1 conducts current through to the D2 cathode. The voltage across D2 builds until 5 V is reached and the output waveform is 5 V positive. The reverse action takes place when the top of D1 goes negative, providing an output waveform of 5 V negative. The total result is a 10 V peak-to-peak square wave to calibrate the scope face.



PARTS LIST FOR ZERO REFERENCE SCOPE CALIBRATOR

D1, D2—5-V, ¼-watt Zener diode
R1—270-ohm, ½-watt resistor



70 Uni-Torque Speed Control

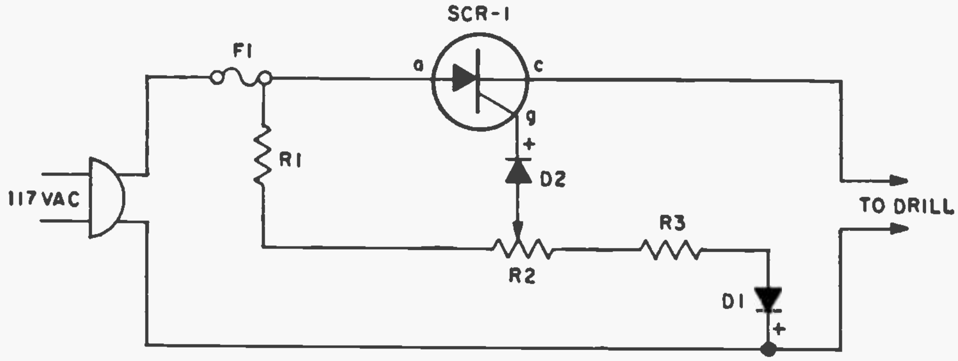
PARTS LIST FOR UNI-TORQUE SPEED CONTROL

D1, D2—500-mA, 200 PIV silicon rectifier
F1—3-A "Slo-blo" fuse
R1—2500-ohm, 5-watt resistor
R2—250-ohm, 4-watt potentiometer
R3—33-ohm, ½-watt resistor
SCR1—3-A, 200-PIV silicon controlled rectifier

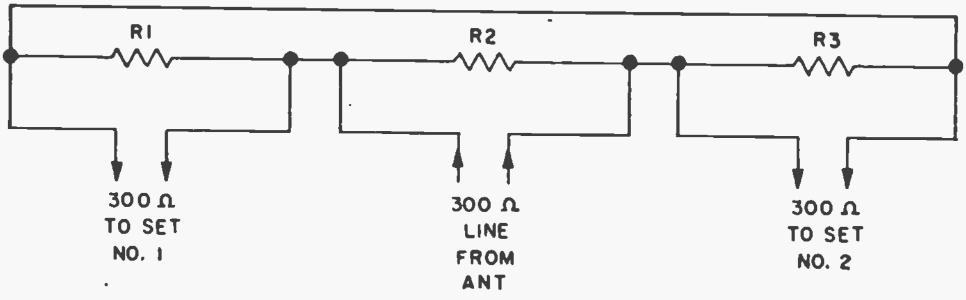
As the speed of an electric drill is decreased by loading, its torque also drops. A compensating speed control like this one puts the oomph back into the motor.

When the drill slows down, a back voltage developed across the motor—in series with the SCR cathode and gate—decreases. The SCR gate voltage therefore increases relatively as the back voltage is reduced. The "extra" gate voltage causes the SCR to conduct over a larger angle and more current is driven into the drill, even as speed falls under load.

The only construction precaution is an extra-heavy heat sink for the SCR. The SCR should be mounted in a ¼-in. thick block of aluminum or copper at least 1-in. square; 2-in. if you drill for extended periods.



71 Two-Set TV Coupler



Direct connection of two TV sets to the same antenna can produce severe ghosting and color degradation. For best results, the two sets must have their inputs electrically isolated from each other. You can do it with this three-resistor two-set coupler. Since there's a small signal loss in the splitting process, signals should be moderately strong, with little or no snow visible.

PARTS LIST FOR 2-SET TV COUPLER

R1, R2, R3—910-ohm, ½-watt resistor
Misc.—Lengths of 300-ohm twinlead, perfboard

72 OTL Amplifier

OTL means "Output Transformer-Less." So right off the bat you save $3 on the cost of this 2-watt amplifier. Not to mention wide frequency response since there's no transformer to lop off lows and highs.

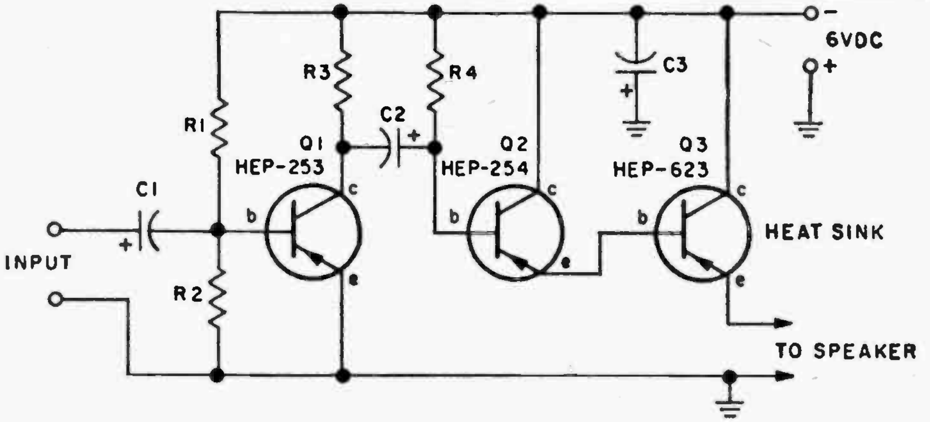
The amplifier should be mounted in a metal cabinet with the cabinet serving as Q3's heat sink. Make certain an insulator is used between transistor Q3's case—the collector connection—and the cabinet. Insure proper heat transfer through the insulator by smearing a bit of silicon transistor grease on both sides of the insulator. You can use a 4-, 8-, or 16-ohm speaker with the amplifier, though the power output will be lower as the impedance increases.

Because of transistor differences there might be excessive distortion. If this occurs, alter R4's value slightly (not more than 50,000 ohms) until distortion is reduced.

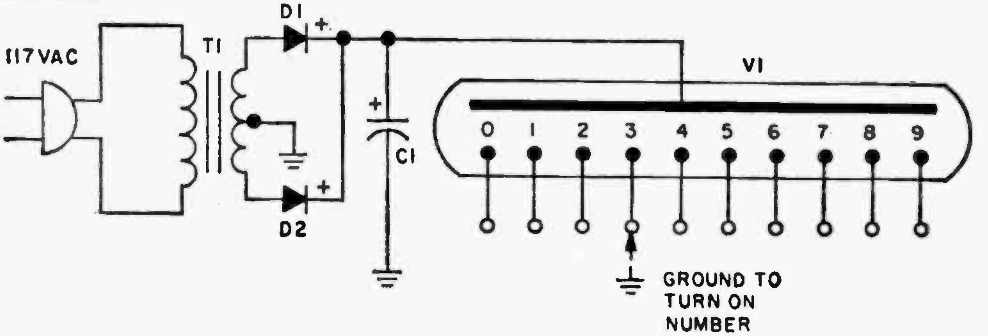
If a volume control is needed, connect a potentiometer of 10,000 ohms or higher between the input terminals and C1.

PARTS LIST FOR OTL AMPLIFIER

C1, C2—10-uF, 6-VDC electrolytic capacitor
C3—50-uF, 6-VDC electrolytic capacitor
Q1—Motorola HEP-253 pnp transistor
Q2—Motorola HEP-254 pnp transistor
Q3—Motorola HEP-623 pnp transistor
R1—100,000-ohm, ½-watt resistor
R2—15,000-ohm, ½-watt resistor
R3—1000-ohm, ½-watt resistor
R4—200,000-ohm, ½-watt resistor



73 Nixie Numbers



Using *Nixie* tubes you can transmit numerical signals or even ball scores over long distances.

The Nixie—actually a peanut-size tube—has 10 numerical-shaped neon lamps (0 through 9). By shorting the appropriate lead to ground, an internal neon lamp corresponding to that number is illuminated.

Transformer T1 is 250V center-tapped, providing an output voltage (peak DC) of approximately 200. Though current requirements are very low, D1 and D2 should be line-voltage type silicon rectifiers of 200 mA minimum.

The same power supply can be used for additional *Nixies*, each connecting to the top of C1.

The neon numbers can be turned on either through an 11-position (one position for off) rotary switch or individual toggle switches.

PARTS LIST FOR NIXIE NUMBERS

C1—30-uF, 250-VDC electrolytic capacitor
D1, D2—200-mA, 400-PIV silicon rectifier
T1—117-V primary, 250-V secondary, 25-mA center-tapped power transformer
V1—Neon readout tube (National Electronics NL840)

74 Power Failure Alarm

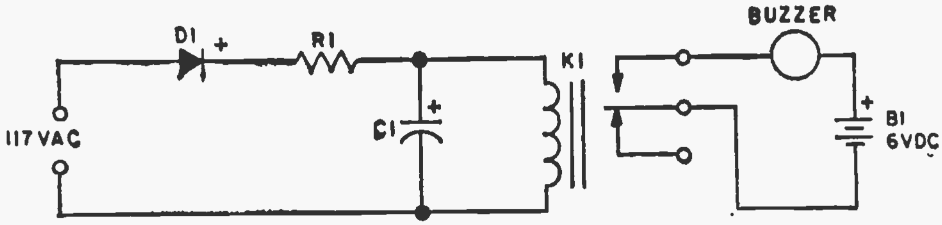
Never fear again that a power failure will knock out your electric alarm clock. The instant the juice fails, the Power Failure Alarm's raucous buzz let's you know about it, even in the wee hours of the morning.

To keep current consumption (and operating costs) at rock bottom, a very sensitive relay is used for K1. As long as AC power is supplied, K1 is activated and the buzzer contacts are held open. When power fails, K1's contact springs back, completing the battery connection to the buzzer.

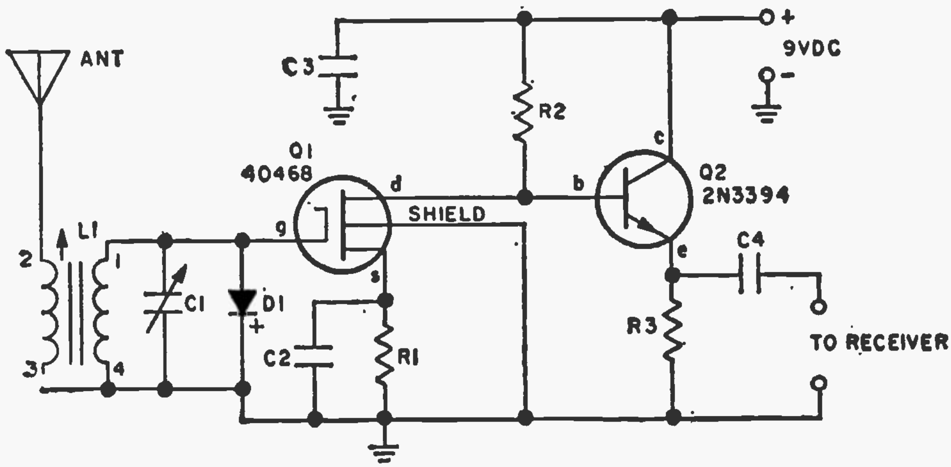
K1 is a "model radio-control" type relay with a pull-in current of approximately 3 mA.

PARTS LIST FOR POWER FAILURE ALARM

- B1—6V dry-cell battery
- C1—25-uF, 150-VDC capacitor
- D1—500-mA, 200-PIV silicon diode
- K1—3000-5000 ohm sensitive relay coil (see text)
- R1—10,000-ohm, ½-watt resistor
- 1—6-VDC commercial home buzzer



75 S-9er for SWLs



Super sensitivity is the feature of this two-transistor shortwave preselector. It provides overall gain as high as 40 dB from 3.5-30 MHz.

Diode D1 protects against excess gate voltage caused by nearby transmitters, while Q1 serves as an emitter follower to match the medium output impedance of the FET transistor to the low input impedance of the receiver.

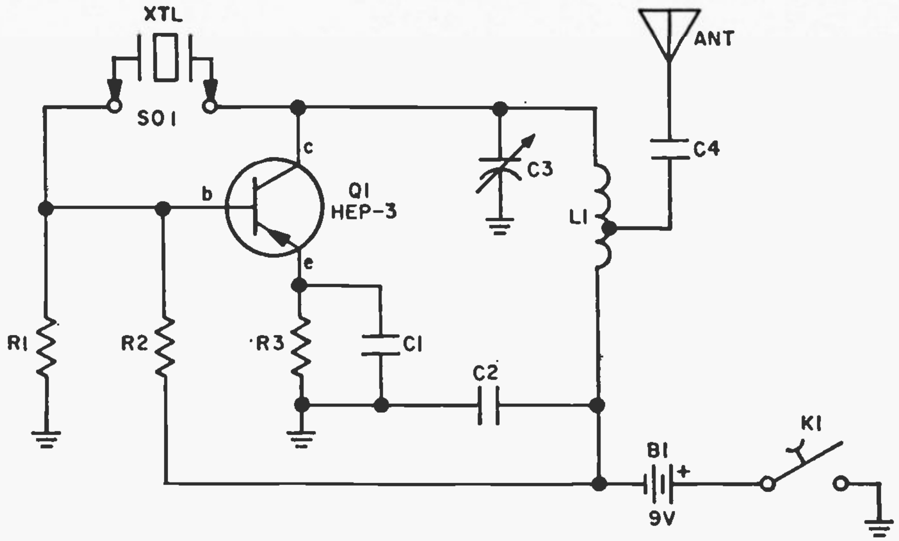
Since Q1 is a MOSFET type with a gate that's very sensitive to static changes, Q1 must be handled with a short-circuit across all leads until just before power is applied. Also, a soldering iron must not be applied to Q1's leads unless they are shorted.

L1's connections are specified in the instructions supplied with the coil. An RG-174U coaxial cable should serve for the output. *(Turn page for parts list)*

PARTS LIST FOR S-NINER FOR SWLS

C1—365-pF tuning capacitor
C2, C3—0.05-uF, 25-VDC capacitor
C4—500-pF, 25-VDC capacitor
D1—1N914 diode
L1—Antenna coil: 1.7-5.5 KHz use Miller B-5495A, 5.5-15 MHz use Miller C-5495A, 12-36 MHz use Miller D-5495-A
Q1—RCA 40468 FET transistor
Q2—2N3394 npn transistor
R1—470-ohm, 1/2-watt resistor
R2—2400-ohm, 1/2-watt resistor
R3—4700-ohm, 1/2-watt resistor

76 Flea Power Transmitter



PARTS LIST FOR FLEA POWER TRANSMITTER

B1—9-V battery, Type 912
C1—0.001-uF, 10-VDC capacitor
C2—0.005-uF, 10-VDC capacitor
C3—30-pF variable or trimmer capacitor
C4—0.005-uF, 100-VDC capacitor
K1—Telegraph key
L1—17 turns of B&W #3007 miniductor tapped at 8 turns from battery end
Q1—Motorola HEP-3 pnp transistor
R1—10,000-ohm, 1/2-watt resistor
R2—51,000-ohm, 1/2-watt resistor
R3—470-ohm, 1/2-watt resistor
SO1—Crystal socket
Xtal—21-MHz fundamental crystal

Any ham can work the world with a California Kilowatt. But working out with 100 milliwatts on 15 meters is the real challenge. Use a metal chassis and good RF wiring techniques to build the rig. Socket SO1 should match the crystal, generally an FT-243 type. The crystal should be the fundamental type. When cutting the Miniductor to length, cut through the plastic supports first—don't try to tear the wire through the supports.

If the oscillator fails to start every time, change R2's value in slight increments until you obtain reliable crystal operation.

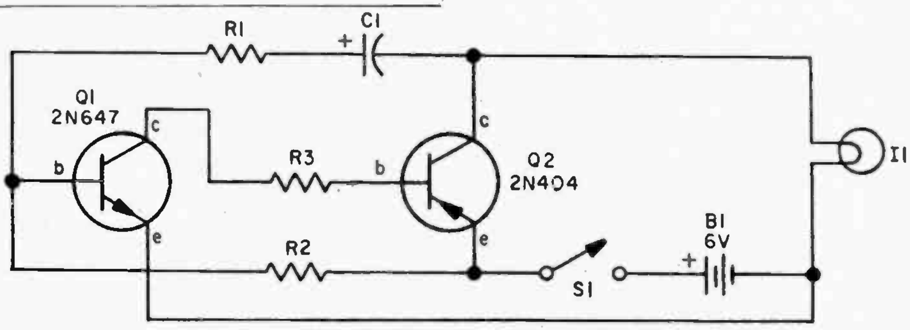
77 Tenna-Blitz

The ballgame is over and your car is buried in the parking lot along with two thousand other cars of the same color. Only yours isn't lost. Sticking above acres of metal is a little lamp going *blink-blink-blink*.

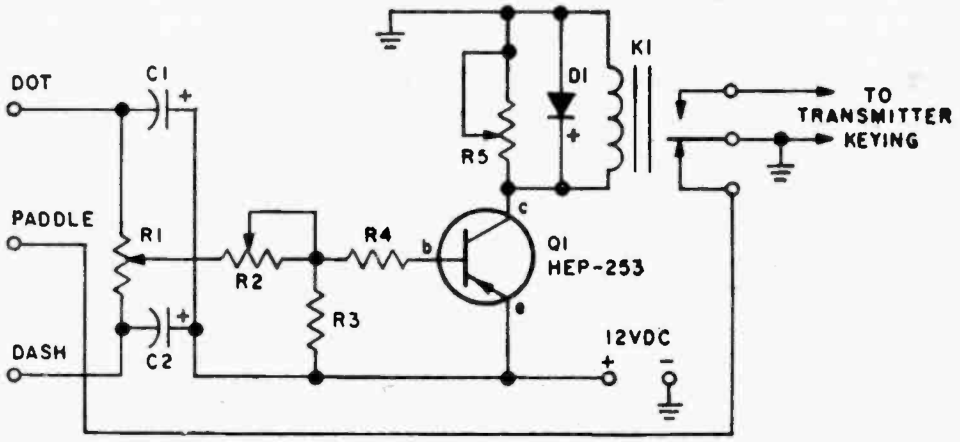
Mount the No. 49 lamp at the top of the antenna and run two wires down to the control unit inside the car. When switch S1 is turned *on* the multivibrator makes the lamp blink away. Changing the capacitor's value will vary the blink rate.

PARTS LIST FOR TENNA-BLITZ

- B1—6-V battery
- C1—2-uF, 10-VDC electrolytic capacitor
- I1—No. 49 pilot lamp
- Q1—2N647 npn transistor
- Q2—2N404 pnp transistor
- R1—470-ohm, ½-watt resistor
- R2—1-megohm, ½-watt resistor
- R3—2700-ohm, ½-watt resistor
- S1—Spst switch



78 Electronic Keyer



PARTS LIST FOR ELECTRONIC KEYER

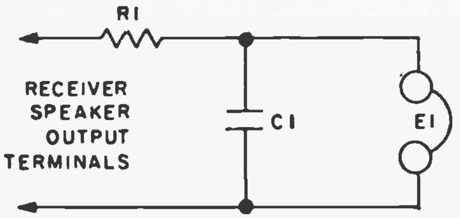
- C1—3-uF, 6-VDC electrolytic capacitor
- C2—10-uF, 6-VDC electrolytic capacitor
- D1—1N60 diode
- K1—12-VDC relay (P&B RS-5D)
- Q1—Motorola HEP-253 pnp transistor
- R1—10,000-ohm linear potentiometer
- R2—50,000-ohm potentiometer
- R3—1200-ohm, ½-watt resistor
- R4—560-ohm, ½-watt resistor

This is not the equal of a $50 electronic keyer, but it's a lot easier to use than an ordinary hand key.

When the paddle terminal connects to the dot terminal, C1 starts to charge. When C1's voltage causes Q1 to conduct, collector current pulls in relay K1, thereby keying the transmitter. When K1 grounds the paddle terminal, C1 discharges, causing Q1 to stop conducting and dropping out the relay. When K1's paddle connection is restored to ground the cycle repeats until the paddle is released.

Dashes work in similar fashion. Potentiometer R1 sets the dot-dash ratio, potentiometer R2 sets the speed. Potentiometer R5 drops out the relay just before Q1 stops conducting and has a slight effect on the dot-space ratio.

79 Headset Q-Peaker



PARTS LIST FOR HEADSET Q-PEAKER

C1—0.005-.05 uF capacitor (see text)
E1—2000-ohm magnetic headset
R1—100,000-ohm, ½-watt resistor

If you're tired of copying CW signals through the grind without a Q-multiplier on your receiver, the 29¢ Headset Q-Peaker is the next best answer. It's the cheapest route to greater selectivity.

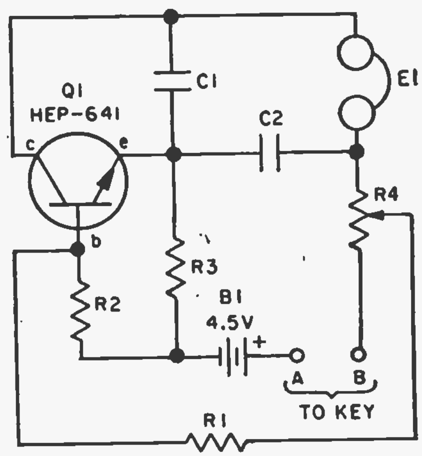
Capacitor C1 plus the inductance of a magnetic headset form a parallel resonant circuit at approximately 1 kHz. All other signals are sharply attenuated so you hear mainly the signal you want. Resistor R1 isolates the resonant circuit to prevent a receiver's low output impedance from reducing the "Q" of the headset circuit.

The exact value of C1 depends on the particular headset. Try different values in the range shown until the desired resonant frequency or peaking action is obtained.

80 Budget CPO

PARTS LIST FOR BUDGET CPO

B1—4.5-V battery
C1—0.02-uF, 10-VDC capacitor
C2—0.22-uF, 10-VDC capacitor
E1—2000-ohm magnetic earphone
Q1—HEP-641 npn transistor (Motorola)
R1—2700-ohm, ½-watt resistor
R2—1500-ohm, ½-watt resistor
R3—27,000-ohm, ½-watt resistor
R4—50,000-ohm potentiometer



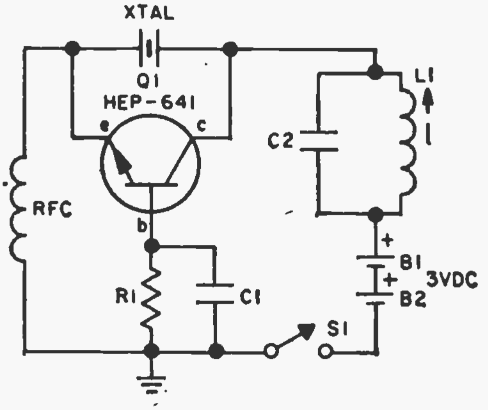
Components you have lying about might make this simple, budget CPO (code practice oscillator). Using component values given, the tone frequency is approximately 800 Hz. It can be changed by substituting different values for C1 and C2, but maintain the same capacity ratio. That is, C2 should always be about 10 times larger than C1. Battery current drain is only about 1 milliampere.

81 100-kHz Freq. Standard

Few shortwave receivers below the deluxe class have really accurate dial calibration. But with a 100-kHz frequency standard you'll know with great precision where the receiver is tuned.

The calibrator is a common-base oscillator producing sufficient signal through the air if constructed in a plastic cabinet. With a metal cabinet, a short antenna approximately 12-in. long should be connected to Q1's collector through a 50-uuF (pF) capacitor. In some instances the antenna will have to be connected to the receiver antenna terminal.

Wiring is not critical and almost any layout will work. If the oscillator doesn't start, change R2's value by approximately 20% until you get consistent oscillator operation.

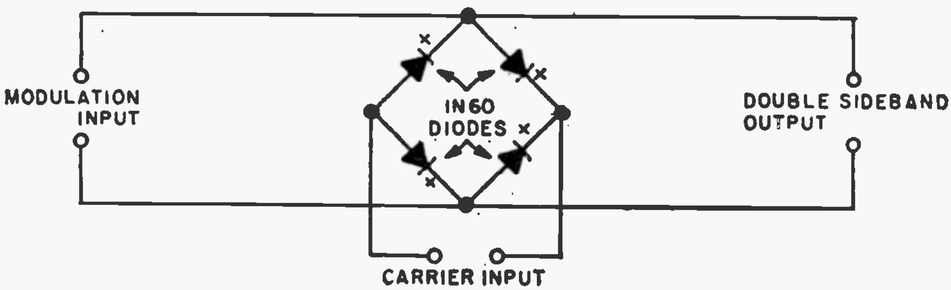


If you want to zero beat the crystal against station WWV, install a 50-pF trimmer in series or in parallel with the crystal. Use whichever connection works since the specific crystal type determines the series or parallel connection.

PARTS LIST FOR
100-kHz FREQUENCY STANDARD

B1, B2—1.5-V AAA battery
C1—0.01-uF, 10-VDC capacitor
C2—200-pF silver mica capacitor
L1—Coil, 2-18 mH
Q1—HEP-641 npn transistor (Motorola)
R1—750,000-ohm, ½-watt resistor
RFC—2.5 mH RF choke
S1—Spst switch
XTAL—100-kHz crystal

82 Sideband Scrambler



Feed audio modulation to one input, a carrier to another and the output of this sideband generator will be upper and lower sideband with supressed carrier. Where is it used? Try a sideband rig or a telephone speech scrambler. Work the scrambled signal into the modulation input to unscramble your speech scrambler output.

83 Carbon Mike Converter

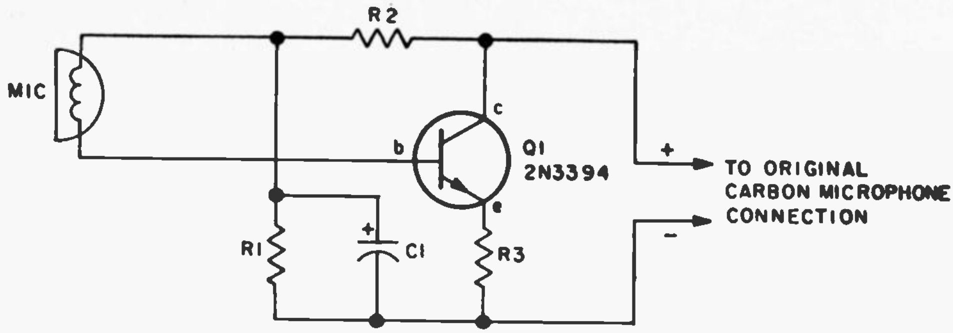
Good pitching beats good hitting—and a good magnetic mike beats a good carbon mike. This one-transistor carbon microphone converter takes a carbon mike input and converts it to the magnetic variety.

Note that no ground connection is used, even if the circuit is built in a metal cabinet. MIC is a replacement-type magnetic element that is substituted for the original carbon element. Using miniature components the entire converter amplifier can also

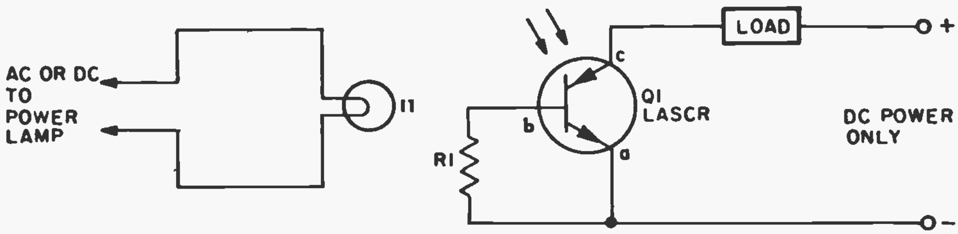
PARTS LIST FOR
CARBON MIKE CONVERTER

C1—10-uF, 10-VDC electrolytic capacitor
MIC—Microphone magnetic replacement element
Q1—2N3394 npn transistor
R1—2200-ohm, ½-watt resistor
R2—6800-ohm, ½-watt resistor
R3—240-ohm, ½-watt resistor

be housed in the original microphone case. To avoid destruction of Q1, the unit must be connected properly the first time. The "+" lead, which goes to Q1's collector, connects to the carbon mike input that supplies a positive voltage.



84 Photo Light Control



Heavy direct current or DC power is easily controlled without the use of massive power switches and wiring by using a LASCR (light activated silicon controlled rectifier) as an interface between the control and controlled circuits. The LASCR is similar to an SCR except that the gate is tripped by light rather than voltage/current.

The triplamp can be any ordinary flashlight bulb powered by two D cells. When the lamp is turned on the LASCR gate is closed, causing current to flow through the load and the LASCR anode (a) cathode (c) circuit.

A suitable LASCR is one from GE's L8B series. Use one with the appropriate PIV rating. Inexpensive LASCRs are occasionally available from "surplus dealers"; though you must make certain the "surplus" unit has the required PIV rating.

PARTS LIST FOR PHOTO LIGHT CONTROL

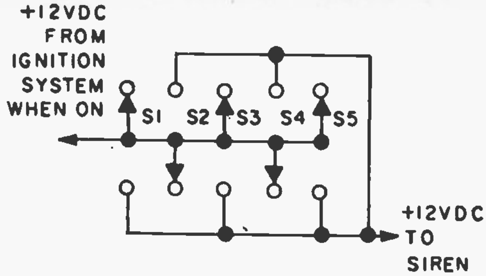
I1—Flashlight bulb or pilot lamp (see text)
Q1—Light-activated-silicon-controlled rectifier (LASCR, GE—see text)
R1—47,000-ohm, ½-watt resistor

85 Electronic Combo Lock

Install an electronic combination lock on your car's dashboard and a thief would have a better chance playing Russian roulette.

Switches S1 through S5 are spdt rather than spst only to keep all external switch markings the same. It would be a dead giveaway if two keying notches or lettering were reversed.

Tracing the circuit will show that only if switches S2 and S4 are down is the siren disabled. The siren sounds if any other switch is down or if S2 or S4 is up when the ignition is turned on. A simple wiring



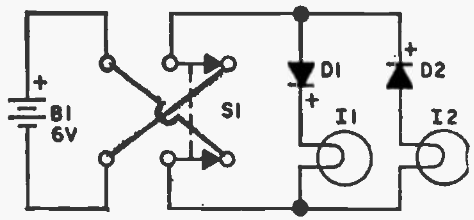
change lets you set any combination.

The switches can be "sporty" auto accessory switches sold individually or in switch banks. Provide labels such as "Carburetor Heater," "Window Washer," etc. and no-one will know the car is wired for "sound."

86 Two-Way Signaller

PARTS LIST FOR TWO-WAY SIGNALLER

- B1—6-V battery, 4 D cells in series
- D1, D2—50-PIV 1 A silicon diode, HEP-154(S)
- I1, I2—6.3-V, 0.15-A, miniature bayonet base pilot lamp
- S1—Dpdt toggle switch (Cutler Hammer 7591-KP)



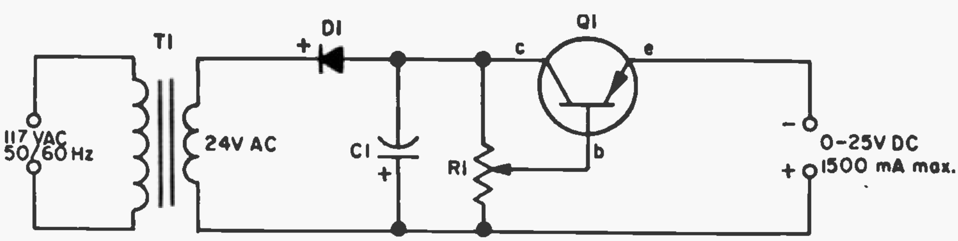
Using diode switching, a single pair of wires controls two circuits that normally require four wires. Though illustrated here with lamps, the same idea can be used for telephone circuits.

When polarity-reversing switch S1 is set so the positive battery terminal feeds the top wire, the D1/I1 circuit is operative and only lamp I1 lights up. Lamp I2 remains off because diode D2 blocks the flow of DC to the lamp.

When battery polarity is reversed, so the top wire is negative, only D2 conducts, illuminating I2. D1 blocks the current flow and I1 is off.

If a carbon mike is connected in series with the battery and the lamps are replaced with headphones, switch S1 determines which of two headphones receives the transmitted signal.

87 NiCad Battery Charger



PARTS LIST FOR NICAD BATTERY CHARGER

- C1—100-uF, 50-V capacitor
- D1—500-mA, 100-PIV silicon rectifier
- Q1—40-W, pnp power transistor
- R1—2000-ohm potentiometer
- T1—24-VAC, 117-VAC primary filament transformer

Providing an adjustable output voltage up to VDC and maximum output current of 1500 mA, this battery charger handles just about any NiCad battery used by experimenters and consumer equipment.

Transistor Q1 must be mounted on a heat sink (which can be a metal cabinet). Since Q1's case is also the collector connection it *must* be insulated from the cabinet with the insulating hardware provided in a transistor mounting kit. For best heat dissipation place a layer of silicone transistor mounting grease on both sides of the mica insulator.

When charging one or a string of series-connected NiCads, connect an ammeter in series with the charger and adjust the current to that specified for the batteries. Never attempt a rapid charge of NiCads (unless so designed) since excess charging current can permanently damage these cells.

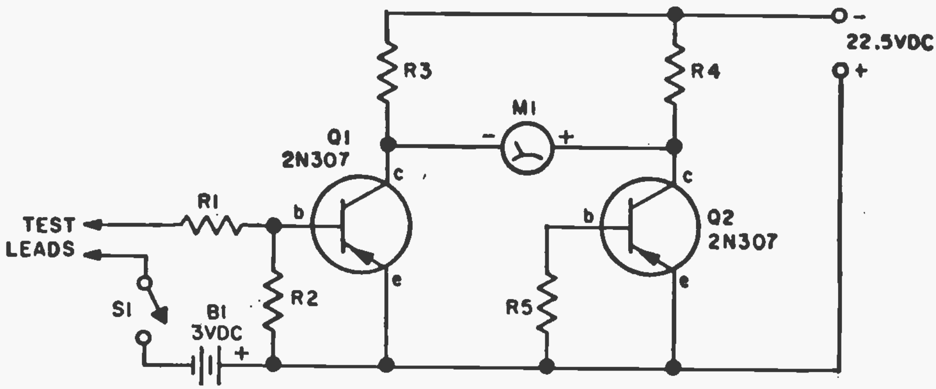
88 Electrolysis Detector

Two transistors and a meter are all it takes a boat owner to keep track of metal-eating electrolysis.

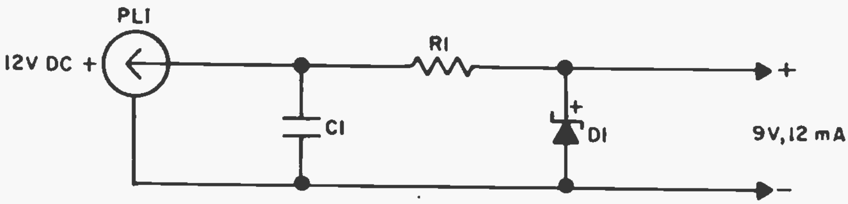
Resistors R3 and R4, transistors Q1 and Q2 and meter M1 form a balanced-bridge meter, with the meter normally indicating zero. The test leads are attached to the boat's submerged metal. As electrolysis takes place, a current flows through the battery circuit, applying base bias to Q1. This unbalances the circuit, causing meter M1 to indicate a reading of other than zero. If the meter reverses and reads off-scale, interchange the meter connections.

PARTS LIST FOR ELECTROLYSIS DETECTOR

B1—3-V battery
M1—0-15 mA DC meter
Q1, Q2—2N307 pnp transistor
R1, R2, R5—220-ohm, ½-watt resistor
R3, R4—1000-ohm, ½-watt resistor
S1—Spst switch



89 Car Voltage for Q Radios



When your auto radio poops out, this regulated voltage adapter keeps you in music from a transistor portable until you're ready to climb under the dash to get at the trouble and fix it.

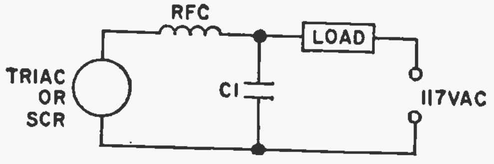
Power is taken from the 12-volt auto battery through a cigar lighter plug. The zener diode can be anything with an approximate rating of 9 volts. For example, you can use a 9.1-volt unit (common in zener kits), or even one rated at 8.6 volts. Make certain the Zener is correctly installed; the end

marked with a band (cathode) connects to the resistor.
The adapter is rated for a current of 12 mA maximum. A good rule of thumb is that a radio powered by a Burgess type 2U6 battery can safely operate on the adapter.

PARTS LIST FOR CAR VOLTAGE FOR Q RADIO

C1—0.05-uF, 400-VDC capacitor
D1—1-watt, 9-V Zener diode
PL1—Cigarette lighter plug
R1—150-ohm, ½-watt resistor

90 Triac & SCR Hash Filter



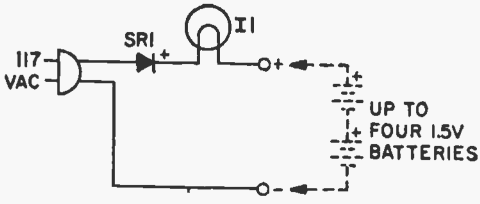
PARTS LIST FOR TRIAC & SCR HASH FILTER

C1—0.1-uF, 200-VDC capacitor
RFC—60-mH coil, 65 turns #18 AWG magnet wire, 2 layers, on 3 x ¼-in. ferrite rod for AM broadcast-band frequencies

Triacs and SCRs used by experimenters in light and motor speed controls generate a considerable amount of electrical "hash". It can cause severe interference to BCB and SW radios located within 50 to 100 feet. The noise is generated when AC line current is regulated into sharp pulses by the SCR or Triac.
An RFI (Radio Frequency Interference) filter connected between the Triac or SCR and the lod can hush the radio interference. Best results are obtained if the filter is located inside a metal box, or in a metal cabinet with the load being controlled.

91 Lamp-Bulb Charger

This circuit in a fancy commercial package will cost you about $5. Build a lamp bulb charger yourself and 50¢ may just about do it.
The lamp maintains constant charging of approximately 20 mA through one to four 1.5-volt batteries. But you can go as high as 22.5 volts for either batteries in series or a single battery.
Give small penlight batteries about 10 hours charge, the C and D cells about 20 hours. Yes, you can recharge NICads stamped with a charge rate of approximately 20 to 25 mA.



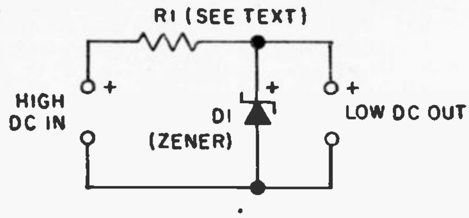
PARTS LIST FOR LAMP-BULB BATTERY CHARGER

I1—No. S-6 6-watt candelabra lamp
SR1—200-PIV, 100-mA minimum silicon rectifier

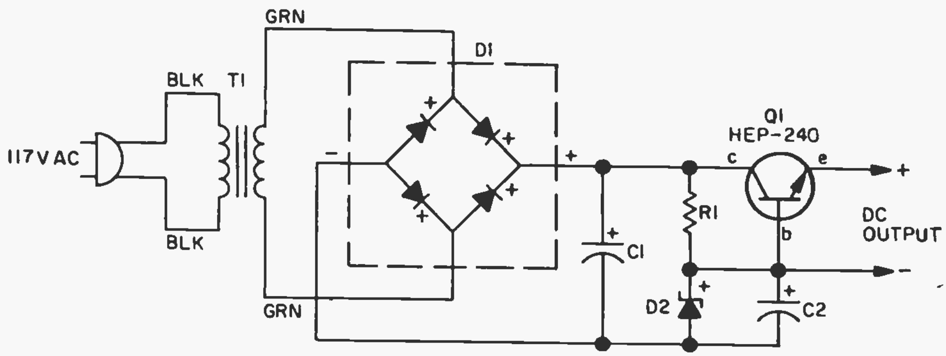
92 Zener Regulator

When the output from an AC power supply is too high for a solid-state project, chop it down to size with a zener diode voltage regulator and keep it on the button.
To calculate R, first add the load current and 1/20 of the load current for the zener's idling current. Then use Ohm's Law (R=E/I to calculate R. The resistor's power rating should be twice the calculated power dissipated by R.

The power rating for the zener diode is determined by the voltage across the diode squared, divided by diode's nominal internal resistance. You can calculate the internal resistance by working backwards from the zener's power rating. As an example: a 9-volt, 1-watt zener would have a nominal internal resistance of $R=E^2/W$, 81/1, or 81 ohms. It's not precisely accurate but close enough. (No parts list)



93 Regulated 9-V Power Supply



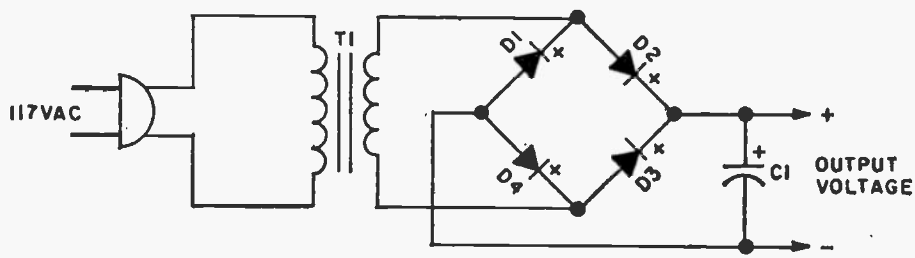
PARTS LIST FOR REGULATED 9-V POWER SUPPLY

- **C1—500-uF, 25-VDC electrolytic capacitor**
- **C2—100-uF, 15-VDC electrolytic capacitor**
- **D1—Motorola HEP-175 50-PIV diode bridge rectifier**
- **D2—Motorola HEP-104, 9.1-V Zener diode**
- **Q1—Motorola HEP-240, 10-watt npn transistor**
- **R1—560-ohm, ½-watt resistor**
- **T1—12-V filament transformer (see text)**

Providing 9 V at approximately 250 mA, this lab-type power supply will handle many experimenter projects. Actually, T1 can be a 6.3-V *imported* filament transformer since they usually give approximately 12 V peak at less than 500 mA output. Change the Zener diode to 12 or 6 volts (and possibly the value of R1) and you get a regulated 12- or 6-volt supply. For 12 volts you must use a 12-V filament transformer.

Filtering is very good since the *electrical* filter capacitor equals the value of C2 times the gain of Q1. It can add up to thousands of microfarads.

94 Power Supply for SS Projects



PARTS LIST FOR POWER SUPPLY FOR SS PROJECTS
C1—2500-uF electrolytic capacitor, voltage rating at least 1.5 times higher than output voltage D1, D2, D3, D4—500-mA, 100-PIV silicon rectifier (see text) T1—Transformer; 117-VAC primary, secondary voltage equal to desired output voltage x 0.707

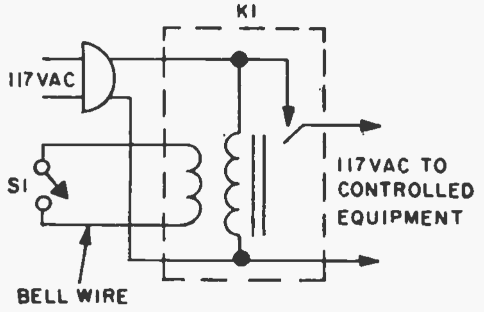
Though the transofrmer isn't center-tapped in this circuit, the bridge rectifier provides full-wave rectification with an easy-to-filter DC output. It forms a handy supply for solid-state projects.

The output voltage is equal to the secondary voltage multiplied by 1.4. Or, working backwards, the secondary voltage must be 0.707 times the desired output voltage.

Silicon rectifiers D1 through D4 must have a PIV rating equal to at least the DC output voltage. Their current rating must at least equal the current requirements of the project being powered by the supply.

95 Low Voltage R/C

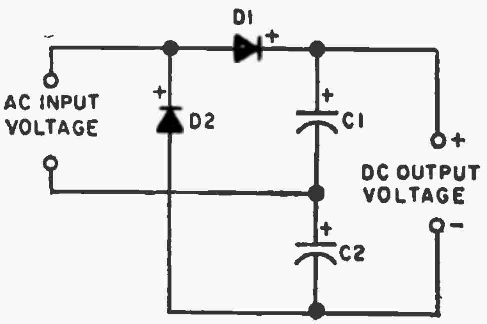
PARTS LIST FOR LOW-VOLTAGE R/C
K1—Hysteresis relay (Alco) S1—Spst switch Misc.—Bell wire



Using ordinary bell wire you can safely control a remote 117 VAC power source. Secret behind it all is a unique hysteresis relay, K1. Normally, K1's coil represents a high impedance; no current flows through the coil so the relay contacts stay open. When S1 closes the loop on the hysteresis coil, the impedance of the main coil drops. Current flows and the contacts close.

When S1 is open, the voltage across its terminals from the hysteresis coil is approximately 30V. When S1 is closed, current through the hysteresis loop is almost unmeasurable. It's safe enough for ordinary bell wire to do the controlling.

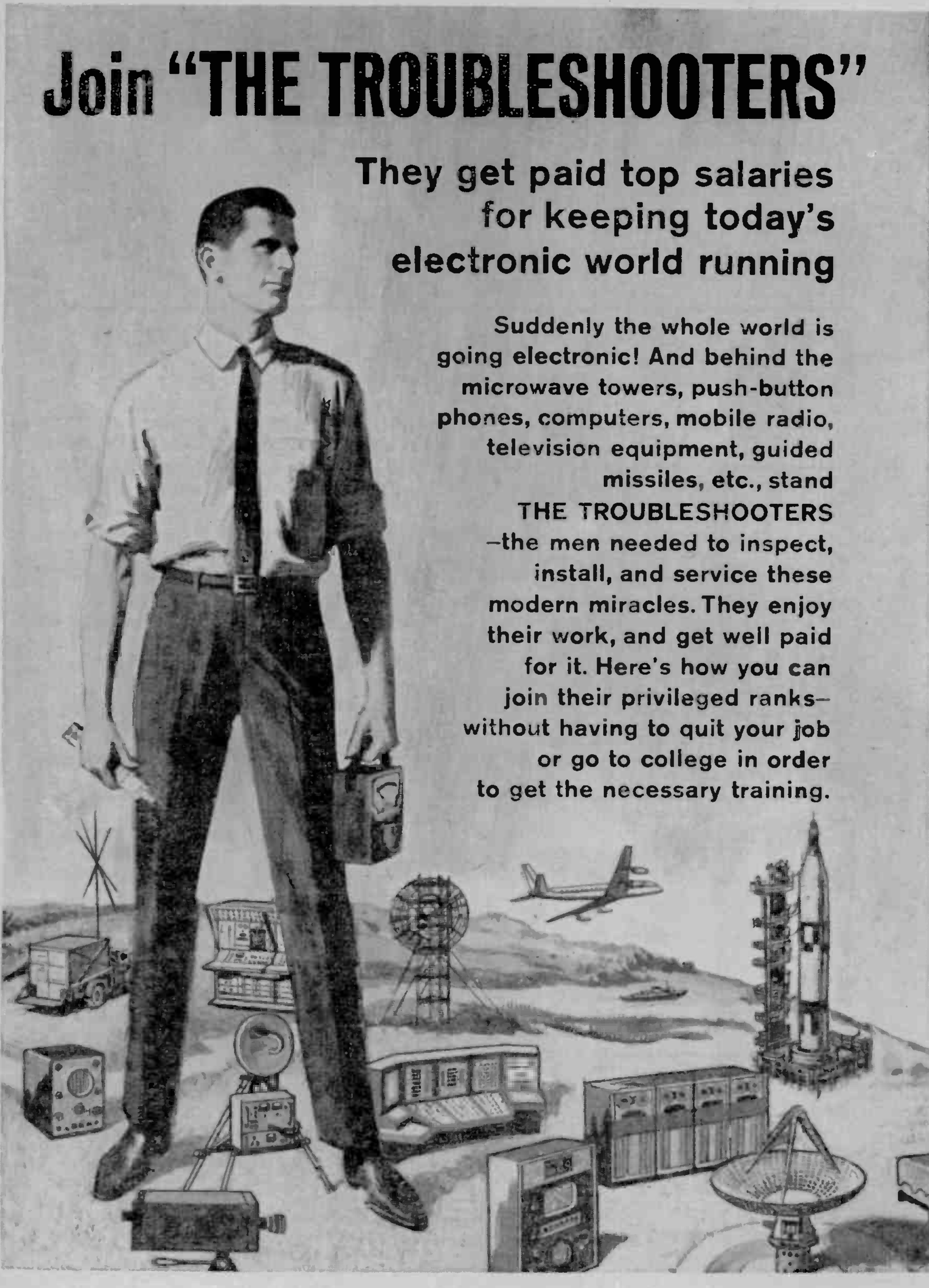
96 Voltage Doubler



Found in many CB transceivers, the full-wave voltage doubler provides reasonably good regulation with DC output voltage twice the AC input. Capacitors C1 and C2 should be a minimum of 100 uF and rated at twice the DC output voltage. The larger the capacity, the greater will be the filtering.

On the positive half-cycle, C1 is charged through silicon diode D1. On the negative half-cycle, C2 is charged through D2. The DC output voltage is the sum of the charge across C1 and C2.

PARTS LIST FOR VOLTAGE DOUBLER
C1, C2—100-uF electrolytic capacitor or larger, WVDC should be twice DC output voltage D1, D2—500-milliampere (or larger) rectifying diode rated PIV at least twice DC output voltage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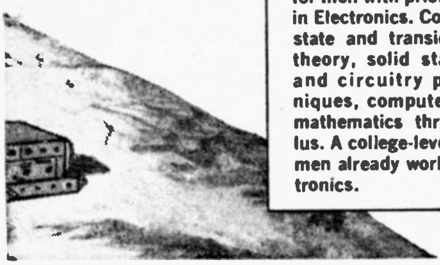

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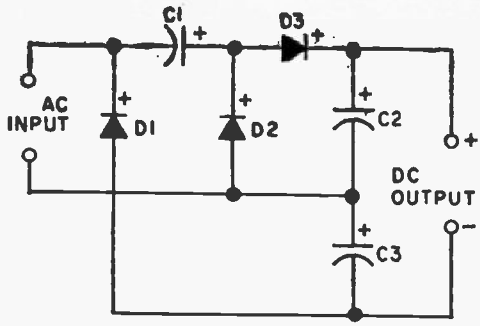
97 Voltage Tripler



When you need high voltage but don't have a power transformer, a voltage tripler may work. It provides DC output approximately three times higher than the line voltage.

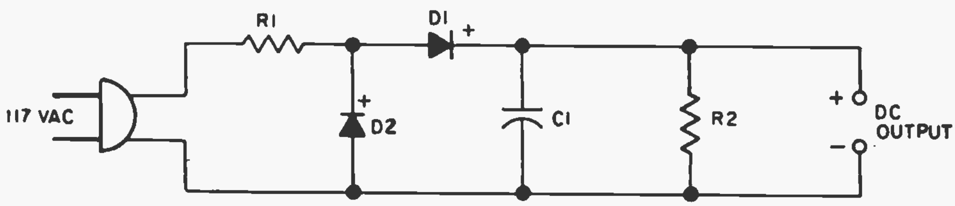
C1 is approximately 8 to 20 uF at 150VDC, and C2 and C3 should be a minimum of 100 uF at 250VDC. The larger the value for C2 and C3, the better the filtering.

On the negative half-cycle, C1 charges through diode D2, while C3 charges through D1. On the positive-half cycle, C1's charge, plus the line voltage, charges C2 through D3. The output is the voltage across C2, which is the line voltage plus the charge from C1, plus the added voltage of C3. The total is almost three times the line voltage.

PARTS LIST FOR VOLTAGE TRIPLER

C1—16-uF, 150-VDC electrolytic capacitor
C2, C3—140-uF, 300-VDC electrolytic capacitor
D1, D2, D3—HEP-160(S) 1000-PIV, 1-A diode (Motorola)

98 Low-Ripple Supply Preamp



PARTS LIST FOR LOW-RIPPLE SUPPLY FOR PREAMPS

Output V	I max*	R1	C1	R2
12	1 mA	43,000-ohm, ½-watt	250-uF, 15-VDC	180,000-ohm, ½-watt
12	2 mA	22,000-ohm, ½-watt	250-uF, 15-VDC	100,000-ohm, ½-watt
25	2 mA	18,000-ohm, ½-watt	250-uF, 30-VDC	180,000-ohm, ½-watt

*For lower current, decrease value of R2

Just a handful of components are needed for a line-powered low-voltage low-current supply for powering audio preamplifiers.

The values for different voltage and current outputs are given in the Parts List. Pick the set you need and wire up.

D1 and D2 are silicon rectifiers rated at a minimum of 200 PIV at any current.

99 Shortwave Spotter

Can't find that rare, week SW signal from Lower Slobbovia? You will if you use this SW frequency spotter. Obtain crystals on or near your favorite SW stations, plug 'em into the spotter and you'll transmit powerhouse markers on the shortwave bands. If your receiver has a BFO it will sound a loud *beep* when you tune the spotter's signal. With no BFO, simply tune around the frequency until the receiver gets deathly quiet. Either way, you'll calibrate your receiver with great accuracy.

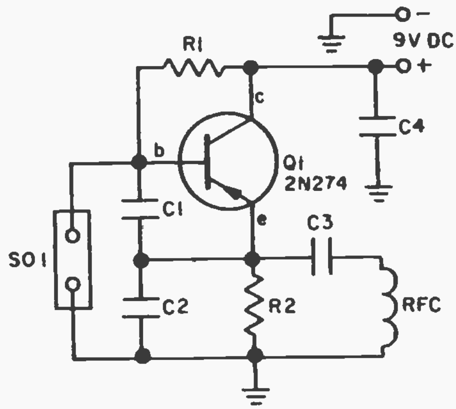
The spotter can be assembled on a small section of perfboard with flea clips for tie points. For good performance, all components must be firmly mounted and well soldered. A common 2U6 9-volt battery in the circuit will last for months, if not for its total shelf life.

Crystals in this circuit are fundamental type, not overtone. Many low-cost surplus crystals are available, but even if you can't get the correct frequency, 25¢ might get you right next door. A few dollars for a new crystal will put you directly on frequency if you want the utmost accuracy.

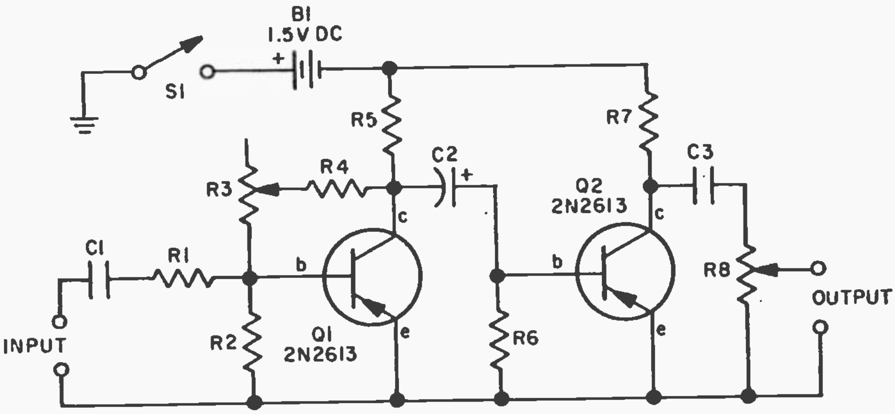
A connection between the spotter and receiver is not needed. Simply position the spotter near the receiver antenna and start tuning until you find the marker signals.

PARTS LIST FOR SHORTWAVE SPOTTER

- C1—1200-pF silver mica capacitor
- C2—75-pF silver mica capacitor
- C3—250-pF, 100-V disc capacitor
- C4—0.01-uF, 25-VDC capacitor
- Q1—RCA 2N274 pnp transistor
- R1—220,000-ohm, ½-watt resistor
- R2—1000-ohm, ½-watt resistor
- RFC—1-mH RF choke
- SO1—Crystal socket



100 Fancy Fuzzbox



Add that 'way-out NOW sound to any electric guitar by connecting the Fuzzbox between your guitar and amplifier. Potentiometer R3 sets the degree of fuzz, R8 the output level.

Since the fuzz effect cannot be completely eliminated by R3, fuzzy-free sound requires a bypass switch from the input to output terminals. The switch should completely disconnect the fuzzbox output; the input can remain in parallel with the bypass switch.

PARTS LIST FOR FANCY FUZZBOX

- B1—1.5-V AA battery
- C1, C3—0.1-uF, 3-VDC capacitor
- C2—5-uF, 3-VDC electrolytic capacitor
- Q1, Q2—2N2613 pnp transistor
- R1, R6—22,000-ohm, ½-watt resistor
- R2—18,000-ohm, ½-watt resistor
- R3—1-megohm potentiometer
- R4—100,000-ohm, ½-watt resistor
- R5, R7—10,000-ohm, ½-watt resistor
- R8—50,000-ohm, audio-taper potentiometer
- S1—Spst switch

Electricity, Magnetism and the Atom

traveled through the tube from the negative to positive terminal (opposite to the direction conventionally held as the direction of the flow of current).

This "cathode ray" beam also traveled in a straight line and was deflected by electric or magnetic forces applied perpendicular to the beam. What Thompson did was to use these facts to determine for one of the mysterious particles comprising the beam of cathode rays the relationship of its mass, *m*, to its electric charge, *e*. By deflecting the beam with a known electric force (Fig. 1)

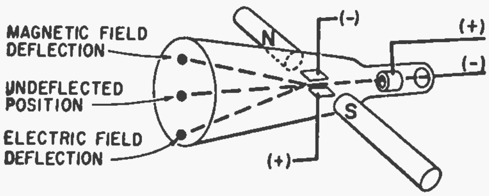


Fig. 1. Electron beam, like that in a TV picture tube (CRT), can be deflected magnetically or by an electric field. Force needed "measured" the electron.

and then measuring what magnetic force applied in the opposite direction would bring the beam back to its original undeflected position, he could determine the relationship of *e* to *m*. He established a definite value for *e/m* and thereby "discovered" the electron which, as we now know, is 1,837 times smaller in mass than the lightest atom, the hydrogen atom. It also carries the smallest charge that occurs in nature; every electric charge is actually an integral multiple of the charge of the electron.

From Minus to Plus. With the discovery of the electron, it was still over a dozen years into the 20th century before a graphic conception of the atom evolved. Since the atom is electrically neutral and electrons are negatively charged, the existence of positively charged particles was a necessity, and the existence of a *proton* was postulated. Eventually the nuclear model of the atom was evolved. Each atom was conceived to resemble a solar system in miniature. The nucleus—positively charged—is surrounded by a number of electrons revolving around it; the charges balance and the atom is electrically neutral (Fig. 2). Further research in the 20th century has gone on to reveal more elementary particles than you can shake a

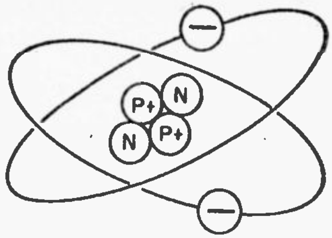


Fig. 2. Charge of each electron balances that of a proton. Other particles affect atomic mass but can be ignored in study of electronics.

stick at: neutrons, positrons, neutrinos, mesons, and more. The number continues to grow and yet the ultimate nature of matter remains a riddle. But, in a discussion of basic electricity, only the electron and proton need concern us.

Electrons in Orbit. An atom of matter has a number of electrons orbiting around its nucleus. A hydrogen atom, for example, has a single electron; carbon on the other hand has 6. These electrons are arranged in rings or shells around the central nucleus—each ring having a definite maximum capacity of electrons which it can retain. For example, in the copper atom shown in Fig. 3 the maximum number of electrons that can exist in

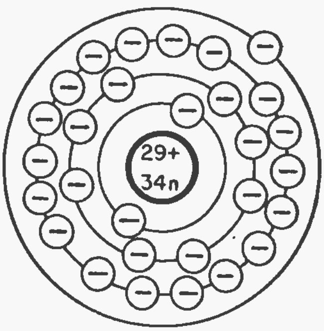


Fig. 3. The number of electrons to each ring are limited—2 in first; 8 in second; 18 for the third and a total of 32 in fourth orbital ring.

the first ring (the ring nearest the nucleus) is two. The next ring can have a maximum of eight, the third ring a maximum of 18, and the fourth ring a maximum of 32. However, the outer ring or shell of electrons for any atom cannot exceed eight electrons. However, heavier atoms may have more than four rings.

The Outer Orbit. The ring of electrons furthest from the atom's nucleus is known as the *valence ring* and the electrons orbiting in this ring are known as *valence electrons*. These valence electrons, being further from the nucleus, are not held as tightly in their orbits as electrons in the inner rings and can therefore be fairly easily dislodged by an external force such as heat, light, friction, and electrical potential. The fewer electrons in the valence ring of an atom, the less these electrons are bound to the central nucleus. As an example, the copper atom has only one electron in its valence ring. Consequently, it can be easily removed by the application of only the slightest amount of external energy. Ordinary room temperature is sufficient to dislodge large numbers of electrons from copper atoms; these electrons circulate about as free electrons. It is because of these large numbers of free electrons that copper is such a good electrical conductor. There could be no electrical or electronics industry as we know it today if it were not for the fact that electrons can fairly easily escape, or be stripped from the valence ring of certain elements.

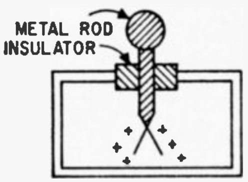


Fig. 4. Electroscope is a simple device to indicate electrical charges that are too weak to be measured with standard meters.

Electronic Charges. If an electron is stripped from an atom, the atom will assume a positive charge because the number of positively charged protons in its nucleus now exceed the number of negatively charged orbiting electrons. If, on the other hand, the atom should gain an electron, it will become negatively charged as the number of electrons now exceeds the protons in its nucleus. The atom with the deficiency of electrons is known as a *positive ion*, while an atom with a surplus of electrons is known as a *negative ion*.

Presence of an electrical charge on a body can be illustrated by use of an electroscope (Fig. 4). Two leaves of aluminum or gold foil hang from a metal rod inside a glass case so they're free from air disturbances. When the meal rod is touched by a charged body, the leaves acquire static electricity of the same polarity and, since like charges repel, they stand apart. The greater the charge, the further apart the leaves spread.

Electron Flow. When an electrical conductor is placed between these two oppositely charged bodies, free electrons are attracted by the positive body—free electrons will move through the wire. This movement of free electrons will continue only until the excess of electrons is equally divided between the two bodies. Under these conditions, the charges on both bodies will be equal and the electron flow will end.

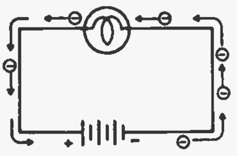


Fig. 5. Electron flow in any circuit is from negative to positive — this is opposite to current, which flows from positive toward negative terminal.

In Fig. 5 are a battery, lamp and connecting leads between the battery and lamp. In this instance, the battery serves as an electric charge pump—free electrons continually developed at its negative terminal by chemical action flow through the connecting leads and lamp back to the positive terminal of the battery by the attraction of oppositely charged bodies. The battery, connecting leads, and lamp form an electrical circuit which must be complete before the free electrons can flow from the battery's negative terminal to its positive terminal via the lamp. Thus, the battery serves as a source of potential difference or voltage by continually supplying a surplus of electrons at its negative terminal. Summing up, we can say a flow of electric current consists of the movement of electrons between two oppositely charged bodies.

We cannot progress very far into the study of electricity without first becoming familiar with the basic properties of electrical circuits. Just as we define distance in feet and inches, so do we define electrical properties in specific terms and units.

Potential. Earlier, we saw that an electric charge difference has to exist between the ends of an electrical conductor in order to cause a flow of free electrons through the conductor. This flow of electrons constitutes the electric current. The electric charge difference, or potential difference exerts a force on the flow of free electrons, forcing them through the conductor. This electric force or pressure is referred to as electromotive force, abbreviated EMF.

The greater the charge or potential difference, the greater will be the movement of free electrons (current) through the conductor as there will be more "push and pull" on the free electrons. The symbol used to designate electrical potential is the letter E which

Electricity, Magnetism and the Atom

stands for electromotive force. The quantity of EMF is measured by a unit called the volt. Hence, the common name most often used in place of EMF is *voltage*.

Current Intensity. We have learned that an electric current consists of a flow of charge carrriers (generally free electrons) between two points of different electrical potential. The rate of flow of these charges determines the intensity or strength of this current flow. Current strength is expressed in units known as *amperes*. One ampere of current flows in a circuit when 6,240,000,000 electrons flow out of a negative terminal, through a conductor, and back into a positive terminal in one second. The symbol for the ampere is the letter *I* which stands for intensity.

Resistance. The flow of electric current through a conductor is caused by the movement of free electrons present in the atoms of the conductor. A bit of thought then indicates that the greater the number of free electrons present in the atoms of a particular conductor, the greater will be its electrical conductivity. Gold, silver, and copper rank as excellent electrical conductors as their atoms readily release free electrons. On the other hand, the atoms of such elements as sulphur have almost no free electrons available and they are thus very poor electrical conductors. Such materials are known as electrical insulators. Between these extremes, lie elements such as carbon whose atoms have a moderate number of free electrons available and thus are moderately good electrical conductors.

Even the best electrical conductors offer some opposition to the passage of free electrons. This opposition is called resistance. You might consider electrical resistance similar to mechanical friction. As in the case of mechanical friction, electrical resistance generates heat. When current flows through a resistance, heat is generated; the greater the current flow, the greater the heat. Also, for a given current flow, the greater the resistance, the greater the heat produced.

Electrical resistance can be both beneficial and undesirable. Toasters, electric irons, etc. all make use of the heat generated by current flowing through wire coils. Resistance is also often intentionally added to an electrical circuit to limit the flow of current. This type of resistance is generally lumped together in a single unit known as a resistor.

There are also instances where resistance is undesirable. Excessive resistance in the connecting leads of an electrical circuit can cause both heating and electrical loss. The heating, if sufficient can cause a fire hazard, particularly in house wiring, and the circuit losses are a waste of electrical power.

Electrical resistance is expressed by a unit known as the *ohm*, indicated by the letter *R*. An electrical conductor has a resistance of one ohm when an applied EMF of one volt causes a current of one ampere to flow through it.

Resistance Factors. There are other factors beside the composition of the material that determine its resistance. For example, temperature has an effect on the resistance of a conductor. As the temperature of copper increases, for example, its resistance increases. The increase in temperature causes the electrons in the outer ring of the atom to resist release to the free electron state. This increase in resistance with an increase in temperature is known as a *positive temperature coefficient*. Not all conductors show this increase in resistance with an increase in temperature; their resistance decreases with an increase in temperature. Such materials are said to have a *negative temperature coefficient*. Certain metallic alloys have been developed which exhibit a *zero temperature coefficient:* their resistance does not change with changes in temperature.

As you might suspect, the length of a conductor has an effect upon its resistance. Doubling the length of a conductor will double its resistance. By the same token, halving the length of a conductor will cut its resistance in half. Just remember that the resistance of a conductor is *directly proportional to its length*.

The cross-sectional area of a conductor also determines its resistance. As you double the cross-section of a conductor, you halve its resistance; halving its cross-section doubles its resistance. Here again, the "why" of this is pretty easy to see: there are more current carrying electrons available in a large cross-section conductor than in a small cross-section conductor of the same length. Therefore, the resistance of a conductor is *inversely proportional to its cross-sectional area*.

Circuit Relationship. Now that we have a basic understanding of voltage, current, and resistance, let's take a look at just how they

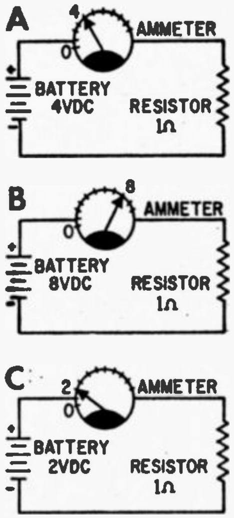


Fig. 6. In A, B and C, (above left) the value of the resistor remains constant while the supply voltage is raised and then lowered with a resulting current change.

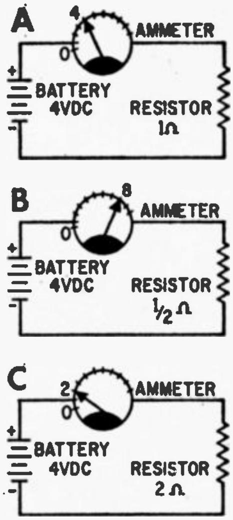


Fig. 7. Battery voltage in A, B and C (above) is held constant while resistor is halved and doubled in value. Resulting current increase, decrease are basis for Ohm's law.

interact under circuit conditions.

Fig. 6A shows a battery, ammeter (a device to indicate current strength), and resistor connected in series. Notice that the ammeter indicates that 4 amperes are flowing in the circuit.

Fig. 6B shows the identical setup with the exception that the battery voltage has now been doubled. The ammeter now shows that twice the original current, or 8 amperes, are now flowing in the circuit. Therefore, we can see that doubling the voltage applied to the circuit will double the current flowing in the circuit.

In Fig. 6C the same circuit appears again; this time, however, the battery voltage is one-half its original value. The ammeter shows that one-half of the original current or 2 amperes, are now flowing in the circuit. This shows us that halving the voltage applied to the circuit will halve the current flowing through the circuit.

All this boils down to the fact that assuming the same circuit resistance in all cases, *the current flowing in a circuit will be directly proportional to the applied voltage*—increasing as the voltage is increased, and decreasing as the applied voltage is decreased.

In Fig. 7A we again see the circuit consisting of the battery, ammeter, and resistance. Notice that the ammeter indicates that 4 amperes are flowing through the circuit.

In Fig. 7B we see that the value of resistance has been cut in half and as a result, the ammeter indicates that twice the original current, or 8 amperes, is now flowing in the circuit. This leads us to the correct assumption that for a given supply voltage, halving the circuit resistance will double the current flowing in the circuit.

Fig. 7C again shows our basic circuit, but with the resistance now doubled from its original value. The ammeter indicates that the current in the circuit is now one-half of its original value.

Summing things up: for a given supply voltage, *the current flowing in a circuit will be inversely proportional to the resistance in the circuit.*

Ohm's Law. From what you have seen so far, you are probably getting the idea that you can determine the current flowing in a circuit if you know the voltage and resistance present in the circuit, and the voltage if you know the current and resistance, or the resistance if the voltage and current are known.

All this is quite correct, and is formally stated by Ohm's Law as follows:

$$I = \frac{E}{R}$$

Where: E = voltage
I = current
R = resistance

Now, let's take a look at how this formula is used:

To find voltage:

E (voltage) = I (current) x R (resistance)

To find current . . .

$$I\ (\text{current}) = \frac{E\ (\text{voltage})}{R\ (\text{resistance})}$$

To find resistance:

$$R\ (\text{resistance}) = \frac{E\ (\text{voltage})}{I\ (\text{current})}$$

A handy way to remember Ohm's Law is by means of the triangle shown in Fig. 8. Simply cover the quantity (voltage, current, or resistance) that you want to determine, and read the correct relationship of the remaining two quantities. For example if you

Electricity, Magnetism and the Atom

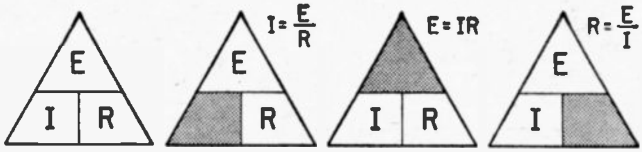


Fig. 8. Shaded portion of triangle indicates unknown quantity in the formula. Visible factors appear in their proper mathematical relation. Just fill in the known values and go on with multiplication or division.

want to know the correct current (I), put your finger over I and read $\frac{E}{R}$. Covering E or R will yield I x R or $\frac{E}{I}$, respectively.

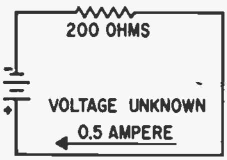


Fig. 9. Unknown quantity, voltage, found easily by applying Ohm's law. Using known factors (ohms and amperes) in a simple multiplication process the voltage is calculated.

Ohm's Law to Determine Voltage. Let's delve a bit more deeply into Ohm's law by applying it to a few cases where we want to determine the unknown voltage in an electrical circuit. Take a look at Fig. 9, which shows a simple series circuit consisting of a battery and resistor. The value of this resistor is given as 200 ohms, and 0.5 ampere of current is flowing through the circuit. We want to find the value of battery voltage. This is easily done by applying Ohm's law for voltage as follows:

$$E = I \times R$$

E (unknown voltage) = 0.5 (current in amperes) x 200 (resistance in ohms) = 100 V.

Let's go through this again, this time using a practical illustration. Fig. 10 shows a string

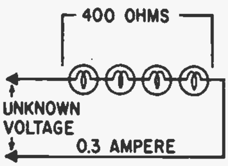


Fig. 10. Although problem looks different the basic circuit is same as that for Fig. 9. Putting triangles in Fig. 8 to use is simplest, easiest way to determine formula.

of light bulbs, the total resistance of which is 400 ohms. You find that the bulbs draw 0.3 amperes when lighted. Let's say you would like to operate this string of bulbs from the standard 120-volt house current, but you don't know the voltage rating of the individual bulbs. By using Ohm's law for voltage, you can easily determine the voltage to light the bulbs as follows: E (unknown voltage) = 0.3 (amperes) x 400 (bulb resistance) = 120 volts.

Ohm's Law to Determine Current. Now, let's take a look at a few examples of how

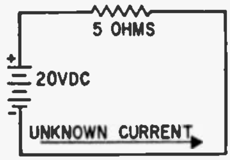


Fig. 11. Formula needed here is different since current is unknown. Just look for triangle in Fig. 8 that has I shaded and substitute values for E and R—simple division.

to determine the value of unknown current in a circuit in which both the voltage and resistance are known.

Fig. 11 shows a series circuit with a battery and resistor. The battery voltage is 20 volts DC and the value of resistance is 5 ohms. How much current is flowing through the circuit?

$$\text{Ohm's law for current } I = \frac{E}{R}$$

$$I \text{ (unknown current)} = \frac{20 \text{ (battery voltage)}}{5 \text{ (resistance in ohms)}}$$

$$I = 4 \text{ amperes}$$

Again to get a bit more practical, let's take

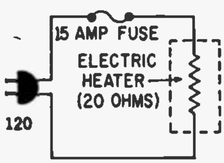


Fig. 12. Basic circuit is same as that in Fig. 11. Although three factors are given, current is unknown quantity because the problem is to decide proper rating for fuse.

a look at Fig. 12. Here we see an electric heater element connected to the 120-volt house line. We know that this particular heater element has a resistance of 20 ohms. The house current line is fused with a 15-ampere fuse. We want to know whether the heater will draw sufficient current to blow the fuse. Here's how to find this out by use of Ohm's law for current.

$$I \text{ (unknown current)} = \frac{120 \text{ (line voltage)}}{20 \text{ (Heater resistance in ohms)}}$$

$$I = 6 \text{ amperes}$$

We find from the above use of Ohm's law for current that the heater draws 6 amperes, so it can be safely used on the line fused with the 15 ampere fuse. In fact, a 10 ampere fused line can also do the job.

Ohm's Law to Determine Resistance. Ohm's law for resistance enables us to determine the unknown value of resistance in a circuit. Fig. 13 again shows a simple series

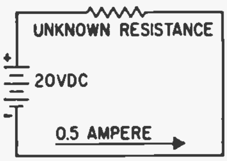


Fig. 13. Most Ohm's law problems are simple series circuits or can be reduced to simple series circuits and then solved using the formula with known values substituted.

circuit with the battery voltage given as 20 volts and the current flowing through the circuit as 0.5 ampere. The unknown resistance value in this circuit is found as follows:

$$\text{Ohm's law for resistance } R = \frac{E}{I}$$

$$R \text{ (unknown resistance)} = \frac{20 \text{ (battery voltage)}}{0.5 \text{ (current in amperes)}}$$

$$R = 40 \text{ ohms}$$

Fig. 14 is a practical example of how to determine unknown resistance. Here, we

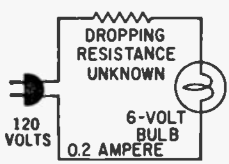


Fig. 14. This Ohm's law problem is somewhat more complex since dropping resistance must take care of voltage, from source, not needed by 6-volt bulb in circuit.

want to operate a 6-volt light bulb from the 120-volt house line. What value of series dropping resistor do we need to drop the 120-volt house current down to 6 volts? The bulb draws 0.2 ampere.

We must first determine the voltage which must be dropped across the series dropping resistor. This is done by subtracting the line voltage (120) from the bulb's voltage (6). This gives us a value of 114 volts which we use in conjunction with Ohm's law for resistance as follows:

$$R \text{ (unknown resistance)} = \frac{114 \text{ (voltage dropped by resistor)}}{0.2 \text{ (bulb current in amperes)}}$$

$$R = 570 \text{ ohms}$$

Resistance in Series. Many practical electrical and electronic circuits use two or more resistances connected in series. The point to remember in this case is that the total resistance is the sum of the individual resistances. This is expressed by the formula:

$$R \text{ (total resistance)} = R1 + R2 + R3 + \text{etc.}$$

where R1, R2, R3, etc. are the individual

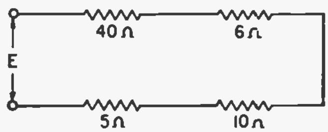


Fig. 15. Resistances in series are added. As far as voltage applied and current flow is concerned the individual resistors are only one.

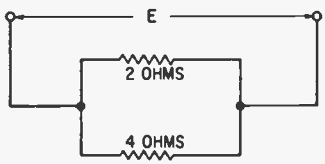


Fig. 16. Resistors in parallel are added algebraically — the result will always be a value less than that of the lowest in the circuit.

resistances. Thus, in Fig. 15 the total of the individual resistances is R (total) = 40 + 6 + 10 + 5 = 61 ohms.

Resistances may also be connected in parallel in a circuit as in Fig. 16. In this case the current flowing in the circuit will divide between the resistances, the greater current flowing through the lowest resistance. Also, the total resistance in the circuit will always be less than the smallest resistance since the total current is greater than the current in any of the individual resistors. The formula for determining the combined resistance of the two resistors is:

$$R \text{ (total)} = \frac{R1 \times R2}{R1 + R2}$$

Electricity, Magnetism and the Atom

Thus, in Fig. 16 the effective resistance of R1 and R2 is:

$$R\ (\text{total}) = \frac{2 \times 4}{2 + 4} = \frac{8}{6} \text{ or } 1.33 \text{ ohms.}$$

In a circuit containing more than two parallel resistors as in Fig. 17 the easiest way to determine the total circuit resistance is as follows: first, assume that a 6-volt battery is connected across the resistor network. Pick a value that will make your computations simple. Then determine the current flowing through each of the resistors using Ohm's law.

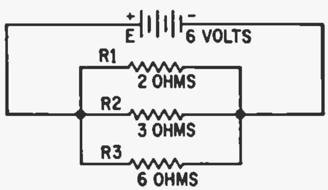


Fig. 17. Ohm's law can be used to determine the equivalent resistance of two or more resistors in parallel. Total current—then solve for ohms.

$$I = \frac{E}{R1} = \frac{6}{2} = 3 \text{ amperes}$$

$$I = \frac{E}{R2} = \frac{6}{3} = 2 \text{ amperes}$$

$$I = \frac{E}{R3} = \frac{6}{6} = 1 \text{ ampere}$$

Next, add the individual currents flowing through the circuit:

2 amperes + 3 amperes + 1 ampere

I = 6 amperes

Inserting this 6 amperes in Ohm's law, the total circuit resistance is found to be:

$$R = \frac{6}{6} = 1 \text{ ohm}$$

The combined equation for determining the total resistance of *n* number of resistances would be:

$$\frac{1}{R} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + \dots \frac{1}{Rn}$$

Quite often an electronic circuit will contain a combination of series and parallel re-

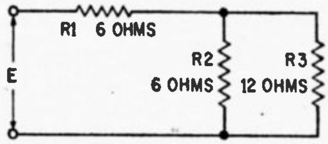


Fig. 18. Series-parallel circuit is not really difficult. Add R2 and R3 algebraically. Add effective resistance to R1 for total resistance.

sistances as in Fig. 18. To solve this type of problem, first determine the combined resistance of R2 and R3:

$$R\ (\text{total})\ \frac{6 \times 12}{6 + 12} = \frac{72}{18} = 4 \text{ ohms}$$

This total value of R2 and R3 may be considered a single resistance which is in series with R1, and forms a simple series circuit. This simple series circuit is solved as follows:

R (total) = 6 + 4 or a total of 10 ohms.

Power. The amount of work done by electricity is termed the *watt* and one watt is equal to one volt multipled by one ampere. This may be expressed as: P = E x I where E = voltage in volts, I = the current in amperes. Also:

$$P = \frac{E^2}{R} \text{ and } P = I^2R$$

As an example, assume that a toaster draws 5 amperes at an applied voltage of 115 volts.

Its wattage would then be:

P = 115 x 5 or 575 watts.

Magnetism and the Electron. The atom, and a concept of its structure were a necessary preface to our discussion of basic electricity. By the same token, both are necessary to understanding basic magnetism.

As we've mentioned, electrons are in continual motion about the nucleus. The orbit is, in fact, a small loop of current and has a magnetic field that's associated with a current loop. In addition, experimental and theoretical investigation seems to indicate that the electron itself has a spin. Each electron, having its own axis, is a spinning sphere of electric charge. *Electron spin*, like the quantum and wave theories of light, is not so much a literal interpretation of a phenomenon, but a useful concept that holds water when applied to the phenomenon of magnetism.

When the electron spins, the charge that is in motion produces a magnetic field. And, to briefly state the electronic explanation of magnetism, it seems that the magnetic properties of matter can be attributed to the orbital and spinning motion of the electrons comprising the atoms of the matter.

Millennia of Magnetism. Some of the basic principles and effects of magnetism have been known for centuries. The Greeks are credited as the ones who first discovered magnetism. They noted that a certain type of rock had the ability of attracting iron. Later, the Chinese noted that an elongated piece of this rock had the useful property of always pointing in a North-South direction when suspended by a string. This was the beginning of our compass.

This strange stone which intrigued people over the centuries is actually a form of iron ore known as magnetite. Not all magnetite shows magnetic properties. Another name for the magnetic variety of magnetite is lodestone—the term lodestone being derived from two separate words, lode and stone. The term lode stands for guide, hence lodestone mean "guide stone."

All magnets, whether natural or man made, possess magnetic poles, which are commonly known as the magnet's north and south poles. As is the case of the electrical charges (which we studied earlier) between unlike magnetic poles and repulsion between like poles, it has been found that this magnetic attraction and repulsion force varies inversely as the square of the distance from the magnetic poles.

The Magnetic Field. We all know how a magnet exerts a force of attraction on a piece of magnetic material such as iron or

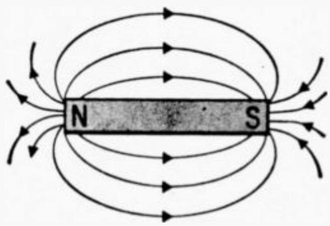


Fig. 19. Lines of force around bar magnet can be made visible by sprinkling iron filings onto white paper over magnet. Tap paper gently.

steel. Also, when the north poles of two magnets are brought close together, they will try to repel each other, while there will be attraction between the north and south poles of two magnets. Although it is not clearly understood just what this force of magnetic attraction and repulsion is, it is convenient to visualize magnetic lines of force which extend outward from one magnetic pole to the other as illustrated in Fig. 19.

Permeability. Magnetic lines of force can pass through various materials with varying ease. Iron and steel, for example, offer little resistance to magnetic lines of force. It is because of this that these materials are so readily attracted by magnets. On the other hand, materials such as wood, aluminum and brass do not concentrate or encourage the passage of magnetic lines of force, and as a consequence are not attracted by magnets.

The amount of attraction a material offers to magnetic lines of force is known as its permeability. Iron and steel, for example, possess high permeability since they offer

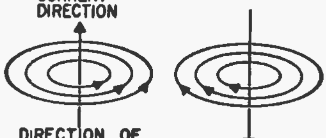


Fig. 20. Direction of flux lines is changed by direction of the current. Heavy current is needed to make flux lines visible with sprinkled filings.

little resistance to magnetic lines of force. Nonmagnetic materials have low permeability. For practical purposes, we can say that reluctance is to magnetic lines of force what resistance is to an electrical current.

Electromagnetism. Any electrical conductor through which flows an electrical current will generate a magnetic field about it which is perpendicular to its axis as shown in Fig. 20. The direction of this field is dependent upon the direction of current flow, and the magnetic field strength proportional to the current strength. If this current-carrying conductor is wound into a coil, forming a solenoid, the magnetic field will be increased by each individual turn that is added. If an iron core is inserted in this current carrying coil, the generated field will be increased still further. This is because the lines of force are concentrated within the iron core which has considerably less reluctance than the surrounding air.

Electricity, Magnetism and the Atom

The magnetizing power of a multi-turn current-carrying coil through which a core is inserted is proportional to the current flowing through the coil as well as the number of turns in the coil. The current through the coil is termed *ampere turns.* As an example, if a coil consisting of 200 turns is carrying 2 amperes, its ampere turns equal:

Ampere turns = 200 turns x 2 amperes or

400 ampere turns

Similarly a coil of 100 turns through which a current of four amperes flows also has 400 ampere turns.

Electromagnetic Induction. We saw earlier how a current carrying conductor will generate a magnetic field which is perpendicular to the conductor's axis. Conversely, a current will be induced in a conductor when the conductor is passed through a magnetic field. The strength of this induced current is proportional to both the speed at which it passes through the field and the strength of the field. One of the basic laws pertaining to electromagnetic induction is Lenz's law which states: "The magnetic action of an induced current is of such a direction as to resist the motion by which it is produced."

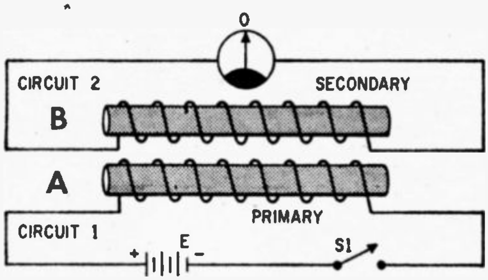


Fig. 21. Two-core transformer is inefficient since an air gap at either end does not have permeability of a ferrous metal and some flux lines do not go through core of secondary winding (B)—their effect is lost.

Fig. 21 illustrates two coils, A and B, which are placed in close proximity to each other. Coil A is connected in series with a switch and battery so that a current may be sent through it when the switch is closed, and coil B is connected with a current-indicating DC meter. When the switch is closed, current will flow through coil A, causing a magnetic field to be built up around it. In the brief instant that the field is building up to maximum, it will "cut" the turns of coil B, inducing a current in it, as indicated by a momentary flick of the indicating meter. When the switch is opened, breaking the current flow through coil A, the field around coil A will collapse, and in so doing will again induce a current in coil B. This time, however, the flow of current will be in the opposite direction. The meter will now flick in an opposite direction than it did when the switch was closed. The important thing to remember is that the conductor must be in motion with respect to the magnetic field or vice versa in order to induce a current flow. You can perform this simple experiment using two coils made of bell wire wrapped around large nails, a few dry cells in series, and a DC zero-center scale meter.

Self Induction. As mentioned a short while ago, a magnetic field is built up around a coil at the application of current through the coil. As this field is building up, its moving lines of flux will cut the turns of the coil inducing a counterelectromotive force

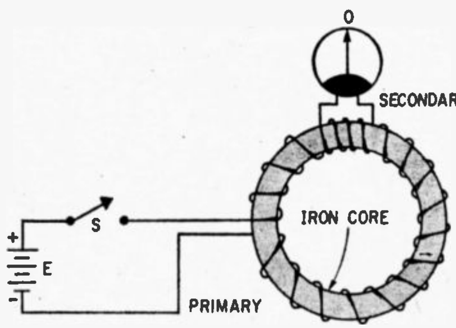


Fig. 22. Toroidal core is highly efficient but is very difficult to manufacture. Familiar C- and E-shape core has less waste and windings are slipped over the core. Efficiency is good—about 90 percent for most designs.

or counter EMF which opposes the current flowing into the coil.

The amount of counter EMF generated depends upon the rate of change in amplitude of the applied current as well as the inductance of the coil. This value of inductance is dependent upon the number of turns in the coil; a coil with many turns will have greater inductance than a coil with few turns. Also, if an iron core is inserted into the coil, the inductance of the coil will increase sharply. The unit of inductance is known as the *henry.*

The Transformer. One of the most im-

(Continued on page 110)

Test Equipment

What do you need?

by the
Editors of
Science
and
Electronics

■ Test equipment can be extremely simple or highly complex, cheap or expensive. In the early days of electronics, there were but few pieces of test equipment available. Much of it was designed for use by electricians. These meters were quite insensitive—and drew considerable current from the circuit under test. Of course, this made them almost useless in performing tests on the early *radio* circuits. And way-back-then, *radio* was the whole electronics industry.

Inexpensive Testers. One of the most basic tests is for continuity. This test can be done with a source of voltage and an indicator. As shown in Fig. 1 all you need is a dry cell and a high-frequency buzzer or a flashlight bulb, a few feet of flexible wire (for test leads), a probe and a clip. Of course there are refinements you can make—like putting both indicators and the battery in one box with 5-way binding posts to make connections to the external circuitry easier. This is a *continuity* tester.

When the test leads are applied to a circuit, the buzzer sounds if the circuit is closed and does not sound if the circuit is open. Its use is limited to very-low-resistance devices and circuits since insufficient current will flow to make the buzzer sound if the resistance of the circuit being tested is too high. It's very handy for testing cables and tracing wires.

This is suitable for low resistances only. Any amount of resistance in the circuit and neither the buzzer or flashlight bulb will give any indication. Mainly this tester is used to indicate properly wired connections (in cables in particular) and those accidental connections called *shorts*.

A neon-lamp voltage tester (Fig. 2) is a handy gadget. It can be used to detect the presence of voltage and determines whether the voltage is AC or DC. It can also be used for determining if a chassis is hot with respect to ground and for identifying the grounded side of the AC power line. It consists of a tiny neon lamp with a resistor connected in series with it to limit the current through the lamp. The value of the resistor depends upon the type of lamp used. These testers usually sell for a dollar or so and are available in almost every hardware store.

The neon lamp will not light until the voltage being tested is in excess of about 70 volts. Hence, when used to check voltages in elec-

Test Equipment

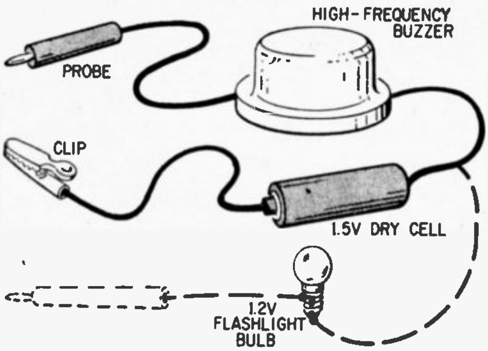


Fig. 1. This simple continuity tester can be a great help around the electronics experimenter's work area.

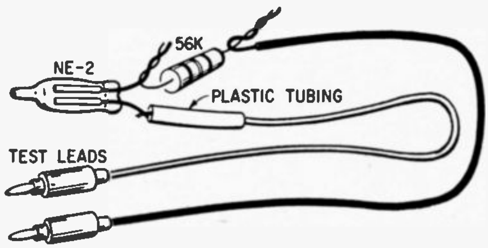


Fig. 2. Neon test lamp is inexpensive. Is constructed in several different ways. A slightly different circuit uses a calibrated potentiometer to indicate approximate voltage. Lamp (below) indicates AC or DC.

tronic equipment, you will know that the voltage is more than about 70 volts if the lamp glows and by its brilliance you can, with some experience, determine if the voltage is around 115 volts or much higher. If the voltage is DC, only one half of the lamp will light up (glow around plate).

To find out if a chassis is hot with respect to ground, connect one of the test leads to the chassis and the other to a wire leading to an earth ground (water pipe, radiator, etc.). To determine which side of the AC power line is grounded, touch one test lead to the screw holding the plate of the electric outlet and push the other test lead into one of the outlet slots—then the other. The side of the power line that is not grounded is the one that makes the lamp light. This will work only when the outlet box is grounded, which it should be.

Test lamps can be used for other voltages too. Generally these are limited to testing power-source voltages and testing for open fuses. Incandescent lights draw much more current than the neon type, which is only a fraction of a watt, but they can be used on low-voltage systems where neon lamps are useless. Incandescent lamps will also indicate the presence of abnormal resistance in a power circuit since the current drawn will drop voltage across any series resistance.

High-frequency voltage and high voltage (like those in the CRT power supply and sweep in a TV set) will make a neon lamp glow without any direct connections to the leads.

Voltmeters. There are several kinds of voltmeters—some are seldom seen on the test bench of the electronics technician. Often they are expensive and generally are used only for special applications where a conventional D'Arsonval (moving coil) meter cannot be used. Since few experimenters have budgets that will allow several-thousand dollars for a laboratory-type instrument we'll just forget about them for now.

The most common type of voltmeter is the moving-coil meter movement with a series resistance to limit the current through the coil. Actually the moving-coil meter movement is a milliammeter or microammeter. The movement actually indicates the current flowing in the meter and multiplier-resistor circuit (Fig. 3). The amount of cur-

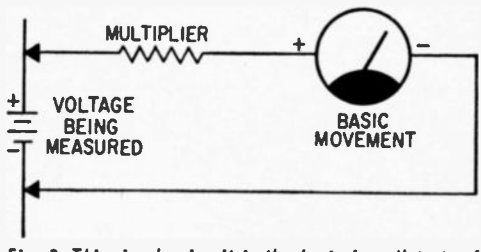


Fig. 3. This simple circuit is the basis for all tests of voltage in all electronics and electrical circuitry.

rent that can flow through a resistance, when a voltage is applied, is expressed by Ohm's law. Therefore the meter scale can be calibrated in *volts* although the meter is actually indicating the *current* flow in the metering circuit.

Maximum range (full-scale calibration) of the voltmeter is determined by the series, or multiplier resistor, and the sensitivity of the meter movement. (The sensitivity of a meter movement is indicated by its full-scale rating in milli- or microamperes.)

For example, if the meter is a 0-1 DC

milliammeter, and the resistor has a value of 1000 ohms, the voltmeter will indicate "1", its full-scale point when the voltage being measured is one volt. However, we have not taken into account the internal resistance of the meter. If it is 100 ohms, the meter will actually indicate less than full scale. Therefore, the multiplier resistor should have a value of 900 ohms. Now the total circuit resistance is 1000 ohms and the current through it, with one volt applied, is 0.001 ampere—one milliampere.

The accuracy of a voltmeter also depends upon the meter and the multiplier. Most panel meters are rated ± 1 or ± 2 percent accuracy of the full-scale value. Ordinary carbon resistors have values within 20 percent of their rating and slightly more expensive types are rated at 10 percent and 5 percent. There are also precision resistors accurate to better than 1 percent.

If the meter is accurate to ± 2 percent and the resistor is within ± 1 percent of its rated value, the total error could be as much as ± 3 percent. It could be less if the meter indicated 2-percent high and the resistor were 1 percent higher than its marked value.

In the example previously given the milliammeter is used as a 0-1 DC voltmeter and it is not necessary to recalibrate the meter scale since the indications are correct for volts or milliamperes.

By changing the multiplier value to 10,000 ohms, less 100 ohms (9900 ohms), to allow for the internal resistance of the meter, full-scale meter indication will occur when 10 volts are applied—we now have a 0-10 voltmeter. Change the resistor to 99,900 ohms, we have a 0-100 DC voltmeter, and so on. By providing a switch (S1) for selecting

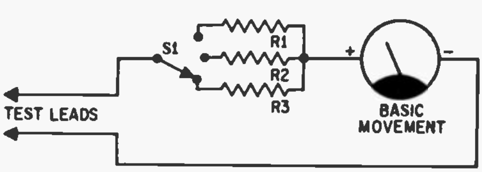


Fig. 4. Basic multirange voltmeter circuit has remained unchanged for nearly a hundred years of use.

various multiplier resistors, as shown in Fig. 4, we have a multirange voltmeter.

Many DC voltmeters employ a more sensitive meter—one that has a full scale of 50 microamperes. The series resistor must be of a higher value than when a 0-1 DC milliammeter is used. Including the meter's internal resistance, the series resistor is calculated on the basis of 20,000 ohms per volt. For full scale reading with one volt applied, the resistor value is 20,000 ohms—200,000 ohms for 10 volts, and so on.

Current meters. The same basic DC meter can be used for measuring current. Obviously, a 0-1 DC milliammeter will read full scale when one milliampere flows through its coil. But, if we shunt a resistor

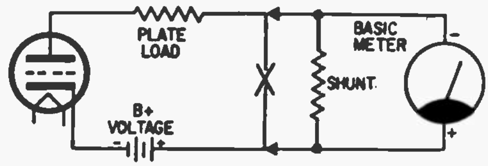


Fig. 5. Current measurement circuit remains the same whether you measure 1/10, 1, 10 or 100 amperes.

across the meter terminals, as shown in Fig. 5, part of the current flows through the meter and part through the shunt resistor. If the internal meter resistance is 100 ohms and the shunt resistor also has a value of 100 ohms, the range of the meter will be doubled. The range can be further increased by reducing the value of the shunt resistor. A multirange current meter can be formed by using a selector switch (S1), as shown in

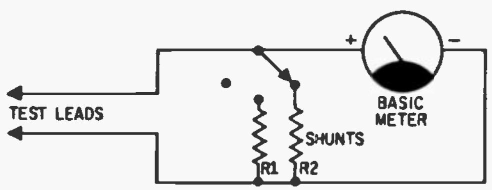


Fig. 6. Switch-selected shunts are used only for the lower current ranges. Contact resistance is a problem.

Fig. 6, to select various values of shunt resistors.

When measuring voltage, the meter is connected across the voltage to be measured through a series resistor. But, when measuring current, the meter is inserted in series with the circuit as shown in Fig. 5 which shows how tube plate current can be measured. The circuit is broken at X and the meter is then inserted in the circuit.

Current can also be measured by determining the voltage or IR drop across a resistor which is in series with the circuit being metered and then calculating the current's value. As shown in Fig. 7, we are trying to measure the current flowing through R1 and R2, which are in series, and through which the same current flows. If it is known that R1 is 90 ohms and R2 is 10 ohms, and the meter reads 0.9 (when R3, the meter series multiplier resistor has a value of 10,-

Test Equipment

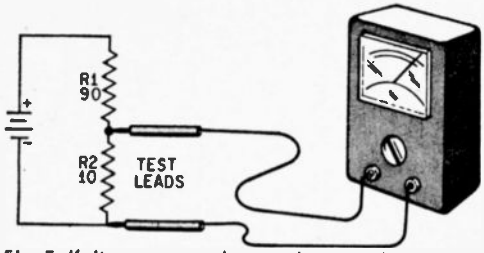


Fig. 7. Voltage measured across known resistance can be used to calculate current flow through the circuit.

000 ohms), we also know that there is a 9-volt drop across R2. Since current in amperes is equal to *E/R* (voltage divided by resistance), we can calculate that the current is 0.9 ampere since 9 divided by 10 equals 0.9.

Ohmmeters. The same basic DC meter can also be used to measure resistance by using the circuit shown in Fig. 8A. If the

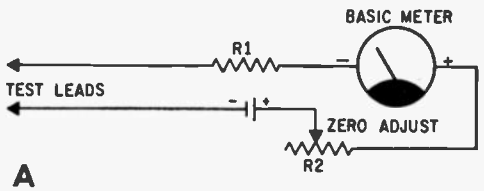


Fig. 8A. Basic resistance-measuring circuit will read full scale when test lead tips are shorted together.

internal voltage is 1.5 volts we will require 1500 ohms of series resistance in the circuit to obtain full-scale deflection on a 0-1 DC milliammeter when the test leads are short-circuited. If the internal resistance of the meter is 100 ohms, we need 1400 ohms more resistance. We can make R1 a 1200-ohm resistor and R2 a 300-ohm rheostat. With the test lead terminals shorted, R2 is adjusted until the meter indicates full-scale deflection before going further; R2 is the zero adjust control, which makes up for drop in battery voltage (due to aging) and error in R1.

Now, if we connect a 3000-ohm resistor across the test-lead terminals, the meter will read 0.33 milliammeters (0.00033 amperes) since the total circuit resistance is now 4500 ohms. Hence, the meter scale can be calibrated directly in ohms.

A slide-back ohmmeter circuit is given in Fig. 8B. This circuit is used for measuring

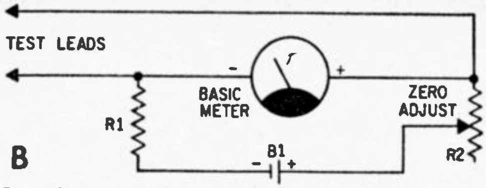


Fig. 8B. Meter will read full scale with leads open. Resistance under test acts like shunt—reduces reading.

very-low values of resistance. Here, R1 and R2 have the same values as in Fig. 7, but the test leads are connected across the meter. When the leads are shorted, the meter will read zero, and when they are open, the meter will indicate full scale. But, if the leads are connected across a 100-ohm resistor, the meter will read 0.5 milliamperes since half the current flows through the meter coil and half through the resistance being measured. The smaller the value of resistance being measured, the lower the current through the meter, just opposite to the effect obtained when using the circuit shown in Fig. 7.

AC Voltmeters. The same basic meter can be used to measure AC voltage. If we

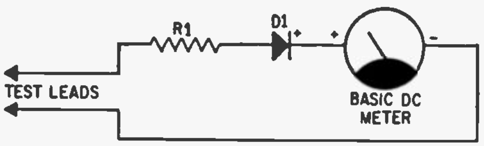


Fig. 9. Series diode in the basic voltmeter circuit will give an indication of AC voltage on meter scale.

add a diode rectifier to the circuit in Fig. 9, the meter will read DC voltage when the positive terminal of the measured voltage is applied to the test lead connected to the anode of the diode and the series resistor. If we reverse the test leads so that the negative side of the circuit is connected to the anode of the diode, the meter will not indicate since the diode blocks passage of current. But, if we apply an AC voltage to the circuit, the diode rectifies the AC—and DC flows through the meter, and it doesn't matter which way the test leads are connected.

A more commonly used circuit is shown in Fig. 10. Here, two diodes are used, one in series with the meter circuit and the other shunted across the meter coil. The second diode shunts off any negative voltage that might leak through the first diode. As in DC voltmeter circuit (Fig. 3) series resistor R determines the full-scale range of the meter.

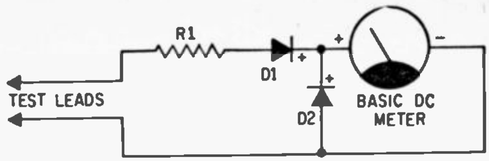


Fig. 10. Two diodes improve meter rectification and give better indication of AC voltage being measured.

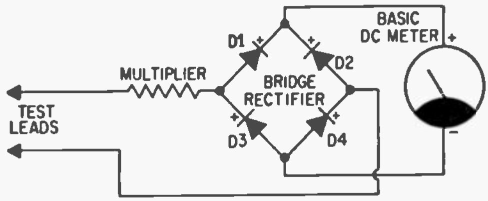


Fig. 11. Four diodes in bridge circuit improve the AC measurements. Both halves of AC cycle flow in meter.

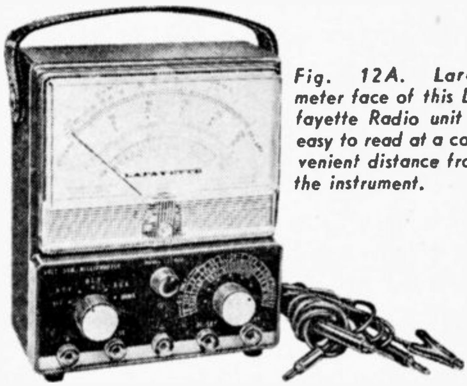


Fig. 12A. Large meter face of this Lafayette Radio unit is easy to read at a convenient distance from the instrument.

Fig. 12B. The mirrored scale improves accuracy of this Olson Electronics 100,000-ohm-per-volt instrument.

Still another meter-rectifier circuit is shown in Fig. 11. Here, four diodes are used in a full-wave bridge circuit.

Volt-ohm-milliameters. The most widely used test instrument is the volt-ohm-miliiameter—known as the VOM or multimeter. It combines current, voltage and resistance measuring circuitry in one instrument. Typical VOMs are shown in Fig. 12.

Meter sensitivity has gone up—the needs of modern circuitry has far out distanced the 1000-ohm per volt VOM abilities. A 20,000-ohm-per volt meter is just about minimum standard now—and 30,000, 50,000 and 100,000-ohm-per-volt instruments are in the range of any experimenter's budget. Some imported models sell for less than $25.

Reading the Scale. The many ranges of a VOM make it harder to read than a single calibration. Usually the top scale is calibrated in *ohms* for measuring resistance, as in Fig. 13. The second and third arcs of calibrations are for AC and DC—*volts* and *miliamperes*. The position of the range

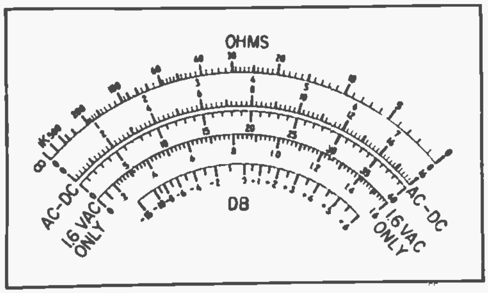


Fig. 13. Meter face of multimeter is easy to read after you work with instrument for a while. Just like anything else—practice makes perfect. With mirrored scale reading is made when needle reflection is behind needle—close one eye—to avoid parallax.

switch and test lead jacks determine the function to which the VOM has been set.

There is a special calibration for the 1.6-volts AC range—the counterclockwise end of the scale is particularly nonlinear because of the action of the meter rectifier at low voltages. (This is a problem in its own right so we won't waste time going over the explanation for that here).

The innermost calibrations are for audio power measurements—generally across a 600-ohm impedance (AC resistance). Making a measurement across any other load will only give indications of relative voltage and special calculations must be made to compensate for the differences in load. The power level for an indication of −2db across a 4-ohm speaker will not be the same as the −2db indication across an 8-ohm load—and neither will the same as the −2db that is indicated when the test leads are connected across the 600-ohm load for which the range was calibrated. Decibel (db) measurements are one of the most complex measurements possible with the VOM and require much more than a paragraph or two of explanation. The AC voltage indicated will be a true indication regardless of the value of the load.

Vacuum-Tube Voltmeters. The sensitivity of the meter movement used in the VTVM is not an indication of the characteristics of this instrument. The VTVM has a constant input resistance (generally 11 megohms—11,000,000 ohms—for radio and TV service-type instruments) on all ranges. For ranges above 550 volts the 20,000-ohm-per-volt VOM has a higher input resistance than the service-type VTVM. The meter movement measures the current through an amplifier tube or the voltage difference between plates of a pair of tubes in a push-pull type circuit.

In the circuit shown in Fig. 14, the meter is connected in series with the plate of the tube and indicates plate current. By adjusting bias control R2, we can set the negative

Fig. 16A. Peak-to-peak AC volts, ohms, rms AC, and DC volts are indicated with Electronic Measurements instrument. A special circuit also permits unit to measure capacitance.

Fig. 16B. Audio (AC) VTVMs have fewer knobs than multimeter type. This EICO unit's low range is 1 millivolt or –60 db across 600 ohms.

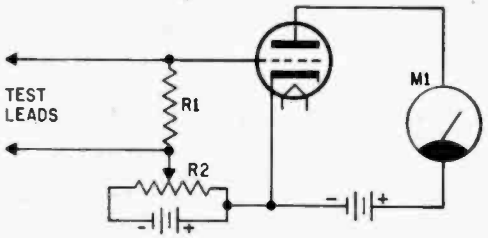


Fig. 14. Slide-back VTVM circuit measured plate current resulting when test voltage changed grid bias.

Fig. 16C. Most VTVMs, like this Knight (Allied Radio) model, use same circuitry. Basic circuit has not changed in 20 years.

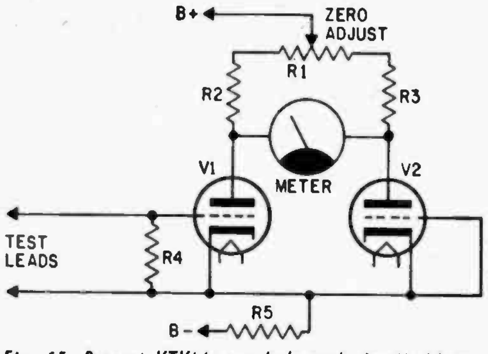


Fig. 15. Present VTVMs use balanced circuit. Meter indicates voltage between plates (or cathodes).

grid voltage to a value that will cause the plate-current meter to read full-scale. Then, if we apply a DC voltage to the test leads, which are shunted by R1, the voltage applied across R1 will be in series with the bias voltage fed in from R2. If the voltage applied to the grid end of R1 is negative, the bias on the tube will be increased and less current will flow through the tube and meter—the meter pointer will slide *back* toward zero. This slide-back VTVM circuit is seldom used because the linearity of the meter calibrations are governed by the characteristics of the vacuum tube used in the amplifier circuit.

A more popular basic VTVM circuit is given in Fig. 15. Two triodes are used in a balanced circuit. The meter is connected from one tube plate to the other. The meter reads zero when both tubes draw the same plate load resistances (R2 and R3) are equal.

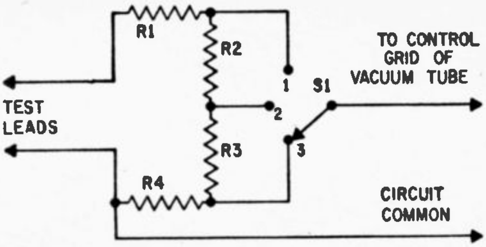


Fig. 17. Basic voltage divider is range switch for any VTVM. R1 is usually housed in probe of test leads.

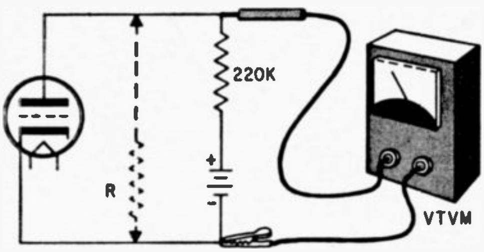


Fig. 18. Any service-type voltmeter draws current from circuit—VTVM draws least at low voltages.

When making measurements R1 is adjusted for a zero meter reading when there is no test voltage across the test lead terminals and R4.

When a positive voltage is applied to the grid end of R4, V1 draws more current than V2 and the voltage at the plate of V1 is lower than the voltage at the plate of V2, causing the meter to deflect. The higher the applied voltage, the greater the circuit unbalance and, hence, the greater the meter reading.

Potentiometer R1 can also be set so that the meter pointer normally rests at mid-scale. Thus, when a negative voltage is applied to the grid end of R4, the meter needle moves counterclockwise from its mid-scale position. The needle moves in the opposite direction when the input voltage is positive. Hence it is easy to denote whether the measured voltage is positive or negative.

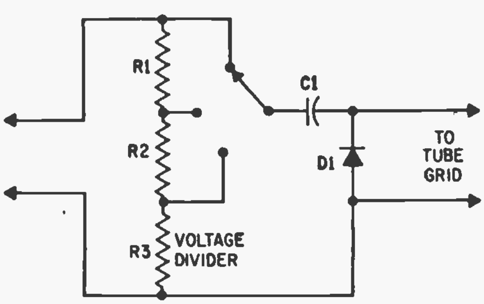


Fig. 19. Meter rectifier for VTVM lets some AC sneak through to reduce meter readings below correct value.

Multirange VTVMs (Fig. 16) have a voltage divider at the input, as shown in Fig. 17. Selector switch S1 taps the voltage divider at various points. The resistance values could be so selected as to provide 0-10 volt full-scale reading when set to position 1, 0-100 at position 2 and 0-1000 at position 3.

The big advantage of a VTVM over a VOM is that it has only a slight loading effect (at low-voltage range settings) on the circuit being metered. When any meter is used to measure voltage (at the plate of a tube, as shown in Fig. 18) the voltage drops when the meter is connected and the true normal voltage is not indicated. If the voltmeter is of the type shown in Fig. 3, using a 0-1 DC milliammeter and a 100,000-ohm series resistance, the meter will indicate a much lower voltage than is actually there when the meter is not connected across the circuit. The meter loading is the same as adding the shunt resistor R, shown connected in dotted lines from plate to ground.

If the meter is a 0-50 DC microammeter, the loading effect will be only 5 percent as severe since the meter and its series resistor for 0-100 volt full-scale reading will represent a load of two megohms. But, the input resistance of a vacuum-tube voltmeter is usually a minimum of 11 megohms and has but slight loading effect on the circuit.

AC Vacuum-Tube Voltmeters. Some vacuum-tube voltmeters are designed for DC or AC measurements only, while some can be used for measuring both. All that is necessary to convert a DC VTVM for AC measurements is to add a rectifier at the input.

A basic circuit given in Fig. 19, shows an input-voltage divider for range selection and a shunt diode rectifier. When the applied AC voltage swings negative, current flows through the diode to ground and capacitor C is charged in the indicated polarity. When the AC voltage swings positive, the diode no longer conducts since it is reverse-biased and the positive charge in C1 is applied to the grid of the tube in the instrument.

Audio (AC) VTVMs. The AC measurements of the Volt-Ohm type of VTVM are generally limited to the higher ranges. The lowest range between 2.5 and 10-volts AC.

The low-range of the Audio (AC) VTVM is often as low as .010 volt (10 millivolts) for service-type instruments while high-priced laboratory-type instruments go to .001 volt (1 microvolt). These instruments are, basically, audio amplifiers and will not

Test Equipment

pass DC voltages and are suitable for AC voltage measurement only. The frequency range of some of the more expensive models starts around 2 Hz (cps) and can go as high as 4 mHz (mc). Of course the bandwidth is less in lower-priced instruments, like those used for hi-fi and radio-TV repair shop work.

With a little experience and some calculations a wideband oscilloscope (often called a *scope* for short) can be used to make many of the measurements that are made by the Audio (AC) VTVM. Relatively inexpensive service-type scopes, like those used for color-TV servicing will reach the 5-mHz range but the meters are accurately calibrated over their entire range—you'll have to calibrate the oscilloscope yourself.

Oscilloscopes. The most useful piece of test equipment in many respects is the oscilloscope. You can measure voltage, current, power and other quantities with it and you can observe the waveform of electrical voltages and currents. An oscilloscope employs a cathode-ray tube, somewhat similar to a television picture tube or radar display tube. Its cathode squirts a narrow stream of electrons toward a screen which glows when the electrons strike it. The electron stream can be swung so that it scans the screen from left to right in a straight line at a fast rate, extinguishing its beam during the return trip from right to left. This is done by applying a sawtooth-wave signal to its horizontal deflection plates. Then, if a signal is applied to its vertical plates, the spot on the screen can be made to vary up or down.

There are so many applications for an oscilloscope that it would require an entire book to describe them. Scopes can be bought in kit or ready-made from at prices ranging from about $45 to several thousand dollars. A scope contains a sawtooth timing generator, vertical and horizontal amplifiers and, of course, a power supply, is shown in Fig. 20.

All scopes look pretty much alike (Fig. 21). Most employ tubes throughout, but at least one employs transistors and can be operated from batteries—making it useful in the field as well as on the bench.

Fig. 21. This 5-inch DC scope by Heathkit has a good many features of scopes used in engineering laboratories.

Signal Generator. Another valuable instrument for the experimenter is a signal generator, but what kind? There are so many. It depends upon whether you're working with audio or RF, and how high in frequency.

For audio work there is a wide selection of audio signal generators, sometimes called audio oscillators. You can get a single-frequency unit—that operates at 1000 cycles only for a few dollars from one of the big mail-order houses, or you can pay several hundred dollars for a lab-type instrument.

(Continued on page 108)

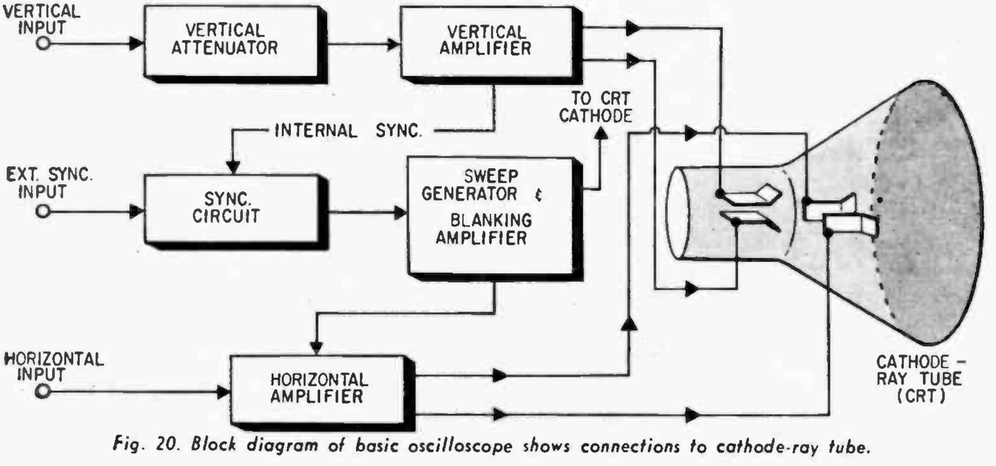
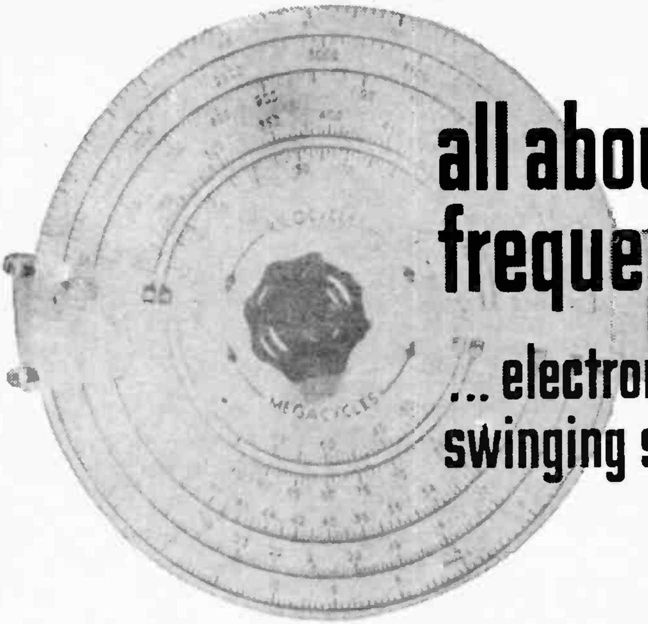


Fig. 20. Block diagram of basic oscilloscope shows connections to cathode-ray tube.



all about frequency

... electronics' swinging side

Almost the whole field of electronics is based on the use of frequencies—rectified, multiplied, or divided.

■ In electronics, we are most often concerned with *frequency*, as the rate at which something electrical occurs even though the term is applicable to all repeating actions. These frequencies range from DC to billions of cycles per second. Table 1 lists the various frequency bands and Table 2 lists the terms used for defining frequencies.

While cps, kc and mc are still used by many (because they are most easily recognized) the electronics industry is adopting *Hertz* (Hz) in place of *cycles per second* (cps) in honor of Heinrich Hertz, just as volts and watts honor men who have contributed to the art.

**TABLE 1.
FREQUENCY BANDS**

Designation	Abbreviation	Freq. Range
Sub-Audio	2/M	0-50 Hz (cps)
Power	2/M	25-1000 Hz
Audio	2/M	50-15,000 Hz
Very low frequency	VLF	10-30 kHz (kc)
Low frequency	LF	30-300 kHz
Medium frequency	MF	300-3000 kHz
High frequency	HF	3-30 MHz (mc)
Very high frequency	VHF	30-300 MHz
Ultrahigh frequency	UHF	300-3000 MHz
Superhigh frequency	SHF	3-30 gHz (gc)

**TABLE 2.
FREQUENCY ABBREVIATIONS**

Commonly used	FCC	World Wide	Designation
cps	C/s	Hz	cycles per sec.
kc	Kc/s	kHz	kilocycles per sec.
mc	Mc/s	MHz	megacycles per sec
gc	Gc/s	gHz	gigacycles per sec.

1000 Hz = 1 kHz   1000 kHz = 1 MHz
1000 MHz = 1 gHz

The pitch of a sound is its *frequency*. An AC sine wave (house current or pure, steady audio tone) has a specific frequency. A square wave or almost any signal (except a pure sine wave) contains *harmonics* in addition to its fundamental frequency. (A harmonic is a multiple of a fundamental frequency.) A train of evenly spaced pulses transmitted at a steady rate has a specific *pulse repetition rate* (PRR) or *pulse repetition frequency* (PRF) often stated in PPS (*pulses per second*). Its PRF or PRR has a fundamental frequency plus other frequencies. Fig. 1 shows some common wave forms.

Frequency

DC and AC. DC (direct current) has no frequency since it flows in one direction. But, when DC is interrupted or changed in amplitude, it does have a frequency characteristic. The output of a battery or dry cell for example, is at zero but connect a switch into the circuit and flip it *on* and *off* and then the DC output has frequency. The same is true of a carbon microphone, as shown in Fig. 2. When the microphone picks up no sound, zero-frequency DC flows through it. But, when it picks up sound, the amplitude of the DC is varied at one or more frequencies.

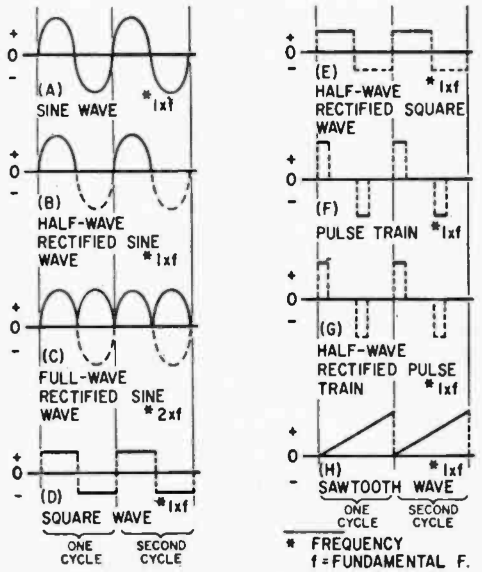


Fig. 1. Frequency comes in all shapes and sizes. The dotted lines show current missing in ideal waveform.

AC (alternating current) changes its direction of flow at some constant frequency. House current, for instance, reverses its direction of flow 60 times per second. Take a look at Fig. 1 (A). Here, the line voltage rises from zero to 161 volts positive, drops back to zero, rises to 161 volts negative, and then drops back to zero during one cycle. The RMS (root mean square) voltage is 115 volts, the peaks are alternately +161 volts and −161 volts. The peak-to-peak voltage, therefore, is 322 volts. For practical purposes, we call this a 115-volt circuit.

If the load is resistive, the direction of current flow reverses with the polarity of the voltage and the instantaneous current is proportional to the instantaneous voltage.

AC Sources. When a coil of wire is rotated within a magnetic field, as in Fig. 3,

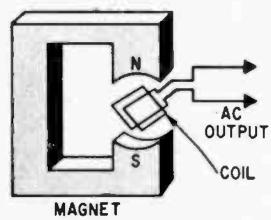


Fig. 3. Steady magnetic field will generate AC voltage if coil is moved (rotated) to break lines of force.

an *alternator* is formed. An alternator is an AC generator which, when correctly designed, produces sine wave AC (as in Fig. 1). As the coil (rotor) passes the poles of the magnet the north pole induces an EMF (electromotive force) in one direction and the south pole in the opposite direction. The frequency of the AC depends upon the speed of rotor rotation and the number of magnetic poles used. The voltage depends upon the number of rotor coil turns and the strength of the magnetic field.

AC is also generated with a magnetic microphone, as shown in Fig. 4. This is another form of AC generator whose output frequency depends upon the frequency of the picked-up sounds. A crystal microphone

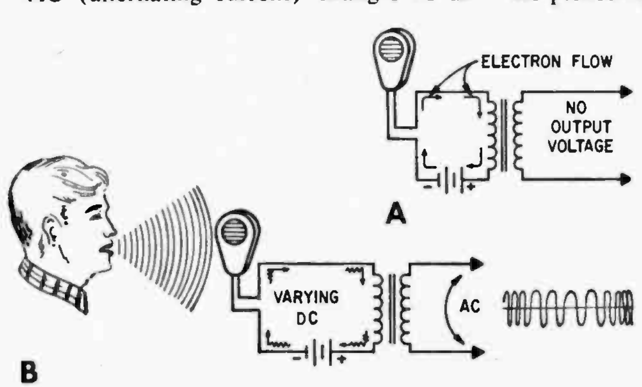


Fig. 2. With no signal the constant DC flow through transformer primary can't induce any voltage into the secondary winding (A). When speaking into microphone, varying DC changes the magnetic field producing an audio (AC) voltage (B).

is also an AC generator which converts sound waves into an AC voltage.

DC Sources. The most common DC source is a dry cell or a battery. It may be a primary cell, such as a dry cell, or a rechargeable (secondary) cell or battery. DC can also be generated by a thermocouple which produces a difference of potential when it is heated. Selenium or solar cells generate DC by applying light. While light also has frequency, it is so high that the cell does not respond to its alternations.

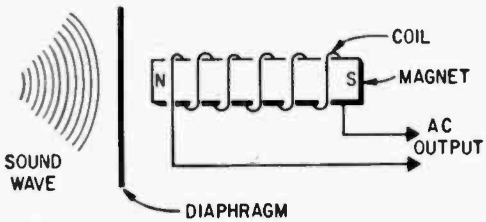


Fig. 4. Vibrating diaphragm affects flow of magnetic lines of force between poles generating weak voltage.

AC into DC. The AC output of an alternator can be converted into DC by redesigning the machine into a *dynamo* or DC generator. It too employs a magnetic field and a rotor (which is now called an armature). The rotor coils are connected to a commutator from which electrical energy is picked off with carbon brushes. As the armature rotates, the commutator and brushes select coils in such a manner that the output voltage does not reverse its polarity. The output voltage, however, is not pure DC since it contains commutator ripple—small variations in voltage caused during the switching action of the commutator. This ripple has a frequency which depends upon the commutator switching rate. By connecting a filter capacitor across the dynamo output, as shown in Fig. 5, the ripple can be removed and the output voltage will be relatively pure DC.

AC can be converted into DC by using a rectifier, as shown in Fig. 6. The rectifier (D1) allows current to pass in only one direction.

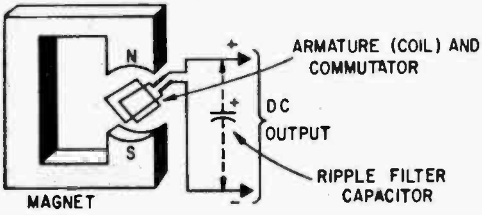


Fig. 5. Rotating coil produces pulsating DC when output connections are switched by added commutator.

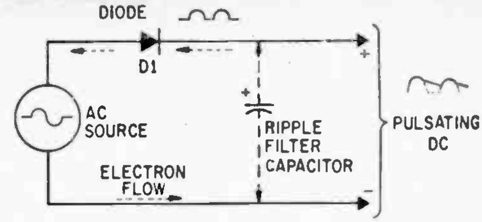


Fig. 6. Single diode converts AC to half-wave, pulsating DC. Dotted lines in output waveform are filled in by a filtering capacitor connected across output.

The output voltage is pulsating DC which has the same frequency as the AC source. By using a full-wave rectifier, as shown in Fig. 7, the rectifiers (D1-D2) alternately pass current during each half cycle, causing the pulsating DC output to have a ripple frequency twice that of the AC source. As in the case of a dynamo, a filter capacitor will smooth out the ripple.

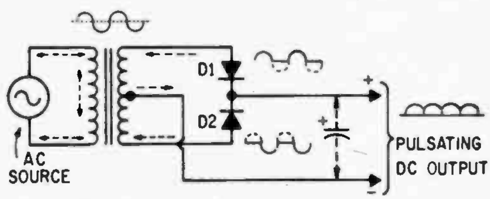


Fig. 7. Two diodes and center-tapped transformer put both halves of the sine wave to work. At twice the ripple frequency smaller filter capacitors are used.

DC into AC. DC can be converted into a form of AC by reversing the polarity of the DC with a switch, as shown in Fig. 8. This causes square wave AC to be produced. If the DC potential is 12 volts, the square-wave output voltage will alternate from +12 volts to −12 volts and the peak-to-peak voltage will be 24 volts.

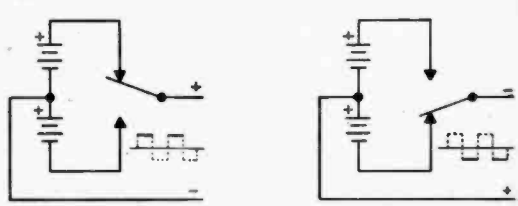


Fig. 8. Rapidly flipping a switch back and forth is one way to generate square waves—there are better.

For a more practical device, the switch would be replaced by a vibrator, connected as shown in Fig. 9. The energizing coil vibrates causing the switching contacts to reverse the direction of current flow through the primary of transformer T1. The AC voltage at the secondary of T1 is neither a pure square wave, nor a sine wave. The shape of the square wave is altered by the

Frequency

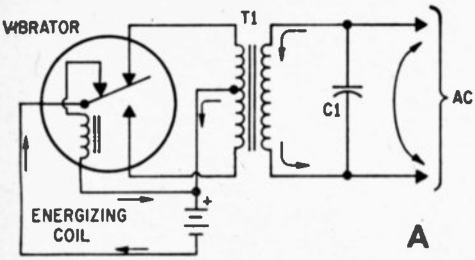
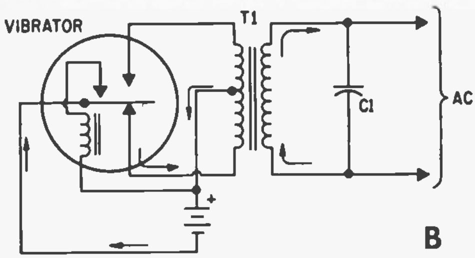


Fig. 9. Constant-frequency, vibrator-generated square waves are modified by the combination of T1 and C1.



effects of the transformer's inductance and buffer capacitor C1.

AC can be produced electronically with an *oscillator*, as shown in Fig. 10. Here, the

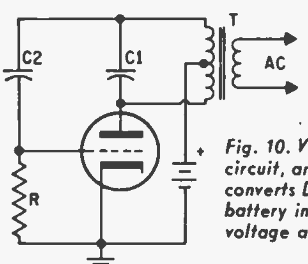


Fig. 10. Vacuum-tube circuit, an oscillator, converts DC of the battery into alternating voltage and current.

DC powers the oscillator (the output is generally an AC sine wave) and whose frequency depends upon the values of L1-C1, a parallel-resonant circuit. The AC frequency can be as low as a few cycles per second or

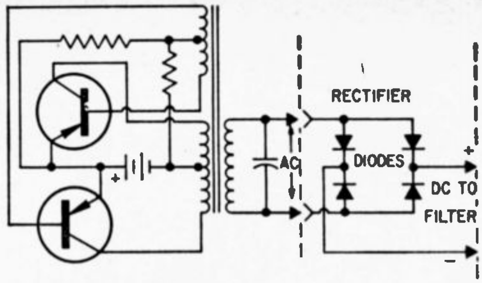


Fig. 11. Transistors acting like vibrators generate AC which is rectified, filtered for high-voltage DC.

high in the megacycle range.

Transistors are used in solid state DC-to-AC inverters in an oscillator circuit. The transistors function as switches, keyed *on* and *off* at a frequency determined by circuit constants. The same technique is used in CB sets and commercial mobile radio units—followed by a rectifier. DC is converted into AC and back into DC at a higher voltage, as shown in Fig. 11.

The frequency of the AC produced by vibrators or switching transistors can be at 60 Hz (cps). However, in DC-to-AC-to-DC power supplies, the switching frequency is usually higher, making it easier to fiter out the ripple and permits the use of smaller transformers.

Frequency Standards. Throughout the United States, with rare exceptions, the electric power-line frequency is 60 Hz (cps). In some parts of Los Angeles, it is 50 Hz. And, the Pennsylvania Railroad uses 25-Hz AC to power its electric locomotives. On some aircraft and various military applications, 400-cycle (Hertz) AC is used.

Electric clocks keep accurate time because the frequency of the power system is maintained exactly (at 60 cycles) over a 24 hour period. A 60-cycle clock powered by a 50-cycle line will run slow and lose time. A 60-cycle record player cannot usually be operated successfully from a 50-cycle power source. And, a 60-cycle inductance (non-

TABLE 3. NBS STANDARD FREQUENCY TRANSMISSIONS

Station	Frequencies							
	20kHz	60kHz	2.5MHz	5MHz	10MHz	15MHz	20MHz	25MHz
WWV			X	X	X	X	X	X
WWVH*			X	X	X	X		
WWVB		X						
WWVL	X							

*Located in Hawaii, all others at Fort Collins, Colorado after December 1,1966. kHz = kc MHz = mc.

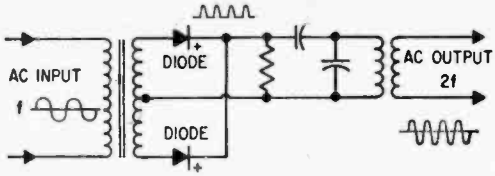


Fig. 12. Full-wave rectifier circuit is frequency doubler when filter circuit is replaced with a tuned circuit—set for twice the input frequency. It works but is not efficient and finds very few applications.

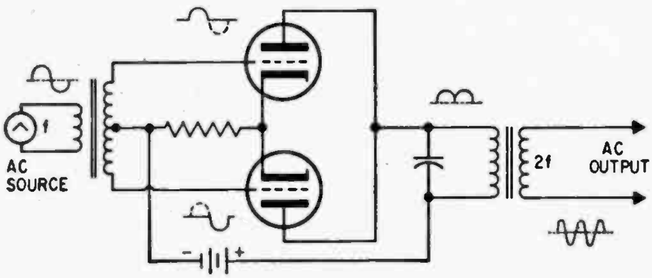


Fig. 13. Push-pull input, parallel output, vacuum-tube circuit (left) uses same number of transformers as circuit above—but amplifies.

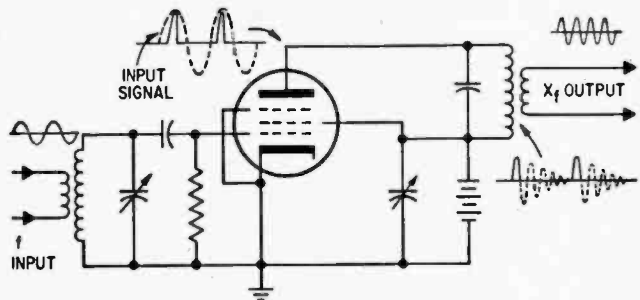


Fig. 14. Single-pentode amplifier is biased class-C. Changes sine wave to sharp current spikes which generate damped oscillations in output tuned circuit. Ringing is at tuned harmonic.

resistive) load (motor, radio or TV with power transformer, etc.) will probably burn out if connected to a 25-cycle power source.

The National Bureau of Standards transmits standard AF and RF frequencies as well as time signals (primary standards) over WWV and its other stations, as noted in Table 3. These signals are used to check the accuracy of secondary frequency standards — oscillators, frequency controlled by tuning forks or resonant reeds, used as audio-frequency reference standards or crystal-controlled oscillators used as radio-frequency standards.

Varying Frequency. The ouput frequency of an alternator can be varied by adjusting the speed of the rotation. To get a power frequency, other than the AC line, an alternator is driven by a constant speed motor through a speed-adjusting mechanism. Where DC is available, a variable-speed DC motor is used to drive the alternator or inverter.

When an electronic oscillator is used as an AC source, frequency can be varied by changing the tuning of the oscillator. AF and RF signal generators are variable-frequency AC generators. While the output-power capability of a signal generator is usually very low, amplifiers can increase the power to a kilowatt or more.

Frequency Multiplication. A AC signal frequency can be doubled by passing it through a full-wave rectifier, as shown in Fig. 12, or a *push-push* amplifier, as shown in Fig. 13.

Many transmitters, (and some special receivers), multiply frequency in Class-C amplifier stages. In Fig. 14, for example, the input of the amplifier is tuned by L1-C1 to the frequency of the input signal—L2-C2, at the output, is tuned to a multiple (harmonic) of the input signal. L1-C1 could be tuned to 1.5 MHz and L2-C2 to 4.5 MHz to form a frequency *tripler*. By cascading frequency-multiplier stages (using one after another), it is possible to increase the frequency of an input signal hundreds of times.

Frequency multiplication is possible in a Class-C amplifier, because it is biased beyond cut off—plate current flows only during the peak positive input-signal excursions. The output signal is distorted and rich in harmonics. The desired harmonic is extracted with a resonant circuit (L2-C2) which restores the signal into a sine wave because of the *ringing* effect within the resonant circuit.

Frequency

Varactor diodes are now being used as frequency multipliers in circuits such as the one in Fig. 15. A varactor diode is a non-linear device, as is a Class-C amplifier, and therefore distorts the applied signal, causing the production of harmonics. Varactors operate at ultrahigh frequencies, they can be used in VHF and UHF transmitters and receivers as non-power consuming frequency multipliers.

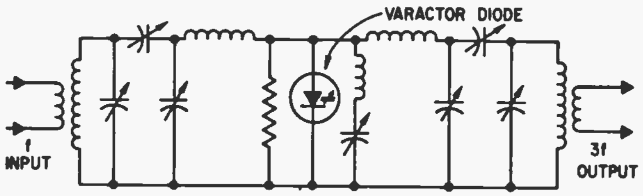


Fig. 15. Varactor diode is more efficient as frequency multiplier than full-wave circuit in Fig. 12. Although little power is taken by varactor diode there is level loss that must be made up.

Quartz crystals are often used as the input tuned circuit in frequency multiplier applications. Many CB sets, for example, use third-overtone crystals. The crystal's fundamental frequency is much lower than the output frequency. The oscillator output circuit (Fig. 16) is tuned to the crystal's third overtone (fourth harmonic) frequency within the Citizens Radio band.

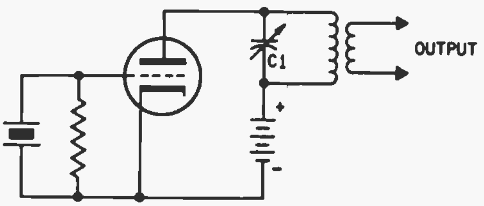


Fig. 16. Vacuum-tube crystal oscillator has output tuned circuit (tank) tuned to fourth harmonic of crystal by variable C1.

Frequency Conversion. Signal output of frequency multipliers is an exact multiple of the input frequency. By using a frequency *up-converter* or *down-converter*, a frequency may be raised or lowered. A frequency converter has a *local* or built-in oscillator whose frequency is combined with the input signal to produce a hetrodyne or beat signal at a desired frequency.

Pentagrid Converter. This technique is used in vacuum-tube superhetrodyne receivers as typified in Fig. 17. If the incoming signal is at 1000 kHz (kc) and the local oscillator is at 1455 kHz, a 455-kHz beat (IF) signal is produced. In this circuit (using a pentagrid converter tube), grids 1 and 2 form a triode Hartley oscillator. The incoming radio signal is fed to grid 3—which is isolated from grid 1 by Grid 2 and from grid 5 (suppressor grid) by grid 4. Grids 2 and 4 are connected together, grid 2 functioning as the oscillator plate and grid 4 as the circuits screen grid.

The Hartley oscillator modulates the cathode-to-plate electron stream at its frequency. The incoming radio signal, fed to grid 3, also modulates the electron stream. If the oscillator operates at 1455 kHz, for example, and the signal at grid 3 is at 1000 kHz, both of these signals will be at the plate. Their sum frequency, 2455 kHz, and their difference frequency, 455 kHz, will also be at the plate. In addition, signals at other frequencies, such as harmonics and various intermodulation products will be present.

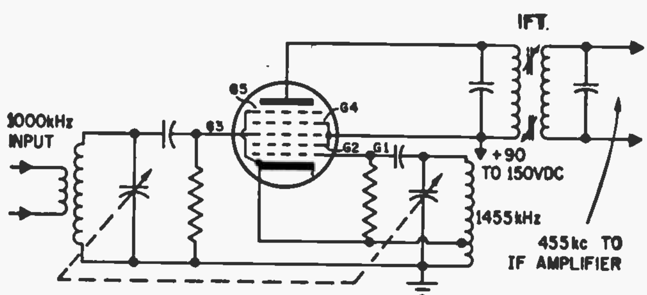


Fig. 17. This converter circuit has been standard in most superhetrodyne sets for many years—only the parts have changed physically.

By feeding the plate current through an IF transformer (IFT) tuned to 455 kc, the difference frequency (455 kc) will be passed and all other signals will be greatly attenuated. The oscillator and input tuning capacitors (C1, C2) are ganged so as to maintain the oscillator frequency 455 kHz.

A pentagrid converter (mixer) tube is used in most tube-type BCB receivers. In transistor-type sets, however, a single transistor is often used in an autodyne circuit (Fig. 18).

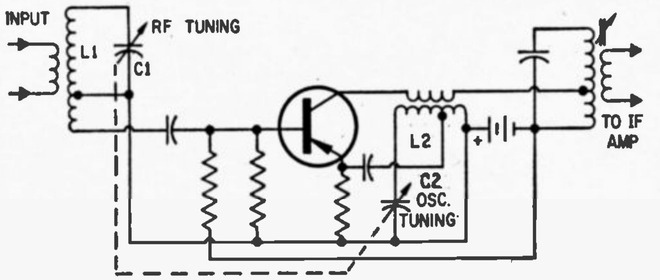


Fig. 18. This circuit can be compared to that for tubes in Fig. 17. Three element transistor must oscillate and amplify in superhetrodyne.

The input circuit (L1-C1) is tuned to the incoming frequency and the oscillator (L2-C2) is tuned 455 kc above L1-C1. The IF transformer (IFT), of course, is tuned to 455 kc. Here a single transistor functions as both the mixer and local oscillator.

A converter can employ separate mixer and oscillator tubes or transistors. For example, two triodes are used in the circuit given in Fig. 19. The signal from V2 is capacitively coupled to the grid of V1. In some cases, when the two triodes are within the same tube envelope, the capacitor isn't required because of the internal capacitance between the two triodes.

Semiconductor-Crystal Mixer. The mixer can also be a crystal diode while the oscillator could be either a tube or transistor, as shown in Fig. 20. Crystal mixers are commonly used in microwave receivers in conjunction with a klystron (microwave tube) local oscillator.

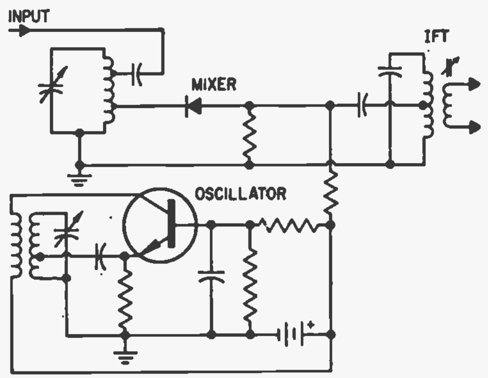


Fig. 20. Mixer diode is biased to prevent rectification, a technique much used for UHF front ends.

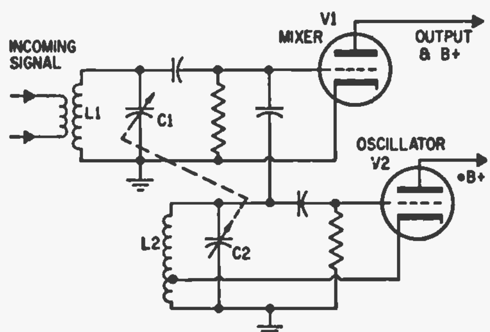


Fig. 19. Two triodes are used here in a circuit similar to that used in many of the early TV-set front ends.

Up-Converter. An up-converter shifts a frequency upward. A CB transceiver can be used as a 2-meter (144-148 mHz) band ham rig by connecting an up-converter to the transmitter output as shown in Fig. 21. If the CB unit is set to 27.105 MHz, for example, and its output is heterodyned with a 118-MHz signal in the converter, the new output signal will be at 145.105 mHz—within the novice portion of the 2-meter band.

A down-converter could be used to change a 145.105 MHz signal to 27.105 MHz by heterodyning it with a 118 mHz signal. The same local oscillator could be used for both transmitting and receiving.

To avoid using expensive 118-MHz crys-

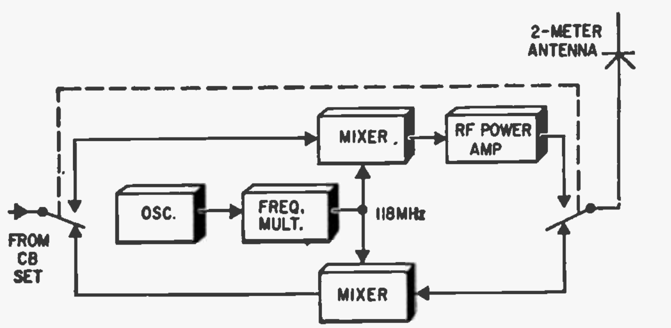


Fig. 21. Mixers can be used for transmitter output as well as receiver input to change frequency to one that can't be reached with a multiplier circuit.

Frequency

tals, a lower-frequency crystal and frequency multipliers are often used, as shown in Fig. 22.

Down-Converter. A commercial down-converter circuit is shown in Fig. 23. Here, the input signal can be anywhere in the 108-174 MHz range, depending upon the crystal used. The RF amplifier is tuned to the receiving frequency with trimmer C1—mixer tuning is with trimmer C2. The mixer output is fed to an automobile radio, forming a dual-conversion superheterodyne receiving system.

Multi-Conversion. Two down-converters are used in dual-conversion superheterodyne

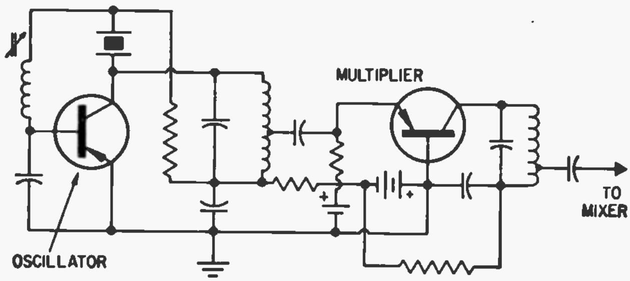


Fig. 22. Superhetrodyne oscillator uses low-frequency crystal and frequency multiplier where exact-frequency crystals aren't available or are too expensive.

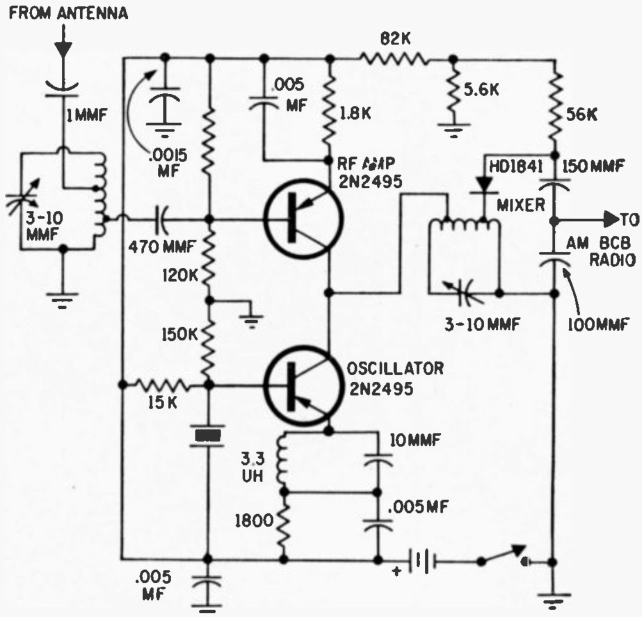


Fig. 23. Down-converter is crystal-controlled for VHF fixed-frequency reception. High frequency is for above the broadcast band normally tuned by the receiver it feeds.

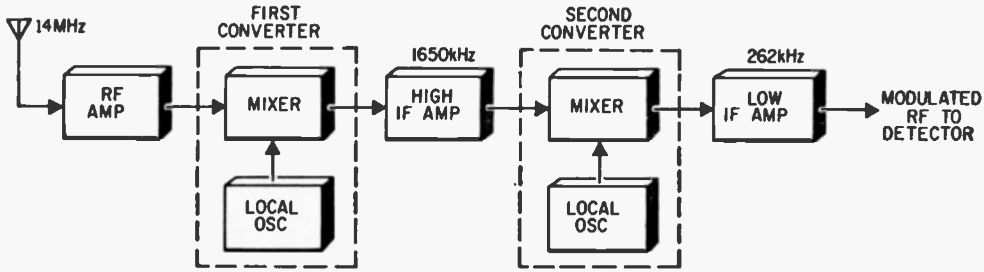


Fig. 24. Dual conversion is illustrated in this block diagram. High-IF amplifier is fixed-tuned to the top end of AM broadcast band. First converter and RF amplifier can be circuit in Fig. 23, above.

receivers (Fig. 24) and three in a triple-conversion receiver. Both frequency multipliers and converters are used in some VHF and UHF receivers. Multipliers are used to permit utilization of relatively-low frequency crystals in local oscillator chains as previously shown in Fig. 22. A single converter, a frequency multiplier chain and a frequency doubler are used in an early VHF receiver, as shown in block diagram Fig. 25. The second limiter is used as a doubler. It doubles the IF signal frequency which at the same time doubles the FM signal frequency deviation, making it easier to demodulate the FM.

shown in Fig. 27. Since the *frequency* of the signal is modulated, and not the amplitude as in AM, the distortion introduced in the frequency multiplication process has negligible effect on the modulation except to increase the deviation—the amount the frequency changes.

Heterodyne Converters. Until recently, most microwave transmitters employed Klystron oscillators (operating at the carrier frequency) or lower-frequency crystal-controlled oscillators, driving a chain of frequency multipliers. Now heterodyne techniques are commonly used, as shown in Fig. 28. Similar techniques are used in TV trans-

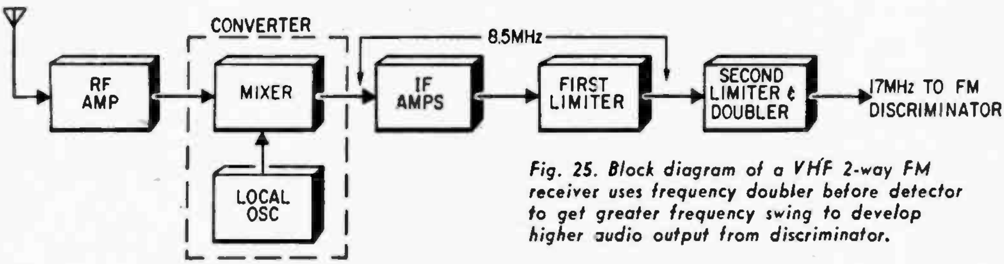


Fig. 25. Block diagram of a VHF 2-way FM receiver uses frequency doubler before detector to get greater frequency swing to develop higher audio output from discriminator.

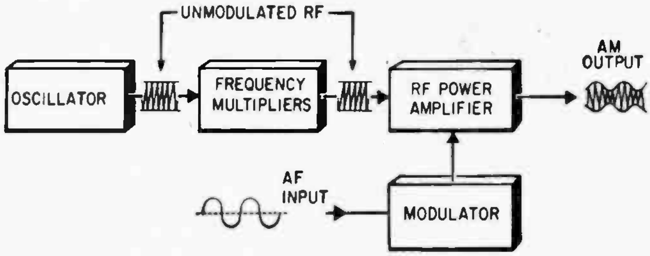


Fig. 26. Modulation is applied to AM transmitter after frequency multiplication to prevent audio distortion.

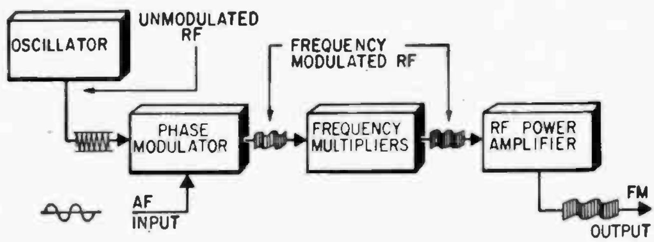


Fig. 27. FM transmitter is modulated before frequency is multiplied. This increases frequency swing without using high-power stages.

Multiplier Applications. The use of frequency multipliers in AM receivers, except in local oscillator chains, would cause serious distortion and loss of modulation. In AM transmitters, the frequency multipliers, when they are required, are between the oscillator and the RF power amplifier which is modulated. Signals through the multipliers (Fig. 26), are not modulated.

In an FM transmitter the modulation is applied before the frequency multipliers, as

lators. As illustrated in Fig. 29, a VHF-band TV signal is picked up and translated by an up-converter for retransmission on a UHF-TV channel.

In frequency conversion, two signals are heterodyned to produce a beat signal above or below the input-signal frequency. The converter (essentially a detector) is a form of modulator. For example, when a CB transmitter operating at 27.105 MHz is modulated by a 3000-Hz audio tone, three signals

Frequency

are transmitted, the carrier at 27.105 MHz, the sum frequency (upper sideband) at 27.108 MHz (+3 kHz) and the difference frequency (lower sideband) at 27.102 MHz (−3kHz).

Frequency Dividers for AF and RF. In frequency multiplication, a signal is increased in frequency to a multiple or harmonic of the input frequency. A signal's frequency can also be decreased by passing it through one or more flip-flops as shown in Fig. 30. Each flip-flop divides the frequency in two (reduces it by half) since it requires two input cycles to reset the flip-flop to its original state.

Frequency Division Modulation. FDM is thethe term used to define a multiplexing technique—it's not the same as dividing a single frequency. Ordinarily, a telephone line or a radio system conveys one channel (voice or music) of intelligence. The same pair of telephone wires can often be used to carry several telephone conversations by using FDM multiplex. As shown in Fig. 31, one is sent directly over the wires. The

(Continued on page 116)

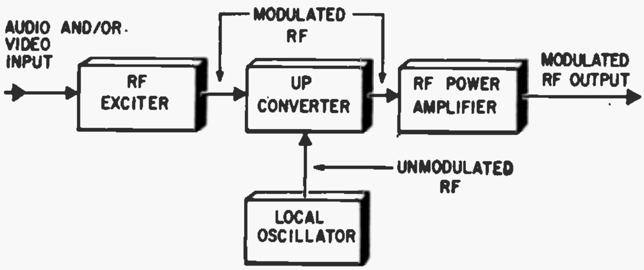


Fig. 28. Hetrodyne converter is a form of modulator used at microwave frequencies.

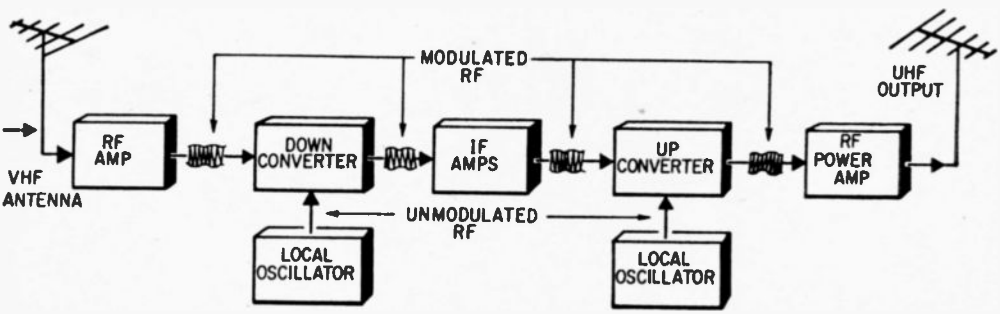


Fig. 29. TV translator shifts TV-channel frequencies to prevent interference.

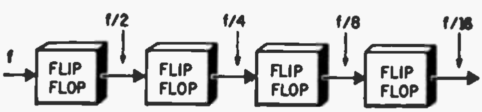


Fig. 30. Flip flops, a form of multivibrator, are used to divide frequency.

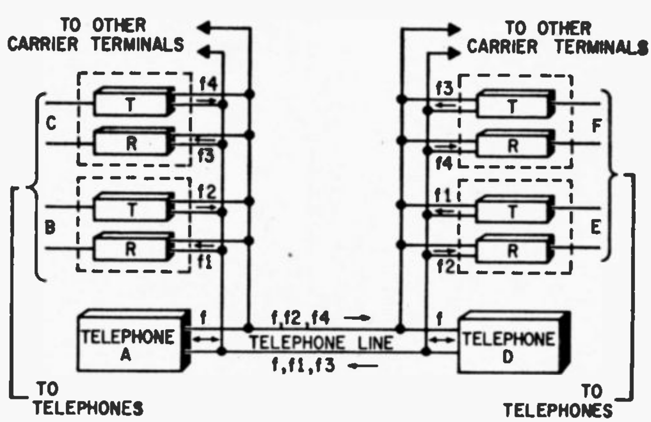


Fig. 31. FDM (frequency division modulation) is one way to multiplex many signals over a single pair of telephone wires.

Electronic Circuits

Continued from page 12

shaped) about ⅜-in. diameter, and are rated at 75-100 watts. Heavy-duty units may have tips as large as 1-in. diameter and be rated as high as 400 watts.

A soldering gun, rated as between 100 and 200 watts, is the best general-purpose soldering tool. If a lot of work is to be done with transistorized circuits, a small pencil gun is useful, and, equipped with various de-soldering tips, is essential for extensive printed circuit work. The best soldering iron for general use would be a 75-150-watt unit, but, unless a thermostatic iron holder is used, care must be taken to unplug the iron at times to keep it f om getting excessively hot. Larger irons, and even propane torches are sometimes required for special work involving heavy-duty components.

Solder comes in various mixtures of tin and antimony, and the exact mixture is usually a matter of individual choice. It is essential that only rosin core solder be used in electronic wiring. Good joints are hard to make with plain solder, and acid core solder should not be used under any conditions.

Acid core solder, or acid fluxes should never be used because of their electrolytic action. Wet batteries consist of two metals in an acid solution, and the acid residue and the metals of the connection (zinc and copper, tin and copper, etc.) made with acid core solder or flux may create a small battery. The minute voltage and current from this battery would interfere with circuit operation, and the continued action of the acid residue would corrode the metals.

The same is true, to a lesser degree, of other soldering fluxes. Most kit manufacturers specify that flux not be used, and guarantees are void if they are. The purpose of a flux is to keep the air from oxidizing the metal as it is heated during soldering, and different fluxes have different acid contents. There may be cases where it is necessary to use a flux to get a good connection with a minimum of heat. But if used, the flux should have a very low acid content and should be used sparingly.

In soldering, the joint or connection should be heated enough to permit the solder to flow readily, and then not moved until the solder has set. The most common types of poor solder joints are those where the heat was insufficient, and the solder is merely tacked on (usually in the form of globules). Another type of poor joint is where the heat is sufficient and the solder flowed, but the joint was disturbed before the solder set, and the joint cracked.

The first step to good soldering is to have the joint clean. Terminal lugs and wire should be scraped with a knife or razor blade until the metal shines. Where wires are involved, the dry joint (before the solder is applied)should be made as tight as possible, by crimping the wire. The soldering gun or iron tip should then be placed against the joint until it gets hot. Solder is then applied to the JOINT, still holding the tip against the joint. Allow the solder to flow over the joint. If a small amount is used, where the weight isn't a factor, it will tend to flow toward the heat. When the entire joint is covered with a thin coat of solder, remove the heat and the solder, taking care not to disturb the joint until the solder sets. When liquid, solder shines brightly, and glazes over or dulls when it sets.

In applying heat to the joint, be careful to prevent excessive heat from damaging components. This is particularly important in transistors, which can be ruined by excessive heat. One precaution is to limit the heat by using the proper size gun or iron, and applying it only long enough to properly melt the solder. Another is to grasp the wire leading to the component with long-nose pliers to dissipate the heat from the wire, through the pliers, before it reaches the component.

Various types of wire are used in electronic wiring. Plastic insulated wire, either solid or stranded, is often used for general wiring, and is referred to as hook-up wire. Shielded wire, with a braided shield over a central conductor, is used for some low-level audio or RF applications, and may or may not have an insulated covering over the braid. Occasionally cable is used in wiring, and sometimes a number of wires are collected in cable form by lacing cable, or waxed string.

Wiring. Stripping the ends of wire for connection purposes consists of removing the insulation from the wires at both ends. This can be done with special stripping tools, but the more common way is to cut around the insulation (about ¼-in. from the end of the wire), and then pull the insulation off.

Stripping shielded wire requires two operations: cutting the shielding back about ⅜-in. from the end, and then preparing the inner wire as above. One way to do this (if braided, uninsulated shieldding is used) is as follows: Cut the wire to the desired length, and then bunch up the shielding somewhat, by pushing each end in toward the center. Then the shielding can be slid along the wire. Slide it until one end of the shield is about 1-in. from one end of the wire. Then, holding that end of the shielding in position, smooth it out to its original length, and cut off the part that extends beyond the other end of the wire. Bunch it up again, slide it back so equal parts of wire stick out at each end, smooth it out evenly, and you'll have about ½-in. of insulated inner wire sticking out of each end of the shielding.

In stripping cable, the first step is to remove the sheath. With plastic or rubber sheaths, one way to do this is to bend the cable double at the

Electronic Circuits

Continued from page 103

point where the sheath is to be cut. Holding the cable in a tight bend, lightly cut through the sheath at the top of the bend. Due to the tension at the top of the bend, the sheath will split open before you cut into the insulation of the wires inside. By turning the cable, bending it double, and making cuts around the sheath, you can cut completely around the sheath without damaging the inner wires, and then pull the section of sheath off the end. If quite a bit of sheath is to be removed, a series of cuts such as this might have to be made.

In wiring, sequence is most important. It is highly desirable to have all connections to a given lug made before soldering, but in wiring procedures and spacing of components, all connections might not be made at the same time. In a kit, instructions usually tell you when to solder, and in other cases, if a pictorial diagram is available, you can readily see all of the connections that have to be made to a given point. When working from a schematic only, however, care must be taken to be sure all connections have been made to a point before soldering, and that all joints have been soldered before the job is finished.

Generally speaking, straight wiring (where only wire leads are involved) should be done first. This permits the wires to lie flat on the chasis allowing components (resistors, capacitors, etc.) to hold them in place. Furthermore, it places the most trouble free thing (wiring) at the bottom, allowing accessible space above for components that might have to be replaced later.

Wiring appears neater if kept straight, running directly between connection points, or making right angle bends around components. It makes wiring easier to trace, but takes more time, and usually requires the use of solid, rather than stranded, hook up wire, to make them stay in the desired position.

When a number of components have to be connected to ground or chassis, a bare ground wire lead running through the chassis is helpful. This lead should then be connected to the chassis at one point. This not only simplifies connecting components to ground, but prevents the possibility of eddy through the chassis at grounding points.

All components and wiring should be securely mounted, lest movement of the unit create loose connections, or even broken wires. Each unit should be built as though it were to be placed in mobile service, as far as component mounting is concerned. If not, even moving a unit across the bench might cause enough component movement to result in a loose or broken connection.

Handling Parts. While some components (such as tube sockets, some transformers, etc.) have lugs to which components can be fastened, tie points are usually necessary. These come in a variety of forms and are bolted to the chassis (perhaps with a mounting bolt used for a component, such as transformers, etc.). The tie point lugs, most of which are insulated from the chassis, can then be used as connection points for various components and wiring.

Vector tube sockets are another means of mounting components. These are sockets with an insulated rod molded to the bottom of the socket, at the end of which are a number of mounting lugs. Small components, such as resistors and capacitors, can then be mounted between the regular tube socket pin lugs and the lugs at the end of the rod. They are available for many types of sockets, in various rod lengths, depending on the size of the components and chassis depth.

All components, no matter how small, should be properly supported. You should never make a connection between a component (without a lug connection) and a wire, except at a tie point or other lug, such as on another component or grounding lug. One exception to this might be a connection between a small component and a stiff, well-mounted grounding bus wire. Many small components are small and light enough, and have stiff enough leads that soldering the leads to lugs or tie points is suitable. In large tubular capacitors, however, a mounting strap for the body of the capacitor should be used, unless the leads are particularly stiff and short.

One method of wiring, which ensures excellent component mounting, is the use of terminal boards. Here, all parts are mounted between lugs on a terminal board, and the board mounted on the chassis. Wire then runs between lugs on the terminal board and those on other terminal boards or other chassis-mounted components. Using terminal boards results in efficient, compact wiring, and ready accessibility for parts replacement.

Metal Work. In building electronic units, certain metal work is involved in chassis and panel preparation, unless kits are involved. If layouts are furnished, the chassis and panel can be marked by making a full-scale drawing of the layout, taping it to the chassis or panel, and then center punching all of the holes. If desired, pilot holes can be drilled through the paper layout and metal, using the drill for the smallest hole involved. Then the layout can be removed, and the various holes enlarged to the proper size.

In drilling larger holes (1/8 to 1/2-in.), a pilot hole should be drilled first to assure proper centering. Larger round holes (1/2-in. and up) are best made with metal screw punches, which come in various sizes from 1/2-in. up to nearly 3-in. Punches are also available for special-shaped tube socket holes, and square holes up to 1½-in.

Large square holes can be made with a hacksaw or nibbling tool. In either case, the first step is to scribe the area to be cut out. If a hacksaw is to be used, a hole big enough for the hacksaw blade is drilled at each corner of the square, and then saw cuts made along the scribed lines. The corners are then squared off with the hacksaw or a file.

With the nibbling tool, a ⅜-in. hole is drilled at one corner, the tool inserted in this hole, and then the metal is cut out along the scribed lines. This tool can also be used for making slots (¼-in. wide or larger), or cutting irregularly-shaped holes.

After the chassis and panel have been completely drilled and punched, all chassis- and panel-mounted components should be fastener in place before wiring starts. When it is known that tie points are to be used, they should also be mounted.

In some cases it is necessary to drill a hole in a chassis or panel after wiring is completed. This involves the danger of damage due to the blow of center punching, short circuits due to metal drilling chips getting in the wiring, and the possibility of the drill breaking through into a component or wiring. To minimize these dangers:

A. Remove all delicate removable components, such as tubes, meters, etc.
B. Place a square of heavy adhesive tape over the point where the hole is to be drilled. Mark the center on the tape, and center-punch through the tape, using a fairly light blow.
C. Build a circular dam of putty around the center point, to catch the drilling chips.
D. Place a section of tubing around the drill, whose length will just permit the drill to penetrate the metal.
E. Drill through adhesive tape to minimize need for deeply-punched center.

Shield is sometimes required in electronic circuits. Sometimes it is for low frequency AC (to minimize hum), and sometimes for high frequency RF (to prevent interference between circuits). If required for AC, a ferrous magnetic-type metal, such as soft iron, must be used for effective shielding. These metals are also effective for RF, but if only RF is involved, aluminum or copper may be used, the latter being the most effective.

Tube shields are usually made of steel for complete shielding, but usually coil shields are aluminum, since RF shielding is the object.

Sometimes it is desirable to shield an area in the unit from the rest of the unit. This is usually done by covering the entire area with a shield can. For most effective results, sometimes the area is shielded both above and below the chassis. Sometimes the desired result can be secured by only a partition shield between the two areas, without completely covering the area.

In all shielding, wires, individual components, or areas, it is essential that the shielding material be well-grounded. If low frequency AC is involved, it is important that the chassis, as well as the shielding material, be steel. Proper grounding not only involves bolting the shielding material to the chassis, but a soldered wire braid connection between the two.

Electronic Hardware. Certain specialized hardware is used in electronic units. Machine screws and nuts are often used in assembly, varying from the small 2-56 size up to 12-24 size. For fastening parts to a chassis, round head, truss head or binding head screws are usually used. For panel-mounted parts, these may be used, or sometimes countersunk flat head, or oval head screws with cup washers are used. The spade bolt, which comes in several styles, is convenient for mounting terminal boards or shielding sections or cans to a chassis.

Lock washers, or self locking nuts should be used with machine screws, and care should be taken to be sure that the washer is small enough to permit the teeth to press against the nut if regular nuts are used. Both internal and external lock washers are used, and some are large enough for use with controls and switches.

As well as regular hex nuts and self locking nuts, wing nuts and binding post nuts are used where frequent loosening is required. Cap nuts are used where appearance is important, as on panels.

Wherever wires go through holes in chassis or panels, rubber grommets should be used to protect the insulation from the sharp edges of the hole. Hole plugs can be used to cover access holes (for seldom used controls), or even to plug mistakes. Other items of specialized hardware include spacers (both metal and fiber), lugs, cable clamps, switch and control plates, etc.

In addition to soldering equipment, certain specialized tools are required for electronic work. Some are essential, others merely helpful. Below is a list of tools for an electronic shop, including comments about certain specialized types:

Utility screwdriver (⅛- to 3/16-in. blade width)
Screw-holding screwdriver, with ⅛-in. blade (for starting and holding screws in those hard-to-reach places)
Screw-holding screwdriver, with ¼-in. blade
Thin 3/32-in. blade screwdriver (for knobs and other set screws)
Jeweler's screwdriver (for extremely small screws)
Philips screwdrivers #0, #1, and #2
Diagonal wire cutters
Side cutter pliers
Needlenose pliers (for holding wires, etc., where space is very limited)
Tweezers (for picking up objects in cramped

Test Equipment

Continued from page 92

One that is extremely useful puts out either a sine-wave or a square-wave signal.

A signal generator is simply an oscillator which can be tuned over a broad range of frequencies and whose output signal level can be varied. An audio-signal generator is often used for making amplifier frequency-response measurements and for signal tracing. RF-signal generators are mainly used for producing a reference signal at a desired frequency when aligning the circuits of a radio receiver.

Tube Testers. To test vacuum tubes you either need your own tube tester or access to a do-it-yourself tester at the neighborhood supermarket or drug store. The kind of tube tester you need depends upon what you plan to use it for. The simple two or three dollar tube testers that are sold by mail are not really tube testers. All they do is check tube heater (filament) continuity.

In the next higher price bracket are the *emission* type testers (Fig. 22) which will tell you whether a tube is totally defunct, very tired or apparently still useful. In an emission tester, the tube heater is operated at normal temperature and the total cathode current is measured when an AC or DC voltage is applied to all of the elements.

More critical tests can be made with a *transconductance* or *mutual dynamic conductance* type tube tester which operates the tube at somewhat near its actual operating conditions and measures the change in plate current when a small voltage change takes place at the grid. There are more knobs to set and a reading other than *good*, *fair* or *replace* can be obtained. But, they cost much more than emission type testers.

Some have a *grid emission* test feature which is important when checking certain tubes. Separate grid emission testers are also available. They do not check tube merit, but instead check interelement leakage and grid emission, which is a common failing of some types of tubes, even brand new ones.

The best test for a tube, however, is the substitution method. When checking amplifiers, for example, feed a square-wave signal into the amplifier and monitor the amplifier output with a scope. Then, replace each tube, one-at-a-time, and note if there is any difference in the shape or amplitude of the output waveform. Or when checking a radio receiver or hi-fi tuner, feed a very small RF signal into the antenna connector and meter the AVC voltage in an AM set or limiter voltage in an FM set (with a sensitive VTVM) and try inserting new tubes, one-at-a-time, and noting whether there is any increase in metered voltage.

Fig. 22. Book-sized tube tester is inexpensive. This emission tester (Lafayette Radio Electronics) uses four-position slide switches for "free-point" tube-pin connections to prevent obsolescence, when new tubes are introduced, over a period of many work years.

What to buy and where to buy it. All radio parts stores sell test equipment normally used for servicing or by experimenters. Laboratory-grade test equipment is usually sold directly from the factory to the user through manufacturer's representatives. The electronics mail order catalogs list many kinds and makes of test equipment and will give you an idea of what's available.

Test equipment is available in kit form, too, from several sources including Allied, Lafayette, Heath and Eico. Whether to assemble your own or to buy ready-made equipment depends mainly upon which is worth more to you, time or money. The kit-type instrument is good. Many are in use in laboratories by engineers whose employers can usually afford to buy ready-made equipment.

The important thing is you can never fully understand the VOM, VTVM, signal generator, oscilloscopes and tube testers unless you use them. ■

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. . . The Atom

Continued from page 84

portant and widely used applications of magnetic induction is the transformer. Transformers find the major application in stepping up or down voltage and current in countless applications.

Fig. 22 shows the basic construction of a typical transformer. While two separate windings are shown here, some transformers can have as many as five or six windings.

A transformer consists of two or more separate windings, electrically insulated from each other. One winding, which is known as the primary winding, is fed from a source of alternating current.

The alternating currents flowing through the primary induce a current in the secondary winding by virtue of magnetic induction. The transformer core is constructed from a relatively high permeability material such as iron which readily conducts magnetic flux between the primary and secondary windings.

The alternating current flowing in the primary of the transformer produces a variation in the magnetic flux circulation in the transformer core which tends to oppose the current flowing in the primary winding by virtue of self-induction. The counter EMF is just about equal to the voltage applied to the primary winding when no load is connected to the transformer's secondary winding. This accounts for the fact that very little current flows through the primary winding when no load is connected to the secondary. The negligible current that does flow under this no-load condition is known as the transformer magnetizing current. As the current drawn from the secondary winding increases, the primary current will increase proportionately due to the reduction in the counter EMF developed in the primary winding of the transformer.

In any transformer the ratio of the primary to secondary voltage is equal to the ratio of the number of turns in the primary and secondary windings. This is expressed mathematically as follows:

$$\frac{Ep}{Es} = \frac{Np}{Ns}$$

where EP = primary supply voltage
Es = voltage developed across secondary
Np = number of primary turns
Ns = number of secondary turns

The above formula assumes that there are no losses in the transformer. Actually, all transformers possess some losses which must be taken into account.

Transformer Losses. No transformer can be 100 per cent efficient due to losses in the magnetic flux coupling the primary and secondary windings, eddy current losses in the transformer core, and copper losses due to the resistance of the windings.

Loss of magnetic flux leakage occurs when *not all* the flux generated by current flowing in the primary reaches the secondary winding. The proper choice of core material and physical core design can reduce flux leakage to a negligible value.

Practical transformers have a certain amount of power loss which is due to power being absorbed in the resistance of the primary and secondary windings. This power loss, known as the copper loss, appears as heating of the primary and secondary windings.

There are several forms of core loss—hysteresis and eddy current losses. Hysteresis losses are the result of the energy required to continually realign the magnetic domain of the core material. Eddy current loss results from circulating currents induced in the transformer core by current flowing in the primary winding. These eddy currents cause heating of the core.

Eddy current loss can be greatly reduced by forming the core from a stack of individual sheets, known as laminations, rather than from a single solid piece of steel. Since eddy current losses are proportional to the square of core thickness, it is easy to see that the individual thin laminations will have much less eddy current loss as compared with a single thick core.

Another factor which effects eddy current loss is the operating frequency for which the transformer is designed to operate. As the operating frequency is increased, the eddy current losses increase. It is for this reason that transformers designed to operate at radio frequencies often have air cores and are void of ferrous metals.

Only the Surface. We've come a long way from our initial discussion of the atom and its importance for an understanding of electricity and magnetism. And there's still a long way to travel to understand all about the subatomic nucleus and its satellites and how they are being harnessed in an ever-expanding electronics technology. ■

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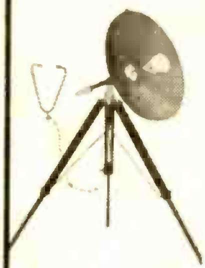

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- ★ CODE OSCILLATOR

- ★ No Knowledge of Radio Necessary
- ★ No Additional Parts or Tools Needed
- ★ EXCELLENT BACKGROUND FOR TV
- ★ SCHOOL INQUIRIES INVITED
- ★ Sold In 79 Countries

YOU DON'T HAVE TO SPEND HUNDREDS OF DOLLARS FOR A RADIO COURSE

The "Edu-Kit" offers you an outstanding PRACTICAL HOME RADIO COURSE at a rock-bottom price. Our Kit is designed to train Radio & Electronics Technicians, making use of the most modern methods of home training. You will learn radio theory, construction practice and servicing. THIS IS A COMPLETE RADIO COURSE IN EVERY DETAIL.

You will learn how to build radios, using regular schematics; how to wire and solder in a professional manner; how to service radios. You will work with the standard type of punched metal chassis as well as the latest development of Printed Circuit chassis.

You will learn the basic principles of radio. You will construct, study and work with RF and AF amplifiers and oscillators, detectors, rectifiers, test equipment. You will learn and practice code, using the Progressive Code Oscillator. You will learn and practice trouble-shooting, using the Progressive Signal Tracer, Progressive Signal Injector, Progressive Dynamic Radio & Electronics Tester, Square Wave Generator and the accompanying instructional material.

You will receive training for the Novice, Technician and General Classes of F.C.C. Radio Amateur Licenses. You will build Receiver, Transmitter, Square Wave Generator, Code Oscillator, Signal Tracer and Signal Injector circuits, and learn how to operate them. You will receive an excellent background for television, Hi-Fi and Electronics.

Absolutely no previous knowledge of radio or science is required. The "Edu-Kit" is the product of many years of teaching and engineering experience. The "Edu-Kit" will provide you with a basic education in Electronics and Radio, worth many times the low price you pay. The Signal Tracer alone is worth more than the price of the kit.

THE KIT FOR EVERYONE

You do not need the slightest background in radio or science. Whether you are interested in Radio & Electronics because you want an interesting hobby, a well paying business or a job with a future, you will find the "Edu-Kit" a worth-while investment.

Many thousands of individuals of all ages and backgrounds have successfully used the "Edu-Kit" in more than 79 countries of the world. The "Edu-Kit" has been carefully designed, step by step, so that you cannot make a mistake. The "Edu-Kit" allows you to teach yourself at your own rate. No instructor is necessary.

PROGRESSIVE TEACHING METHOD

The Progressive Radio "Edu-Kit" is the foremost educational radio kit in the world, and is universally accepted as the standard in the field of electronics training. The "Edu-Kit" uses the modern educational principle of "Learn by Doing." Therefore you construct, learn schematics, study theory, practice trouble shooting—all in a closely integrated program designed to provide an easily-learned, thorough and interesting background in radio.

You begin by examining the various radio parts of the "Edu-Kit." You then learn the function, theory and wiring of these parts. Then you build a simple radio. With this first set you will enjoy listening to regular broadcast stations, learn theory, practice testing and trouble-shooting. Then you build a more advanced radio, learn more advanced theory and techniques. Gradually, in a progressive manner, and at your own rate, you will find yourself constructing more advanced multi-tube radio circuits, and doing work like a professional Radio Technician.

Included in the "Edu-Kit" course are Receiver, Transmitter, Code Oscillator, Signal Tracer, Square Wave Generator and Signal Injector Circuits. These are not unprofessional "breadboard" experiments, but genuine radio circuits, constructed by means of professional wiring and soldering on metal chassis, plus the new method of radio construction known as "Printed Circuitry." These circuits operate on your regular AC or DC house current.

THE "EDU-KIT" IS COMPLETE

You will receive all parts and instructions necessary to build twenty different radio and electronics circuits, each guaranteed to operate. Our Kits contain tubes, tube sockets, variable, electrolytic, mica, ceramic and paper dielectric condensers, resistors, tie strips, hardware, tubing, punched metal chassis, Instruction Manuals, hook-up wire, solder, selenium rectifiers, coils, volume controls and switches, etc.

In addition, you receive Printed Circuit materials, including Printed Circuit chassis, special tube sockets, hardware and instructions. You also receive a useful set of tools, a professional electric soldering iron, and a self-powered Dynamic Radio and Electronics Tester. The "Edu-Kit" also includes Code Instructions and the Progressive Code Oscillator, in addition to F.C.C. Radio Amateur License training. You will also receive lessons for servicing with the Progressive Signal Tracer and the Progressive Signal Injector, a High Fidelity Guide and a Quiz Book. You receive Membership in Radio-TV Club, Free Consultation Service, Certificate of Merit and Discount Privileges. You receive all parts, tools, instructions, etc. Everything is yours to keep.

Progressive "Edu-Kits" Inc., 1189 Broadway, Dept. 501FC, Hewlett, N. Y. 11557

FREE EXTRAS

• SET OF TOOLS

- SOLDERING IRON
- ELECTRONICS TESTER
- PLIERS-CUTTERS
- VALUABLE DISCOUNT CARD
- CERTIFICATE OF MERIT
- TESTER INSTRUCTION MANUAL
- HIGH FIDELITY GUIDE • QUIZZES
- TELEVISION BOOK • RADIO TROUBLE-SHOOTING BOOK
- MEMBERSHIP IN RADIO-TV CLUB: CONSULTATION SERVICE • FCC AMATEUR LICENSE TRAINING
- PRINTED CIRCUITRY

SERVICING LESSONS

You will learn trouble-shooting and servicing in a progressive manner. You will practice repairs on the sets that you construct. You will learn symptoms and causes of trouble in home, portable and car radios. You will learn how to use the professional Signal Tracer, the unique Signal Injector and the dynamic Radio & Electronics Tester. While you are learning in this practical way, you will be able to do many a repair job for your friends and neighbors, and charge fees which will far exceed the price of the "Edu-Kit." Our Consultation Service will help you with any technical problems you may have.

FROM OUR MAIL BAG

J. Stataitis, of 25 Poplar Pl., Waterbury, Conn., writes: "I have repaired several sets for my friends, and made money. The "Edu-Kit" paid for itself. I was ready to spend $240 for a Course, but I found your ad and sent for your Kit."

Ben Valerio, P. O. Box 21, Magna, Utah: "The Edu-Kits are wonderful. Here I am sending you the questions and also the answers for them. I have been in Radio for the last seven years, but like to work with Radio Kits, and like to build Radio Testing Equipment. I enjoyed every minute I worked with the different kits; the Signal Tracer works fine. Also like to let you know that I feel proud of becoming a member of your Radio-TV Club."

Robert L. Shuff, 1534 Monroe Ave., Huntington, W. Va.: "Thought I would drop you a few lines to say that I received my Edu-Kit, and was really amazed that such a bargain can be had at such a low price. I have already started repairing radios and phonographs. My friends were really surprised to see me get into the swing of it so quickly. The Trouble-shooting Tester that comes with the Kit is really swell, and finds the trouble, if there is any to be found."

UNCONDITIONAL MONEY-BACK GUARANTEE

Please rush my Progressive Radio "Edu-Kit" to me, as indicated below:
Check one box to indicate choice of model

- ☐ Regular Model $26.95.
- ☐ Deluxe Model $31.95 (Same as Regular Model except with Superior Parts and Tools plus Valuable Radio and T.V. Tube Checker).

Check one box to indicate manner of payment

- ☐ I enclose full payment. Ship "Edu-Kit" post paid.
- ☐ I enclose $5 deposit. Ship "Edu-Kit" C.O.D. for balance plus postage.
- ☐ Send me FREE additional information describing "Edu-Kit."

Name ....

Address ....

City & State .... Zip ....

PROGRESSIVE "EDU-KITS" INC.
1189 Broadway, Dept. 501FC Hewlett, N. Y. 11557

PRINTED CIRCUITRY

At no increase in price, the "Edu-Kit" now includes Printed Circuitry. You build a Printed Circuit Signal Injector, a unique servicing instrument that can detect many Radio and TV troubles. This revolutionary new technique of radio construction is now becoming popular in commercial radio and TV sets.

A Printed Circuit is a special insulated chassis on which has been deposited a conducting material which takes the place of wiring. The various parts are merely plugged in and soldered to terminals.

Printed Circuitry is the basis of modern Automation Electronics. A knowledge of this subject is a necessity today for anyone interested in Electronics.