RCA

Solid-State Hobby Circuits Manual

Over 60 Useful Circuits for Beginners and Experts

Technical Series HM-91

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Contents

Solid-State Hobby Circuits Manual

This new edition of the Hobby Circuits Manual presents more than 60 practical and useful solid-state circuits which can be built by electronics hobbyists ranging from beginners to experts. The operation of each circuit is described in detail, and photographs, schematic diagrams, parts lists, and construction layouts are given. A guide to circuits by area of interest (e.g., amateur radio, photography, audio, etc.) is included to permit easy selection of the most useful circuits for specific applications.

The Manual includes brief descriptions of the theory and operation of the semiconductor devices used in the various circuits (silicon rectifiers, transistors, field-effect transistors, thyristors, and integrated circuits), and of the basic circuit "building blocks" employed. Sections containing construction tips and information on tools required, soldering techniques, testing, and trouble-shooting are also included.

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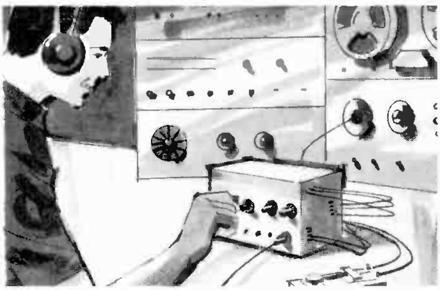
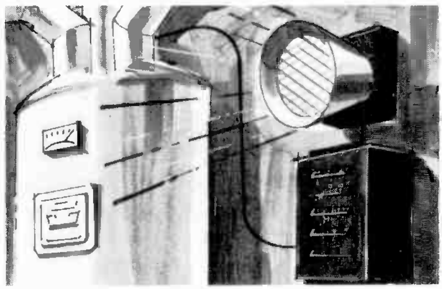
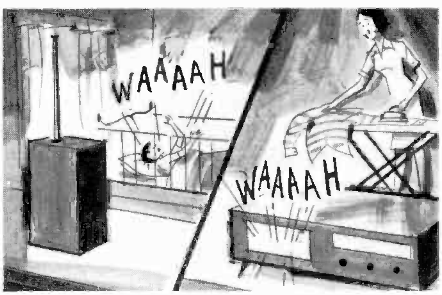
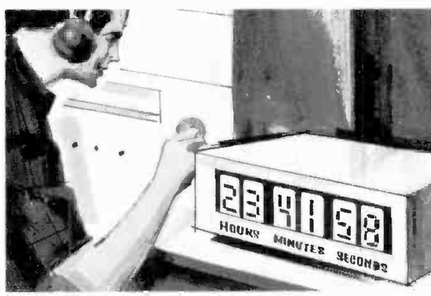
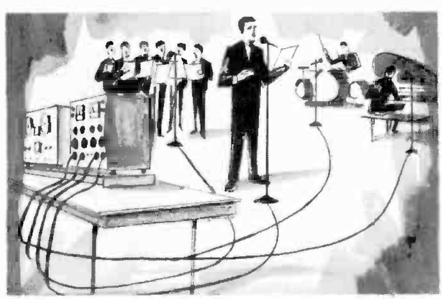
Illustrations of a few useful applications of some of the many circuits in this Manual











Theory and Operation of Solid-State Devices

SOLID-STATE or semiconductor devices are versatile units that can perform a variety of functions in electronic equipment. Like other electron devices, they have the ability to control almost instantly the movement of charges of electricity. However, in addition, semiconductor devices have many important advantages over other types of electron devices. They are very small and light in weight and have no filaments or heaters; therefore, they require no warm-up time or heating power. Their total power consumption is very low. They are free from microphonic noise and are rugged because of their solid construction.

SEMICONDUCTOR MATERIALS

Unlike other electron devices, which depend for their functioning on the flow of electric charges through a vacuum or a gas, semiconductor devices make use of the flow of current in a solid. In general, all materials may be classified as conductors, semiconductors, or insulators depending upon their ability to conduct an electric current. As the name implies, a semiconductor material has poorer conductivity (more resistance to current flow) than a conductor, but better conductivity (less resistance to current flow) than an insulator.

The materials most often used in semiconductor devices are germanium and silicon. Germanium is used in many low- and medium-power diodes and transistors. Silicon is more suitable for high-power devices because, among other things, it can be used at much higher temperatures.

The conductivity of semiconductor materials can be increased and controlled by the addition of small amounts of elements known as "dopants" or "impurities." For example, boron might be used as a dopant for silicon. The use of different types of dopants produces either n-type material, which has excess electrons, or p-type material, which has a shortage of electrons in its crystal structure. A position in the crystal structure from which an electron is missing is called a "hole."

P-N Junctions

When a junction is formed of n-type and p-type materials, as shown in Fig. 1, an interaction takes place in which some of the excess

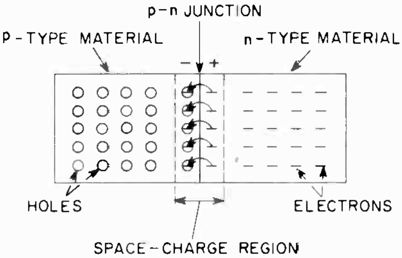


Fig. 1 - Interaction of holes and electrons at a p-n junction.

electrons from the n-type material diffuse across the junction and combine with the holes in the p-type material. This interaction creates a small space-charge region (often called the transition region or depletion layer) in the immediate vicinity of the junction. The p-type material in this region acquires a slight negative charge as a result of the addition of electrons; conversely, the n-type material acquires a slight positive charge as a result of the loss of excess electrons. The total effect is that of an imaginary battery connected across the junction having the polarity shown in Fig. 1. In the absence of external circuits and voltages, the voltage difference or potential gradient across the space-charge region discourages further diffusion across the p-n junction and preserves the differences in the characteristics of the two types of materials.

Current Flow

When an external battery is connected across the p-n junction, the amount of current that flows is determined by the polarity of the applied voltage and its effect on the space-charge region. Fig. 2(a) shows a battery connected to produce reverse bias. This connection effectively increases the width of the space-charge region, and the potential gradient increases until it approaches the potential of the external battery; current flow is then extremely small. Under the forward-bias condition shown in Fig. 2(b), the space-charge region becomes effectively narrower,

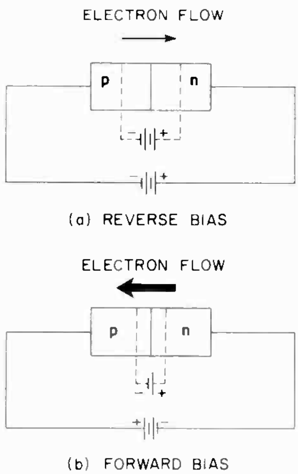


Fig. 2 - Electron current flow in biased p-n junctions.

and the potential gradient decreases to a very low value; electrons then continue to flow as long as the forward voltage is applied.

The positive to negative current flow defined as conventional current flow is satisfactory for use in circuit analysis. However, in the study of semiconductors, it is helpful to think of current flow in terms of electron flow and "hole" flow. Electron current flows from negative to positive; "hole" current flows from positive to negative.

TYPES OF DEVICES

Silicon Rectifiers

Structurally, the silicon rectifier (or semiconductor diode) is a p-n junction; its schematic symbol is shown in Fig. 3. Rectifiers of this type can be operated at ambient

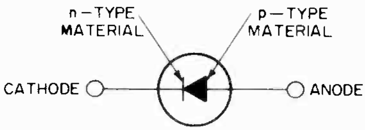


Fig. 3 - Schematic symbol for a silicon rectifier.

temperatures up to 200°C and at current levels as high as 400 amperes, with voltage levels as high as 1300 volts. Parallel or series arrangements of two or more rectifiers can be used to provide even higher current or voltage capabilities.

Because of their high forward-to-reverse current ratios, silicon rectifiers can achieve rectification efficiencies greater than 99 per cent. They have excellent life characteristics that are little affected by aging, moisture, or temperature variation. They can, however, be easily damaged by sudden rises in junction temperature caused by either surges of high current or excessive ambient-temperature changes. They are very small and light-weight, and can be made relatively impervious to shock.

Fig. 4 shows the voltage-current characteristic for a silicon rectifier under both negative-bias and positive-bias conditions. When forward

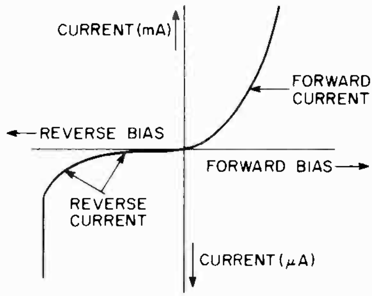


Fig. 4 - Voltage-current characteristic for a silicon rectifier.

bias is applied (anode positive with respect to cathode), the rectifier behaves very much like a low resistance. The forward voltage drop +V (usually about 0.6 volt) is the potential required to overcome the potential gradient of the space-charge region at the p-n junction. This voltage drop remains substantially constant as long as the average current in the circuit is within the rated value of the rectifier. However, if the voltage applied to the device is increased (either deliberately or as a result of a voltage surge) to the point where the rated current is appreciably exceeded, the forward voltage drop becomes excessive and the rectifier may be permanently damaged.

Under normal reverse-bias conditions, the rectifier limits current flow to a few microamperes. If the reverse bias exceeds the rated peak reverse voltage (PRV) shown in Fig. 4, however, the reverse current increases very rapidly. Any increase in bias beyond the maximum rating may damage the rectifier. More than one rectifier can be connected in series in a bridge or full-wave circuit to obtain the PRV values required for high-voltage power-supply applications.

A zener diode is a special type of rectifier designed to maintain the voltage constant across a portion of a circuit in spite of relatively large fluctuations in current input to the zener diode.

Bipolar Transistors

A bipolar transistor can be viewed as two diodes (p-n junctions) connected back-to-back, as shown in Fig. 5. The thick end layers are made of the same type of material (n-type in this case), and are separated by a very thin layer of the opposite type of material (p-type in the device shown). With a battery connected as shown, the p-n junction on the left is positively (forward) biased and conducts current easily (low resistance);

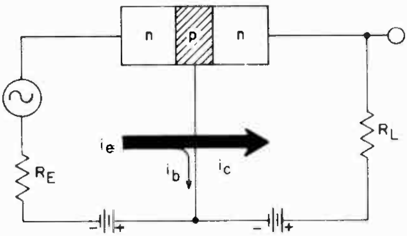


Fig. 5 - N-P-N transistor structure biased for power gain. Arrows denote electron flow.

the p-n junction on the right is negatively (reverse) biased and impedes current flow (high resistance). Almost all of the current in the forward-biased junction passes through the thin center region and flows through the reverse-biased junction. The small remaining current flowing through the base determines the degree of current flow through the reverse-biased junction. Because a small amount of current controls a much larger current, a power gain is achieved. This power gain makes the transistor useful as an amplifier and a signal-control (switch) device. (It should be noted that the transistor is a current-amplifying device, rather than a voltage-amplifying device like the vacuum tube.)

The schematic symbols for transistors are shown in Fig. 6. The three electrodes of the device are called the emitter (E), the base (B), and the collector (C). In normal operation

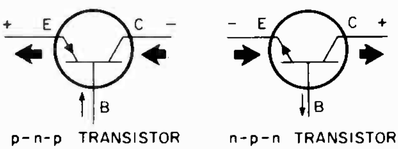


Fig. 6 - Schematic symbols for p-n-p and n-p-n transistors. Arrows denote electron flow.

the emitter-to-base junction is biased in the forward direction and the collector-to-base junction in the reverse direction. The arrow on the emitter lead identifies the transistor as a p-n-p or n-p-n type, and indicates the direction of conventional current flow in a circuit. This arrow always points toward the n-type material, and is always in the direction of emitter current flow. The operation of p-n-p devices is similar to that shown in Fig. 5 for the n-p-n device, except that the bias-voltage polarities are reversed, and electron-current flow is in the opposite direction.

Transistors can be used in three possible circuit configurations: common-base, common-emitter, and common-collector. Diagrams of these three configurations are shown in Fig. 7. In all three configurations the emitter current is the sum of the base and collector currents. Table I lists the properties of the three configurations.

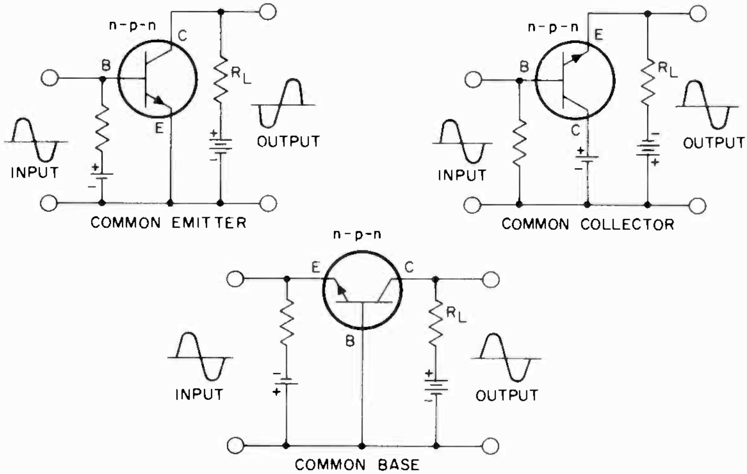


Fig. 7 - Common-emitter, common-collector, and common-base transistor circuit configurations.

Table I

Important Properties of the Three Transistor Circuit Configurations

	Common-Base	Common-Emitter	Common-Collector
Voltage Gain	200 or more	200 or more	slightly less than 1
Current Gain	slightly less than I	approx. 50	approx. 50
Power Gain (Voltage Gain x Current Gain)	200 or more (approx. same as voltage gain)	as high as 10,000	approx. 50 (same as current gain)
Phase Reversal	no	yes	no
Input Signal Applied to	emitter	base	base
Output Impedance (ohms)	high (2000 to 10,000)	high (50 to 50,000)	low (5 to 5,000)
Input Impedance (ohms)	low (10 to 50)	low (20 to 5,000)	high (5,000 to 1000,000)
Output Signal taken from	collector	collector	emitter

Field-Effect Transistors

Unlike the other transistors described in this book, which are bipolar devices (i.e., performance depends on the interaction of two types of charge carriers, holes and electrons), field-effect transistors are unipolar devices (i.e., operation is a function of only one type of charge carrier, holes in p-channel devices and electrons in n-channel devices).

The operation of field-effect devices can be explained in terms of a charge-control concept. A metal control electrode, which is called a gate, acts as a charge-storage or control element. A charge placed on the gate induces an equal but opposite charge in a semiconductor layer, or channel, located beneath the gate. The charge induced in the channel can then be used to control the conduction between two contacts, called the source and the drain, made to opposite ends of the channel.

In MOS (metal-oxide-semiconductor) field-effect transistors, one or more metal gate electrodes are separated from the semiconductor material by an insulator, as shown in Fig. 8. These insulated-gate electrodes can deplete the source-to-drain channel of active carriers when suitable bias voltages are applied, or can increase the conductivity of the channel without increasing steady-state input current or reducing power gain. All field-effect transistors used in the circuits in this Manual are insulated-gate types.

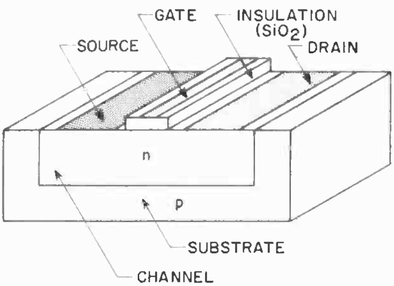


Fig. 8 - Structure of an MOS field-effect transistor.

MOS field-effect transistors are either depletion or enhancement types. In the depletion type, charge carriers are present in the channel when no bias voltage is applied to the gate. A reverse gate voltage is one which depletes this charge and thereby reduces the channel conductivity. A forward gate voltage draws more charge carriers into the channel and thus increases the channel conductivity. In the enhancement type, the gate must be forward-biased to produce the active carriers and permit conduction through the channel. No useful channel conductivity exists at either zero or reverse gate bias. Depletion-type MOS transistors are particularly well suited for use as voltage amplifiers, rf amplifiers, and voltage-controlled attenuators. Enhancement-type MOS transistors are particularly suitable for switching applications.

Because MOS transistors can be made to utilize either electron conduction (n-channel) or hole conduction (p-channel), four distinct types of MOS field-effect transistors are possible. As shown in Fig. 9, the schematic symbol for an MOS transistor indicates whether it is n-channel or p-channel, depletion-type or enhancement-type.

The direction of the arrowhead in the symbol identifies the n-channel device (arrow pointing to-

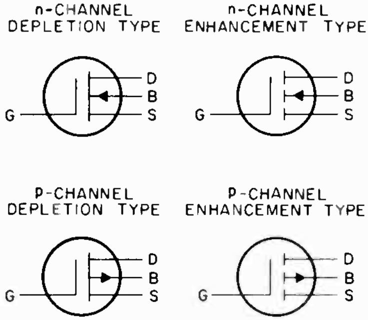


Fig. 9 - Schematic symbols for MOS transistors (G = gate, D = drain, B = active bulk, S = source).

ward the channel) or the p-channel device (arrow pointing away from the channel). The channel line itself is made solid to identify the "normally ON" depletion type, or is interrupted to identify the "normally OFF" enhancement type.

Dual-gate MOS field-effect transistors have two independent insulated gates. The dual-gate transistors exhibit all the features of single-gate field-effect transistors, but perform better in certain applications.

Fig. 10 shows a schematic representation of a dual-gate MOS field-effect transistor. The transistor includes three diffused regions connected by two channels, each of which is controlled by its own independent gate.

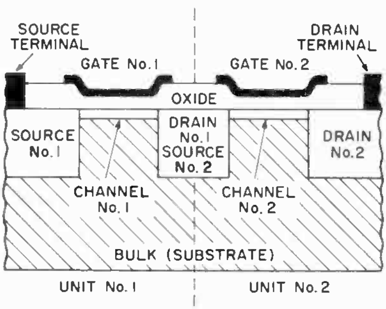


Fig. 10 - Schematic representation of a dual-gate MOS field-effect transistor.

Unit No. 1 acts as a conventional single-gate MOS field-effect transistor, with the central diffused region acting as the drain and unit No. 2 acting as a load resistor. Similarly, unit No. 2 can be used as an independent triode with unit No. 1 acting as a source resistor. Fig. 11 shows these configurations from a circuit viewpoint, together with the circuit diagram for the dual-gate unit.

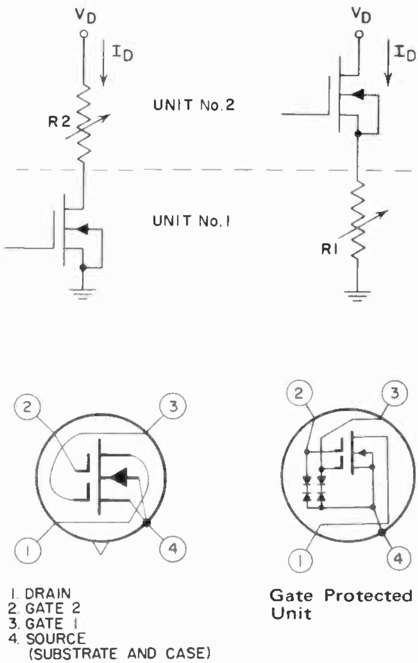


Fig. 11 - Equivalent circuit representation of the two units in a dual-gate MOS transistor and the terminal diagram for the transistor.

Fig. 11 also shows the symbol for an RCA dual-gate protected rf MOS transistor. These transistors incorporate back-to-back diodes between each gate and the source; this arrangement permits the device to handle a wide dynamic signal swing and still provide excellent rf performance. The low junction capacitance of the diodes adds little to the total capacitance shunting the gate. Furthermore, the resistive components of these diodes are such that they do not materially affect the over-all noise performance of the unit. The net result is a transistor that offers protection against discharge during handling operations without the need for external shorting mechanisms, protection against in-circuit transients, and a device more rugged than any other solid-state amplifier providing comparable performance.

A dual-gate MOS transistor can be cut off if either gate is made sufficiently negative with respect to the source. When one gate is biased to cutoff, a change in the voltage on the other gate is equivalent to a change in the value of a resistance in series with a cut-off transistor.

Thyristors

The term thyristor is the generic name for a group of semiconductor devices that have characteristics similar to those of thyratron tubes. This group includes bistable semiconductor devices that have three or more junctions (i.e., four or more semiconductor layers) and that can be switched between conducting states (from OFF to ON or from ON to OFF). The two most popular types of thyristors are the silicon controlled rectifier (SCR) and the triac.

A silicon controlled rectifier (SCR) is basically a four-layer p-n-p-n device that has three electrodes (a cathode, an anode, and a control electrode called the gate). Fig. 12 shows the junction diagram, principal voltage-current characteristic, and

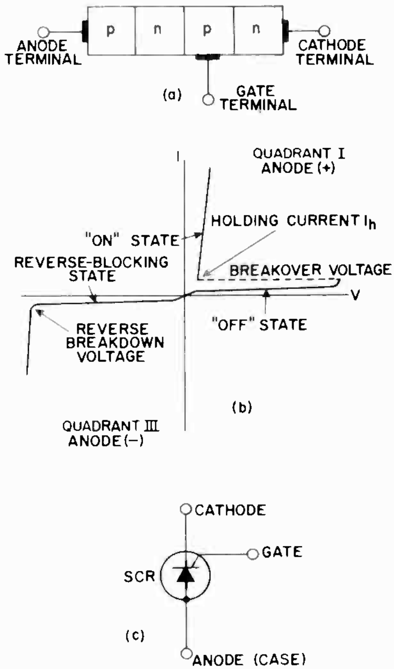


Fig. 12 - Junction diagram (a) principal voltage-current characteristic (b) and schematic symbol (c) for an SCR.

schematic symbol for an SCR. A triac also has three electrodes (main terminal No. 1, main terminal No. 2, and gate) and may be considered as two parallel p-n-p-n structures oriented in opposite directions to provide symmetrical bidirectional electrical characteristics. Fig. 13 shows the junction diagram, voltage-current characteristic, and schematic symbol for a triac.

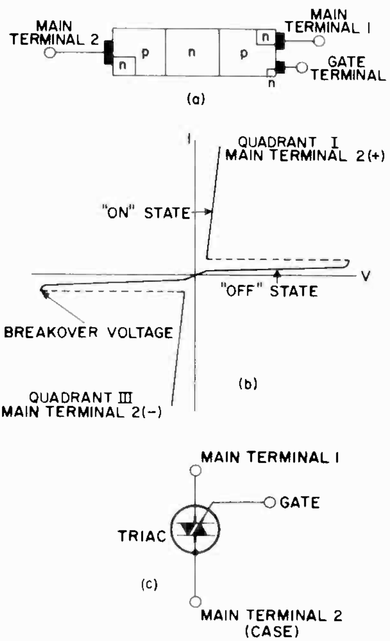


Fig. 13 - Junction diagram (a) principal voltage-current characteristic (b) and schematic symbol (c) for a triac.

Fig. 12(b) shows that under reverse-bias conditions (anode negative with respect to cathode) the SCR has a very high internal impedance, and only a slight amount of reverse current, called the reverse blocking current, flows through the p-n-p-n structure. This current is very small until the reverse voltage exceeds the reverse breakdown voltage; beyond this point, however, the reverse current increases rapidly. The value of the reverse breakdown voltage differs for individual SCR types.

During forward-bias operation (anode positive with respect to cathode), the p-n-p-n structure of the SCR is electrically bistable and may exhibit either a very high impedance (forward-blocking or OFF state) or a very low impedance (forward-conducting or ON state). In the forward-blocking state, a small forward current, called the forward OFF-state current, flows through the SCR. The magnitude of this current is approximately the same as that of the reverse-blocking current that flows under reverse-bias conditions. As the forward bias is increased, a voltage point is reached at which the forward current increases rapidly, and the SCR switches to the ON state. This value of voltage is called the forward breakover voltage.

When the forward voltage exceeds the breakover value, the voltage drop across the SCR abruptly decreases to a very low value, referred to as the forward ON state voltage. When an SCR is in the ON state, the forward current is limited primarily by the impedance of the external circuit. Increases in forward current are accompanied by only slight increases in forward voltage when the SCR is in the state of high forward conduction.

An important feature of the SCR is its low power loss as compared with the amount of power it controls. For example, an SCR can control as much as 350 watts with a maximum power loss of less than two watts (3.2 max amperes x 0.6 volt), an insignificant amount compared to the power loss in a rheostat required to control the same amount of power.

As shown in Fig. 13(b), a triac exhibits the forward-blocking, forward-conducting voltage-current characteristic of a p-n-p-n structure for either direction of applied voltage. This bidirectional switching capability results because, as mentioned previously, a triac consists essentially of two p-n-p-n devices of opposite orientation built into the same crystal.

The device, therefore, operates basically as two SCR's connected in parallel, but with the anode and cathode of one SCR connected to the cathode and anode, respectively, of the other SCR. As a result, the operating characteristic of the triac in the first and third quadrant of the voltage-current characteristics are the same, except for the direction of current flow and applied voltage. The triac characteristics in these quadrants are essentially identical to those of an SCR operated in the first quadrant. For the triac, however, the high-impedance state in the third quadrant is referred to as the OFF state rather than as the reverse-blocking state. Because of the symmetrical construction of the triac, the terms forward and reverse are not used in reference to this device.

Thyristors are ideal for switching applications. When the working voltage of a thyristor is below the breakover point, the current through the device is extremely small and the thyristor is effectively an open switch. When the voltage across the main terminals increases to a value exceeding the breakover point, the thyristor switches to its high-conduction state and is effectively a closed switch. The thyristor remains in the ON state until the current through the main terminals drops below a value which is called the holding current. When the source voltage of the main-terminal circuit cannot support a current equal to the holding current, the thyristor reverts back to the high-impedance OFF state.

The breakover voltage of a thyristor can be varied, or controlled, by injection of a signal at the gate, as indicated by the family of curves shown in Fig. 14. Although this family of curves is shown in the first

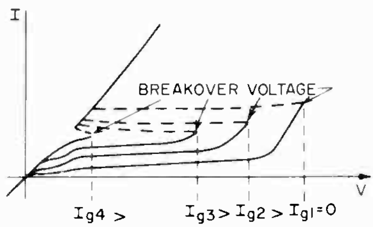


Fig. 14 - Curves showing breakover characteristics of a thyristor for different values of gate current.

quadrant and is typical of SCR operation, a similar set of curves can also be drawn for the third quadrant to represent triac operation. When the gate current is zero, the principal voltage must reach the breakover value $V_{(BO)}$ of the device before breakover occurs. As the gate current is increased, however, the value of breakover voltage becomes less until the curve closely resembles that of a rectifier. In normal operation, thyristors are operated with critical values well below the breakover voltage and are made to switch ON by gate signals of sufficient amplitude to assure that the device is switched to the ON state at the instant desired.

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

Integrated Circuits

The fundamental requirement of an integrated circuit is that components be processed simultaneously on a common substrate. A variety of technologies can be used to satisfy this requirement. The technology presently used is based on the silicon planar technology developed for transistors. The basic steps of the silicon process are shown in Fig. 15. The starting material is a uniform single crystal of p-type silicon called the chip. Successive diffusion pro-

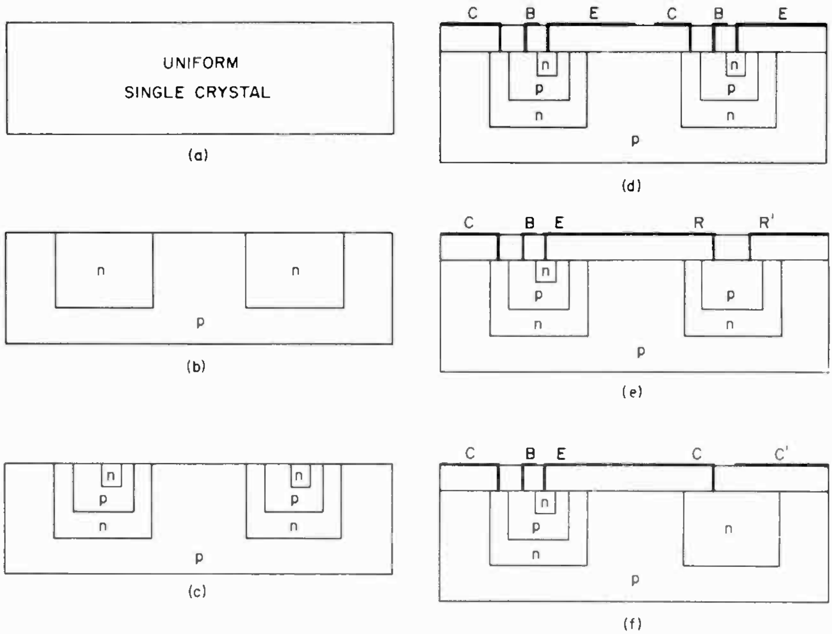


Fig. 15 - Basic steps in integrated-circuit production using the silicon process: (a) silicon wafer used as starting material for an integrated circuit; (b) diffusion of n-type areas to provide isolated circuit nodes; (c) diffusion of additional p-type and n-type regions to form transistors; (d) addition of metalized contacts to transistor elements; (e) connection of contacts to p-type region to form integrated resistor; (f) use of oxide as a dielectric to form integrated capacitor.

cessing steps permit the introduction of impurities to desired depths and widths in the starting material to form transistors, resistors, and capacitors. Vertical penetration of the impurities is controlled by the diffusion temperature and time, and lateral control of the diffusions is made possible by a combination of the masking properties of silicon dioxide with photo-chemical techniques. The silicon wafer is then coated with an insulating oxide layer which is opened selectively to permit metalization and interconnection.

Fig. 16 shows the combination of the three types of elements on a

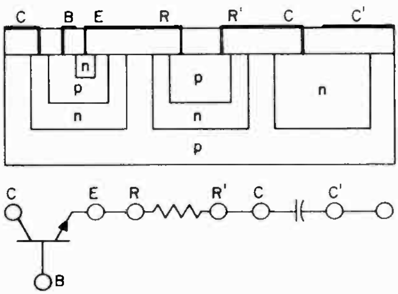


Fig. 16 - Completed silicon chip containing transistor, resistor, and capacitor.

single wafer, together with the equivalent circuit. Fig. 17 shows an enlargement of a completed integrated circuit, the KD2115, together with the corresponding circuit diagram. The callouts on the photograph denote the location of the components shown in the circuit diagram. The actual chip is about 1/4 the size of terminal 4 as shown in the photograph.

Because the basic fabrication process for integrated circuits is almost identical with that used to fabricate transistors, transistors formed by this technology are similar to discrete units. Integrated resistors, however, are significantly different from conventional, discrete versions. Discrete resistors are normally made in standard sizes, and different values are obtained by variations in the resistivity of the material. In integrated circuits, the resistivity of the material is determined by the optimum value required for the transistor base diffusion and cannot be varied to provide different resistance values. Therefore, the value of the resistor depends primarily on the ratio of its length to its width; high-valued resistors are long and narrow and low-valued resistors are short but wide.

The value of an integrated capacitor depends on its area, its dielectric constant, and the thickness of the oxide layer. Because the oxide thickness is kept constant, capacitor values vary directly with area.

SENSORS

Photocells

Fig. 18 shows a typical photoconductive cell, a 1/4-inch-diameter broad-area cadmium-sulfide device. Photocells of this type, which are also known as photoresistors or light-dependent resistors, have a polycrystalline photosensitive surface and are characterized by high sensitivity to visible radiation and moderate speed of response to changes in illumination. The resistance of the cell decreases as the illumination level increases, as shown in Fig. 19.

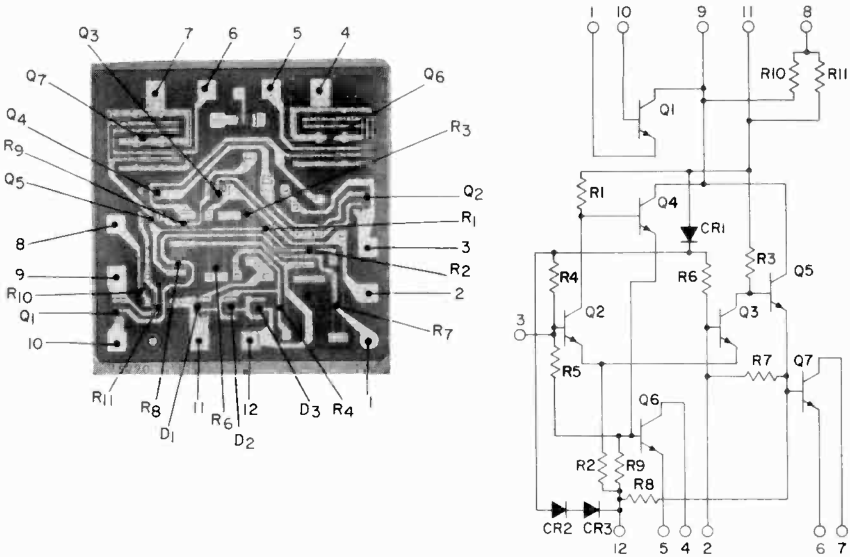


Fig. 17 - Metalization pattern, component location, and circuit diagram for the KD2115 integrated circuit.

Fig. 18 - Photoconductive cell contained in RCA Add-On Light-Sensor Experimenter's Kit KD2106.

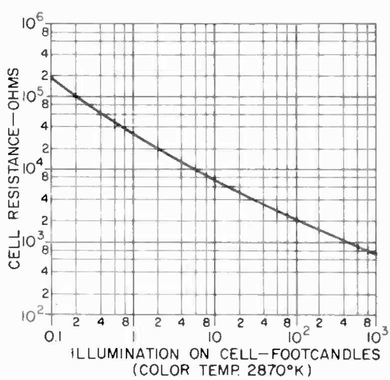


Fig. 19 - Resistance of photocell KD2106 as a function of illumination.

Thermistors

A thermistor is a solid-state device that has a very large, controlled, negative or positive resistance-temperature characteristic. This unique characteristic makes thermistors very useful in applications that interrelate thermal data. Fig. 20 shows resistance-temperature characteristics for three thermistors which have a negative temperature coefficient (i.e., resistance decreases with increasing temperature).

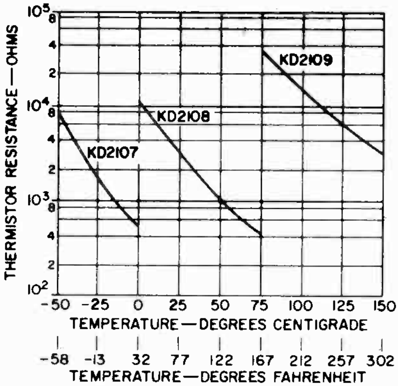


Fig. 20 - Resistance-temperature characteristics of thermistors contained in RCA Add-On Heat-Sensor Experimenter's Kit KD2110.

General Circuit Considerations

THE CIRCUITS described in this chapter are the basic elements of a great many electronic circuits in common use. They represent the "building blocks" or foundations on which the majority of circuits in this Manual are constructed. An understanding of the functioning of these fundamental circuits will be of great help in understanding the operation of the practical circuits presented later. The simplified diagrams in this chapter show only the basic configuration for each circuit; component values and construction information are given with the complete practical circuit.

AMPLIFIERS

There are many different types of amplifiers; the type used in any given circuit depends on the application for which the circuit is intended. Power output, load, signal characteristics, and cost are but a few of the many factors that must be considered before an amplifier can be chosen for a particular job.

The circuit in Fig. 21 shows a very basic amplifier; a circuit in which a small current controls a much larger current. Resistor R1 is the bias resistor, R2 is the collector load resistor; and capacitor C1 blocks dc from the output.

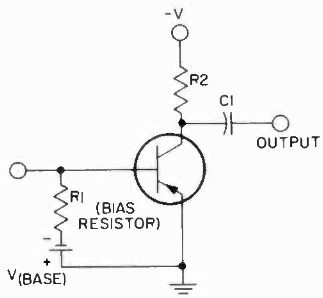


Fig. 21 - A basic transistor amplifier.

The battery voltage establishes, through R1, a small current in the base-emitter junction of the transistor. This current is a steady-state current; that is, it flows all the time. The small base-emitter current establishes a much greater current in the collector-emitter junction. The larger current is controlled by the signal input to the base of the transistor; the large signal output of the amplifier, therefore, varies with the small input signal.

Additional components may be added to this basic configuration to improve such qualities as stability and fidelity; however, the principle of operation remains the same.

Voltage – Variable Resistor (VVR)

Because the drain-current/drain-voltage characteristic of MOS transistors remains linear at low drain-to-source voltages, the devices can be used as low-distortion voltage-controlled or voltage-variable resistors (VVR's). The principal advantages of MOS transistors in this application are negligible gate-power requirements and large dynamic range. Fig.22 shows a voltage-variable resistor circuit using an MOS transistor.

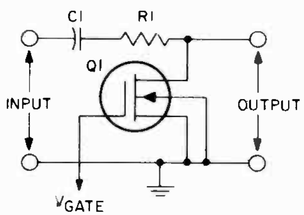


Fig. 22 - A voltage-variable resistor circuit using an MOS transistor.

Series Regulator

A series regulator circuit is essentially a direct-coupled amplifier that is used to amplify an error or difference signal obtained from a comparison between a portion of the output voltage and a reference source. Series regulators maintain a constant voltage output and are used in regulated power supplies. Fig. 23 shows the circuit of a typical series regulator. The reference-voltage source V_R is placed in the emitter circuit of the amplifier transistor Q1 so that the error or difference signal

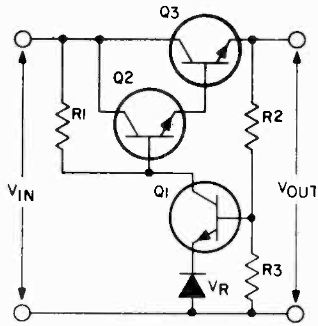


Fig. 23 - A typical series regulator circuit.

between V_R and some portion of the output voltage V_{OUT} is developed and amplified. The amplified error signal forms the input to the regulating element consisting of transistors Q2 and Q3; the output from the regulating element develops a controlling voltage across the resistor R1.

Shunt Regulator

Shunt regulator circuits are not as efficient as series regulator circuits for most applications, but they have the advantage of greater simplicity. In the shunt voltage-regulator circuit in Fig. 24, the current through the shunt element consisting of tran-

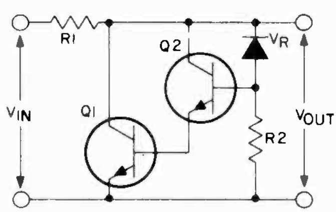


Fig. 24 - A typical shunt regulator circuit.

sistors Q1 and Q2 varies with changes in the load current or input voltage. This current variation is reflected across the resistance R1 in series with the load so that the output voltage V_{OUT} is maintained nearly constant. Transistor Q1, the shunt element, must be capable of absorbing all power input to the circuit by the supply when load current is very low.

OSCILLATORS

An oscillator circuit is similar in many respects to an amplifier, except that a portion of the output power is returned to the input network in phase with the starting power (positive or regenerative feedback) to provide a self-generating or self-repeating current or voltage variation at a definite rate. Oscillators can be made to produce many different waveshapes; the two oscillators described below generate sine waves.

Fig. 25(a) is a transistor version of the Colpitts oscillator. Positive feedback is obtained from the voltage-divider circuit consisting of capacitors C2 and C3 in parallel with the primary winding of the transformer. The voltage developed across C3 is the feedback voltage and is applied to the emitter of the transistor. The frequency and the amount of feedback voltage can be controlled by adjustment of either or both capacitors. Base bias is provided by resistors R2 and R3; R4 is the collector load resistor. R1 develops the emitter input signal and acts as the emitter stabilizing resistor.

Figs. 25(b) and 25(c) show the MOS field-effect transistor in use in two forms of the Colpitts oscillator circuit. These circuits are commonly used in vhf and uhf equipment.

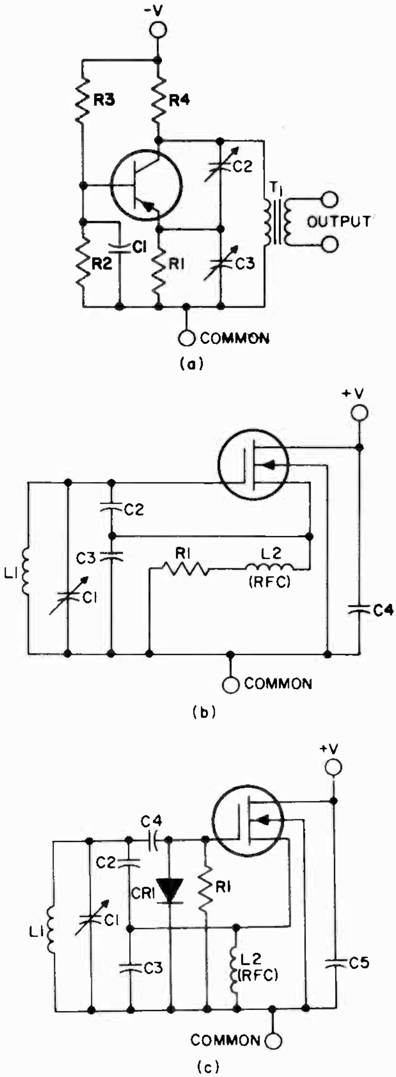


Fig. 25 - Colpitts oscillator circuits: (a) is a bipolar-transistor version, (b) and (c) are MOS field-effect transistor versions.

Feedback in the MOS-transistor Colpitts oscillator is controlled by the ratio of the value of C2 to C3. Improved circuit stability is supplied by rectifier CR1 in Fig. 25(c); the rectifier provides automatic amplitude control and maintains voltage swings within the capability of the MOS transistor.

BASIC TWIN-T BRIDGE OSCILLATOR

The circuit in Fig. 26 represents a basic twin-T bridge oscillator. The oscillator takes its name from the frequency-determining and dc-blocking RC network in the left-hand

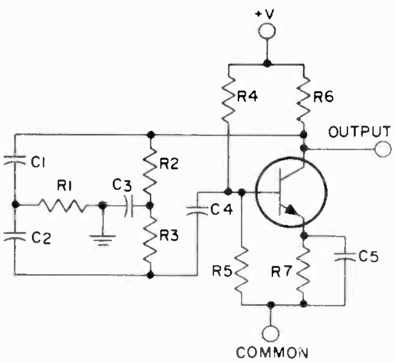


Fig. 26 - A basic twin-T bridge oscillator.

part of the circuit (C1, C2, C3, R1, R2, R3). Resistors R4, R5, R6, and R7 provide the necessary bias conditions for the transistors. Resistor R7 is the emitter-stabilizing resistor; C5, R5, and R7 along with the transistor comprise the transistor amplifier. Capacitor C4 couples the oscillator signal to the base of the transistor and also blocks dc. Capacitor C5 bypasses ac signals and prevents degeneration.

SWITCHES

Astable and Monostable Pulsers or Clock Circuits

Astable (free-running) pulsers are oscillators used to generate pulses at specific frequencies in such applications as light flashers, pulse generators, and clock-pulse sources. Monostable ("one-shot") pulsers are used principally for pulse shaping and as time-delay circuits.

The basic astable pulser circuit is shown in Fig. 27. Transistors Q1 and Q2 form a regenerative switch. This switch has a very high impedance until it is triggered into conduction; after triggering it has a very low impedance. When power is applied to the circuit, capacitor C2 charges through the emitter of Q1, turning it on and causing the regenerative switch to conduct.

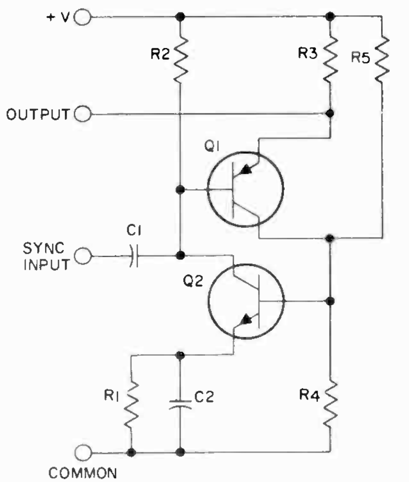


Fig. 27 - The basic astable pulser or clock circuit.

When capacitor C2 charges, the emitter of Q2 becomes more negative and turns the regenerative switch off. The high impedance of the switch in the OFF condition causes C2 to discharge through R1. As the charge on C2 decreases, the emitter of Q2 becomes less negative and the switch begins to conduct again. This process is repeated as long as power is applied to the circuit.

The basic monostable pulser is shown in Fig. 28. Transistors Q1 and Q2 form a regenerative switch similar to the one described above for the astable pulser. When switch S1 is closed, a voltage is applied across the series combination of C1 and R5; the voltage at the output terminals is the same as that across R5. Capacitor C1 starts to charge. When the voltage across the series combination of C1 and R5 reaches the triggering level of the regenerative switch, the switch conducts. C1 then discharges through R5 and the regenerative switch. The regenerative switch stays in the conductive state as long as S1 is closed. Because the voltage across the conducting regenerative switch is very low and because the regenerative switch is in parallel with the C1 R5 combination, the output voltage is also very low. The circuit will remain in the state described until S1 is reoperated.

Multivibrator (Astable)

Oscillator circuits that produce nonsinusoidal outputs can use a regenerative circuit in conjunction with resistance-capacitance (RC) or resistance-inductance (RL) components to produce a switching action. The charge and discharge times of the reactive elements are used to produce sawtooth, square, or pulse output waveforms.

A multivibrator is essentially a nonsinusoidal two-stage oscillator in which one stage conducts while the other is cut off until a point is reached at which the conditions of the stages are reversed. This type of oscillator is normally used to produce a square-wave output. In the

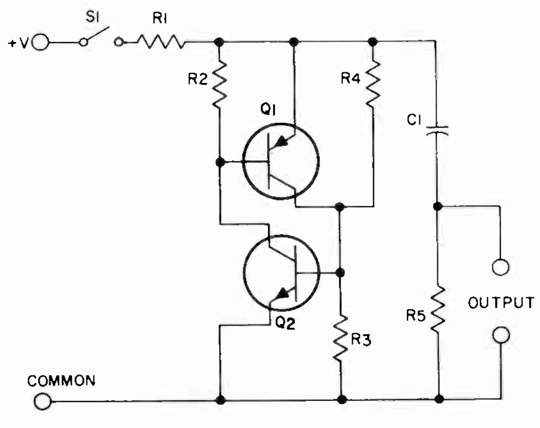


Fig. 28 - The basic monostable pulser.

RC-coupled common-emitter multivibrator shown in Fig. 29, the output of transistor Q1 is coupled to the input transistor Q2 through the feedback capacitor C1, and the output of Q2 is coupled to the input of Q1 through the feedback capacitor C2.

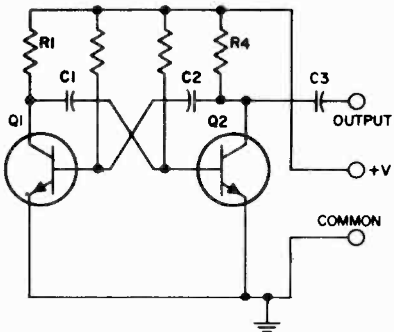


Fig. 29 - An RC-coupled common-emitter multivibrator.

In the multivibrator circuit, an increase in the collector current of transistor Q1 causes a decrease in the collector voltage which, when coupled through capacitor C1 to the base of transistor Q2, causes a decrease in the collector current of Q2. The resultant rising voltage at the collector of Q2, when coupled through capacitor C2 to the base of Q1, drives Q1 further into conduction. This regenerative process occurs rapidly, driving Q1 into heavy saturation and Q2 into cutoff. Q2 is maintained in a cutoff condition by C1 (which has previously charged to the supply voltage through resistor R1) until C1 discharges through R3 toward the collector-supply potential. When the junction of C1 and R3 reaches a slight positive voltage, however, transistor Q2 begins to conduct and the regenerative process reverses. Q2 then reaches a saturation condition, Q1 is cut off by the reverse bias applied to its base through C2, and the C2R2 junction starts charging toward the collector supply voltage. The oscillating frequency of the multivibrator is determined by the values of resistance and capacitance in the circuit.

Typical Digital Flip-Flop

A typical digital flip-flop of the type used in counters and computers is shown in Fig. 30. The operation of the flip-flop depends on how the input terminals T_R and T_S are connected. In the circuits described in this Manual, connections are made in

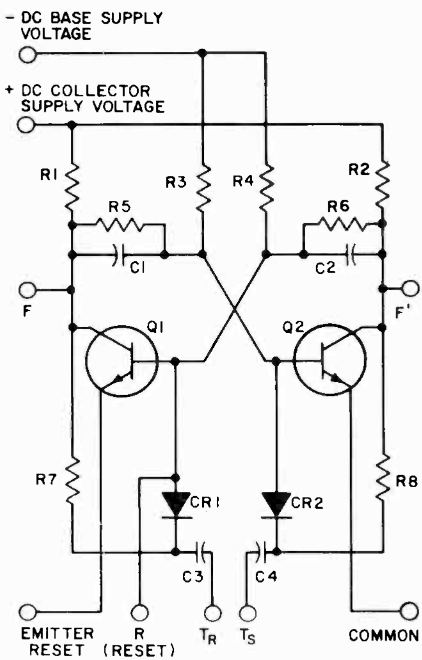


Fig. 30 - A typical digital flip-flop.

one of two ways: the first way, T_R and T_S connected together, identifies the circuit as a Toggle flip-flop; the second way, T_R and T_S connected to different signal inputs, identifies the circuit as a Set-Reset flip-flop.

The Toggle flip-flop is so called because it toggles or changes state, in the same manner as a toggle switch, each time a trigger pulse is applied to it. The flip-flops described in the circuits in this Manual are affected only by a negative trigger pulse; diodes CR1 and CR2 block positive pulses. When a negative trigger pulse is applied to a Toggle flip-flop, it is passed to transistors Q1 and Q2 through capacitors C3 and C4, and diodes CR1 and CR2. The function of C3 and C4 is to reduce the pulse width of the input negative pulse. The transistor that is conducting or on is turned off by the pulse. The other transistor, the one that is off or not conducting, is not affected by the negative trigger pulse but is turned on, through the feedback and biasing network composed of R1 through R6, as a result of the changes in biasing in the circuit caused by the change of condition (from on to off) of the first transistor. For example, if Q1 is on and Q2 off when a negative trigger pulse is applied, Q1 is turned off, a condition in which its collector voltage is close to the supply voltage. This voltage, imposed on the base of Q2 through R5, turns Q2 on. C1, in parallel with R5, reduces the time required for Q1 to turn Q2 on (C2 operates in the same way with R6 when Q2 is turning Q1 on.)

A flip-flop in a given state cannot change state unless a trigger pulse is applied or the emitter current of the ON transistor interrupted, because the biasing imposed on one transistor by the other locks each in its existing condition. In digital terms, the transistor that is turned off is said to "go high"; the transistor that is turned on is said to "go low". The condition of the output terminals associated with each transistor follows the transistor terminology; e.g., when Q1 is low, F is also said to be low. When a transistor is set high the signal at its output terminal is said to represent a 1; when a transistor is set low its output terminal signal is said to be 0. When a transistor state changes from low to high (0 to 1), a positive signal is produced at its output terminal, F or F'; when it goes from high to low (1 to 0), a negative signal is produced. This negative signal can be used to trigger other flip-flops.

In the second type of input-terminal connection of Fig. 30, when T_R and T_S are not connected together but to different trigger sources, the flip-flop becomes the Set-Reset flip-flop. In this arrangement, a negative input pulse applied, for example, to terminal T_S turns Q2 off, if it is on, and sets it and F' high corresponding to a 1 at the output terminal. As Q2 turns off, it turns Q1 on, as described above, and the state of the flip-flop is changed. If Q2 were already off and F' already high, the negative input pulse would have no effect on Q2 or the state of the circuit. On the other hand, if Q2 were off and F' high and a negative pulse were applied to T_R,Q_1 would be turned off, Q2 would be turned on, and F' would go low. If, however, Q2 were on and F′ already low, Q1 would already be off and no change in the condition of Q2 or F′ or change of state of the flip-flop would take place.

The major difference between the Toggle and Set-Reset flip-flop arrangements is that the Toggle circuit always changes state with a trigger pulse; the Set-Reset circuit only changes state when the transistor that is on receives the negative trigger pulse.

It is possible to have more than one input signal path to the flip-flop transistors. The flip-flops in the circuits described in this Manual have an R or reset terminal that is used when it is desirable to know that Q1 is off. A negative pulse applied to terminal R turns Q1 off (if it is on), changes F from low to high, and changes the state of the flip-flop. If Q1 is already off the negative pulse has no effect. Because it is not possible to determine the state of a flip-flop by examination, some means must be made available to set it to a known state; in the circuits described in this Manual, the emitter-reset function is used. A positive trigger signal applied at the emitter–reset terminal or disruption of the emitter current allows the flip-flop to be reset to the state corresponding to zero in a counter, i.e., F high (1), F′ low (0).

NAND Gate

A NAND gate, such as that shown in Fig. 31, provides a low output when high inputs are applied simultaneously. When a positive input pulse is applied to only one of the transistors in the NAND gate, that transistor turns on; however, conduction cannot occur because the ON transistor is in series with another transistor that is turned off. When positive pulses are applied to

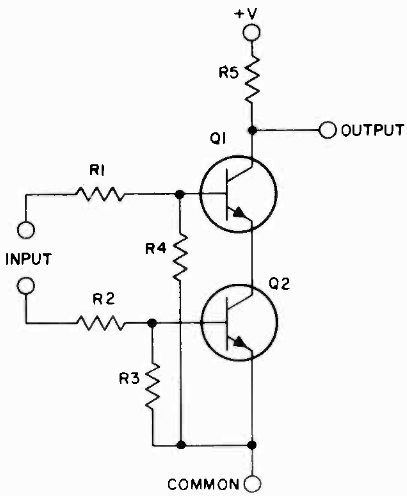


Fig. 31 - A basic NAND gate.

both inputs simultaneously, conduction does occur and a negative output is produced. In a NAND gate the polarity of the output is opposed to that of the input; in an AND gate, input and output polarities are the same.

NOR Gate

The circuits in Figs. 32 and 33 are NOR gates. A positive (high input) signal on any of the inputs large enough to turn the transistor on causes the output to go negative (low output) or to substantially ground potential. When the output polarity is opposite to the input polarity the circuit is a NOR gate; when input and output polarities are identical, the circuit is called an OR gate.

The diode in the positive-action diode-transistor NOR gate shown in Fig. 32 eliminates some of the losses associated with resistive input cir-

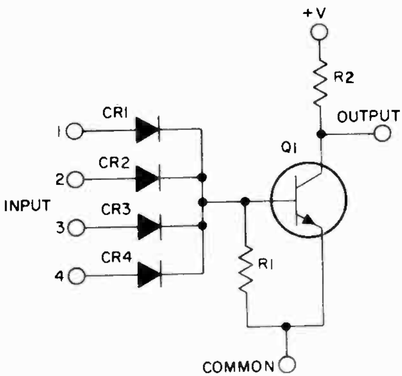


Fig. 32 - A positive-action diode-transistor NOR gate.

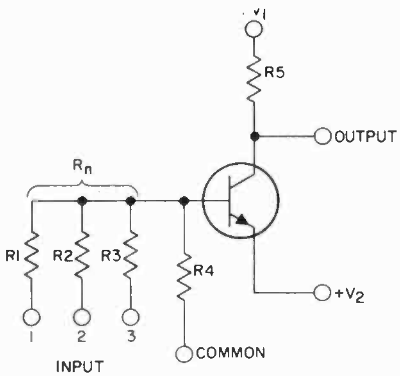


Fig. 33 - A positive-action resistor-transistor NOR gate.

cuits and thereby increases the number of possible outputs for a given transistor and switching speed. The diode does not conduct any appreciable current when the input is low and has a high stored charge when forward-biased. Therefore, when the transistor is turned off, the stored charge of the diode compensates that of the transistor.

In a positive-action gate there are only two states, on and off; there is no state in which a limited amount of conduction takes place.

INDICATOR-LAMP CIRCUIT

A positive signal applied to the base of Q1 in Fig. 34 turns Q1 on and permits current to flow through R2 and R3. Because R2 is in parallel with the base-emitter junction of Q2, the current passing through it puts a forward bias on Q2 and causes it to turn on. Conduction through Q2 lights the lamp, I1.

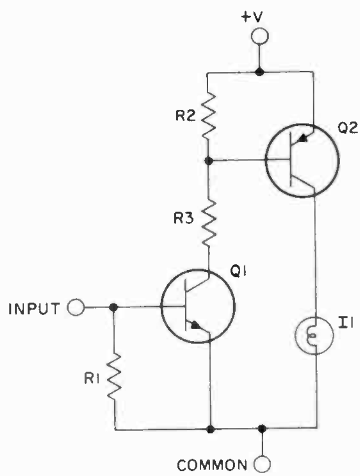


Fig. 34 - An indicator-lamp driver circuit.

Mechanical Considerations

GOOD CONSTRUCTION is important to the satisfactory operation of any circuit. Knowledge of soldering and chassis-wiring techniques and of component-handling and safety precautions is as important to satisfactory circuit operation as is a knowledge of the electrical characteristics of a circuit. This section contains the mechanical information needed by the circuit builder; it should be read thoroughly before work on any circuit is started. A great deal of time and effort can be saved by planning a job thoroughly before beginning construction.

CONSTRUCTION PRACTICES

All of the circuits in this Manual can be constructed with hand tools of the type available through any radio-supply, mail-order retail, or hardware store. The greater the variety of tools on hand, the simpler the construction job will be; however, all required work can be accomplished with the basic set of tools listed in Table II.

The continuing satisfactory performance of tools depends on the care they are given. Drills should be sharpened at frequent intervals so that critical cutting angles are maintained. Particular care should be taken of the soldering iron. The iron should not be run at full voltage for extended periods when it is not being used; if it is abused in this way, burn-out and tip corrosion can result. For stand-by purposes, voltage to the iron can be reduced sufficiently by connecting an incandescent lamp in series with it. The tip of an iron that is not preplated should be cleaned with steel wool after each period of use and should be kept well tinned (coated with solder). A pitted tip should be filed smooth and bright and should be retinned immediately. Preplated tips should not be filed; they can be cleaned after each use with a wet sponge.

Table II.
Tools Required for Circuit Construction

Awl or scriber for marking chassis
Long-nose pliers, 6 inch
Diagonal cutters, 6 inch
Wire stripper
Screwdrivers, 6 to 7 inch, 1/4-inch blade
Screwdrivers, 4 to 5 inch, 1/8-inch blade
Electric hand drill, 1/4-inch or larger chuck, variable-speed type is best.
Electric soldering iron, 45 watts, 1/4-inch tip
Center punch for marking hole centers
Straightedge
File: assortment of flat, round, half-round, and triangular including one large, flat, coarse file and one 1/2-inch-diameter round file.
Drills: assortment including
Nos. 32 (0.116 inch),
50 (0.070 inch), 55
(0.052 inch), 58
(0.042 inch), 60
(0.040 inch).
Solder, rosin-core
Hacksaw

Additional Helpful Tools
Bench vise, 4-inch jaws
Taper reamers, 1/2 and 1 inch
Phillips screwdriver
Screwdriver with screw-holding clip and long shank
Nut drivers

Materials

A list of materials required for the construction of each circuit is given with the circuit schematic. Only rosin-core solder should be used in making connections; acid-core solder intended for plumbing and sheet-metal work is not suitable for circuit wiring.

Chassis Preparation

The building of an electronic circuit on a metal chassis is not difficult when the proper tools are used. Aluminum is preferred to steel because of its superior shielding and contact properties and because it is easier to work. However, aluminum cannot be soldered to, and additional wires or bolted-in solder lugs must be used for ground connections.

The recommended positioning of components mounted on circuit boards is indicated on the diagrams included with the circuit write-up. Drilling and printed-circuit-board templates are printed in the back pages of this book. It is a good idea to mount each drilling template on cardboard before it is used so that it will not tear readily and become unsatisfactory for repeated use. The drilling template should be fastened securely to the circuit board or chassis before holes are drilled through it. For those circuits not mounted on circuit boards, suggested layouts are given where they will help the builder.

Drilling and Cutting Holes

Holes drilled in metal should be located or started with a center punch; the material to be drilled should be held in a vise. Pressure on the drill point should be relaxed when the drill begins to break through. If a two-speed or variable-speed electric drill is used, it is a good idea to shift to a slower speed for large-diameter holes (3/8 inch or larger) and just prior to breakthrough in any case. Holes more than 1/4 inch in diameter should be started with a small drill and enlarged with a larger drill, a reamer, or a rat-tail file. By far the easiest method of hole enlargement is reaming with a tapered reamer; however, a large rat-tail file also makes a good reamer. Enlargement of holes by filing is a tedious process. If the hole is too large to be completed by a larger drill or reamer, a method easier than filing is to drill a series of small holes, as close together as possible, around the inside diameter of the large hole. The center can then be knocked out with a cold chisel and the edge of the hole filed smooth.

When a number of larger holes of the same diameter are to be made, socket punches can be used. Holes in steel plate should be made with an adjustable circle cutter. The cutter should be tried on a block of wood first to make sure that it is set properly.

Square holes may be prepared by drilling small holes inside an edge marking as previously described. Socket hole punches and square punches are of considerable value in making large rectangular openings.

Burrs and rough edges remaining after drilling or cutting can be removed with a file or a sharp knife.

Bending Chassis Material

Metal pieces too large to be cut conveniently with a hacksaw can be marked with deep scratches (scribed) on either side of the metal along the line of the intended separation. If the sheet is then clamped in a vise and bent back and forth, it will break along the scribed line. If the sheet is bent too far in either direction before weakening occurs, the edge of the sheet may become bent. Rough edges remaining after this operation can be filed away. Bends are made by a similar process but without the scratching or scribing step.

Chassis and Circuit-Board Wiring

Wire to be used in the circuits should be selected with due consideration to the maximum current it must handle and the maximum voltage that its insulation can stand. In this Manual, high-power circuits (such as the SCR circuits) and portions of other circuits carrying high power are wired with No. 16 or No. 18 insulated wire; all other wiring is done with No. 24 insulated wire unless otherwise specified. "Spaghetti"-type insulation is used on component leads where necessary.

As much as possible, all wiring should be run parallel to the chassis edges, and all bends should be right-angle bends. In addition, all components should be mounted parallel to chassis edges. In both low- and high-frequency work, input and output leads should be kept well separated to avoid feedback effects which can cause unwanted oscillations. In high-frequency-circuit chassis wiring, leads should be kept as short as possible. Fig. 35 shows an example of a well arranged, professionally wired, low-frequency circuit.

The terminals on the wired circuit boards shown in this book are made of about 1 to 1-1/4 inch of No. 18 wire bent into a "U" shape. The

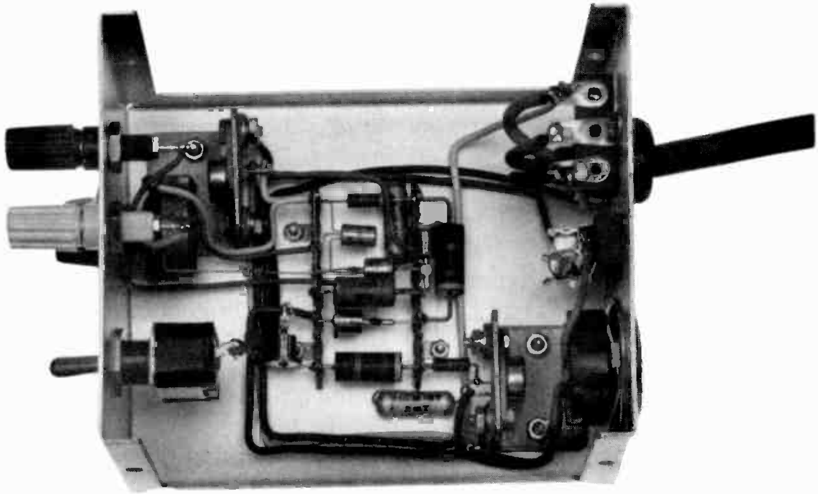


Fig. 35 – A professionally wired low-frequency circuit.

ends of the U-shaped wire are forced into the terminal holes with enough of the ends projecting through the bottom of the board to allow connections to be made. Terminal ends can be trimmed after soldering is completed. Two types of wired-board material are recommended: a paper-based phenolic type identified as XXXP, and a glass-epoxy type identified as G-10. Although G-10 is the more expensive, it is the type used for the wired boards shown in the photographs in this Manual because of its superior strength.

Printed Circuit Boards

Both printed-circuit and wired boards are suitable for use in the circuits in this Manual; the decision about which to use is up to the builder. It should be noted, however, that the stated performance for a circuit is based on the use of the board given with that circuit. Wired boards can be made for the Manual circuits that are supplied with printed-board templates by using the printed-board template as a drilling template and then wiring by following the circuit schematic diagram.

The choice of the type of material used to make the printed-circuit board is left to the builder. The most common and economical material is 1/16-inch, 1-ounce copper, XXXP; this material is a paper-based phenolic board 1/16-inch thick that has 1-ounce of copper per square foot deposited on it. A second type of board is the copper-surfaced, G-10, glass-epoxy board; this board material is stronger and more suitable for use in high-frequency circuits. The G-10 material was used to make the boards shown in the photographs in this Manual. Both board materials come in a number of standard sizes that can be cut to the sizes shown in this Manual with a hacksaw.

The process of making a printed circuit board can be divided into three steps: transferring the image, applying the resist, and etching. Two methods of circuit-board fabrication, manual and photographic, are described below; the etching process is the same for each.

In the manual method, which is the best method for making single boards, the printed-circuit patterns shown at the back of this Manual are transferred to the copper side of a board by tracing the outlines of the black areas through a piece of carbon paper. Any holes indicated in the pattern should be accurately traced. When the tracing is complete the holes are drilled and a resist, more properly called the etch-resistant solution, such as nail polish, is applied to those areas of the copper that are to remain, the areas within the tracing. When the resist is completely dry, the board is ready for etching.

If a number of boards of the same pattern are needed, it is best to follow the photographic method. In this method, a transparency of the pattern is made for use with a photosensitive board. There are two ways to make a transparency: one is to make a photographic negative of the board, the method that results in the most professional looking board; the second is to make a duplicate of the pattern on a piece of clear plastic. In the second, which is the less expensive method, the plastic is placed over the pattern and the areas to be etched (the white areas) are painted over with some opaque material, such as nail polish. Home-made presensitized boards can be made, but the process is time consuming and the results inconsistent unless elaborate precautions are taken. Therefore, the commercially presensitized boards available through many of the larger electronics mail-order supply houses are recommended. The commercial boards come in lightproof packages and require handling under subdued lighting conditions; they are most sensitive to ultraviolet light.

To make a printed circuit board from a presensitized board, the transparency is sandwiched between the unexposed board and a piece of window glass called the pressure plate. It is important that the correct side of the transparency face the glass to avoid producing a mirror image of the circuit. The "sandwich" is exposed to a light source, such as a sunlamp, photoflood, or sunlight in accordance with the board manufacturer's instructions. The exposure takes approximately five to ten minutes; however, the exact amount of exposure varies with board manufacturer and is also a function of the light source and the type of glass used in the pressure plate. Some types of glass are more resistant to ultraviolet rays than others; a few tests on some small pieces of board may be necessary to find the correct exposure time. When in doubt, it is usually best to start with exposure times longer than the manufacturer specifies. Overexposure is preferable to underexposure: a board underexposed by one minute may be ruined; a board overexposed by five minutes is still good.

After exposure the board is ready to be developed in a printed-circuit-board developing solution; such solutions are also available from electronics mail-order supply houses. The board should be moved around in this solution for several minutes to complete the development process. The unexposed photosensitive material will then have been dissolved, leaving only the hardened exposed material in the form of the desired conductive pattern. After the board is developed, it is no longer photosensitive and should be washed under clear running water and dried. The board is now ready for etching.

The catalogs of the electronics mail-order houses should be consulted for the availability of ready-mixed etchants. Because etching solutions become exhausted with use, they must be replaced occasionally.

The etchant used to make the boards shown in this Manual was ferric chloride solution. CAUTION: This solution must be handled with care as it produces fumes that should not be inhaled, is a skin irritant that should be washed from the skin immediately upon contact, and is of a deep red-brown color that produces an indelible stain. Etching should be performed in a shallow glass tray slightly larger than the board to be etched; only enough etchant to cover the bottom of the tray is required. The board should be floated copper-side down in the etchant and agitated occasionally so that the chemicals can act equally over the surface of the board and speed the etching process. Etching time can also be accelerated by heating the etchant to about 90° to 115°F. CAUTION: Excessive heating of the solution will cause excessive fuming. The etching process takes about five to fifteen minutes depending on the strength of the etchant and its temperature. When etching is complete, the board should be washed throughly in fresh water and the resist material remaining on the board removed with some fine steel wool or a solvent, such as acetone or nail-polish remover.

Printed-circuit boards are fairly rugged; however, some care must be taken not to cause open circuits by scratching through the copper; hairline scratches may be repaired by solder bridging. Boards should also be examined before use to assure that there are no short circuits caused by unwanted residual copper.

Soldering

The right amount of heat is important in good soldering. Too little heat will result in a cold solder joint; too much heat can seriously damage a component. All soldering should be performed with a soldering iron rated at 45 watts or less; a soldering gun should not be used. The tip of the iron should be kept clean by brushing it frequently with a paper towel. The choice of solder for a particular job is determined by its melting point. 50-50 solder (50% lead; 50% tin) melts at 425°F; 60-40 solder melts at 371°F; 63-37 solder melts at 361°F. 60-40 solder is used in most circuit wiring work.

When transistors, IC's, and crystal diodes are soldered, the lead being soldered should be gripped with pliers close to the unit. The pliers act as a heat path or sink and conduct away damaging heat. If the lead cannot be conveniently gripped with pliers, an alligator clip or commercial heat sink may be used. Components should be mounted in such a way that the leads are protected from mechanical strain.

Before solder is applied, a good mechanical connection should be made by twisting the wire around the terminal post or lug. Soldering should be considered a means for making a good electrical connection, not a mechanical one.

For good heat conduction between the soldering iron and the mechanical joint, a small amount of solder should be applied to the tinned portion of the soldering-iron tip, and this surface should be applied to the joint. The solder is then applied to the joint, but is not brought into contact with the iron; when the solder melts, the joint is properly soldered. This procedure avoids a cold solder joint that could cause trouble at some future time. It is a good idea for the inexperienced circuit builder to practice soldering with some pieces of scrap wire.

The stripped ends of heavy solid wire or flexible multistrand wire such as used in line cords should be tinned by flowing rosin-core solder onto them before the mechanical connection to the lug or terminal is made. This tinning procedure ensures a quick, clean, hot-solder joint. Tinning of heavy terminals such as those used on toggle switches is also a good practice. Tinning of ordinary hookup wire is not necessary.

When a knife is used to strip the insulation from the end of a wire, it should be a dull one so that it will not nick the wire. If diagonal cutters are used, they should be squeezed only tightly enough to cut and pull the insulation. Wirestrippers must be set properly so that the wire being stripped is not nicked. A nicked wire can break and result in an inoperative circuit.

Heat Sinking

The dc power input to a semiconductor device generates heat within the device and raises its temperature. The maximum allowable device temperature rise limits the amount of electrical power input. Because the temperature rise depends not only on how much heat is generated, but on how fast that heat is carried away and dissipated, the amount of input power allowed is directly related to the heat-dissipation methods.

Medium- and high-power transistors are usually so constructed that they can be attached tightly to a chassis or to a heat sink. To aid in carrying heat away from the transistor junction, the collector junction is internally connected to the transistor case in most power transistors. Therefore, when the transistor case is connected to the chassis, the collector is also connected to the chassis, and some provision must be made to prevent shorting out of the dc and ac voltages on the collector. Although it is possible to rearrange the circuit to allow the collector to be at chassis potential, the most usual practice is to insulate the transistor case from the chassis. This insulation must isolate the transistor from the chassis electrically while providing the least possible interference to the flow of heat from the transistor mounting base to the chassis. Very thin (on the order of a few thousandths of an inch) mica, plastic, or anodized aluminum washers are used for this purpose. When anodized aluminum washers are used, care must be taken to remove any burrs on the transistor or chassis that might cut through the anodizing and destroy its insulating properties. To ensure the best possible heat transfer, a silicone grease or oil can be applied to both surfaces of the washer. The oil or grease fills any voids between the washer and transistor mounting base and the washer and chassis.

In the absence of a suitable metal chassis or in cases in which the device itself cannot be attached to a metal chassis, a heat sink is used. Heat sinks are produced in various sizes, shapes, and materials; they can be flat or cylindrical and can have vertical or horizontal fins attached to them.

Heat sinks also take the form of aluminum angle brackets. The device is normally attached to the angle bracket which is, in turn, attached to but electrically insulated from the chassis by the methods described above.

Grounding

A ground is a common reference point in a circuit; ground potential means that there is no potential difference, no voltage, between the point at ground potential and the earth.

Ground points need not actually be connected to the earth, but if the connection were made, there would be no effect on the circuit. A chassis ground designates a common point in a circuit at which power supplies and metal chassis are electrically tied together.

Good grounds are sometimes very important to proper circuit operation. In an amplifier, for example, the ground prevents regeneration and minimizes the possibility that changes in the output will be reflected in the input. A good ground is one that evidences extremely low resistance and that displays essentially no difference in potential between connections to the same ground point.

Fig. 36 shows the symbols for earth ground, or the common circuit reference point, and chassis ground.

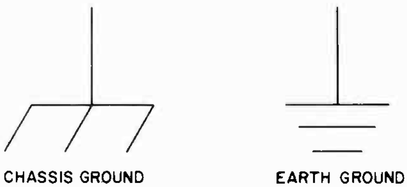


Fig. 36 – Symbols for chassis ground and earth ground or common circuit reference point.

TERMINAL DIAGRAMS

Fig. 37 shows the terminal diagrams for the semiconductor devices and the Numitrons used in this Manual.

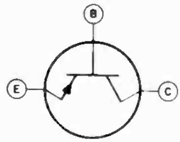
SPECIAL HANDLING CONSIDERATIONS

Transistors

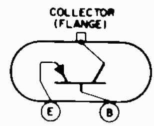
The collector, base, and emitter terminals of transistors can be connected to associated circuit elements by means of sockets, clips, or solder connections to the leads or pins. If

SK NUMBERS

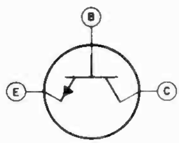
SK3004
SK3005



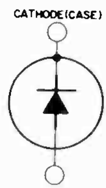
SK3009



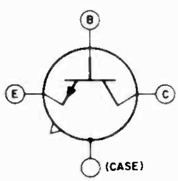
SK3010



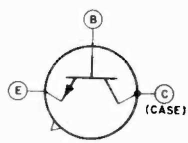
SK3016
SK3030
SK3031

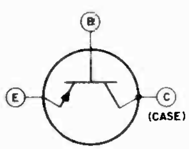


SK3018
SK3019

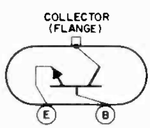


SK3020
SK3024
SK3038

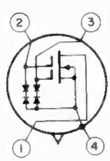




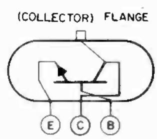
SK3025



SK3026
SK3027



SK3050

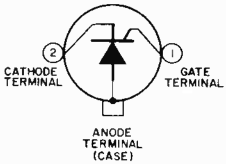


SK3054

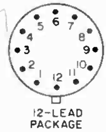
Fig. 37 – Terminal diagrams for the semiconductor devices and the RCA Numitrons used in this Manual. *(Cont'd on page 35 and 36.)*

KD NUMBERS

KD2100

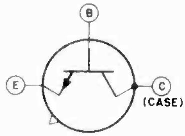


KD2114
KD2115

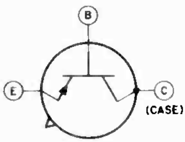


KD2116

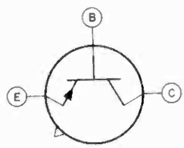
KD2118



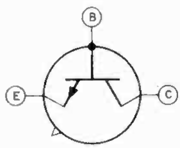
KD2120



KD2123

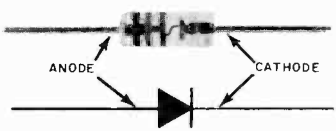


KD2124



DIODES

IN270
IN34A
IN914



IN3193

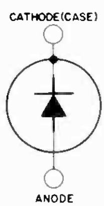
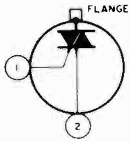


Fig. 37 – Terminal diagrams for the semiconductor devices and the RCA Numitrons used in this Manual. *(Cont'd on page 36.)*

TRIACS

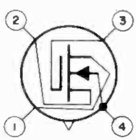
40429
40502
40503



Pin 1 – Gate
Pin 2 – Main Terminal 1
Flange, Case – Main Terminal 2
Case, Flange (40429) – Main Terminal 2
Case, Flange, Heat Radiator (40502, 40503) – Main Terminal 2

MOS TRANSISTORS

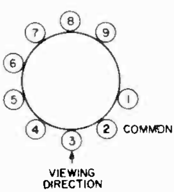
3N139



1 – Drain
2 – Source
3 – Insulated Gate
4 – Bulk (Substrate) and Case

NUMITRON AND DECODER DRIVER

DR2000
Numitron



CD2500E
Decoder-Driver

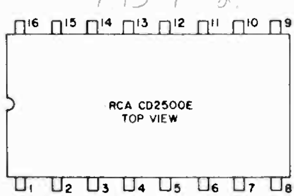


Fig. 37 – Terminal diagrams for the semiconductor devices and the RCA Numitrons used in this Manual.

connections are soldered close to the lead or pin seals, care must be taken to conduct excessive heat away from the seals; otherwise the heat of the soldering operation may crack the glass seals and damage the transistor.

Under no circumstances should the mounting flange of a transistor be soldered to a heat sink because the heat of the soldering operation may permanently damage the transistor.

When the metal case of a transistor is connected internally to the collector, the case operates at the collector voltage. If the case is to operate at a voltage appreciably above or below ground potential, consideration must be given to the possibility of shock hazard and suitable precautionary measures taken.

Transistors should be handled carefully because the semiconductor material inside the case is brittle and can be damaged if the transistor is dropped. A drop of about 4-1/2 inches onto a hardwood surface can subject a transistor to a shock of about 500 times the force of gravity.

MOS Transistors

The performance of MOS transistors depends on the condition of a very thin insulating layer between the control electrode (gate) and the active channel. If this layer is punctured by accidental application of excess voltage to the external gate connection, irreversible damage can occur. If the damaged area is small enough, the additional leakage may not be noticed in most applications. However, greater damage may degrade the device to the point at which it becomes unusable. It is very important, therefore, that appropriate precautions be taken to ensure that the gate-voltage ratings of MOS transistors are not exceeded.

Static electricity represents the greatest threat to the gate insulation in MOS transistors. A large electrostatic charge can build up on the gate electrode if the transistor is allowed to slide around in plastic containers or if the leads are brushed against fabrics such as silk or nylon. This type of charge build-up can be avoided completely by wrapping the leads in conductive foils or fine wire, by use of conductive containers, or by otherwise electrically interconnecting the leads when the transistors are being transported.

A second cause of electrostatic charge damage to the gate insulation can be traced to the people who handle the transistors. At relative humidity levels of 35 per cent, a person may accumulate an electrostatic potential that could range into the thousands of volts. If such a "charged" person grasps an MOS transistor by the case and plugs it into a piece of equipment, or in any other way causes the gate lead to contact "ground" before the other leads, there is a good chance that the accumulated electrostatic charge may break down the gate insulation. To avoid this eventuality, those handling MOS transistors should make sure that they are grounded before touching the device.

In most applications, circuit impedances are low enough to prevent any accumulation of electrostatic charge. Thus, although the gate insulation may be damaged by improper handling of MOS transistors before they are connected into actual circuits, thousands of hours of operation under practical circuit conditions have shown that the gate insulation is reliable under the stress of long-term operation within published ratings.

Dual-gate-protected MOS transistors are protected against static discharge during handling and from in-circuit transients by the back-to-back diodes connected to each gate as shown in Fig. 11; these transistors do not require the external shorting mechanisms described in the preceding paragraphs.

Integrated Circuits

The fabrication of any integrated circuit (IC) involves extreme care. Special handling of the IC from the receipt of raw materials to the shipment of the finished product is the rule. If the IC is to operate satisfactorily in its final application, this same special care must be followed in mounting and soldering. The best method of mounting transistor-can-type IC packages is to bend each lead out from the can slightly so that the lead ends describe a circle as close to the diameter of the mounting or socket holes as possible. Care must be used in bending the leads to avoid breaking them off at the package base. After the leads have been bent, they can be inserted one by one into the socket or mounting holes.

The tab on the base of the IC designates the location of the highest-numbered lead. If the device is to be inserted into a socket, the tab should be matched with the tab or notch on the socket. If the IC is to be mounted on a printed-circuit board, for example, the leads should first be correctly positioned and inserted into the mounting holes. The top of the IC is then pushed down to move it closer to the board. All leads can then be soldered. Serious damage to the IC can result from incorrect connection of leads.

When an IC lead is being soldered, a pair of long-nose pliers, an alligator clip, or other heat sink should be clamped to it between the soldering iron and the case. The soldering iron used should be small (45 watts); it should be very hot and in contact with a lead for the shortest possible period of time.

Correct polarity should be observed when a battery is installed in a circuit containing an IC; improper installation could seriously damage the IC.

Thermistors

Thermistors are fragile devices that require special handling, particularly when they are being soldered to a mounting or when leads are being soldered to them. Only solder containing silver should be used; attempts to use common lead-tin solder will prove futile and will result in the removal or burning off of the silver coating on the thermistor. The solder recommended is a rosin-core type composed of 70 per-cent lead, 27 per-cent tin, and 3 per-cent silver.

Fig. 38 shows some of the many possible mounting arrangements for thermistors. In mounting A, the thermistor is soldered between a brass cap screw and a flexible lead. This type of mounting is useful at sub-freezing temperatures when one

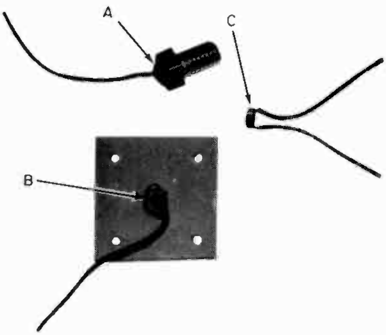


Fig. 38 – A few of the many possible thermistor mounting arrangements.

end of the thermistor is electrically connected to the frame or housing of the controlled device. In mounting B, the thermistor is mounted on a large heat sink so that short-duration, locally directed heat currents do not cause premature triggering of the circuit that the thermistor is controlling. (For example, in a freezer, it is not desirable to trigger the alarm each time the door is opened for food removal.)

The soldering technique used in attaching a thermistor to a cap screw is representative of that to be used in all thermistor mounting operations. The technique is as follows:

1. Place the cap screw, head up, on an asbestos board or a sheetmetal pedestal held in a vise.
2. Heat the cap screw by use of the small blue flame of a butane torch and apply enough silver solder to form approximately a 1/4-inch puddle on the top of the screw head; then remove the heat so that the puddle can solidify.
3. Reheat the cap-screw head until the solder melts. Then remove the heat and, by use of tweezers or long-nose pliers, carefully drop the thermistor on the melted solder and press it against the cap screw head until the solder resolidifies. Then attach the flexible lead to the top surface of the thermistor by use of a small-tip soldering iron. Wipe away any lead-tin solder from the tip of the iron with a piece of cloth before the following steps are taken.
4. Tin the soldering iron and the lead end with silver solder.
5. Place the tinned surface of the soldering-iron tip on the thermistor; apply a little solder to the thermistor to provide better heat conduction. Extra care is necessary at this point; too much heat will melt the solder between the thermistor and the cap screw and may appreciably alter the characteristics of the thermistor. When a puddle of solder forms between the soldering iron and the thermistor, remove the iron and press the tinned end of the lead lightly into the solder; blow on the joint or fan it so that it cools quickly.

A similar procedure using a torch and a soldering iron should be used in preparing mounting B. A soldering iron is the only tool required to attach leads to a thermistor (mounting C).

Thermistor characteristics can change as much as 20 per cent as a result of the heat of a soldering iron. The original characteristics are restored, however, after the thermistor has been in use for several hours. Excessive heat can cause a wider change in characteristics and, therefore, a longer restoration period.

Photocells

A photocell can be conveniently connected to a circuit by use of a slightly modified, commercially available, auto-radio antenna connector. The photocell and an exploded view of the disassembled antenna connector, H.H. Smith No. 1300, are shown in Fig. 39.

The only modification required in the connector is the drilling out of the brass insert in the black bushing nearest the photocell as shown in Fig. 39. In addition, the leads of the photocell should be covered with "spaghetti"-type insulation to minimize the possibility of shorts.

Fig. 39 also shows the completely assembled device ready for use. The connector is a standard Amphenol microphone connector and the lead is an insulated-shield microphone cable.

SAFETY PRECAUTIONS

Many of the circuits in this Manual are designed to operate from conventional 120-volt ac household power. Much thought and care has been given to the design of these circuits to make them as safe as possible. However, certain precau-

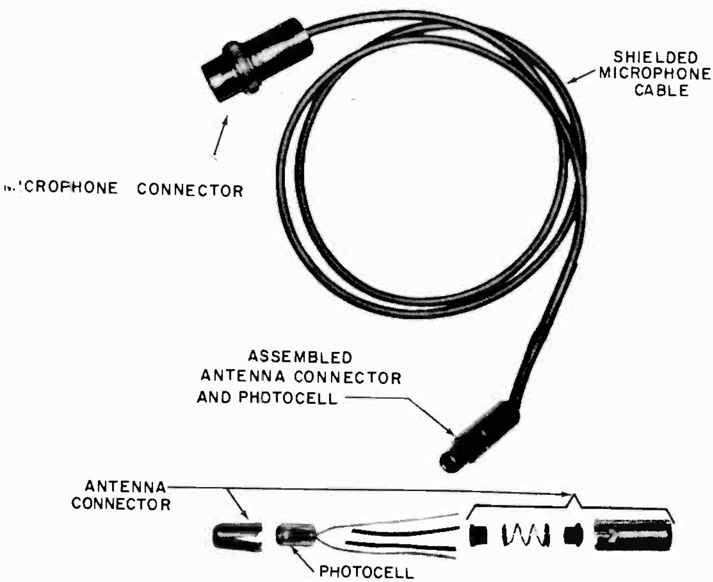


Fig. 39 – Method of mounting photocell for connection to a circuit.

tions must be taken by the circuit builder to ensure maximum safety.

Three-wire input-power and output-load connectors are recommended; where possible completely enclose all wiring and components. Ground a chassis containing a 120-volt circuit by connecting the pigtail lead on the input plug to the grounded housing of the 120-volt outlet. Always remove this plug from the outlet when the chassis is being serviced. Even if the fuse has blown, internal circuit components may still carry dangerous potentials. If voltage readings are desired during trouble-shooting, the circuit may be energized; however, it must be remembered that the case of some devices and other areas of the circuit carry dangerous voltages and should not be touched.

A good rule to follow during trouble-shooting of an energized circuit is to keep one hand away from the chassis, in a pocket if possible. It is also recommended that trouble-shooting never be undertaken alone. Use safety glasses, especially during soldering; solder splashes are painful and can be dangerous. Also remove rings, braclets, wristwatches, and the like during trouble-shooting because they represent an electrical hazard.

Testing and Troubleshooting

SUCCESS IN troubleshooting the circuits in this Manual is directly related to the circuit builder's familiarity with the instructions presented. The test instruments available and the way in which they are used are also very important factors. Always observe the safety precautions described in the section concerning Mechanical Considerations when testing or troubleshooting.

Although waveshapes taken with an oscilloscope are not absolutely essential for troubleshooting, they can be valuable as an aid to understanding the operation of a circuit. Waveshapes taken when the circuits (especially the power-control type) are operating normally can be very useful for comparison purposes when trouble occurs. Waveshapes shown in this book can be taken with an RCA WO-33A oscilloscope or its equivalent. Voltage and current readings can also be very helpful in troubleshooting; only meters rated at 20,000 ohms-per-volt or higher should be used to test the circuits in this Manual. The RCA WV-38A Volt-Ohm-Milliammeter (VOM) and the RCA WV-77E VoltOhmyst* are good instruments for such readings.

The following checkout procedure is recommended when a circuit is first turned on or when troubleshooting is attempted:

1. Before power is applied to the circuit for the first time, check the wiring for agreement with the schematic and check the load to ensure that it is within the circuit capabilities and is of the proper type.
2. If the circuit fails to operate, visually check the load for any signs of energization, such as the flash of a lamp or the start of a motor.
3. If trouble is evident remove the power-input cord from the power receptacle and check the fuse.
4. If the fuse has blown, recheck the wiring for short

*Trademark Reg. U.S. Pat. Off.

circuits; give special attention to the polarity of the electrolytic capacitors and rectifiers.

5. If the fuse has not blown and the load shows no evidence of being energized, recheck the wiring; an open circuit caused by faulty wiring is the most probable cause of the trouble.
6. Voltage and resistance checks by VOM are the next step in isolating the trouble area. If one of the active components (transistors, rectifiers, diodes, or thyristors) is suspected, test it for "go/no-go" operation with one of the temporary circuits described and illustrated later in this section. (The tests that can be performed with the temporary circuits will only indicate whether the component under test is internally open- or short-circuited; they will not indicate how well or with what gain the component operates in the circuit.) More complete testing of transistor circuits can be accomplished through the use of a transistor tester such as the RCA WT-501A described at the end of this section. If all active components are found to be in working order, check the passive components, resistors and capacitors: capacitors for shorts and leakage, wire-wound resistors and potentiometers for discontinuities. These components, especially new ones that display no visible irregularities, are usually trouble-free and therefore are least likely to be the cause of circuit failure.
7. If the circuit is operating but the performance is not as expected, the trouble might be caused by the fact that the actual value of each component is a little higher or lower than its stated value. If all or substantially all of the components are off in the same direction (either higher or lower) the sum of the small differences in individual resistance and capacitance might be enough to affect circuit performance. If this problem is suspected, a change to the next higher or lower resistance or capacitance value or the substitution of another component of the same value may produce a significant change in circuit operation. As mentioned previously, success in this type of troubleshooting depends to a large extent on the experimenter's familiarity with and understanding of the circuits involved.

TEST CIRCUITS FOR CIRCUIT COMPONENTS

The simple, temporary circuits shown in this section are designed to give the typical home circuit builder, who does not have professional-type testing equipment at his disposal, a means of testing circuit components.

Observe the safety precautions described in the section concerning Mechanical Considerations when testing.

Fig. 40 shows a simple "go/no-go" test circuit for rectifiers operating at 120 volts. With the connection shown, the lamp operates at half-power. When the switch is closed, the lamp should brighten if the rectifier under test is good. If there is no change in brightness when the switch is closed, the lamp was burning at full power with the switch open; in this case, the rectifier is shorted. If the lamp is out with the switch open but lights when the switch is closed, the rectifier is open.

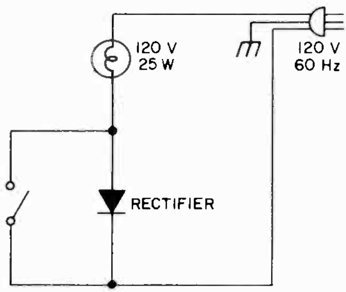


Fig. 40 – "Go/no-go" test circuit for high-voltage rectifiers.

Fig. 41 shows a "go/no-go" tester for all diodes in this Manual that operate at low voltages except the RCA 1N34A, RCA 1N270, and the type 1N914. The test circuit for these three types is shown in Fig. 42.

With a diode connected as shown in Fig. 41 and with the polarity of the battery as shown, the lamp should light; when the polarity of the battery is reversed, the lamp should not light. If the lamp lights regardless of the polarity of the battery, the diode is shorted; if the lamp does not light with either polarity, the diode is open.

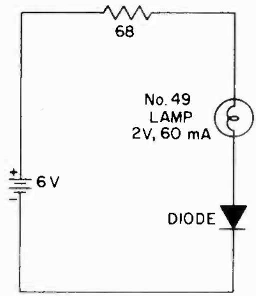


Fig. 41 – "Go/no-go" test circuit for low voltage diodes excluding RCA types 1N34A, 1N270, and the type 1N914.

When the anode of a 1N34A or 1N270 diode is connected to terminal No. 1 in Fig. 42, the lamp should not light if the diode is good; when the anode is connected to terminal No. 2 the lamp should light. If the

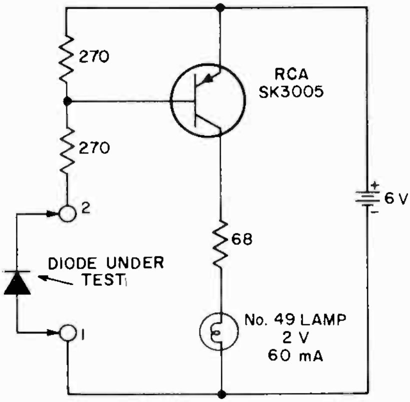


Fig. 42 – "Go/no-go" test circuit for RCA diode types 1N34A, 1N270, and the type 1N914.

lamp remains lit regardless of the connection, the diode is shorted; if the lamp is off regardless of the connection, the diode is open.

Fig. 43 shows a "go/no-go" tester for bipolar transistors. The connections shown are for an n-p-n transistor. When the base resistor is connected to the plus side of the battery, the No. 49 lamp should light if the transistor is operative. When the base resistor is connected to the minus side of the battery, the lamp should go out. For p-n-p transistors, the same results should be obtained with the battery polarities reversed.

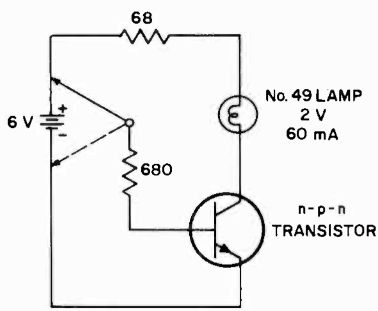


Fig. 43 — "Go/no-go" test circuit for bipolar transistors.

A quick check can be made of transistors prior to their installation in a circuit by resistance measurements with an electronic voltmeter such as the RCA VoltOhmyst. Resistance between any two electrodes should be very high (more than 10,000 ohms) in one direction and considerably lower in the other direction (100 ohms or less between emitter and base or collector and base; about 1,000 ohms between emitter and collector). It is very important to limit the voltage used in such tests (particularly between emitter and base) so that the breakdown voltages of the transistor will not be exceeded; otherwise the transistor may be damaged by excessive currents.

No practical "go/no-go" circuits suitable for use by hobbyist or experimenter exist for checking MOS transistors; they can only be tested by observing their performance after installation in a functional circuit. Probing of the MOS transistor leads with any kind of meter probe can destroy the transistor.

SCR's can be tested by means of the circuit shown in Fig. 44. When the switch is closed, a current of approximately 20 milliamperes flows

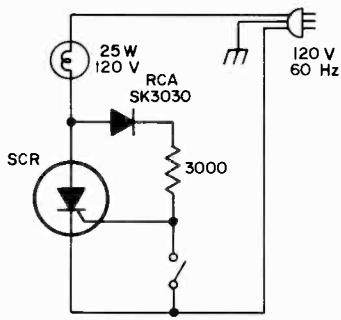


Fig. 44 — Simple test circuit for SCR's.

through the 25-watt lamp, the 3000-ohm resistor, and the switch; this amount of current is not enough to light the lamp. When the switch is opened, the lamp should brighten to approximately half maximum brightness. Under these conditions, the SCR should be triggered into operation (shunting the 3000-ohm resistor) on each positive half-cycle of input by the 20-milliampere current flowing in the gate-cathode circuit. If the lamp lights to full brightness, the SCR is shorted. If the lamp does not brighten regardless of the position of the switch, the SCR is open.

There are no practical "go/no-go" test circuits for checking IC's. For this reason, a table of voltage readings at the terminals of an IC installed in a properly operating circuit is given with each IC circuit in this Manual.

The test circuit shown in Fig. 45 can be used to check a two-transistor regenerative switch. When the

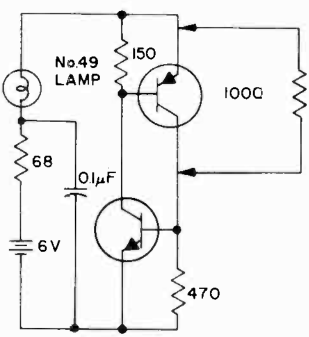


Fig. 45 – Simple test circuit for the two-transistor regenerative switch.

1000-ohm resistor is inserted in the circuit, the No. 49 lamp lights. If the transistor switch is operating properly, the lamp should remain lighted when the 1000-ohm resistor is removed.

RESISTOR AND CAPACITOR COLOR CODES

Standard color codes indicate the values of resistors and capacitors. Fig. 46 shows common composition resistors and the location of identifying marks; Table III explains the significance of the markings. A resistor with four stripes – yellow, black, green, and silver, respectively, from left to right – is a 4-megohm resistor with a ± 10 per-cent tolerance. A resistor with green, blue, and red stripes is a 5600-ohm resistor with a ±20-per-cent tolerance.

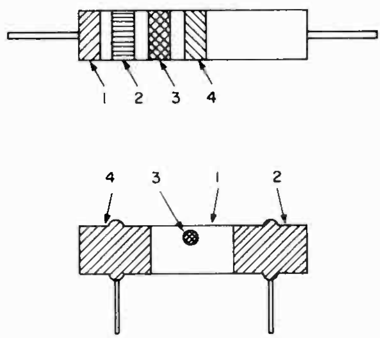


Fig. 46 – Location of identifying marks on common composition resistors: (1) first significant figure of resistance in ohms, (2) second significant figure, (3) decimal multiplier, (4) resistance tolerance in per cent (no color is ± 20%).

Fig. 47 shows common types of capacitors and the location of their identifying markings; Table III explains the color-coded markings found on the capacitors. A flat or "postage-stamp" capacitor with 3 dots, left to right, of red, black, and red has a capacitance of 2000 picofarads or 0.002 microfarad. A capacitor with 6 dots–top row, left to right, of brown, black, black, and

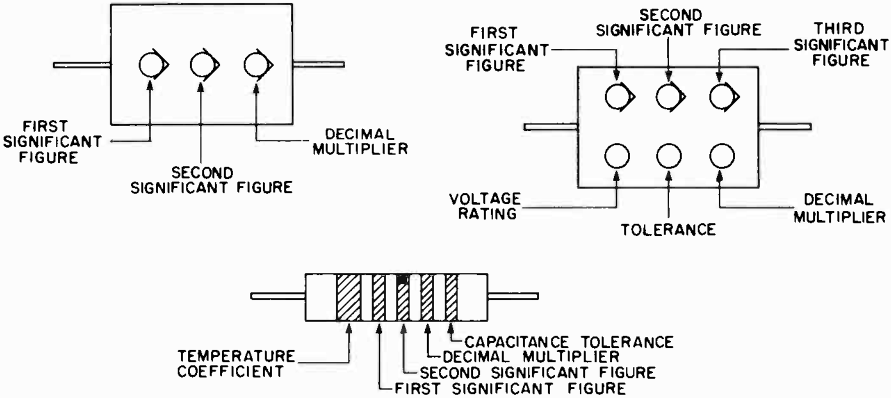


Fig. 47 – Location of identifying marks on common types of capacitors.

Table III.

Resistor/Capacitor Color Codes

Color	Significant Figure	Decimal Multiplier	Voltage Rating[1] (V)	Tolerance[2] (%)	(±%)	(pF)
Black	0	1	-	-	120	2
Brown	1	10	100	1	1	-
Red	2	100	200	2	2	-
Orange	3	1,000	300	3	-	-
Yellow	4	10,000	400	4	-	-
Green	5	100,000	500	5	5	0.5
Blue	6	1,000,000	600	6	-	-
Violet	7	10,000,000	700	7	-	-
Gray	8	100,000,000 (0.01 for ceramic capacitors)	800	8	-	0.25
White	9	1,000,000,000 (0.1 for ceramic capacitors)	900	9	10	1
Gold	-	0.1	1000	5	-	-
Silver	-	0.01	2000	10	-	-
No Color	-	-	500	20	-	-

1. Does not apply to resistors or ceramic capacitors.

2. The first column through tolerance 9 applies to non-ceramic capacitors only; the remainder of the column applies to non-ceramic capacitors and resistors. The second column applies to ceramic capacitors valued at more than 10 picofarads. The third column applies to ceramic capacitors valued at less than 10 picofarads.

bottom row, right to left, of black, gold, green—has a capacitance of 100 picofarads, a tolerance of ± 5 per-cent, and a 500-volt rating.

Ceramic capacitors are valued in picofarads. They look much like resistors and are marked with bands (sometimes dots) to denote their characteristics. A capacitor with a broad violet band and successive narrow bands or dots of green, brown, black, and red has a capacitance of 51 picofarads and a capacitance tolerance of ± 2 per-cent.

TRANSISTOR TESTER

Convenience and efficiency in the testing and troubleshooting of transistor circuits is possible through the use of testers such as the RCA WT-501A, Fig. 48, a battery-operated completely portable transistor tester that can measure "beta" at the current level appropriate to a particular transistor. Beta is the common-emitter forward current transfer ratio. In the common-emitter circuit shown in Fig. 7 the base is the input

Fig. 48 — The RCA WT-501A Transistor Tester.

electrode and the collector is the output electrode. The dc beta, therefore, is the ratio of the dc collector current I_C to the dc base current I_B.

The WT-501A tests transistors out of circuit for dc beta from 1 to 1000, collector-to-base leakage (I_{CBO}) as low as 1.0 microampere, and collector-to-emitter leakage (I_{CEO}) from 20 microamperes to 1 ampere. Reliable in-circuit testing of transistor-current gain is made possible by special low-resistance circuits. The collector current I_C is continuously adjustable from 10 microamperes to 1 ampere so that both low-power and high-power transistors can be tested.

Two sockets are provided on the panel, one socket for n-p-n transistors and the other for p-n-p transistors. Three color-coded test leads are provided for in-circuit testing, or for use with transistors that do not fit the panel socket.

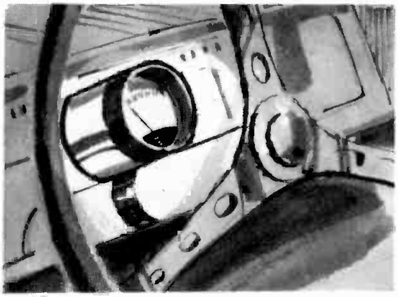
Suggested Circuit Uses

THE CIRCUITS in this Manual have been designed for maximum versatility; many of them have a range of applications limited only by the imagination and ingenuity of the circuit builder. The following descriptions, then, are to be used only as a guide by those who wish to know what circuit best applies to a certain hobby area. For maximum value from the Manual, all circuits should be examined and some thought given to how each could be applied to the area of interest.

MOTORIST

There are six circuits in the **Hobby Circuits Manual** that can be used to advantage by the motorist: the temperature alarm, the tachometer, the battery charger, the light minder, and the IC alarm.

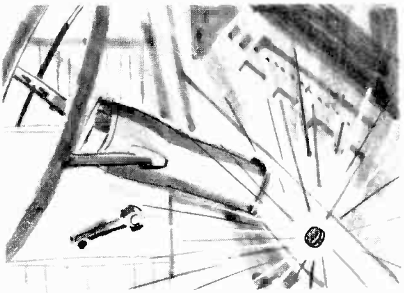
The temperature alarm is very sensitive; when its sensor is mounted outside the car, the alarm signals the driver when road icing conditions exist so that he can adjust his speed accordingly.



Tachometer

The tachometer adds to car engine life by providing an indication of engine speed, an indication that allows the driver to shift a car with a manual transmission at the optimum engine speed or to monitor the shifting of a car with an automatic transmission to determine whether it is shifting properly. Besides saving wear on the engine, proper shifting saves gas.

The light minder is a particularly good device to have on those days when fog or rain requires that headlights be used in the daylight hours.



Light Minder

Anyone who has returned to his car after several hours to find the battery dead as a result of having left the lights on will appreciate the function performed by this device.

Of the two battery-charger circuits contained in the **Hobby Circuits Manual** the 6-volt type, which has a charging rate of 1 ampere, is designed for use with low-ampere-hour batteries such as those used in motorcycles and photoflash units. This charger may also be used to charge automobile batteries, but the charging time is longer. If the charger is used at regular intervals, however, it will prove more than sufficient to keep an auto battery up to full charge. The 12-volt battery charger was designed specifically for use in charging automobile batteries.

The IC alarm, when connected to hood and trunk, will produce an alarm signal if either is tampered with.

RADIO AMATEUR

There are a great number of circuits in the Manual that can be used to advantage by the radio amateur. They are as follows:

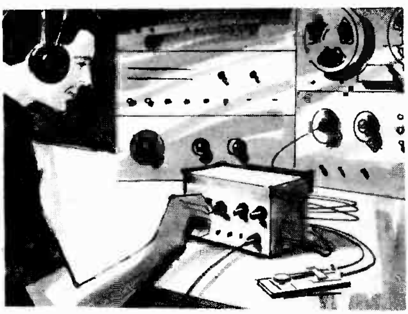
Microphone Preamplifiers (3)
Audio Oscillators (2)
Telegraph Keyers (2)
Audio Tape Keyer
Frequency-Selective AF Amplifier
Audio Amplifiers (4)
Mixers and Line Amplifiers (5)
Dip/Wave Meter
Variable-Frequency Oscillator
Calibrators (2)
Audio-Frequency-Operated Switch
Video Line Amplifier
Twenty-Four-Hour Clock
Power Supplies

The microphone preamplifiers include an all-purpose type, an IC design that is particularly useful when portability and low power dissipation are important, and a high-dynamic-range type that is useful when particularly loud inputs are expected, such as would be the case if someone were singing or speaking with the microphone held very close to his lips.

Audio Oscillator

The audio oscillator circuits, one of them incorporating an IC, can be used for code practice, as a side-tone oscillator to monitor code sending, and for equipment test and adjustment purposes.

Two telegraph keyers are included in the Manual, one semiautomatic and the other automatic. The semiautomatic keyer generates a dot or a series of dots depending on how long the paddle-key is held in the dot position; dashes must be made manually. The fully automatic keyer, on the other hand, generates both dots and dashes automatically. The dot repetition rate of both keyers and the dash repetition rate of the fully automatic keyer can be varied by means of a speed potentiometer. Both of these keyers make quality code transmission easier.



Audio Tape Keyer

The audio tape keyer is a magnetic-tape keying system that can record and transmit voice as well as code, and that can be used as a variable-speed constant-pitch code-practice device as well as a code monitor.

The frequency-selective audio-frequency amplifier is designed to amplify signals at only one predetermined frequency; at this frequency the voltage gain is about 20 to 30. At other frequencies the gain is approximately unity. This circuit is very useful under conditions of heavy interference because it has the ability to eliminate side noise and let the desired signal through.

There are four amplifiers in the Manual ranging in power output from the 500-milliwatt IC unit through the 7.5- and 15-watt complementary-symmetry types to the 30-watt quasi-complementary-symmetry amplifier. All are high-fidelity amplifiers except the IC unit, which serves best in portable applications, and are compatible with other audio equipment in the Manual.

The five mixers and line amplifiers include both monaural and stereo units that can combine a number of inputs into a high-quality output; the units that incorporate compression are of special interest to a ham because they permit a transmitter to be modulated at its maximum level and thus assure maximum intelligence of transmission. The headphone or line amplifier is particularly useful when the transmitter or receiver is mounted at some distance from the microphone or headphone, respectively.

The dip/wave meter is an extremely useful tool for the radio amateur or experimenter in electronics because it allows him to measure the resonant frequency and consequently the inductance and capacitance of both energized and unenergized radio-frequency circuits. The meter is battery-operated and hand-held.

Control of frequencies from 3.5 MHz through 148 MHz on the amateur bands is possible with the variable-frequency oscillator circuit when the circuit is used with appropriate frequency multipliers. The MOS field-effect transistor used in the circuit requires an operating potential of only 10 volts; this voltage can be obtained from an automobile or dry battery through a regulator, or from one of the low-voltage power supplies described in this Manual. Because the MOS transistor generates so little heat, the entire vfo can be enclosed in a box with its tuning coils and capacitors.

Audio Mixer, Compressor, and Line Amplifier

The vfo calibrator can be used by a ham operator to accurately establish calibration points on a vfo dial even though the points lie outside the tuning range of an amateur-band receiver. Both the 100-kHz output provided by the calibrator and the output of the vfo can be used to calibrate receivers and test equipment, such as grid-dip meters and signal generators.

The most common use of the audio-frequency-operated switch for the radio amateur is to control a radio transmitter. The af switch eliminates the need for manual action and is designed with a slight delay action on turn-off so that pauses in speech will not cause the transmitter to turn off.

The video line amplifier is a versatile piece of equipment that can be used to amplify a vfo signal or couple a signal into an oscilloscope. It is also useful as a line driver for sending rf signals over coaxial lines.

Twenty-Four Hour Clock

The twenty-four-hour clock displays the time digitally down to seconds and, with proper adjustment, is accurate to ± 10 seconds or better per year.

Five general power supplies are shown; the voltages of three are predetermined and fixed; the voltages of the other two are continuously variable within the rated values of the supplies. The output voltage of the fixed supplies is determined by fixed circuit components. The universal series power supply is designed to provide output voltages from 6 volts to 35 volts; the universal shunt supply provides 6 volts or less; the IC supply provides 9 volts. The two continuously variable supplies are designed to deliver voltages in the ranges of 4.5 to 12 volts and zero to 12 volts, respectively. The 4.5-to-12-volt design is the simpler, more economical of the two. The maximum output current for all but the IC supply is 1 ampere; the maximum current for the IC supply is 250 milliamperes.

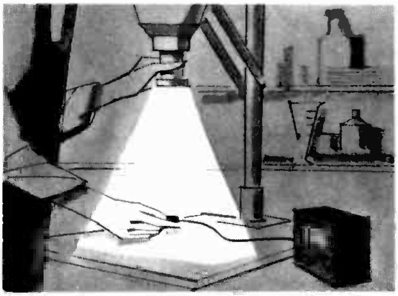
PHOTOGRAPHER

Of particular interest to the photographer are the universal timer, the enlarger exposure meter, the temperature alarm, the metronome, the 6-volt battery-charger, the counting circuits, and the stop clock or interval timer.

The universal timer circuit is a very stable, resettable circuit that can be adjusted over a wide range of times. It can be used for precise timing of enlarger exposures, print-development sequences, and other darkroom procedures.

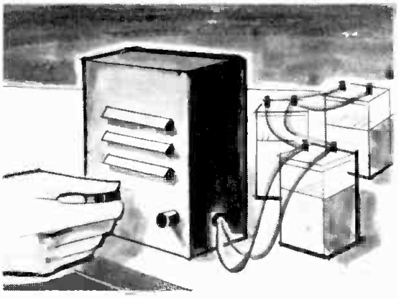
The stop clock is an extremely accurate timepiece that can record times up to 9 minutes, 69.9 seconds. Its visual readout makes it easily readable in the darkroom, even through a safety-filter glass. The counting circuits, some of which are included in the stop clock, can be adapted to any counting application.

The enlarger exposure meter makes use of a photocell circuit to permit extremely accurate timing of enlargements. The meter greatly simplifies the work required to set up the enlarger and to obtain consistently good reproductions.



Enlarger Exposure Meter

The temperature alarm can be used to check the temperature of any solution in the darkroom (that is, whether it is warm or cool enough to perform its function satisfactorily). When used in a running-water bath, the temperature alarm will signal a harmful change of temperature instantly.



Battery Charger

The metronome circuit is a very useful tool in the darkroom because it permits time to be measured audibly. If the "click" rate of the timer is set at 1 second, the passage of an amount of time can be noted simply by counting the "clicks."

The 6-volt battery-charger circuit was originally designed for the prime purpose of providing photographers with a means of recharging the batteries of their portable strobe units. The savings in battery cost realized when the charger is used are substantial. Although this charger can be used to charge auto batteries, its special slow charging rate makes it more applicable to the charging of smaller batteries.

MUSIC LOVER

There are many circuits in the Manual that will add to the enjoyment of music lovers whose delight is in listening, as well as those who prefer to make their own music.

The four amplifiers provide a range of output powers from the 500 milliwatts of the IC amplifier, which is ideally suited to use as a portable unit, through the 7.5- and 15-watt complementary-symmetry amplifiers, to the 30-watt quasi-complementary-symmetry amplifier. The 7.5-, 15-, and 30-watt amplifiers qualify as extremely high-quality high-fidelity units and are compatible with other audio equipment in this Manual.

Stereo Mixer

The mixers and line amplifiers permit the audio buff to mix the input from a number of sources for output to a recorder, amplifier, or other audio equipment. Some mixers include compression stages that provide the uniform audio levels required in the production of very-high-quality tape recordings. The headphone or line amplifier is very useful in audio work when the power amplifier is located at some distance from the microphone.

The three microphone preamplifiers include an all-purpose preamplifier, an IC preamplifier that is particularly suited to applications in which portability and low power dissipation are required, and a high-dynamic-range unit that easily accommodates loud passages of music or close talking while producing negligible distortion in the output.

The photoelectric audio attenuator makes possible the adjustment of the volume of an amplifier, radio, or TV from a remote position with no hum or deterioration in the audio-output signal.

The phonograph preamplifier is designed for use with a magnetic pickup capable of supplying an input signal of at least 5 millivolts and has provisions for tape and tuner input. At the 5-millivolt signal level, the preamplifier delivers an output of at least 1 volt.

Fuzz Box

The fuzz box is intended to be used with a guitar; however, it may be used with any instrument whose musical output is electrically amplified. It can be used with the audio power amplifier circuit described in the Manual. The fuzz box changes

Organ

the character of the sound produced by an instrument and makes possible the generation of a variety of sounds of which the instrument alone is not capable.

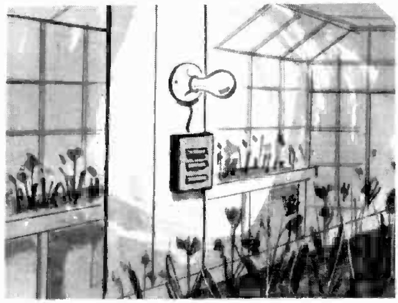
The single-voice organ operates through six octaves and has variable tone character, volume, and tremolo depth controls. A full, rich note is produced that can be amplified by the audio-amplifier circuit to produce a true organ sound.

The metronome functions over a continuous, wide range of time intervals, and has an advantage over the mechanical type in that it does not have to be re-wound.

HOME OWNER

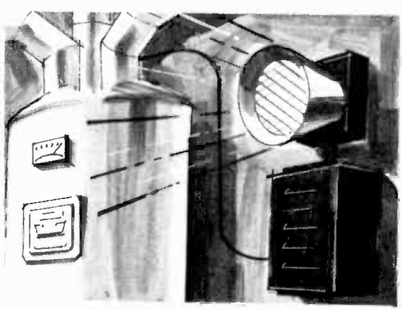
Eleven circuits in the **Hobby Circuits Manual** have been designed with the home owner in mind. These circuits, some for use indoors, some for use outdoors, some battery-operated, and some requiring house power, will make the home owner's life more pleasant by saving steps or unnecessary labor or by adding to the appearance of his home; some circuits also increase the safety of the home.

The temperature alarm, for example, can be used to warn of high



Temperature Alarm

temperature in a freezer or low temperature out-of-doors. It can also be used as a fire alarm or to warn of abnormally high temperatures in a furnace room. Because the alarm is provided with a standby battery, it is not dependent upon utility-company power and will continue to operate during a power failure. The IC alarm circuit can be used as a fire alarm in some of the same applications as the



IC Alarm Circuit

temperature alarm. The IC alarm can also be connected to doors and/or windows as an intruder alarm and will sound a loud warning should the doors or windows be tampered with.

The lamp dimmer can be used in the dining, living, or play room to attain the exact lighting level desired. The simplicity of the lamp dimmer makes it extremely easy to build.

The light-operated switch is a particularly versatile circuit that allows lights to be automatically and remotely turned on and off. If the house is left unattended for some time, the switch will ensure that house and yard lights are on during the night. The switch can also be set to turn on when headlights are shined on the triggering mechanism; in a similar application dock lights may be turned on by a boat owner as he returns to port for the night. In both of these applications the light sensor is mounted at the end of a long tube so that the switching circuit is activated only when the light shines down the tube.

Metal Detector

The metal detector is a handy device for locating underground pipes and for retrieving metal articles lost in sand, grass, or loose earth. The metal detector can also be used for "treasure" hunting by the amateur archaeologist and vacation beachcomber.

The motor speed control is most useful around the shop, where it can be used to adjust and regulate (maintain constant speed under conditions of changing load) the speed of drills, buffers, and jigsaws. A power drill operated through the motor speed control can be made to rotate very slowly so that the drill can be used as a power screwdriver. Floor polishers, hair dryers, and commercial food mixers can also be controlled by this circuit.

The primary use of the flasher is for switching decorative lights or signs on and off to add to their attractiveness. An address sign illuminated by a flashing light is a great help to visitors looking for that address for the first time.

The time delay is useful for activating an auditory device to signal the end of a time interval (e.g., to limit card and chess players to one minute of "thinking time"), or for making another device "wait" for a short time until some action can be taken.

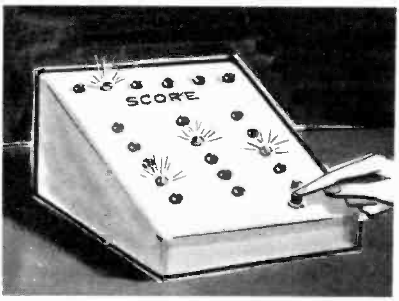
The photoelectric audio attenuator is a step-saving device that is used to adjust the volume of an amplifier, radio, or TV from a remote position while producing no hum or deterioration in the final audio-output signal.

The twelve-hour clock displays the time digitally in illuminated numbers. The modernistic readout makes the clock an attractive addition to the home.

NOVELTY AND MISCELLANEOUS CIRCUITS

The novelty and miscellaneous circuits include games, a model-vehicle control, a siren, power supplies, digital displays, three clocks, an IC wireless microphone, counting circuits, and the shift register.

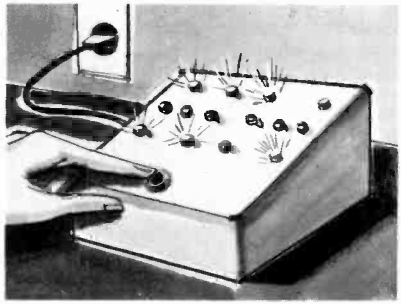
The game circuits are the electronic slot machine and the electronic die. The slot-machine game duplicates the operation of the well-known Las Vegas model except that a push-button replaces the lever and three vertical columns of lights



Electronic Slot Machine

replace the spinning wheels. Instead of paying off in coin, the electronic slot machine indicates a score through one of six scoring lamps on its face.

The dice circuit displays, by means of lights, any of the dot patterns that exist on the faces of conventional dice. The siren circuit is battery-operated and can be used in conjunction with a burglar alarm or as a warning or signaling device. The siren makes a sound similar to that of a police siren but is not as loud.



Electronic Dice

The model train and race-car speed control provides smooth and continuous control of the speed of model vehicles designed to operate at dc voltages up to 12 volts. Model speed can be adjusted over the complete range from zero to full speed.

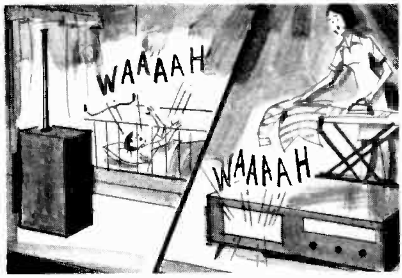
Stop Clock

The three clocks in the Manual, a twenty-four-hour clock, a twelve-hour clock, and a stop clock, cover just about every timing application. The twenty-four-hour clock has its own timing source and, when properly adjusted, is accurate to ± 10 seconds or better per year; it will continue to keep time accurately in spite of power failures. The twelve-hour clock displays time digitally, as does the twenty-four-hour clock, but in the conventional 12-hour cycle. The stop clock is an extremely accurate device that can also be used as an interval timer; it records times up to 9 minutes, 69.9 seconds.

A number of displays are described in the Manual that have a great variety of uses. The large-scale lamp display can be used for displaying scores at athletic events; the scorekeeper can be located at some distance from the display. The meter display presents a count as the meter needle points to a number on its face. With the power supply given, up to ten meters can be cascaded to provide a total count of up to 10 billion. The Numitron display, the one used in the clocks, consists of a numerical readout composed of illuminated numbers.

Single counting circuits capable of counting from zero through sixteen, but which can be cascaded to count to any desired number, can be used in counting events of any sort. These same counting circuits are used in the clock circuits to count the seconds, minutes, and hours.

The transmission of the IC wireless microphone can be picked up by any FM broadcast-band receiver operating within the range of from 88 to 108 MHz when the receiver antenna and microphone are within 150 feet of each other.



IC Wireless Microphone

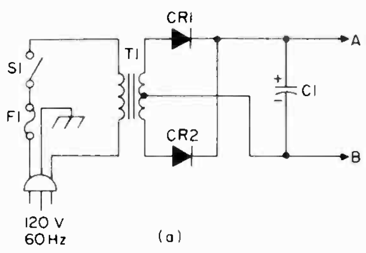
Five power supplies are shown; the voltages of three are predetermined and fixed; the voltages of the other two are continuously variable within the rated values of the supplies. The output voltage of the fixed supplies is determined by fixed circuit components. The universal series power supply is designed to provide output voltage from 6 volts to 35 volts; the universal shunt supply provides 6 volts or less; the IC supply provides 9 volts. The two continuously variable supplies are designed to deliver voltages in the ranges of 4.5 to 12 volts and zero to 12 volts, respectively; the 4.5-to-12-volt design is the simpler, more economical of the two. The maximum output current for all but the IC supply is 1 ampere; the maximum current for the IC supply is 250 milliamperes.

Circuits

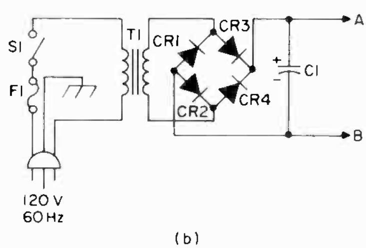
CIRCUIT NO. 1 – POWER SUPPLIES – GENERAL INFORMATION AND TRANSFORMER–RECTIFIER STAGES

Of the four power supplies shown, two provide fixed voltages and two continuously variable voltages within their rated values. In the fixed-voltage supplies, Circuits No. 2 and No. 3, the output voltage can be adjusted to a set value by replacement of certain circuit components with other components of different value. The universal series power supply, Circuit No. 2, is designed for use with electrical circuits requiring at least 6 volts but less than 35 volts. The universal shunt power supply, Circuit No. 3, is most suitable for applications requiring 6 volts or less.

The exact dc output voltage of a fixed supply is dependent on the regulator circuit, on the transformer used in the transformer-rectifier stage, and on the configuration of that stage. Fig. 49 shows the two



(a)



(b)

Parts List

C1 = capacitor, electrolytic, see Table IV for value

CR1 CR2 CR3 CR4 = rectifier, RCA SK3030

F1 = fuse, 1 ampere, slow blow

S1 = toggle switch; 125 volts, single pole, single throw

T1 = transformer, primary 120 volts, secondary current rating 1 ampere, see Table IV for voltage. If the secondary voltage in Table IV is 6.3 use Stancor No. P-8190 or equivalent; if voltage is 12.6 use Stancor No. P-8130 or equivalent. For all other voltages use Stancor No. TP-4 or equivalent.

Fig. 49 – Transformer-rectifier stages used with the fixed power supplies.

Table IV.
Fixed Power Supply Design Chart

DC Output Voltage	Transformer-Rectifier Stage: Transformer Secondary Voltage (V) Ckt.49(a)	Ckt.49(b)	C1 (min) (μF/Volts)	Regulator Circuit: Circuit Type	CR1 Voltage Ratings (V)	R1 (ohms-watt)
3	12.6	6.3	2500/10	shunt	3 forward biased RCA SK 3020's in series	5-5
4 1/2	12.6	6.3	2500/10	shunt	3.3	5-5
6	20	10	4000/15	shunt	4.7	5-5
				series	7.5	390-1/2
9	30	15	4000/15	series	10	820-1/2
10	30	15	4000/25	series	11	680-1/2
12	30	15	4000/25	series	13	330-1/2
15	40	20	2500/50	series	16	680-1/2
18	–	22.5	2500/50	series	10 and 9.1 in series	1000-1/2
20	–	28.5	2500/50	series	11 and 11 in series	470-1/2
29	–	38	2500/50	series	15 and 15 in series	1200-1/2
35	–	40	2500/75	series	36	680-1/2

transformer-rectifier stages; Table IV shows the possible dc output voltages and the regulator circuit (series or shunt) and transformer-rectifier stage to be used to produce each output voltage.

In Fig. 49 (a), transformer T1 isolates and steps down the line voltage, which is then full-wave rectified by CR1 and CR2 and filtered by capacitor C1. When the circuit shown in Fig. 49 (b) is used, the series or shunt circuit receives full-wave rectified ac from a bridge rectifier rather than from a two-rectifier center-tapped transformer secondary. The bridge rectifier arrangement provides the regulator with a high input voltage. Fig. 50 shows a fixed supply.

In the variable-voltage supplies, the output voltage can be varied during operation by means of a potentiometer control. The limited-range variable supply, Circuit No. 4, delivers from about 4.5 to 12 volts. The full-range variable supply, Circuit No. 5, delivers any voltage between zero and 12 volts. Fig. 51 is a photograph of a variable supply.

The power supplies are suitable for use with the circuits in this Manual and for many other applications. The specific supply used is determined by the power requirements of the intended application. The maximum output current of any of these supplies is 1 ampere.

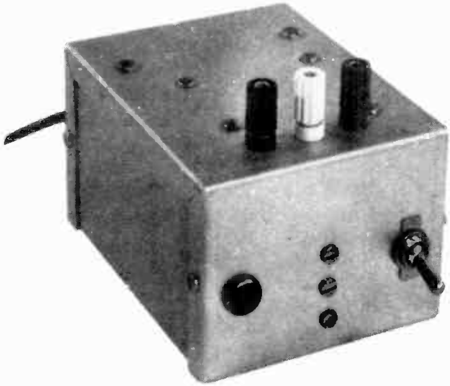


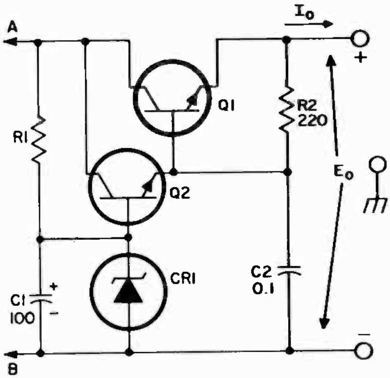
Fig. 50 – Fixed-voltage power supply.

Fig. 51 – Variable-voltage power supply.

CIRCUIT NO. 2 – UNIVERSAL SERIES POWER SUPPLY

The universal series power supply is a fixed voltage supply that performs best with circuits requiring at least 6 volts and any intermediate voltage up to a maximum of 35 volts.

The schematic diagram and parts list for the universal series power supply are shown in Fig. 52. The full-wave rectified voltage received from the transformer-rectifier combination of Fig. 49 is applied across the regulator circuit consisting of transistors Q1 and Q2 and zener diode CR1. The purpose of the regulator circuit is to maintain a constant voltage across the load; without this circuit an increased load would result in decreased load voltage. The operation of the regulator can best be understood by assuming that a constant voltage exists across the zener diode and the base-emitter junctions of Q1 and Q2 under all load conditions. When a decrease in load voltage occurs, through an increase in load current or a decrease



Parts List

C1 = 100 microfarads, electrolytic, see text
C2 = 0.1 microfarad, 50 volts or greater
CR1 = zener diode, 1 watt, see Table IV for voltage
Q1 = transistor, RCA SK3027
Q2 = transistor, RCA SK3020
R1 = resistor, 1/2 watt, 10%, see Table IV for value
R2 = 220 ohms, 1/2 watt, 10%

Fig. 52 – Schematic diagram and parts list for the universal series power supply.

in line voltage, the base of transistor Q2 becomes more positive than its emitter and more base current flows. The increase in base current in Q2 increases the collector-to-emitter current which, when applied to the base of transistor Q1, reduces its collector-to-emitter voltage. This action on the part of Q1 maintains load voltage constant.

When the load voltage increases, through a decrease in load current or an increase in line voltage, an effect opposite to that described above takes place. The base current of transistor Q2 decreases, resulting in a decrease in its collector-to-emitter current. This collector-to-emitter current is applied to the base of Q1 and raises its collector-to-emitter voltage, again satisfying the conditions for constant load voltage.

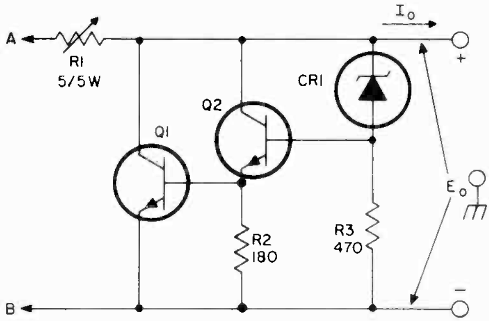
In actual circuit operation, the voltage across the zener diode and the emitter-base junctions of Q1 and Q2 changes slightly with a change in load current. However, because the polarity of the drop across the zener diode is opposite to the drop across the junctions, the effects of each tend to cancel.

The voltage rating of the transformer secondary and the value of C1 in Fig. 49, and the voltage rating of the zener diode and the values of C1 and R1 in Fig. 52 depend on the required amounts of load voltage E_o and load current I_o. Table IV shows these values and ratings as a function of output voltage. The voltage rating of C1 in Fig. 52 should be higher but as close as possible to the voltage rating of CR1.

CIRCUIT NO. 3 – UNIVERSAL SHUNT POWER SUPPLY

The universal shunt power supply is a fixed power supply designed to perform best when providing 6 volts or less.

The schematic diagram and parts list for the universal shunt power supply are shown in Fig. 53. The principles of operation of the shunt supply are similar to those of the series supply except that a resistor R1 rather than a transistor is used as the voltage-dropping element. The output voltage is held constant by Q1, which regulates the current



Parts List

CR1 = zener diode, 1 watt, see Table IV for voltage
Q1 = transistor, RCA SK3027
Q2 = transistor, RCA SK3020
R1 = resistor, adjustable, 5 ohms, 5 watts
R2 = 180 ohms, 1/2 watt, 10%
R3 = 470 ohms, 1/2 watt, 10%

Fig. 53 – Schematic diagram and parts list for the universal shunt power supply.

through, and therefore the voltage drop across, R1.

As in the universal series power supply, load voltage is maintained constant by a regulator circuit composed of a zener diode in series with the base-emitter junctions of transistors Q1 and Q2. As load current increases, the base current of transistor Q2 decreases and reduces the collector-to-emitter current flowing to the base of transistor Q1. This action reduces the collector current of Q1 so that less current flows through resistor R1. When load current decreases, the regulator circuit increases the flow of current through resistor R1 and thus maintains a constant load voltage condition.

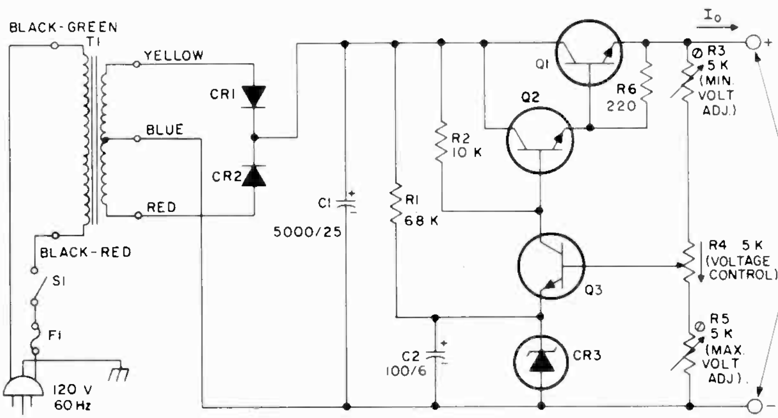
The voltage rating of the transformer secondary and the value of C1 in Fig. 49, and the voltage rating of the zener diode and the value of R1 in Fig. 53 depend on the required amounts of load voltage and load current. Table IV shows these ratings and values as a function of output voltage. R1 of Fig. 54 should be adjusted so that it passes a current of 1.15 amperes, an ammeter is required for this adjustment.

CIRCUIT NO. 4 – LIMITED-RANGE VARIABLE-VOLTAGE POWER SUPPLY

The limited-range variable-voltage power supply is a continuously adjustable supply capable of delivering from about 4.5 volts to 12 volts at a maximum current of 1 ampere.

The schematic diagram and parts list for the limited-range variable-voltage power supply are shown in Fig. 54. The voltage-regulating circuit in this supply uses a transistor Q3 in conjunction with a zener diode. The base of Q3 is connected to the voltage-control resistor R4, which, along with trimmer controls R3 and R5, is in parallel with the load. Therefore, any change in load or output voltage affects the voltage at the base of transistor Q3. If the output voltage tends to increase, the base of Q3 becomes more positive and more collector current flows. The increased collector current makes the base of Q2 less positive and reduces the collector-to-emitter current supplied to the base of transistor Q1. Reduced base current in Q1 results in an increased collector-to-emitter voltage drop in Q1; this voltage drop maintains load voltage at the desired level. The opposite effect occurs when the load voltage tends to decrease.

Resistors R3 and R5 are used to set the upper and lower voltage limits of the supply; these values normally need be set only once. Screwdriver-adjust trimmer-type potentiometers are the best type for R3 and R5.



Parts List

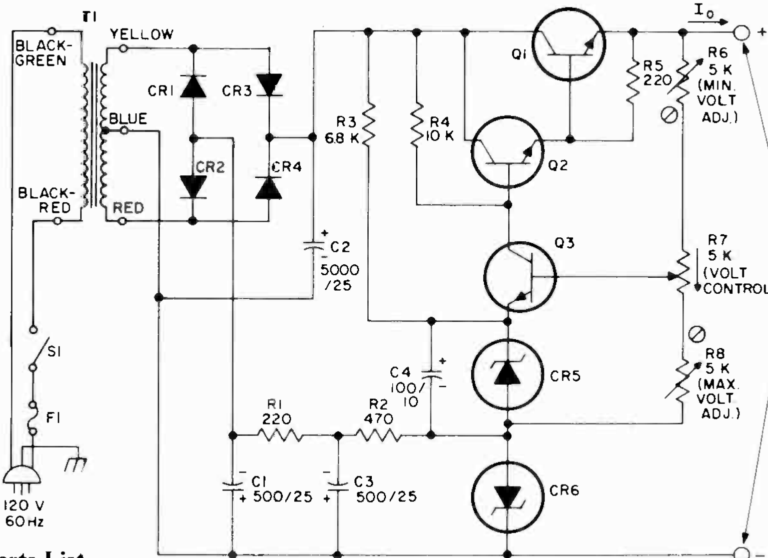
C1 = 5000 microfarads, 25 volts, electrolytic
C2 = 100 microfarads, 6 volts, electrolytic
CR1 CR2 = rectifier, RCA SK3030
CR3 = zener diode, 3.9 volts, 1/2 watt
F1 = fuse, 1 ampere, 120 volts, slow blow
Q1 = transistor, RCA SK3027
Q2 Q3 = transistor, RCA SK3020
R1 = 6800 ohms, 1/2 watt, 10%
R2 = 10,000 ohms, 1 watt, 10%
R3 R5 = trimmer potentiometer, 5000 ohms, 1/4 watt; Mallory MTC-1 or equivalent
R4 = potentiometer, 5000 ohms, linear taper
R6 = 220 ohms, 1/2 watt, 10%
S1 = toggle switch; 120 volts, 1 ampere, single-pole, single-throw
T1 = transformer, primary 117 volts, secondary 16 volts, 1.5 ampere, Stancor No. TP4 or equivalent

Fig. 54 – Schematic diagram and parts list for the limited-range variable-voltage power supply.

CIRCUIT NO. 5 – FULL-RANGE VARIABLE-VOLTAGE POWER SUPPLY

The full-range variable-voltage power supply is a continuously variable supply capable of delivering up to 12 volts at a maximum current of 1 ampere.

The schematic diagram and parts list for the full-range variable-voltage power supply are shown in Fig. 55. The regulator circuit in this supply receives full-wave rectified ac from a bridge rectifier rather than from a two-rectifier center-tapped transformer secondary as in the other power supplies described. This



Parts List

C1 C3 = 500 microfarads, 25 volts, electrolytic
C2 = 5000 microfarads, 25 volts, electrolytic
C4 = 100 microfarads, 10 volts, electrolytic
CR1 CR2 CR3 CR4 = rectifier, RCA SK3030
CR5 = zener diode, 6.8 volts, 1 watt
CR6 = zener diode, 12 volts, 1 watt
F1 = fuse, 1 ampere, 120 volts, slow blow
Q1 = transistor, RCA SK3027
Q2 Q3 = transistor, RCA SK3020
R1 R5 = 220 ohms, 1/2 watt, 10%
R2 = 470 ohms, 1/2 watt, 10%
R3 = 6800 ohms, 1/2 watt, 10%
R4 = 10,000 ohms, 1/2 watt, 10%
R6 R8 = trimmer potentiometer, 5000 ohms, Mallory MTC-1 or equivalent
R7 = potentiometer, 5000 ohms, linear taper
S1 = toggle switch, 120 volts, 1 ampere, single-pole, single-throw
T1 = transformer, primary 117 volts, secondary 16 volts, 1.5 ampere, Stancor No. TP-4 or equivalent

Fig. 55 – Schematic diagram and parts list for the full-range variable-voltage power supply.

arrangement provides the regulator with a high input voltage. This supply also differs from the others described in that it contains an additional zener diode, CR6, connected in opposition to zener diode CR1. The transistors in the regulator circuit operate in the same manner as those in the other supplies, but handle twice as much voltage. This voltage does not appear across the load, however, because of CR6. The voltage across CR6 is that across the center taps of the transformer and rectifiers CR1 and CR2. The load voltage is equal to the regulator voltage minus the voltage across zener diode CR6. When the two voltages are equal, the load voltage is zero. If the regular-circuit voltage falls below 12 volts, the base-emitter junction of transistor Q3 becomes reverse-biased and the transistor turns off. As a result, Q2 and Q1 also turn off and prevent the load voltage from reversing polarity (becoming negative).

Power-Supply Operation

The power supplies described are self-regulating after the desired output conditions are set through the use of an ammeter and voltmeter. In some applications, it may be desirable to have the ammeter and voltmeter connected as an integral part of the power supply so that output conditions can be monitored.

Construction

For best performance, the supplies should be well ventilated. Transistor Q1 should be mounted on a heat sink if its maximum power dissipation (determined by multiplying collector current by collector-to-emitter voltage) is expected to exceed 6 watts. Heat sinks are discussed in the section on **Mechanical Considerations**. Maximum power dissipation occurs when the supply is set for minimum output voltage at an output current of 1 ampere.

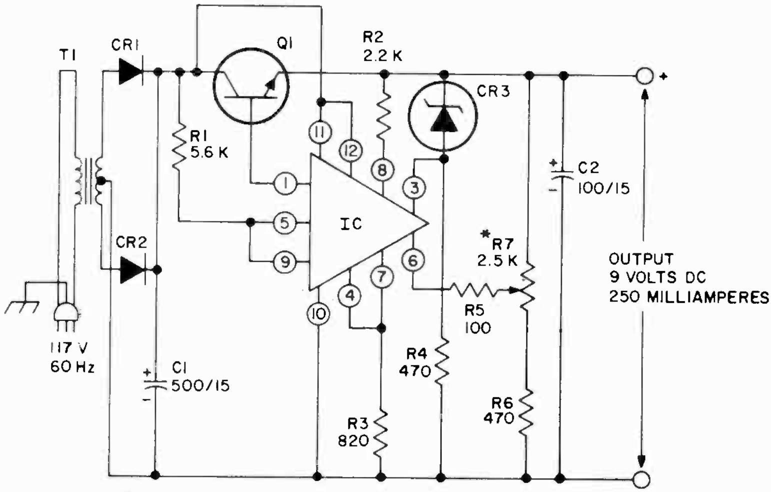
All power supply transformers should have a dc resistance of at least 1 ohm. If the transformer used has a dc resistance of less than 1 ohm, a 1-ohm, 2-watt resistor should be inserted in series with the secondary. If a center-tapped supply is used, the resistance should be placed in series with the center tap. No special precautions are required if the transformers specified in the parts list are used.

CIRCUIT NO. 6 – IC 9-VOLT REGULATED POWER SUPPLY

The 9-volt regulated power supply is useful as a transistor-radio battery eliminator and as a power source for experimenter projects and for test-bench applications, such as the servicing of portable transistorized equipment. It can deliver a dc output of 9 volts with a voltage regulation of less than 3 per cent at a maximum current of 250 milliamperes. (This circuit is available in kit form as RCA Project Kit KC-4004.)

Circuit Operation

The schematic diagram and parts list for the power supply are shown in Fig. 56; the schematic diagram for the KD2114 IC is shown in Fig. 57. In the following discussion Q1 is the transistor shown in Fig. 56 as part of the circuit external to the IC; Q2,



*ADJUST R7 FOR 9 VOLTS DC OUTPUT

Parts List

C1 = 500 microfarads, 15 volts, electrolytic
C2 = 100 microfarads, 15 volts, electrolytic
CR1 CR2 = diode, type 1N3193
CR3 = zener diode, 6 volts
IC = integrated circuit, RCA KD2114 (Available in KD2117 Variety Pack)
Q1 = transistor, RCA KD2118 (Available in KD2118 Five Pack)
R1 = 5600 ohms, 1/2 watt, 10%
R2 = 2200 ohms, 1/2 watt, 10%
R3 = 820 ohms, 1/2 watt, 10%
R4 R6 = 470 ohms, 1/2 watt, 10%
R5 = 100 ohms, 1/2 watt, 10%
R7 = potentiometer, 2500 ohms, 1/4 watt (Trim-Pot)
T1 = power transformer; Stancor TP-3 or equivalent

Fig. 56 – Schematic diagram and parts list for the IC 9-volt regulated power supply.

Q3, Q4, and Q5 are within the IC as shown in Fig. 57. The transistors in the IC are formed on a common substrate and are isolated from it by an integral diode which is part of the IC but which is not shown in the IC schematic diagram as it functions only as an isolation device for the IC circuit and not as a part of the external circuit in which the IC is applied.

The output voltage of the power supply is kept constant by an automatic variation of the voltage drop

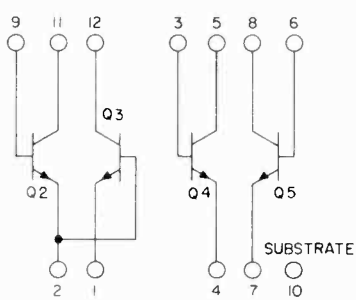


Fig. 57 – Schematic diagram for the KD2114 IC.

across Q1. The automatic variation operates as follows: when the output voltage tends to change, as the result of a load change or an input voltage change, the bias on Q4 changes by the same amount because the drop across the zener diode is constant. The output of Q4 is applied to the input of the Darlington combination consisting of Q2 and Q3, and to Q1. The output of the high-gain Darlington drives the base of Q1 and causes it to change its impedance and, therefore, to regulate the output voltage; i.e. to maintain it at some preset value. Small changes in the output voltage are made by adjusting potentiometer R7 which controls the bias on Q5. A change in the base bias of Q5 changes the operating point of Q4 and thus the output voltage by the process just described. Table V shows the voltages that should exist at the terminals of the IC if the circuit is operating properly.

Adjustments

When the circuit has been completely assembled, a dc voltmeter should be connected across the output terminals and R7 adjusted for an output of 9 volts.

Construction

A printed-circuit-board template for the 9-volt regulated power supply is shown at the back of this Manual; a combined component placement diagram and photograph of a completed board is shown in Fig. 58.

Table V

Voltages at IC Terminals in 9-Volt Regulated Power Supply

Terminal	Voltage (Volts)
1	9.6
3	3.1
4	2.4
5	10.8
6	3.1
7	2.4
8	6.2
9	10.8
11	20
12	20

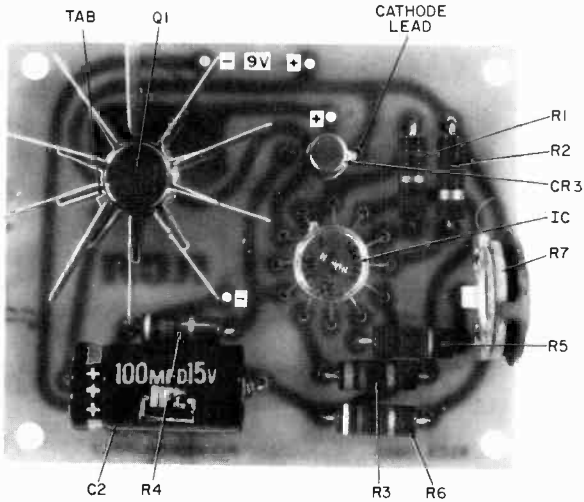


Fig. 58 – Completed circuit board showing component placement for the 9-volt regulated power supply.

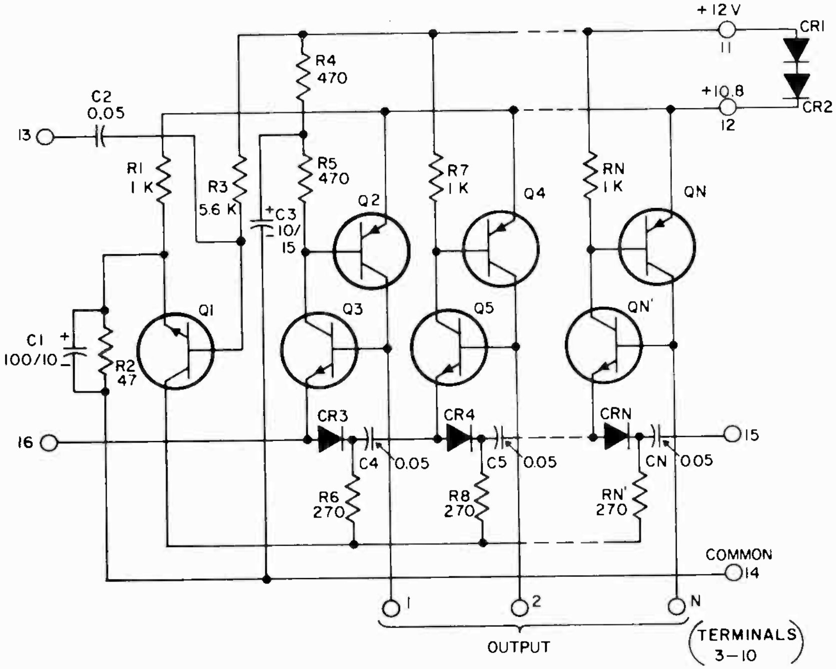
CIRCUIT NO. 7 – SHIFT REGISTER

In a shift register, the successive outputs from the various stages are delayed (or shifted) from those of the preceding stages by a controlled time interval (i.e., the duration between input trigger pulses). These outputs can be used to operate lamps (as shown in Circuits No. 57 and No. 58) or can be coupled through OR gates to establish a timing sequence for various operations of other equipment. If terminal 15 of the circuit (Fig. 59) is connected to terminal 16, the register becomes regenerative and can be used as a ring counter. (In the component placement diagram of Fig. 60, CN connects terminals 15 and 16.) In a ring counter, each stage follows in sequence as if placed around a circle or ring. Each pulse input to the ring advances the counter one stage; when the last stage is reached, the next pulse activates the first stage. The cycle repeats until input pulses are stopped. The shift register may incorporate as many stages as desired.

Circuit Operation

The schematic diagram and parts list for a 10-stage shift register are shown in Fig. 59. The 10.8-volt dc supply voltage is obtained from two diodes connected in series as shown in Fig. 59. With these voltages applied, switching transistor Q1 is immediately turned on by the positive voltage applied to its base through R3. One of the register stages must be triggered simultaneously to provide a complete path for the current through the switching transistor.

Each register stage is basically a two-transistor regenerative switch that employs an n-p-n and a p-n-p transistor. If either of the transistors in a register stage starts to conduct,



Parts List

C1 = 100 microfarads, 10 volts, electrolytic
C2 C4 C5 CN = 0.05 microfarad, 25 volts or greater
C3 = 10 microfarads, 15 volts, electrolytic
CR1 CR2 = rectifier, RCA SK3030
CR3 CR4 CRN = diode, RCA 1N270
Q1 Q3 Q5 QN′ = transistor, RCA KD2124 (Available in KD2124 Five Pack)
Q2 Q4 QN = transistor, RCA KD2123 (Available in KD2123 Five Pack)
R1 R7 RN = 1000 ohms, 1/2 watt, 10%
R2 = 47 ohms, 1/2 watt, 10%
R3 = 5600 ohms, 1/2 watt, 10%
R4 R5 = 470 ohms, 1/2 watt, 10%
R6 R8 RN′ = 270 ohms, 1/2 watt, 10%

Fig. 59 – Schematic diagram and parts list for a 10-stage shift register.

both of them are quickly driven into saturation by the regenerative action of that stage.

When power is applied to the shift-register circuit, capacitor C3 starts to charge. The charging action provides Q2 with a base current and turns it on. Q2 then turns Q3 on. The stage composed of Q2 and Q3 is then in conduction and provides an output at terminal 1. Q3 conducts through Q1. The voltage across R6 charges C4 through CR2 and R8. The circuit remains in this state until an input trigger pulse is applied.

To shift the register to the next stage, a negative pulse of 2 volts or more is applied to the base of Q1 through C2. This pulse turns off Q1 momentarily, interrupts the emitter circuit of Q3, and turns that stage off. When Q1 is off, all stages are nonconducting. When Q1 returns to its conducting state, the first stage does not turn on because C3 is fully charged; however, the charge on C4 places a forward bias on the emitter of Q5 and it turns on. Q4 is then turned on and produces an output. When Q4 is in conduction, C5 charges and ensures that the third stage will trigger with the next input pulse. In this way, the operation of the register is shifted from one stage to the next each time a negative trigger pulse is applied. By interrupting the power and allowing C3 to discharge, the register can be reset so that operation starts with the first stage.

It is important that the load connected to the outputs (1, 2, N) be 1000 ohms or less. The load current should not exceed 200 milliamperes. It is also important to note that excessive ripple in the supply voltage or negative input pulses that are too large can cause the shift register to misfire or act erratically.

Construction

The printed circuit template for a 10-stage shift register is shown at the back of this Manual; a photograph of the completed circuit board and a component placement diagram are shown in Figs. 60 and 61, respectively.

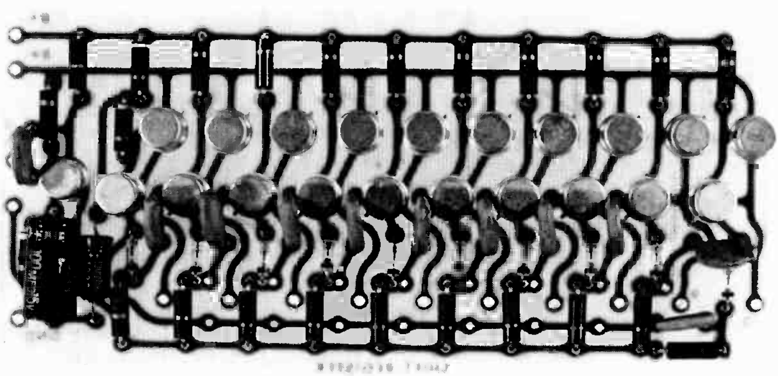


Fig. 60 – Completed circuit board for the 10-stage shift register.

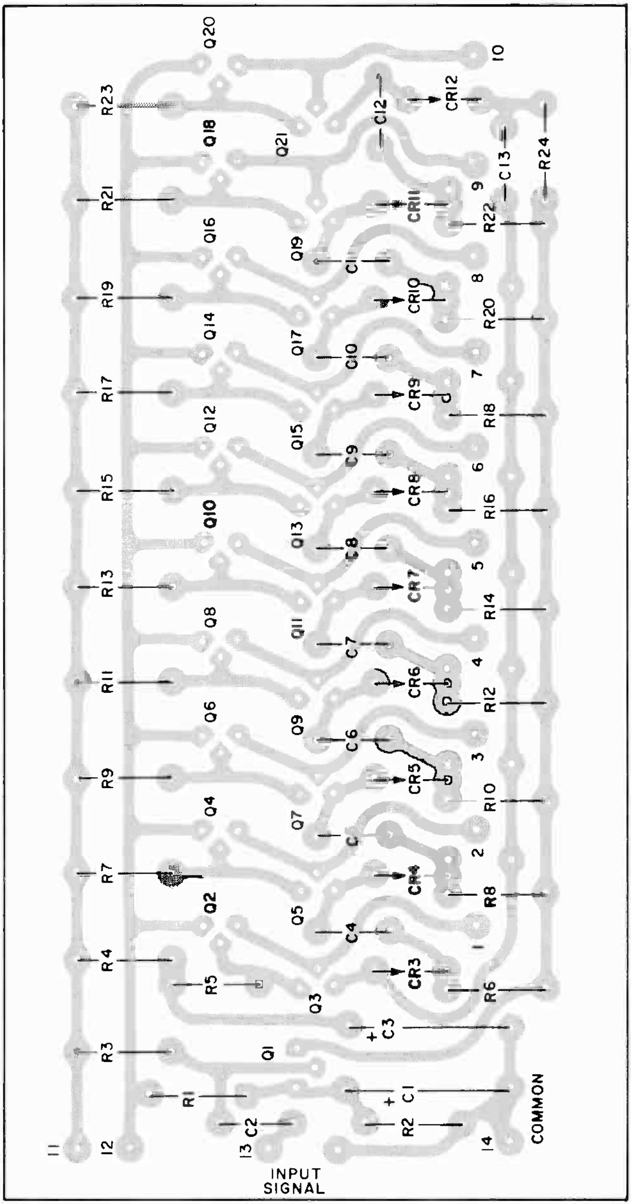


Fig. 61 – Component placement diagram for the 10-stage shift register.

CIRCUIT NO. 8 – COUNTING CIRCUITS

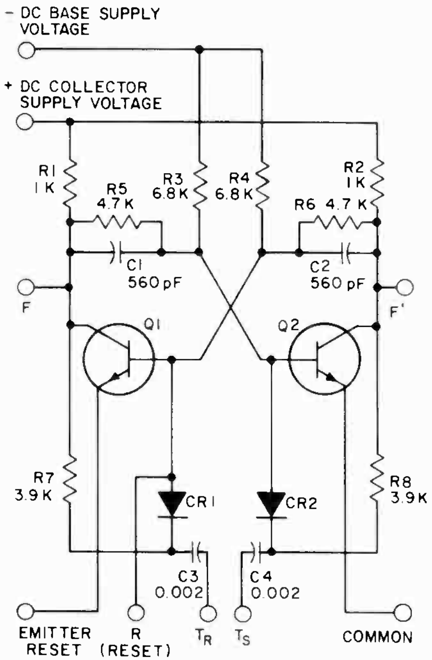
The counting circuits described in this Manual are used in the electronic clocks and can be used in conjunction with the display circuits in other counting applications. The counting circuits can accommodate input signals at any frequency up to 150 kHz with the components shown.

Circuit Operation

Events to be counted are presented to a counting circuit in the form of pulses, one pulse for each event. These "event" pulses are the negative pulses that change the state of the flip-flop (FF) as described under flip-flop circuit operation in the chapter concerning **General Circuit Considerations**. A circuit that produces one output pulse for every two input pulses is called a "divide-by-two" circuit; a circuit that produces one output pulse for every five input pulses is called a "divide-by-five" circuit. A "count-by" circuit is a "divide-by" circuit that produces output signals in a definite order. All count-by circuits are divide-by circuits, but not all divide-by circuits are true count-by circuits. In this Manual, with the exception of the divide-by-fifteen circuit in the twelve-hour clock, Circuit No. 13, all divide-by circuits are also count-by circuits and produce a true BCD or Binary Coded Decimal output. The binary codes for decimal numbers are given in ones and zeroes; for example, a decimal number of 7 is represented in binary code by 0111. These codes are described further below and are shown in the tables that accompany each of the counting circuits. A knowledge of the binary number system is not required to understand, build, or operate any of the circuits in this Manual; other sources should be consulted for information on number systems.

The counting circuits in this Manual consist of a series of FF's whose schematics are identical with that described under FF circuit operation in the chapter concerning **General Circuit Considerations**. The schematic diagram and parts list for the flip-flop used for all counting circuits is shown in Fig. 62. In the counting circuits shown in the following pages, each FF is shown as a rectangle with only signal input and output terminals marked.

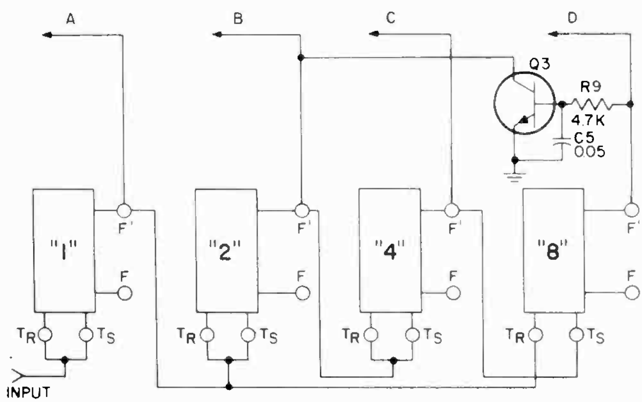
An understanding of counting circuits in general can best be gained by examining a typical one, the count-by-ten, sometimes referred to as a decade, in Fig. 63 and Table VI. Although the count can begin anywhere in a counting cycle, depending on the state of the FF's, for this explanation it is assumed that the count begins at zero; i.e., with each FF set at zero, F′ low or at 0. This zero set can be accomplished through the R or emitter reset terminals shown in Fig. 30 (**General Circuit Considerations**). The emitter reset is a manual reset, usually performed by means of a push-button switch that opens the emitter circuit momentarily. The R reset is used to electronically reset a FF to the zero state and requires the circuitry shown in Fig. 64. The effect of the use of either type of reset on the FF is described under the FF circuit description; the application of these reset functions is described as necessary in connection with the Manual circuits with which they are



Parts List

C1 C2 = 560 picofarads, 25 volts or greater
C3 C4 = 0.002 microfarad, 25 volts or greater
CR1 CR2 = diode, RCA 1N270
Q1 Q2 = transistor, RCA KD2118 (Available in KD2118 Five Pack)
R1 R2 = 1000 ohms, 1/2 watt, 10%
R3 R4 = 6800 ohms, 1/2 watt, 10%
R5 R6 = 4700 ohms, 1/2 watt, 10%
R7 R8 = 3900 ohms, 1/2 watt, 10%

Fig. 62 – Schematic diagram and parts list for the flip-flop used in the counting circuits.



Parts List

C5 = 0.05 microfarad, 25 volts or greater
Q3 = transistor, RCA KD2118 (In KD2118 Five Pack)
R9 = 4700 ohms, 1/2 watt, 10%
Fig. 62 contains parts list for FF's "1", "2", "4", "8".

Fig. 63 – Count-by-ten or decade counting circuit.

Table VI.
Truth Table for Count-by-Ten Circuit

Count	(Counting Circuit of Fig. 63) "8"	"4"	"2"	"1"	(Second Counting Circuit) "1"
0	0	0	0	0	
1	0	0	0	1	
2	0	0	1	0	
3	0	0	1	1	
4	0	1	0	0	
5	0	1	0	1	
6	0	1	1	0	
7	0	1	1	1	
8	1	0	0	0	
9	1	0	0	1	
10	0	0	0	0	1

used. Neither the R nor the emitter reset terminal is shown on the basic counting circuit diagram to aid clarity.

Table VI shows the condition of the FF's in the circuit for each true count. The numbers shown at the left in the table under the column headed "Count" represent the true count represented by the state of the counting circuit FF's; for this reason the table is called a "truth" table. The numbers in the columns marked "8", "4", "2", "1", represent the condition at F′ for each of the matching FF rectangles in Fig. 63.

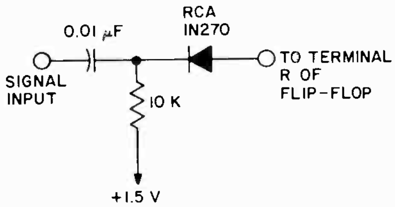


Fig. 64 — Circuit required to set a flip-flop to zero through the R reset terminal.

For example, at the true count of zero, the condition, as shown in the table, of all F′ terminals of all FF's in the count-by-ten circuit is 0 or low. The FF's in the counting circuit are numbered as they are for a special reason; the number represents the true count at which the FF represented by that number will put out a signal. Through proper circuitry, this signal can be used to light a lamp representing the number. For example, when the count is 1 a lamp connected to the "1" FF will light; when the count is 2, a lamp connected to the "2" FF will light, and so on for the true counts of "4" and "8". This statement can be checked in the truth table, Table VI. Each time a 1 appears in the table, it means that the condition of the F′ terminal of the FF represented is 1 or high and that a lamp connected to that FF will light. True counts not represented by FF's are obtained by adding the counts of the "8", "4", "2", and "1" FF's. For example, a true count of 7 is obtained by adding the true counts of FF's "4", "2", and "1": 4 plus 2 plus 1 equals 7. The true count for 7 and other counts can be checked in Table VI.

In the following description it is assumed that the column headings in Table VI are represented by lamps connected to the corresponding FF's in Fig. 63. Lamps can be connected to the FF's in an actual circuit by means of the indicator-lamp circuit described in the chapter concerning **General Circuit Considerations**. When the first negative pulse is applied at the point in Fig. 63 marked "input", it changes the state of the FF in the "1" rectangle; i.e., it changes the condition at F′ from 0 to 1 and the lamp associated with the "1" FF lights. On the next negative input pulse, the FF "1" changes state back to 0 and in so doing applies a negative pulse to FF "2" that changes its state from 0 to 1, as illustrated in the table for a count of 2. The lamp representing the count of 1 then goes out and the lamp connected to FF "2" (representing a count of 2) goes on.

The third input to FF "1" changes its state from 0 to 1 and lights the lamp at "1". Because the change of state from 0 to 1 does not produce the negative pulse required to change the state of FF "2", it remains in its existing state and its lamp stays on. (In Table VI the lamps corresponding to the "1" count plus the "2" count equal an actual or true 3 count.) With succeeding negative pulses, the FF's change state down the line, as indicated in Table VI. For example, in the 7 count lamps in position "4", "2", and "1" are lit for a count of 4 plus 2 plus 1 which equals 7.

The inputs to the "8" FF are connected in a split toggle arrangement so that once a transistor in that FF is turned off it will remain off and hold its opposing transistor on until the on transistor receives a negative pulse that turns it off. On the eighth input pulse the F′ of the "8" FF is set high by the pulse input to T_S of FF "8" from FF "4" as the latter changes state from high to low. The negative pulses fed to T_R of the "8" FF through its connection with the "1" FF do not keep changing the state of the "8" FF because, as should be remembered, the transistor connected to T_R is initially off and therefore is not affected by negative pulses. When the count goes from 7 to 8 and the lamp corresponding to FF "8" lights as all other lamps go off, a signal fed through R1 to Q1 clamps the "2" FF in the low position. When the next negative pulse is applied to the counting circuit for the 9 count, the "1" FF goes high. On the next negative pulse, the tenth one, the "1" FF goes from high to low and feeds trigger pulses to the "2" FF and to T_R of FF "8". FF "8" goes low but FF "2" cannot change state because of the clamping action of transistor Q1; therefore it stays low. All FF's are now in the low state, the condition of the zero count, and the counter is ready to begin another cycle.

Capacitor C1 in the feedback circuit delays the turnoff of the clamping transistor Q1 so that FF "2" will not become unclamped while the tenth pulse, which initiates the unclamping action, is still present at the input terminals of the FF's. The count-by-ten circuit goes to an actual count of 0, as shown in Table VI, after the count of 9. One way to view the return to the 0 count as the ten count is to read the 0 count as the ten count after the first time that the circuit has completed the sequence 0 through 9. Another way to understand the ten count is to realize that if a second counting circuit were connected to that of Fig. 63 at F′ of FF "8", the tenth pulse that sets FF "8" low would initiate a carry pulse which would set FF "1" of the next counting circuit to 1 so that the true count represented by the two counting circuits would actually be 10. This explanation is illustrated in Table VI. It should be noted that all of the counting circuits can be connected in a variety of ways to obtain almost any count desired.

Two count-by-ten circuits connected in cascade constitute a count-by-100 circuit or, from another point of view, a two-digit counter from 0 through 99. A count-by-ten circuit and a count-by-six circuit in cascade constitute a count-by-sixty circuit.

The circuit just described, the count-by-ten circuit, is, along with the single FF or count-by-two circuit, the most common counting circuit. Other counting circuits covering counts of 3 through 16 are described on the following pages. All of the counting circuits operate similarly; as a result, the descriptions of the split toggle and clamping arrangements given for the count-by-ten circuit can be applied to all circuits.

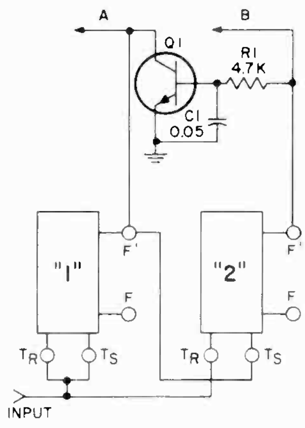
All of the counting circuits in this Manual always count sequentially through all the numbers up to what might be called their maximum count. For example, the count-by-six circuit, when connected to the proper display, will count through each number from 0 through 5.

Count-by-Two

The count-by-two circuit consists of one flip-flop. The schematic diagram and parts list for the flip-flop are shown in Fig. 62.

Count-by-Three

A count-by-three circuit is constructed of two FF's, as shown in Fig. 65. The first stage uses a toggle and the second a split toggle. A clamp transistor is connected to FF "1" and activated by FF "2". The



Parts List

C1 = 0.05 microfarad, 25 volts or greater

Q1 = transistor, RCA KD2118 (Available in KD2118 Five Pack)

R1 = 4700 ohms, 1/2 watt, 10%

Fig. 62 contains parts list for FF's "1", "2".

Fig. 65 – Schematic diagram and parts list for a count-by-three circuit.

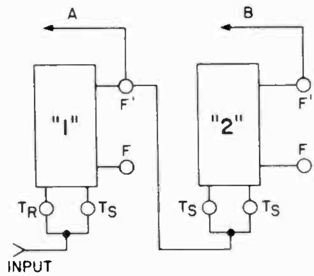
first input pulse or count causes FF "1" to go high. On the second pulse, FF "1" goes low and FF "2" high. The third pulse causes FF "2" to go low again, but FF "1" remains low because of the clamp. The action of the flip-flops can be followed in Table VII.

Table VII.
Truth Table for Count-by-Three Circuit

Count	"2"	"1"
0	0	0
1	0	1
2	1	0

Count-by-Four

The count-by-four circuit consists of two single FF's cascaded as shown in Fig. 66.

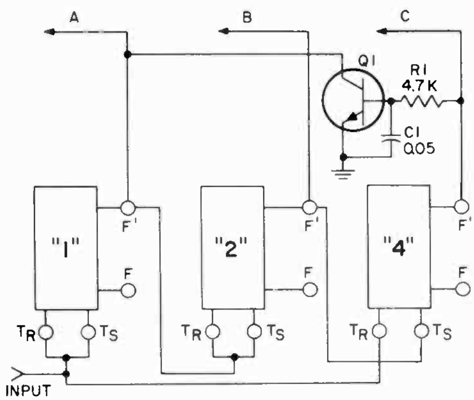


Parts List
Fig. 62 contains parts list for FF's "1", "2".

Fig. 66 – Schematic diagram and parts list for a count-by-four circuit.

Count-by-Five

A count-by-five circuit is constructed of three FF's as shown in Fig. 67. FF's "1" and "2" are toggled in the normal manner but FF



Parts List
C1 = 0.05 microfarad, 25 volts or greater
Q1 = transistor, RCA KD2118 (In KD2118 Five Pack)
R1 = 4700 ohms, 1/2 watt, 10%
Fig. 62 contains parts list for FF's "1", "2", "4", "8".

Fig. 67 – Schematic diagram and parts list for a count-by-five circuit.

"4" is connected in a split toggle configuration. A clamp transistor is connected to FF "1" and activated by FF "4". The truth table for this circuit is Table VIII.

Table VIII.
Truth Table for Count-by-Five Circuit

Count	"4"	"2"	"1"
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0

Count-by-Six

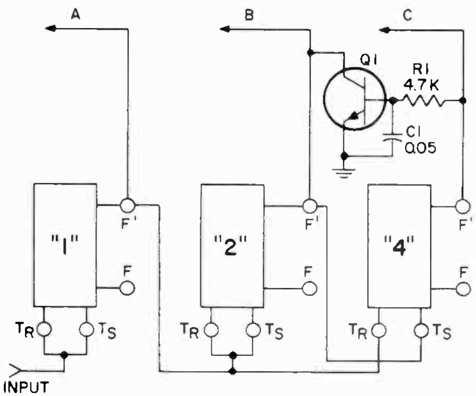
The count-by-six circuit is essentially the same as the count-by-five circuit except that the connection for the split-toggle and clamping functions is made to FF "2" rather than FF "1" as shown in Fig. 68. A truth table for the count-by-six circuit is shown in Table IX.

Table IX.
Truth Table for Count-by-Six Circuit

Count	"4"	"2"	"1"
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1

Count-by-Seven

A count-by-seven circuit, shown in Fig. 69, requires three flip-flops and interconnections that are more



Parts List

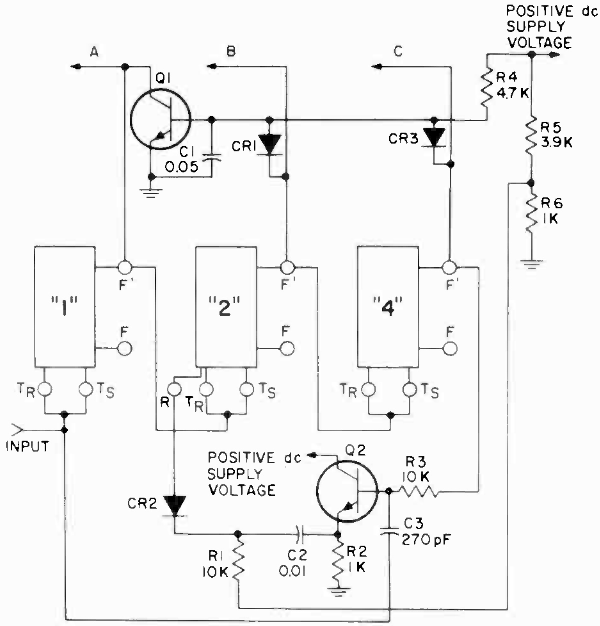
C1 = 0.05 microfarad, 25 volts or greater

Q1 = transistor, RCA KD2118 (Available in KD2118 Five Pack)

R1 = 4700 ohms, 1/2 watt, 10%

Fig. 62 contains parts list for FF's "1", "2", "4".

Fig. 68 – Schematic diagram and parts list for a count-by-six circuit.



Parts List

C1 = 0.05 microfarad, 25 volts or greater

C2 = 0.01 microfarad, 25 volts or greater

C3 = 270 picofarads, 25 volts or greater

CR1 CR2 CR3 = diode, RCA 1N270

Q1 Q2 = transistor, RCA KD2118 (Available in KD2118 Five Pack)

R1 R3 = 10,000 ohms, 1/2 watt, 10%

R2 R6 = 1000 ohms, 1/2 watt, 10%

R4 = 4700 ohms, 1/2 watt, 10%

R5 = 3900 ohms, 1/2 watt, 10%

Fig. 62 contains parts list for FF's '1", "2", "4".

Fig. 69 – Schematic diagram and parts list for a count-by-seven circuit.

complex than those used in the previous counting circuits. The clamp transistor connected to FF "1" is activated through a diode-transistor NAND gate from FF's "2" and "4"; the operation of the NAND gate is described under **General Circuit Considerations**. Another gate is connected to the reset terminal of FF "2" through a diode. This diode is reverse-biased by about one volt to keep it from conducting on small signals. When FF's "4" and "2" are high, the clamp transistor stops FF "1" from going high. As soon as FF "4" goes high, pulses appear at the reset terminals of FF "2". These pulses have no effect during the 5th pulse because FF "2" is already low. It also has no effect on the 6th pulse because the width of the 6th pulse is much narrower than the toggle pulse arriving from FF "1". On the seventh pulse, FF "2" is returned to low causing FF "4" to return to low. The action of the circuit can be followed in the truth table for the count-by-seven circuit shown in Table X.

Table X.
Truth Table for Count-by-Seven Circuit

Count	"4"	"2"	"1"
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1
6	1	1	0

Count-by-Eight

The count-by-eight circuit consists of three flip-flops cascaded as shown in Fig. 70.

Count-by-Nine

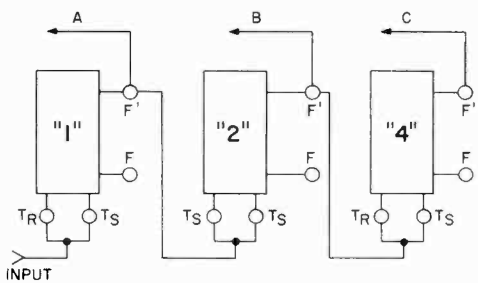
In the count-by-nine circuit shown in Fig. 71, a clamp transistor clamps FF "1" in the low position after the eighth pulse; FF "8" is returned to low on the 9th pulse. The truth table for a count-by-nine circuit is shown in Table XI.

Count-by-Ten

The count-by-ten circuit has already been described.

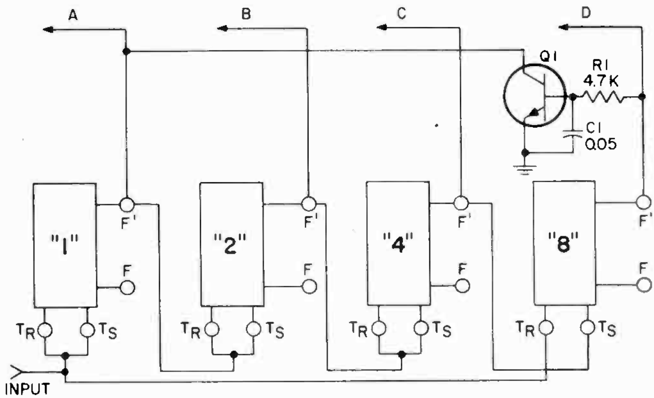
Count-by-Eleven

Although a count-by-eleven is seldom needed, the circuit of Fig. 72 shows how it can be accomplished. FF's "1" and "4" are clamped by a diode transistor NAND gate from FF "2" and FF "8". FF "2" is gated into the low state through a transistor gate by a signal from FF "8" and the input signal. The truth table for the count-by-eleven circuit is shown in Table XII.



Parts List
Fig. 62 contains parts list for FF's "1", "2", "4".

Fig. 70 — Schematic diagram and parts list for a count-by-eight circuit.



Parts List

C1 = 0.05 microfarad, 25 volts or greater

Q1 = transistor, RCA KD2118 (In KD2118 Five Pack)

R1 = 4700 ohms, 1/2 watt, 10%

Fig. 62 contains parts list for FF's "1", "2", "4", "8".

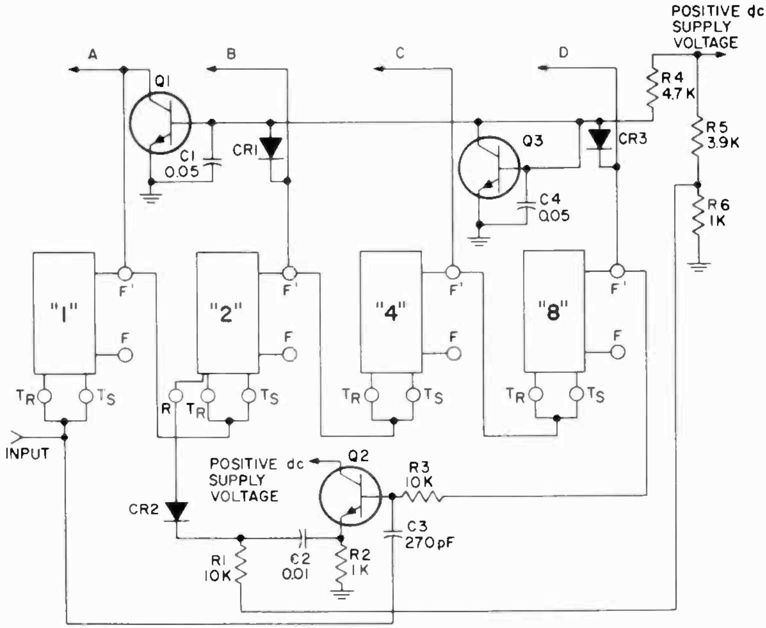
Fig. 71 – Schematic diagram and parts list for a count-by-nine circuit.

Table XI.
Truth Table for Count-by-Nine Circuit

Count	"8"	"4"	"2"	"1"
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0

Table XII.
Truth Table for Count-by-Eleven Circuit

Count	"8"	"4"	"2"	"1"
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	0	0	0	0
9	1	0	0	1
10	1	0	1	0



Parts List

C1 C4 = 0.05 microfarad, 25 volts or greater

C2 = 0.01 microfarad, 25 volts or greater

C3 = 270 picofarads, 25 volts or greater

CR1 CR2 CR3 = diode, RCA 1N270

Q1 Q2 Q3 = transistor, RCA KD2118 (Available in KD2118 Five Pack)

R1 R3 = 10,000 ohms, 1/2 watt, 10%

R2 R6 = 1000 ohms, 1/2 watt, 10%

R4 = 4700 ohms, 1/2 watt, 10%

R5 = 3900 ohms, 1/2 watt, 10%

Fig. 62 contains parts list for FF's "1", "2", "4", "8".

Fig. 72 – Schematic diagram and parts list for a count-by-eleven circuit.

Count-by-Twelve

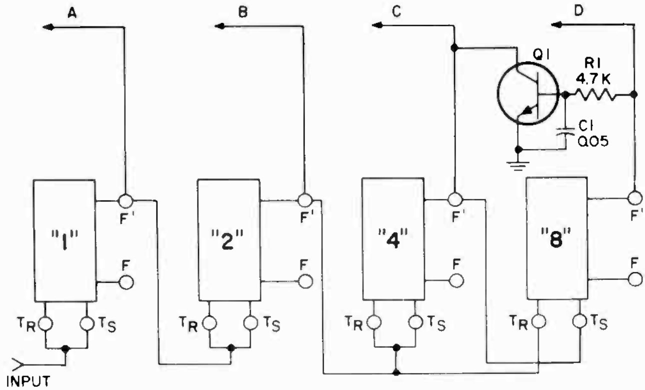
In the count-by-twelve configuration, Fig. 73, FF "4" is clamped low after the eighth pulse. The truth table for the circuit is given in Table XIII.

Count-by-Thirteen

This circuit is another that is not used very often but is given here for reference. In the circuit, Fig. 74, FF "1" is clamped low after the twelfth pulse through a diode-transistor NAND gate, and FF "4" is reset through a transistor gate by signals from FF "8" and the input pulse. A truth table is given in Table XIV.

Count-by-Fourteen

The count-by-fourteen circuit shown in Fig. 75 is another seldom used circuit that is given here mainly



Parts List

C1 = 0.05 microfarad, 25 volts or greater
Q1 = transistor, RCA KD2118 (Available in KD2118 Five Pack)
R1 = 4700 ohms, 1/2 watt, 10%
Fig. 62 contains parts list for FF's "1", "2", "4", "8".

Fig. 73 – Schematic diagram and parts list for a count-by-twelve circuit.

Table XIII.
Truth Table for Count-by-Twelve Circuit

Count	"8"	"4"	"2"	"1"
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
10	1	0	1	0
11	1	0	1	1

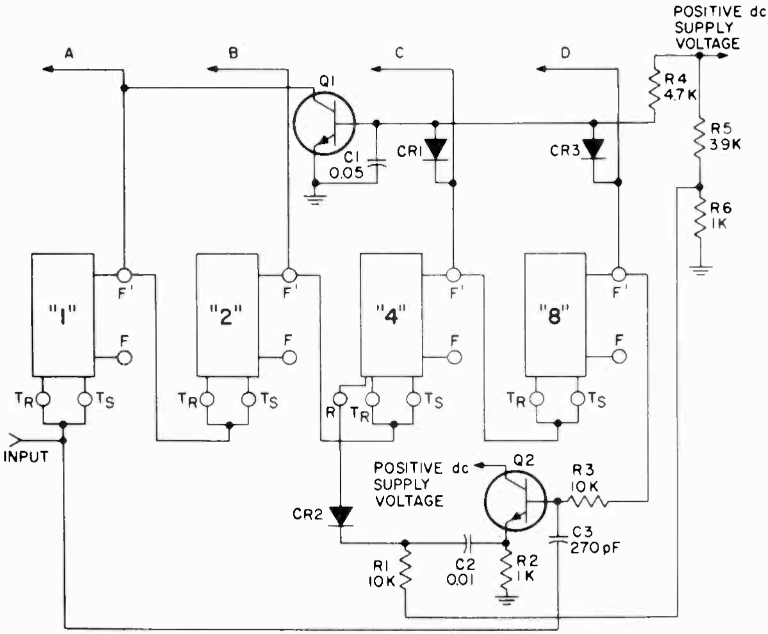
for reference. FF "2" is clamped low after the 13th count and FF "4" is reset on the 14th count. The truth table is given in Table XV.

Table XIV.
Truth Table for Count-by-Thirteen Circuit

Count	"8"	"4"	"2"	"1"
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
10	1	0	1	0
11	1	0	1	1
12	1	1	0	0

Count-by-Fifteen

The count-by-fifteen circuit, Fig. 76, is often used when the input pulses are to be provided from a



Parts List

C1 = 0.05 microfarad, 25 volts or greater

C2 = 0.01 microfarad, 25 volts or greater

C3 = 270 picofarads, 25 volts or greater

CR1 CR2 CR3 = diode, RCA 1N270

Q1 Q2 = transistor, RCA KD2118 (Available in KD2118 Five Pack)

R1 R3 = 10,000 ohms, 1/2 watt, 10%

R2 R6 = 1000 ohms, 1/2 watt, 10%

R4 = 4700 ohms, 1/2 watt, 10%

R5 = 3900 ohms, 1/2 watt, 10%

Fig. 74 – Schematic diagram and parts list for a count-by-thirteen circuit.

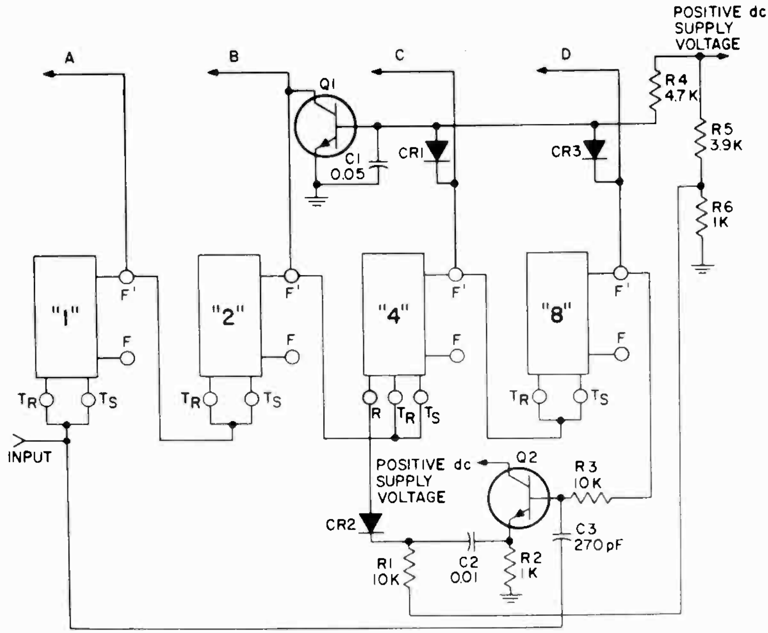
60-Hz power line; the circuit, when combined with a count-by-four circuit, furnishes an accurate 1-pulse-per-second output. FF "1" is held low after the 14th pulse by a clamp imposed through a diode-transistor NAND gate from all other FF stages. FF "2" is reset on the 15th pulse through a transistor gate by the input signal and a signal from FF "8". A truth table for the count-by-fifteen circuit is given in Table XVI.

Count-by-Sixteen

The count-by-sixteen circuit consists of four flip-flops cascaded as shown in Fig. 77.

Construction

Table XVII assigns terminal numbers to the external connections of the flip-flop and count-by-ten circuits. These flip-flop and counting



Parts List

C1 = 0.05 microfarad, 25 volts or greater

C2 = 0.01 microfarad, 25 volts or greater

C3 = 270 picofarads, 25 volts or greater

CR1 CR2 CR3 = diode, RCA 1N270

Q1 Q2 = transistor, RCA KD2118 (Available in KD2118 Five Pack)

R1 R3 = 10,000 ohms, 1/2 watt, 10%

R2 R6 = 1000 ohms, 1/2 watt, 10%

R4 = 4700 ohms, 1/2 watt, 10%

R5 = 3900 ohms, 1/2 watt, 10%

Fig. 62 contains parts list for FF's "1", "2", "4", "8".

Fig. 75 – Schematic diagram and parts list for a count-by-fourteen circuit.

circuit terminal numbers are used in the remainder of the circuits in this Manual. For example, the table shows that the function that terminal 8 serves in the counting circuits of the twenty-four-hour clock, Circuit No. 12, is the emitter reset.

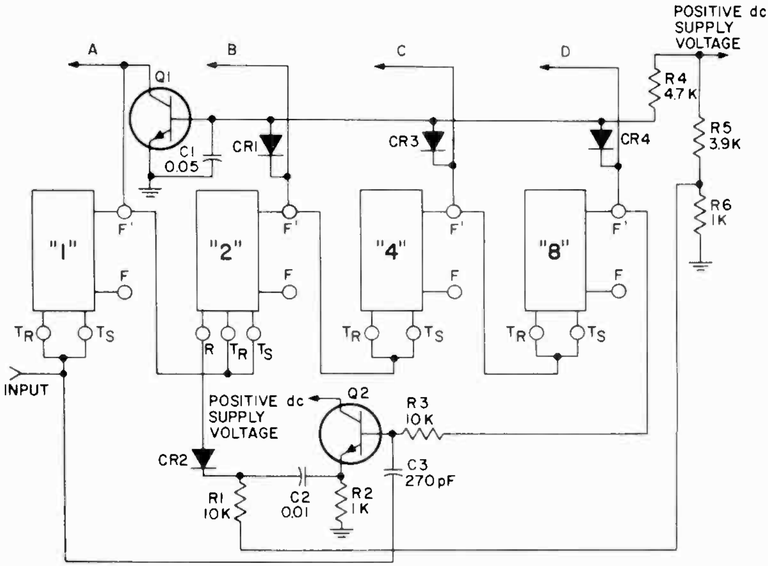
The printed-circuit-board template given for the counting circuits at the back of this Manual and the component placement diagram shown in Fig. 78 are for the count-by-ten circuit. All other counting circuits including the single flip-flop can be assembled on this board by using only a portion of the board and/or by adding the components required in the circuits shown in Figs. 65 through 77 and Fig. 62. A photograph of a completed count-by-ten circuit is shown in Fig. 79. Fig. 80 shows a plug-in arrangement that can be used to mount counting-circuit boards.

Table XV.
Truth Table for Count-by-Fourteen Circuit

Count	"8"	"4"	"2"	"1"
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
10	1	0	1	0
11	1	0	1	1
12	1	1	0	0
13	1	1	0	1

Table XVI.
Truth Table for Count-by-Fifteen Circuit

Count	"8"	"4"	"2"	"1"
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
10	1	0	1	0
11	1	0	1	1
12	1	1	0	0
13	1	1	0	1
14	1	1	1	0



Parts List

C1 = 0.05 microfarad, 25 volts or greater

C2 = 0.01 microfarad, 25 volts or greater

C3 = 270 picofarads, 25 volts or greater

CR1 through CR4 = diode, RCA 1N270

Q1 Q2 = transistor, RCA KD2118 (Available in KD2118 Five Pack)

R1 R3 = 10,000 ohms, 1/2 watt, 10%

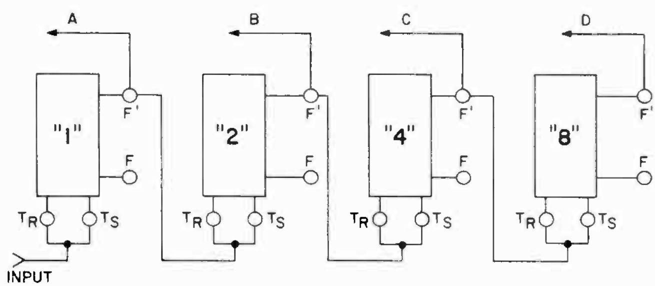
R2 R6 = 1000 ohms, 1/2 watt, 10%

R4 = 4700 ohms, 1/2 watt, 10%

R5 = 3900 ohms, 1/2 watt, 10%

Fig. 62 contains parts list for FF's "1", "2", "4", "8".

Fig. 76 – Schematic diagram and parts list for a count-by-fifteen circuit.



Parts List

Fig. 62 contains parts list for FF's "1", "2", "4", "8".

Fig. 77 – Schematic diagram and parts list for a count-by-sixteen circuit.

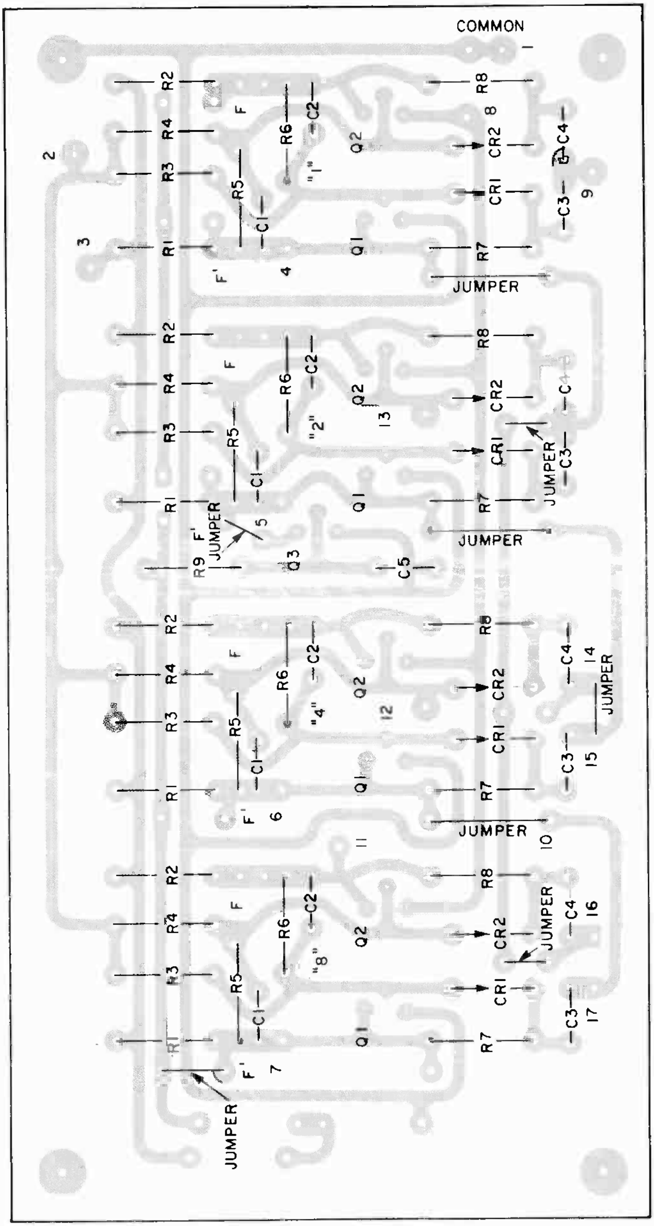


Fig. 78 – Component placement diagram for the count-by-ten or decade counting circuit.

Table XVII.
Flip-Flop and Counting Circuit Terminal Numbers

Terminal	Function
1	Common
2	-1.2 V
3	+6 to +12 volts depending on FF circuit components
4	FF "1", F′ (A)
5	FF "2", F′ (B)
6	FF "4", F′ (C)
7	FF "8", F′ (D)
8	Emitter Reset
9	FF "1", Input
10	FF "8", T_S
11	FF "8", F
12	FF "4", R
13	FF "2", R
14	FF "4", T_R
15	FF "4", T_S
16	FF "8", T_R
17	FF "8", T_S

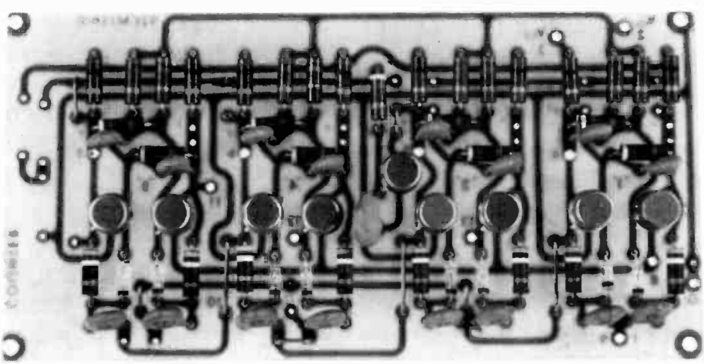


Fig. 79 – Completed circuit board for the count-by-ten or decade counting circuit.

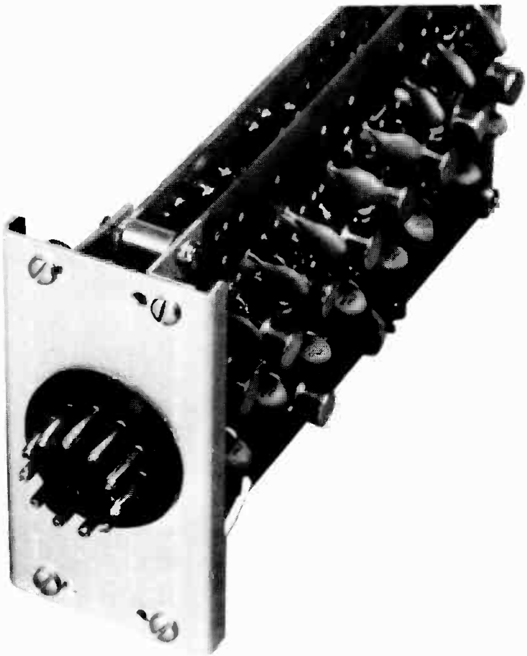


Fig. 80 – Suggested plug-in arrangement for mounting counting-circuit boards.

CIRCUIT NO. 9 – METER DISPLAY

The meter display, shown in Fig. 81, is used with a count-by-ten circuit or decade to display the true numbers 0 through 9; if more digits are required, any number of meter displays can be connected in cascade. The power supply shown with this circuit description can power up to ten displays; i.e., ten digits.

Circuit Operation

The schematic diagram and parts list for the meter display circuit is shown in Fig. 82. The meter display operates by totaling the emitter currents of all Q1's in the decade-counting-circuit flip-flops. If the circuit is to operate properly, the emitter current of transistor Q1 in each of flip-flops "1", "2", "4", and "8", must be in the ratio of 1 to 2 to 4 to 8, respectively; the trimming method described below under Adjustment assures the existence of this ratio. Fig. 83 shows the schematic diagram and parts list for a power supply capable of driving up to ten meter displays.

Adjustment

The random selection of flip-flop resistors with 10-per-cent tolerance usually produces good enough registration so that the current ratios described above are correct and no trimming is necessary; however, if maximum accuracy of calibration is desired, the following procedure

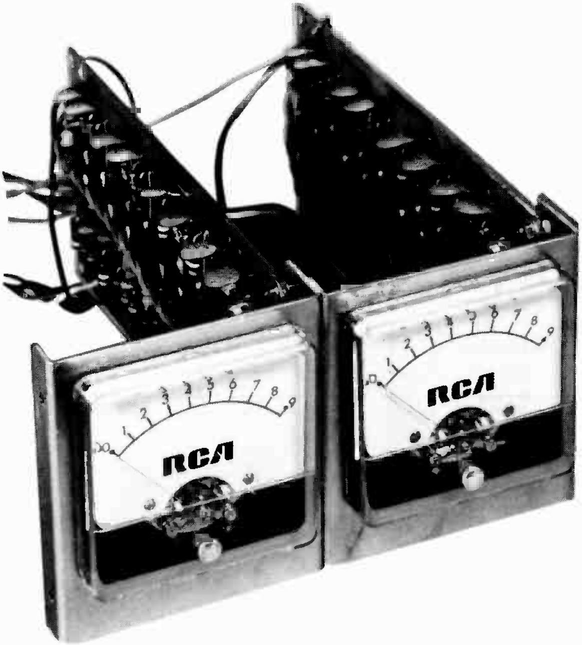
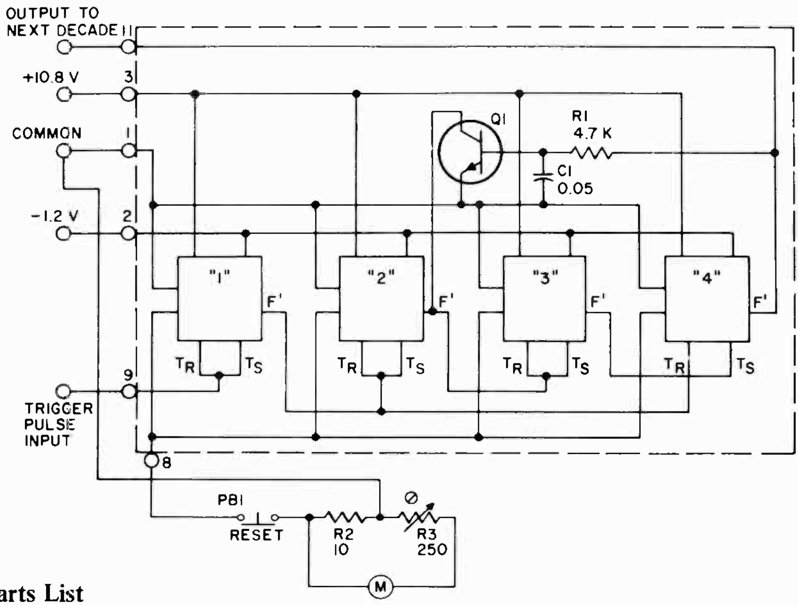


Fig. 81 – Two-digit meter display.

should be followed. An arrangement of a 50,000-ohm potentiometer in series with a 4,700-ohm resistor with alligator clips connected to each free end of the series arrangement is first constructed; a volt-ohm meter or a Voltohmyst* is needed to measure the resistance of the combination once the proper amount of trim resistance has been found.

Power is applied to the decade with the input disconnected and the counter reset to zero by operating the reset switch PB1 so that the meter reads 0. The counter is next set to a count of 1 by momentarily shorting the case of Q1 of FF "1" to ground (the case is connected internally to the collector). The meter should now read a value near 1. Potentiometer R3 is adjusted until the meter reads exactly 1. The count is then advanced by shorting the case of Q2 of FF "1" to ground; the meter should read 2. If the meter reads high, R2 should be replaced by another resistor whose value is 10-percent higher than that shown in the parts list for R2. If the meter reads low, the condition can be corrected by adding a resistor in parallel with R2 of FF "2". The value of the parallel resistor is found by connecting the potentiometer/resistor arrangement in parallel with R2 by means of the alligator clips and

*Trademark Reg. U.S. Pat. Off.



Parts List

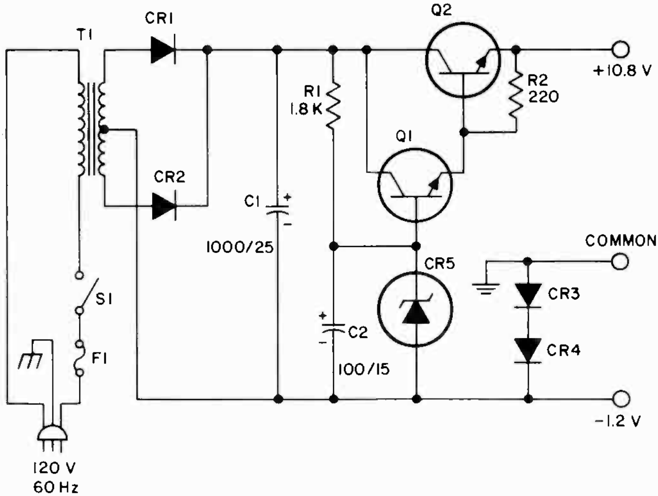
C1 = 0.05 microfarad, 25 volts, ceramic (Part of count-by-ten circuit, Fig. 63)
M = meter, 0 to 1 milliampere
PB1 = push-button switch, normally closed
Q1 = transistor, RCA KD2118 (Available in KD2118 Five Pack, part of count-by-ten circuit, Fig. 63)
R1 = 4700 ohms, 1/2 watt, 10% (Part of count-by-ten circuit, Fig. 63)
R2 = 10 ohms, 1/2 watt, 10%
R3 = potentiometer, 250 ohms, 1/4 watt, 10%

Parts List for FF's "1", "2", "4", "8"; see Fig. 62 for schematic diagram.

	"1"	"2"	"4"	"8"
C1 C2	180 picofarads	330 picofarads	560 picofarads	0.001 microfarad
C3 C4	560 picofarads	0.001 microfarad	0.002 microfarad	0.005 microfarad
CR1 CR2	1N270	1N270	1N270	1N270
Q1 Q2*	KD2118	KD2118	KD2118	KD2118
R1 R2	3900 ohms	2000 ohms	1000 ohms	470 ohms
R3 R4	27000 ohms	15000 ohms	6800 ohms	3900 ohms
R5 R6	22000 ohms	10000 ohms	4700 ohms	2700 ohms
R7 R8	15000 ohms	6800 ohms	3900 ohms	2200 ohms

*Available in KD2118 Five Pack.

Fig. 82 – Schematic diagram and parts list for the meter display.



Parts List

C1 = 1000 microfarads, 25 volts, electrolytic
C2 = 100 microfarads, 15 volts, electrolytic
CR1 through CR4 = rectifier, RCA SK3030
CR5 = zener diode, 13 volts
F1 = fuse, 1 ampere, 125 volts, slow-blow
Q1 = transistor, RCA SK3020
Q2 = transistor, RCA SK3054
R1 = 1800 ohms, 1/2 watt, 10%
R2 = 220 ohms, 1/2 watt, 10%
S1 = toggle switch; single-pole, single-throw; 125 volts, 3 amperes
T1 = transformer; primary: 120 volts, 60 Hz; secondary: 25 volts center-tapped at 1 ampere; Stancor No. R6469 or equivalent.

Fig. 83 – Schematic diagram and parts list for a meter-display power supply capable of driving up to ten displays.

adjusting the potentiometer so that the meter reads exactly 2. The potentiometer/resistor is then removed and its value measured on the VOM. The 10-per-cent-tolerance resistor whose value is nearest that of the VOM reading is then permanently connected in parallel with R2.

The count is next advanced to 3 by again shorting the case of Q1 of FF "1" to ground; the meter should now read 3. By advancing the count to 4 and checking the meter reading, the accuracy of the 4 count can be checked. If the meter does not read close to 4, then the value of R2 in FF "4" must be corrected in the same way that R2 of FF "2" was corrected. The meter reading for the 8 count is next checked and corrected by correcting the value of R2 in FF "8" as needed.

The decade counter is now reset to zero by operating the reset switch and the counter tested for proper operation by running it through several counts. An input pulse for testing purposes can be induced by alternately shorting Q1 and Q2 of FF "1" to ground. If the counter is operating properly, the pulse input can be reconnected and normal operation begun.

Construction

The printed-circuit-board template for all counting circuits is shown at the back of this Manual; a component placement diagram and a photograph of a completed count-by-ten or decade circuit board are shown in the description of the counting circuits, Circuit No. 8. The meter faces shown in Fig. 81 were made by applying dry transfers to a standard blank meter face; a standard precalibrated meter scale of 0 through 10 can be used but the needle will return to 0 after the 9 count. Fig. 84 shows how the meter display can be assembled with both meter and circuit board mounted on a small piece of aluminum that can be joined with any number of similar assemblies.

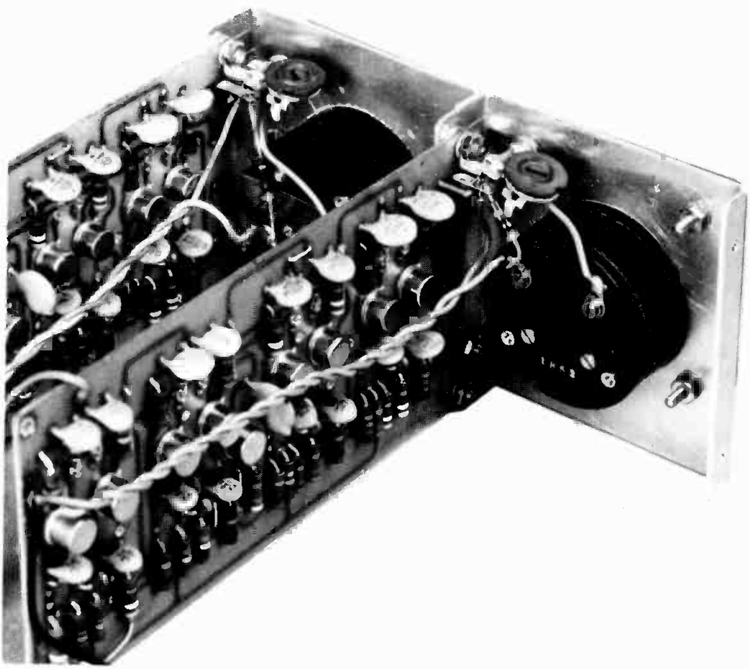


Fig. 84 – Suggested method of construction of two-digit meter display.

CIRCUIT NO. 10 – LARGE-SCALE LAMP DISPLAY

The large-scale lamp display, shown in Fig. 85 displaying the number 503, can be used to display the timing and scores of an athletic event. The numerals in the display measure 4 by 6 inches. One large-scale lamp display circuit is required for each number between 0 and 9.

Circuit Operation

The schematic diagram and parts list for the large-scale lamp display are shown in Fig. 86. Signals are

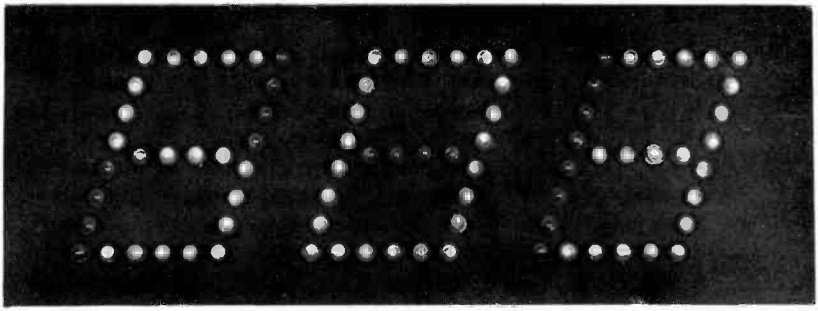
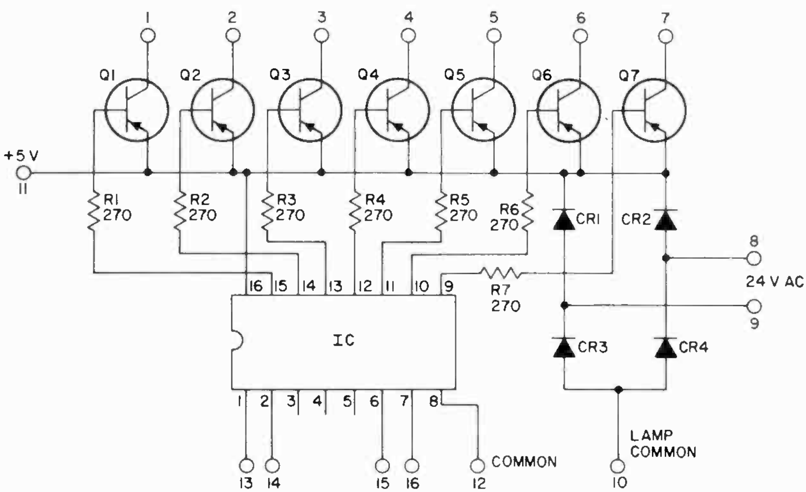


Fig. 85 – Face of the large-scale lamp display.



Parts List

CR1 through CR4 = rectifier, RCA SK3030

IC = integrated circuit, RCA decoder/driver CD2500E

Q1 through Q7 = transistor, RCA KD2120 (Available in KD2120 Five Pack)

R1 through R6 = 270 ohms, 1/2 watt, 10%

Fig. 86 – Schematic diagram and parts list for the large-scale lamp display.

input to the decoder/driver through terminals 13 through 16; the decoder/driver determines which transistors, Q1 through Q7, will be turned on and, thus, which of the seven elements of the numeral will be lit. The seven elements, composed of four pilot lamps each in this circuit (see Fig. 85), correspond to the elements in the numitron described in the numitron display, Circuit No. 11. Power for the lamps is obtained from the full-wave, rectified, unfiltered supply composed of rectifiers CR1 through CR4; decoder/driver power is derived from a 5-volt regulated power supply, such as one of those described in the front of this Manual.

If elapsed time is to be displayed, four large-scale-display circuits will be needed. The decoder/drivers and large numerals of this circuit will then replace the decoder/drivers and numitrons shown in the schematic diagram of the stop clock, Circuit No. 14, Fig. 109. If scores are to be displayed, the input signals to the decoder/drivers are produced by means of the rotary switches of the input unit shown in Fig. 87. One rotary switch is required for each numeral; note that the switches shown in Fig. 87 are set to display the number 503 as shown in Fig. 85. Fig. 88 shows the schematic diagram and parts list for the input unit.

Construction

The printed-circuit-board template for the large-scale lamp display is shown at the back of this Manual; a component placement diagram and a photograph of a completed circuit board are shown in Figs. 89 and 90, respectively. A detailed photograph showing the method of construction of numerals is shown in Fig. 91.

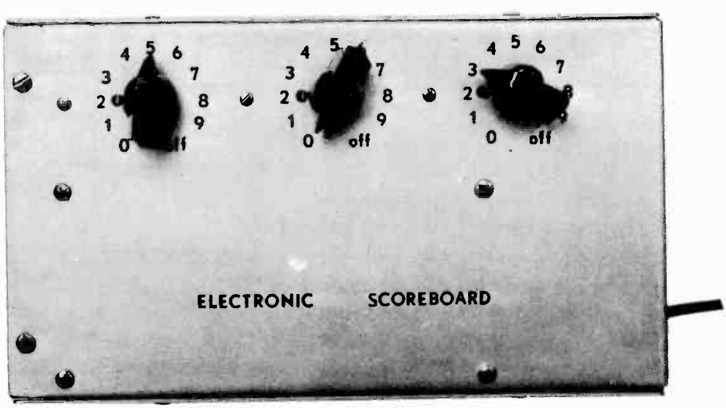


Fig. 87(a) – Face of unit used to provide input signals for the decoder/drivers.

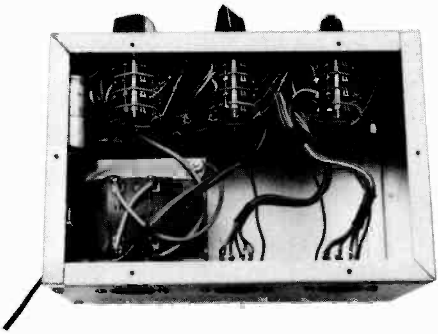
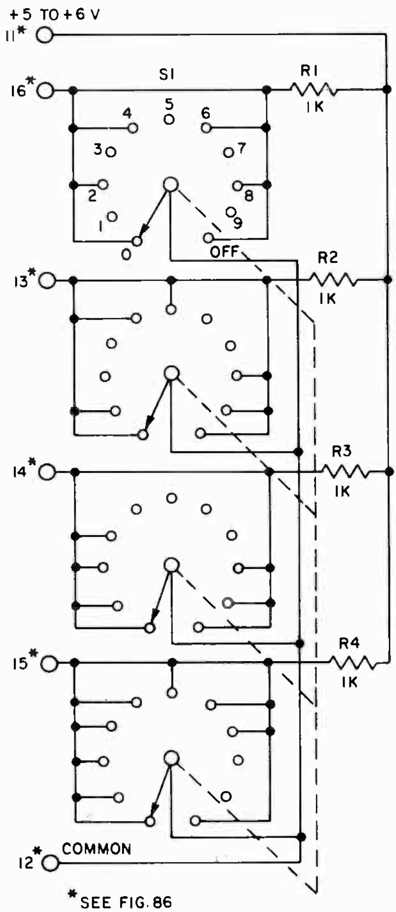


Fig. 87(b) – Interior of unit used to provide input signal for the decoder/drivers.



Parts List

R1 through R4 = 1000 ohms, 1/2 watt, 10%

S1 = rotary wafer switch; 4-pole 11-position, shorting type

Fig. 88 – Schematic diagram and parts list for the signal-input unit.

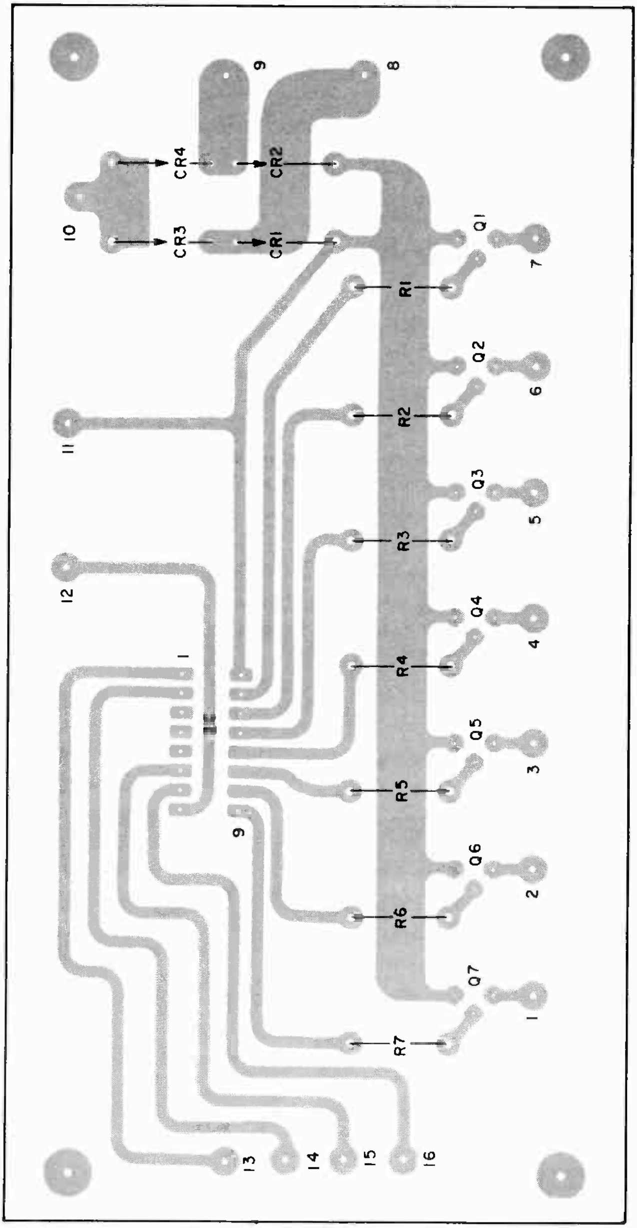


Fig. 89 – Component placement diagram for the large-scale lamp display.

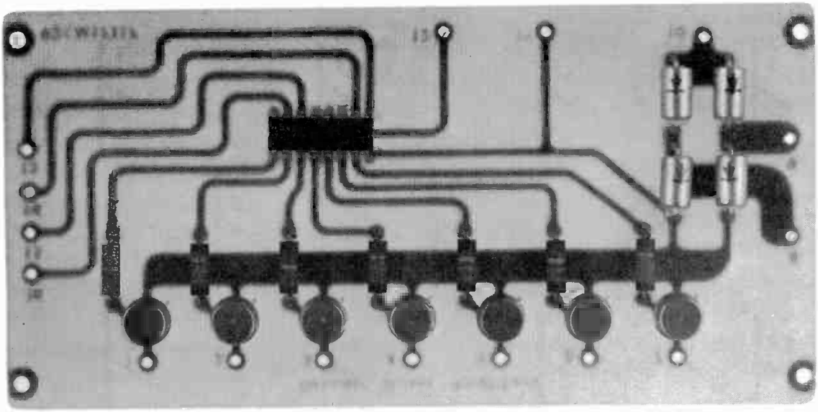


Fig. 90 — Completed circuit board for the large-scale lamp display.

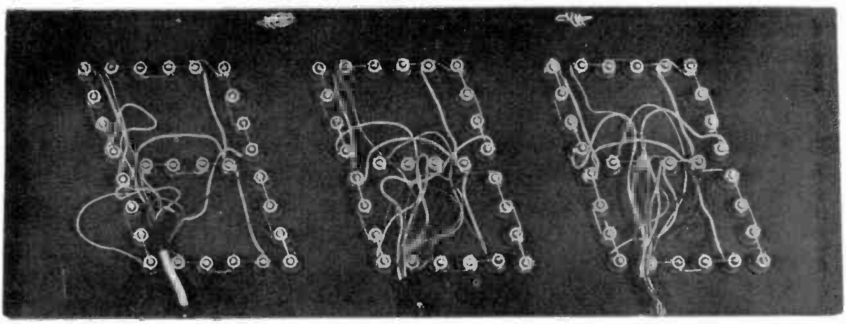


Fig. 91 — Suggested method of construction of the large-scale lamp display.

CIRCUIT NO. 11 – NUMITRON DISPLAY

The numitron display is a unique and professional-looking incandescent-type digital display that makes use of the recently developed RCA Numitron, shown displaying the number 8 in Fig. 92. Filaments within the tube light to form the numbers 0 through 9; the numbers shown can be made any desired color by placing an appropriate color filter in front of the tube. Numitrons are as rugged as any vacuum tube and require no special handling; they have a minimum life expectancy of 100,000 hours or more than eleven years. Unlike other tubes that display numbers, all of the numbers in a numitron appear at the front of the tube on a black surface and thus can be viewed clearly from a wide angle; the brightness of the number can be varied.

Fia. 92 – RCA Numitron displaying the number 8.

The Numitron

The RCA Numitron is a vacuum tube that contains seven wire filaments, called segments, mounted on a non-conductive plate. The seven segments are arranged as shown in Fig. 93. The number eight requires that all segments be lit; the number four is formed when segments 6, 7, 2, and 3 are lit; the number six makes use of segments 1, 6, 5, 4, 3, and 7; and so on. RCA decoder/drivers, manufactured to be compatible with the RCA Numitrons, are used to switch on the various elements in the numitron to cause it to display a number. The decoder/driver has four coded inputs and

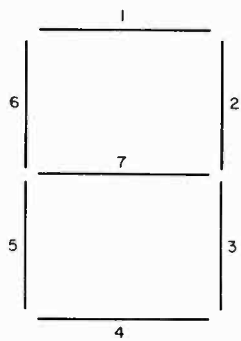


Fig. 93 – Identification of segments in the RCA Numitron.

seven outputs which can represent any decimal number from 0 through 9. A decoder/driver is shown mounted with a numitron in Fig. 94.

Circuit Operation

The schematic diagram for the interconnection of the numitron with the decoder/driver is shown in Fig. 95. The schematic diagram and

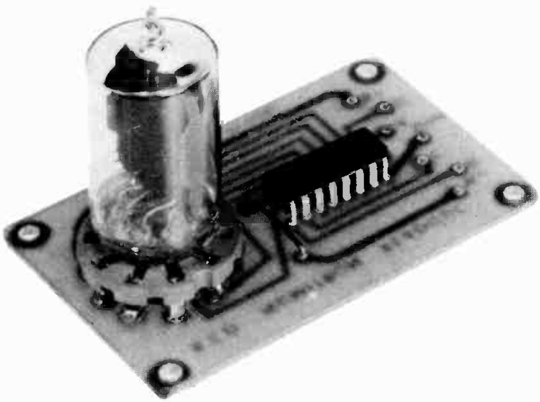


Fig. 94 – Numitron and decoder/driver mounted on a printed circuit board.

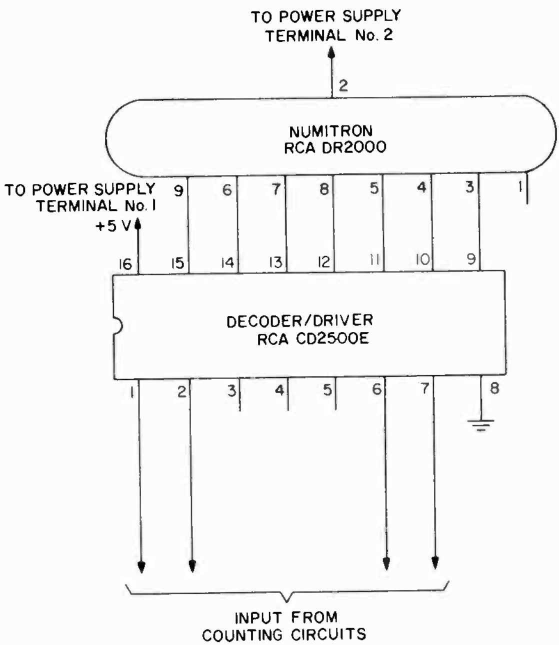
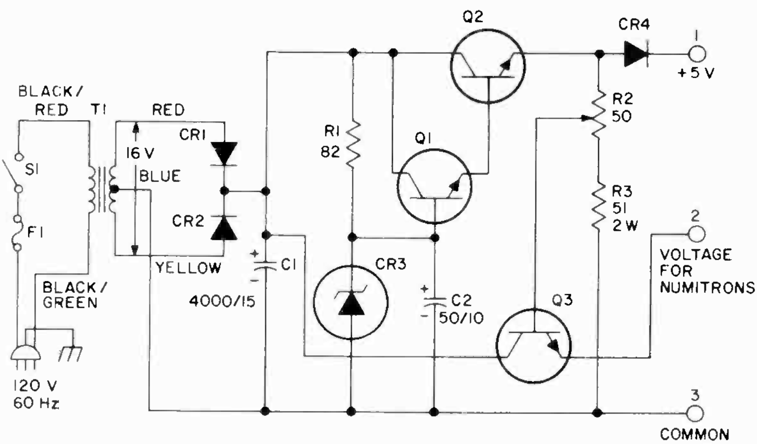


Fig. 95 – Interconnection of the decoder/driver and RCA Numitron.

parts list for the numitron display power supply is shown in Fig. 96. The power supply of Fig. 96 is designed to power up to six numitron displays; it has a fixed, 5-volt, regulated output used to power the decoder/drivers as well as an output variable from 2.5 to 5 volts that is used to power the numitrons. Potentiometer R2 varies the voltage to the numitrons, and, therefore, controls their brightness.

The 5-volt decoder/driver supply is well filtered, but the numitron supply is filtered only enough to allow the series control transistor Q3 to operate properly. The series control transistor provides a variable but regulated voltage that is used to power the numitron segments. The voltage supplied by the series control transistor varies with its base voltage. To assure that the output voltage to the numitrons is at least 5 volts, the base voltage of the series control transistor is designed to be approximately 5.5 volts or 0.5 volt higher than necessary. This voltage must be reduced to 5 volts to provide the dc supply voltage for the decoder/



Parts List

C1 = 4000 microfarads, 15 volts, electrolytic
C2 = 50 microfarads, 10 volts, electrolytic
CR1 CR2 CR4 = rectifier, RCA SK3030
CR3 = zener diode, 7.5 volts, 1 watt
F1 = fuse, 1.4 amperes, slow-blow
Q1 = transistor, RCA SK3020
Q2 = transistor, RCA SK3026
Q3 = transistor, RCA SK3027
R1 = 82 ohms, 1/2 watt, 10%
R2 = potentiometer, 50 ohms, 2 watts, linear taper
R3 = 51 ohms, 2 watts, 10%
S1 = toggle switch; single-pole, single-throw, 125 volts, 3 amperes
T1 = transformer, Stancor TP-4 or equivalent

Fig. 96 – Schematic diagram and parts list for the numitron-display power supply.

drivers; the reduction is accomplished by the forward drop in rectifier CR4.

Fig. 97, the component placement diagram for the numitron display, contains three terminals marked X, Y, and Z. If the display is to be operated from the power supply of Fig. 96, a jumper is connected between X and Z. If the display is to be operated from a fixed 5-volt dc supply with fixed numitron brightness, a jumper is connected between X and Y, 5 volts is applied to terminal 2, and terminal 1 is not used. The terminal numbers subscripted "D" in Fig. 97 are decoder/driver terminal numbers; those not subscripted match the power-supply terminal numbers shown in Fig. 96.

Construction

The printed-circuit-board template for the numitron display is shown at the back of this Manual; a component placement diagram for the display is shown in Fig. 97. The board has been designed so that the numitron can be mounted on it in a 9-pin noval printed-board socket, such as the Cinch Jones 9 PC-B1. The power supply was constructed in a standard 5- by 7- by 2-inch aluminum chassis as shown in Fig. 98; all power-supply components with the exception of the power transformer are mounted within the chassis as shown in Fig. 99. The numitron brightness control is accessible from the top of the power-supply unit.

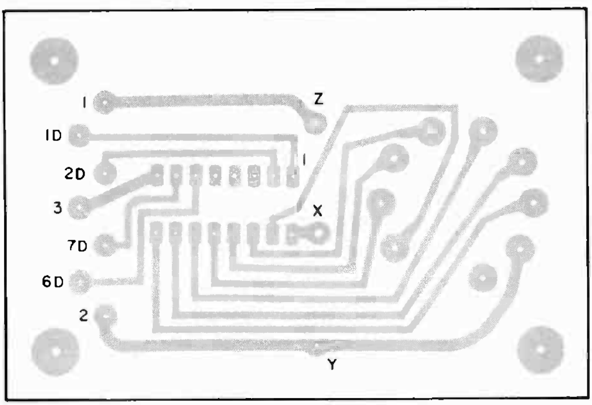


Fig. 97 – Component placement diagram for the numitron display.

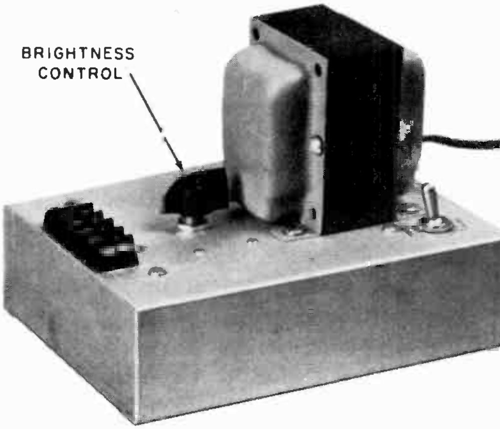


Fig. 98 – Suggested construction of the numitron-display power supply.

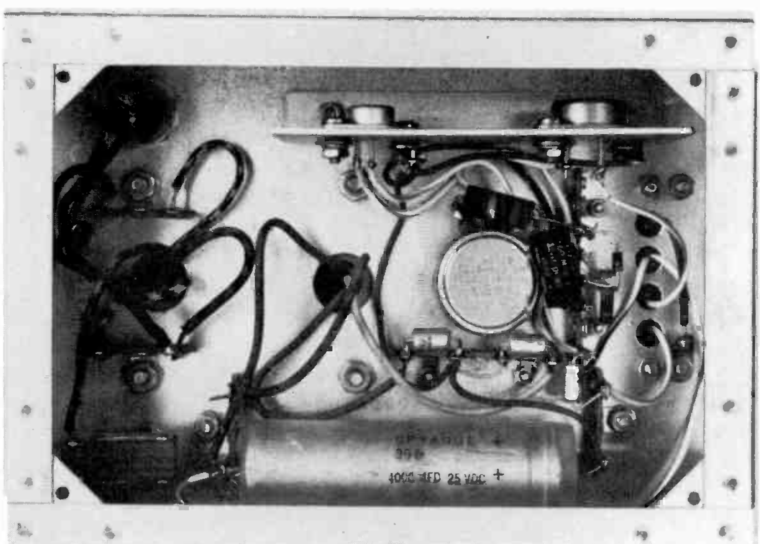


Fig. 99 – Interior of the suggested numitron-display power-supply chassis.

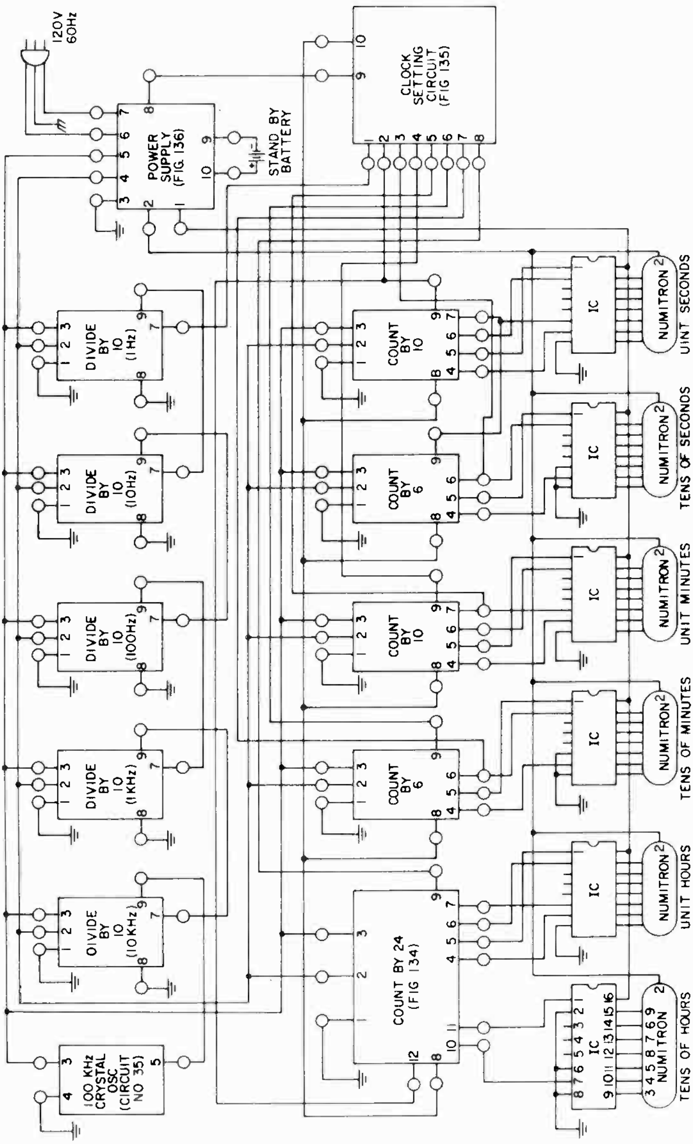
CIRCUIT NO. 12 – TWENTY-FOUR-HOUR CLOCK

The twenty-four-hour clock digitally displays hours, minutes, and seconds to an accuracy of ± 10 seconds or better per year by means of RCA Numitrons. A stand-by battery power source can be used with the clock so that accurate time will be kept in spite of power failures.

Circuit Operation

An interconnection diagram of the twenty-four-hour clock is shown in Fig. 100. The first circuit in the clock is a 100-kHz crystal oscillator; the schematic diagram and parts list for this circuit are shown in Fig. 212. The crystal used in the oscillator circuit determines the accuracy of the clock; a quality crystal is required to produce the accuracy of ± 10 seconds or better mentioned above. The output from the oscillator provides a signal for five cascaded decade-divider circuits which produce the one pulse per second needed by the five counting circuits shown below the divider circuits in Fig. 100. The output from the counting circuits corresponds to seconds, minutes, and hours counts. (The schematic diagrams and parts lists for the counting circuits are given in the description of counting circuits, Circuit No. 8.) The count-by-ten circuit at the right in Fig. 100 counts from 0 to 9 and indicates the unit seconds: 1 second, 2 seconds, etc. The next counter to the left, the count-by-six circuit, counts from 0 through 5 and indicates tens of seconds: 10 seconds, 20 seconds, etc. The next two counters count minutes in the same way. The last counter, the count-by-24 circuit, counts units and tens of hours; 0 hours to 24 hours. The schematic diagram and parts list for the hours counting circuit are shown in Fig. 101.

Fig. 101 shows that the 24-hour counter is made up of two counting circuits interconnected by a special feedback feature: the circuit at the top within the dashed lines, the unit hours counter, is a standard decade or count-by-ten circuit with a pulse reset circuit (CR1, C2, R1) attached to FF "4"; the lower circuit shown within dashed lines, the tens of hours counter, is a special two-flip-flop counter with a signal gate Q3 connected to T_R of the split-toggle of FF "Y". FF's "X" and "Y" are so called only to avoid the confusion which might result in the following discussion if there were two FF "1"'s and two FF "2"'s. The decade counter counts from 0 through 9 as a result of the one input pulse per hour applied to it from the divider circuits of Fig. 101. On the tenth hour the output pulse from FF "8" of the decade causes F′ of FF "X" to go high and display a 1 in the tens-of-hours position of the clock readout. The count then proceeds to the 20th hour when the pulse from FF "8" causes the tens-of-hours counter to display a 2 and turns on clamp transistor Q2. The next four hour-pulses input at terminal 9 advance the count to 23. On the 24th pulse FF "4" sets, or turns on, the signal gate Q3 and sets the pulse reset circuit connected to FF "Y". The first second-pulse input at terminal 12 after the clock reads 24 is passed through the signal gate Q3 to T_R of FF "Y" and causes FF "Y"



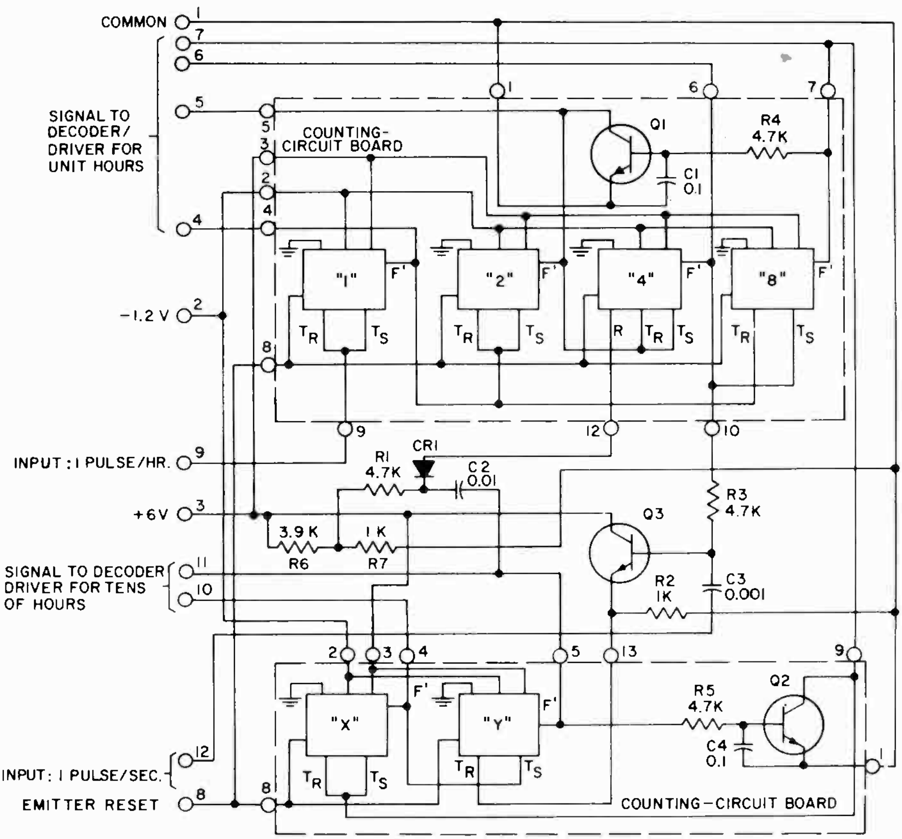
Parts List

IC = integrated circuit, RCA decoder/driver CD2500E

Numitron = RCA DR2000

Battery = see text

Fig. 100 – Interconnection diagram for the circuits of the twenty-four-hour clock.



Parts List

C1 C4 = 0.1 microfarad, 25 volts or greater (part of count-by-ten circuit)

C2 = 0.01 microfarad, 25 volts or greater

C3 = 0.001 microfarad, 25 volts or greater

CR1 = diode, RCA 1N270

Q1 Q2 Q3 = transistor, RCA KD2118 (Available in KD2118 Five Pack; Q1 and Q2 are part of count-by-ten circuit)

R1 R3 R4 R5 = 4700 ohms, 1/2 watt, 10% (R4 and R5 are part of count-by-ten circuit)

R2 R7 = 1000 ohms, 1/2 watt, 10%

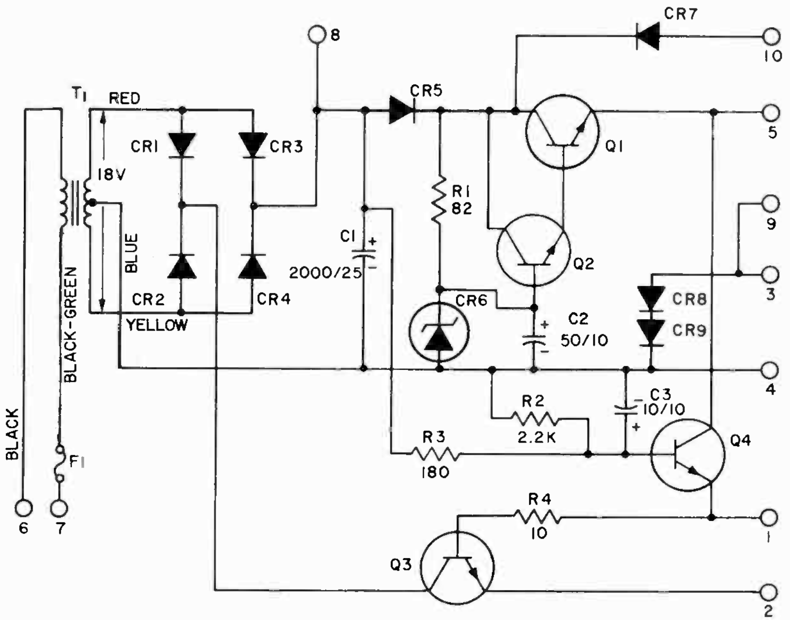
R6 = 3900 ohms, 1/2 watt, 10%

Fig. 62 contains parts list for FF's "1", "2", "4", "8", "X" and "Y".

Fig. 101 – Schematic diagram and parts list for the count-by-twenty-four circuit.

to go low. Consequently, FF "4" is set low through the pulse-reset circuit, but FF "8" remains low because of the continued clamping action of Q2. At this point the clock display reads 00 hours, 00 minutes, and 01 second.

The schematic diagram and parts list for the clock power supply are shown in Fig. 102. A stand-by battery power connection may be made to the power supply at terminals 9 and 10 as shown in Fig. 100. In the event of a power-line



Parts List

C1 = 2000 microfarads, 25 volts, electrolytic
C2 = 50 microfarads, 10 volts, electrolytic
C3 = 10 microfarads, 10 volts, electrolytic
CR1 through CR5, CR7 through CR9 = rectifier, RCA SK3030
CR6 = zener diode, 8.2 volts
F1 = fuse, 1.5 amperes, 125 volts, slow-blow
Q1 Q4 = transistor, RCA SK3026
Q2 = transistor, RCA SK3020
Q3 = transistor, RCA SK3027
R1 = 82 ohms, 1/2 watt, 10%
R2 = 2200 ohms, 1/2 watt, 10%
R3 = 180 ohms, 1/2 watt, 10%
R4 = 10 ohms, 1/2 watt, 10%
T1 = transformer, Stancor TP-4 or equivalent

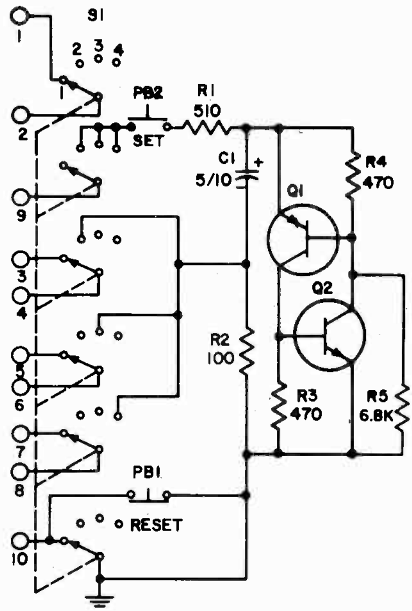
Fig. 102 – Schematic diagram and parts list for the twenty-four-hour-clock power supply.

failure, the battery will cut in and keep the clock counters working so that there will be no loss of count. To conserve battery energy, power to both the decoder/drivers and the RCA Numitrons is automatically switched off during battery operation; as a result there will be no display under such operation. However, as soon as power from the power supply returns, the numitrons will be switched on again automatically and will immediately display correct time. Six D cells, such as the RCA VS036, can supply stand-by power for approximately 5 hours; one 9-volt lantern battery, such as the RCA VS140, can supply stand-by power for 2 to 3 days.

Adjustment

After the frequency of the 100-kHz oscillator has been set as described under Circuit No. 40, the clock may be set to the proper time. The schematic diagram and parts list for the setting circuit are shown in Fig. 103.

Selector switch S1 of the setting circuit is rotated to position 4 which corresponds to the hours set; with the switch in this position (or any position other than 1) the clock will stop counting. The reset button PB1 should now be depressed to reset all numitrons to zero. The desired hours count is set by depressing the set button PB2 once for each hour. S1 should now be advanced to position 3 and the tens of minutes set by depressing the set button the required number of times. The selector switch is again rotated, this time to position 2 and the unit minutes set. When the time of some reliable source (such as a radio station) indicates that the time is



Parts List

C1 = 5 microfarads, 10 volts, electrolytic
PB1 = pushbutton switch, normally closed
PB2 = pushbutton switch, normally open
Q1 = transistor, RCA KD2120 (Available in KD2120 Five Pack)
Q2 = transistor, RCA KD2118 (Available in KD2118 Five Pack)
R1 = 510 ohms, 1/2 watt, 10%
R2 = 100 ohms, 1/2 watt, 10%
R3 R4 = 470 ohms, 1/2 watt, 10%
R5 = 6800 ohms, 1/2 watt, 10%
S1 = rotary wafer switch; 6-pole, 4-position, shorting type

Fig. 103 – Schematic diagram and parts list for the clock setting circuit.

exactly that shown on the clock, the selector switch is flipped to position 1 so that the clock can begin keeping time. When the selector switch S1 is in position 1, the clock setting and resetting circuits are disabled.

Construction

The printed-circuit-board template for all counting circuits is shown at the back of this Manual. A component placement diagram and a photograph of a completed count-by-ten circuit board are shown in the description of the counting circuits, Circuit No. 8. The construction of the remainder of the circuits used in the clock is left to the builder.

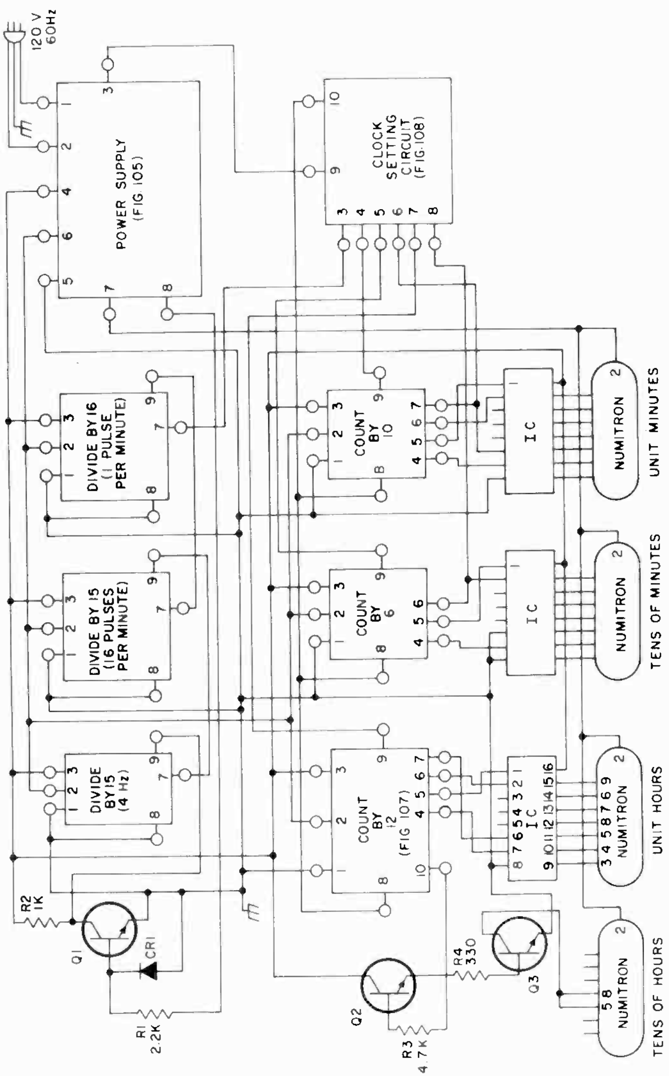
CIRCUIT NO. 13 – TWELVE-HOUR CLOCK

The twelve-hour clock, a simplified, less costly unit than the twenty-four-hour clock, is controlled by the 60-Hz ac power-line frequency rather than a frequency produced by a crystal oscillator. The twelve-hour clock has a digital readout and displays hours and minutes.

Circuit Operation

An interconnection diagram for the twelve-hour clock is shown in Fig. 104. A 60-Hz signal from the ac power transformer, T1 of Fig. 105, is fed to a clipper-squarer circuit composed of Q1, CR1, R1, and R2 through terminal 8 of the power supply. The output of Q1 in turn feeds a cascade of three counting circuits: two divide-by-fifteen and one count-by-sixteen circuit. As described under counting circuits, Circuit No. 8, the special divide-by-fifteen circuits used in the twelve-hour clock are not true counting circuits; i.e., they do not produce a true sequential count; their only purpose is to divide the signals input to them by 15. For this reason, the schematic diagram for the circuit, shown with part list in Fig. 106, need not be as complex as that of the true count-by-fifteen circuit. The difference between the true counting circuit and the divide-by-fifteen circuit of Fig. 106 is that the zero count is eliminated in the divide circuit by means of the clamping circuit composed of Q1, C1, R1, and CR1, CR2, and CR3. This circuit clamps FF "1" high on the 16th pulse, the only time in the cycle at which the F′ of each of FF's "2", "3", and "4" are high simultaneously, a condition required for the clamping circuit to work. On the 17th pulse, capacitors C3 and C4 of FF "1" (these capacitors are shown in Fig. 62) allow the flip-flop to go low just long enough to permit the pulse to get through and to reset to zero FF's "2", "3", and "4", and remove the clamp. FF "1" immediately returns to the condition of F′ high, however, the condition for the count of 1, and the divide cycle begins again.

The cascade of divide-by-fifteen and count-by-sixteen circuits produces one output pulse per minute. The count-by-six and the count-by-ten circuits count and display these output pulses in tens and unit minutes, respectively, up to fifty-nine minutes. The carry pulse from the count-by-six circuit is produced once an hour and is passed to the 12-hour counter.



Parts List

IC = integrated circuit, RCA decoder/driver CD2500E

Numitron = RCA Numitron DR2000

Q1 Q2 Q3 = transistor, RCA KD2118 (Available in KD2118 Five Pack)

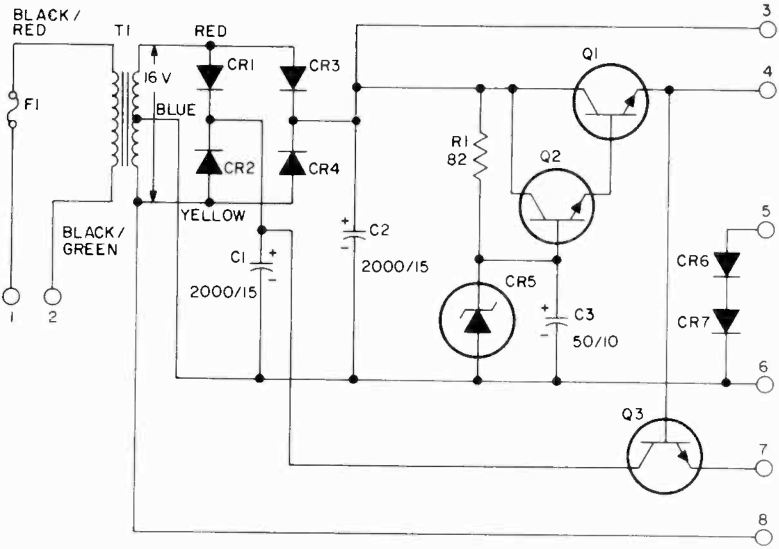
R1 = 2200 ohms, 1/2 watt, 10%

R2 = 1000 ohms, 1/2 watt, 10%

R3 = 4700 ohms, 1/2 watt, 10%

R4 = 330 ohms, 1/2 watt, 10%

Fig. 104 – Interconnection diagram for the twelve-hour clock with list of parts not contained in other clock circuits.

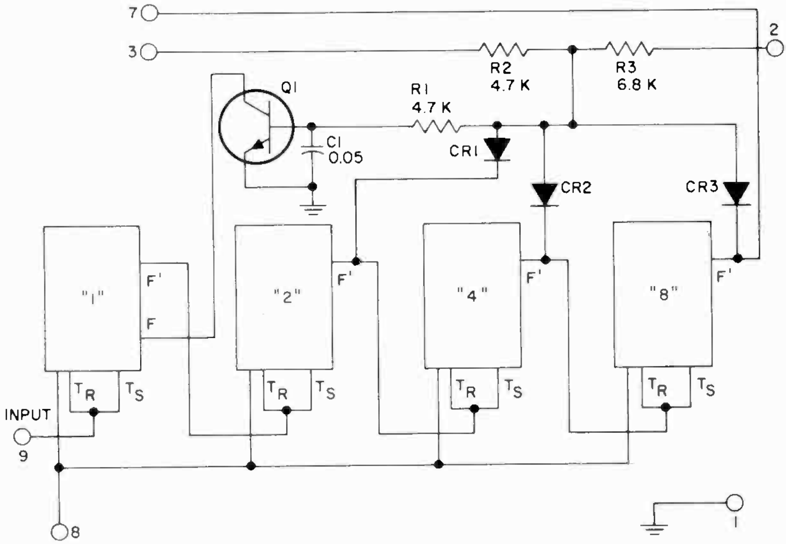


Parts List

C1 C2 = 2000 microfarads, 15 volts, electrolytic
C3 = 50 microfarads, 10 volts, electrolytic
CR1 through CR4, CR6 CR7 = rectifier, RCA SK3030
CR5 = zener diode, 8.2 volts, 1 watt
F1 = fuse, 1.5 amperes, 125 volts, slow-blow
Q1 = transistor, RCA SK3026
Q2 = transistor, RCA SK3020
Q3 = transistor, RCA SK3027
R1 = 82 ohms, 1/2 watt, 10%
T1 = transformer, Stancor TP4 or equivalent

Fig. 105 – Schematic diagram and parts list for the power supply for the twelve-hour clock.

The schematic diagram and parts list for the 12-hour counter are shown in Fig. 107. A standard decade or count-by-ten circuit is used for the unit hours and an additional single flip-flop, FF "X", for the tens of hours. The counts through 9 are standard, but on the 10th pulse, F′ of FF "X" goes high and turns Q3 on. The decade returns to zero count with the result that the clock readout displays 10 o'clock; the tens of hours numitron is lit by Q2 and Q3 of Fig. 104 when F′ of FF "X" is high. The decade progresses again through the count from 0 to 2 until the hours count is 12. At this time, Q2 of Fig. 107 is turned on as F′ of FF "2" goes high. Transistor Q2 of Fig. 107 then passes the next input pulse to T_R of FF "X" causing FF "X" to change state; i.e., F′ of FF "X" goes low. This change of state causes FF "2" to be set low, through its pulse reset terminal R, by the signal passed through the pulse-reset circuit composed of C4 and rectifier CR1. Transistor Q3, which is held ON by



Parts List

C1 = 0.05 microfarad, 25 volts or greater

CR1 CR2 CR3 = diode, RCA 1N270

Q1 = transistor, RCA KD2118 (In KD2118 Five Pack)

R1 R2 = 4700 ohms, 1/2 watt, 10%

R3 = 6800 ohms, 1/2 watt, 10%

Fig. 62 contains parts list for FF's "1", "2", "4", "8".

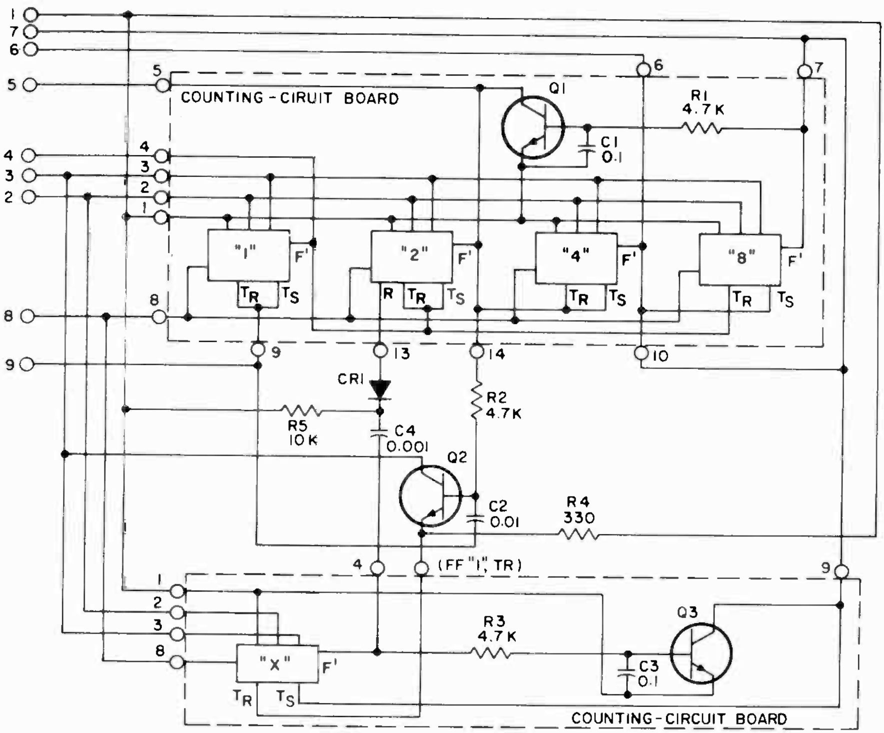
Fig. 106 – Schematic diagram and parts list for the divide-by-fifteen circuit.

the action of R3 and C3, clamps FF "4" so that it cannot go high. The result of all of the above is that every FF is low with the exception of FF "1", a circuit condition that causes the hours count to indicate 1 o'clock.

The schematic diagram and parts list for the power supply for the twelve-hour clock are shown in Fig. 105; this supply is identical with that shown with the stop clock, Circuit No. 14.

Adjustment

The schematic diagram and parts list for the clock setting circuit are shown in Fig. 108. The selector switch, S1, of the setting circuit is first rotated to position 4, the hours-set position. With switch S1 in this position (or any position other than 1) the clock will stop counting. The reset button PB1 should now be depressed to set all numitrons to zero. The desired hours count is set by depressing the set button PB2 once for each hour. S1 should now be advanced to position 3 and the tens of minutes set by depressing the set button the required number of times. The selector switch is again rotated, this time to position 2 and



Parts List

C1 C3 = 0.1 microfarad, 25 volts or greater

C2 = 0.01 microfarad, 25 volts or greater

C4 = 0.001 microfarad, 25 volts or greater

CR1 = diode, RCA 1N270

Q1 Q2 Q3 = RCA KD2118 (Available in KD2118 Five Pack)

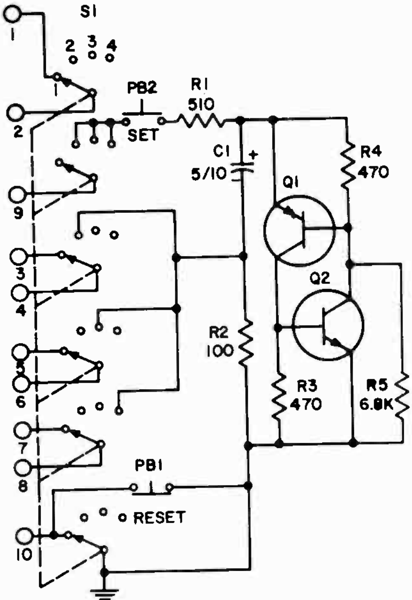
R1 R2 R3 = 4700 ohms, 1/2 watt, 10%

R4 = 330 ohms, 1/2 watt, 10%

R5 = 10,000 ohms, 1/2 watt, 10%

Fig. 62 contains parts list for FF's "1", "2", "4", "8", "X".

Fig. 107 – Schematic diagram and parts list for the count-by-twelve circuit.



Parts List

C1 = 5 microfarads, 10 volts, electrolytic
PB1 = pushbutton switch, normally open
PB2 = pushbutton switch, normally closed
Q1 = transistor, RCA KD2120 (Available in KD2120 Five Pack)
Q2 = transistor, RCA KD2118 (Available in KD2118 Five Pack)
R1 = 510 ohms, 1/2 watt, 10%
R2 = 100 ohms, 1/2 watt, 10%
R3 R4 = 470 ohms, 1/2 watt, 10%
R5 = 6800 ohms, 1/2 watt, 10%
S1 = rotary wafer switch; 6-pole, 4-position, shorting type

Fig. 108 – Schematic diagram and parts list for the clock setting circuit.

the unit minutes set. When the time of some reliable source (a radio station) indicates that the time is exactly that shown on the clock, the selector switch is flipped to position 1 so that the clock can begin keeping time. When the selector switch S1 is in position 1, the clock setting circuit is disabled.

CIRCUIT NO. 14 – STOP CLOCK

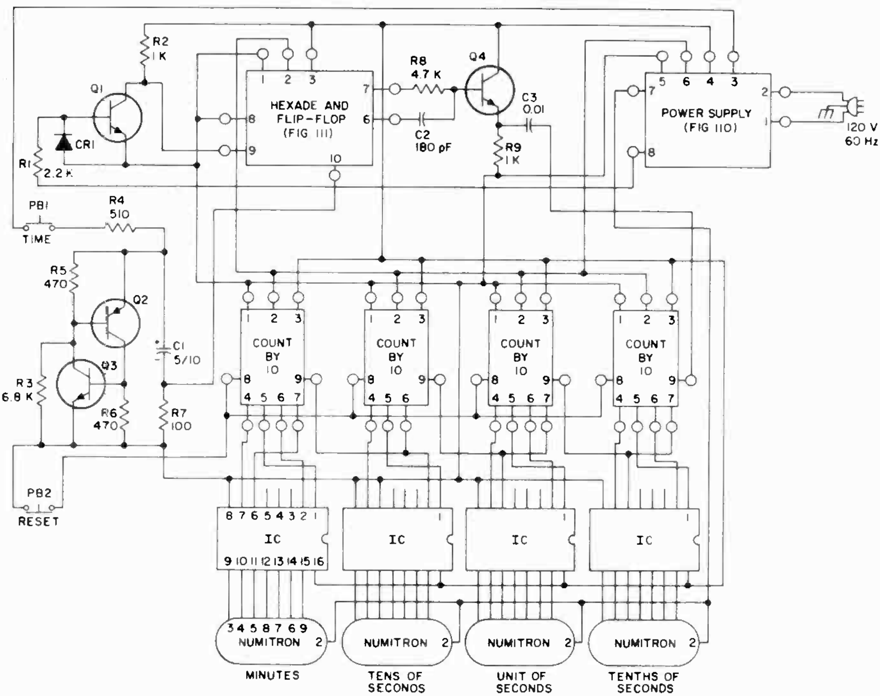
The electronic stop clock is useful in timing athletic events, in laboratory work, or in any application in which a stop watch is normally used. The electronic stop clock can display elapsed time up to 9 minutes 69.9 seconds digitally by means of numitrons or the large-scale lamp display of Circuit No. 10.

Construction

The printed-circuit-board templates for the counting circuits used in the twelve-hour clock are shown at the back of this Manual. A component placement diagram and a photograph of a completed counting circuit are shown under Circuit No. 8, counting circuits.

Circuit Operation

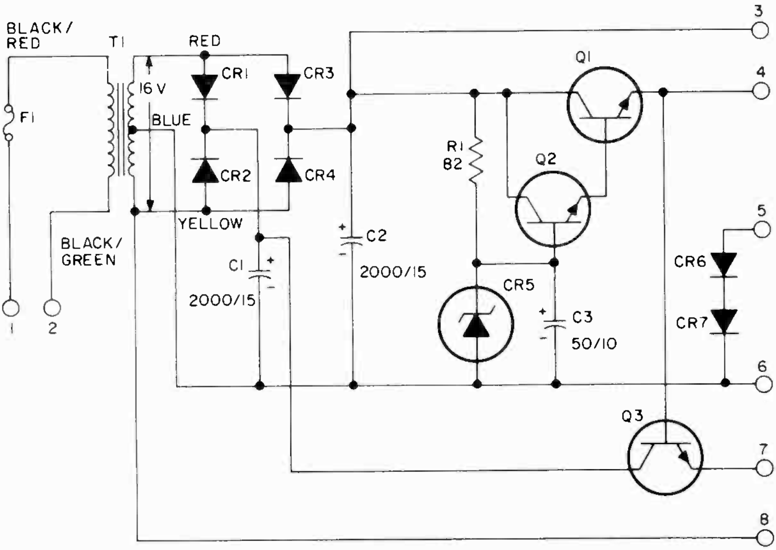
The interconnection diagram for the electronic stop clock is shown in Fig. 109. The 60-Hz signal from the ac power transformer, T1 of Fig. 110, is fed to a clipper-squarer circuit composed of Q1, R1, R2, and CR1. The output of this circuit feeds a count-by-six or hexade circuit and a



Parts List

C1 = 5 microfarads, 10 volts, electrolytic
C2 = 180 picofarads
C3 = 0.01 microfarad, 50 volts or greater
CR1 = diode, RCA 1N270
PB1 = push-button switch, normally open
PB2 = push-button switch, normally closed
Q1 Q3 Q4 = transistor, RCA KD2118 (Available in KD2118 Five Pack)
Q2 = transistor, RCA KD2120 (Available in KD2120 Five Pack)
R1 = 2200 ohms, 1/2 watt, 10%
R2 R9 = 1000 ohms, 1/2 watt, 10%
R3 = 6800 ohms, 1/2 watt, 10%
R4 = 510 ohms, 1/2 watt, 10%
R5 R6 = 470 ohms, 1/2 watt, 10%
R7 = 100 ohms, 1/2 watt, 10%
R8 = 4700 ohms, 1/2 watt, 10%

Fig. 109 – Interconnection diagram for the stop clock with list of parts not contained in other clock circuits.

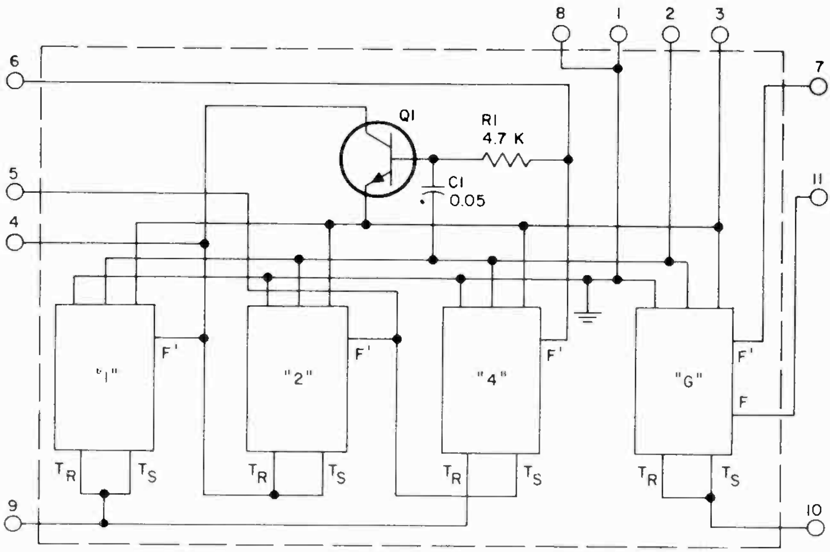


Parts List

C1 C2 = 2000 microfarads, 15 volts, electrolytic
C3 = 50 microfarads, 10 volts, electrolytic
CR1 through CR4, CR6 CR7 = rectifier, RCA SK3030
CR5 = zener diode, 8.2 volts
F1 = fuse, 1.5 amperes, 125 volts, slow-blow
Q1 = transistor, RCA SK3026
Q2 = transistor, RCA SK3020
Q3 = transistor, RCA SK3027
R1 = 82 ohms, 1/2 watt, 10%
T1 = transformer, Stancor TP-4 equivalent

Fig. 110 – Schematic diagram and parts list for the stop-clock power supply.

flip-flop gate circuit. The schematic diagram and parts list for this combination of circuits is shown in Fig. 111. FF "G" in Fig. 111 is used as a start-stop gate while the remaining three flip-flops form a hexade that divides the input, 60-Hz pulse by six to yield the 1/10-second timing pulses. When the TIME push-button switch PB1 of Fig. 109 is depressed, a pulse generated by the Q2, Q3 combination is applied to the gate flip-flop, FF "G" of Fig. 110, causing it to change state and turn on Q4, the main component of the input AND gate. Pulses from the hexade circuit then trigger the counter so that it continues the count until the push-button TIME switch, PB1, is pushed again. The second pulse created by pushing the TIME switch the second time returns the gate flip-flop to the low or off position, removes the trigger pulses to the counter and stops the counting action. The numerical display remains on the readout (numitron or large-scale lamp display) until the reset push-button switch, PB1, is depressed.



Parts List

C1 = 0.05 microfarad, 25 volts or greater

Q1 = transistor, RCA KD2118 (In KD2118 Five Pack)

R1 = 4700 ohms, 1/2 watt, 10%

Fig. 62 contains parts list for FF's "1", "2", "4", "8".

Fig. 111 – Schematic diagram and parts list for the hexade and flip-flop gate circuit.

The count-by-ten circuit on the extreme right of Fig. 109 counts 1/10 seconds; the next counting circuit, seconds; the count-by-six circuit, tens of seconds; and the final count-by-ten circuit, minutes. The power supply for the stop clock, shown in Fig. 110, is identical with that used in the twelve-hour clock, Circuit No. 13.

Construction

The printed-circuit-board templates for the counting circuits are shown at the back of this Manual. A component placement diagram and photograph of a completed counting circuit board are shown under counting circuits, Circuit No. 8.

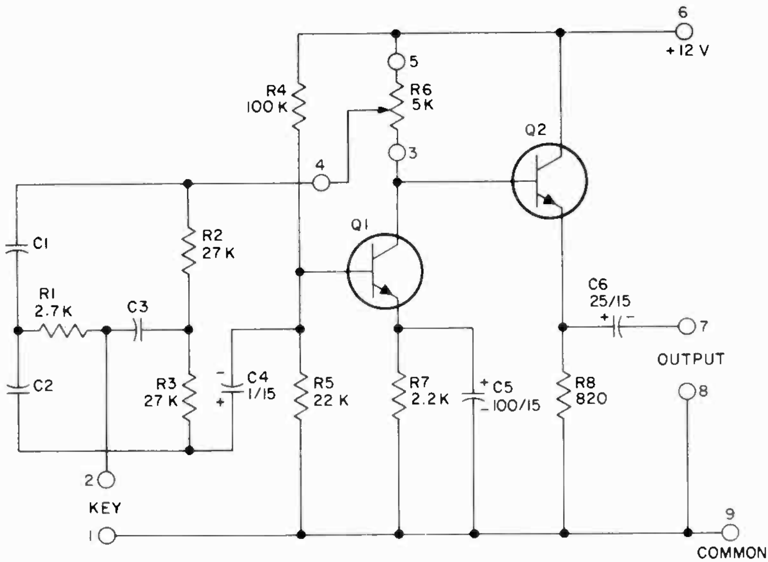
CIRCUIT NO. 15 – AUDIO AND CODE-PRACTICE OSCILLATOR

The audio and code-practice oscillator provides a single-tone sine-wave output at any frequency from 10 Hz to 175 kHz and can be operated from a wide range of operating voltages. The circuit has an extremely good wave shape, a low output impedance, and excellent keying characteristics. The oscillator is useful in testing high-fidelity audio equipment and can also be used as a code-practice oscillator or a side-tone generator. When the output signals from two oscillators are mixed the result is a signal ideal for the testing of amateur single-sideband transmitters.

Circuit Operation

The schematic diagram and parts list for the audio and code-practice oscillator is shown in Fig. 112.

Transistor Q1 operates as an audio amplifier. Oscillation is produced as some of the output of Q1 is fed back to its base through a twin-T network consisting of C1, C2, C3, R1, R2, and R3. The frequency characteristic of the feedback network determines the frequency of oscillation of the circuit; the phase shift of the signal through the network is 180°, thus providing the positive feedback required to support



Parts List

C1 C2 C3 = see Table XVIII
C4 = 1 microfarad, 15 volts, electrolytic
C5 = 100 microfarads, 15 volts, electrolytic
C6 = 25 microfarads, 15 volts, electrolytic
Q1 Q2 = transistor, RCA SK3020
R1 = 2700 ohms, 1/2 watt, 10%
R2 R3 = 27,000 ohms, 1/2 watt, 10%
R4 = 100,000 ohms, 1/2 watt, 10%
R5 = 22,000 ohms, 1/2 watt, 10%
R6 = potentiometer, linear taper, 5000 ohms
R7 = 2200 ohms, 1/2 watt, 10%
R8 = 820 ohms, 1/2 watt, 10%

Fig. 112 – Schematic diagram and parts list for the audio and code-practice oscillator.

oscillation. Table XVIII shows how oscillator frequency can be varied by choice of network capacitor value. Potentiometer R6 is used to obtain the best waveform with the lowest distortion when the circuit is used as an audio oscillator; the potentiometer is adjusted to feed just enough signal back to support oscillation. However, when the circuit is used as a code-practice oscillator, the potentiometer is adjusted for the best keying characteristic rather than the best waveform. Capacitor C4 prevents the dc potential on the potentiometer arm from reaching the base circuit of transistor Q1. If the connection between C3, R1, and ground is interrupted, oscillation stops; therefore, the key is inserted in this lead as shown in Fig. 112. Transistor Q2 acts as a buffer between oscillator and load.

Table XVIII.
Frequency vs. Feedback–Network Capacitor Value

Approximate Frequency (Hz)	C1, C2	C3
175,000	50 pF	Twice the value of C1 or C2
95,000	100 pF	
20,000	500 pF	
10,000	0.001 μF	
2,000	0.005 μF	
1,000	0.01 μF	
750*	0.015 μF	
200	0.05 μF	
100	0.1 μF	
20	0.5 μF	
10	1 μF	

*This frequency best for code practice.

Construction

The printed-circuit-board template for the audio and code-practice oscillator is shown at the back of this Manual; a component placement diagram and a photograph of a completed circuit board are shown in Figs. 113 and 114, respectively.

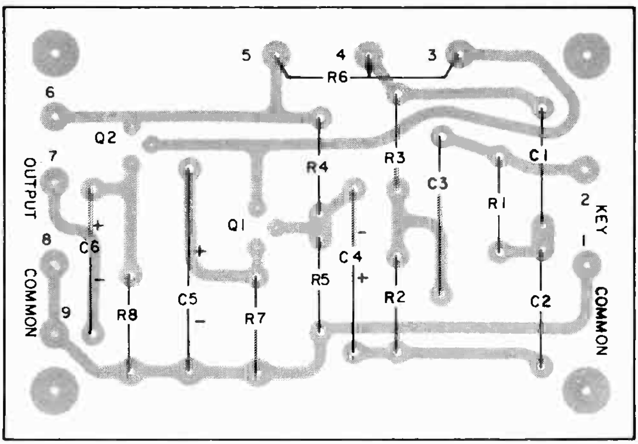


Fig. 113 – Component placement diagram for the audio and code-practice oscillator.

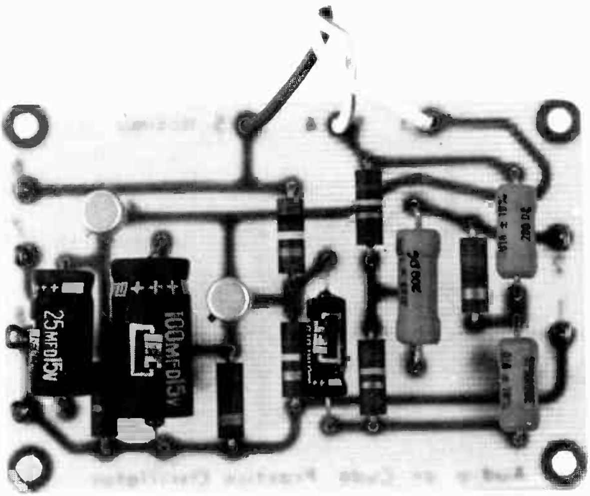


Fig. 114 – Completed circuit board for the audio and code-practice oscillator.

CIRCUIT NO. 16 – IC AUDIO OSCILLATOR

The IC audio oscillator may be used as a test oscillator or as a code-practice unit. It can also be used to test high-fidelity equipment and radio transmitters. Fig. 115 shows the IC audio oscillator in use in a single-sideband two-tone test circuit. The oscillator has a relatively distortion-free output of 1.4 volts when connected to a load impedance of 3000 ohms or greater. (This circuit is available in kit form as

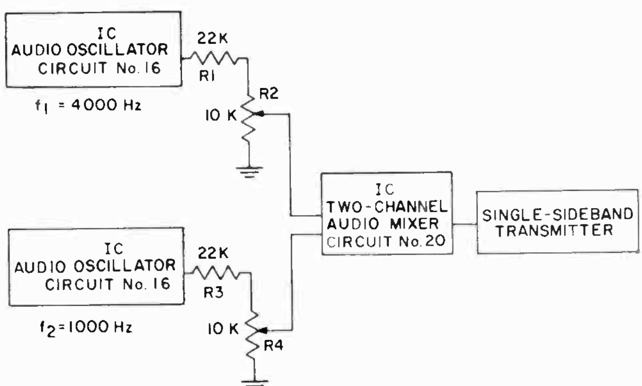


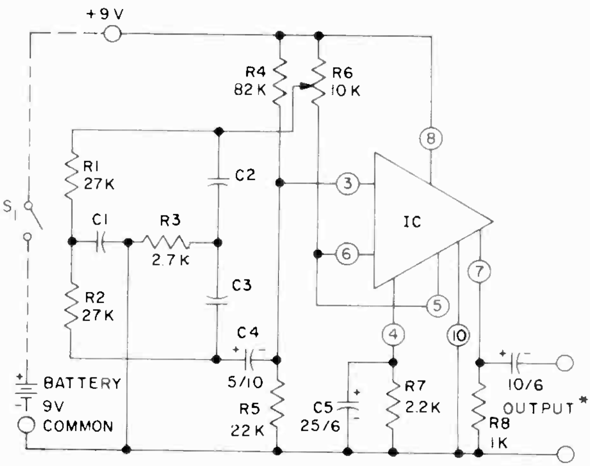
Fig. 115 – Single-sideband two-tone test circuit using two IC audio oscillators and an IC two-channel mixer.

RCA Project Kit KC-4002. A pre-punched case, input and output jacks, on-off switch, and all necessary hardware for housing the KC-4002 kit are included in Kit KC-4500.)

Circuit Operation

The schematic diagram and parts list for the IC audio oscillator are shown in Fig. 116; the schematic diagram of the KD2114 IC is shown in Fig. 117. The transistors in the IC are formed on a common substrate and are isolated from it by an integral diode which is part of the IC but which is not shown in the IC schematic as it functions only as an isolation device for the IC circuit and not as a part of the external circuit in which the IC is applied.

The audio-oscillator circuit is basically a two-stage amplifier. Part of the output from the first stage, Q1, is applied to the twin-T network, R1, R2, R3, C1, C2, and C3, that determines the frequency of oscillation. By changing the values of the capacitors in the network, the frequency of oscillation can be changed. The output of the network is applied to the base of Q1 and



* RECOMMENDED LOAD 3000 OHMS MINIMUM; UNDISTORTED OUTPUT APPROX 1.4 VOLTS.

Parts List

C1 C2 C3 = see Table XX
C4 = 5.0 microfarads, 10 volts
C5 = 25 microfarads, 6 volts
C6 = 10 microfarads, 6 volts
IC = integrated circuit KD2114 (Available in KD2117 Variety Pack)
R1 R2 = 27,000 ohms, 1/2 watt, 10%
R3 = 2700 ohms, 1/2 watt, 10%
R4 = 82,000 ohms, 1/2 watt, 10%
R5 = 22,000 ohms, 1/2 watt, 10%
R6 = 10,000 ohms, trim-pot, 1/4 watt, 10%
R7 = 2200 ohms, 1/2 watt, 10%
R8 = 1000 ohms, 1/2 watt, 10%

Fig. 116 – Schematic diagram and parts list for the IC audio oscillator.

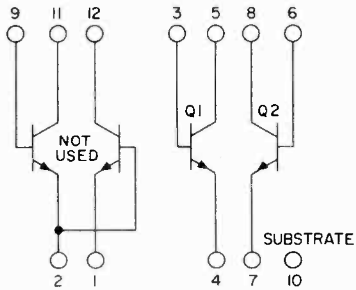


Fig. 117 – Schematic diagram for the KD2114 IC.

provides the regenerative feedback required for oscillation to occur. Transistor Q2 acts as a buffer between the oscillator and the load.

The best waveform is obtained when potentiometer R6 is adjusted to the point at which the circuit first begins to oscillate. Table XIX shows voltages at the terminals of an IC in a properly operating circuit.

Table XIX.
Voltages at IC Terminals in Audio Oscillator Circuit

Terminal	Voltage (Volts)
3	1.7
4	1
5	4.2
6	4.2
7	3.5
8	9

Adjustments

The values of capacitors C1, C2, and C3 are chosen according to Table XX to produce oscillator frequencies ranging from 20 Hz to 100 kHz. For the best output waveshape, potentiometer R6, shown in Fig. 116, is turned so that its arm is closest to the +9-volt terminal. The arm is then slowly turned back until the unit just starts to oscillate. When the oscillator is used for code practice or as a keying monitor, the best keying characteristics are obtained when the arm is turned back a bit more from the point at which oscillation starts.

Table XX.
Frequency as a Function of Feedback-Network Capacitor Value

Approx. Freq. (Hz)	C1*	C2*	C3*	
100,000	200	100	100	picofarads
20,000	1000	500	500	picofarads
10,000	0.002	0.001	0.001	microfarads
2,000	0.01	0.005	0.005	microfarads
1,000	0.02	0.01	0.01	microfarads
200	0.1	0.05	0.05	microfarads
100	0.2	0.1	0.1	microfarads
20	1.0	0.5	0.5	microfarads

*12 volts or greater

Construction

The printed-circuit-board template for the IC audio oscillator is shown at the back of this Manual. A combined component placement diagram and photograph of a completed circuit board is shown in Fig. 118.

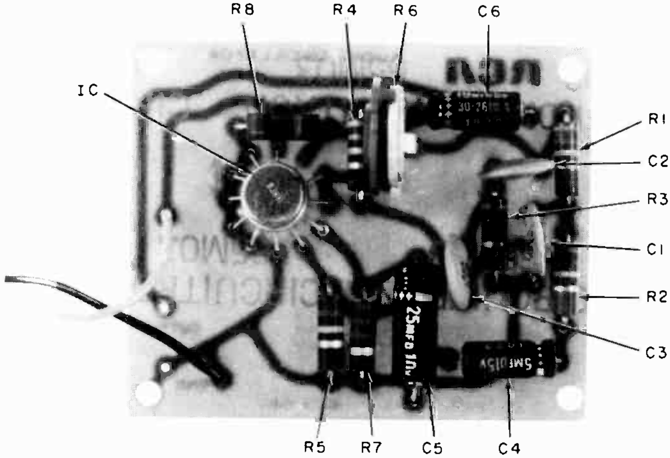


Fig. 118 – Completed circuit board showing component placement for the IC audio oscillator.

CIRCUIT NO. 17 – ALL-PURPOSE MICROPHONE PREAMPLIFIER

The microphone preamplifier is capable of boosting the output of a dynamic microphone to a 0.5- to 1-volt level. This level is compatible with the mixer, volume compressor, and line amplifier (Circuit No. 23) and the 7.5-watt audio amplifier (Circuit No. 29) described in this Manual. The frequency response of the preamplifier is 20 to 35,000 Hz.

Circuit Operation

The schematic diagram and parts list for the microphone preamplifier are shown in Fig. 119. The circuit consists of a two-stage direct-coupled amplifier that is stabilized by the use of dc feedback. The circuit works well with dynamic microphones having impedances from 200 ohms to 30,000 ohms.

When the circuit is in operation, base bias current for the input transistor Q1 is obtained from the emitter of output transistor Q2 through R5. Q2 obtains its base bias current through the collector resistor of Q1, R3. This unique bias circuit provides dc feedback for stabilization of the operating points of the transistors. For example, if the operating current of Q1 increases, the collector voltage of Q1 decreases and reduces the voltage at the base of Q2. This lower voltage causes a reduction in the operating current of Q2. When the operating current of Q2 decreases, the voltage at the emitter of Q2 also decreases. This voltage decrease is reflected back to the base of Q1, which undergoes a current

Manual directly and can also be used with the headphone or line amplifier, Circuit No. 22 or the multi-input mixer, Circuit No. 21. The amplifier has a gain of 1500 to 2000 and can provide a maximum undistorted output voltage of 2 volts rms to a load impedance of 500 ohms or more. The maximum undistorted input is 400 millivolts rms. The frequency response of the preamplifier is flat from 20 Hz to 30 kHz.

Circuit Operation

The schematic diagram and parts list for the high-dynamic-range microphone preamplifier are shown in Fig. 122. The preamplifier consists of two stages of current-stabilized amplifiers separated by a gain control and an RC filter, consisting of R7 and C5, that prevents motorboating. Resistors R5 and R12, placed in the emitter circuits of transistors Q1 and Q2, improve the frequency response of the preamplifier by providing some emitter degeneration. The output of the preamplifier is shunted with a resistor, R15, to make the circuit compatible with the zero-point switching capability used in other circuits in the Manual. The output impedance of the preamplifier is low, about 60 ohms. Table XXI shows the value of R1 to be used with microphones of various impedances; R1 is not shown in the schematic diagram but is connected across the microphone input jack.

Table XXI.
Value of R1 as a Function of Microphone Impedance

Microphone Impedance (ohms)	R1 (ohms)
200	220
500	560
4,000	R1 not used

Construction

The printed-circuit-board template for the microphone preampli-

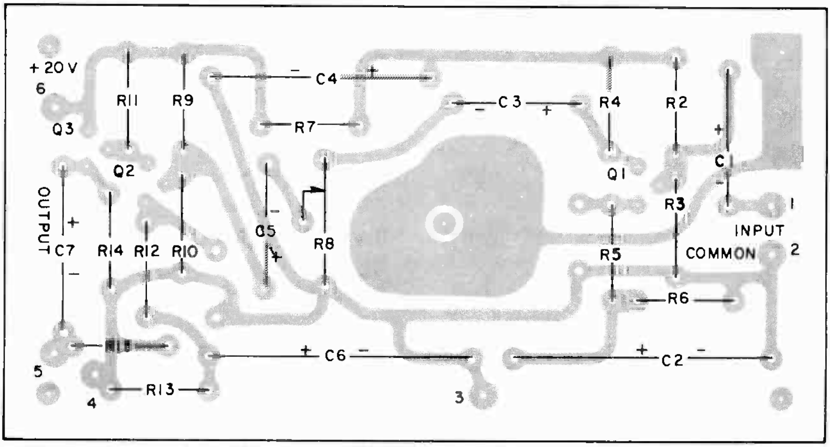
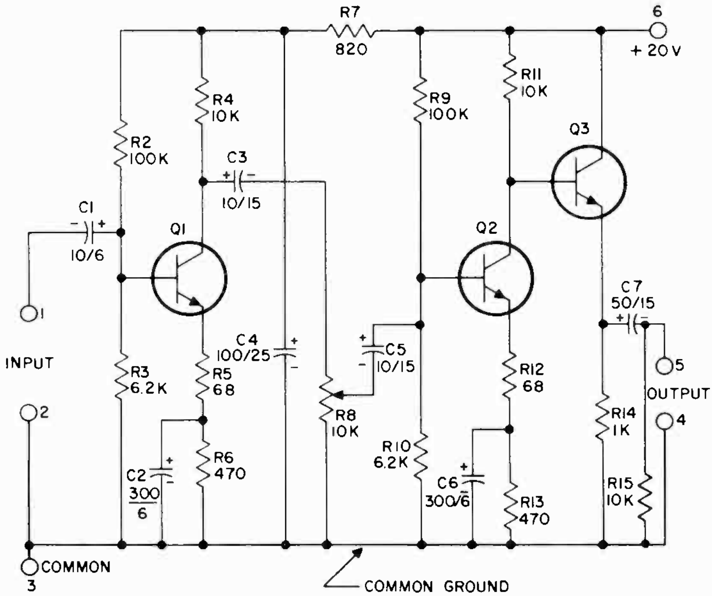


Fig. 123 – Component placement diagram for the high-dynamic-range microphone preamplifier.

CIRCUIT NO. 18 – HIGH-DYNAMIC-RANGE MICROPHONE PREAMPLIFIER

The high-dynamic-range microphone preamplifier, intended to be used with low-impedance dynamic microphones, is designed to handle loud passages of music or close talking without adverse effect on the output. It is capable of driving any of the amplifiers included in this



Parts List

C1 C5 = 10 microfarads, 6 volts, electrolytic
C2 C6 = 300 microfarads, 6 volts, electrolytic
C3 = 10 microfarads, 15 volts, electrolytic
C4 = 100 microfarads, 25 volts, electrolytic
C7 = 50 microfarads, 15 volts, electrolytic
Q1 Q2 = transistor, RCA SK3038
Q3 = transistor, RCA SK3020
R1 = see Table XXI for value and text for location
R2 R9 = 100,000 ohms, 1/2 watt, 10%
R3 R10 = 6200 ohms, 1/2 watt, 10%
R4 R11 R15 = 10,000 ohms, 1/2 watt, 10%
R5 R12 = 68 ohms, 1/2 watt, 10%
R6 R13 = 470 ohms, 1/2 watt, 10%
R7 = 820 ohms, 1/2 watt, 10%
R8 = potentiometer, 10,000 ohms, audio taper
R14 = 1000 ohms, 1/2 watt, 10%

Fig. 122 – Schematic diagram and parts list for the high-dynamic-range microphone preamplifier.

graph of the completed circuit board are shown in Figs. 120 and 121 respectively. A single preamplifier circuit fits on a 3- by 2-inch circuit board; two can be built on a 3- by 4-inch board, and three on a 3- by 6-inch board. If the circuit is not constructed on a board, a ground bus should be used to ground the preamplifier to the circuits that follow it at one point only, preferably at the input to the circuits.

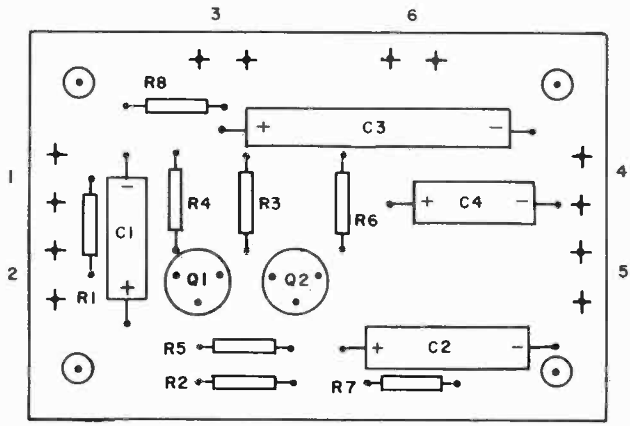


Fig. 120 – Component placement diagram for the all-purpose microphone preamplifier.

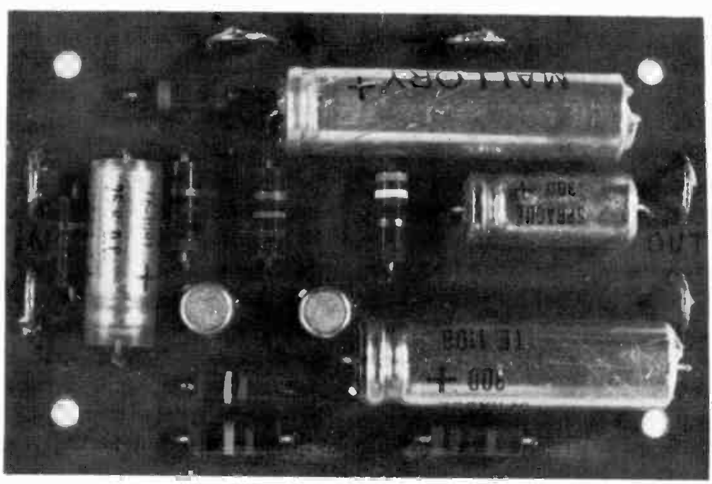
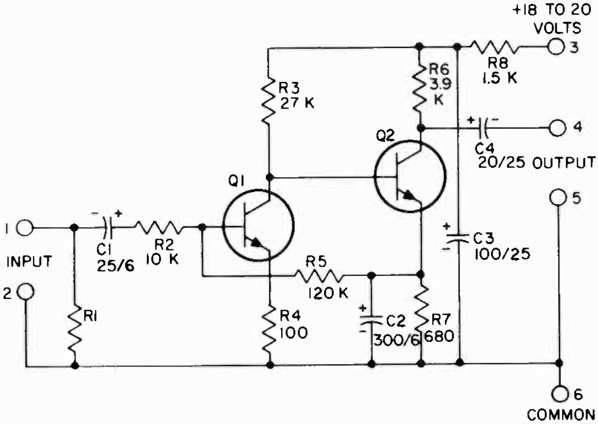


Fig. 121 – Completed circuit board for the all-purpose microphone preamplifier.



Parts List

C1 = 25 microfarads, 6 volts, electrolytic
C2 = 300 microfarads, 6 volts, electrolytic
C3 = 100 microfarads, 25 volts, electrolytic
C4 = 20 microfarads, 25 volts, electrolytic
Q1 Q2 = transistor, RCA SK3020
R1 = 220 ohms for low-impedance microphone, 270,000 ohms for high-impedance microphone, 1/2 watt, 10%
R2 = 10,000 ohms, 1/2 watt, 10%
R3 = 27,000 ohms, 1/2 watt, 10%
R4 = 100 ohms, 1/2 watt, 10%
R5 = 120,000 ohms, 1/2 watt, 10%
R6 = 3900 ohms, 1/2 watt, 10%
R7 = 680 ohms, 1/2 watt, 10%
R8 = 1500 ohms, 1/2 watt, 10%

Fig. 119 – Schematic diagram and parts list for the all-purpose microphone preamplifier.

reduction that offsets the initial increase.

This preamplifier circuit is designed to operate from an 18- to 20-volt source; voltage in this range can be obtained from batteries or from a power supply. The power circuit can be common to the power amplifier. The preamplifier circuit can tolerate voltages greater than 20 volts if R8 is increased about 400 ohms for every volt above 20 volts. The current drain of the preamplifier is approximately 2.5 milliamperes; the voltage gain is about 1700.

Special Considerations

When the preamplifier is used with a low-impedance dynamic microphone (such as the RCA-HK97 in the low-impedance mode), R1 should be 220 ohms; when a microphone with an impedance of about 30,000 ohms is used (such as the RCA-HK97 in the high-impedance mode), R1 should be 270,000 ohms.

Construction

The drilling template for the microphone preamplifier is shown at the back of this Manual; a component placement diagram and a photo-fier is shown at the back of this Manual; a component placement diagram and a photograph of a completed board are shown in Figs. 123 and 124, respectively. It is important that all ground connections in this circuit be made to the same point, as shown in the schematic diagram of Fig. 122, to prevent the formation of ground loops. This common ground feature is already incorporated in the pattern of the printed board and must be followed if some method of circuit construction other than the printed board is used. In addition, all preamplifier connections to external circuits should be made to the same ground point. The presence of ground loops in the circuit will almost certainly lead to hum in the output.

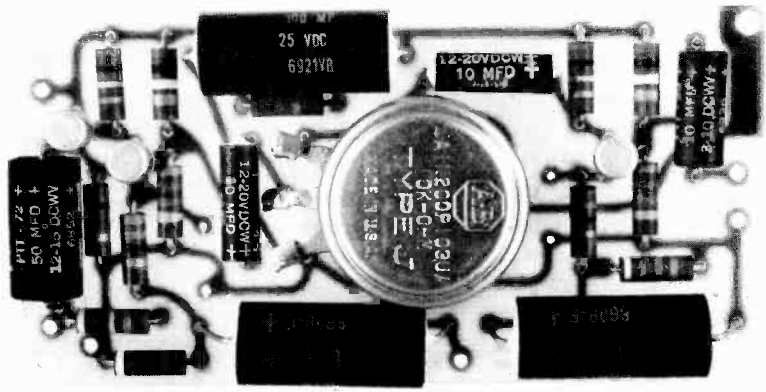


Fig. 124 – Completed circuit board for the high-dynamic-range microphone preamplifier.

CIRCUIT NO. 19 – IC MICROPHONE PREAMPLIFIER

The IC microphone preamplifier is a high-gain, low-noise high-fidelity preamplifier that accommodates both low- and high-impedance dynamic microphones. It can be used with tape recorders and audio systems, or with radio transmitters. The maximum output of the circuit is 1.4 volts. Figs. 125 and 126 show how the IC microphone preamplifier may be used to connect microphone inputs to a tape recorder or high-fidelity amplifier system. (This circuit is available in kit form as RCA Project Kit KC-4000. A pre-punched case, input and output jacks, on-off switch, and all necessary hardware for housing the KC-4000 kit are included in kit KC-4500.)

Circuit Operation

The schematic diagram and parts list for the IC microphone preamplifier are shown in Fig. 127; the schematic diagram for the KD2114 IC is shown in Fig. 128. The transistor numbers given below can be identified in the IC in Fig. 128. The transistors in the IC are formed on a common substrate and are isolated from it by an integral diode

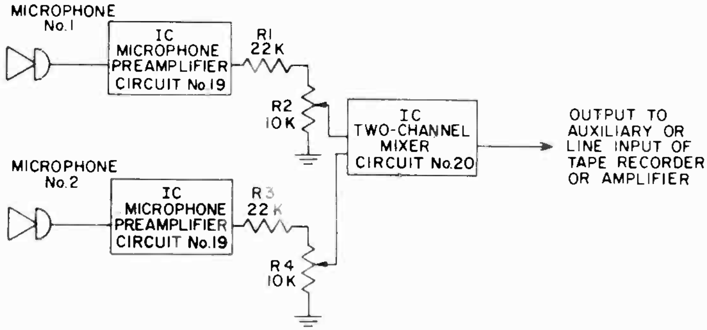


Fig. 125 – Two IC microphone preamplifiers used with an IC two-channel mixer to provide input for a tape recorder.

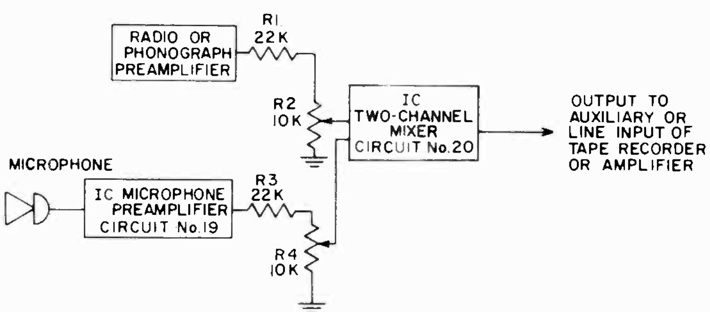
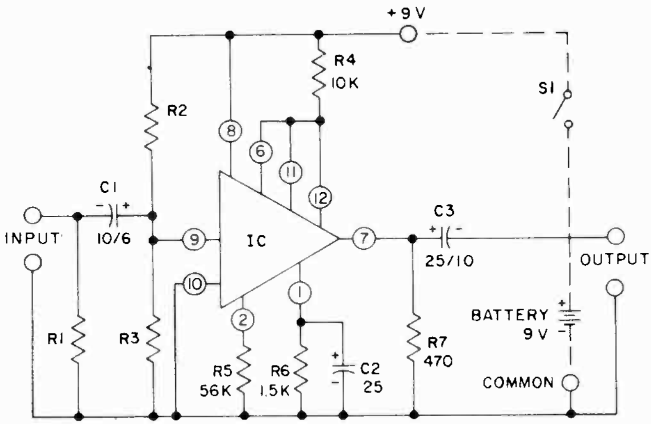


Fig. 126 – An IC microphone preamplifier used with a second source and an IC two-channel mixer to provide input for a tape recorder.



Parts List

C1 = 10 microfarads, 6 volts, electrolytic
C2 = 25 microfarads, 6 volts, electrolytic
C3 = 25 microfarads, 10 volts, electrolytic
IC = integrated circuit RCA KD2114 (Available in KD2117 Variety Pack)
R1 R2 R3 = see Table XXII
R4 = 10,000 ohms, 1/2 watt, 10%
R5 = 56,000 ohms, 1/2 watt, 10%
R6 = 1500 ohms, 1/2 watt, 10%
R7 = 470 ohms, 1/2 watt, 10%

Fig. 127 – Schematic diagram and parts list for the IC microphone preamplifier.

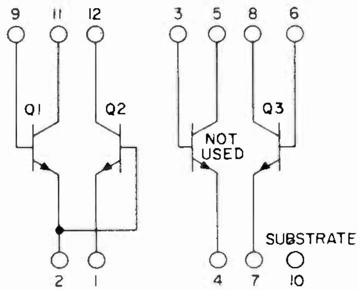


Fig. 128 – Schematic diagram for the KD2114 IC.

which is part of the IC but which is not shown in the IC schematic as it functions only as an isolation device for the IC circuit and not as a part of the external circuit in which the IC is applied.

The microphone preamplifier is a three-stage amplifier; the choice of resistors at the input permits impedance matching of dynamic microphone and preamplifier. The input signal from the microphone is applied to the base of Q1. Transistors Q1 and Q2 are connected within the IC as shown in Fig. 128 to form a Darlington configuration, a configuration that provides the microphone

Table XXII.
Resistor Values as a Function of Microphone Type

RESISTORS*	MICROPHONE TYPE	
	LOW IMPEDANCE	HIGH IMPEDANCE
R_1	270 ohms	not used
R_2	220,000 ohms	1,000,000 ohms
R_3	56,000 ohms	270,000 ohms

*1/2 watt, 10%

preamplifier with a high-gain high-impedance input. The output of Q2 is applied directly to the base of Q3 which is connected as an emitter-follower, a type of circuit that has a high input impedance and a low output impedance. The emitter-follower isolates the output load from the input. Table XXIII shows voltages at the terminals of an IC in a properly operating circuit.

Construction

The printed-circuit template for the IC microphone preamplifier is shown at the back of this Manual. A combined component placement diagram and photograph of the completed circuit board is shown in Fig. 129. Shielded cable should always be used when connecting the output terminals of the IC pre-amplifier to an audio system so that the instability and hum sometimes encountered with high-gain audio amplifiers are minimized.

Table XXIII.
Voltages at IC Terminals in Microphone Preamplifier Circuit

Terminal	Voltage (Volts)
1	0.5
2	1.2
6	4.5
7	3.7
8	9
9	1.8
11	4.5
12	4.5

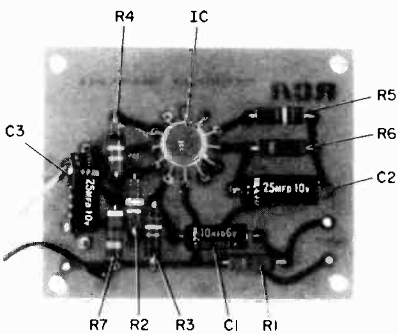


Fig. 129 – Completed circuit board showing component placement for the IC microphone preamplifier.

CIRCUIT NO. 20 – IC TWO-CHANNEL MIXER

The IC two-channel mixer is used to combine two input signals into a single output. It can be used to channel the inputs from two microphones or stereo preamplifiers into a tape recorder or high-fidelity audio system, as shown in Fig. 130, or it can be used in a test setup for a single-sideband two-tone test as shown in Fig. 131. The input impedance of the circuit is approximately 4700 ohms; the output impedance is 5000 ohms. The voltage gain of the mixer is greater than 10 volts. (This circuit is available in Kit form as RCA Project Kit KC-4001. A prepunched case, input and output jacks, on-off switch, and all necessary hardware for housing the KC-4001 kit are included in Kit KC-4500.)

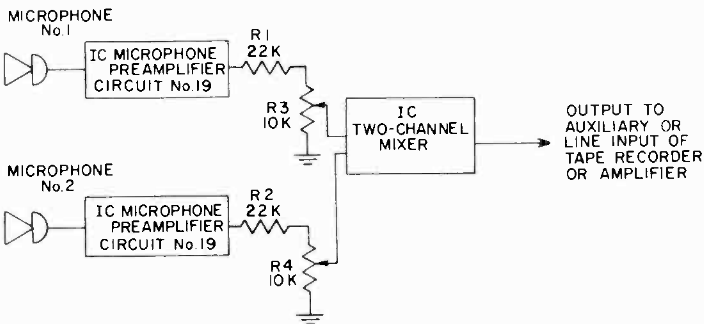


Fig. 130 – IC two-channel mixer used with two IC microphone preamplifiers to mix the input from two microphones.

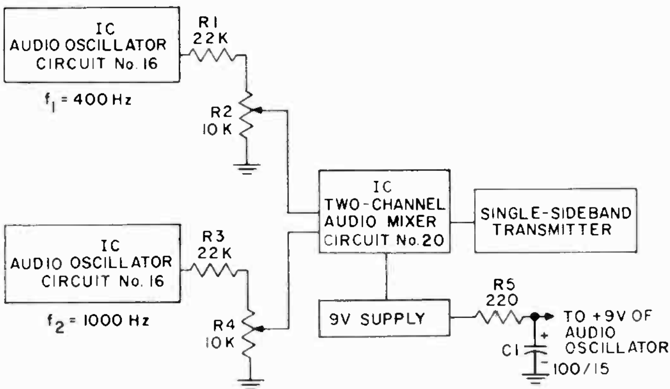


Fig. 131 – Single-sideband two-tone test circuit using an IC two-channel mixer to mix the input from two audio oscillators.

Circuit Operation

The schematic diagram and parts list for the IC two-channel mixer are shown in Fig. 132. Fig. 133 shows the schematic diagram of the KD2116 IC.

The mixer circuit uses two Darlington-connected amplifiers, Q1 and Q2, Q3 and Q4, to combine the two input signals and provide a voltage gain. Each amplifier shares a common load resistor, R5. Because the collectors of all transistors in the IC are common, the signal from one is mixed with the signals from the others. Mixer output is passed from the collectors through terminal 1 and coupling capacitor C4 to the load.

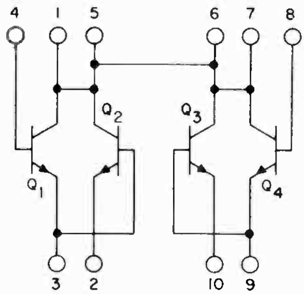
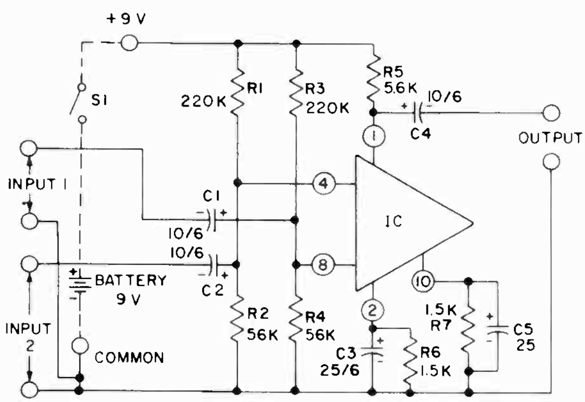


Fig. 133 – Schematic diagram for the KD2116 IC.

If mixing without gain is desired, bypass capacitors C3 and C5 may be omitted. Table XXIV shows voltages at the terminals of an IC in a properly operating circuit.



Parts List

C1 C2 C4 = 10 microfarads, 6 volts, electrolytic
C3 C5 = 25 microfarads, 6 volts, electrolytic
IC = integrated circuit, RCA KD2116 (Available in KD2117 Variety Pack)
R1 R3 = 220,000 ohms, 1/2 watt, 10%
R2 R4 = 56,000 ohms, 1/2 watt, 10%
R5 = 5600 ohms, 1/2 watt, 10%
R6 R7 = 1500 ohms, 1/2 watt, 10%

Fig. 132 – Schematic diagram and parts list for the IC two-channel mixer.

Construction

The printed-circuit template for the IC two-channel mixer is shown at the back of this Manual. A combined component placement diagram and photograph of the completed circuit board is shown in Fig. 134.

Table XXIV.
Voltages at IC Terminals in Two-Channel Mixer Circuit

Terminal	Voltage (Volts)
1	4.0
2	0.6
4	1.8
8	1.8
10	0.6

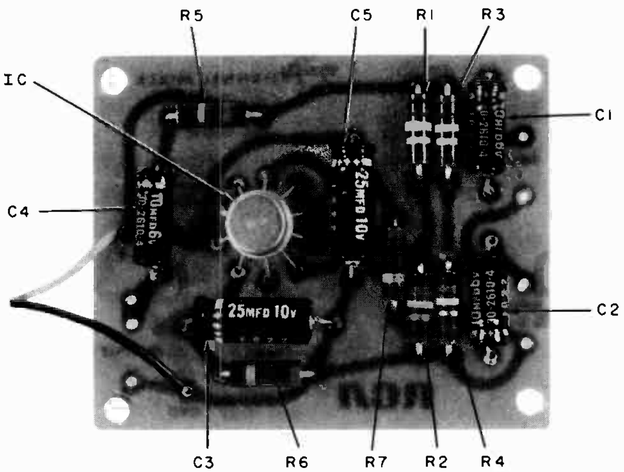


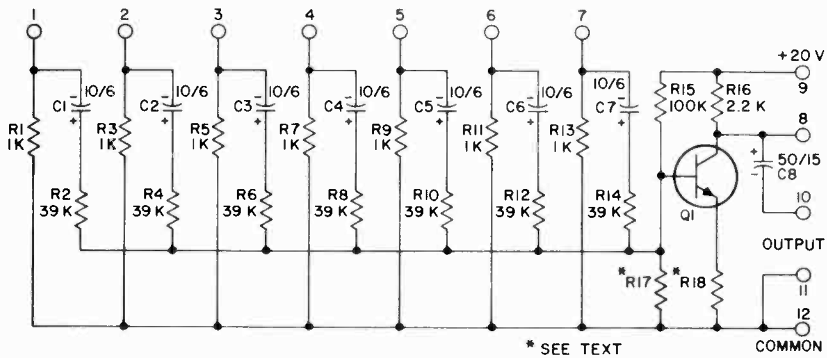
Fig. 134 – Completed circuit board showing component placement for the two-channel mixer.

CIRCUIT NO. 21 – MULTI-INPUT MIXER

The multi-input mixer is designed to mix the inputs from up to seven sources, usually microphones, for input to an amplifier, recorder, or other piece of audio equipment. The mixer has a gain of approximately unity and, therefore, has no effect on the system in which it is installed. If more than seven inputs are required, as many as three mixers can be wired in parallel.

Circuit Operation

The schematic diagram and parts list for the multi-input audio mixer are shown in Fig. 135. The resistance network shown at the left in the figure is designed not only to provide the mixing function but also to make possible zero-point switching of the out. The amplifier portion of the circuit, shown at the right in the schematic diagram, is current-stabilized by the emitter resistor. This resistor is not bypassed, thereby providing a greater degree of degeneration and a reduction in the over-all gain of the mixer to unity.



Parts List

C1 through C7 = 10 microfarads, 6 volts, electrolytic
C8 = 50 microfarads, 15 volts, electrolytic
Q1 = transistor, RCA SK3020
R1 R3 R5 R7 R9 R11 R13 = 1000 ohms, 1/2 watt, 10%
R2 R4 R6 R8 R10 R12 R14 = 39,000 ohms, 1/2 watt, 10%
R15 = 100,000 ohms, 1/2 watt, 10%
R16 = 2200 ohms, 1/2 watt, 10%
R17 R18 = see table XXV

Fig. 135 – Schematic diagram and parts list for the multi-input mixer.

inputs. In the zero-point switching method used in this unit, the capacitors at the output of the microphone preamplifiers as well as the input capacitor of the mixer are kept charged by connecting a resistor across the output and input; thus there is no disturbance, no cracks or pops, when inputs are switched in or out.

Some adjustment of resistor values is required if less than seven inputs are used. Table XXV shows these resistor values for from 2 to 7 inputs. When up to three mixers are paralleled to accommodate more than seven inputs, not only must the outputs of the mixers be paralleled but the points marked "X" on each

Table XXV.
Values of R17 and R18 as a Function of Number of Inputs

Number of Inputs	R17 (ohms)	R18 (ohms)
2	8.2K	120
3	7.5K	110
4	6.8K	91
5	6.8K	82
6	6.2K	75
7	6.2K	68

circuit board must be connected; the gain of the mixer thus connected is somewhat less than unity.

Construction

The component placement diagram for the multi-input mixer is shown in Fig. 136; a photograph of a completed board is shown in Fig. 137. The printed-circuit-board template for the multi-input mixer is shown at the back of this Manual.

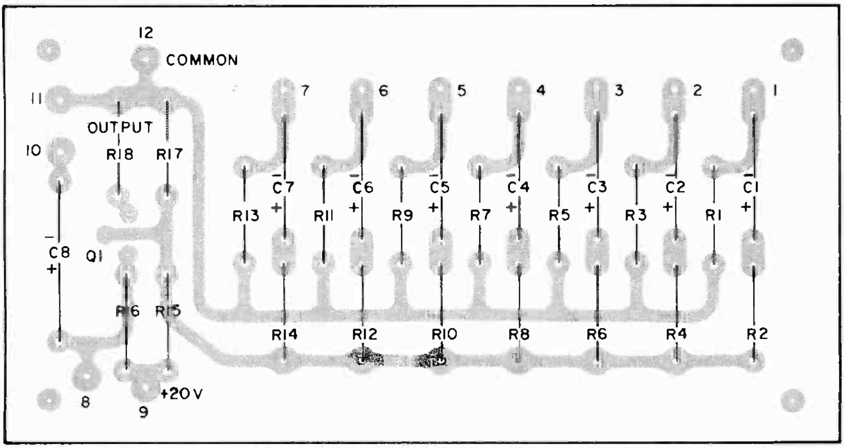


Fig. 136 – Component placement diagram for the multi-input mixer.

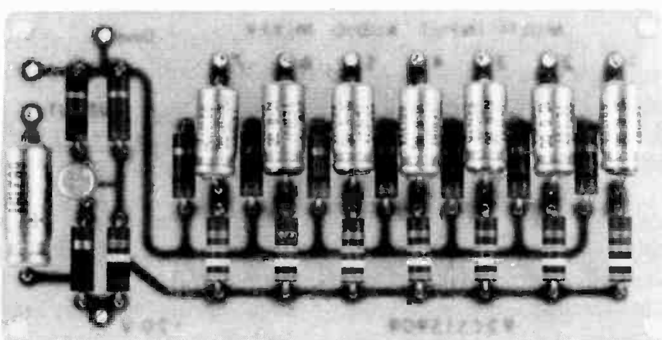


Fig. 137 – Completed circuit board for the multi-input mixer.

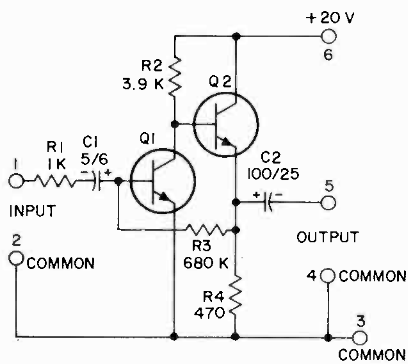
CIRCUIT NO. 22 – HEADPHONE OR LINE AMPLIFIER

The headphone or line amplifier is very useful in audio work when the power amplifier is located at some distance from the microphone. If preceded by a microphone preamplifier, such as that of Circuit No. 18, high-dynamic-range microphone preamplifier, or Circuit No. 17, all-purpose microphone preamplifier, the amplifier makes a very useful remote pickup; it is also very useful in driving the line inputs of tape recorders.

The headphone or line amplifier has a voltage gain of 100 and is capable of driving any line impedance of 250 ohms or greater. It has a maximum undistorted output of 3 volts rms into a 500-ohm line and has a frequency response flat from 20 to more than 25,000 Hz; the input impedance is 1,800 ohms.

Circuit Operation

The schematic diagram and parts list for the headphone or line amplifier are shown in Fig. 138. The interconnection of the transistors in the amplifier makes the operating conditions of the amplifier self-adjusting, i.e., the amplifier is able to maintain itself in a stable operating state in spite of variations in power-supply voltage and ambient temperature. Stability is accomplished by means of feedback through R3. If the emitter current of Q1 should increase, the base voltage of Q2 would decrease because of the additional voltage drop in R2. However, the decreased base voltage of Q2 results in a drop in the emitter current of Q2, a reduction of feedback voltage to Q1, and hence a decrease in the collector current of Q1. This decreased collector current causes an increase in the base voltage of Q2 that compensates for the original decrease and the amplifier is stabilized. The use of the output transistor as an emitter-follower makes possible the low output impedance of the amplifier.



Parts List

C1 = 5 microfarads, 6 volts, electrolytic
C2 = 100 microfarads, 25 volts, electrolytic
Q1 = transistor, RCA SK3020
Q2 = transistor, RCA SK3024
R1 = 1000 ohms, 1/2 watt, 10%
R2 = 3900 ohms, 1/2 watt, 10%
R3 = 680,000 ohms, 1/2 watt, 10%
R4 = 470 ohms, 1/2 watt, 10%

Fig. 138 – Schematic diagram and parts list for the headphone or line amplifier.

Construction

The printed-circuit-board template for this circuit is shown at the back of this Manual; Figs. 139 and 140 show a component placement diagram and a photograph of a completed board, respectively.

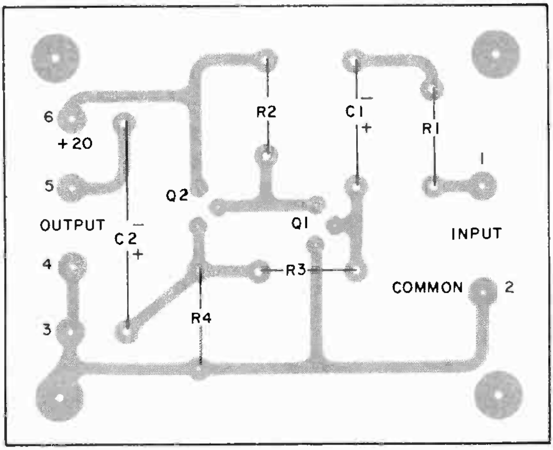


Fig. 139 – Component placement diagram for the headphone or line amplifier.

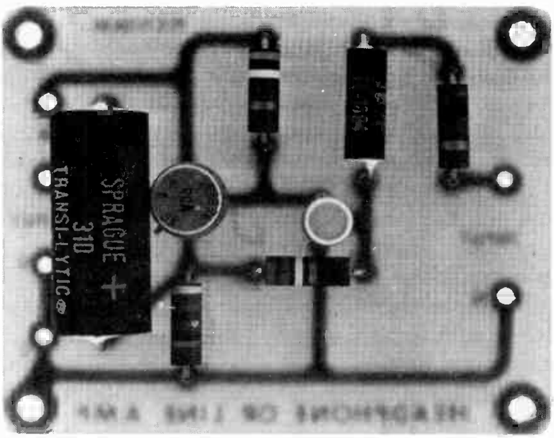


Fig. 140 – Completed circuit board for the headphone or line amplifier.

CIRCUIT NO. 23 – MIXER, COMPRESSOR, AND LINE AMPLIFIER

The audio mixer, compressor, and line amplifier is an indispensable piece of equipment for the audio enthusiast who requires uniform audio levels such as those necessary in the production of very-high-quality tape recordings. The frequency response of this circuit ranges from 20 to 35,000 Hz. Fig. 141 is a photograph of a suggested enclosure for this circuit.

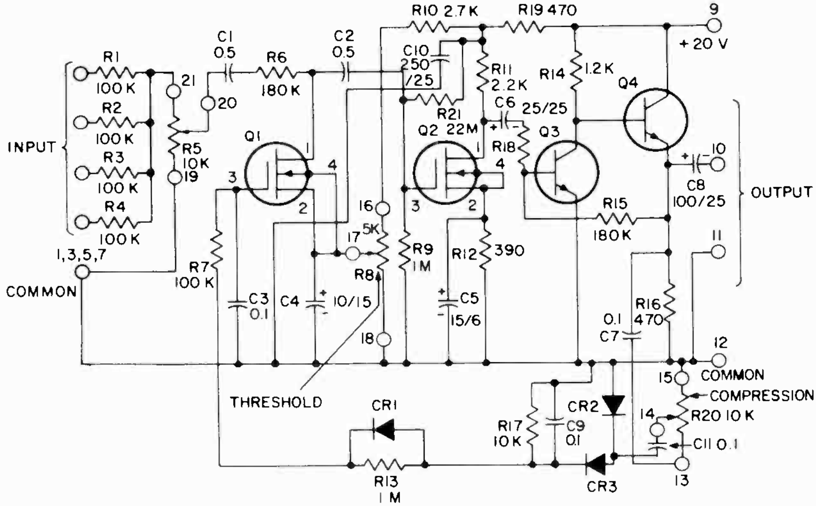
Fig. 141 – Suggested enclosure for the mixer, compressor, and line amplifier.

Circuit Operation

The schematic diagram and parts list for the mixer, compressor, and line amplifier are shown in Fig. 142. The circuit consists of a four-channel resistive mixer, an MOS transistor, Q1, that acts as a voltage-variable resistor, a high-impedance MOS transistor amplifier, Q2, and a two-stage bipolar line driver. The characteristics of an MOS field-effect transistor that make it usable as a voltage-variable resistor are discussed in the section on **Theory and Operation of Solid-State Devices**; Q1 operates as described in that section and, with R6, forms an incoming-signal voltage divider.

Circuit inputs are designed to be driven by the preamplifier circuits described in Circuit Nos. 17 through 19 or by any source capable of providing a 50- to 1000-millivolt signal. The gain of each input can be controlled by use of a 50,000-ohm potentiometer between the output of the preamplifier or other source and the input of the mixer stage. Potentiometer R5 is the master gain control; it controls all channels simultaneously.

The initial bias voltage for Q1 is set by adjustment of potentiometer R8 and is known as the threshold. It sets the level at which compression will start. When Q1 is biased off, it has an effective drain-to-source resistance of several megohms. This high resistance allows nearly all of the signal voltage appearing at the potentiometer arm of R5 to appear at the gate of Q2. The signal is amplified by Q2 and passed to the output-amplifier and line-driver transistors Q3 and Q4. The output signal of Q4 is rectified by CR2 and CR3 and the resultant dc signal is fed back to the gate of Q1. The amount of signal fed back is controlled with potentiometer R20. The rectified output signal is polarized in such a way that its application to Q1



Parts List

C1 C2 = 0.5 microfarad, 50 volts or greater, paper
C3 C9 C11 = 0.1 microfarad, 50 volts or greater, paper
C4 = 10 microfarads, 15 volts, electrolytic
C5 = 15 microfarads, 6 volts, electrolytic
C6 C7 = 25 microfarads, 25 volts, electrolytic
C8 = 100 microfarads, 25 volts, electrolytic
C10 = 250 microfarads, 25 volts, electrolytic
CR1 CR2 CR3 = diode, RCA 1N270
Q1 Q2 = MOS field-effect transistor, RCA 3N139
Q3 Q4 = transistor, RCA SK3020
R1 R2 R3 R4 R7 = 100,000 ohms, 1/2 watt, 10%
R5 = 10,000 ohms, potentiometer, audio taper
R6 R15 = 180,000 ohms, 1/2 watt, 10%
R8 = 5000 ohms, potentiometer, linear taper
R9 R13 = 1 megohm, 1/2 watt, 10%
R10 = 2700 ohms, 1/2 watt, 10%
R11 = 2200 ohms, 1/2 watt, 10%
R12 = 390 ohms, 1/2 watt, 10%
R14 = 1200 ohms, 1/2 watt, 10%
R16 R19 = 470 ohms, 1/2 watt, 10%
R17 = 10,000 ohms, 1/2 watt, 10%
R18 = 1000 ohm, 1/2 watt, 10%
R20 = potentiometer, 10,000 ohms, linear taper
R21 = 22.0 megohms, 1/2 watt, 10%

Fig. 142 – Schematic diagram and parts list for the mixer, compressor, and line amplifier.

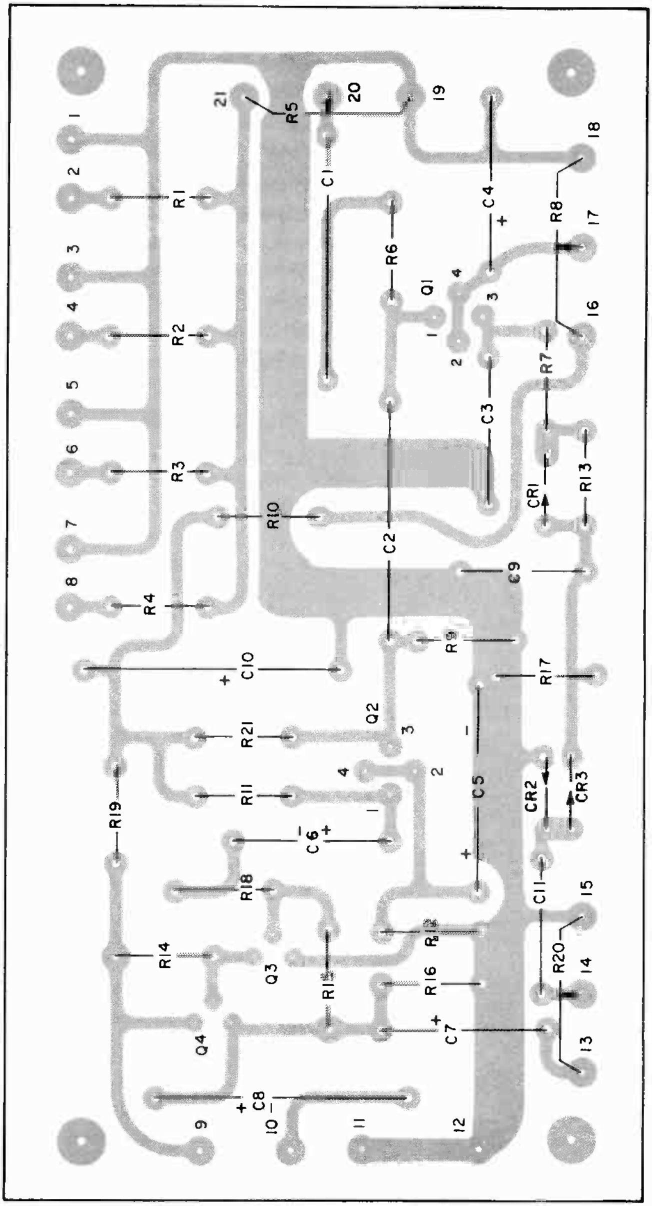


Fig. 143 – Component placement diagram for the mixer, compressor, and line amplifier.

reduces the drain-to-source resistance of that transistor. The result is a reduced input to Q2 and an over-all reduction in amplifier gain. CR1 is inserted in the feedback line so that the rectified dc signal can be applied very rapidly to the gate of Q1 and C3. During this application, C3 is charged at a very fast rate. The discharge time of C3 is slow because CR1 forces the discharge current to flow through R13. The product of this arrangement of CR1, R13, and C3 is a circuit that has a fast attack time and a relatively slow release time. A fast attack time is a very desirable characteristic in a circuit of this type because it provides for immediate reduction in system gain and consequent prevention of the overload that could occur with a loud passage of speech or music. The delayed release time helps to maintain a constant level of output during short pauses in speech or music.

Q4 is connected as an emitter-follower to provide the amplifier with a low output impedance. The line driver is designed for operation at approximately 1 to 2 volts rms into a line of 250 ohms. The circuit can be adjusted so that any input signal level between 50 millivolts and 1 volt will result in an output of approximately 1 volt or zero level. Circuit current drain is about 32 milliamperes at 20 volts.

Construction

The printed-circuit-board template for the audio mixer, compressor, and line amplifier is shown at the back of this Manual; a photograph of the completed circuit board and a component placement diagram are shown in Figs. 143 and 144, respectively.

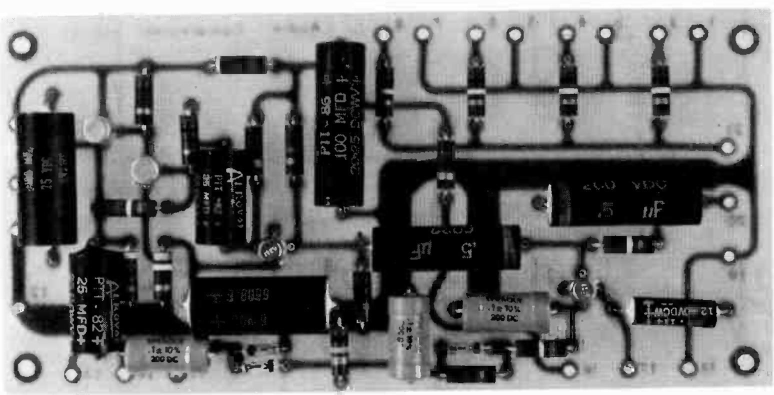


Fig. 144 – Completed circuit board for the mixer, compressor, and line amplifier.

CIRCUIT NO. 24 – STEREO PREAMPLIFIER AND MIXER

The stereo preamplifier and mixer is a versatile preamplifier of particular interest to those wishing to produce high-quality tape recordings. The preamplifier has four microphone and two line inputs that can be switched to left, right, or both channels. In addition, two auxiliary inputs are provided, one for each channel; the auxiliary inputs cannot be switched. All of the inputs that can be switched are controlled from the front panel; the two auxiliary inputs may be controlled from the

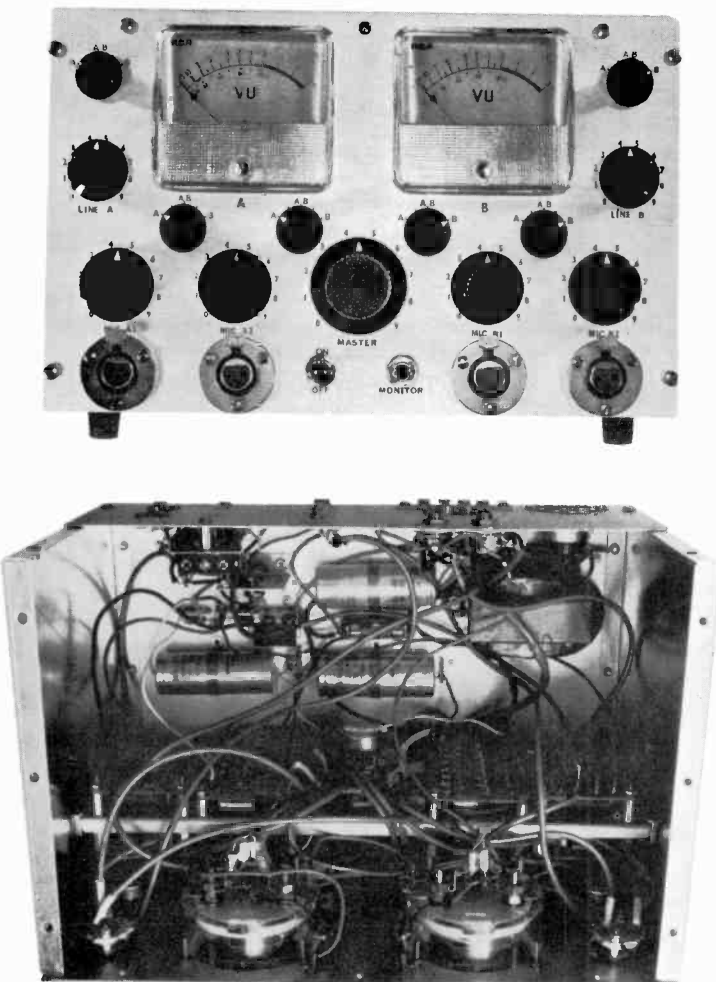
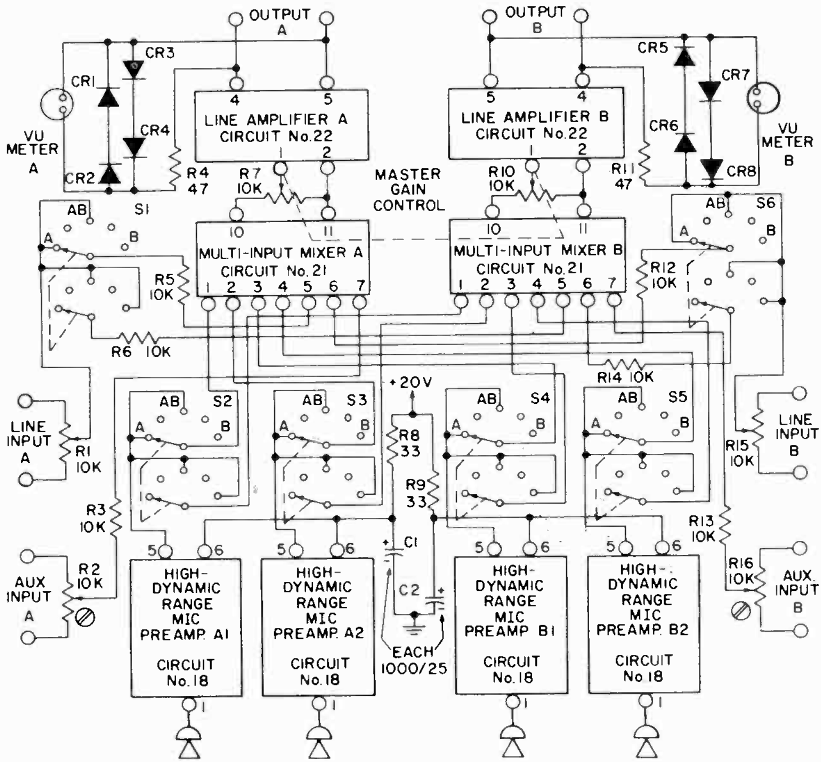


Fig. 145 – (a) Front panel arrangement and (b) interior of a suggested enclosure for the stereo preamplifier and mixer.

rear of the unit. Each output channel has its own VU meter. The arrangement of the front panel of a suggested enclosure for the stereo preamplifier and mixer is shown in Fig. 145 (a); Fig. 145 (b) shows the interior of the unit.

Circuit Operation

The stereo preamplifier and mixer is made up of three circuits



Parts List

C1 C2 = 1000 microfarads, 25 volts, electrolytic
CR1 through CR8 = rectifier, RCA SK3030
Meter = VU meter
R1 R2 R15 R16 = Potentiometer, 10,000 ohms, linear taper
R3 R5 R6 R12 R13 R14 = 10,000 ohms, 1/2 watt, 10%
R4 R11 = 47 ohms, 1/2 watt, 10%
R7 R10 = dual, 10,000 ohms-per-section potentiometer, linear taper
R8 R9 = 33 ohms, 1/2 watt, 10%
S1 through S6 = rotary switch, 2-pole, 5-position, shorting type

Fig. 146 – Interconnection diagram and parts list for the stereo preamplifier and mixer.

discussed elsewhere in this Manual and a minimum of interconnecting wiring. The three circuits are the high-dynamic-range microphone preamplifier (Circuit No. 18), the multi-input mixer (Circuit No. 21), and the headphone or line amplifier (Circuit No. 22); the interconnection diagram and parts list is shown in Fig. 146.

As shown in the interconnection diagram, the output of each microphone preamplifier is fed to a switch which can connect the output of the preamplifier to channel A (the left channel), channel B (the right channel), or both channels A and B simultaneously. The output of these switches as well as the line input for each channel is fed into the multi-input mixers. A master gain control combines or gangs the outputs from the mixers installed in each channel so that they can be simultaneously controlled. The combined signal is then fed to the line amplifiers, each of which is equipped with a VU meter. The diode limiting circuit used with each VU meter keeps the meter from being damaged during the charging and discharging of the large coupling capacitors in the line-amplifier circuit, Fig. 138. Two RC decoupling filters consisting of R8 and C1 and R9 and C2 assure circuit stability. Each filter services two microphone preamplifiers.

Construction

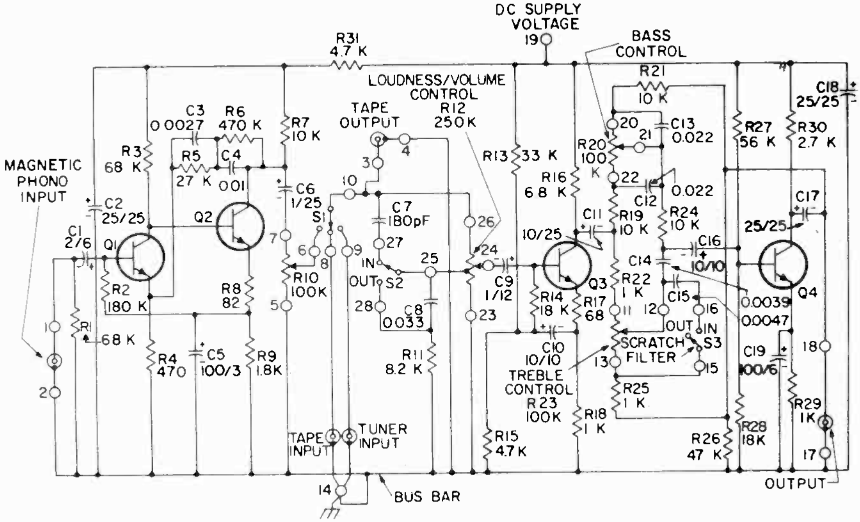
The stereo preamplifier and mixer is made up of a number of circuits as described above. The description of each of these circuits should be consulted for information on circuit boards and component placement diagrams. The individual circuit boards and the interconnecting wiring required for the stereo preamplifier and mixer may be assembled as desired by the builder.

CIRCUIT NO. 25 – PHONOGRAPH PREAMPLIFIER

The phonograph preamplifier can be used with the 7.5-watt audio amplifier of Circuit No. 29 to provide an excellent high-fidelity system. The preamplifier is designed for use with a magnetic pickup capable of supplying an input signal of at least 5 millivolts and has provisions for tape and tuner input. At the 5-millivolt signal level, the preamplifier delivers an output of at least 1 volt.

Circuit Operation

The schematic diagram and parts list for the phonograph preamplifier are shown in Fig. 147. Transistor Q1 is a low-noise transistor and is directly coupled to Q2. A frequency-shaping network in the feedback circuit of Q2 provides frequency compensation when the preamplifier is used with a magnetic phonograph pickup. The output circuit of Q2 contains a level control R10 that feeds the loudness control S2 through the selector switch S1. The loudness control, in turn, drives the tone-control circuits of the preamplifier. Tape, tuner, or phono inputs can be selected by means of the selector switch; a connector in the arm of the selector switch permits tape recordings to be made without affecting volume or loudness and vice versa.



Parts List

C1 = 2 microfarads, 6 volts, electrolytic

C2 C17 C18 = 25 microfarads, 25 volts, electrolytic

C3 = 0.0027 microfarad, 200 volts, paper

C4 = 0.01 microfarad, 200 volts, paper

C5 = 100 microfarads, 3 volts, electrolytic

C6 = 1 microfarad, 25 volts, electrolytic

C7 = 180 picofarads, 500 volts, mica

C8 = 0.033 microfarad, 200 volts, paper

C9 = 1 microfarad, 12 volts, electrolytic

C10 C16 = 10 microfarads, 10 volts, electrolytic

C11 = 10 microfarads, 25 volts, electrolytic

C12 C13 = 0.022 microfarad, 200 volts, paper

C14 = 0.0039 microfarad, 200 volts, paper

C15 = 0.0047 microfarad, 200 volts, paper

C19 = 100 microfarads, 6 volts, electrolytic

Q1 Q2 Q3 Q4 = transistor, RCA SK3020

R1 R3 = 68,000 ohms, 1/2 watt, 10%

R2 = 180,000 ohms, 1/2 watt, 10%

R4 = 470 ohms, 1/2 watt, 10%

R5 = 27,000 ohms, 1/2 watt, 10%

R6 = 470,000 ohms, 1/2 watt, 10%

R7 R19 R21 R24 = 10,000 ohms, 1/2 watt, 10%

Fig. 147 – Schematic diagram and parts list for the phonograph preamplifier.

Parts List (Cont'd)

R8 = 82 ohms, 1/2 watt, 10%
R9 = 1800 ohms, 1/2 watt, 10%
R10 = potentiometer, 100,000 ohms, audio taper
R11 = 8200 ohms, 1/2 watt, 10%
R12 = potentiometer, 250,000 ohms, audio taper with tap
R13 = 33,000 ohms, 1/2 watt, 10%
R14 R28 = 18,000 ohms, 1/2 watt, 10%
R15 R31 = 4700 ohms, 1/2 watt, 10%
R16 = 6800 ohms, 1/2 watt, 10%
R17 = 68 ohms, 1/2 watt, 10%
R18 R22 R25 R29 = 1000 ohms, 1/2 watt, 10%
R20 R23 = potentiometer, 100,000 ohms, linear taper
R26 = 47,000 ohms, 1/2 watt, 10%
R27 = 56,000 ohms, 1/2 watt, 10%
R30 = 2700 ohms, 1/2 watt, 10%
S1 = switch, single-pole, 3-position, wafer
S2 = toggle switch, single-pole, double-throw
S3 = toggle switch, single-pole, single-throw

Fig. 148 shows the response of the treble and bass tone controls as a function of frequency. Boost of 10 dB and cut of 15 dB are available for deep bass and high treble frequencies. Each control operates independently so that precise tone shaping is possible. When both controls are in the center position, the response is flat; the bass and treble frequencies are equally mixed.

Output distortion is low at all frequencies for any setting of either the bass or the treble tone control.

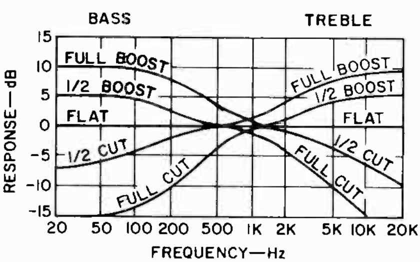


Fig. 148 – Response of treble and bass tone controls as a function of frequency.

The collector-to-base feedback in Q3 and Q4 works with the tone controls to provide the over-all tonal response of the preamplifier.

Included in the preamplifier is a loudness/volume control switch S2. With the loudness control in, lower tones are enhanced at low output levels and a more pleasing sound is produced; when the loudness control is switched out, the volume control attenuates all tones equally, as shown in Fig. 149 (a).

The scratch filter attenuates somewhat the frequencies at which scratch noise from scratched records is most prevalent. Fig. 149 (a) shows frequencies attenuated by the scratch filter; S3 controls the filter. Fig. 149 (b) compares the measured response of the preamplifier with an ideal response.

A magnetic-pickup level control is provided so that the preamplifier does not have to be readjusted when the input is changed from magnetic phonograph to tape, for example.

DC power for the preamplifier can be obtained from a 20-volt

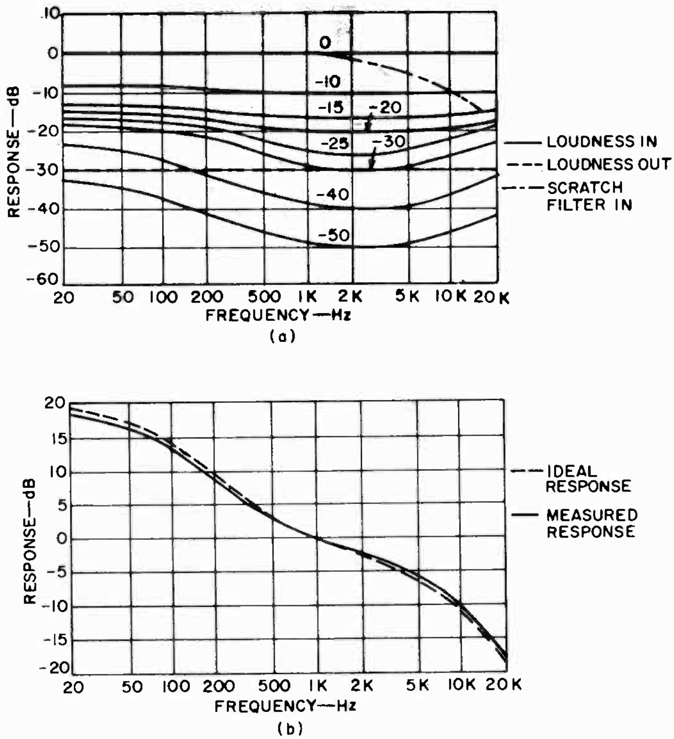


Fig. 149 – (a) Effect of loudness control and scratch filter, and (b) comparison of measured response with ideal response.

power supply or from the 7.5-watt audio amplifier supply (Circuit No. 29) through the RC circuit shown in Fig. 150. A 300-millivolt input level from a tuner or tape recorder is required to produce a 1-volt output; a 5-millivolt input level is required from a magnetic phonograph pickup to produce the same output. The current drain for the phonograph preamplifier is 7.5 milliamperes at 20 volts.

Construction

To keep the hum level at a minimum, a requirement in any high-gain audio system, a progressive grounding method or common bus

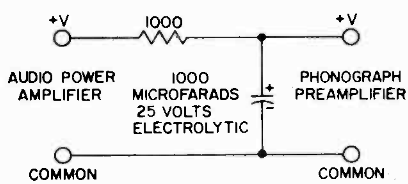


Fig. 150 – RC circuit required to adapt the power supply of the 7.5-watt audio amplifier (Circuit No. 29) to the phonograph preamplifier.

has been used. In this system, shown in Fig. 151, a bus wire made from a length of No. 18 wire is connected between the common input and the common output terminals. All grounds of the preamplifier circuit are then connected to this common bus.

If the preamplifier is used by itself, the external ground connection can be made at either end of the bus bar, whichever produces the lowest hum level. If the preamplifier is used with the audio power amplifier, the preamplifier is grounded through the power amplifier and no physical ground is made to the preamplifier itself.

The drilling template for the phonograph preamplifier is shown at the back of the Manual; a component layout diagram and a photograph of a complete circuit board are shown in Figs. 152 and 153, respectively.

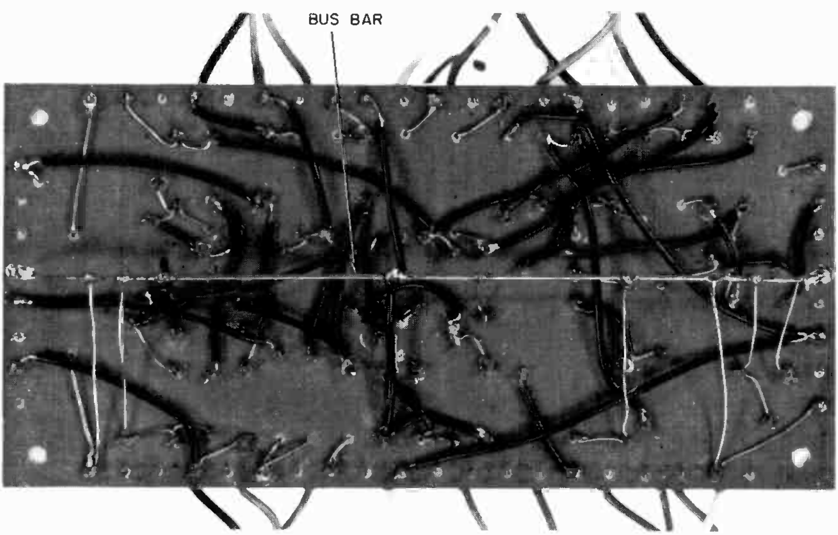


Fig. 151 – Back of phonograph preamplifier circuit board showing bus bar.

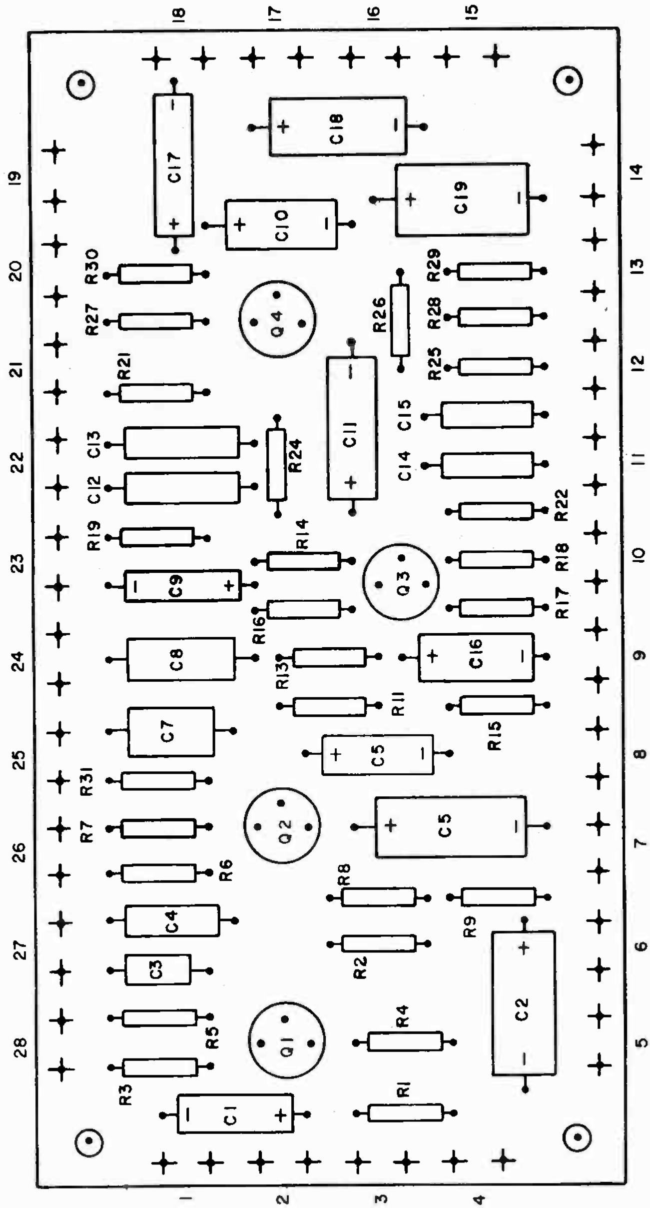


Fig. 152 – Component placement diagram for the phonograph preamplifier.

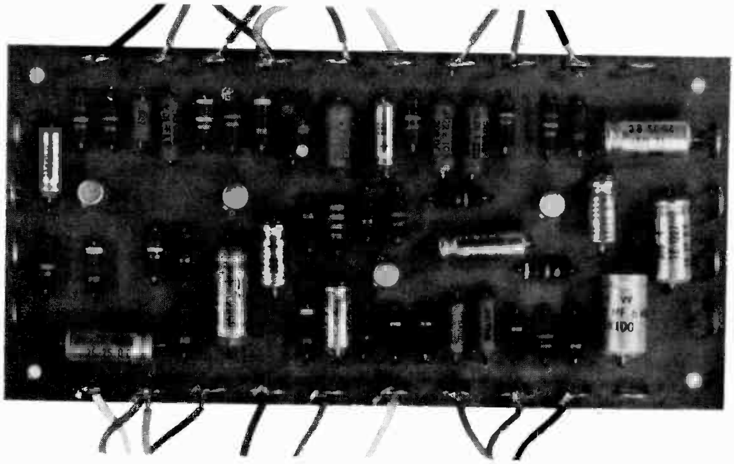


Fig. 153 – Completed circuit board for the phonograph preamplifier.

CIRCUIT NO. 26 – PHOTOELECTRIC AUDIO ATTENUATOR

The photoelectric audio attenuator makes possible the adjustment of the volume of an amplifier, radio, or TV set from a remote position with no hum or deterioration in the final audio-output signal. There is practically no limit to the distance from which an audio system can be controlled. Fig. 154 shows the photoelectric-audio-attenuator power supply in a suggested chassis.

Circuit Operation

The schematic diagram and parts list for the photoelectric audio attenuator power supply are shown in Fig. 155. The remote volume-control potentiometer R2, which is external to the supply, controls the output voltage of transistor Q1; Q1 provides filtered dc to the pilot lamp I1. Filtered dc must be used to power the lamp because any hum modulation in the lamp would be passed on to the audio system. When the output of Q1 is varied by means of R2, the voltage and thus the brightness of the pilot lamp are also varied. The brightness of the lamp directly affects the conduction capability of the photoconductive cell. When no light falls on the cell its resistance is very high, more than 1 megohm; in a solid-state amplifier,

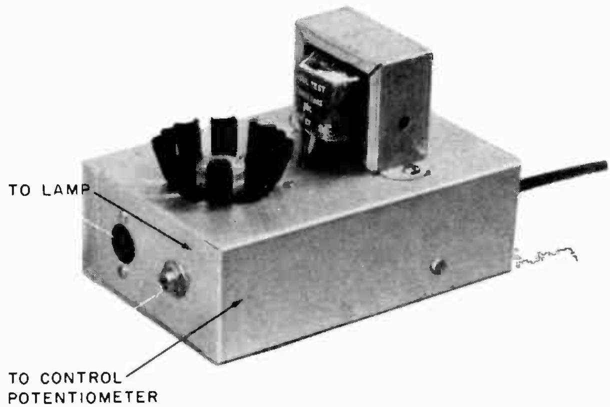
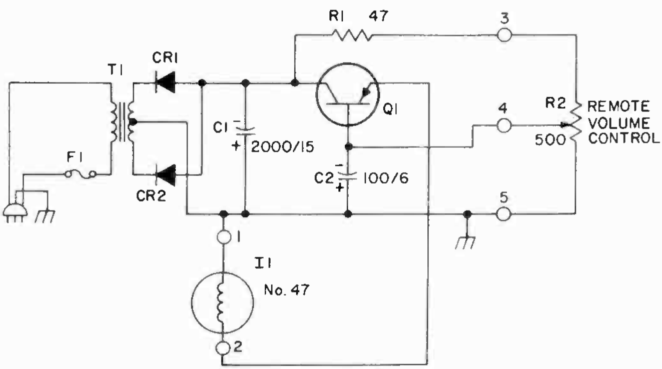


Fig. 154 – Suggested enclosure for the photoelectric-audio-attenuator power supply.



Parts List

C1 = 2000 microfarads, 15 volts, electrolytic
C2 = 100 microfarads, 6 volts, electrolytic
CR1 CR2 = rectifier, RCA SK3030
F1 = fuse, 1 ampere, 125 volts
I1 = lamp, No. 47
Photocell = RCA KD2106
Q1 = transistor, RCA SK3009
R1 = 47 ohms, 1/2 watt, 10%
R2 = potentiometer, 500 ohms, linear taper
T1 = transformer; primary 12.6 volts, secondary center-tapped at 2 amperes; Stancor No. P8130 or equivalent.

Fig. 155 – Schematic diagram and parts list for the photoelectric-audio-attenuator power supply.

with the cell in series with the audio signal, the volume of the audio system controlled is minimum under this condition. When fully illuminated by the pilot lamp, the cell has a resistance of about 200 ohms, and the volume of the audio system controlled is maximum. The major advantage of the method of volume control used in this circuit is that no audio signal is carried in the volume control line; therefore, no undesirable effects can be imposed on the audio signal. Remote controls that carry the audio signal through shielded cable suffer from a capacitive effect that degrades the high-frequency characteristics of the audio system.

Although intended to be placed in series with the input of the amplifiers shown elsewhere in this Manual, the photoelectric audio attenuator can be used with any audio circuit. When used with high-impedance circuits, such as vacuum-tube audio circuits, the cell should be connected as shown in Fig. 156. The effect of lamp brightness on gain is now reversed from that described above: when the lamp is extinguished the gain is maximum; when the lamp is at full brightness, the gain is minimum.

Construction

Special care must be taken in the construction of this circuit to prevent ambient light from falling on the photoconductive cell and limiting the maximum resistance of the cell. One method of protecting the cell from extraneous light is to slip the photocell and the pilot lamp into a short piece of heat-shrinkable tubing so that the photosensitive portion of the photocell faces the lamp and then shrink the tubing around the

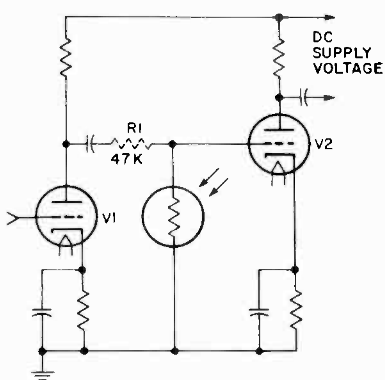


Fig. 156 – Method of connecting the photocell in high-impedance (vacuum tube) circuits.

two to form a light-tight covering as shown in Fig. 157. The same result can be accomplished, although not as neatly, by wrapping cell and lamp in black plastic tape.

Because of the small number of components used in this circuit, the layout is left to the circuit builder. Fig. 158 shows a suggested layout of the interior of the photoelectric-audio-attenuator power-supply chassis pictured in Fig. 154.

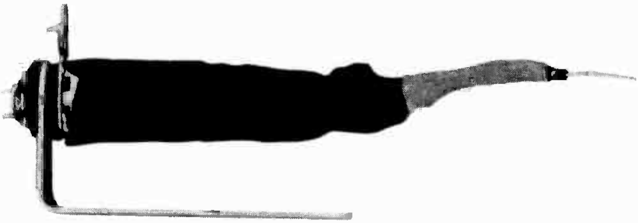


Fig. 157 – Method of mounting the lamp and photocell facing each other within a piece of heat-shrinkable tubing.

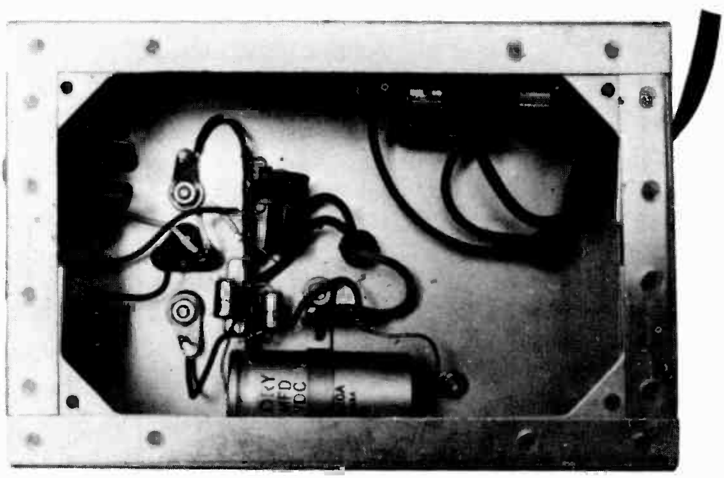


Fig. 158 – Interior of the photoelectric-audio-attenuator power-supply chassis.

CIRCUIT NO. 27 – IC WIRELESS MICROPHONE

The wireless microphone, shown in Fig. 159, can transmit on any FM broadcast-band frequency within the range of 88 to 108 MHz. Its range is approximately 50 to 150 feet depending on the location of the receiver antenna relative to the antenna of the wireless microphone. The length of the wireless microphone antenna has been designed to maintain radiation well within FCC regulations.

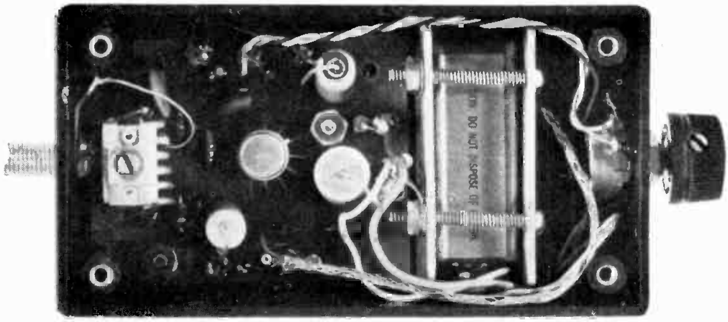


Fig. 159 – Interior of suggested enclosure for the IC wireless microphone.

Circuit Operation

The schematic diagram and parts list for the IC wireless microphone are shown in Fig. 160 (a); Fig. 160 (b) shows the schematic diagram for the IC. Q1 is used as an oscillator and

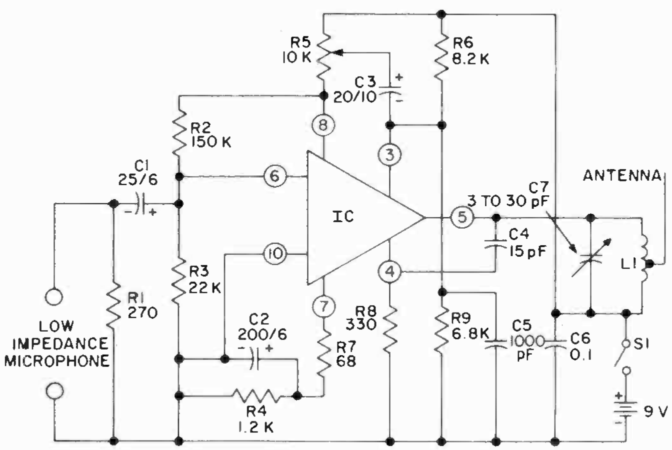


Fig. 160 (a) – Schematic diagram for the IC wireless microphone. Parts list on next page.

Parts List

C1 = 25 microfarads, 6 volts, electrolytic
C2 = 200 microfarads, 6 volts, electrolytic
C3 = 20 microfarads, 10 volts, electrolytic
C4 = 15 picofarads, silver mica, 100 volts or greater
C5 = 1000 picofarads, 25 volts or greater, ceramic
C6 = 0.1 microfarad, 25 volts or greater, ceramic
C7 = 3 to 30 picofarads, trimmer type, mica compression type
IC = integrated circuit; RCA KD2114 (Available in KD2117 Variety Pack)
L1 = 6 turns No. 12 wire; coil I.D. 5/16 inch, length 3/4 inch
R1 = 270 ohms, 1/2 watt, 10%
R2 = 150,000 ohms, 1/2 watt, 10%
R3 = 22,000 ohms, 1/2 watt, 10%
R4 = 1200 ohms, 1/2 watt, 10%
R5 = 10,000 ohms, trimmer potentiometer
R6 = 8200 ohms, 1/2 watt, 10%
R7 = 68 ohms, 1/2 watt, 10%
R8 = 330 ohms, 1/2 watt, 10%
R9 = 6800 ohms, 1/2 watt, 10%
S1 = switch; single-pole, single-throw, slide type
Antenna = 3/16-inch-diameter rod, 2-1/2 inches long
Microphone = low-impedance, 200 to 600 ohms, RCA HK-99 or equivalent

Q2 as a microphone amplifier. Q1 is operated in an rf-grounded base circuit that permits application of the audio signal to its base. When operated in this manner, the output of oscillator transistor Q1 is frequency modulated.

Table XXVI shows voltages at the terminals of an IC in a properly operating circuit.

Construction

Because of the small number of parts in the circuit, the assembly is left to the builder.

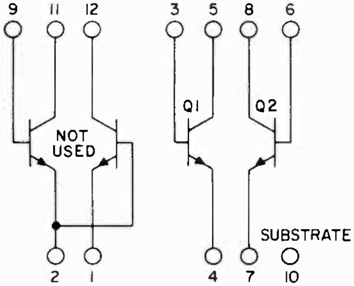


Fig. 160 (b) – Schematic diagram for the KD2114 IC.

Table XXVI. Voltages at IC Terminals in Wireless Microphone Circuit

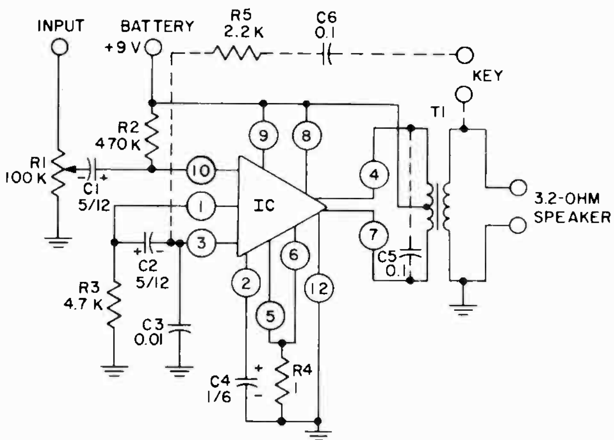
Terminal	Voltage (Volts)
3	3
4	3
5	9
6	0.85
7	0.2
8	7

CIRCUIT NO. 28 – IC AUDIO AMPLIFIER-OSCILLATOR

The IC audio amplifier-oscillator can be used as an amplifier in portable systems, such as portable phonographs, or in any application that requires a low-power, portable, light-weight unit. The amplifier requires an input signal of 40 millivolts, and provides an output power of 1/2 watt. Two amplifiers may be used to form a stereo system. The audio oscillator can be used with a telegraph key as a code practice oscillator or with an on-off switch to provide a continuous tone. (This circuit is available in kit form as RCA Project Kit KC-4003.)

Circuit Operation

The schematic diagram and parts list for the IC audio amplifier-oscillator are shown in Fig. 161. The KD2115 is a wideband power amplifier that includes a voltage regulator, buffer or amplifier, dif-



Parts List

C1 C2 = 5 microfarads, 12 volts, electrolytic

C3 = 0.01 microfarad, 25 volts or greater

C4 = 1 microfarad, 6 volts, electrolytic

C5 C6 = 0.1 microfarad, 25 volts or greater (not used in amplifier)

IC = integrated circuit, RCA KD2115 (Available in KD2117 Variety Pack)

R1 = potentiometer; 100,000 ohms, 1/2 watt, linear taper

R2 = 470,000 ohms, 1/2 watt, 10%

R3 = 4700 ohms, 1/2 watt, 10%

R4 = 1 ohm, 1/2 watt, 10%

R5 = 2200 ohms, 1/2 watt, 10%

T1 = transformer; United Transformer Company, HCA308 or equivalent; primary, 200 ohms; secondary, 3.2 ohms, 500 milliwatts

Fig. 161 – Schematic diagram and parts list for the IC audio amplifier/oscillator.

ferential amplifier and phase splitter, driver, and power-output amplifier; Fig. 162 shows the schematic diagram of the IC. The voltage regulator consists of diodes CR1, CR2, and CR3, along with resistors R10 and R11. The regulator keeps

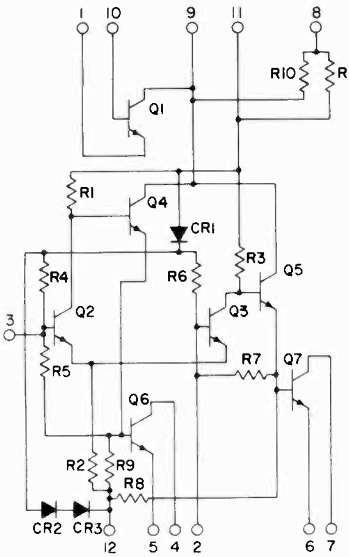


Fig. 162 – Schematic diagram for the KD2115 IC.

power dissipation constant within the -55 to + 125°C temperature range and supplies two voltages to the differential amplifier: a base supply voltage of about 1.4 volts and a collector supply voltage of about 2.1 volts.

The differential-amplifier and phase-splitter circuit consists of transistors Q2 and Q3, collector resistors R1 and R3, emitter resistor R2, and biasing resistors R4, R5, R6, and R7. The ac signal voltage is applied to the buffer amplifier Q1 through terminal 10; the output of Q1 is coupled from its emitter, terminal 1, to the base of Q2, terminal 3.

The ac signal, after being phase split by transistors Q2 and Q3, is applied to the emitter-follower transistors Q4 and Q5 which, along with emitter resistors R8 and R9, form the driver stage. Feedback resistors R5 and R7 provide dc and ac stability in the differential amplifier. Application of the feedback voltages from Q4 and Q5 to the differential amplifier through R5 and R7 compensates for any imbalance. If these resistors were not used, the dc voltage between the collectors of Q2 and Q3 might vary from zero.

Power transistors Q6 and Q7 accept the ac signal from the emitters of Q4 and Q5 and deliver power to the load. Table XXVII shows voltages at the terminals of an IC in a properly operating circuit.

Table XXVII.
Voltages at IC Terminals in Audio Amplifier-Oscillator

Terminal	Voltage (Volts)
1	3.8
2	0.8
3	0.8
4	9
7	9
8	9
9	9
10	4.5

Special Considerations

Components C5, C6, and R5 are not required in the amplifier. In the oscillator circuit, the potentiometer acts as a tone control. A 3-volt power supply should be sufficient for most oscillator uses; the 9-volt supply tends to make the audio output level too high for comfort.

Construction

The drilling template for the IC audio amplifier-oscillator is shown at the back of this manual. A combined component placement diagram and photograph of the completed circuit board is shown in Fig. 163.

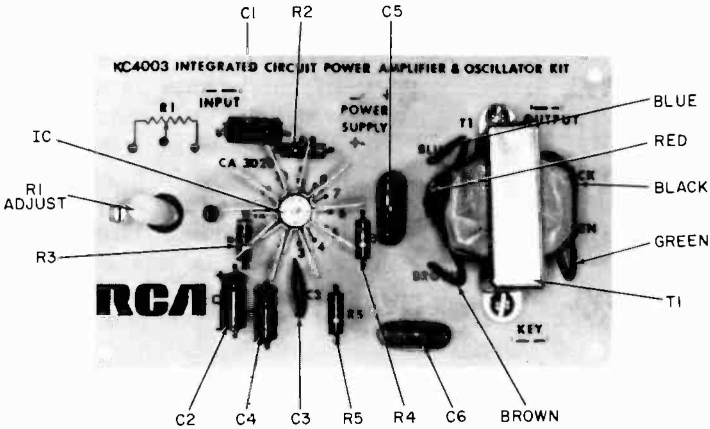


Fig. 163 – Completed circuit board showing component placement for the IC audio amplifier/oscillator.

CIRCUIT NO. 29 – 7.5-WATT AUDIO AMPLIFIER

The 7.5-watt audio amplifier is compatible with all of the circuits in this Manual. A suggested chassis layout for the amplifier is shown in Fig. 164.

Circuit Operation

The schematic diagram and parts list of the audio power amplifier are shown in Fig. 165. This circuit is designed for use with the universal series supply (Circuit No. 2); however, the simpler unregulated supply shown in Fig. 166 may also be used.

The output stage of the amplifier is a class B complementary-symmetry circuit that allows the speaker to be driven directly without the need of a transformer. The fundamental operation of a complementary-symmetry circuit can best be understood by examining the circuit conditions at three points in the output-voltage cycle: the point at which the instantaneous output voltage is zero

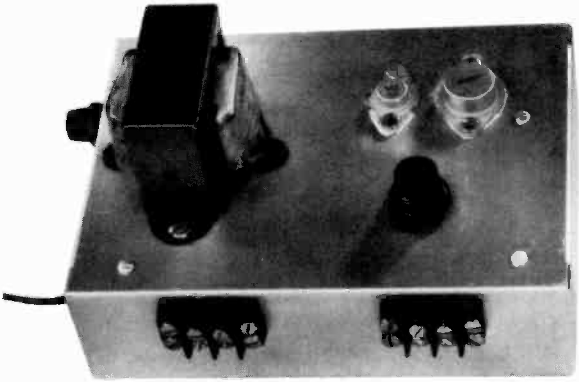


Fig. 164 – Suggested enclosure for the 7.5-watt audio amplifier.

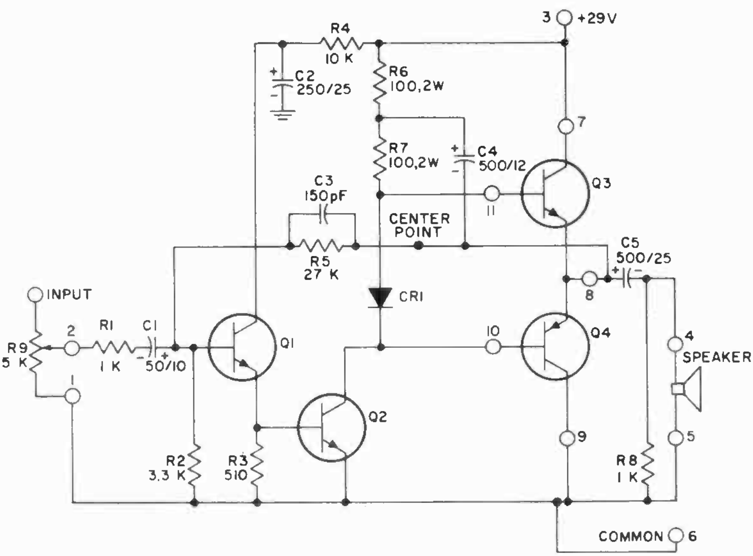


Fig. 165 – Schematic diagram for the 7.5-watt audio amplifier. Parts list on next page.

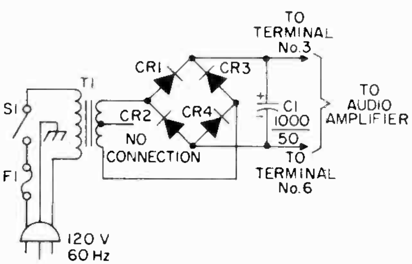
Parts List

C1 = 50 microfarads, 10 volts, electrolytic
C2 = 250 microfarads, 25 volts, electrolytic
C3 = 150 picofarads, 50 volts or greater
C4 = 500 microfarads, 12 volts, electrolytic
C5 = 500 microfarads, 25 volts, electrolytic
CR1 = rectifier, RCA SK3030
Q1 = transistor, RCA SK3020
Q2 = transistor, RCA SK3024 with heat sink, Wakefield NF209 or equivalent.
Q3 = transistor, RCA SK3026
Q4 = transistor, RCA SK3009
R1 R8 = 1000 ohms, 1/2 watt, 10%
R2 = 3300 ohms, 1/2 watt, 10%
R3 = 510 ohms, 1/2 watt, 10%
R4 = 10,000 ohms, 1/2 watt, 10%
R5 = 27,000 ohms, 1/2 watt, 10%
R6 R7 = 100 ohms, 2 watts, 10%
R9 = potentiometer, 5000 ohms, linear taper
Speaker = 8 ohms

(the dc condition), the point at which the voltage is peak positive, and the point at which the output voltage is peak negative. It is assumed that the frequency of operation is high enough to prevent a change in voltage across the capacitors during the output cycle.

When no signal voltage is applied to the circuit, the center-point voltage is 12 volts (the center point is indicated on the circuit schematic). The operating-point voltage of the driving transistor Q2, and consequently the dc voltage at the center point, is established by the beta and base-to-emitter voltage of Q2 and the values of resistors R2, R5, R6, and R7. The bias voltage that establishes the idling or no-signal current in the output stage is developed across CR1. At idle, the rectifier voltage equals the base-to-emitter voltages of the two output transistors, Q3 and Q4.

When a negative signal is applied to Q1, the base current of Q2 is reduced. The reduction in base current reduces the collector current of Q3. Capacitor C4 maintains a



Parts List

C1 = 1000 microfarads, 50 volts, electrolytic
CR1 CR2 CR3 CR4 = rectifier, RCA SK3030
F1 = fuse, 1 ampere, 125 volts, slow-blow
S1 = toggle switch, 125 volts, 1 ampere, single-pole, single-throw
T1 = filament transformer, 115 volts primary, 24 volts secondary, Triad No. F-45X or equivalent

Fig. 166 – Simple unregulated power supply for use with the 7.5-watt audio amplifier.

constant voltage and, therefore, a constant current through R7. Because of this constant current in R7, the base current in Q3 increases by the same amount that the collector current in Q2 decreases. Q3 turns on and applies a positive voltage to C5 and the speaker load.

When a positive signal is applied to Q1, the base current of Q2 increases. The higher base current, in turn, increases the collector current of Q2. Then, because the current through R7 is constant, the additional current required in the collector of Q2 flows out of the base of Q4 and Q4 turns on. Capacitor C5 applies a negative voltage across the load through Q4. The frequency of the signal and the value of C5 are high enough so that the voltage of C5 goes through negligible change during the half-cycle.

Capacitor C3 reduces the cross-over distortion through feedback. An input of approximately 0.5 volt is required for full power output. The current drain for this circuit is about 95 milliamperes with no signal.

Construction

The drilling template for the audio power amplifier is shown at the back of the Manual; a photograph of the interior of the suggested enclosure and a component placement diagram are shown in Figs. 167 and 168, respectively. The layout given is the best for this circuit. Transistors Q3 and Q4 are mounted external to the circuit board on a heat sink (Wakefield No. NC401K or equivalent) or on a metal chassis. The wires connecting Q3 and Q4 to the circuit board should be as short as possible so that there is no lead resistance and no possibility of capacitive coupling to other circuits. Transistor Q2 must be fitted with a heat radiator such as a Wakefield NF209 or equivalent.

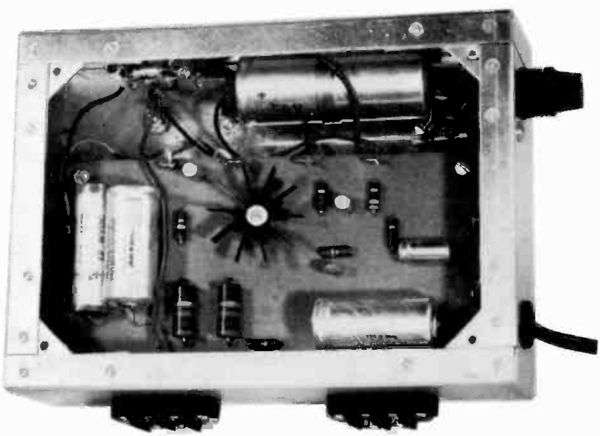


Fig. 167 – Interior of the enclosure suggested for the 7.5-watt audio amplifier.

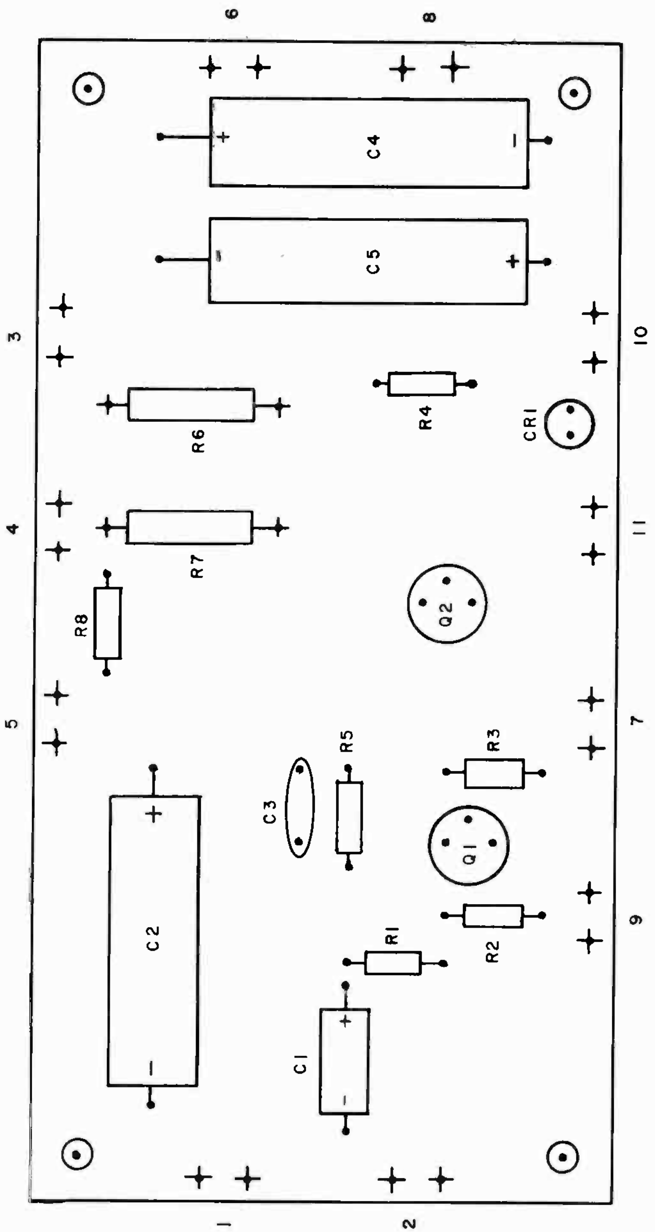


Fig. 168 – Component placement diagram for the 7.5-watt audio amplifier.

The power-supply transformer should have a dc resistance in the secondary of at least 1 ohm. If it does not, a 1-ohm 2-watt resistor should be inserted in series with the secondary. If a center-tapped supply is used, the resistance should be placed in series with the center tap. No special precautions are required if the transformer specified in the parts list is used.

Under no circumstances should the output terminals be shorted when there is a signal applied to the input; a burned-out output transistor can result. To help protect the output transistor a 3/4-ampere slow-blow fuse may be inserted in the output circuit.

CIRCUIT NO. 30 – 15-WATT STEREO AMPLIFIER

The 15-watt stereo amplifier shown in a suggested enclosure in Fig. 169 is rated at 15 watts per channel continuous power output and more than 20 watts per channel music power output; an input signal of from 100 to 300 millivolts is required for full output. The amplifier, whose frequency response is essentially flat from 20 Hz to well over 20,000 Hz, may be used directly with the phonograph preamplifier of Circuit No. 25, the stereo preamplifier and mixer of Circuit No. 24, or any commercial FM stereo tuner.

The amplifier circuit, shown with parts list in Fig. 170, is of the complementary-symmetry type; the two power-output stages are powered by one power supply consisting of a full-wave bridge-rectifier system and one filter capacitor.

Construction

With the exception of the power transformer, the filter capacitor, the output coupling capacitors, and the output transistors, all amplifier components are contained within a 5- by 7- by 3-inch aluminum chassis.

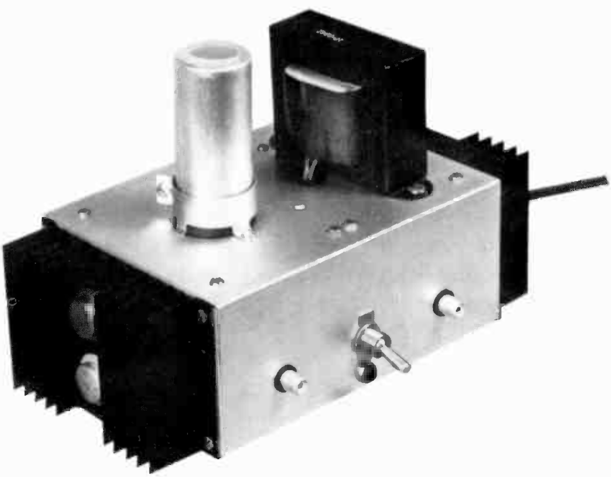
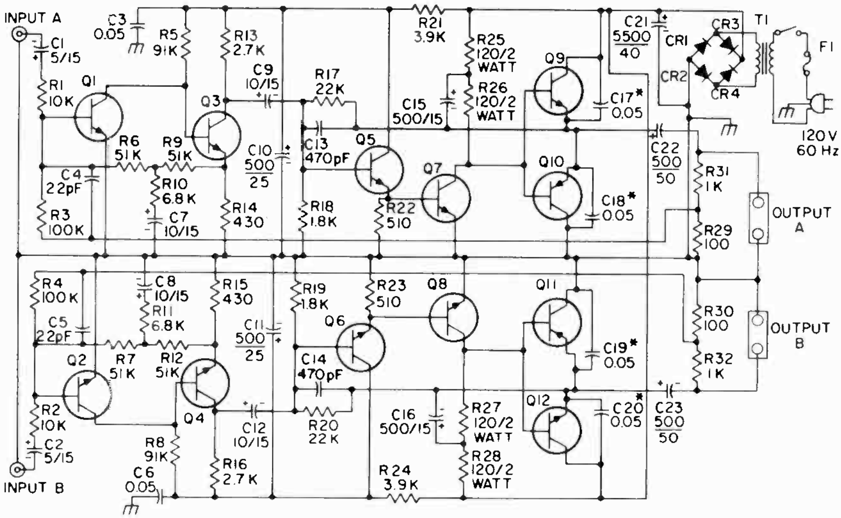


Fig. 169 – Suggested enclosure for the 15-watt stereo amplifier.



* CONNECT CAPACITORS BETWEEN COLLECTOR AND EMITTER AT TRANSISTOR

Parts List

C1 C2 = 5 microfarads, 15 volts, electrolytic

C3 C6 C17 C18 C19 C20 = 0.05 microfarad

C4 C5 = 22 picofarads

C7 C8 C9 C12 = 10 microfarads, 15 volts, electrolytic

C10 C11 = 500 microfarads, 25 volts, electrolytic

C13 C14 = 470 picofarads

C15 C16 = 500 microfarads, 15 volts, electrolytic

C21 = 5500 microfarads, 40 volts, electrolytic

C22 C23 = 500 microfarads, 50 volts, electrolytic

CR1 through CR4 = rectifier RCA SK3030

F1 = fuse, 1.5 amperes, slow-blow

Q1 through Q6 = transistor, RCA SK3020

Q7 Q8 = transistor, RCA SK3024

Q9 Q12 = transistor, RCA SK3027

Q10 Q11 = transistor, RCA SK3009

R1 R2 = 10,000 ohms, 1/2 watt, 10%

R3 R4 = 100,000 ohms, 1/2 watt, 10%

R5 R8 = 91,000 ohm, 1/2 watt, 10%

R6 R7 R9 R12 = 51,000 ohms, 1/2 watt, 10%

R10 R11 = 6800 ohms, 1/2 watt, 10%

R13 = 2700 ohms, 1/2 watt, 10%

R14 R15 = 430 ohms, 1/2 watt, 10%

Fig. 170 – Schematic diagram and parts list for the 15-watt stereo amplifier.

Parts List (Cont'd)

R16 = 2700 ohms, 1/2 watt, 10%
R17 R20 = 22,000 ohms, 1/2 watt, 10%
R18 R19 = 1800 ohms, 1/2 watt, 10%
R21 R24 = 3900 ohms, 1/2 watt, 10%
R22 R23 = 510 ohms, 1/2 watt, 10%
R25 R26 R27 R28 = 120 ohms, 2 watts, 10%
R29 R30 = 100 ohms, 1/2 watt, 10%
R31 R32 = 1000 ohms, 1/2 watt, 10%
S1 = toggle switch; single-pole, single-throw; 125 volts, 3 amperes
T1 = transformer, Stancor TP-4 or equivalent

The voltage amplifiers and drivers for each channel are mounted on printed-circuit boards; Fig. 171 shows the circuit boards, supported by 1-inch threaded bushings, mounted within the chassis. The placement of components on the circuit boards is shown in Fig. 172; the board template is shown at the back of this Manual. Fig. 173 is a photograph of a completed circuit board. The output coupling capaci-

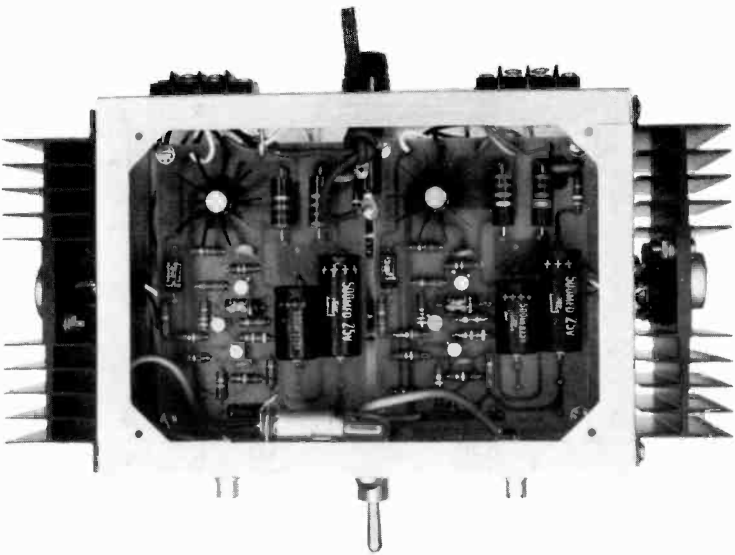
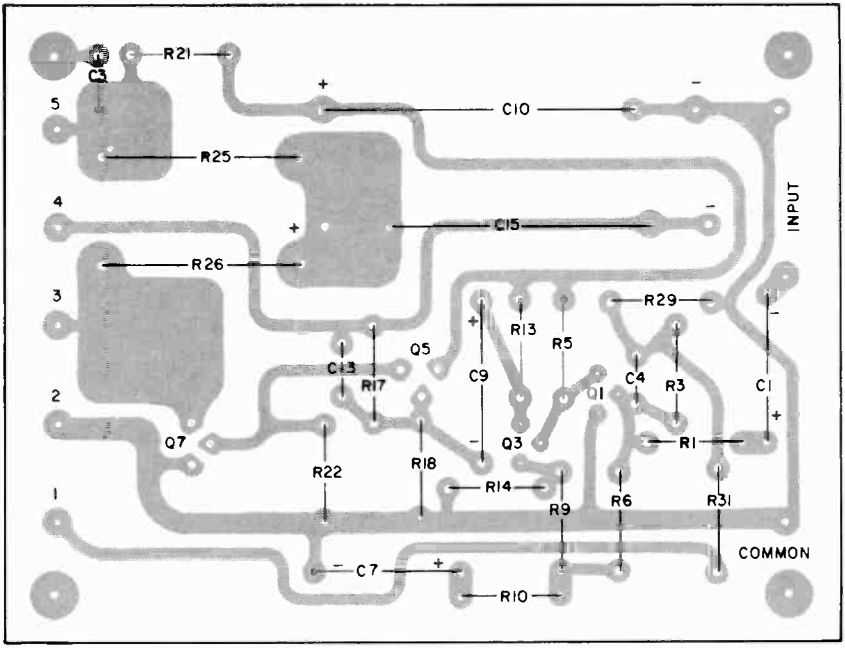


Fig. 171 – Interior of the suggested enclosure showing mounted circuit boards.



Channel A	Channel B	Channel A	Channel B
R1	R2	C3	C6
R3	R4	C4	C5
R5	R8	C7	C8
R6	R7	C9	C12
R9	R12	C10	C11
R10	R11	C13	C14
R13	R16	C15	C16
R17	R20	C17	C20
R18	R19	C18	C19
R21	R24	C22	C23
R22	R23		
R25	R28	Q1	Q2
R26	R27	Q3	Q4
R29	R30	Q5	Q6
R31	R32	Q7	Q8
		Q9	Q12
C1	C2	Q10	Q11

Fig. 172 – Component placement diagram for one channel of the 15-watt stereo amplifier; the table below identifies the components for the second channel. The channel B component is mounted in place of the channel A component.

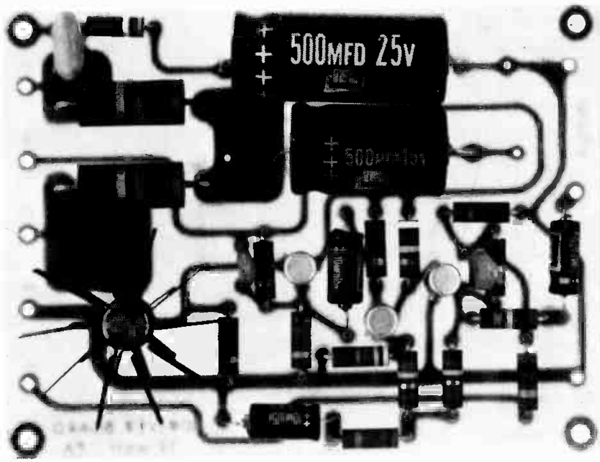


Fig. 173 – Completed circuit board for the 15-watt stereo amplifier.

tors C22 and C23 as well as the bridge rectifiers are mounted on small tie-strips bolted to the under side of the top of the chassis. A hole should be cut in the chassis so that the filter capacitor can be mounted with about one quarter of its length extending into the chassis. Heat sinks are attached to both ends of the chassis; the heat sink on one end contains the output transistors for one channel, the heat sink on the other end, the output transistors for the second channel. The transistors are mounted on the heat sink, as shown in Fig. 174, and holes drilled or punched under the heat sink to allow wiring of the transistors to components inside the chassis before the sink is permanently attached; the transistor/heat-sink mica insulating washers that are supplied with the transistors can be used as drilling templates to locate the transistor on the heat sink. A heat-sink compound must be used between the washer and the transistor and the washer and the heat sink when the transistor mounting is made; the use of washer and compound prevents undesirable chassis currents.

No. 18 or heavier wire should be used to connect the output transistors to the printed-circuit-board components and output capacitors. The input connections to the amplifier are made through small phono-type jacks while the output connections are made through a pair of two-terminal barrier blocks.

Circuit Tests

Two 8-ohm speakers should be connected, one to each output, and amplifier power turned on. The voltage at the collector of Q9 should then be measured with a VOM or Voltohmyst*; the reading should be 38 volts for a line voltage of 120 volts. The hum in the speakers should be almost inaudible and there should be no hiss of any kind. If a hiss occurs, or if any of the output transistors become warm to the touch after a few minutes of operation it is probably an indication of an unwanted oscillation in the amplifier. The most likely causes of this oscillation are poor bypassing, poor grounding, or the use of wire of too small a gauge for the interconnection of the output transistors and the circuit boards. When the speaker output is free of hiss the amplifier power should be turned off and an input signal connected to the input. The signal source can be a good FM tuner or other similar stereo signal source. When the amplifier is turned on again, the result should be pleasing, high-quality sound.

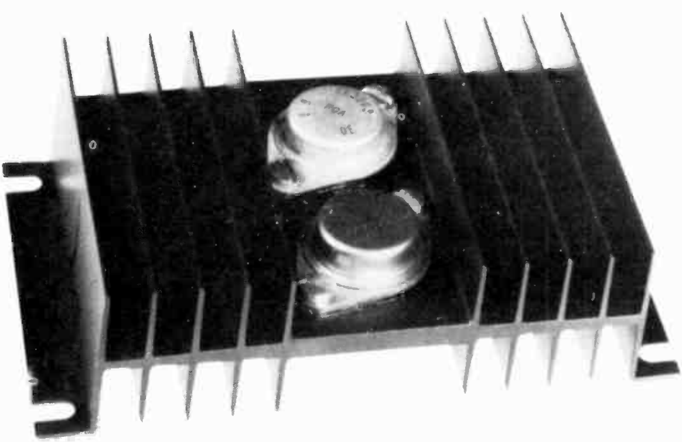


Fig. 174 – Output transistors mounted on heat sink.

CIRCUIT NO. 31 – 30-WATT AUDIO AMPLIFIER

The 30-watt amplifier is rated at 30 watts continuous-power output (45-watts music-power output) and has a frequency response that is flat within 1/2 dB from 20 to 20,000 Hz. At a power output of 20 watts the total harmonic distortion is only 0.15 per cent. An input signal of only 100 millivolts is sufficient to produce full output power. The amplifier may be used directly with an FM tuner, but requires a preampli-

*Trademark Reg. U.S. Pat. Off.

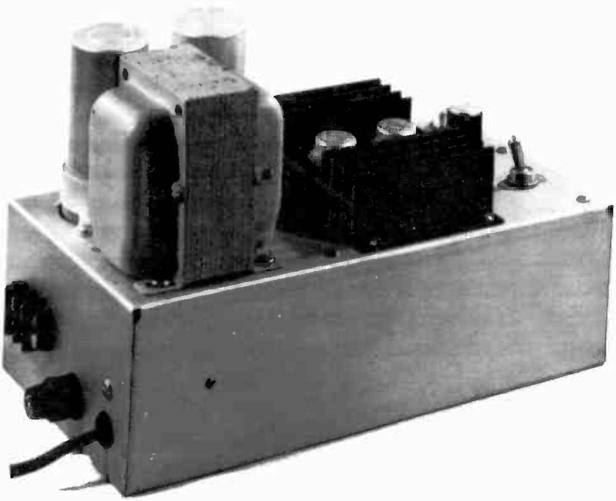


Fig. 175 – Suggested enclosure for the 30-watt audio amplifier.

fier when used with a phonograph; the phonograph preamplifier shown in Circuit No. 25 is ideal. A suggested enclosure for the amplifier is shown in Fig. 175.

Circuit Operation

The schematic diagram and parts list for the amplifier is shown in Fig. 176. The amplifier is of the quasi-complementary configuration and includes a protection circuit; the protection circuit is shown shaded. If the output becomes shorted or if the output impedance is reduced to a point at which the amplifier would otherwise destroy itself, the protection circuit automatically reduces the gain to a safe level. This protection feature in no way degrades amplifier performance in normal operation, and will save the experimenter-hobbyist many hours of trouble shooting plus the expense of "blown" transistors.

Construction

All of the components within the dashed line in Fig. 176 are mounted on a printed-circuit board. When two amplifiers are used in a stereo system, R5 and R6 in one of the units are replaced by a trim potentiometer that permits adjustment of the gain for balance. Fig. 177 shows a photograph of a completed circuit board.

The output transistors Q9 and Q10, diodes CR1 through CR9, and capacitors C21 and C22 are mounted on a heat sink. Capacitors C21 and C22 must be mounted as closely as possible to transistors Q9 and Q10, respectively. The diodes, fastened to the under side of the heat sink by means of small metal cable clamps, as shown in Fig. 178, are compensating diodes; i.e., they assure that the voltage drop is the same across the

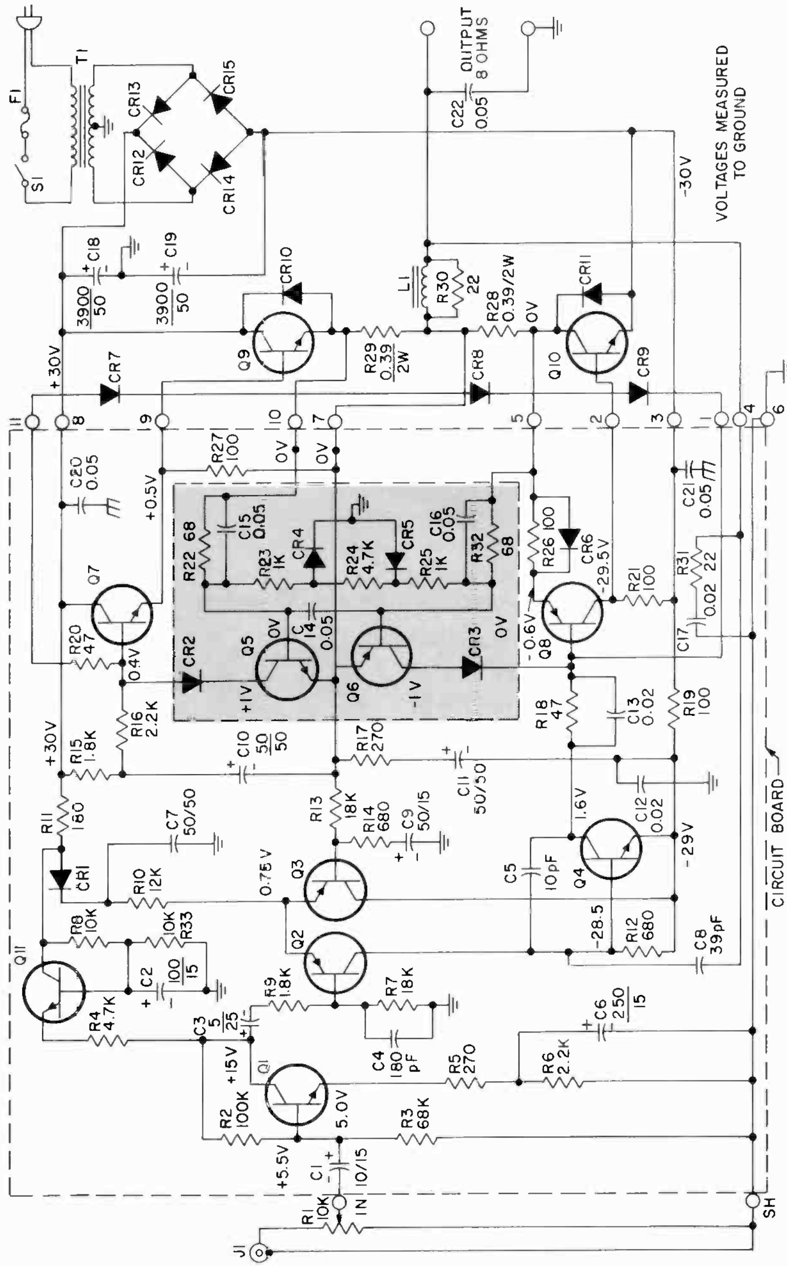


Fig. 176 — Schematic diagram for the 30-watt audio amplifier. Parts list on next page.

Parts List

C1 = 10 microfarads, 15 volts, electrolytic
C2 = 100 microfarads, 15 volts, electrolytic
C3 = 5 microfarads, 25 volts, electrolytic
C4 = 180 picofarads, 50 volts or greater, ceramic
C5 = 10 picofarads, 50 volts or greater, ceramic
C6 = 250 microfarads, 15 volts, electrolytic
C7 C10 C11 = 50 microfarads, 50 volts, electrolytic
C8 = 39 picofarads, 50 volts or greater, ceramic
C9 = 50 microfarads, 15 volts, electrolytic
C12 C13 C17 = 0.02 microfarad, 50 volts or greater, ceramic
C14 C15 C16 C20 C21 C22 = 0.05 microfarads, 50 volts or greater, ceramic
C18 C19 = 3900 microfarads, 50 volts, electrolytic; Sprague No. 36D392G050AC2A or equivalent; mounting hardware required with these capacitors depends on type of capacitor used and is available where capacitor is sold.
CR1 through CR15 = rectifier, RCA SK3030
F1 = fuse, 1.5 amperes, slow-blow
J1 = any phonograph jack
L1 = rf choke, 10 microhenries 1500 milliamperes; Miller 4622 or equivalent
Q1 Q11 = transistor, RCA SK3020
Q2 Q3 Q6 Q8 = transistor, RCA SK3025
Q4 Q5 Q7 = transistor, RCA SK3024
Q9 Q10 = transistor, RCA SK3027
R1 = resistance equal to line impedance, 10,000 ohms maximum
R2 = 100,000 ohms, 1/2 watt, 10%
R3 = 68,000 ohms, 1/2 watt, 10%
R4 R24 = 4700 ohms, 1/2 watt, 10%
R5 R17 = 270 ohms, 1/2 watt, 10%
R6 R16 = 2200 ohms, 1/2 watt, 10%
R7 R13 = 18,000 ohms, 1/2 watt, 10%
R8 R33 = 10,000 ohms, 1/2 watt, 10%
R9 R15 = 1800 ohms, 1/2 watt, 10%
R10 = 12,000 ohms, 1/2 watt, 10%
R11 = 180 ohms, 1/2 watt, 10%
R12 R14 = 680 ohms, 1/2 watt, 10%
R18 R20 = 47 ohms, 1/2 watt, 10%
R19 R21 R26 R27 = 100 ohms, 1/2 watt, 10%
R22 R32 = 68 ohms, 1/2 watt, 10%
R23 R25 = 1000 ohms, 1/2 watt, 10%
R28 R29 = 0.39 ohm, 2 watts, 10%
R30 R31 = 22 ohms, 1/2 watt, 10%
S1 = toggle switch single-pole single-throw, 125 volts, 3 amperes
T1 = power transformer; primary 117 volts, 60 Hz; secondary 42 volts center tapped at 1 ampere. Stancor type TP-4, Triad type F-924, Thordarson 23V119, or equivalent

Parts List (Cont'd)

Trim potentiometer = 2500 ohms; 1/4 watt replaces R5 and R6 for an adjustable-gain amplifier

Diode clamps = General Cement cable-clamp No. Z7243 or equivalent, 3 required

Heat sink = Wakefield NC-403K or equivalent

p-n junctions of transistors Q9 and Q10. The diodes are mounted on the heat sink so that they will be at the same temperature as the transistors. The mica insulating washer supplied with the transistors and used between the transistor and heat sink should be coated with a good heat-sink compound, such as silicone grease, to insure a good thermal connection. The method of mounting these transistors on the heat sink is shown in Fig. 179; the mounted transistors are shown in Fig. 180. The diodes are covered with an insulating sleeve and require no additional insulation. The exact layout of the holes for mounting the output transistors on the heat sink can be obtained by using the mica washers supplied with the transistors as drilling templates.

A component placement diagram for the components within the dashed line of Fig. 176 is shown in Fig. 181; the printed-circuit-board template is shown at the back of this Manual. If a wired board is used in lieu of the printed circuit supplied with this circuit, it is recommended

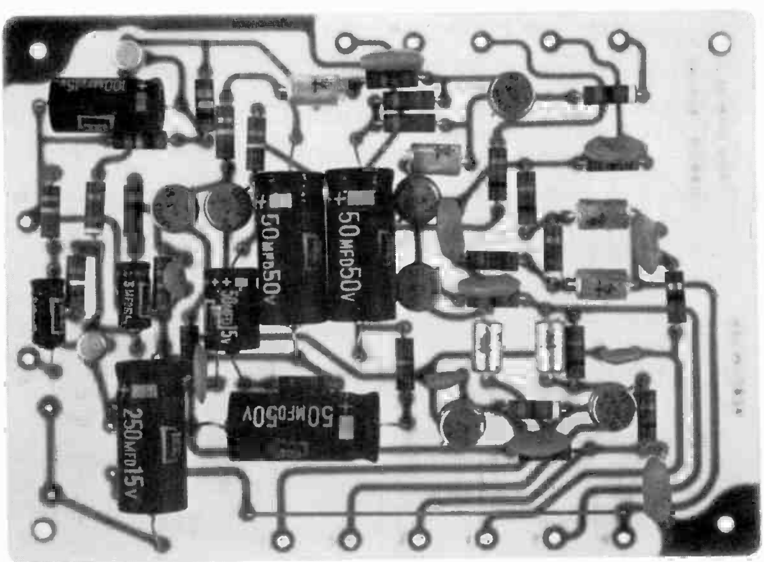


Fig. 177 – Completed circuit board for the 30-watt audio amplifier showing trimming potentiometer replacing R5 and R6.

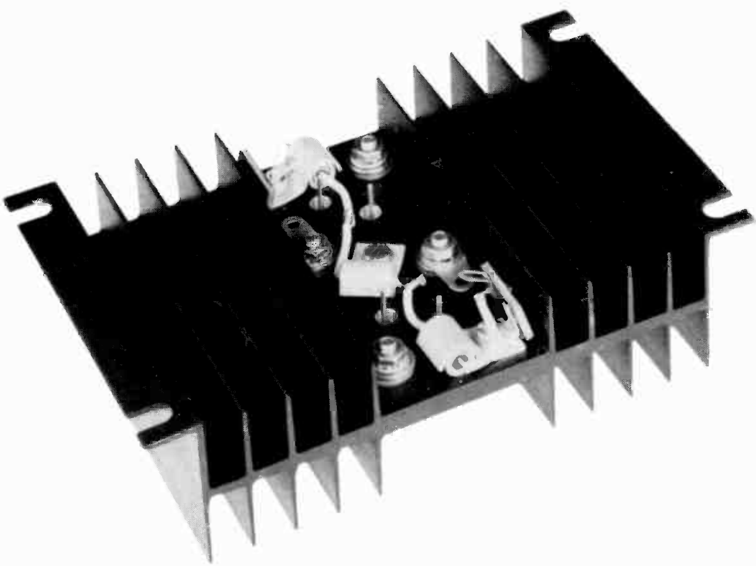


Fig. 178 – Underside of output-transistor heat sink showing method of mounting compensating diodes.

that a progressive-ground bus be used; this type of grounding system is constructed by starting at terminal SH and progressively picking up grounds in the circuit until terminal 6 is reached. Terminal 6, the center tap of the power transformer, and the ground side of each filter capacitor are then connected to the same point on the chassis to eliminate ground current loops. Capacitor C22 helps to prevent oscillations and must be mounted directly at the output terminals.

Circuit Tests

After the amplifier has been completely wired and a visual check made of all connections, a power-off ohmmeter test should be made. In this test, the resistance at the output terminals of the amplifier is measured with the speaker disconnected. The ohmmeter leads are then reversed and the output terminal resistance is checked again. In both measurements, the resistance should be about 1500 ohms. If it is less than 1000 ohms, there is probably a short circuit in the wiring; if it is greater than 5000 ohms, the problem could be an open circuit. The power-off resistances from terminals 8 and 3 to ground should be checked and then checked again with ohmmeter leads reversed; in either case the resistance should be greater than 400 ohms. When making this test, allow about 30 seconds for the capacitors to charge before noting readings.

The collector-supply voltage should be checked next by measuring the voltage between terminals 4 and 10 with the amplifier plugged in. The

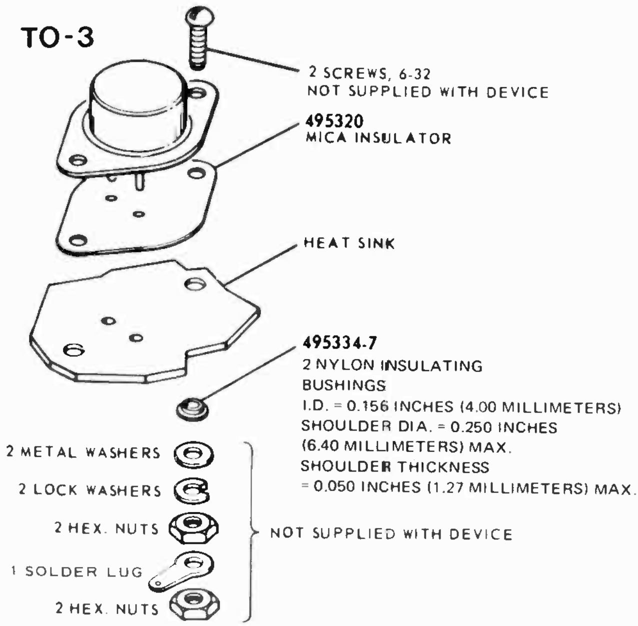


Fig. 179 — Details of output transistor mounting.

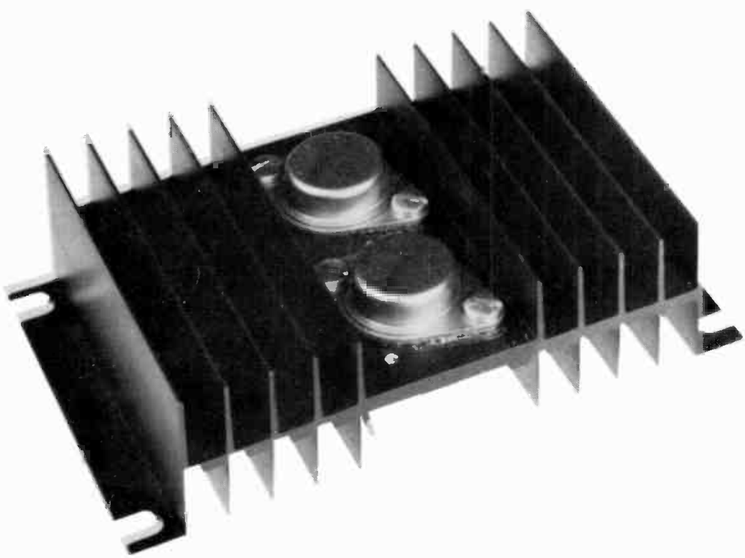


Fig. 180 — Output transistors mounted on heat sink.

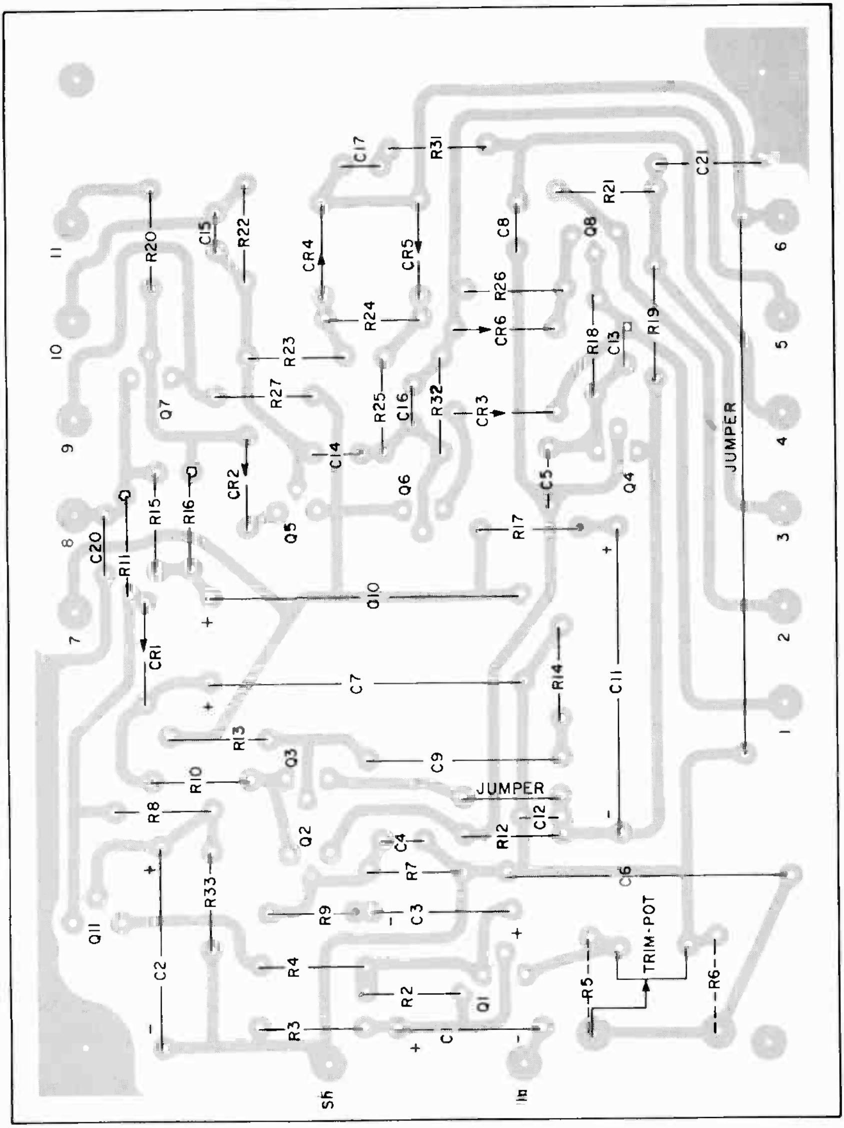


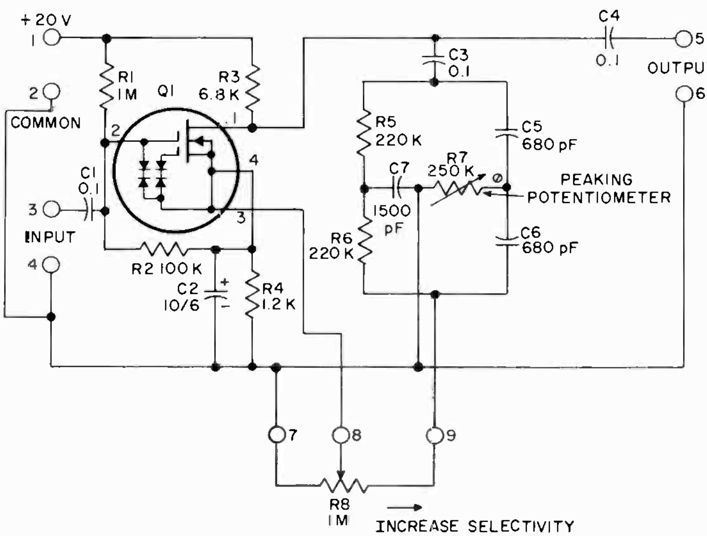
Fig. 181 – Component placement diagram for 30-watt audio amplifier.

voltage should be between 26 and 30 volts with a positive potential at terminal 8 and a negative potential at terminal 3.

With a good 8-ohm speaker connected to the output terminals and a signal fed into the input jack, the sound produced by the amplifier should be loud, crisp, and clear.

CIRCUIT NO. 32 – FREQUENCY-SELECTIVE AF AMPLIFIER

The frequency-selective audio-frequency amplifier amplifies signals at only one predetermined frequency. At that frequency the voltage gain is 20 to 30; at other frequencies the voltage gain is unity or less. Circuits of this type are useful in screening out undesirable



Parts List

C1 C3 C4 = 0.1 microfarad, 25 volts or greater

C2 = 10 microfarads, 6 volts, electrolytic

C5 C6 = 680 picofarads, 25 volts or greater

C7 = 1500 picofarads, 25 volts or greater

Q1 = MOS field-effect transistor, RCA SK3050

R1 = 1 megohm, 1/2 watt, 10%

R2 = 100,000 ohms, 1/2 watt, 10%

R3 = 6800 ohms, 1/2 watt, 10%

R4 = 1200 ohms, 1/2 watt, 10%

R5 R6 = 220,000 ohms, 1/2 watt, 10%

R7 = potentiometer, 250,000 ohms, linear taper, trim-pot

R8 = potentiometer, 1 megohm, linear taper

Fig. 182 – Schematic diagram and parts list for the frequency-selective audio-frequency amplifier.

side signals when copying code or for identifying the frequency of a particular signal.

Circuit Operation

The schematic diagram and parts list for the frequency-selective af-amplifier circuit are shown in Fig. 182. Potentiometer R8 controls the level of the feedback signal; potentiometer R7 is used to adjust or peak the twin-T bridge to the desired frequency. Transistor Q1 acts as a basic audio amplifier. Part of the output of the amplifier is applied to the twin-T bridge oscillator through C3. At the predetermined frequency, where most gain occurs, the filter passes the ac at a phase angle that assures positive feedback. The feedback, adjusted by R8, is added to the incoming signal and causes it to increase.

With the component values shown in the parts list, the frequency of the bridge oscillator and the frequency selected for amplification is approximately 1000 Hz; Table XXVIII shows values of C5, C6, and C7 required for other typical frequencies.

The current drain for this circuit is approximately 1.5 milliamperes. The maximum input signal is 0.1 volt rms.

Construction

The drilling template for the frequency-selective af amplifier is shown at the back of the Manual; a component placement diagram and a photograph of a completed circuit board are shown in Figs. 183 and 184, respectively.

Table XXVIII.
Frequency-Selective AF Amplifier Bridge Capacitor Values for Various Frequencies

Approximate Frequency (Hz)	C5, C6 (pF)	C7 (pF)
150	5600	12,000
300	2700	6,200
600	1300	3,000
1200	680	1,500
2400	330	750
4800	160	360
9600	82	180

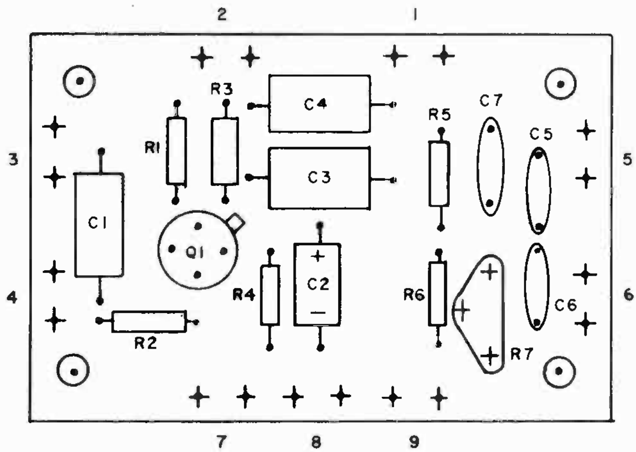


Fig. 183 – Component placement diagram for the frequency-selective audio-frequency amplifier.

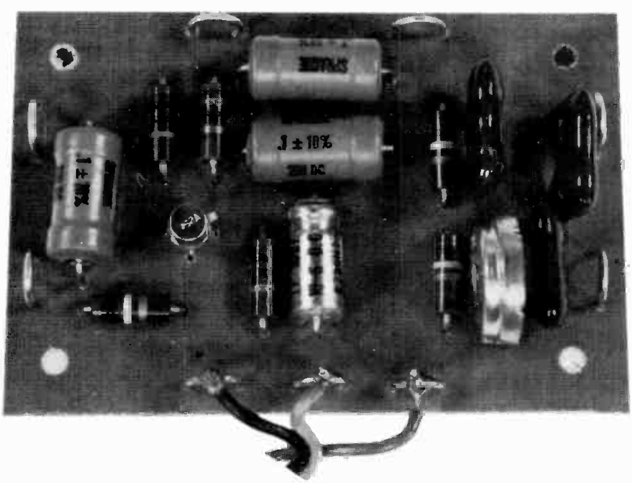


Fig. 184 – Completed circuit board for the frequency-selective audio-frequency amplifier.

CIRCUIT NO. 33 – SEMIAUTOMATIC KEYER

The semiautomatic Morse-code keyer or "bug" generates a single dot or a series of dots, depending upon how long the paddle-key is depressed; the dash must be made manually. The rate at which dots are generated can be varied.

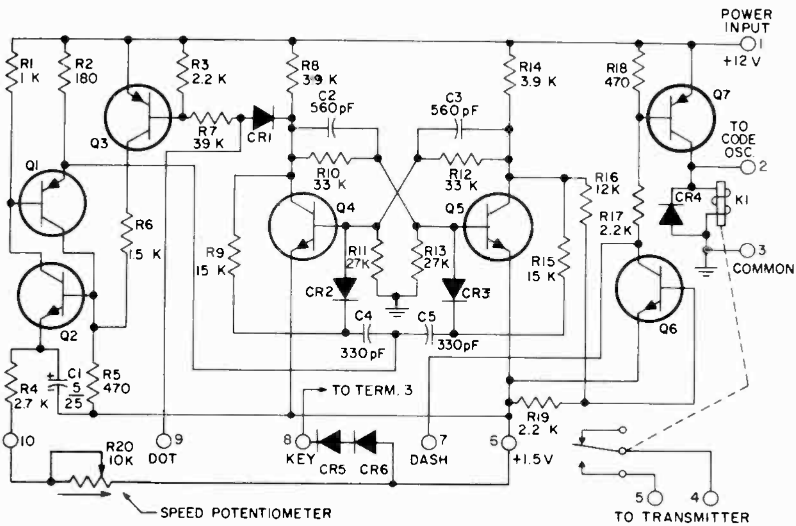
Circuit Operation

The schematic diagram and parts list for the semiautomatic keyer are shown in Fig. 185. The dot repetition rate is determined by R4, C1, and the speed potentiometer R20. These components control the regenerative switch consisting of transistors Q1 and Q2. This switch has a very high impedance before it is triggered and a very low impedance afterward. When the paddle-key is moved to the dot position, the current applied to the base of Q3 turns it on and permits C1 to begin charging through the emitter of Q2. At the same time, Q2 turns on and triggers the regenerative switch into conduction. As capacitor C1 charges, the emitter of Q2 becomes more and more positive until the regenerative switch is cut off. When cutoff occurs, the impedance of the regenerative switch becomes very high and C1 is forced to discharge through R4 and the speed potentiometer R20. As the charge on C1 decreases, the emitter of Q2 becomes less positive and the regenerative switch begins to conduct again. This process repeats itself as long as the paddle-key is held in the dot position. The polarity of the regenerative switch in conduction is such that a negative pulse is applied to the base of transistors Q4 and Q5 in the flip-flop. This negative pulse is sufficient to turn on transistor Q4. Q5 turns off automatically as a result of normal flip-flop action. When Q5 is off, its collector voltage is applied to Q6 through R16, and Q6 turns on. Current through Q6 activates Q7 which, in turn, closes the output relay. Diode CR4 is placed across the relay to protect Q7 from the high-voltage inductive discharges which occur when current to the relay coil is interrupted and its coil field collapses.

When the paddle-key is released from the dot position with Q4 off (i.e., when the paddle-key is released at the end of a dot), Q3 turns off and interrupts the C1 charging path, with the result that the regenerative-switch pulses that cause the dots are stopped. When the paddle-key is released from the dot position with Q4 on (i.e., when the paddle-key is released in the middle of a dot), Q3 continues to conduct because its base current continues to flow through Q4. The regenerative switch pulses once more to complete the dot cycle. Dot-cycle completion is accomplished when the final regenerative-switch pulse returns the flip-flop to its original state and turns Q4, and consequently Q3, off.

If instead of batteries a power supply is used to power this circuit, the 1.5 volts needed (shown as an input at circuit-board terminal No. 6) can be obtained from the drop across the two rectifiers CR5 and CR6 connected in series, as shown in Fig. 185.

When the paddle-key is in the dash position, the relay is not under the control of a transistor, but operates directly.



Parts List

C1 = 5 microfarads, 25 volts, electrolytic
C2 C3 = 560 picofarads, 50 volts or greater
C4 C5 = 330 picofarads, 50 volts or greater
CR1 CR2 CR3 = diode, RCA 1N270
CR4 CR5 CR6 = rectifier, RCA SK3030
K1 = relay, 12 volts, 1350 ohms, Potter and Brumfield No. RS5D or equivalent
Q1 Q3 Q7 = transistor, RCA SK3005
Q2 Q4 Q5 Q6 = transistor, RCA SK3020
R1 = 1000 ohms, 1/2 watt, 10%
R2 = 180 ohms, 1/2 watt, 10%
R3 R17 R19 = 2200 ohms, 1/2 watt, 10%
R4 = 2700 ohms, 1/2 watt, 10%
R5 R18 = 470 ohms, 1/2 watt, 10%
R6 = 1500 ohms, 1/2 watt, 10%
R7 = 39,000 ohms, 1/2 watt, 10%
R8 R14 = 3900 ohms, 1/2 watt, 10%
R9 R15 = 15,000 ohms, 1/2 watt, 10%
R10 R12 = 33,000 ohms, 1/2 watt, 10%
R11 R13 = 27,000 ohms, 1/2 watt, 10%
R16 = 12,000 ohms, 1/2 watt, 10%
R20 = potentiometer, 10,000 ohms, linear taper

Fig. 185 – Schematic diagram and parts list for the semiautomatic keyer.

The current drain for this circuit is approximately 5 milliamperes.

Construction

The semiautomatic electronic keyer is built on the same circuit board as the automatic keyer, Circuit No. 34. The drilling template for both circuits is shown at the back of this Manual; a component placement diagram is shown in Fig. 189.

CIRCUIT NO. 34 – AUTOMATIC KEYER

The fully automatic keyer produces either dots or dashes continuously for as long as the paddle-key is held in the dot or dash position. The speed of the dots and dashes can be varied to suit the operator. The keyer circuit is composed of a number of the building blocks described in the section on **General Circuit Considerations**: the pulser or clock, the flip-flop, and the lamp driver. The 12-volt supply is needed to power the keyer; eight flashlight batteries in series or a 12-volt supply such as that described in Circuit No. 2 may be used.

Circuit Operation

The schematic diagram and parts list for the fully automatic keyer are shown in Fig. 186. The dot or dash repetition rate of the keyer is determined by speed-control potentiometer R29; the potentiometer controls the frequency of the pulser or clock oscillator consisting of transistors Q1 and Q2. When the paddle-key is moved to the dot position (i.e., when terminals 8 and 9 on the circuit board are connected), a current is transmitted to the base of Q3, this current turns Q3 on. Q3 in turn activates the regenerative switch consisting of Q1 and Q2 and permits C1 to begin charging through the emitter of Q2. As capacitor C1 charges, the emitter of Q2 becomes more and more positive until Q2 is cut off. When cutoff occurs, the total impedance of Q1 and Q2 becomes very high and C1 is forced to discharge through R4 and the speed-control potentiometer R29. As the charge on C1 decreases, the emitter of Q2 becomes less positive and transistors Q1 and Q2 begin to conduct again. This process repeats itself as long as the paddle-key is held in the dot or dash position. Q1 and Q2, when in conduction, produce a negative pulse that is applied to the bases of transistors Q4 and Q5 in the flip-flop. This negative pulse is sufficient to turn off transistor Q5; Q4 is turned on automatically as a result of normal flip-flop action. When Q5 is off, current is conducted through R12, CR10, and R27; this current turns Q9 on. Current through Q9 activates Q10 which, in turn, energizes the output relay.

The dash flip-flop composed of transistors Q6 and Q7 is held inoperative during the dot cycle by the clamping transistor Q8 which is held in the conductive state by current through R17 and R16. Rectifier CR11 is placed across the relay to protect Q10 from the high-voltage pulse produced when current to the relay is interruped and its coil field collapses.

When the paddle-key is released from the dot position with Q4 off

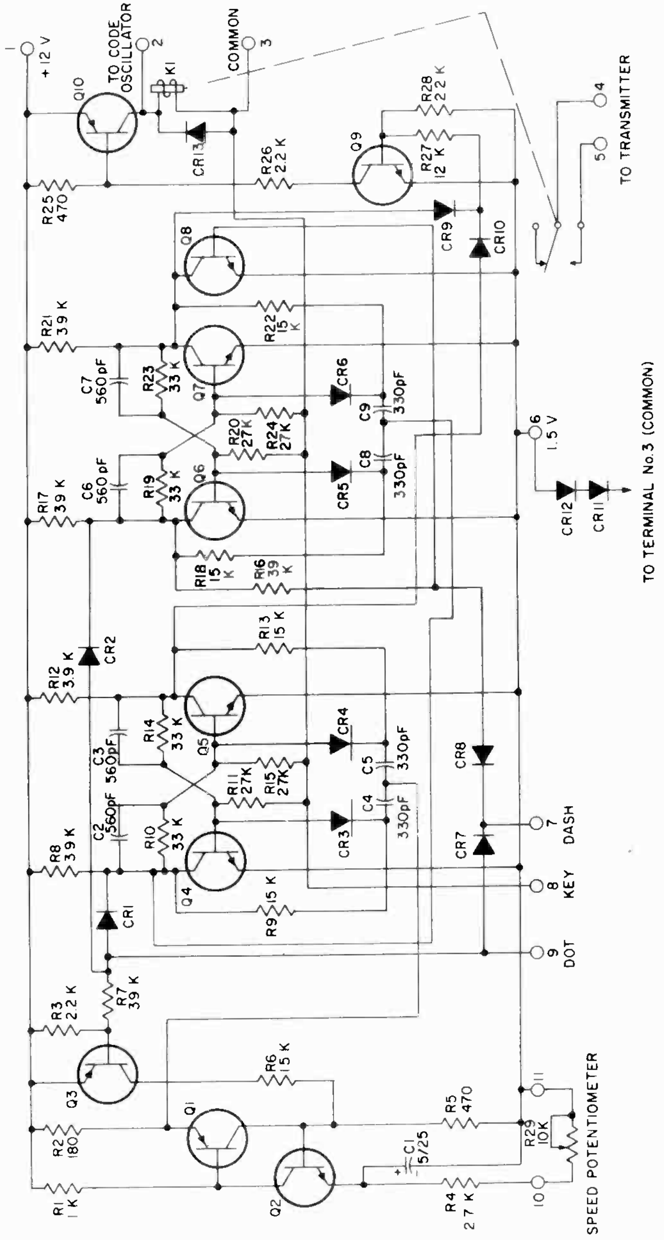


Fig. 186 – Schematic diagram and parts list for the automatic keyer.

Parts List

C1 = 5 microfarads, 25 volts, electrolytic
C2 C3 C6 C7 = 560 picofarads, 25 volts or greater
C4 C5 C8 C9 = 330 picofarads, 25 volts or greater
CR1 through CR10 = diode, RCA 1N270
CR11 CR12 CR13 = rectifier, RCA SK3030
K1 = relay, 12 volts, 1350 ohms, Potter and Brumfield No. RS5D or equivalent
Q1 Q3 Q10 = transistor, RCA SK3005
Q2 Q4 Q5 Q6 Q7 Q8 Q9 = transistor RCA SK3020
R1 = 1000 ohms, 1/2 watt, 10%
R2 = 180 ohms, 1/2 watt, 10%
R3 R26 R28 = 2200 ohms, 1/2 watt, 10%
R4 = 2700 ohms, 1/2 watt, 10%
R5 R25 = 470 ohms, 1/2 watt, 10%
R6 = 1500 ohms, 1/2 watt, 10%
R7 R16 = 39,000 ohms, 1/2 watt, 10%
R8 R12 R17 R21 = 3900 ohms, 1/2 watt, 10%
R9 R13 R18 R22 = 15,000 ohms, 1/2 watt, 10%
R10 R14 R19 R23 = 33,000 ohms, 1/2 watt, 10%
R11 R15 R20 R24 = 27,000 ohms, 1/2 watt, 10%
R27 = 12,000 ohms, 1/2 watt, 10%
R29 = potentiometer, 10,000 ohms, linear taper

(i.e., when the paddle-key is released during a space at the end of a dot or a series of dots), Q3 turns off and the oscillator pulses that cause the dots are no longer generated. When the paddle-key is released from the dot position with Q4 on (i.e., when the paddle-key is released in the middle of a dot), Q3 continues to conduct and permits the oscillator pulse to complete the dot cycle. This last pulse turns Q4, and consequently Q3, off, and the oscillator pulses cease.

A dash or series of dashes is produced when terminals 7 and 8 are connected (i.e., when the paddle-key is moved to the dash position). Under this condition Q3 is turned on by a signal applied to its base through R7 and CR7. At the same time Q8 is turned off by the grounding of its base through CR8. The first pulse from the clock oscillator sets both the dot and dash flip-flops to the output state. Q3 receives a base signal not only from the paddle-key but from the dash flip-flop through CR2 and the dot flip-flop through CR1. Q9 receives a dash signal from either the dash or dot flip-flop through their respective diodes CR9 or CR10. The second pulse from the oscillator sets the dot flip-flop to the no-output state but does not disturb the dash flip-flop, and Q9 remains in the conducting state. The third pulse sets the dot flip-flop to the output state and the dash flip-flop to the no-output state, and Q9 remains conductive. When a fourth pulse is developed, both flip-flops are in the no-output state and Q9 is turned off. If at this time the paddle-key is in the neutral or middle position (circuit-board terminals 7 and 8 disconnected), Q3 is also turned off and the system returns to its quiescent state. If the key is still in the dash position, the cycle repeats. Fig.

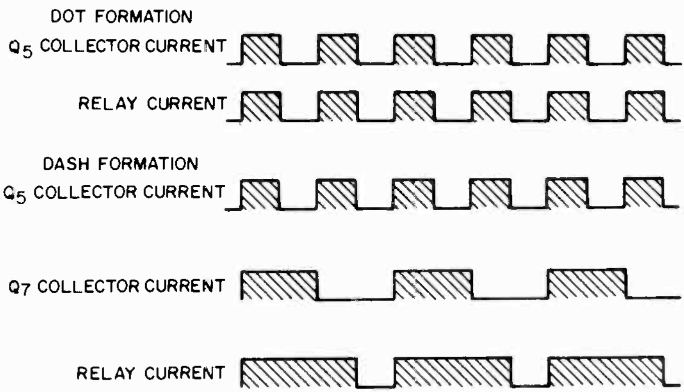


Fig. 187 – Voltage and current waveforms at selected points in the automatic keyer circuit.

187 shows the voltage and current wave forms at selected points in the circuit. Relay current during a single dash cycle flows for a time equal to three dots and is cut off for a period equal to one dot.

The current drain for this circuit is approximately 20 milliamperes.

Special Considerations

If instead of batteries a power supply is used to power this circuit, the 1.5 volts needed (shown as an input at circuit-board terminal No. 6) can be obtained from the drop across the two rectifiers CR12 and CR13 connected in series, as shown in Fig. 186.

Construction

The drilling template for the automatic keyer is shown at the back of this manual. A photograph of the completed circuit board and a component placement diagram are shown in Figs. 188 and 189, respectively.

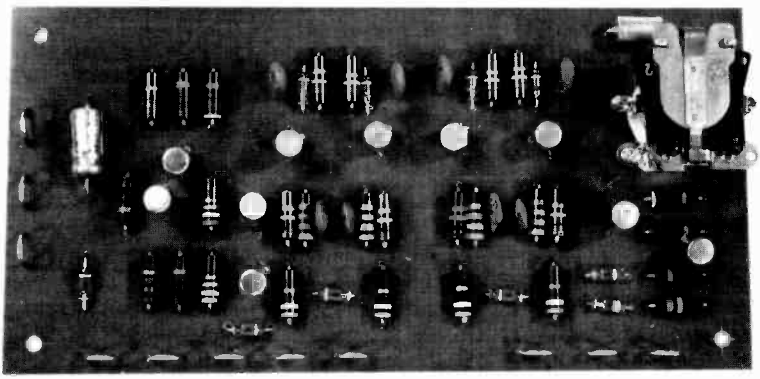


Fig. 188 – Completed circuit for the automatic keyer.

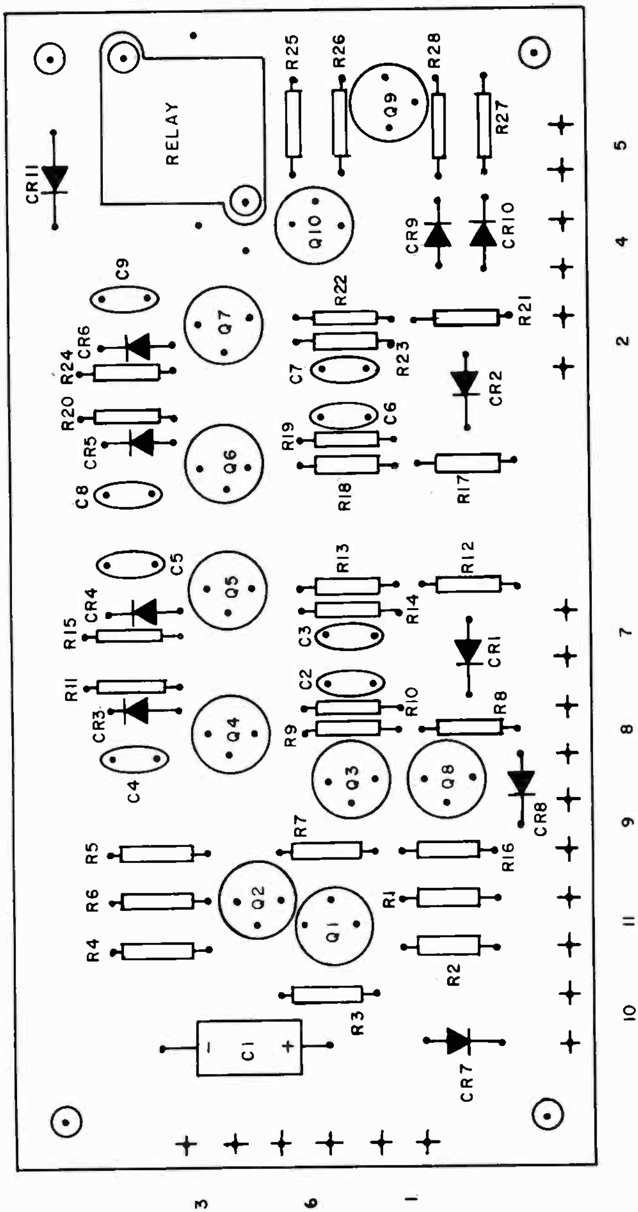


Fig. 189 – Component placement diagram for the automatic keyer.

CIRCUIT NO. 35 – AUDIO TAPE KEYER

The audio tape keyer, shown in a suggested enclosure in Fig. 190, is actually a magnetic-tape keying system that is useful in code recording and transmission. Such equipment can be a desirable addition to the ham shack. Not only can it be used for "skeds" and for automatic-calling in contests, but to provide code instruction as well. Code can be recorded at one speed and played back at another; thus it is possible to double or even halve the original rate.

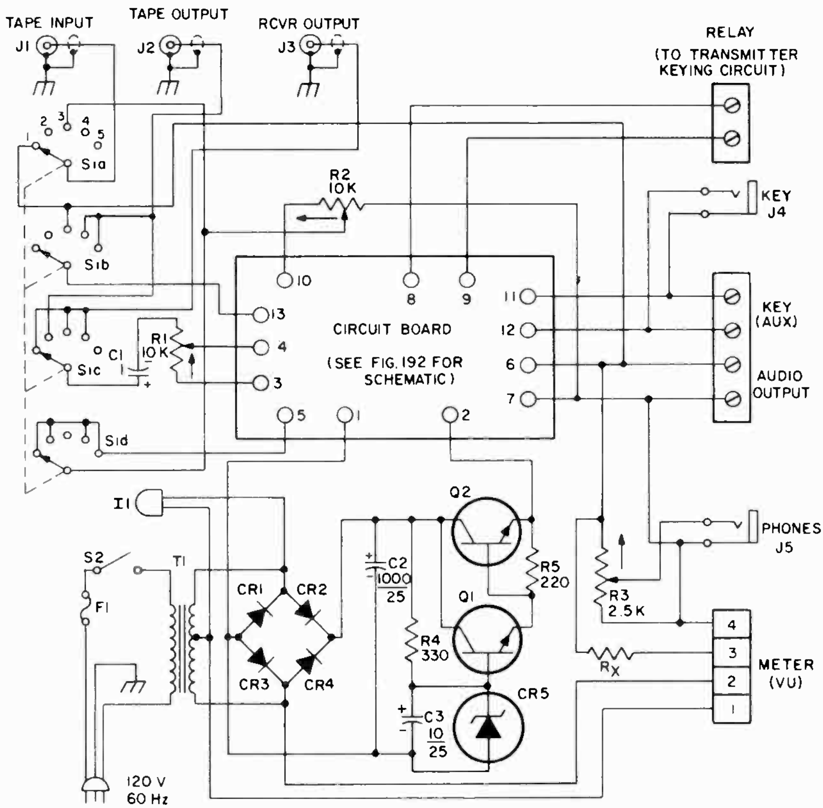
Actually more than a simple keyer, the magnetic tape-to-code converter can also be used to record voice transmissions. As an additional feature, its side-tone oscillator can be combined with the mixer to form an excellent code-monitoring device.

The basic elements of the system consist of a tape recorder, tape-to-relay converter, keying relay, code oscillator, and key. No alterations are required of the tape recorder and use of the converter is extremely simple. The code oscillator is built in so that pitch will not vary with code speed.

Fig. 190 – Suggested enclosure for the audio tape keyer.

Construction

Fig. 191 shows the schematic diagram and parts list for the entire audio-tape-keyer circuit; Fig. 192 shows the schematic diagram and parts list for the circuit on the board shown in Fig. 191. Fig. 193 shows a component placement diagram for the board, and Fig. 194 a photograph of the completed board. Fig. 195 shows the board installed in the suggested enclosure of Fig. 190;



Parts List

C1 = 1 microfarad, 25 volts, electrolytic, for solid-state receivers; 0.5 microfarad, 400 volts, paper for tube-type receivers

C2 = 1000 microfarads, 25 volts, electrolytic

C3 = 10 microfarads, 25 volts, electrolytic

CR1 CR2 CR3 CR4 = rectifier, RCA SK3016

CR5 = zener diode, 15 volts, 1 watt

Fig. 191 – Schematic diagram and parts list for the entire audio-tape-keyer system.

Parts List (Cont'd)

F1 = fuse, 1 ampere, slow-blow
I1 = lamp No. 47
J1 J2 J3 = RCA type phono jack
J4 J5 = single-circuit phone jack
Q1 = transistor, RCA SK3020
Q2 = transistor, RCA SK3024
R1 R2 = 10,000 ohms, potentiometer, linear taper
R3 = 2500 ohms, potentiometer, linear taper
R4 = 330 ohms, 1/2 watt
R5 = 220 ohms, 1/2 watt
RX = VU meter calibration resistor; will vary with meter
S1 = rotary switch, 4-pole, 5-position
S2 = toggle switch, single-pole, single-throw, 3 amperes
T1 = filament transformer, 12.6 volts at 2 amperes

spacers separate the circuit board from the metal of the enclosure. The drilling template for the keyer is shown in the back of this Manual.

Keyer Connections

The keyer is readied for operation by making the connections described below and illustrated in Fig. 196.

The Rcvr Output jack, J3, on the keyer is first connected to the headphone jack on the communications receiver. The shielded wire from the Tape Input jack, J1, on the keyer is then connected to the Line or Aux input on the tape recorder. If the recorder has a Line or Aux output jack, shielded wire should also be connected from that jack to the Tape Output jack, J2, on the keyer. If the tape recorder does not have a Line or Aux output, some modification of recorder wiring will be required prior to making this third connection; the modification is shown in Fig. 197.

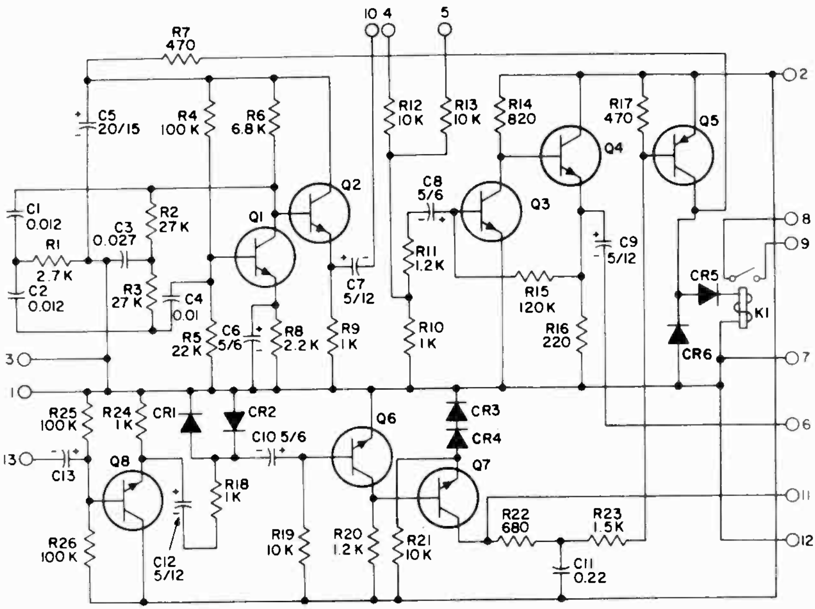
The transmitter keying-relay contacts are next connected to the Relay terminals on the keyer and a hand or auto key plugged in at the Key jack, J4. The magnetic-tape keyer control is now ready for use.

Note that both hand and auto keys can be connected simultaneously, if desired, by using the Key plug on the front of the keyer for one key and the Key terminals on the side of the keyer for the second key. Volume-controlled audio output is available through the Phones plug, J5, on the keyer, or through the receiver speaker (if the keyer Audio Output terminals are reconnected to the receiver). The loudness of the signal in the phones is controlled by means of the Phone Gain control, R3, on the keyer. The loudness of the signal in the receiver speaker is controlled by the volume control on the receiver. The Receiver control, R1, on the keyer is the input volume control and varies the signal level in both phones and speakers simultaneously.

Keyer Operation

Fig. 196 shows the interconnections of the entire magnetic-tape keying system.

To operate the keyer, the Selector switch is set to position No. 1 and a strong, readable, cw signal tuned in. The Receiver control should be approximately in mid-



Parts List

C1 C2 = 0.012 microfarad, 200 volts, paper

C3 = 0.027 microfarad, 200 volts, paper

C4 = 0.01 microfarad, 200 volts, paper

C5 = 20 microfarads, 15 volts, electrolytic

C6 C8 C10 = 5 microfarads, 6 volts, electrolytic

C7 C9 C12 = 5 microfarads, 12 volts, electrolytic

C11 = 0.22 microfarad, 200 volts, paper

C13 = 5 microfarads, 25 volts, electrolytic for solid-state receiv-

Fig. 192 – Schematic diagram and parts list for the circuit board identified in Fig. 191.

Parts List (Cont'd)

ers; 0.5 microfarad, 400 volts, paper for tube-type receivers
CR1 CR2 CR3 CR4 CR5 CR6 = rectifier, RCA SK3030
K1 = relay, Potter and Brumfield, type RS5D (12-volt coil) or equivalent
Q1 Q2 Q3 Q4 Q6 Q7 Q8 = transistor, RCA SK3020
Q5 = transistor, RCA SK3005
R1 = 2700 ohms, 1/2 watt, 10%
R2 R3 = 27,000 ohms, 1/2 watt, 10%
R4 R25 R26 = 100,000 ohms, 1/2 watt, 10%
R5 = 22,000 ohms, 1/2 watt, 10%
R6 = 6800 ohms, 1/2 watt, 10%
R7 R17 = 470 ohms, 1/2 watt, 10%
R8 = 2200 ohms, 1/2 watt, 10%
R9 R10 R18 R24 = 1000 ohms, 1/2 watt, 10%
R11 R20 = 1200 ohms, 1/2 watt, 10%
R12 R13 R19 R21 = 10,000 ohms, 1/2 watt, 10%
R14 = 820 ohms, 1/2 watt, 10%
R15 = 120,000 ohms, 1/2 watt, 10%
R16 = 220 ohms, 1/2 watt, 10%
R22 = 680 ohms, 1/2 watt, 10%
R23 = 1500 ohms, 1/2 watt, 10%

position after this adjustment. In switch-position No. 1, the keyer amplifier is connected directly to the receiver through mixer input No. 1, and to the side-tone oscillator through mixer input No. 2. The gain control on the tape recorder is then adjusted to the proper recording level. A VU meter is a valuable tool in determining this level and in producing good tapes. If the tape recorder being used does not have a built-in VU meter, an external meter can be inserted into the circuit by use of the Meter plug on the side of the keyer.

The hand key should now be depressed and the Side Tone control, R2, adjusted so that the signal from the side-tone oscillator is at the same level as the incoming cw signal. The keyer is now set to act as a monitor of incoming and outgoing signals and to permit manual keying of the transmitter and recording of both incoming and outgoing signals.

Some text should now be recorded on the tape with the Selector switch in position No. 1. The tape should then be rewound, the Selector switch set in position No. 2, the tape playback position, and proper operation of the keyer and recorder confirmed by listening to the playback. When the Selector switch is in position No. 2, the tape recorder output is connected to mixer input No. 1 instead of to the receiver. Switch position No. 2 is used whenever taped material is to be checked.

In position No. 3, the selector switch connects the receiver to mixer input No. 1 and the amplifier output to the input of the audio keyer section of the keyer. The output of the side-tone oscillator is then impressed upon the tape recorder so that the tone recorded on the tape is that of the side-tone oscillator and not that of the actual incoming signal. The transmitter may be

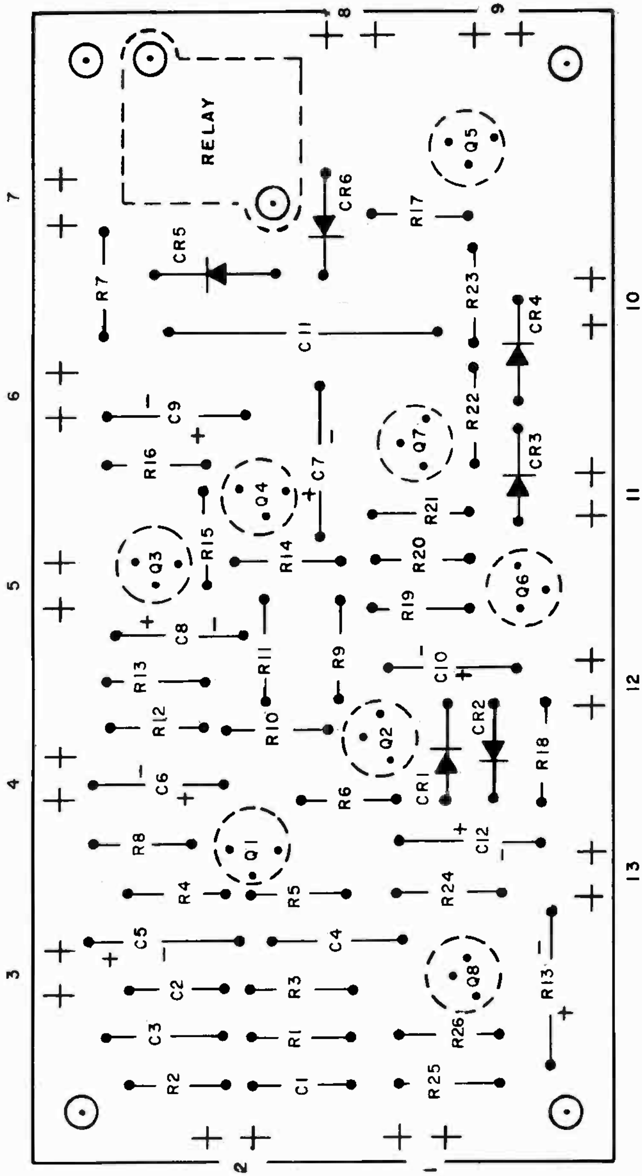


Fig. 193 – Component placement diagram for audio-tape-keyer circuit board.

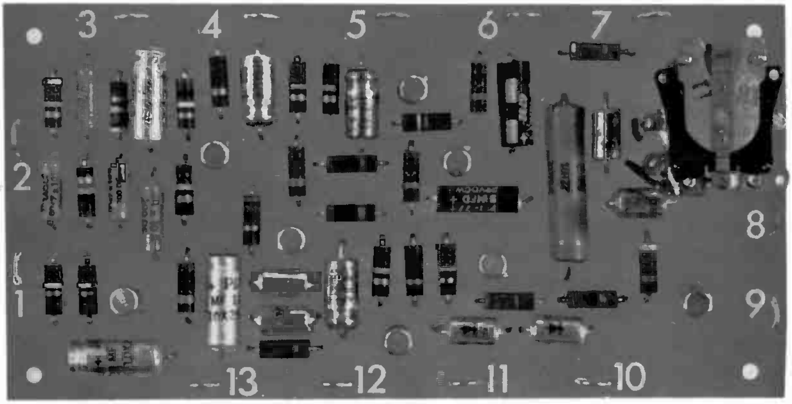


Fig. 194 – Completed circuit board for the audio tape keyer.

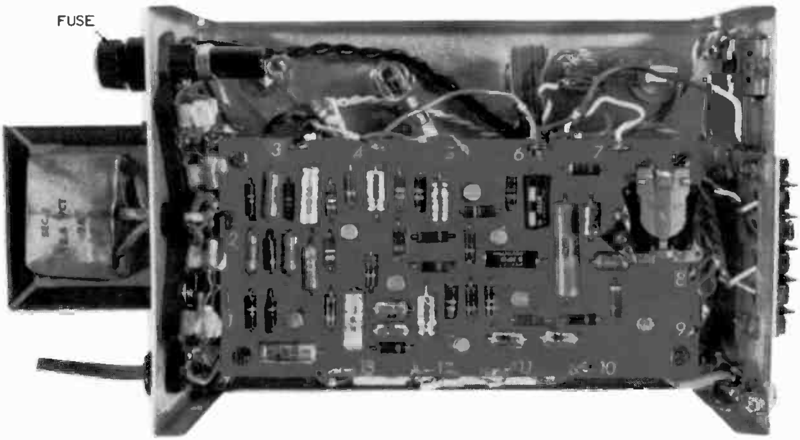


Fig. 195 – Circuit board mounted within the suggested enclosure.

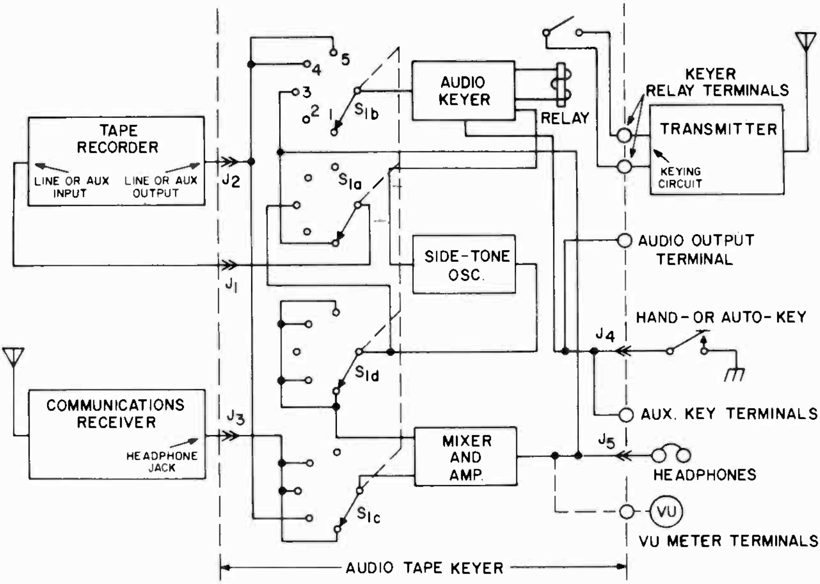


Fig. 196 – Interconnection of audio tape keyer with the equipment it serves.

manually keyed and monitored when the Selector switch is in this position.

The tape should now be rewound again and the Selector switch set to position No. 4. In this setting, the receiver is connected to mixer input No. 1, and the side-tone oscillator to the amplifier through mixer input No. 2. In addition, the Line or Aux output of the recorder is now connected to the input of the audio-keyer section of the keyer. Position No. 4 of the Selector switch is the setting to be used to key a transmitter from a previously recorded tape. In this position, both incoming

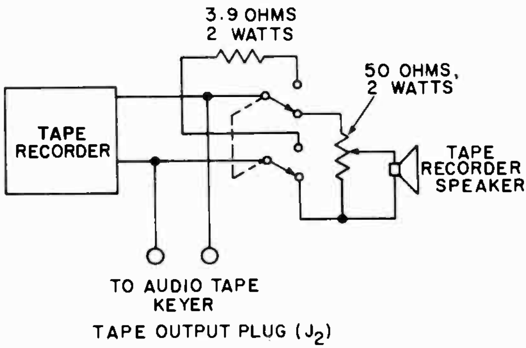


Fig. 197 – Modification required of tape recorder that has no "Line or Aux." output to make the recorder compatible with the audio tape keyer.

and outgoing signals may be heard and the transmitter may also be keyed manually.

To key the transmitter by tape, the tape must be rewound and the output level of the tape recorder adjusted until the relay starts to operate and the side tone is heard in the headphones. Keying should be loud and clear. A signal of 1 to 3 volts is required at terminal No. 13 of the circuit board for satisfactory transmitter keying.

Selector switch position No. 5 is the same as position No. 4 except that incoming signals cannot be heard.

When the system is used for code instruction, the keyer's Selector switch should be in position No. 4. A recording made at a tape speed of 7-1/2 inches per second and a code speed of 20 words per minute can be used to teach code at 10 words per minute by halving the playback tape speed to 3-3/4 inches per second. For inexpensive recorders – in which tape speed is changed by manually changing the capstan – new capstans can be made that will permit transmission of code at almost any speed. The output of the amplifier in the keyer is sufficient to drive up to 10 pairs of high-impedance headphones or to feed the Line or Aux input of any tape recorder.

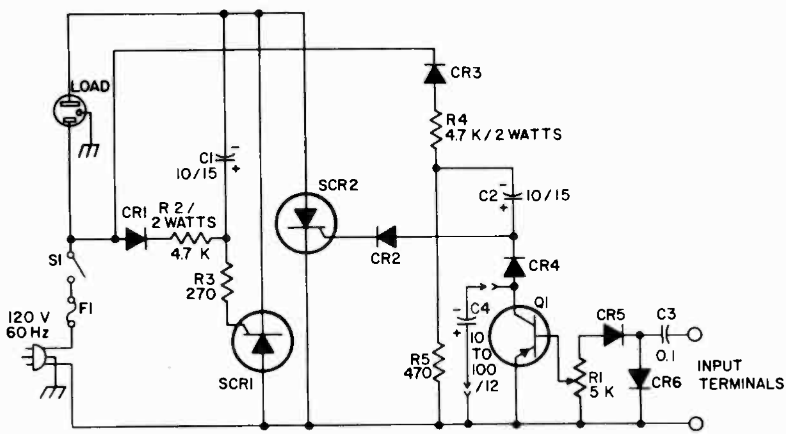
Table XXIX summarizes the functions of the keyer in the various Selector switch positions.

Table XXIX.
Keyer Functions

Selector Switch Position	Receive	Tape Key	Record	Playback	Monitor
1	Yes	No	Yes	No	Incoming receiver signal and manually keyed side tone.
2	No	No	No	Yes	Tape output and manually keyed side tone.
3	Yes	No	Yes	No	Incoming receiver signal.
4	Yes	Yes	No	No	Incoming receiver signal and manually- and tape-keyed side tone.
5	No	Yes	No	No	Same as Position 4.

CIRCUIT NO. 36 – AUDIO-FREQUENCY-OPERATED SWITCH

The audio-frequency-operated-switch circuit can be used to turn on a load rated up to one kilowatt when the sound level increases above a predetermined level. The load continues to receive power until the sound level drops below the predetermined level. The circuit can be activated by an audio signal provided by a microphone preamplifier such as that described in Circuit No. 17. The circuit can be used to control electrical systems, such as alarms, transmitters, and remote intercoms. It can also be used to measure noise level; in such applications, it activates some device when a predetermined noise level is reached. The level of input to this switch should be approximately 1 volt. The integrated-circuit amplifier described in Circuit No. 28 will satisfy the input preamplifier requirements of the audio-frequency-operated switch.



Parts List

C1 C2 = 10 microfarads, 15 volts, electrolytic
C3 = 0.1 microfarad, 25 volts or greater
C4 = 10 to 100 microfarads, 12 volts, electrolytic, to increase release time
CR1 CR3 = rectifier, RCA SK3031
CR2 CR4 = rectifier, RCA SK3030
CR5 CR6 = diode, RCA 1N34A
F1 = fuse, 125 volts, ampere rating depends on load (10 amperes maximum)
Q1 = transistor, RCA SK3005
R1 = potentiometer, 5000 ohms, 2 watts, linear taper
R2 R4 = 4700 ohms, 2 watts, 10%
R3 = 270 ohms, 1/2 watt, 10%
R5 = 470 ohms, 1/2 watt, 10%
S1 = toggle switch, 125 volts, 15 amperes, single-pole, single-throw
SCR1 SCR2 = silicon controlled rectifier, RCA KD2100

Fig. 198 – Schematic diagram and parts list for audio-frequency-operated switch.

Circuit Operation

The schematic diagram and parts list for the audio-frequency-operated switch are shown in Fig. 198. The audio- or radio-frequency signal applied to the input terminals is rectified by CR5 and CR6. The resulting signal is applied to the base of Q1 through the potentiometer R1. The amount of noise required to activate the circuit can be controlled by adjustment of the potentiometer. The signal applied to the base of Q1 causes it to conduct provided that the emitter of Q1 is positive. The current conducted by Q1 charges Q2 through the charging path CR3, CR4, and R4.

On the following half-cycle, the charge on capacitor C2 is applied to the gate of SCR2 and turns it on; a voltage is thus placed across the load. The load voltage is also applied to the combination of CR1, R2, and C1, and causes the capacitor to charge. The charge on C1 turns on SCR1 during the next half-cycle. This process repeats as long as there is a sufficient audio- or radio-frequency signal present at the input terminals to cause Q1 to conduct.

When the signal is removed, Q1 becomes nonconductive; the charging path for capacitor C2 is thus opened. If C2 cannot charge, SCR2 cannot turn on. The result is an open circuit to the load. Because there is no voltage across the load, capacitor C1 cannot obtain the charge it needs to turn on SCR1 during the next half-cycle. Therefore, both SCR's remain off until another signal is received at the input terminals.

The release time, or the time that it takes for the switch to turn

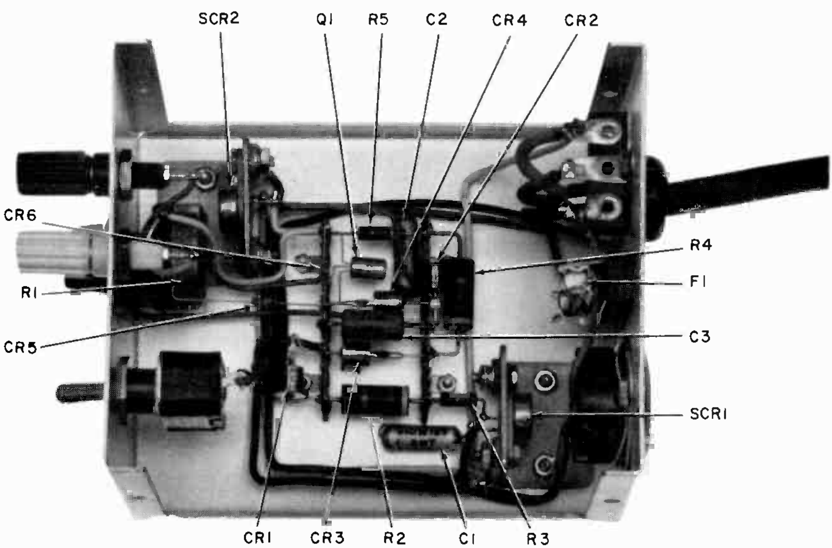


Fig. 199 – The audio-frequency-operated switch in a 3- by 4- by 5-inch chassis.

off after the input signal ceases, can be increased so that the switch does not open during momentary interruptions (e.g., between syllables). This increase in release time is accomplished by connection of a capacitor between the emitter and the collector of Q1. Values of capacitance up to 100 microfarads (15 volts) can be used.

Construction

The photograph in Fig. 199 shows the audio-frequency-operated switch assembled in a 3- by 4- by 5-inch chassis.

CIRCUIT NO. 37 – DIP/WAVE METER

One of the most useful instruments available to the electronics experimenter working in rf is the MOS field-effect-transistor dip/wave meter. A photograph of the unit is shown in Fig. 200. The meter is essentially an oscillator that can be used to measure resonant frequencies. With the power switch OFF the meter becomes an absorption-type wavemeter that measures the resonant frequency of energized rf circuits; with the power switch ON, the meter measures the resonant frequency of unenergized rf circuits. Then, if the inductance of the circuit is known, the capacitance can be calculated; if the capacitance is known the inductance can be calculated.

In operation, the coil of the meter is placed close to the tuned circuit to be measured. Capacitor C1 is then tuned until a movement of the meter needle is observed. If the dip/wave meter is being used to measure an energized circuit, the needle will jump upward slightly when the frequency of the meter oscillator matches that of the LC

Fig. 200 – A suggested method of assembling the dip/wave meter.

circuit being measured. If the dip/wave meter is being used to measure the frequency of an unenergized LC circuit, the needle will dip sharply at the point of resonance. If the meter gives no indication a different meter coil should be tried.

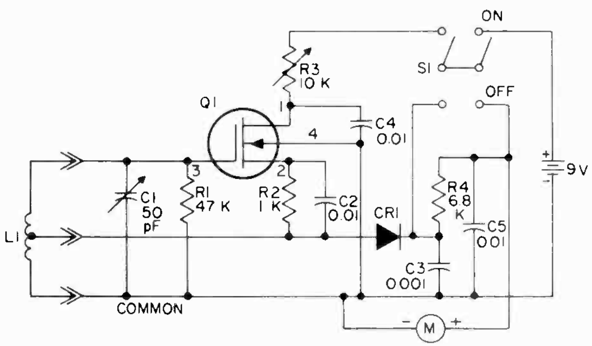
Circuit Operation

Fig. 201 shows the schematic diagram and parts list of the dip/wave meter, which is essentially an MOS field-effect-transistor oscillator.

Oscillator feedback is provided by return of the source to a tap on the coil; transistor operating bias is obtained through the bypassed source resistor R2. Oscillator rf voltage is rectified by diode CR1 and measured with the microammeter M. Potentiometer R3 adjusts the supply voltage to the oscillator and the intensity of oscillations or sensitivity of the dip/wave meter; R3 also controls the meter reading. C1 sets the frequency of the dip/wave meter.

Care should be taken when the dip/wave meter is being operated as a wave meter not to overdrive the field-effect transistor; this condition is encountered when the meter is deflected beyond full scale.

Power is supplied to the dip/wave meter by a 9-volt transistor battery. The current drain for this circuit is 2 milliamperes maximum.



Parts List

Battery = 9 volt transistor type, RCA VS323 or equivalent

C1 = variable capacitor, 50 picofarads; Hammarlund HF-50 or equivalent

C2 C4 C5 = 0.01 microfarad, 50 volts or greater, ceramic

C3 = 0.001 microfarad, 50 volts or greater, ceramic

CR1 = diode, type 1N914

L1 = see Table V

M = microammeter, 0 to 100 microamperes

Q1 = MOS field-effect transistor, RCA 3N139

R1 = 47,000 ohms, 1/2 watt, 10%

R2 = 1000 ohms, 1/2 watt, 10%

R3 = potentiometer, 10,000 ohms, linear taper

R4 = 6800 ohms, 1/2 watt, 10%

S1 = toggle switch, double-pole, double-throw

Fig. 201 – Schematic diagram and parts list for the dip/wave meter.

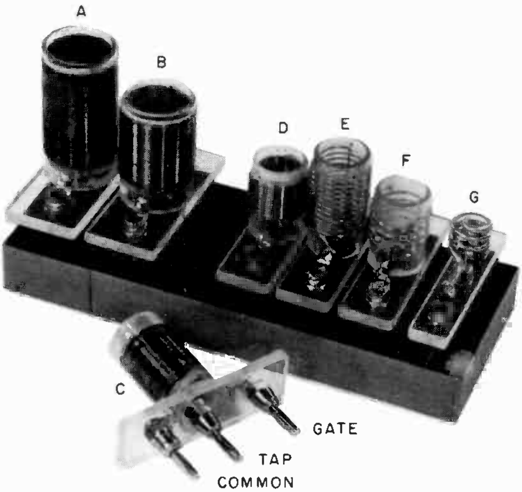


Fig. 202 – Dip/wave meter coils. The coils are described in detail in Table XXX.

Table XXX.
Dip/Wave Meter Typical Coil Characteristics

Coil*	Inductance (μH)	Frequency (MHz) Min.	Max.	Wire Size	Turns Per Coil	Diameter of Coil (inches)	Length of Coil (inches)	Tap Location (No of turns from common end
A	280	1.16	2.25	32+	120-1/2	1	1-1/2	30-1/4
B	99	2	4.1	30+	72-1/2	1	1	18-1/4
C	25	3.9	8	28+	46-1/2	3/4	7/8	12-1/4
D	6.6	7.7	16.1	22+	19-1/2	3/4	9/16	4-3/4
E	1.7	15.4	32.5	20■	11-1/3	3/4	1	3-1/8
F	0.39	32	66	20■	3-3/4	3/4	1/2	7/8
G	0.16	50	110	12■	3	3/8	1/2	1

*Coil A to D close wound on polyethylene forms; E and F space wound on polyethylene forms; G self supporting. The coils are pictured in Fig. 202.
+Enameled
■Tin Plated

Construction

The coils used with the dip/wave meter are wound on polyethylene tubing and glued with acrylic cement to a polyethylene bar containing three banana plugs. The ends of the coil are connected to the two end plugs; the center tap is connected to the center plug. The coil terminals on the dip/wave meter should be recessed so that they cannot be short-circuited, a condition that could cause damage to the MOS transistor. A table of typical values is given in Table XXX. Fig. 202 shows a number of completed coils.

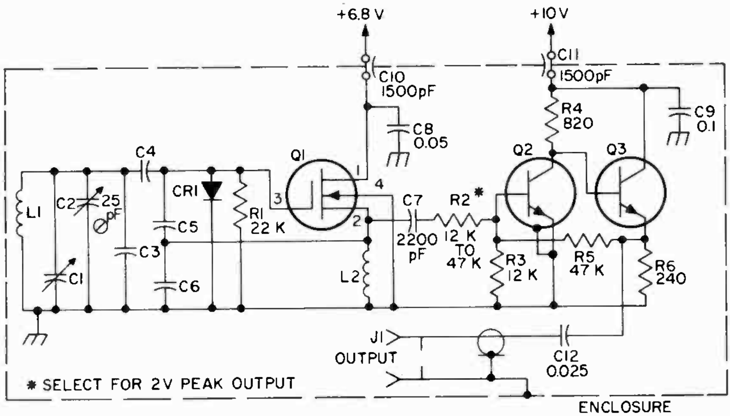
CIRCUIT NO. 38 – VARIABLE-FREQUENCY OSCILLATOR

The variable-frequency oscillator (vfo) circuit can be used with a fixed or mobile radio-amateur transmitter and is capable of excellent performance with minimum frequency drift at frequencies up to and including vhf. Operating potentials can be obtained directly from a 12-volt source, such as an automobile battery, dry battery, or low-voltage power supply (Circuit No. 2). Fig. 203 shows a photograph of the vfo.

Circuit Operation

The schematic diagram and parts list for the variable-frequency oscillator are shown in Fig. 204. This oscillator is basically of the Colpitts type; each of the tuning ranges shown in Table XXXI is band spread over almost all of the tuning dial for accurate calibration and resettability. The effect of changes in transistor-element capacitance is minimized by use of a voltage divider consisting of C4, C5, and C6, with the transistor connected across C5 and C6. The use of fairly large values for C5 and C6 almost completely suppresses the effect of transistor capacitance. A radio-frequency choke L2 provides

Fig. 203 – Suggested enclosure for the variable-frequency oscillator.



Parts List

C1 = variable capacitor, high-quality, double-bearing type, Millen 23100 or 23050 or equivalent (See Table XXXI for value)

C2 = 25 picofarad air-type trimmer capacitor; Johnson type 148-2 or equivalent

C3 C4 C5 C6 = silver mica capacitors, 300 volts or greater (See Table XXXI for values)

C7 = 2200 picofarads, 300 volts or greater, silver mica

C8 = 0.05 microfarad, 50 volts or greater, ceramic disc

C9 = 0.1 microfarad, 50 volts or greater, ceramic disc

C10 C11 = 1500 picofarads, 500 volts, feedthrough type

C12 = 0.025 microfarad, 50 volts or greater, ceramic disc

CR1 = diode, type 1N914

J1 = coaxial connector, chassis-mount vhf type

L1 = see Table XXXI for values

L2 = 2.5 millihenries, miniature rf choke

Q1 = MOS field-effect transistor, type 3N139

Q2 = transistor, RCA SK3018

Q3 = transistor, RCA SK3020

R1 = 22,000 ohms, 1/2 watt, 10%

R2 = 12,000 to 47,000 ohms, 1/2 watt, 10%; select for 2-volt peak output

R3 = 12,000 ohms, 1/2 watt, 10%

R4 = 820 ohms, 1/2 watt, 10%

R5 = 47,000 ohms, 1/2 watt, 10%

R6 = 240 ohms, 1/2 watt, 10%

Fig. 204 – Schematic diagram and parts list for the variable-frequency oscillator.

the needed low IR drop for the source current of the MOS transistor.

Because the MOS transistor by itself will not provide rectified gate current, a diode, CR1, is used in the gate circuit. This diode contributes considerably to the frequency stability of the oscillator by providing automatic bias which tends to compensate for changes in output load and supply voltage.

The vfo output is taken from the source of the MOS transistor through a two-stage negative-feedback amplifier which performs two basic functions:

1. It greatly minimizes the effect on the oscillator of a change in output conditions.

2. It provides a convenient means of adjusting the output voltage of the vfo by changing the value of R2.

The use of silver-mica capacitors assures a fairly stable temperature characteristic.

Power is supplied to the vfo through two 1500-picofarad feed-through capacitors. The 10- and 6.8-volt power levels required can be obtained from a modified universal series supply. The modification is shown in Fig. 205; the universal series supply is described in Circuit No. 2.

Table XXXI.
Tuned-Circuit Data for the VFO

Frequency (MHz)	1.75-1.9	2.5-2.7	3.5-4	5-5.5	8-9	7-7.5
L1 Inductance (μH)	18.3	9.6	5.4	4.4	2.2	1.4
L1 Total Turns	32	19	17	14-3/4	11-1/2	8
L1 Wire Size	24	24	20	20	18	18
L1 Turns/Inch	32	32	16	16	8	8
L1 Diameter/Inches	1	1	1	1	1	1
L1 (B&W No. or equivalent)	3016	3016	3015	3015	3014	3014
C1 (pF)	75	75	100	50	50	50
C2 (pF)	50	50	25	25	25	25
C3 (pF)	100	120	100	None	None	120
C4 (pF)	470	470	390	390	270	390
C5 (pF)	1000	1000	680	680	560	680
C6 (pF)	1000	1000	680	680	560	680

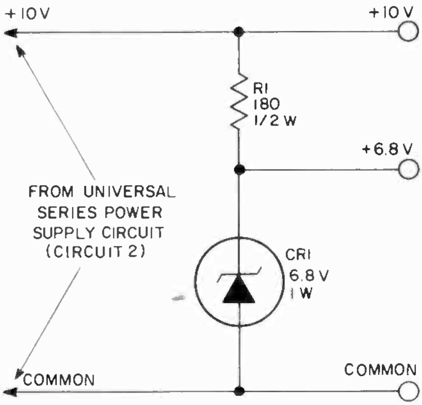


Fig. 205 – Universal-series-power-supply modification for use with the variable-frequency oscillator circuit.

Construction

The complete vfo can be housed in a 4- by 5- by 6-inch aluminum utility box. The MOS transistor oscillator components of the vfo must be rigidly installed in the box. This rigid installation can be accomplished by mounting all oscillator components (less the tuned circuits) on a terminal strip (H.H. Smith No. 1070 or equivalent); the two-stage amplifier can be mounted on a similar strip. This arrangement is shown in Fig. 206. The lower strip in the figure supports the oscillator components; the MOS transistor projects downward from the center of the strip. The upper strip is for the two-stage amplifier; the transistor

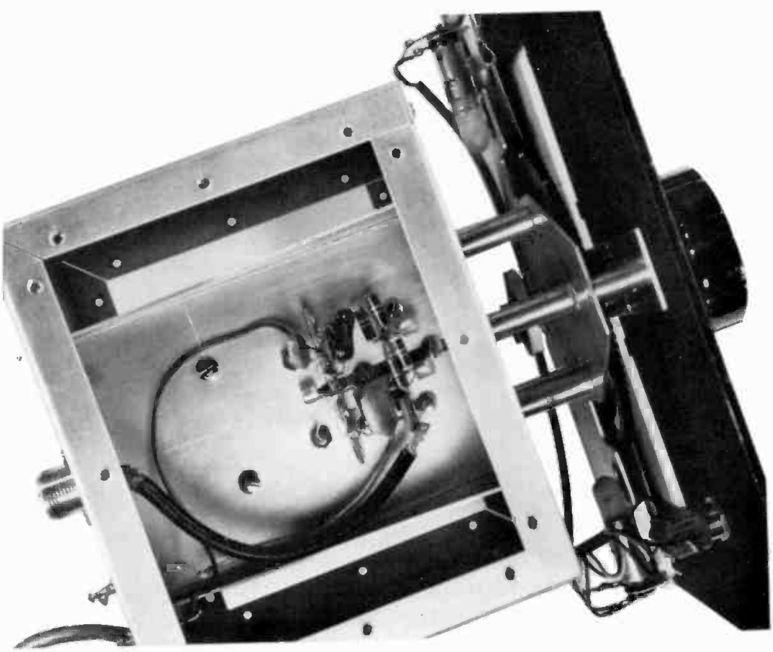


Fig. 206 – Suggested mounting of oscillator and two-stage amplifier components.

projects upward on either side of the mounting screw. The short length of coaxial cable runs to the connector on the rear of the box. The silver-mica capacitors which form part of the tuned circuit must be mounted in such a way that there is no possibility of motion. A photograph of the tuned circuit assembly is shown in Fig. 207. In the figure, the tuned circuit is supported by a bent aluminum sheet extending from the front to the rear of the box. The trimmer capacitor, C2, is mounted on the rear wall, as are the coaxial output connector and feedthrough bypass capacitors for the power leads.

A single-pole double-throw switch can be connected in the circuit so that in one position only the vfo power supply is turned on. With the switch in the other position, power is supplied through the main transmitter supply and the vfo is activated by the transmit/receive switch in the transmitter.

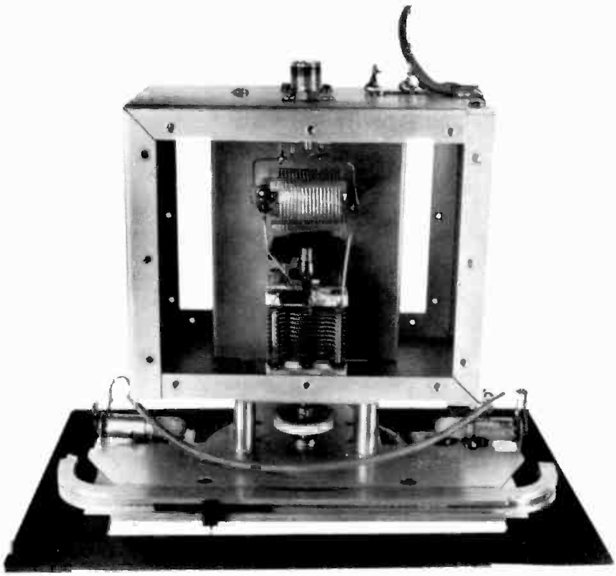


Fig. 207 – Suggested tuned-circuit assembly.

CIRCUIT NO. 39 – VFO CALIBRATOR

In the vfo calibrator, harmonics of a secondary-standard 100-kHz crystal oscillator are beat with the fundamental, or harmonics, of an external vfo to provide audible signals at definite frequencies across the dial. For example, if this unit is used with a 5.0- to 5.5-MHz vfo, the 100-kHz calibration points are the strongest by far. However, the 50-kHz points are also perceptible and, if proper care is exercised, the

33-, 25-, and 20-kHz points can be detected as well. In practice, the calibrator is permanently connected to the rf line between the vfo and the transmitter. A suggested enclosure for the vfo calibrator is shown in Fig. 208.

coupling to the input of the two-stage wave-shaping amplifier, Q4 and Q5, and thus prevent loading of the secondary-standard oscillator. The two-stage wave-shaping amplifier provides the following advantages:

Fig. 208 – Suggested enclosure for the vfo calibrator.

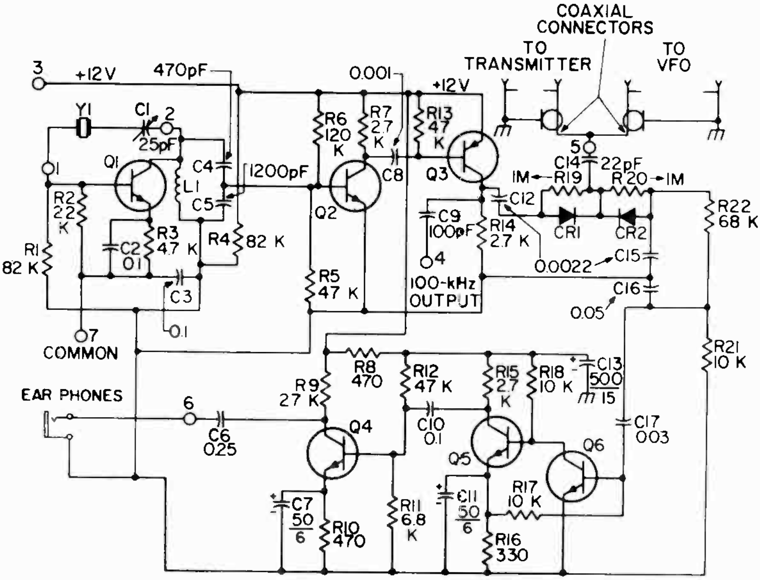
Circuit Operation

The schematic diagram and parts list for the vfo calibrator are shown in Fig. 209. The 100-kHz oscillator, Q3, is of the tuned-collector type, with the crystal Y1 inserted in the base feedback circuit. The 25-picofarad padder capacitor, C4 (crystal adjust), is connected in series with the crystal so that oscillation can be adjusted to exactly 100 kHz. Capacitors C7 and C8 are used as a voltage divider to reduce the

1. It prevents any reflection of the output load from affecting the frequency of the 100-kHz secondary-standard oscillator.

2. It shapes the output wave so that the harmonics are of greater strength.

The output of the two-stage wave-shaping amplifier is connected to one input of a two-diode product detector, CR1 and CR2, and the vfo to be calibrated is connected to the other input. The wave-shaping ampli-



Parts List

C1 = 25 picofarads, adjustable padder type, air dielectric, Hammarlund APC-25 or equivalent
C2 C3 C10 = 0.1 microfarad, 25 volts or greater, ceramic
C4 = 470 picofarads, 500 volts, silver mica
C5 = 1200 picofarads, 500 volts, silver mica
C6 = 0.25 microfarad, 25 volts or greater, paper
C7 C11 = 50 microfarads, 6 volts, electrolytic
C8 = 0.001 microfarad, 25 volts or greater, ceramic
C9 = 100 picofarads, 25 volts or greater, ceramic
C12 C15 = 0.0022 microfarad, 25 volts or greater, ceramic
C13 = 500 microfarads, 15 volts, electrolytic
C14 = 22 picofarads, 25 volts or greater, ceramic
C16 = 0.05 microfarad, 25 volts or greater, ceramic
C17 = 0.03 microfarad, 25 volts or greater, ceramic
CR1 CR2 = diode, RCA 1N34A
L1 = rf choke, 10 millihenries, Miller 70F-102A1 or equivalent
Q1 Q2 Q4 Q5 Q6 = transistor, RCA SK3020
Q3 = transistor, RCA SK3005
R1 R4 = 82,000 ohms, 1/2 watt, 10%
R2 = 22,000 ohms, 1/2 watt, 10%
R3 = 4700 ohms, 1/2 watt, 10%
R5 R12 R13 = 47,000 ohms, 1/2 watt, 10%
R6 = 120,000 ohms, 1/2 watt, 10%
R7 R9 R14 R15 = 2700 ohms, 1/2 watt, 10%
R8 R10 = 470 ohms, 1/2 watt, 10%
R11 = 6800 ohms, 1/2 watt, 10%

Fig. 209 – Schematic diagram and parts list for the vfo calibrator.

Parts List (Cont'd)

R16 = 330 ohms, 1/2 watt, 10%
R17 R18 R21 = 10,000 ohms, 1/2 watt, 10%
R19 R20 = 1 megohm, 1/2 watt, 10%
R22 = 68,000 ohms, 1/2 watt, 10%
Y1 = crystal, 100 kHz, quartz; Anderson Electronics No. AE6-X-202 or equivalent
Earphones = 600 ohms or more

fier output is connected in such a way that the unit can be used as a conventional 100-kHz crystal calibrator. The values of the components shown in the parts list have been chosen for a vfo signal of 2 to 3 volts. For larger signals, the 22-picofarad capacitor C17 must be replaced with some type of capacitance or resistive attenuator.

A three-stage audio amplifier consisting of Q6, Q7, and Q8 is used to amplify the extremely low audio output of the two-diode product detector to a comfortable headphone level.

The crystal socket and the air capacitor used for setting the frequency should be mounted on a small piece of aluminum and attached to one end of the circuit board. If a metal enclosure is used, the circuit board should be separated from it by at least 3/8 of an inch. RF connections to the vfo and transmitter can be made through standard coaxial connectors.

Adjustments and Operation

The adjustment of the 100-kHz secondary-standard oscillator to precisely 100 kHz is easily accomplished by comparison of its harmonic with that of the primary standard, WWV*. For the best beat signal, the 100-kHz output of the calibrator should be loosely coupled to the antenna of the receiver tuned to WWV. Capacitor C1 should then be adjusted through the crystal-adjustment hole (in the back of the enclosure as shown in Fig. 211) until a zero beat exists between the secondary standard and WWV. It would be well to wait for the quiet period of WWV's transmission (when there is no 440-Hz modulation) to be absolutely certain that the secondary standard is beating with the carrier and not with one of the sidebands.

The calibrator is very easy to use. It is inserted in the rf line of the vfo by connecting the vfo to the input coaxial connector and the transmitter to the output connector. When power is applied to the unit, a slight hissing noise should be heard in the earphones. This noise indicates that the audio amplifier is active. At or near the even 100-kHz points on the vfo, low beat notes should be heard. Calibration of the dial can then be performed by zero-beating the vfo at those points. Lower-volume beats may be heard at the 50-kHz points on the dial, and in most cases it is also possible to hear the 33-, 25-, and 20-kHz beats, especially if the fundamental operating frequency of the vfo is below 5 MHz.

With many of today's amateur-radio receivers designed solely for hamband reception, the vfo calibrator is especially applicable to

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oscillators operating at frequencies outside the hambands. In addition, the unit can prove very useful for calibrating certain types of test equipment and for allowing the vfo to be used as a hamband frequency meter. The 100-kHz output can be used to calibrate receivers and test equipment such as grid dip meters.

Construction

The 100-kHz crystal oscillator, the two-stage wave-shaping amplifier, the product detector, and the three-stage audio amplifier are all assembled on a 3- by 4-1/2-inch phenolic circuit board. This method of construction results in a rugged, compact instrument. The drilling template for the vfo calibrator is shown in the back of this Manual; a component placement diagram and a photograph of a completed assembly are shown in Figs. 210 and 211, respectively.

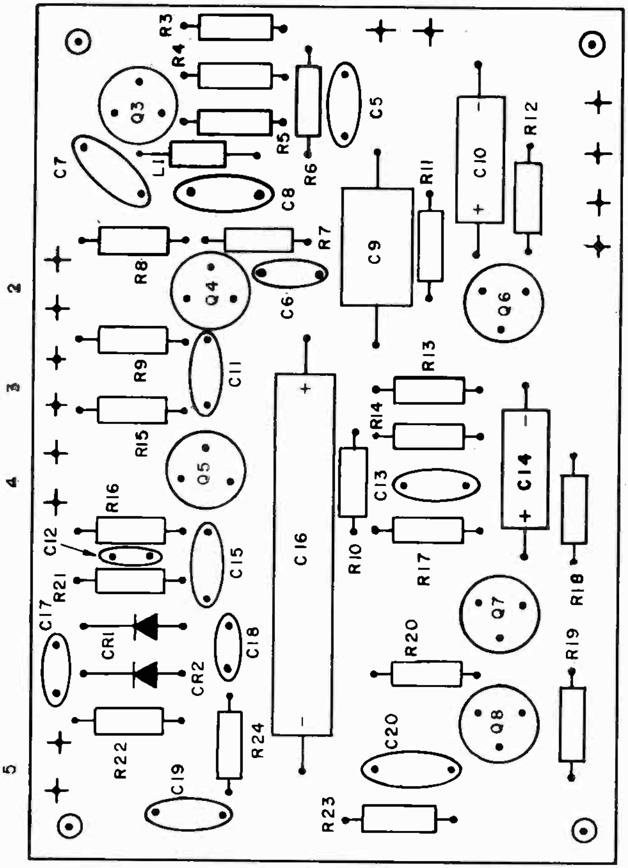


Fig. 210 – Component placement diagram for the vfo calibrator.

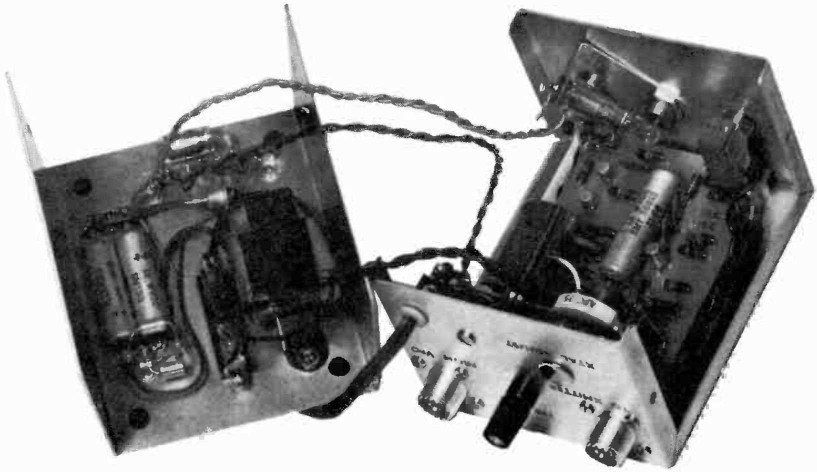


Fig. 211 – The vfo calibrator assembly. Power supply components are mounted on the bottom cover of the aluminum enclosure.

CIRCUIT NO. 40 – 100-kHz CRYSTAL OSCILLATOR

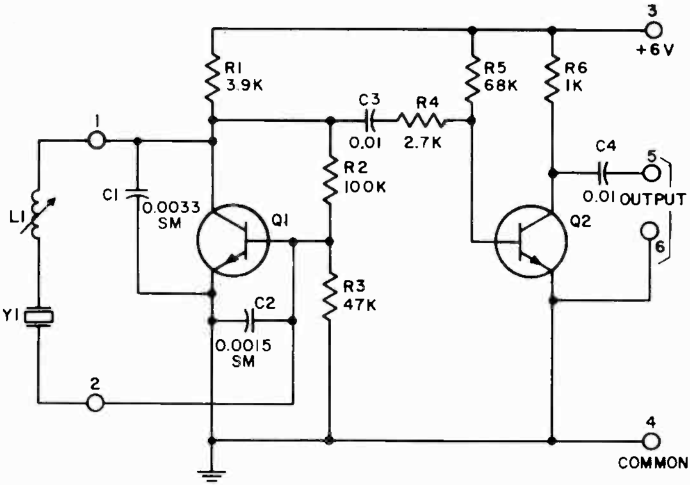
The 100-kHz crystal oscillator can be used to calibrate radio receivers, signal generators, grid-dip oscillators and the like. The radio amateur can use it to locate band edges to assure that his operation is confined within the frequency bands assigned. The oscillator can also be used to generate an extremely precise timing signal that can be used in electronic counters and clocks. The twenty-four-hour clock, Circuit No. 12, uses this crystal oscillator as its prime timing source.

Circuit Operation

The schematic diagram and parts list for the 100-kHz crystal oscillator is shown in Fig. 212. Transistor Q1 is the basis of a conventional Pierce oscillator configuration in which the crystal is connected between the collector and the base of the transistor and the emitter of the transistor is grounded. L1, an adjustable rf coil, is used to set the oscillator frequency to precisely 100 kHz. The output of the oscillator is fed to a wave-shaping amplifier, composed of Q2 and its surrounding circuitry, whose purpose is threefold: 1) it isolates the oscillator from any circuit connected to the output, 2) it amplifies the oscillator signal, and 3) it shapes the characteristics of the oscillator wave so that it is rich in harmonics.

Construction

The printed-circuit board for the 100-kHz crystal oscillator is shown at the back of this Manual; a component placement diagram and a photograph of a completed board are shown in Figs. 213 and 214,



Parts List

C1 = 0.0033 microfarad, silver mica, 10%, 100 volts or greater
C2 = 0.0015 microfarad, silver mica, 10%, 100 volts or greater
C3 C4 = 0.01 microfarad, 50 volts or greater, ceramic
L1 = coil, adjustable, 6 to 16 millihenries; Miller No. 9005 or equivalent
Q1 Q2 = transistor, RCA SK3020
R1 = 3900 ohms, 1/2 watt, 10%
R2 = 100,000 ohms, 1/2 watt, 10%
R3 = 47,000 ohms, 1/2 watt, 10%
R4 = 2700 ohms, 1/2 watt, 10%
R5 = 68,000 ohms, 1/2 watt, 10%
R6 = 1000 ohms, 1/2 watt, 10%
Y1 = crystal, 100 kHz, quartz; Anderson Electronics No. AE6-X-202 or equivalent

Fig. 212 – Schematic diagram and parts list for the 100-kHz crystal oscillator.

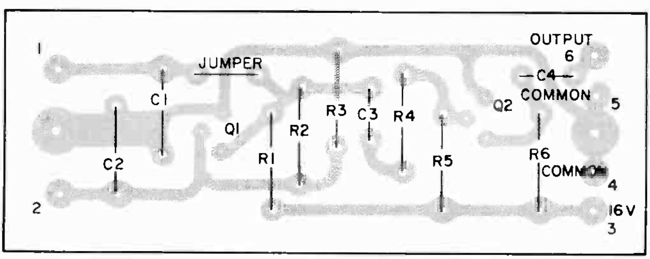


Fig. 213 – Component placement diagram for the 100-kHz crystal oscillator.

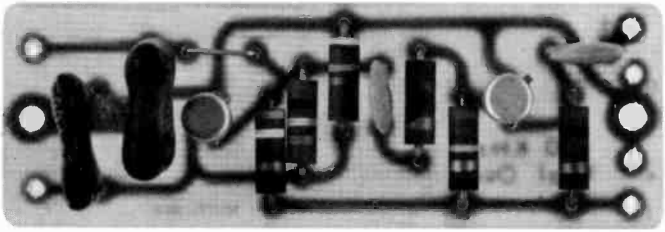


Fig. 214 – Completed circuit board for 100-kHz crystal oscillator.

respectively. Fig. 215 shows the board mounted in an aluminum chassis. The board contains all components needed in the circuit with the exception of the crystal and its zero adjustment coil, L1. precisely 100 kHz by matching it against the carrier frequency of radio station WWV, the frequency standard station of the National Bureau of Standards.* This station operates on 5, 10, and 15 MHz, all

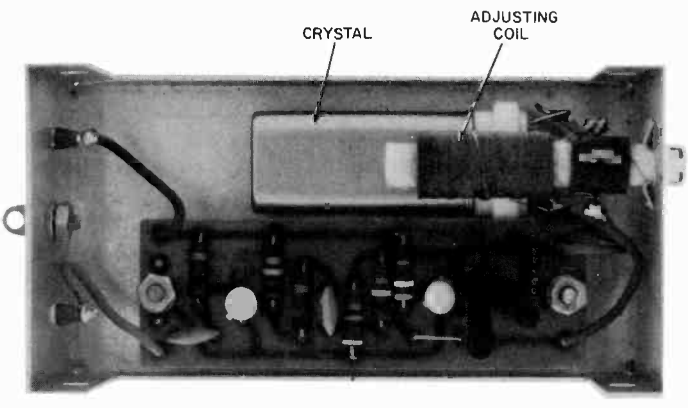


Fig. 215 – Suggested method of assembling the 100-kHz crystal oscillator components in a chassis.

Operation and Adjustment

The application of from 6 to 7 volts to the oscillator produces a strong 100-kHz signal that should be detectable at every 100 kHz, up to at least 40 MHz, on the dial of any radio receiver. The frequency of the crystal oscillator is adjusted to multiples of 100 kHz. Once WWV has been tuned in, the oscillator is turned on and a short length of wire connected to terminal No. 6 brought

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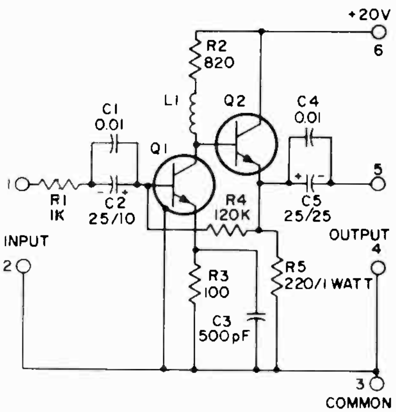
into close proximity to the receiver. L1 should then be tuned until the beat heard becomes zero. Note that WWV is modulated with either 440 or 1000 cycles for four out of every five minutes; therefore, it is wise to zero beat the crystal oscillator during the time that there is no tone modulation on the WWV carrier. This action will prevent any chance of zero beating the oscillator frequency with the WWV side-band frequency rather than its carrier frequency.

CIRCUIT NO. 41 – VIDEO LINE AMPLIFIER

The video line amplifier can be used to aid transmission of video or VFO signals over a 75-ohm coaxial cable and to boost rf and video signals; it isolates input signals from devices connected to its output.

Circuit Operation

The schematic diagram and parts list for the video line amplifier are shown in Fig. 216. Transistors Q1 and Q2 form a two-stage wide-band amplifier that exhibits low output impedance and good frequency response because of the excellent high-frequency characteristics of the transistors. The use of feedback from the output of Q2 to the base of Q1 through R4 assures amplifier stability under varying operating conditions including thermal changes. The high frequency response of the circuit is aided by partially bypassing the emitter resistor R3; a further increase in response is obtained through the use of peaking coil L1. The paired coupling capacitors at the input and output result in a very low impedance to both low and high frequency signals. The response of the amplifier is essentially flat from about 10Hz to 5MHz and is useable to 10 MHz. Input impedance is about 2,000 ohms and output impedance 50 ohms; the voltage gain of the circuit is approximately 6.



Parts List

- C1 C4 = 0.01 microfarad, ceramic, 50 volts or greater
- C2 = 25 microfarads, 10 volts, electrolytic
- C3 = 500 picofarads, mica
- C5 = 25 microfarads, 25 volts, electrolytic
- L1 = radio-frequency choke, 5.6 microhenries
- Q1 = transistor, SK3019
- Q2 = transistor, SK3024
- R1 = 1000 ohms, 1/2 watt, 10%
- R2 = 820 ohms, 1/2 watt, 10%
- R3 = 100 ohms, 1/2 watt, 10%
- R4 = 120,000 ohms, 1/2 watt, 10%
- R5 = 220 ohms, 1 watt, 10%

Fig. 216 – Schematic diagram and parts list for the video line amplifier.

Construction

The printed circuit template for the video line amplifier is shown at the back of this Manual. A component placement diagram and a photograph of a completed circuit board are shown in Figs. 217 and 218, respectively.

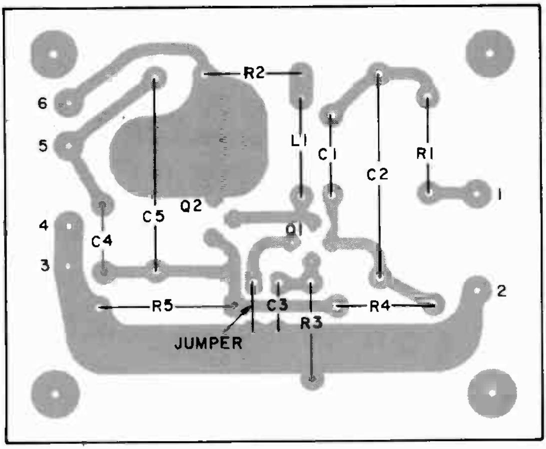


Fig. 217 – Component placement diagram for the video line amplifier.

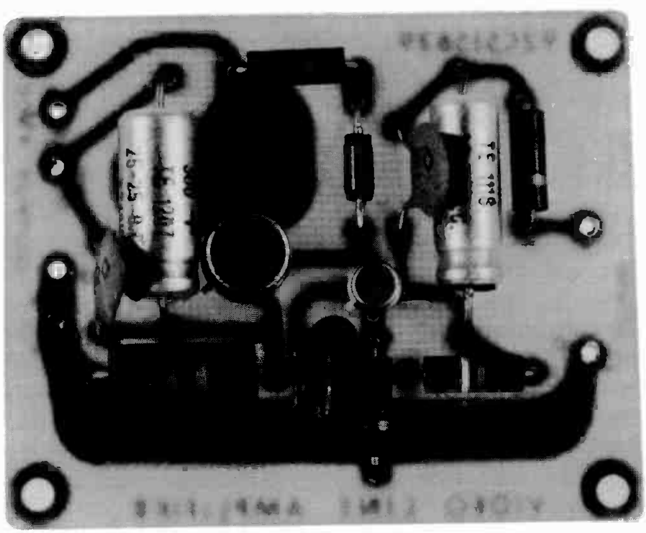


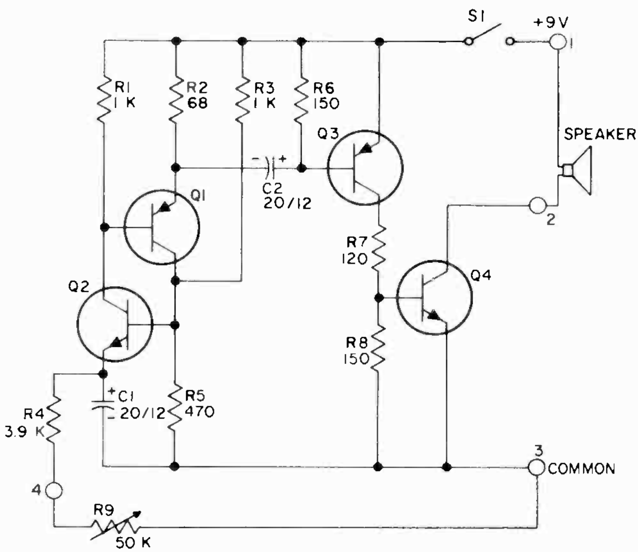
Fig. 218 – Completed circuit board for the video line amplifier.

CIRCUIT NO. 42 –METRONOME

The electronic metronome produces a series of audible clicks at a rate determined by the user. Its most common use is in metering musical cadence, but it may be used in the darkroom to measure time audibly. If the click rate of the timer is set at 1 second, the passage of an amount of time can be noted by counting the clicks. The electronic metronome has an advantage over the mechanical type in that it does not have to be rewound.

Circuit Operation

The schematic diagram and parts list for the electronic metronome are shown in Fig. 219. Transistors Q1 and Q2 form a regenerative switch that has a high impedance until it is triggered, when its impedance becomes very low. When switch S1 is closed, power is applied to the circuit, C1 charges through the emitter of Q2, and the regenerative switch is turned on instantaneously. Q1, the second transistor in the



Parts List

C1 C2 = 20 microfarads, 12 volts, electrolytic
Q1 Q3 = transistor, RCA SK3005
Q2 Q4 = transistor, RCA SK3020
R1 R3 = 1000 ohms, 1/2 watt, 10%
R2 = 68 ohms, 1/2 watt, 10%
R4 = 3900 ohms, 1/2 watt, 10%
R5 = 470 ohms, 1/2 watt, 10%
R6 R8 = 150 ohms, 1/2 watt, 10%
R7 = 120 ohms, 1/2 watt, 10%
R9 = potentiometer, 50,000 ohms, linear taper
S1 = toggle switch; single-pole, single throw
Speaker = 3.2 ohms

Fig. 219 – Schematic diagram and parts list for the metronome.

regenerative switch, turns on as Q2 goes into conduction. Current is then conducted through C2 to the base of Q3. Q3 turns on and conducts current to the base of Q4, which is in series with the speaker. When Q4 turns on, it causes the speaker to emit an audible click. When the charge on C1 increases, the emitter of Q2 becomes more positive, turns off the regenerative switch, and stops the flow of current to Q3. When the regenerative switch is off, C2 must discharge through R2 and the combination of R6 and Q3. As the charge on C1 lessens, the emitter of Q2 becomes less positive, the regenerative switch is triggered into

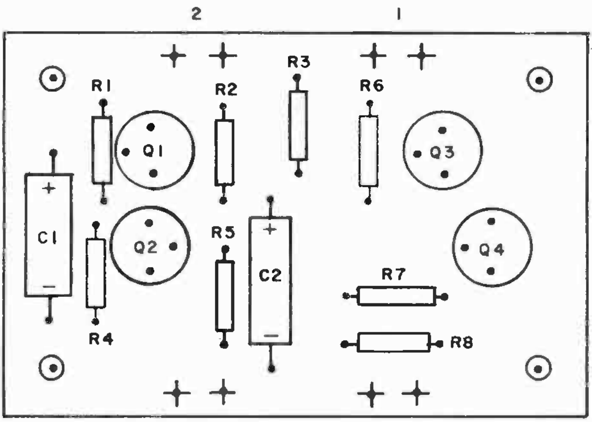


Fig. 220 – Component placement diagram for the metronome.

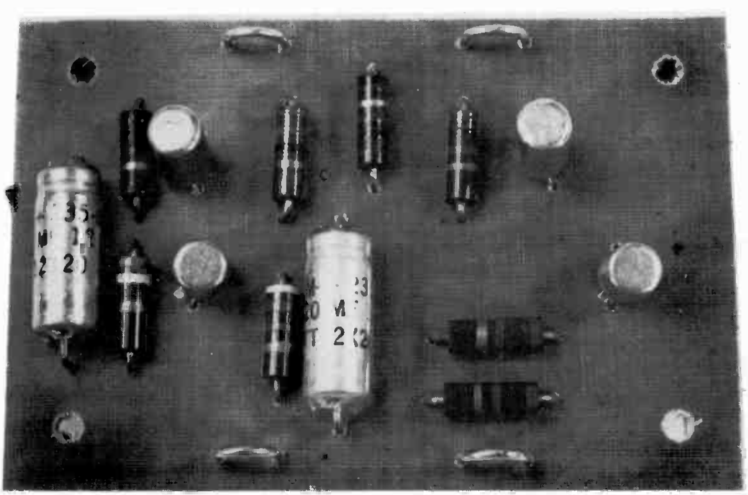


Fig. 221 – Completed circuit board for the metronome.

conduction, and Q3 receives another pulse. This process is repeated as long as power is applied to the circuit. Each time the regenerative switch conducts, an audible click is produced.

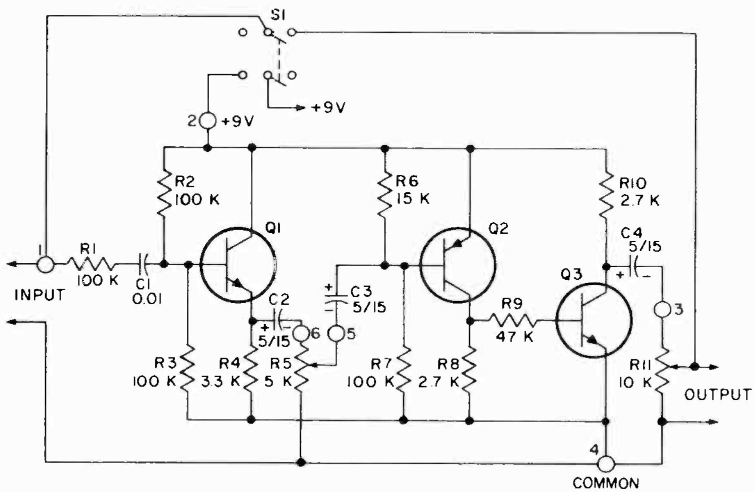
The current drain for this circuit is 20 milliamperes.

Construction

The drilling template for the electronic metronome is shown at the back of the Manual; a component placement diagram and a photograph of a completed circuit board are shown in Figs. 220 and 221, respectively.

CIRCUIT NO. 43 – FUZZ BOX

The fuzz box is intended to be used with a guitar; however, it may be used with any instrument whose musical output is electrically amplified. It can be used with the 7.5-watt audio amplifier circuit described in this Manual. The fuzz box changes the character of the sound produced by an instrument and makes possible the generation of a variety of sounds of which the instrument alone is not capable.



Parts List

C1 = 0.01 microfarad, 25 volts or greater
C2 C3 C4 = 5 microfarads, 15 volts, electrolytic
Q1 Q3 = transistor, RCA SK3020
Q2 = transistor, RCA SK3005
R1 R2 R3 R7 = 100,000 ohms, 1/2 watt, 10%
R4 = 3300 ohms, 1/2 watt, 10%
R5 = potentiometer, 5000 ohms, linear taper
R6 = 15,000 ohms, 1/2 watt, 10%
R8 R10 = 2700 ohms, 1/2 watt, 10%
R9 = 47,000 ohms, 1/2 watt, 10%
R11 = potentiometer, 10,000 ohms, linear taper
S1 = toggle switch, double pole, double-throw

Fig. 222 – Schematic diagram and parts list for the fuzz box.

Circuit Operation

The schematic diagram and parts list for the electronic fuzz box are shown in Fig. 222. The output of transistor Q1, a basic emitter-follower that gives the fuzz box a high-impedance input, is applied to the base of Q2. Q2 is biased at almost cutoff and, therefore, amplifies only half the input signal. Potentiometer R5 is used to adjust the input signal level to Q2 (to approximately 1 volt) and the amount of "fuzz." Transistor Q3 receives the output from Q2 through R9; Q3 is biased in such a way that the top half of the signal input to it is clipped; this clipping action tends to create a square wave. Potentiometer R11 is used to vary the output level of the circuit.

The input voltage of this circuit should be approximately 1 volt. The current drain for this circuit is approximately 5 milliamperes.

Construction

In operation, the fuzz box is normally cut in and out as music is being played. When the fuzz box is cut out the musical instrument is connected directly to the amplifier.

The drilling template for the electronic fuzz box is shown at the back of this Manual; a component placement diagram and a photograph of a completed circuit board are shown in Figs. 223 and 224, respectively.

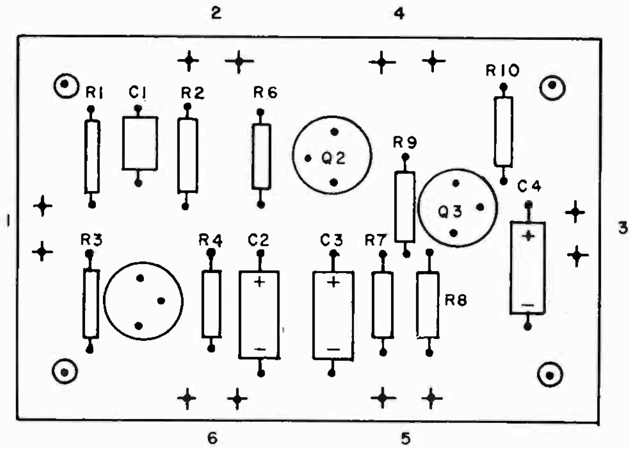


Fig. 223—Component placement diagram for the fuzz box.

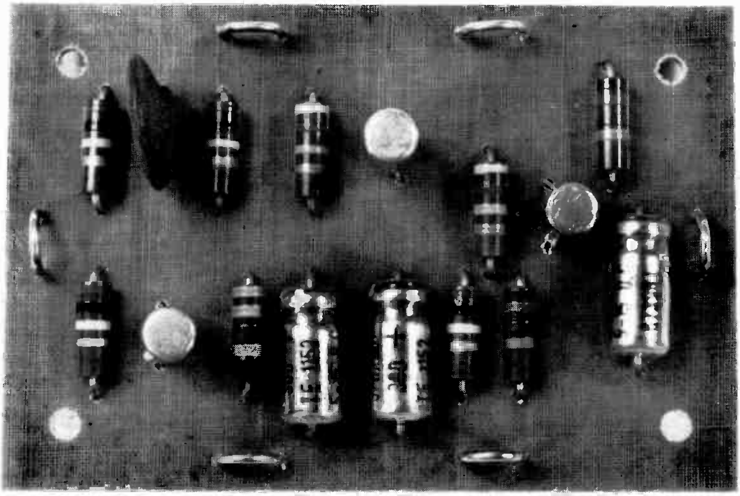


Fig. 224 – Completed circuit board for the fuzz box.

CIRCUIT NO. 44 – SIX-OCTAVE ORGAN

The six-octave, solo organ shown in Fig. 225 is a complete musical instrument. The fact that it plays only one note at a time makes it an excellent solo instrument or lead instrument with accompaniment, particularly piano accompaniment. Its variable tone-character control permits simulation of the sounds of many musical instruments that have a frequency range within the six-octave musical range of the organ; the frequency ranges of both the organ and the instruments within its range are shown in Fig. 226. Volume and tremolo depth controls help to generate a full, rich note that is representative of true organ sound.

Circuit Operation

The block diagram in Fig. 227 traces the operation of the organ from the time that a key is depressed to the emergence of the selected note from the speaker. When a key is depressed along with one of the octave pushbuttons, one of the twenty-five series-connected resistors used to obtain a chromatic scale and one of the five series-connected capacitors used to key the note generated up or down two octaves from the middle octave are connected into the basic tone-generator circuit shown in Fig. 228; the tones are actually produced by transistors Q3 and Q4. Transistors Q1 and Q2 form the tremolo oscillator and frequency-modulate the tone produced by Q3 and Q4 by applying a sine wave to them so that a pulse wave is produced at terminal 7 and a sawtooth wave at terminal 9. R6 controls the depth of tremolo; R14 is the tuning control.

The pulse and sawtooth waves are then applied to the mixer pre-amplifier, which changes the

Fig. 225 – Suggested enclosure for the six-octave electronic organ.

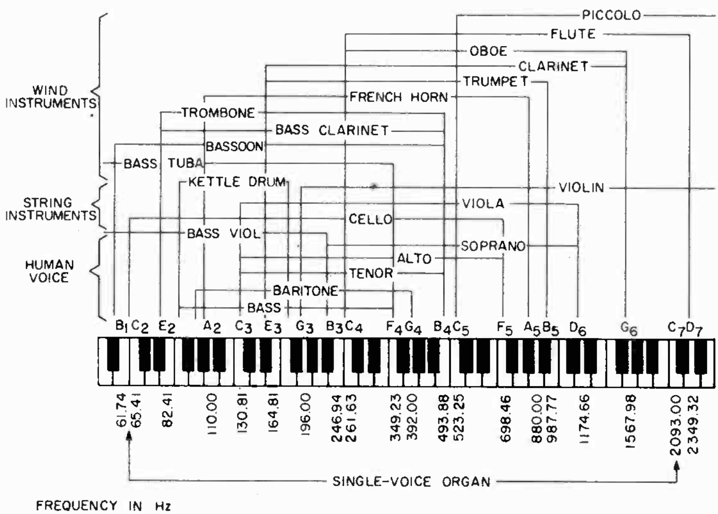


Fig. 226 – Frequency range of the organ and of the instruments with its range.

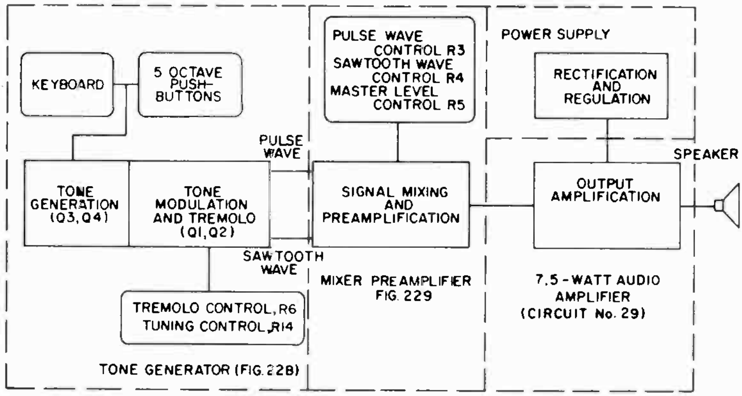


Fig. 227 — Functional block diagram of the organ.

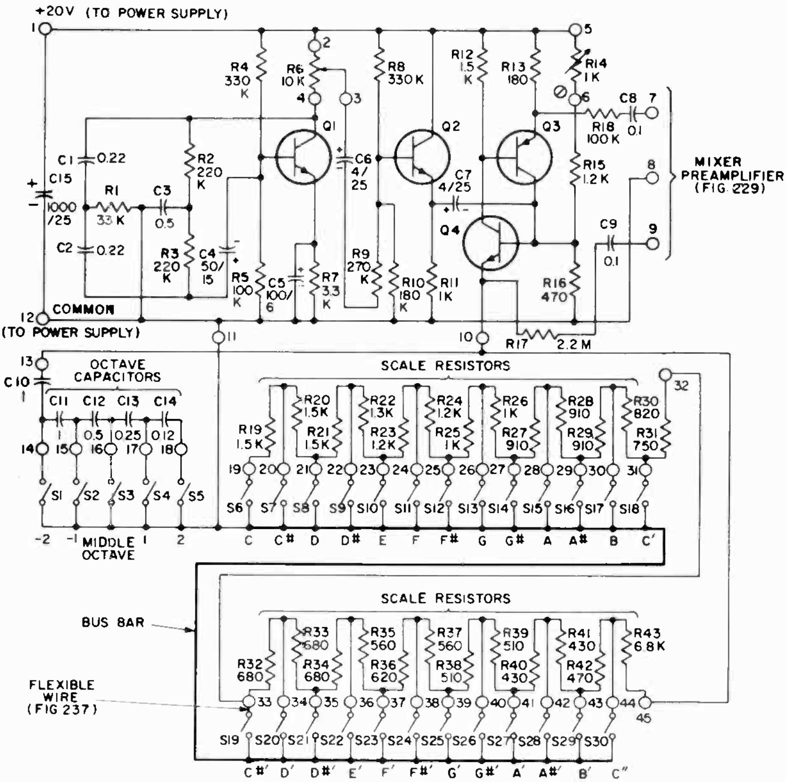


Fig. 228 — Schematic diagram for the organ tone generator. Parts list on next page.

Parts List

C1 C2 = 0.22 microfarad, 25 volts or greater, paper
C3 C12 = 0.5 microfarad, 25 volts or greater, paper
C4 = 50 microfarads, 15 volts, electrolytic
C5 = 100 microfarads, 6 volts, electrolytic
C6 C7 = 4 microfarads, 25 volts, electrolytic
C8 C9 = 0.1 microfarad, 25 volts or greater
C10 C11 = 1 microfarad, 25 volts or greater, paper
C13 = 0.25 microfarad, 25 volts or greater, paper
C14 = 0.12 microfarad, 25 volts or greater, paper
C15 = 1000 microfarads, 25 volts, electrolytic
Q1 Q2 Q4 = transistor, RCA SK3020
Q3 = transistor, RCA SK3005
R1 = 33,000 ohms, 1/2 watt, 10%
R2 R3 = 220,000 ohms, 1/2 watt, 10%
R4 R8 = 330,000 ohms, 1/2 watt, 10%
R5 R18 = 100,000 ohms, 1/2 watt, 10%
R6 = potentiometer, 10,000 ohms, linear taper
R7 = 3300 ohms, 1/2 watt, 10%
R9 = 270,000 ohms, 1/2 watt, 10%
R10 = 180,000 ohms, 1/2 watt, 10%
R11 = 1000 ohms, 1/2 watt, 10%
R12 = 1500 ohms, 1/2 watt, 10%
R13 = 180 ohms, 1/2 watt, 10%
R14 = potentiometer, 1000 ohms, linear taper. (A small screwdriver-adjustable trimmer potentiometer may be used.)
R15 = 1200 ohms, 1/2 watt, 10%
R16 = 470 ohms, 1/2 watt, 10%
R17 = 2.2 megohms, 1/2 watt, 10%
R19 R20 R21 = 1500 ohms, 1/2 watt, 5%, carbon
R22 = 1300 ohms, 1/2 watt, 5%, carbon
R23 R24 = 1200 ohms, 1/2 watt, 5%, carbon
R25 R26 = 1000 ohms, 1/2 watt, 5%, carbon
R27 R28 R29 = 910 ohms, 1/2 watt, 5%, carbon
R30 = 820 ohms, 1/2 watt, 5%, carbon
R31 = 750 ohms, 1/2 watt, 5%, carbon
R32 R33 R34 = 680 ohms, 1/2 watt, 5%, carbon
R35 R37 = 560 ohms, 1/2 watt, 5%, carbon
R36 = 620 ohms, 1/2 watt, 5%, carbon
R38 R39 = 510 ohms, 1/2 watt, 5%, carbon
R40 R41 = 430 ohms, 1/2 watt, 5%, carbon
R42 = 470 ohms, 1/2 watt, 5%, carbon
R43 = 6800 ohms, 1/2 watt, 5%, carbon
S1 through S5 = any normally open easily depressed pushbutton switch
S6 through S30 = If a keyboard is not used, any normally open, easily depressed pushbutton switch may be used.

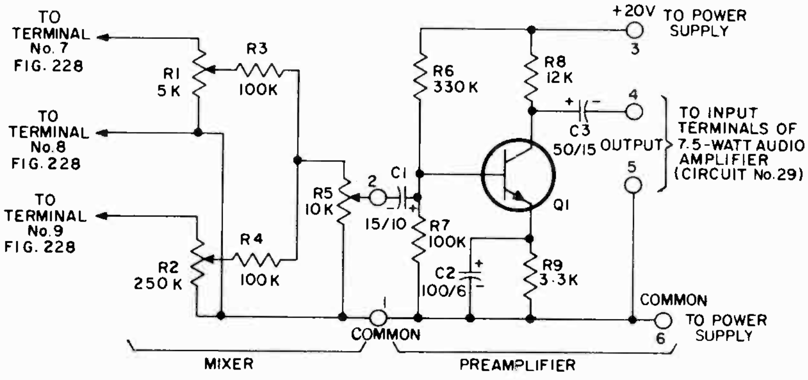
character of the tone by mixing the two waves in various proportions. The schematic diagram and parts list for the mixer preamplifier are shown in Fig. 229. Resistors R1 and R2 in Fig. 229 control the mixing of the pulse and sawtooth waves, respectively; R5 is the master level control, and is customarily called the "swell" control in an organ.

The output of the mixer preamplifier is fed into the amplifier located in the speaker enclosure. The organ amplifier is the same as that described under Circuit No. 29, 7.5-watt audio amplifier. The output of the organ mixer-preamplifier can also be amplified by a TV, radio, or any of the amplifiers described in this Manual. The power supply used with the organ is the universal series power supply, Circuit No. 2.

Construction

The major factor in determining size and layout of the organ is the size of the keyboard or other keying method used. In the model shown in Fig. 225, a toy-piano keyboard is used, and the power supply, regulator, and audio amplifier are combined in a single chassis and placed in a separate speaker cabinet.

The drilling templates for the single-voice organ are shown at the back of this Manual; component placement diagrams for the resistor and capacitor boards are shown in



Parts List

C1 = 15 microfarads, 10 volts, electrolytic
C2 = 100 microfarads, 6 volts, electrolytic
C3 = 50 microfarads, 15 volts, electrolytic
Q1 = transistor, RCA SK3020
R1 = potentiometer, 5000 ohms, linear taper
R2 = potentiometer, 250,000 ohms, linear taper
R3 R4 R7 = 100,000 ohms, 1/2 watt, 10%
R5 = potentiometer, 10,000 ohms, linear taper
R6 = 330,000 ohms, 1/2 watt, 10%
R8 = 12,000 ohms, 1/2 watt, 10%
R9 = 3300 ohms, 1/2 watt, 10%

Fig. 229 – Schematic diagram and parts list for the organ mixer preamplifier.

Figs. 230 and 231, respectively; for the mixer preamplifier in Fig. 232; and for the tone generator in Fig. 233.

Fig. 234 shows board placement within the suggested keyboard enclosure; Fig. 235 shows the arrangement of the interior of the suggested speaker enclosure.

Keying Method

The keying method used in the model organ can be best understood by reference to Figs. 236 and 237. The keyboard shown in Fig. 236 was removed intact from a toy piano. A hole was bored in the end of each plastic key, and a 3/4-inch threaded spacer of the kind used commercially

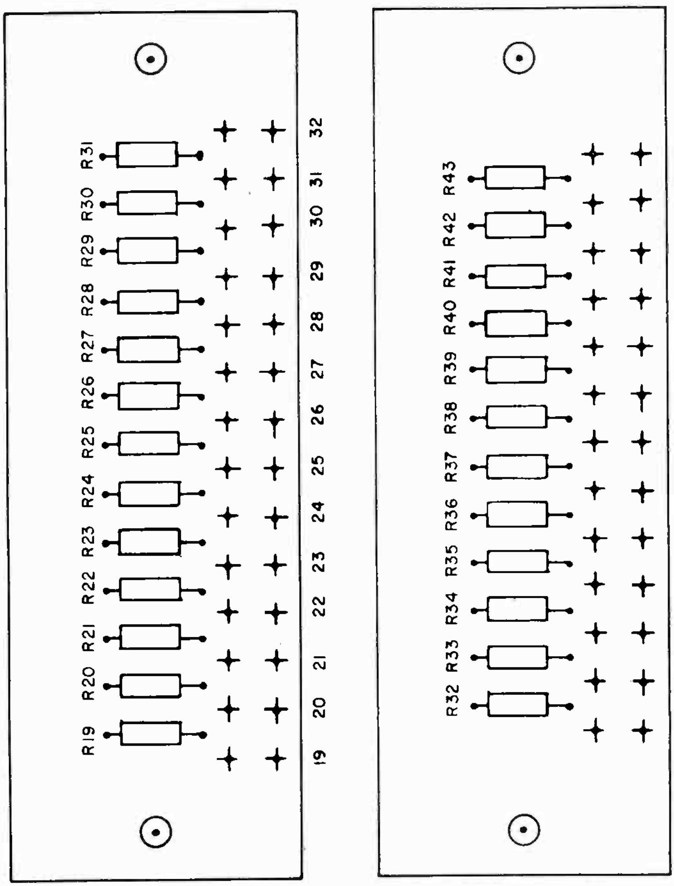


Fig. 230 – Component placement diagram for the tone-generator resistor boards.

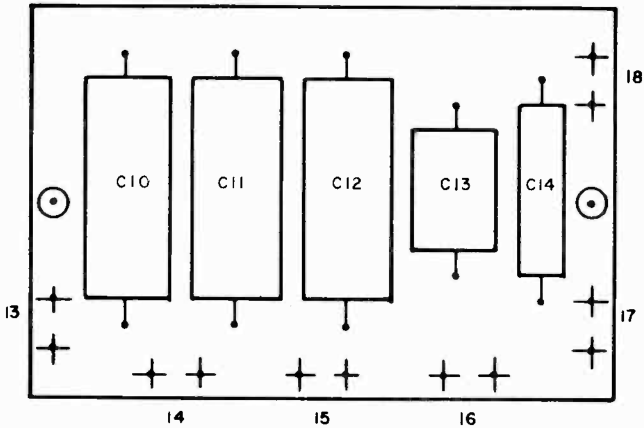


Fig. 231 – Component placement diagram for the tone-generator capacitor boards.

to space circuit boards was attached as shown in Fig. 237. A screw was then inserted into the spacer, and a phosphor-bronze wire was soldered to the screw head (phosphor-bronze wire was used because of its springiness).

When the key is depressed, the bronze wire makes contact with the rigid metal ground-bus bar shown in Figs. 234 and 236. The bus bar, a rigid strip of brass, is represented schematically in Fig. 228. When the wire touches the bus bar, the effect is that of closing one of the switches shown in Fig. 228, and the note selected is generated. When the key is released, the weight of the spacer,

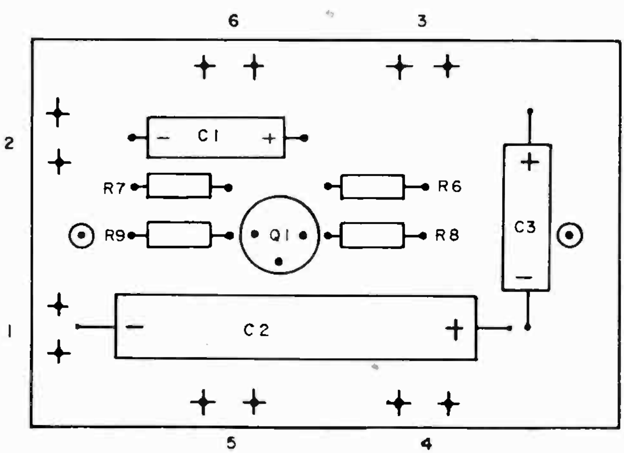


Fig. 232 – Component placement diagram for the mixer preamplifier.

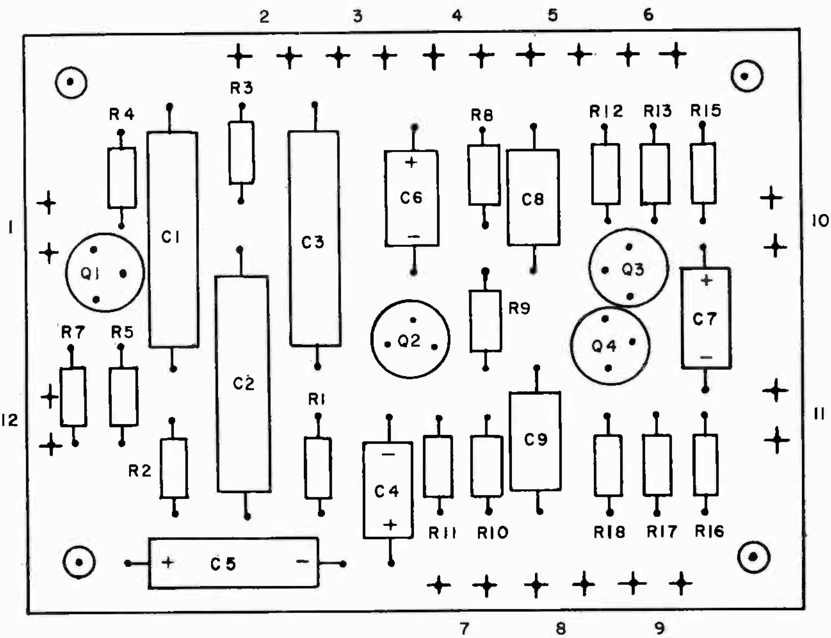


Fig. 233 – Component placement diagram for the tone-generator.

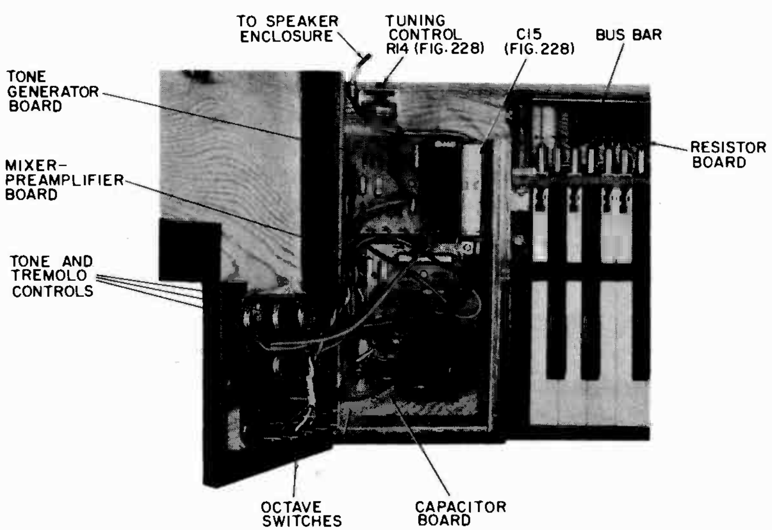


Fig. 234 – Location of circuit boards in the suggested organ enclosure.

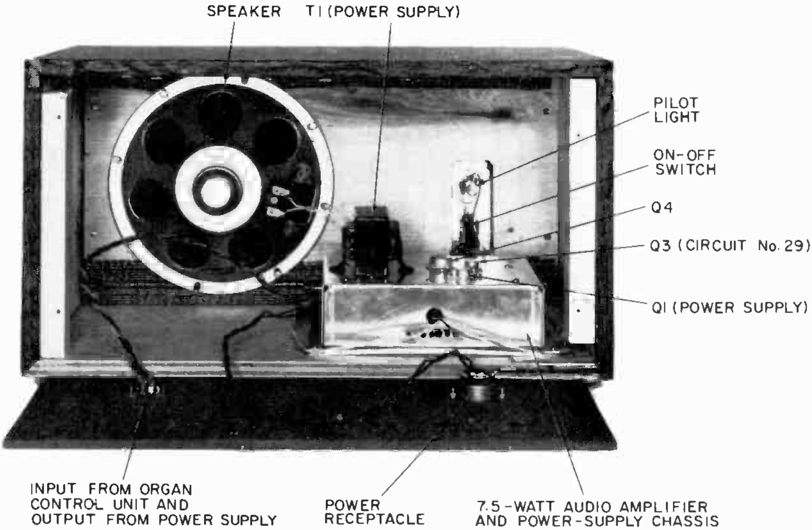


Fig. 235 – Location of organ components in the speaker enclosure.

screws, and wire returns it to its normal position and the switch is opened.

The octave switches are normally open, easily depressed pushbutton switches. Although pushbutton-type switches can also be used to key the scale, the organ is not as easy to play nor does it look as attractive as when the toy piano keys are used.

Both control cabinet and speaker enclosure of the model were constructed of 1/2-inch plywood covered with wood-grained wall cover-

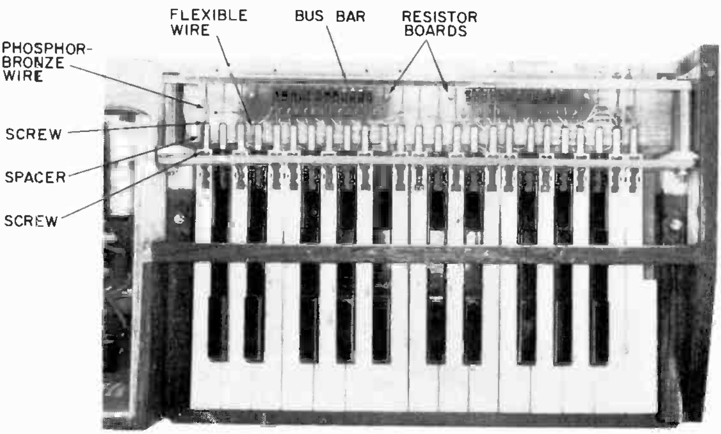


Fig. 236 – The keyboard used in the suggested organ enclosure.

ing. The separate wood pieces were glued and nailed so that there would be no vibration. Screws can, of course, be used in place of nails and glue.

Adjustments

The organ is best tuned by comparison with another instrument, such as a well-tuned piano; R14 in Fig. 228 is the adjustable tuning control. This control is identified in Fig. 234. Some minor tuning adjustments may be necessary to compensate for normal component tolerance; however, once the components are adjusted the organ should remain substantially in tune indefinitely.

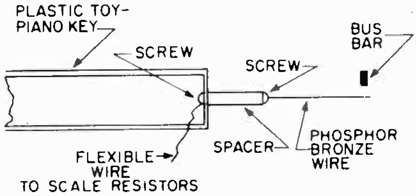


Fig. 237 – Detail of key used in the organ keyboard.

CIRCUIT NO. 45 – FLASHER

The electronic flasher circuit supplies power in short on-off pulses to ac/dc devices that have total power ratings up to 240 watts (nameplate current ratings up to two amperes) and that do not use the frame of the device as a ground. The time of each ON pulse is fixed at approximately one-half second. The time of each OFF pulse can be adjusted to provide the desired number of ON pulses per minute.

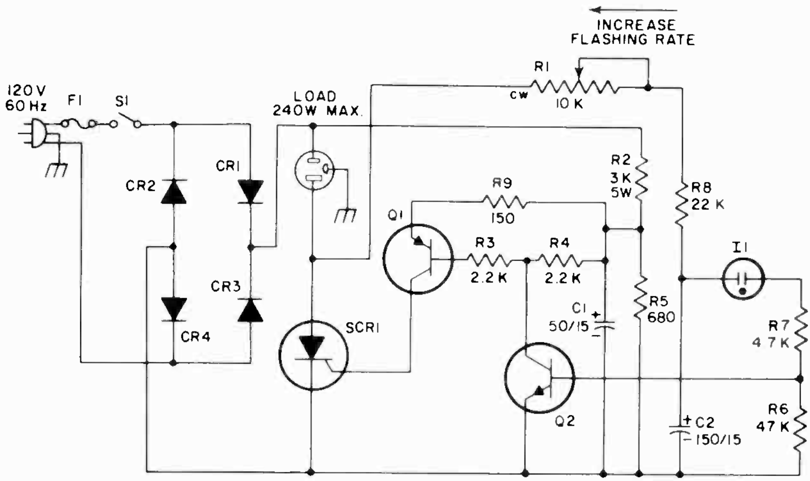
This circuit is useful for controlling the flashing of incandescent-lamp loads (e.g. in Christmas-tree decorations, advertising signs, warning signals, and flashing tower lights) and for actuating an auditory device (e.g., an alarm bell).

Circuit Operation

The schematic diagram and parts list for the flasher are shown in Fig. 238. The power pulse rate (or the length of time between ON periods) is determined by the time required to charge the timing capacitor C2 to the value required to turn on the neon lamp. The charging time for capacitor C2 is controlled by adjustment of potentiometer R1.

When switch S1 is closed, the pulsating dc voltage from the bridge rectifier circuit is applied across the load and the parallel combination of the SCR and the resistance-capacitance circuit R1, R8, and C2. Because the SCR is not conducting, load current is negligible. Therefore, the input pulses charge C2, through resistor R1 and R8, to the firing potential (approximately 80 volts) of the neon lamp. When the neon lamp fires, the current through resistor R7 (approximately two milliamperes) serves as the input signal to the base of transistor Q2.

Transistors Q1 and Q2 are used in this circuit as a two-stage amplifier. Resistor R6 in the base-emitter circuit of Q2 ensures that the transistors remain cut off when I1 is not conducting. The output for the two-stage amplifier triggers the SCR into conduction, and the full pulsating dc input appears across the load (the SCR is a short circuit across R1, R8, and C2). Load current



Parts List

C1 = 50 microfarads, 15 volts, electrolytic
C2 = 50 microfarads, 150 volts, electrolytic
CR1 CR2 CR3 CR4 = rectifier, RCA SK3016
F1 = fuse, 125 volts, 3 amperes
I1 = lamp, neon, NE-83 or equivalent
Q1 = transistor, RCA SK3005
Q2 = transistor, RCA SK3020
R1 = potentiometer, 10,000 ohms, 2 watts, linear taper
R2 = 3000 ohms, 5 watts, 10%
R3 R4 = 2200 ohms, 1/2 watt, 10%
R5 = 680 ohms, 1/2 watt, 10%
R6 = 47,000 ohms, 1/2 watt, 10%
R7 = 4700 ohms, 1/2 watt, 10%
R8 = 22,000 ohms, 1/2 watt, 10%
R9 = 150 ohms, 1/2 watt, 10%
S1 = toggle switch, 125 volts, 3 amperes, single-pole, single-throw
SCR1 = silicon controlled rectifier, RCA KD2100

Fig. 238 – Schematic diagram and parts list for the flasher.

continues to flow for practically 180 degrees of each succeeding half-cycle of input signal until C2 discharges to the extinction voltage of the lamp. (The SCR is actually cut off near the end of each half-cycle and retriggered shortly after the beginning of each succeeding half-cycle by the current applied to the transistors as a result of the stored energy in capacitor C1.) When the charge on C2 is insufficient to maintain conduction in the neon lamp, there is no input to the two-stage transistor amplifier, the flow of gate current to the SCR ceases, and the SCR is not triggered into conduction on the next half-cycle of input. The load current then drops to a negligible value, and the operating cycle starts again.

Adjustments and Special Considerations

The rate of discharge for C2, and therefore the ON time for the flasher, is controlled by the value of resistor R7; the value shown in Fig. 238 provides an ON pulse of approximately one-half second. The charging rate for C2 and therefore the OFF time for the flasher, is controlled by means of potentiometer R1. For warning-signal applications, R1 is normally adjusted to provide 40 flashes per minute, with an ON time of one-half second and an OFF time of one second. Resistors R2 and R5 and capacitor C1 constitute the power supply for the two-stage transistor amplifier; R9 is a current-limiting resistor for transistor Q1.

Fig. 239 shows the electronic flasher assembled in a 3- by 4- by 5-inch chassis.

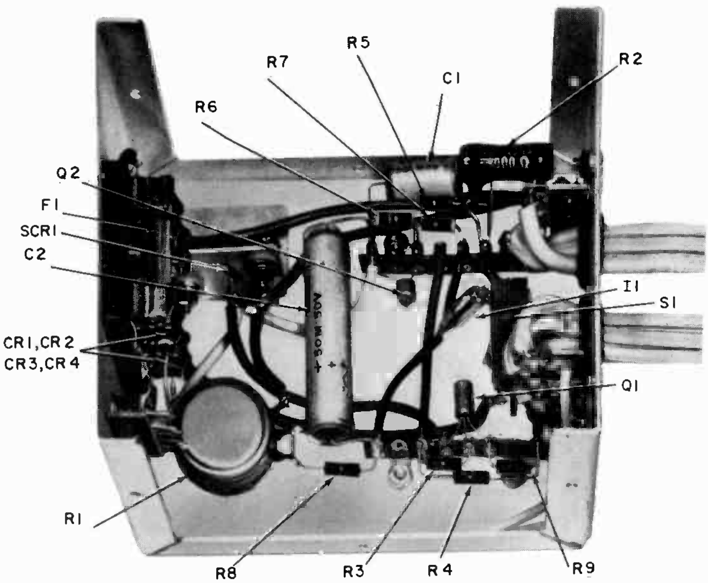


Fig. 239 – The flasher assembled in a 3- by 4- by 5-inch chassis.

CIRCUIT NO. 46 – ENLARGER EXPOSURE METER

The exposure meter, a light intensity meter, provides an excellent means for accurately setting exposure when using an enlarger.

In operation, the required exposure time must first be determined experimentally with a test negative. When this time is established, the photocell of the exposure meter is placed on the easel over the center of interest and the meter is adjusted for zero deflection. The negative to be printed is then inserted into the enlarger carrier and the iris of the enlarger is adjusted so that zero meter deflection is again attained. The photocell of the exposure meter is then removed and the printing paper is inserted and exposed for the predetermined period of time.

The enlarger exposure meter is equipped with a range switch so that it can accommodate either high- or low-intensity light. On the low scale the meter can be adjusted for zero at light intensities of 0.2 to 6 footcandles; on the high scale, zero deflection is attainable between 6 and 400 footcandles.

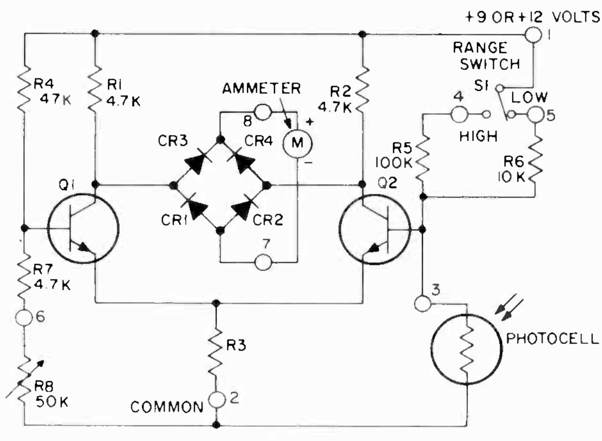
Circuit Operation

The schematic diagram and parts list for the enlarger exposure meter are shown in Fig. 240. Transistors Q1 and Q2 and resistors R1 and R2 form a bridge circuit. The meter connected between the collectors of Q1 and Q2 registers zero deflection when a balanced bridge condition is met. The bridge rectifier assembly composed of rectifiers CR1 through CR4 permits the meter to record both positive and negative unbalance currents. Resistors R1, R2, and R3 are designed for full-scale meter deflection with maximum unbalance current.

Special Considerations

The 9 or 12 volts needed to operate the exposure meter may be obtained from batteries or a power supply. The maximum current drain of the circuit at 12 volts is 3 milliamperes. The maximum current drain at 9 volts is 1.5 milliamperes.

With a 12-volt supply a 1-milliampere meter movement



Parts List

CR1 CR2 CR3 CR4 = diode, RCA 1N270
M = meter, 0 to 1 milliampere, 12 volt, or 0 to 500 microamperes, 9 volt
Photocell = RCA KD2106
Q1 Q2 = transistor, RCA SK3020
R1 R2 R7 = 4700 ohms, 1/2 watt, 10%
R3 = 2200 ohms (12 volts), 3300 ohms (9 volts), 1/2 watt, 10%
R4 = 47,000 ohms, 1/2 watt, 10%
R5 = 100,000 ohms, 1/2 watt, 10%
R6 = 10,000 ohms, 1/2 watt, 10%
R8 = potentiometer, 50,000 ohms, linear taper
S1 = toggle switch, single-pole, double-throw

Fig. 240 – Schematic diagram and parts list for the enlarger exposure meter.

should be used; for a 9-volt supply a 500-microampere meter movement should be used.

Construction

The drilling template for the enlarger exposure meter is shown at the back of this Manual; a photograph of a completed circuit board and a component placement diagram are shown in Figs. 241 and 242, respectively. Fig. 243 shows a method of mounting the photocell in a block of plastic; the alligator clips are clipped to the appropriate circuit-board terminals.

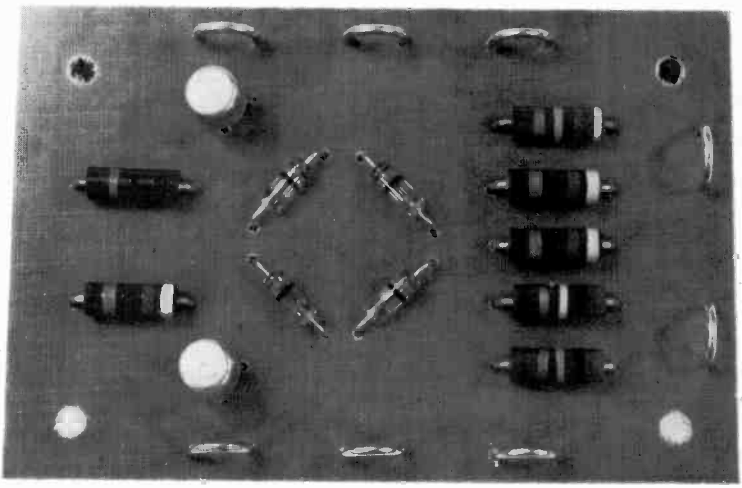


Fig. 241 – Completed circuit board for the enlarger exposure meter.

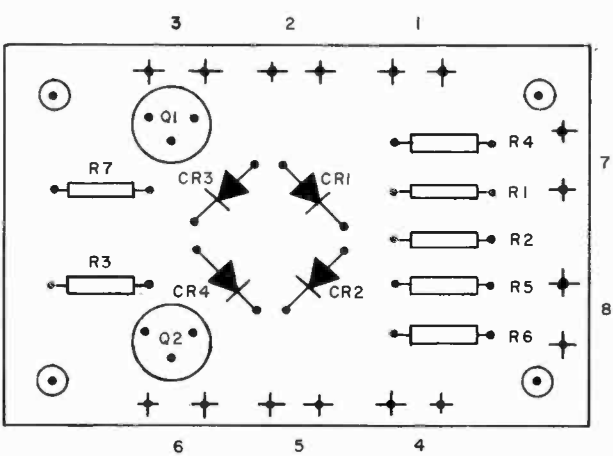


Fig. 242 – Component placement diagram for the enlarger exposure meter.

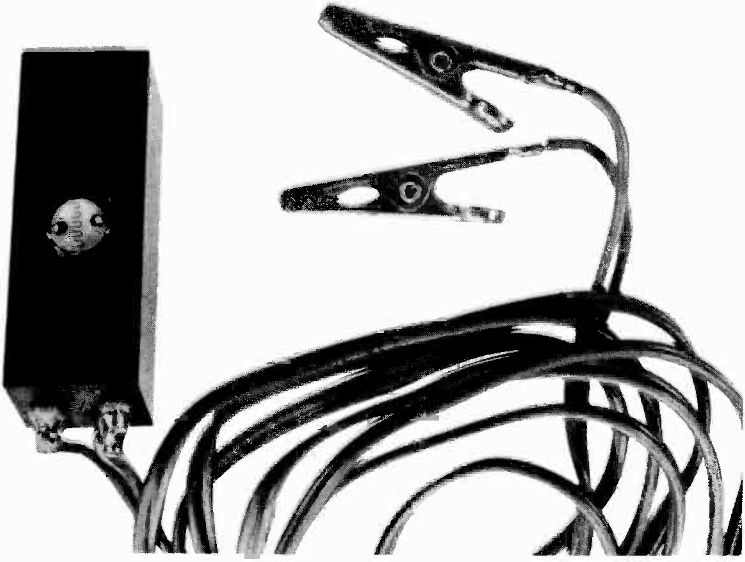


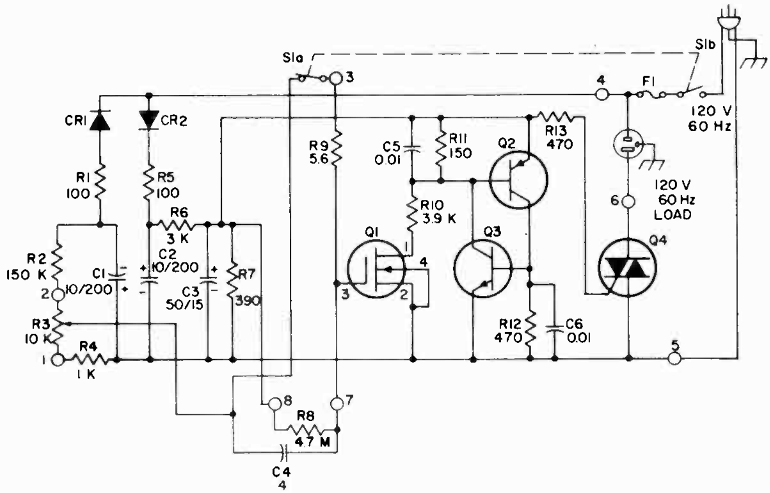
Fig. 243 – Suggested method of mounting the photocell in a block of plastic.

CIRCUIT NO. 47 – UNIVERSAL TIMER

The universal timer turns an electrical device off after a predetermined period of time; the exact time depends on component values and can be calculated as described under Circuit Operation. Because of the high impedance of the MOS field-effect transistor featured in the circuit, electrically and physically smaller, more stable timing capacitors can be used.

Circuit Operation

The schematic diagram and parts list for the universal timer are shown in Fig. 244. When switch S1 is activated (S1a open and S1b closed), capacitors C1 and C2 charge through rectifiers CR1 and CR2 respectively; the voltage across C2 is applied to the gate of triac Q4 through R6 and R13 and turns Q4 on. The voltage across C2 is also applied to the timing-circuit elements R8 and C4; the voltage across R8 and C4 (and consequently circuit timing) can be adjusted by R3. C3 filters the voltage across R8 and C4. When the voltage across capacitor C4 is high enough, Q1 starts to conduct and the MOS transistor turns on and places a forward bias on the base-emitter junction of transistor Q2. As a result, transistor Q2 turns on and triggers the regenerative switch composed of transistors Q2 and Q3. When the regenerative switch conducts, it provides a means for the current to bypass the gate of the triac, Q4, and the triac turns off, thus depriving the load of power. The timer circuit



Parts List

C1 C2 = 10 microfarads, 200 volts, electrolytic
C3 = 50 microfarads, 15 volts, electrolytic
C4 = 4 microfarads, see text
C5 C6 = 0.01 microfarad, 25 volts or greater, 10%
CR1 CR2 = rectifier, RCA SK3030
F1 = fuse, size depends on expected load (5 amperes maximum)
Q1 = MOS field-effect transistor, type 3N139
Q2 = transistor, RCA SK3005
Q3 = transistor, RCA SK3020
Q4 = triac, RCA 40503 or RCA 40429 (The RCA 40429 may be used with Wakefield No. NC401K or equivalent heat sink.)
R1 R5 = 100 ohms, 1/2 watt, 10%
R2 = 150,000 ohms, 1/2 watt, 10%
R3 = potentiometer, 10,000 ohms, linear taper
R4 = 1000 ohms, 1/2 watt, 10%
R6 = 3000 ohms, 5 watts, 10%
R7 = 390 ohms, 1/2 watt, 10%
R8 = 4.7 megohms, 1/2 watt, 10%, see text
R9 = 5.6 ohms, 1/2 watt, 10%
R10 = 3900 ohms, 1/2 watt, 10%
R11 = 150 ohms, 1/2 watt, 10%
R12 R13 = 470 ohms, 1/2 watt, 10%
S1 = toggle switch, 125 volts, double-pole, double-throw, capable of handling the expected load.

Fig. 244 – Schematic diagram and parts list for the universal timer.

remains in this state until switch S1 is opened at least momentarily.

S1, a double-pole double-throw switch, is wired so that the C4 discharge circuit is completed when the line-power circuit is opened. This arrangement allows C4 to discharge rapidly through R9 and permits the timer to be recycled almost immediately.

Special Considerations

If a wider range of time periods is desired than can be obtained with potentiometer R3 alone, a selector switch may be used to permit various values of R8 or C4 to be switched in. Electrolytic capacitors should not be used for C4, and R8 should not exceed 100 megohms; otherwise, an unstable circuit will result. The maximum time period attainable (in seconds) is equal to the product of the values of R8 (in megohms) and C4 (in microfarads) divided by 1.59.

The amount of power that the timer circuit can handle depends on the ratings of the triac and the type of heat sink used. The RCA-40429 triac can handle a load current of 2.7 amperes without a heat sink; when mounted on a suitable heat sink (Wakefield No. NC401K or equivalent), it can handle 6 amperes. The RCA-40503 is supplied with a factory-attached heat radiator that allows it to conduct a maximum of 3.3 amperes. The section on **Mechanical Considerations** contains a further discussion of heat sinks.

The MOS transistor leads should be shorted until the timing components, R8 and C4 are connected. This precaution prevents damage to the MOS transistor. (See the section on **Mechanical Considerations** for MOS transistor handling techniques).

Construction

One critical feature in the layout of this circuit is the placement of R6. This resistor generates heat and should not be located close to other components. The suggested layout shown in Fig. 246 should be used if possible.

A second critical feature involves the placement of the time-determining components R8 and C4. These components and the associated wiring should be shielded as much as possible from dust and dirt that could provide leakage paths and affect circuit timing.

The drilling template for the universal timer is shown at the back of this Manual; a photograph of the completed circuit board and a component placement diagram are shown in Figs. 245 and 246, respectively.

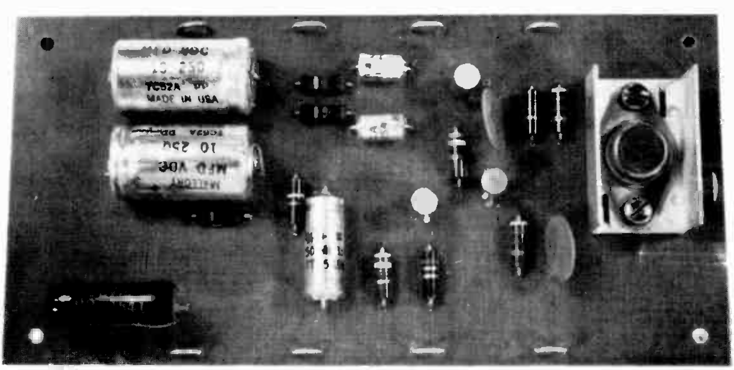


Fig. 245 – Completed circuit board for the universal timer.

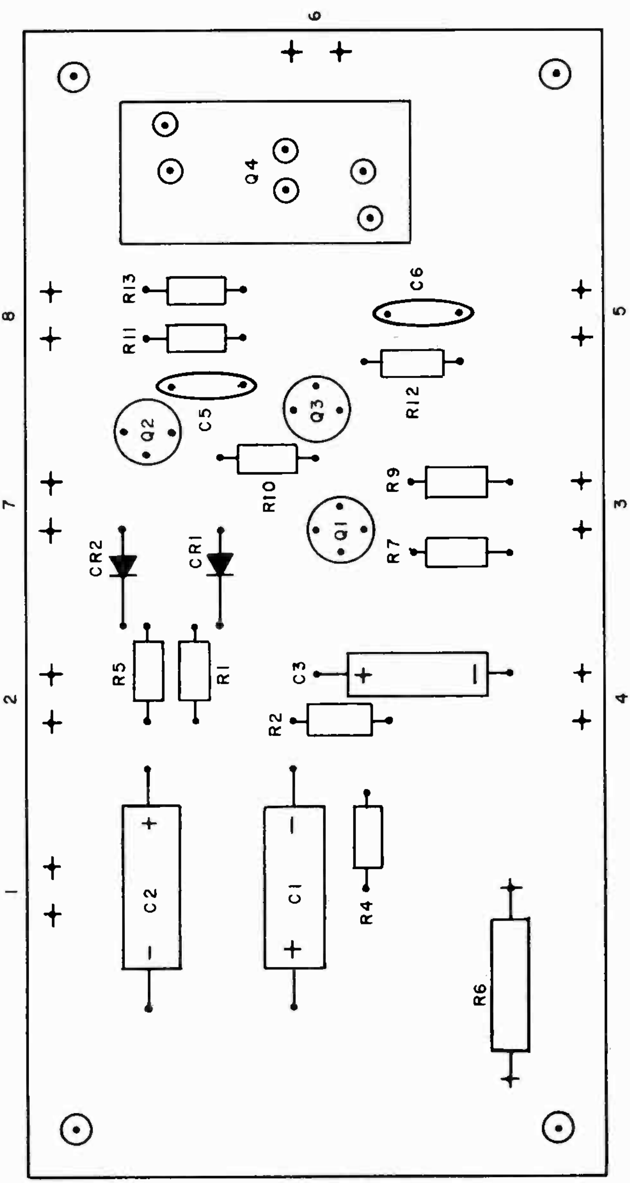


Fig. 246 – Component placement diagram for the universal timer.

CIRCUIT NO. 48 – LAMP DIMMER

The lamp-dimmer circuit provides continuous control of loads up to 700 watts. With it, incandescent lamps can be set at any level up to their maximum brightness. Fig. 247 shows a suggested enclosure for the lamp-dimmer circuit.

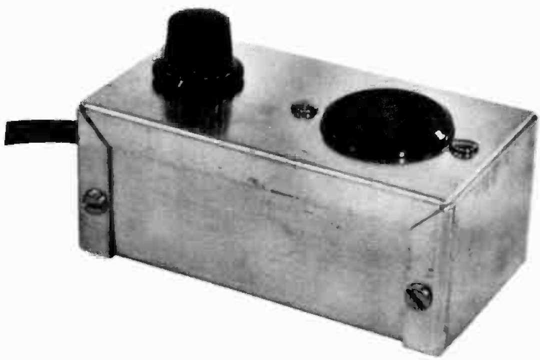


Fig. 247 – Suggested enclosure for the lamp-dimmer circuit.

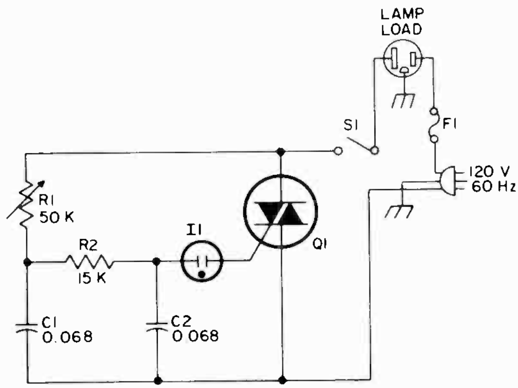
Circuit Operation

The schematic diagram and parts list for the lamp dimmer are shown in Fig. 248. The solid-state device used in the lamp-dimmer circuit is a triac, a type of thyristor that can conduct in either direction and thus permits full-wave control of the load. The triac is triggered into conduction on each half-cycle by a pulse applied to its control lead, the gate. The power delivered to the load is a function of the time in each half-cycle at which the triac is triggered into conduction. The point at which the triac is triggered on each half-cycle is determined by C1, C2, R2, and the potentiometer R1. When the capacitors charge to the triggering level of the neon lamp I1, conduction into the gate of the triac occurs. The triac then conducts for the remainder of that half cycle.

The RCA-40429 triac can handle 2.7 amperes without a heat sink; the RCA-40502 triac can handle 3.3 amperes with its factory-attached radiator. At current levels above these values, the triac must be fitted with a heat sink, such as Wakefield No. NC401K or equivalent. Under no circumstances should load current exceed 6 amperes in this circuit. The section on **Mechanical Considerations** contains a discussion of heat sinks. Any radio interference produced by the lamp dimmer can be reduced by use of the LC-filter described in Circuit No. 60.

Construction

Because of the small number of components used in this circuit, the layout is left to the circuit builder.



Parts List

C1 C2 = 0.068 microfarad, 200 volts, 10%
F1 = fuse, size suitable to load
I1 = lamp, neon, type NE-83
Q1 = triac, RCA 40502 or RCA 40429 (The RCA 40429 may be used with the Wakefield No. NC401K or equivalent heat sink.)
R1 = potentiometer, 50,000 ohms, 2 watts, linear taper
R2 = 15,000 ohms, 1/2 watt, 10%,
S1 = toggle switch, 120 volt, single-pole, single-throw, capable of handling expected load current.

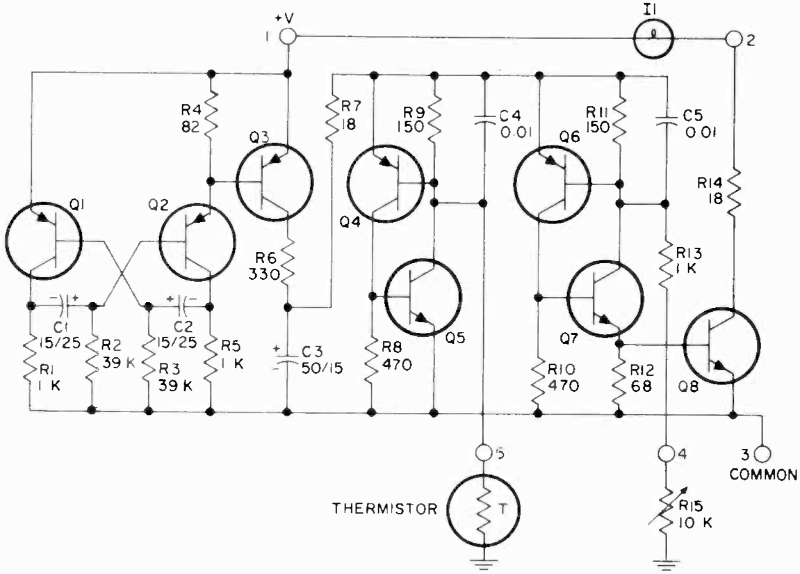
Fig. 248 – Schematic diagram and parts list for the lamp dimmer.

CIRCUIT NO. 49 – TEMPERATURE ALARM

The temperature indicator is an extremely sensitive device that can differentiate fractions of a degree of temperature. A flashing lamp indicates when a predetermined temperature has been reached. Because the circuit can be wired to warn of temperature increases or decreases, it is of practical use as a road-icing indicator for motorists, a frost-warning indicator for farmers, or an indicator to warn of rising temperatures in freezers.

Circuit Operation

The schematic diagram and parts list for the temperature alarm is shown in Fig. 249. The circuit is wired to signal a decrease in temperature below a predetermined level. Transistor pairs Q4–Q5 and Q6–Q7 each form a voltage-dependent regenerative switch. With the circuit wired as shown in the schematic, the triggering level of the Q4–Q5 combination is determined by the thermistor; the triggering voltage of the Q6–Q7 combination is controlled by the sensitivity potentiometer R15 and the resistor in series with it, R13. The two regenerative switches are in parallel; both are driven by Q3 from the same intermittent voltage. Q3 is switched on and off by the multivibrator composed of transistors Q1 and Q2;



Parts List

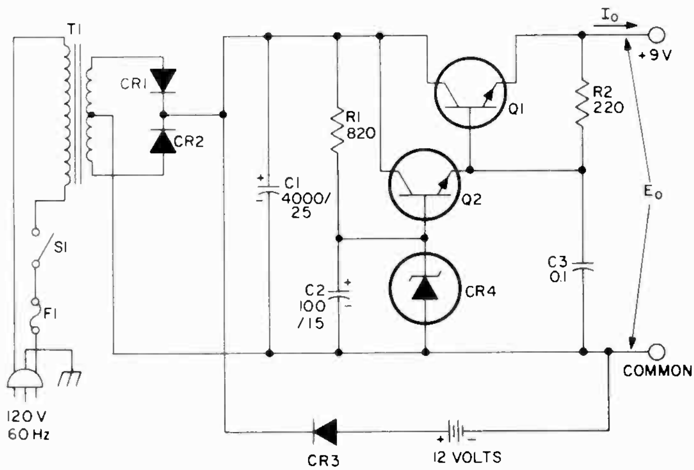
C1 C2 = 15 microfarads, 25 volts, electrolytic
C3 = 50 microfarads, 15 volts, electrolytic
C4 C5 = 0.01 microfarad
Q1 Q2 Q3 Q4 Q6 = transistor, RCA SK3005
Q5 Q7 Q8 = transistor, RCA SK3020
I1 = lamp, No. 47
R1 R5 R13 = 1000 ohms, 1/2 watt, 10%
R2 R3 = 39,000 ohms, 1/2 watt, 10%
R4 = 82 ohms, 1/2 watt, 10%
R6 = 330 ohms, 1/2 watt, 10%
R7 R14 = 18 ohms, 1/2 watt, 10%
R8 R10 = 470 ohms, 1/2 watt, 10%
R9 R11 = 150 ohms, 1/2 watt, 10%
R12 = 68 ohms, 1/2 watt, 10%
R15 = potentiometer, 10,000 ohms, linear taper, 2 watt
Thermistor = RCA KD2108 (supplied in RCA Heat Sensor Kit KD2110)

Fig. 249 – Schematic diagram and parts list for the temperature alarm.

the basic multivibrator is discussed in the section on **General Circuit Considerations**. The intermittent voltage assures that the triggering voltages of the regenerative switches will be sampled once per second so that the switch with the lowest triggering voltage will conduct during the next second. If this sampling were not performed, the first regenerative switch to conduct would continue to do so regardless of the characteristics of the second switch.

As long as the thermistor resistance is lower than that of the R13–R15 combination, the triggering voltage of the regenerative switch composed of Q4 and Q5 is lower than that of the Q6–Q7 combination and the thermistor-controlled switch conducts, effectively shorting out the regenerative switch composed of transistors Q6 and Q7. As thermistor resistance increases (through cooling), the triggering voltage of Q6 and Q7 approaches and finally becomes less than that of the Q4–Q5 combination. When Q6 and Q7 are triggered, they short out the Q4–Q5 switch and permit current to flow to the base of Q8. Q8 then turns on and conducts current to the lamp. The fact that regenerative-switch triggering voltages depend on the resistance of the thermistor or sensitivity potentiometer means that circuit operation is independent of fluctuations of voltage in the power supply.

To modify the circuit so that the lamp will light with an increase in temperature, it is necessary to interchange the thermistor and the sensitivity potentiometer R15 and to



Parts List

C1 = 4000 microfarads, 25 volts, electrolytic
C2 = 100 microfarads, 15 volts, electrolytic
C3 = 0.1 microfarad, 25 volts or greater
CR1 CR2 CR3 = rectifier, RCA SK3030
CR4 = zener diode, 10 volts, 1 watt
F1 = fuse, 1 ampere, 125 volts, slow-blow
Q1 = transistor, RCA SK3026
Q2 = transistor, RCA SK3020
R1 = 820 ohms, 1/2 watt, 10%
R2 = 220 ohms, 1/2 watt, 10%
S1 = toggle switch, 125 volts, 3 ampere, single-pole, single-throw
T1 = transformer, 115 volts primary, 30 volts secondary with center tap. Stancor No. TP-3 or equivalent

Fig. 250 – Schematic diagram and parts list for the temperature-alarm power supply.

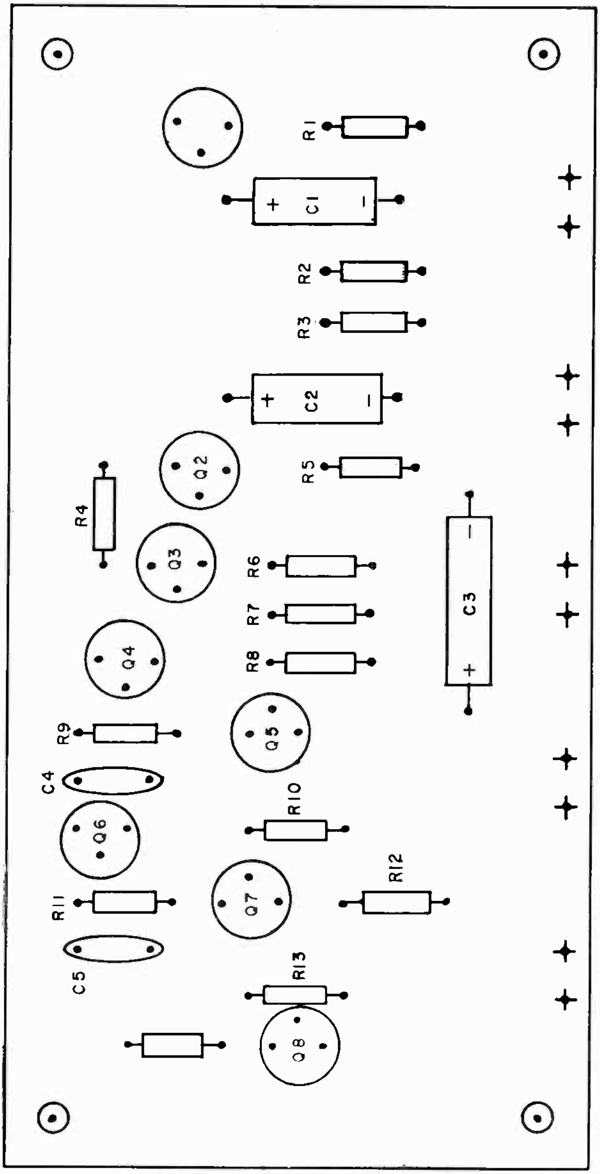


Fig. 251 – Component placement diagram for the temperature alarm.

connect R13 between C4 and terminal 5. The connection between C5 and terminal 4 will be straight wire. The current drain for this circuit averages about 20 milliamperes.

Adjustment and Operation

In adjusting the circuit so that the indicator lamp will flash when the temperature of interest has been reached, the thermistor is placed in a temperature environment similar to that at which the circuit will be expected to give warning. The potentiometer shaft is then rotated until the lamp just stops flashing. At this point the circuit is set to warn of the temperature of interest.

The schematic diagram and parts list for the temperature-alarm power supply are shown in Fig. 250. The power supply features a floating battery that insures circuit operation in spite of power failures. Rectifier CR3 isolates the battery from the secondary voltage of T1. Q1 does not require a heat sink in this application.

The power supply transformer should have a dc resistance in the secondary of at least 1 ohm. If it does not, a 1-ohm 2-watt resistor should be inserted in series with the secondary. If a center-tapped supply is used, the resistance should be placed in series with the center tap. No special precautions are required if the transformer specified in the parts list is used.

Construction

No special precautions need be observed in the construction of this circuit except that the physical and electrical size of the sensitivity potentiometer should be determined by the application in which the circuit is to be used. In most applications the thermistor, the sensitivity potentiometer R15, and the lamp will not be mounted on the circuit board. Thermistor mounting is discussed in the section on **Mechanical Considerations**.

The drilling template for the temperature alarm is shown at the back of this Manual; a component placement diagram and a photograph of the completed circuit board are shown in Figs. 251 and 252, respectively.

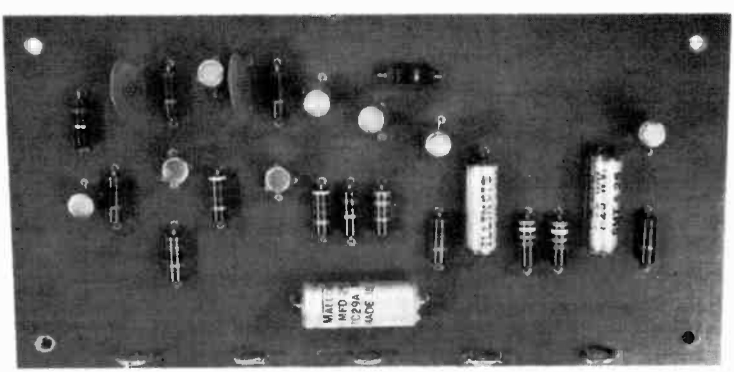


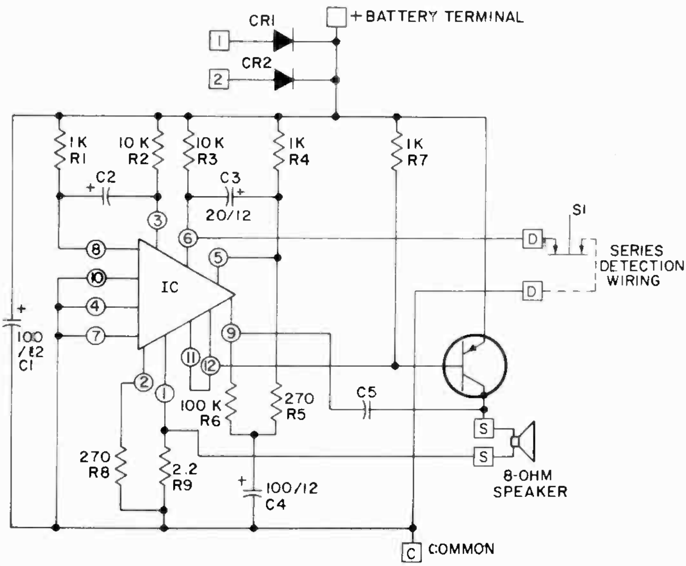
Fig. 252 – Completed circuit board for the temperature alarm.

CIRCUIT NO. 50 – IC ALARM

The IC alarm circuit may be used as either an intruder alarm or a fire alarm. The intruder alarm gives a loud audible warning when a wire detection loop is broken, the fire alarm gives the same type of warning when a heat-sensitive wire melts at about 250°F. A number of points may be protected by either circuit. (A similar circuit to the one described below is available in Kit form as either the RCA KC4005 Intruder Alarm or the RCA KC4006 Fire Alarm.)

Circuit Operation

The schematic diagram and parts list for both the intruder and fire alarms are shown in Fig. 253; the



Parts List

C1 C4 = 100 microfarads, 12 volts, electrolytic

C2 = Fire: 50 microfarads, 12 volts, electrolytic. Intruder: 20 microfarads, 12 volts, electrolytic.

C3 = 20 microfarads, 12 volts, electrolytic

C5 = Fire: 0.02 microfarad, 50 volts. Intruder: 0.01 microfarad, 50 volts

CR1 CR2 = diode, type 1N3193

IC = integrated circuit, RCA KD2114 (Available in KD2117 Variety Pack)

Q5 = transistor, RCA SK3009

R1 R4 R7 = 1000 ohms, 1/2 watt, 10%

R2 R3 = 10,000 ohms, 1/2 watt, 10%

R5 R8 = 270 ohms, 1/2 watt, 10%

R6 = 100,000 ohms, 1/2 watt, 10%

R9 = 2.2 ohms, 1/2 watt, 10%

S1 = Test switch, spring return slide switch, normally closed.

Fig. 253 – Schematic diagram and parts list for the IC alarm circuit.

schematic diagram for the KD2114 IC is shown in Fig. 254. All transistors identified in the following description with the exception of Q5 are part of the IC.

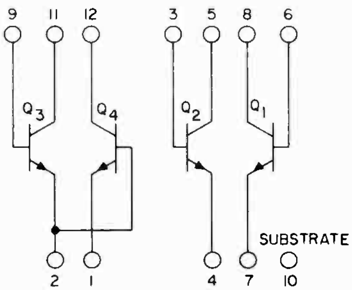


Fig. 254 – Schematic diagram for the KD2114 IC.

Transistors Q1 and Q2 form a free running multivibrator; i.e., they alternately turn on and off approximately twice per second. The output from Q2 is applied to C4 through R5 causing C4 to charge and discharge with the switching of the multivibrator. The charge on C4, imposed through R6, determines the bias level on the base of Q3. Transistors Q3 and Q4 are connected in a Darlington arrangement that provides the alarm circuit with a high-gain, high impedance input. The Darlington configuration is directly coupled to the output transistor Q5 which drives the 8-ohm speaker. Some of the output from Q5 is applied to the input of Q3 through C5. This positive regenerative feedback causes the combination of transistors Q2, Q4, and Q5 to act as an oscillator and thus to produce a frequency that is made audible as a tone. The switching rate of multivibrator transistors Q1 and Q2 determines the wailing frequency of the tone. Capacitor C5 determines the pitch of the tone.

Fig. 255 shows circuit power supply connections when both line supply and stand-by battery are used; the line supply is that of Circuit No.

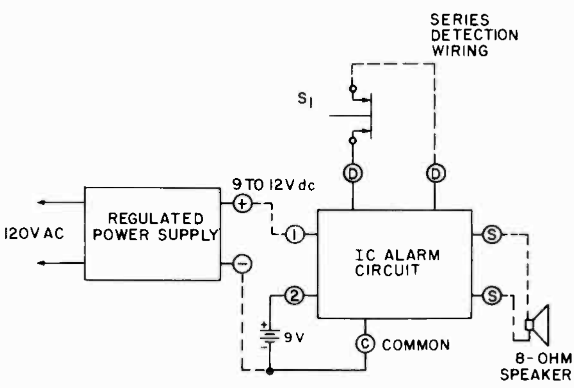


Fig. 255 – Power supply and other external wiring for the IC alarm circuit.

6. Diodes CR1 and CR2 isolate the battery from the line-operated supply when the line supply is in operation; the battery keeps the circuit operative should a power failure occur. If only one type of supply is used, battery or line, it is connected between the positive terminal shown in Fig. 253 and ground or common; terminals 1 and 2 of Fig. 253 are not used. Table XXXII shows voltages at the terminals of an IC in a properly operating circuit.

Table XXXII.
Voltages at IC Terminals in Alarm Circuit

Terminal	Voltage (Volts)
3	0.85
5	0.2
8	9
9	0.2
11	9
12	9

Construction

The printed-circuit template for the IC alarm circuit is shown at the back of this Manual. A combined component placement diagram and photograph of a completed board is shown in Fig. 256.

Intruder Alarm Wiring

Fig. 257 shows a typical detection-circuit wiring diagram for a door and window. One end of an insulated copper wire, such as No. 20, is connected to one of the terminals on the circuit board marked D; the other end is connected to one of the terminals of the test switch S1. S1 should be mounted near the circuit board. Another length of No. 20 wire

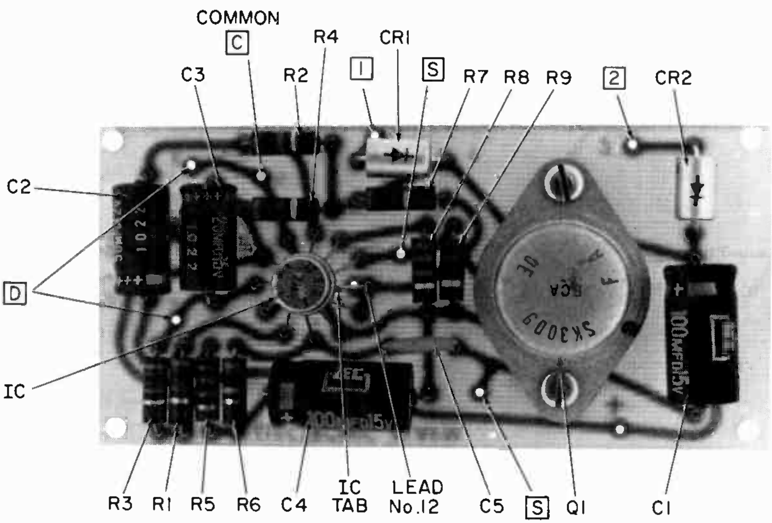


Fig. 256 – Completed circuit board showing component placement for the IC alarm circuit.

is connected between the other side of S1 and security point 1. Security points 2 and 3 and security point 4 and the second terminal D on the printed-circuit board are then connected with No. 20 wire. No. 40 wire, a very thin wire that is easily broken is used to complete the circuit as shown in Fig. 257; if either the door or the window is opened,

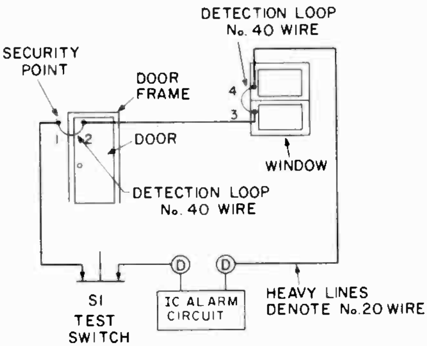


Fig. 257 – Wiring diagram of a typical intruder-alarm circuit.

the No. 40 wire will break and the alarm will sound. The Nos. 20 and 40 wire should be soldered together. The No. 20 wire can be held in place at the security points by means of a small nail or tack. If No. 40 wire is not readily available, narrow strips of aluminum foil may be used instead.

The over-all dc resistance of the wire connected externally to the circuit board between the D terminals determines the total number of points that can be protected; for reliable operation it is recommended that this external dc resistance not exceed 50 ohms. As a guide, typical dc resistance values are 0.01-ohm per foot for No. 20 copper wire, and 1-ohm per foot for No. 40 copper wire.

Fire-Alarm Wiring

Fig. 258 shows a typical fire-detection-circuit wiring diagram. The wiring procedure is the same as that used in the intruder alarm system except that the wire bridging the security points, in the fire alarm circuit a 2- to 5-inch length of heat sensitive wire, cannot be soldered to the No. 20 wire because its melting point is less than that of solder.

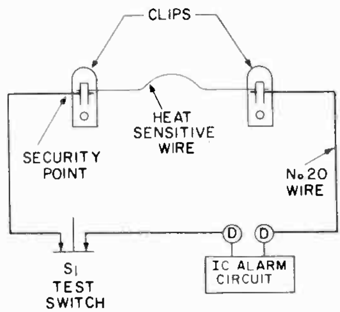


Fig. 258 – Wiring diagram of a typical fire-detection circuit.

Heat-sensitive or thermal wire is available from most scientific-supply mail-order houses; however, as an alternative, No. 20 gauge, 60-40 solder may be used in place of the thermal wire. The heat-sensitive and No. 20 wire can be clipped together as shown in Fig. 258 or mounted as shown in Fig. 259. Again, it is recommended that the dc resistance of the wiring external to the circuit board be less than 50 ohms; the resistance of the heat sensitive wire may be considered negligible.

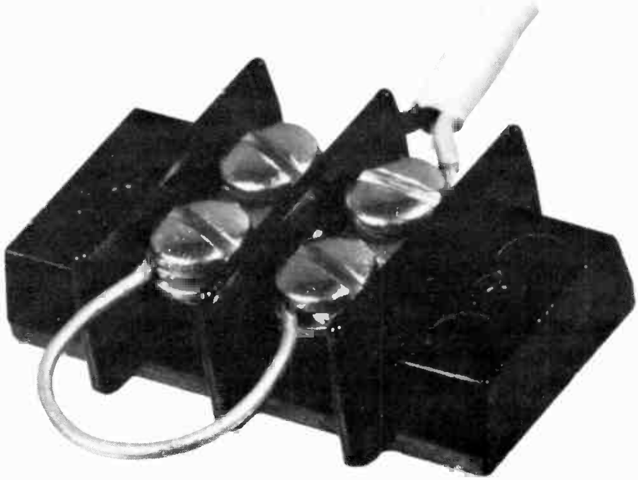


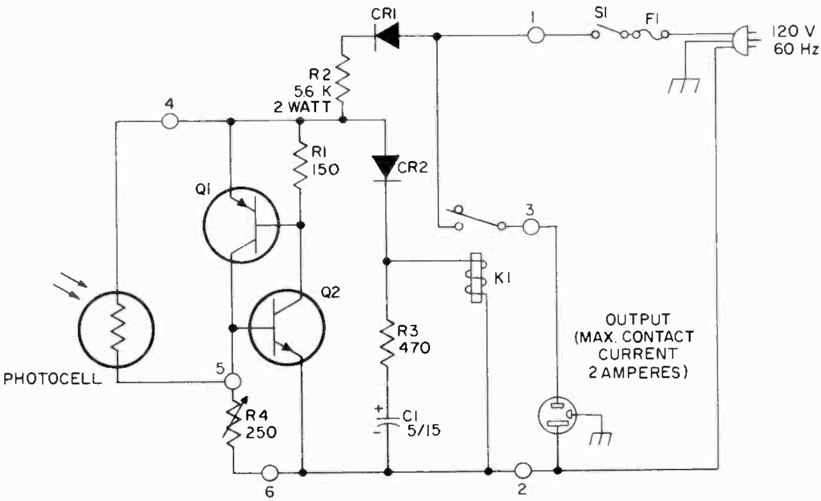
Fig. 259 – Method of mounting the heat-sensitive wire of the fire-detection circuit.

CIRCUIT NO. 51 – POSITIVE-ACTION LIGHT-OPERATED SWITCH

The positive-action photo or light-operated switch can control loads rated at up to 2 amperes. Positive action means that the load is receiving either no power or full power; current to the load does not fluctuate with the amount of light impinging on the photocell. The switch works directly from 120-volt household power, eliminating the needs for batteries. The light level needed to energize the switch can be set by the circuit builder to the value best suited to his application. This switch can be made to turn on or off with an increase in light.

Circuit Operation

The schematic diagram and parts list for the switch are shown in Fig. 260. Transistors Q1 and Q2 form a regenerative switch that exhibits high impedance until the voltage across it reaches a predetermined level. When this level is reached, the switch triggers and its impedance becomes very low. The triggering voltage required is determined by the resistance of the photocell and the setting of the potentiometer R4. When the photocell is exposed to light, its resistance decreases and causes an increase in current to the base of Q2. When the base current is sufficient, Q2 conducts and triggers the regenerative switch into conduction. Because voltage across the regenerative switch is half-wave rectified ac (CR1 is the rectifier), the regenerative switch can be triggered on each positive half-cycle. If the photocell is not exposed to light, the regenerative switch will not trigger. The relay which is connected across



Parts List

C1 = 5 microfarads, 15 volts, electrolytic
CR1 = rectifier, RCA SK3031
CR2 = rectifier, RCA SK3030
F1 = fuse, 3 amperes
K1 = relay, 12 volts, 1350 ohms, Potter and Brumfield No. RS5D or equivalent
Photocell = RCA KD2106
Q1 = transistor, RCA SK3005
Q2 = transistor, RCA SK3020
R1 = 150 ohms, 1/2 watt, 10%
R2 = 5600 ohms, 2 watts, 10%
R3 = 470 ohms, 1/2 watt, 10%
R4 = potentiometer, 250 ohms, linear taper
S1 = toggle switch, 125 volts, 3 amperes, single-pole, single-throw

Fig. 260 – Schematic diagram and parts list for the positive-action light-operated switch.

the regenerative switch operates as long as the regenerative switch is not conducting. As soon as the regenerative switch conducts, the relay releases. The relay contact rating is 2 amperes.

Construction

The drilling template for the positive-action light-operated switch is shown at the back of this Manual; a component placement diagram and a photograph of a completed circuit board are shown in Fig. 261 and 262, respectively.

The board in Fig. 262 shows the relay connected for power off with an increase in light. To have the switch turn on with an increase in light, remove the wire from relay terminal A and reconnect it to terminal B.

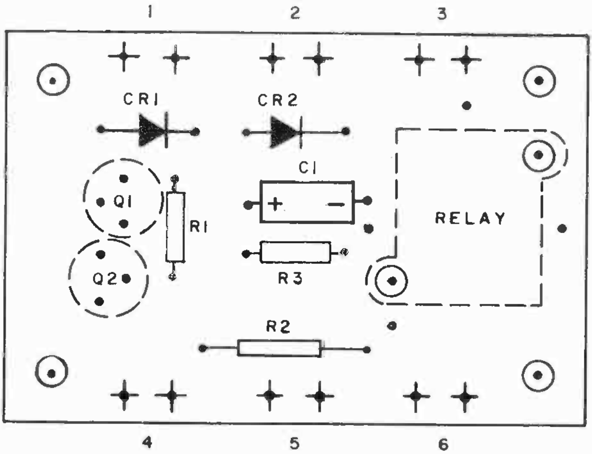


Fig. 261 — Component placement diagram for the positive-action light-operated switch.

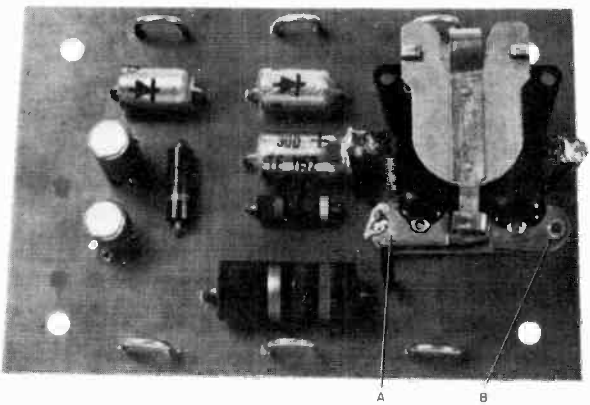


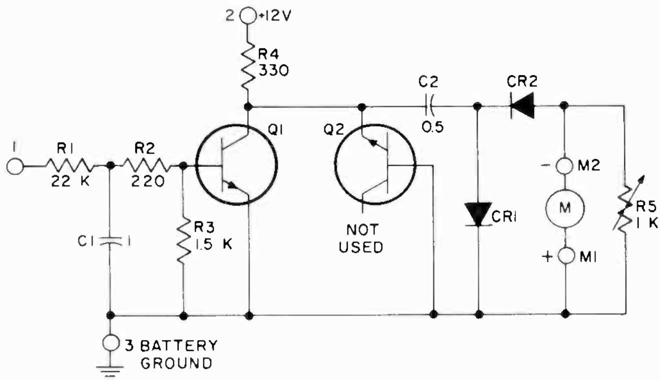
Fig. 262 — Completed circuit board for the positive-action light-operated switch.

CIRCUIT NO. 52 – AUTOMOBILE TACHOMETER

The tachometer circuits are used to indicate the speed, in revolutions per minute, of automobile engines with 12-volt electrical systems. Two circuits are described: one for cars with a negative ground, the other for cars with a positive ground.

Circuit Operation

The schematic diagrams for negative-ground and positive-ground automobile tachometers are shown in Figs. 263 and 264, respectively. The parts list for both circuits is shown in Fig. 263.



Parts List

C1 = 1 microfarad, 50 volts or greater, paper
C2 = 0.5 microfarad, 50 volts or greater, paper
CR1 CR2 = rectifier, RCA SK3030
M = milliammeter, 0 to 1 milliampere range (see text)
Q1 = transistor, RCA SK3025 for positive ground; RCA SK3020 for negative ground
Q2 = transistor, RCA SK3020
R1 = 22,000 ohms, 1/2 watt, 10%
R2 = 220 ohms, 1/2 watt, 10%
R3 = 1500 ohms, 1/2 watt, 10%
R4 = 330 ohms, 1/2 watt, 10%
R5 = potentiometer, 1000 ohms, trimmer type, linear taper

Fig. 263 – Schematic diagram and parts list for the negative-ground tachometer.

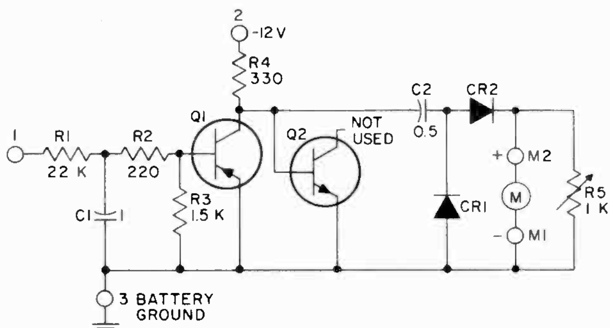


Fig. 264 – Schematic diagram and parts list for the positive-ground tachometer. (The parts list for this circuit is shown in Fig. 263).

Both tachometer systems operate on the same principle. Pulses from the distributor points are applied to the base of Q1 through terminal 1. Q1 turns on and off as the distributor points open and close; capacitor C1 filters out the "ringing" or voltage oscillations that occur when the points open. Capacitor C2, connected to the collector of Q1, charges through CR1 and R4 when Q1 is off, and discharges through R5, CR2, and the meter when Q1 is on. Meter deflection is proportional to the rate at which the points open and close.

To make the circuits insensitive to the variations in voltage normally present in an automobile electrical system, transistor Q2 is reverse-biased at the emitter-base junction so that it acts as a zener diode; any 9- or 10-volt, 1/4-watt zener diode may be substituted for Q2.

Trimmer potentiometer R5 is used to calibrate the tachometer. Accuracy of the tachometer circuit can be checked by comparing the revolutions per minute (r/min) reading indicated by this circuit with the reading indicated by a commercial tachometer, such as that used at service stations.

Both positive- and negative-ground tachometer circuits are configurated identically; the only difference in the circuits is the substitution of p-n-p for n-p-n transistors.

The full-scale r/min reading of the tachometer is determined by the sensitivity of the meter movement. A 1-milliampere movement will have a full-scale reading of 8,000 to 10,000 r/min; lower r/min readings require a more sensitive meter movement.

Construction

The printed circuit template for the automobile tachometers is shown at the back of this Manual; a component placement diagram and photographs of completed circuit boards for positive and negative ground systems are shown in Figs. 265, 266, and 267, respectively. The component placement diagram shows the negative ground arrangement. The polarities of the rectifiers are reversed for positive ground systems.

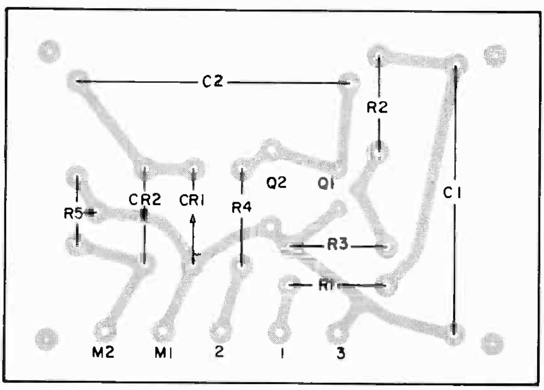


Fig. 265 – Component placement diagram for the tachometer.

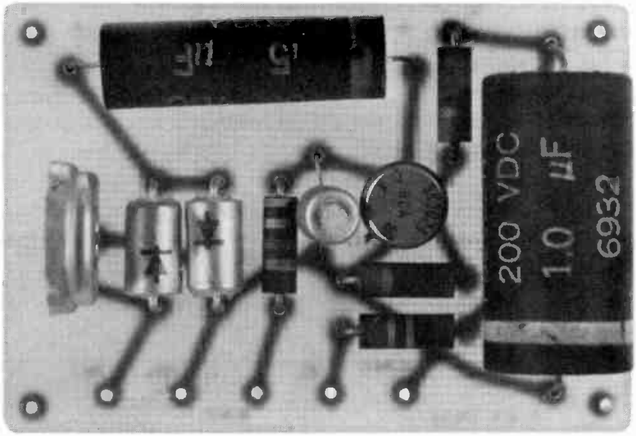


Fig. 266 — Completed circuit board for the positive-ground tachometer.

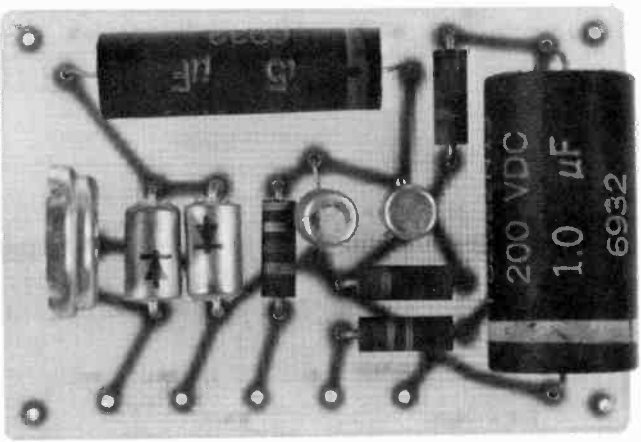


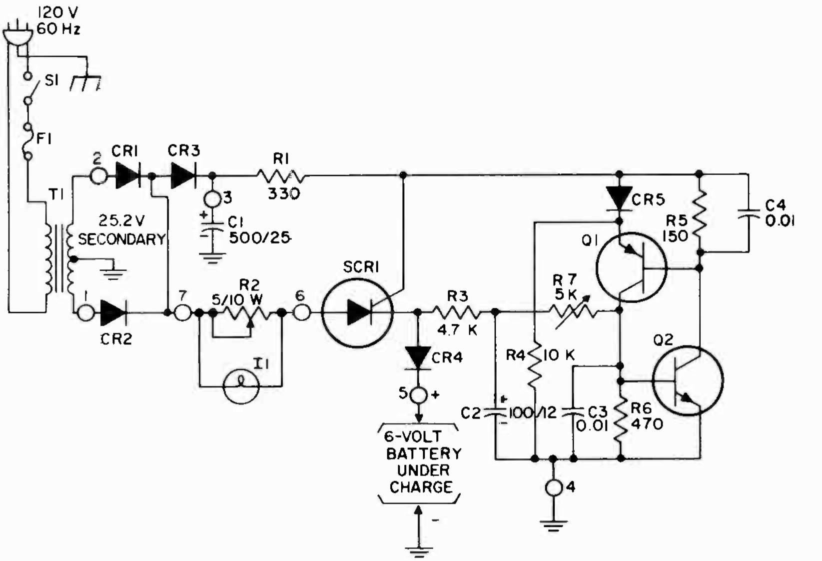
Fig. 267 — Completed circuit board for the negative-ground tachometer.

CIRCUIT NO. 53 – SIX-VOLT BATTERY CHARGER

The battery charger restores to full strength 6-volt lead-acid storage batteries of the type used in motorcycles and photoflash units. The charging rate of 1 ampere per hour is automatically terminated when the battery is fully charged. This charger may be used for automobile or boat batteries if a slow charging rate is acceptable.

Circuit Operation

The schematic diagram and parts list for the battery charger are shown in Fig. 268. The 120-volt line voltage, stepped down to 25.2 volts by transformer T1, is rectified by CR1 and CR2 and applied to the anode of SCR1. Rectifier CR3 prevents capacitor C1, a filter for the gate of SCR1, from discharging through the anode of the SCR when the battery has reached full charge;



Parts List

C1 = 500 microfarads, 25 volts, electrolytic
C2 = 100 microfarads, 12 volts, electrolytic
C3 C4 = 0.01 microfarad, ceramic 25 volts or greater
CR1 through CR5 = rectifier, RCA SK3030
F1 = fuse, 1 ampere, 125 volts, slow-blow
I1 = lamp, No. 47
Q1 = transistor, RCA SK3005
Q2 = transistor, RCA SK3020
R1 = 330 ohms, 1/2 watt, 10%
R2 = adjustable resistor, 5 ohms, 10 watts, 10%
R3 = 4700 ohms, 1/2 watt, 10%
R4 = 10,000 ohms, 1/2 watt, 10%
R5 = 150 ohms, 1/2 watt, 10%
R6 = 470 ohms, 1/2 watt, 10%
R7 = miniature trimmer control, 5000 ohms, 1/4 watt, Mallory No. MTC-1 or equivalent
SCR1 = silicon controlled rectifier, RCA KD2100
S1 = toggle switch, 125 volts, 1 ampere, single-pole, single-throw
T1 = transformer, primary 117 volts, secondary 25.2 volts at 1 ampere, Stancor No. P6469 or equivalent

Fig. 268 – Schematic diagram and parts list for the 6-volt battery charger.

rectifier CR4 prevents the battery from discharging through the charging circuit when the circuit has been turned off.

The full-charge condition is determined by the voltage-sensing circuit at the right in the circuit schematic. The voltage-sensing circuit, essentially a two-transistor regenerative switch that is triggered into conduction when the voltage across it reaches a level determined by the value of R3 and potentiometer R7, turns off SCR1 and terminates the charge by making the SCR gate less positive than the cathode.

Potentiometer R7 can be set by the connection of a fully charged battery or a power supply to the charging terminals of the circuit. The battery used should be the type that will normally be under charge; the power supply should be set to 7 volts for lead-acid type batteries. With a fully charged battery in the output, potentiometer R7 is adjusted until the sensing circuit just triggers. Triggering is indicated by extinction of lamp I1. After a battery has been fully charged and removed from the circuit, the power to the charger should be momentarily interrupted before a second battery is inserted so that the sensing circuit is reset.

It is important that the charging current not exceed the maximum current rating of rectifier CR4. Resistor R2 should be adjusted to 1 ampere or the safe charging rate of the battery, whichever is less. R2 and R7 need not be reset unless the

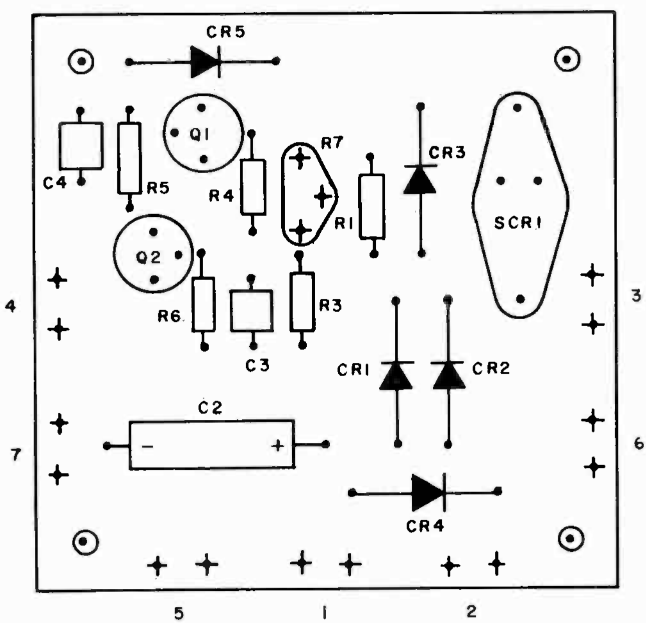


Fig. 269 – Component placement diagram for the 6-volt battery charger.

circuit is to be used to charge a battery different from the type normally charged.

The secondary of the transformer used in the charger should have a dc resistance of at least 1 ohm. If it does not, a 1-ohm 2-watt resistor should be inserted in series with the secondary. No special precautions are required if the transformer specified in the parts list is used.

Construction

The drilling template for the battery charger is shown at the back of this Manual; a component placement diagram and a photograph of a completed circuit board are shown in Figs. 269 and 270, respectively.

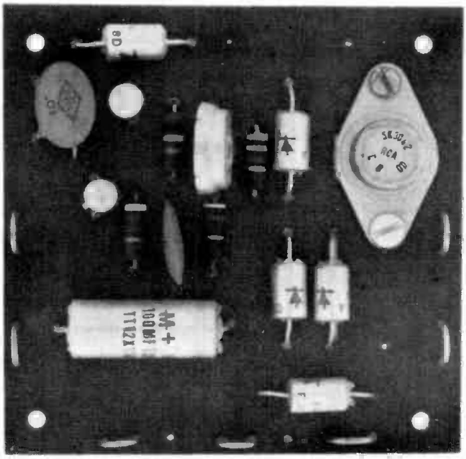


Fig. 270 – Completed circuit board for the 6-volt battery charger.

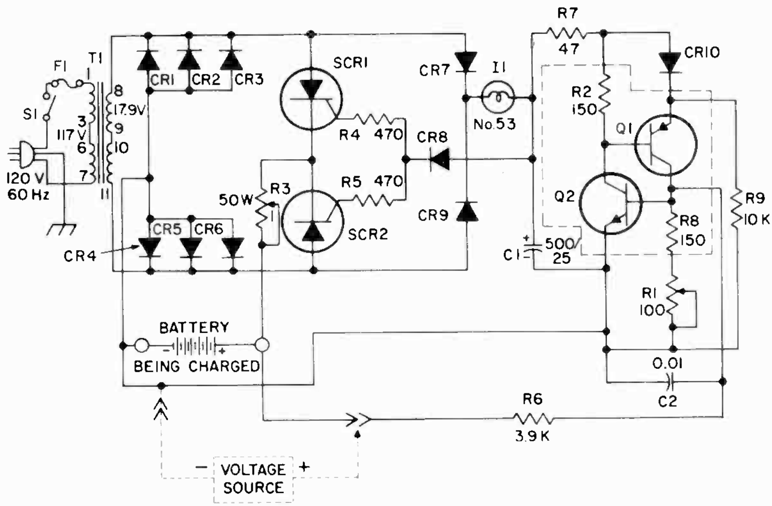
CIRCUIT NO. 54 – TWELVE-VOLT BATTERY CHARGER

The twelve-volt battery charger recharges run-down batteries in automobiles, boats, trailers, or other vehicles in their original mountings and without the need for constant attention. The charger turns off automatically and an indicator lamp lights when the battery reaches full charge. The charging rate is 5 amperes.

Circuit Operation

The schematic diagram and parts list for this circuit is shown in Fig. 271. Line power is stepped down to approximately 17 volts by transformer T1. The output of the transformer is full-wave rectified by the two diode groups CR1 through CR3, and CR4 through CR6, and the two KD2100 SCR's. The diodes are grouped to permit the circuit to operate at the 5-ampere current rating.

The SCR's are triggered early in each cycle through the CR7, I1, CR8, R4 combination or the CR9,



Parts List

C1 = 500 microfarads, 25 volts, electrolytic
C2 = 0.01 microfarad, 1000 volts, disc-ceramic
CR1 through CR10 = rectifier, RCA SK3016
F1 = fuse, 5 amperes, type 3AG, slow-blow
I1 = lamp, indicator, No. 53 or equivalent
Q1 = transistor, RCA SK3005
Q2 = transistor, RCA SK3020
R1 = potentiometer, 100 ohms, 2 watts, linear
R2 R8 = 150 ohms, 1/2 watt
R3 = 1 ohm, 50 watts, adjustable
R4 R5 = 470 ohms, 1/2 watt
R6 = 3900 ohms, 1/2 watt
R7 = 47 ohms, 1/2 watt
R9 = 10,000 ohms, 1/2 watt
S1 = toggle switch; single-pole, single-throw, 3 amperes, 125 volts
SCR1 SCR2 = silicon controlled rectifier, RCA KD2100
T1 = transformer, Stancor RT-206 or equivalent

Fig. 271 – Schematic diagram and parts list for the 12-volt battery charger.

I1, CR8, R5 combination, depending on which half of the input cycle is being conducted by the transformer secondary. The current conducted by the SCR's is used to charge the battery to the predetermined level. When this level is reached, the regenerative switch starts to conduct and turns on the lamp.

When the regenerative switch conducts through the lamp, the gates of the SCR's are bypassed and thus the charging current is terminated. Resistor R6 is the voltage-sensing resistor for the regenerative switch; potentiometer R1 sets the triggering level of the switch. The switch is set to trigger at a desired level by temporarily removing R6 from the positive battery terminal and connecting it to a voltage source, as shown in Fig. 271. The voltage source can be a low-current power supply or battery; it should be set to 14 volts. With the source connected, the potentiometer is set so that the regenerative switch just triggers (so that the lamp just lights). After the voltage source is removed, the regenerative switch can be reset by momentarily operating the power switch. When power to the charger is interrupted, the regenerative switch is reset. Once the calibration has been made, the potentiometer setting need not and should not be changed. A potentiometer that has characteristics similar to those designated for R1 in the parts list but that has a slotted screw-driven shaft and a locking bushing is helpful in maintaining the setting. R3 must be adjusted to slightly less than one ohm so that the current will be limited to 5 amperes or less.

Construction

The 12-volt battery charger is shown built in a suggested chassis, a 6- by 9- by 5-inch utility box, in Fig. 272; Fig. 273 gives drilling details for the chassis. Resistor R3 is mounted external to the chassis and is shielded by perforated metal sheeting (preferably aluminum) or by screening material because the heat it generates could affect internal circuit components; construction details of the resistor shield are shown in Fig. 274. When the resistor is mounted on the outside of the chassis and the perforated metal or screening cover is in place, there is no danger to the operator; if this cover is removed, however, care must be taken to assure that the resistor has cooled enough to permit safe handling.

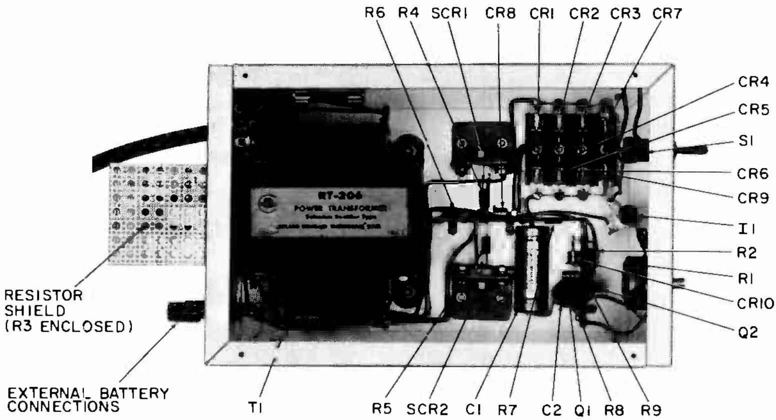


Fig. 272 – Photograph of the interior of a suggested chassis for the 12-volt battery charger.

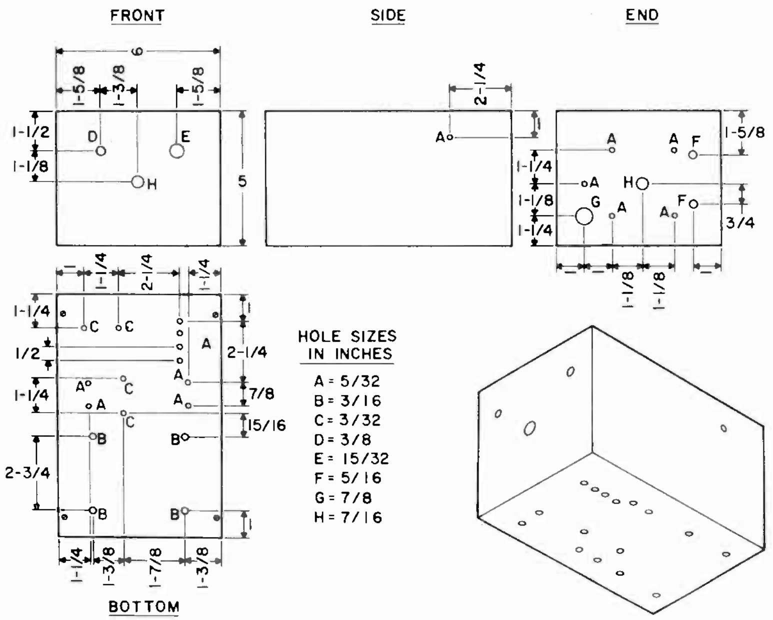


Fig. 273 – Drilling details for the suggested 12-volt battery-charger chassis.

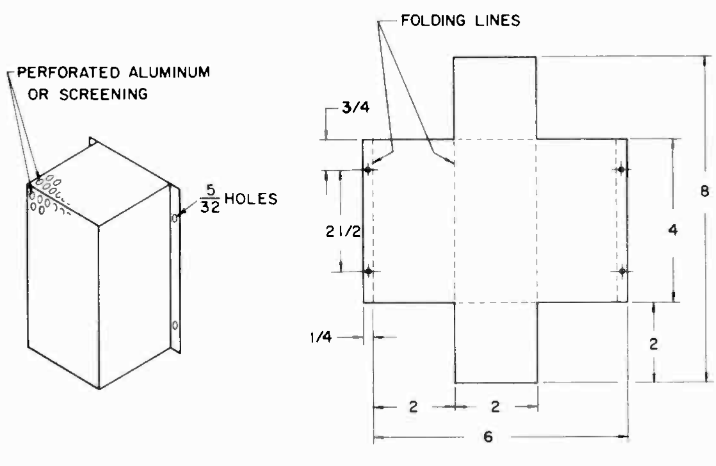


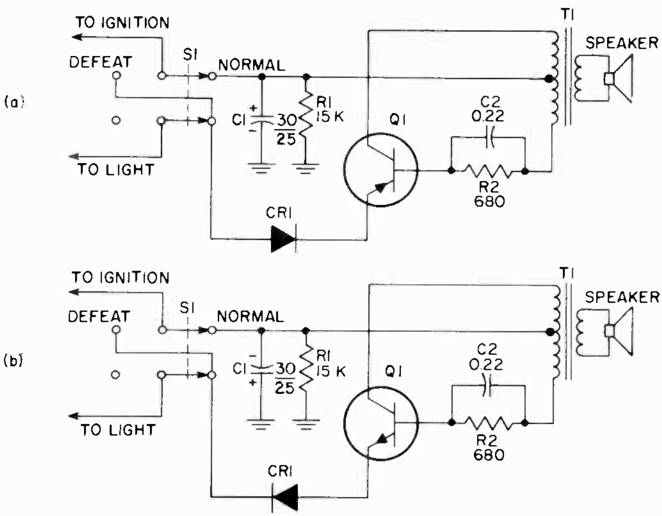
Fig. 274 – Resistor-shield details.

CIRCUIT NO. 55 – AUTOMOBILE LIGHT MINDER

This circuit sounds an alarm if the lights of a car are left on when the ignition is turned off. The alarm stops when the lights are turned off. When the lights are intentionally left on for a period of time, the alarm can be defeated so that no warning sounds. The alarm then sounds when the ignition switch is turned on as a reminder that the system has been defeated and that the switch should be returned to its normal position.

Circuit Operation

Schematic diagrams for a positive-ground and a negative-ground light minder are shown in Fig. 275. The circuit is essentially an oscillator that obtains its supply voltage from two possible sources, the ignition system or the light system of the car. In the normal mode of operation, the ignition system is connected to the collector circuit of Q1 and the light system is connected through CR1 to



Parts List

C1 = 30 microfarads, 25 volts, electrolytic

C2 = 0.22 microfarad, 25 volts or greater

CR1 = rectifier, RCA SK3030

R1 = 15,000 ohms, 1 watt, 10%

R2 = 680 ohms, 1/2 watt, 10%

Q1 = transistor, for negative-ground system, RCA SK3005; for positive-ground system, RCA SK3020

S1 = toggle switch, double-pole, double-throw

Speaker = 3.2 ohms

T1 = Output transformer, primary 500 ohms center tapped, secondary 3.2 ohms, Stancor No. TA-42 or equivalent

Fig. 275 – Schematic diagram and parts list for the automobile light minder: (a) negative-ground system, (b) positive-ground system.

the emitter of Q1. When the ignition switch is on, the collector of the transistor is at the supply voltage. If the lights are on at the same time, the transistor emitter is also at the supply voltage. Because both the emitter and the collector are at the same voltage, the circuit does not oscillate and no alarm sounds. When the ignition is turned off, the collector is returned to ground through R1 and C1, but the emitter remains at the supply voltage and provides the necessary bias for the circuit to oscillate. Turning the lights off removes the supply voltage and stops the oscillation.

In the defeat mode of operation, the ignition system is connected through CR1 to the transistor emitter; the light system is completely disconnected. The lights can then be turned on without the alarm sounding. When the ignition is turned on, it supplies the necessary voltage to the transistor emitter to cause the alarm to sound.

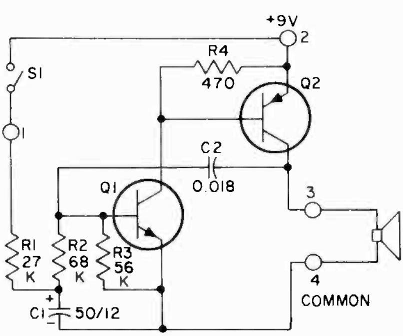
When the alarm is sounding the light-minder current drain is 23 milliamperes; when the alarm is not sounding the current drain is 3 milliamperes.

CIRCUIT NO. 56 – SIREN

The electronic siren produces a sound like that of a wailing police siren; the frequency of the wail slowly increases and then slowly decreases as a push-button switch is depressed and released.

Circuit Operation

The schematic diagram and parts list for the electronic siren are shown in Fig. 276. When switch S1 is closed, capacitor C1 begins to charge. As it does so, it makes the base of Q1 more and more positive and slowly turns it on. Current conducted through transistor Q1 turns Q2 on (Q1 and Q2 form a direct-coupled amplifier). Part of the output from Q2 is applied to the input of Q1 through capacitor C2 and provides the regenerative feedback that causes



Parts List

C1 = 50 microfarads, 12 volts, electrolytic
C2 = 0.018 microfarad, 25 volts or greater
Q1 = transistor, RCA SK3020
Q2 = transistor, RCA SK3009
R1 = 27,000 ohms, 1/2 watt, 10%
R2 = 68,000 ohms, 1/2 watt, 10%
R3 = 56,000 ohms, 1/2 watt, 10%
R4 = 470 ohms, 1/2 watt, 10%
S1 = switch, single-pole pushbutton
Speaker = 3.2 ohms to 8 ohms

Fig. 276 – Schematic diagram and parts list for the siren.

the circuit to oscillate. When switch S1 is opened, C1 discharges through R2 and the base of Q1. The "wailing rate" of the siren can be changed by substituting different values of R1 and C1. An increase in the value of R1 or C1 lengthens the rate at which the frequency of oscillation increases.

Because battery drain with switch S1 open is only about 400 microamperes, a power switch is not considered necessary. However, such a switch will add to battery life.

Construction

The drilling template for the electronic siren is shown at the back of this Manual; a component placement diagram and a photograph of a completed circuit board are shown in Figs. 277 and 278, respectively.

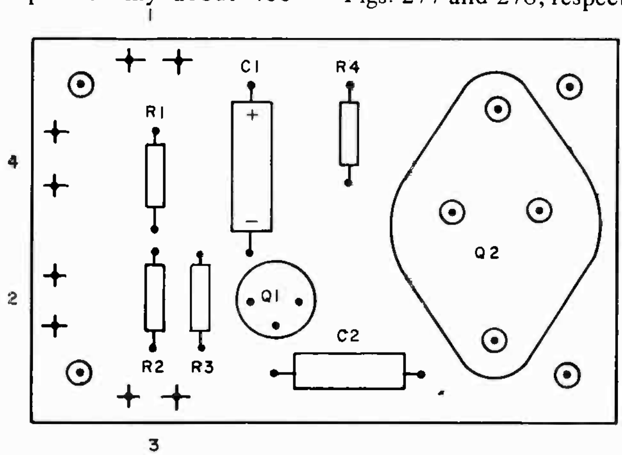


Fig. 277 – Component placement diagram for the siren.

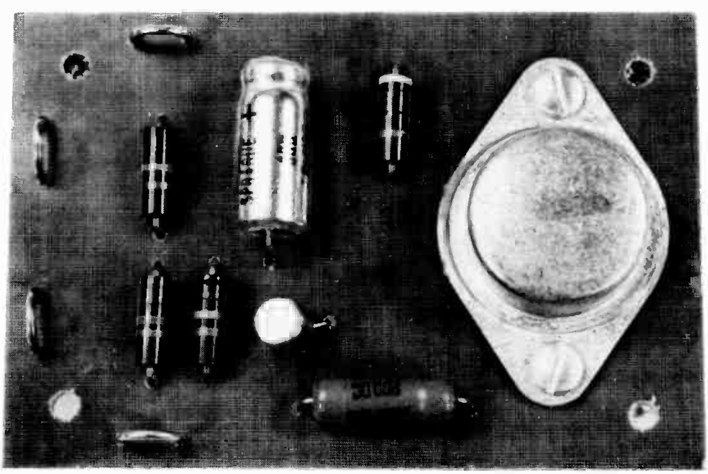


Fig. 278 – Completed circuit board for the siren.

CIRCUIT NO. 57 – SLOT MACHINE

The completed slot machine game resembles, functionally, the well-known Las Vegas slot machine except that a push-button replaces the lever and three vertical columns of lights replace the spinning wheels. Each light corresponds to a lemon, cherry, or other symbol found in the conventional machine. Instead of paying off in coin, the electronic slot machine indicates a score through one of six scoring lamps on its face. A suggested enclosure for the slot machine is shown in Fig. 279.

remains lit in each column; the combination of the three lighted lamps is completely random and determines the score. When no score lamp lights, the score is zero.

The electronic slot machine circuit makes use of the digital circuits described in the section on **General Circuit Considerations**: the NAND and NOR gates, the flip-flop, and the shift register. For this reason the slot machine circuit represents an excellent means of gaining practical experience in digital circuitry.

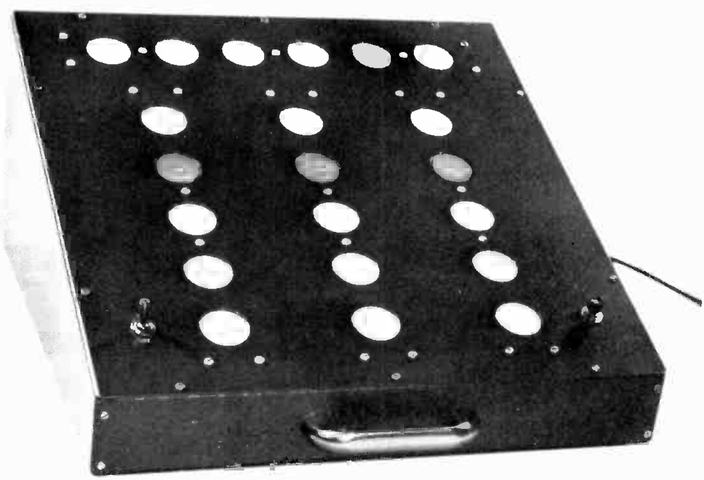


Fig. 279 – Suggested enclosure for the slot machine.

To operate the slot machine, a player depresses the push-button switch momentarily. Each column of lights then starts to flash in sequence; the duration of flashing changes each time the game is played. The maximum time for game completion is approximately four seconds. When the flashing stops, one of the lamps

Circuit Operation

The electronic slot machine circuit consists of a series of building blocks; each block is constructed on a circuit board and interconnected as shown in the diagram of Fig. 280. Detailed interconnections for various portions of the circuit are given in Figs. 281, 282, and 283. Detailed

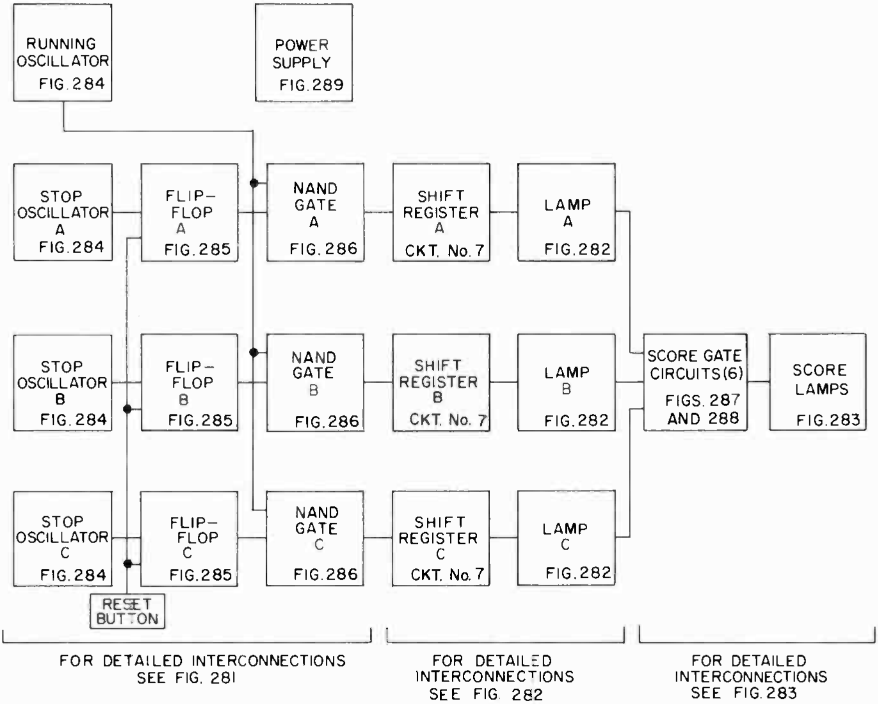


Fig. 280 – Block diagram of the slot machine.

schematics for each building block are shown in Figs. 284 through 289. The parts list for each circuit is shown with the schematic.

When power is applied to the circuit, the "running" and "stop" oscillators begin pulsing. The running oscillator pulses at a very rapid rate; the stop oscillators all pulse at a slightly different rate but produce a pulse approximately once every four seconds. The stop and running oscillators continue to pulse as long as power is on.

When the push-button switch shown in Fig. 281 is depressed, the flip-flop circuits assume the output state; their outputs and the pulses from the running oscillator are applied to the gate circuits. Gate circuits with both inputs (running oscillator and flip-flop) satisfied provide an output each time the running oscillator pulses; this output is applied to the shift register which advances the lighted lamp in each column with each pulse.

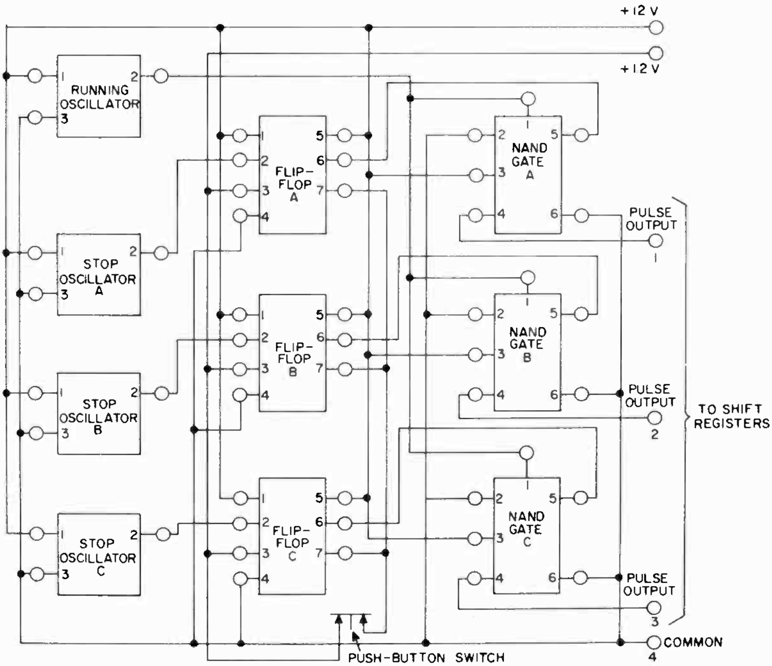
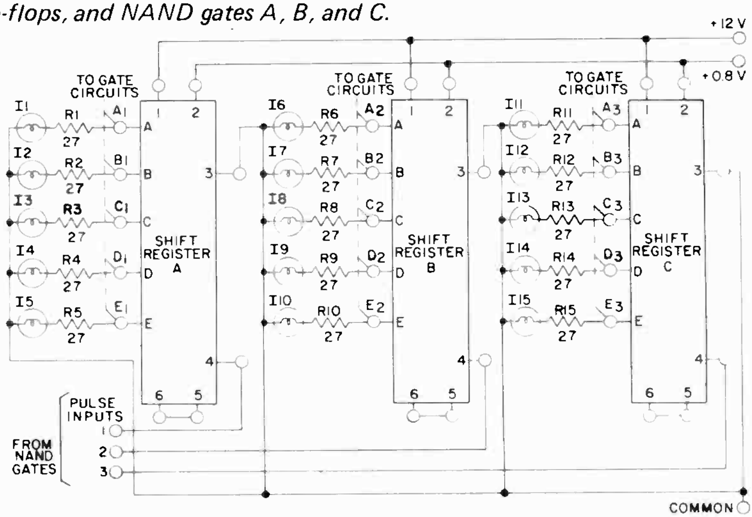


Fig. 281 – Interconnection diagram for the running and stop oscillators, flip-flops, and NAND gates A, B, and C.

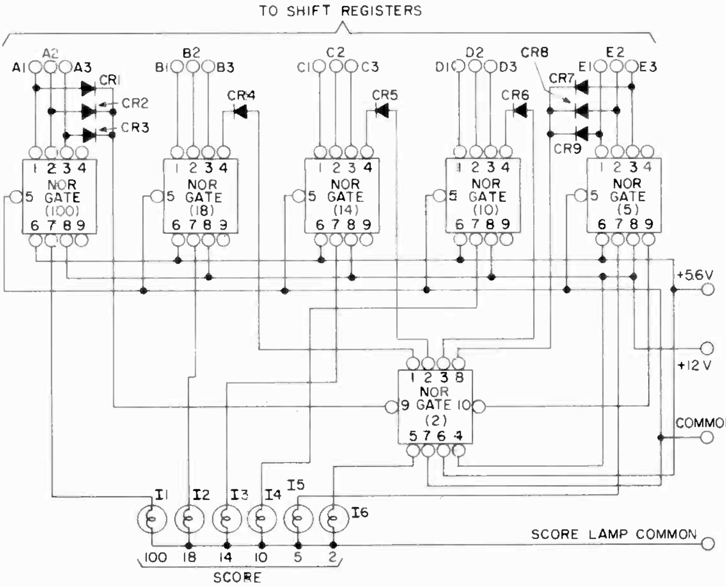


Parts List

I1 through I15 = lamp, No. 47

R1 through R15 = 27 ohms, 1 watt, 10%

Fig. 282 – Interconnection diagram for the shift registers and column lamps.

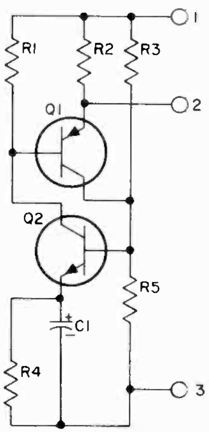


Parts List

I1 through I6 = lamp No. 1488

CR1 through CR9 = rectifier, RCA SK3030

Fig. 283 – Interconnection diagram for the score gate circuits (NOR gates) and the score lamps.



Parts List

Running Oscillator (1 req'd)

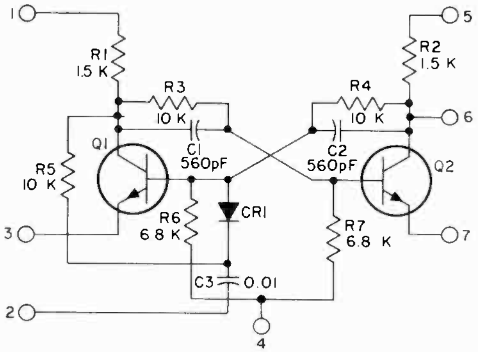
C1 = 2 microfarads, 15 volts, electrolytic

Q1 = transistor, RCA SK3005
Q2 = transistor, RCA SK3020
R1 = 1500 ohms, 1/2 watt, 10%
R2 = 47 ohms, 1/2 watt, 10%
R3 = 1000 ohms, 1/2 watt, 10%
R4 = 15,000 ohms, 1/2 watt, 10%
R5 = 470 ohms, 1/2 watt, 10%

Stop Oscillator (3 req'd)

C1 = 100 microfarads, 15 volts, electrolytic
Q1 = transistor, RCA SK3005
Q2 = transistor, RCA SK3020
R1 R3 = 1000 ohms, 1/2 watt, 10%
R2 = 68 ohms, 1/2 watt, 10%
R4 = 27,000 ohms, 33,000 ohms, 39,000 ohms, one in each of 3 oscillators
R5 = 470 ohms, 1/2 watt, 10%

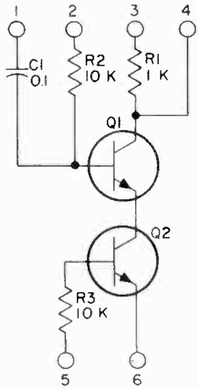
Fig. 284 – Schematic diagram and parts list for the running and stop oscillators.



Parts List

C1 C2 = 560 picofarads, 25 volts or greater
C3 = 0.01 microfarad, 25 volts or greater
CR1 = diode, RCA 1N270
Q1 Q2 = transistor, RCA SK3020
R1 R2 = 1500 ohms, 1/2 watt, 10%
R3 R4 R5 = 10,000 ohms, 1/2 watt, 10%
R6 R7 = 6800 ohms, 1/2 watt, 10%

Fig. 285 – Schematic diagram and parts list for the flip-flops.



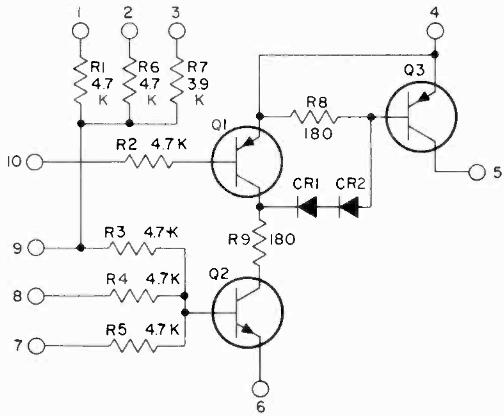
Parts List

C1 = 0.1 microfarad, 25 volts or greater
Q1 Q2 = transistor, RCA SK3020
R1 = 1000 ohms, 1/2 watt, 10%
R2 R3 = 10,000 ohms, 1/2 watt, 10%

Fig. 286 – Schematic Diagram and parts list for the NAND gates (A, B, C).

At this point in the circuit operation, all three columns of lamps are flashing. The score lamps may also flash momentarily at this time as score gate-circuit output conditions are momentarily satisfied. The flashing of the lamps in each column continues until the stop oscillator associated with a particular column pulses once. This pulse can occur, as explained above, at any time up to four seconds after the push-button switch is released. The pulse sets the flip-flop to the no-output state and cuts off the input to the gate. Because the conditions for gate output are not satisfied, running oscillator pulses are not transmitted to the shift-register.

The shift-register outputs that light the lamps in each column are also applied to the input of the score gates. When the final lighted-lamp combination matches one of the



Parts List

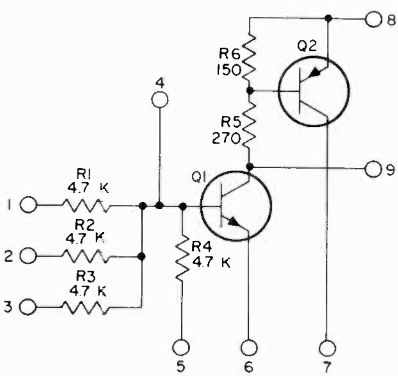
CR1 CR2 = rectifier, RCA SK3030
Q1 Q3 = transistor, RCA SK3005
Q2 = transistor, RCA SK3010
R1 through R6 = 4700 ohms, 1/2 watt, 10%
R7 = 3900 ohms, 1/2 watt, 10%
R8 R9 = 180 ohms, 1/2 watt, 10%

Fig. 287 – Schematic diagram and parts list for the NOR gate circuit and lamp driver for score 2.

preset scoring conditions, a scoring lamp lights. Table XXXIII shows the lamp combinations and associated suggested point values.

Detailed Circuit Considerations

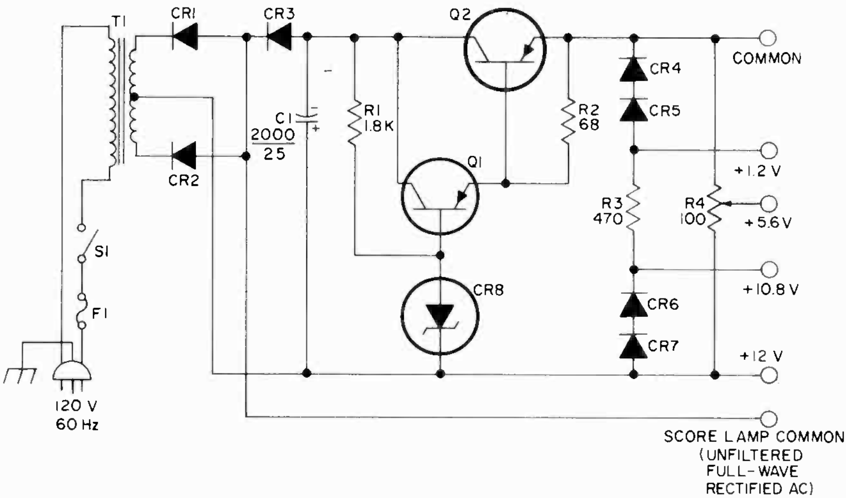
Both the running and stop oscillators shown in Fig. 284 are basically the same circuits, astable pulsers; they differ only in the values of the timing components. The timing capacitor C1 in the stop oscillator is large compared to the timing capacitor C1 in the running oscillator. The charging resistors, R4, in the stop oscillators must differ slightly to insure a complete random action in the score lamps.



Parts List

Q1 = transistor, RCA SK3010
Q2 = transistor, RCA SK3005
R1 R2 R3 R4 = 4700 ohms, 1/2 watt, 10%
R5 = 270 ohms, 1/2 watt, 10%
R6 = 150 ohms, 1/2 watt, 10%

Fig. 288 – Schematic diagram and parts list for the NOR gate circuits and lamp drivers for scores 5 through 100.



Parts List

C1 = 2000 microfarads, 25 volts, electrolytic
CR1 through CR7 = rectifier, RCA SK3030
CR8 = zener diode, 13 volts, 1 watt
F1 = fuse, 1 ampere, type 3AG, slow-blow
Q1 = transistor, RCA SK3005
Q2 = transistor, RCA SK3009
R1 = 1800 ohms, 1/2 watt, 10%
R2 = 68 ohms, 1/2 watt, 10%
R3 = 470 ohms, 1/2 watt, 10%
R4 = 100 ohms, 25 watts, adjustable
S1 = toggle switch, single-pole, single-throw
T1 = transformer, primary 117 volts, secondary 25.2 volts at 1 ampere; Stancor No. P6469 or equivalent

Fig. 289 – Schematic diagram and parts list for the slot-machine power supply.

The astable pulser description in the section on **General Circuit Considerations** contains a statement to the effect that the regenerative switch portion of the pulser conducts immediately with the application of power. The pulse conducted consists of a stop pulse in the negative direction; this pulse is applied to the flip-flop circuits which are in the no-output state when power is applied to the circuit. A momentary depression of the push-button switch places the flip-flops in the output state.

The flip-flop circuit used in the electronic slot machine is the same as that described in the section on **General Circuit Considerations** except that a number of unnecessary components have been omitted. Fig. 285 shows the modified basic flip-flop.

The power supply in Fig. 289 is a modification of the fixed series supply, Circuit No. 2. The slot

Table XXXIII.
Slot-Machine Scores

Lamps Lighted		Suggested Score
All first row		100
All second row		18
All third row		14
All fourth row		10
Any two fifth row lamps		5
Any in first row with:	Any two in second row	18
	Any two in third row	14
	Any two in fourth row	10
	Any one in fifth row	2
None of above		0

machine lamps receive full-wave rectified dc through CR1 and CR2 Rectifier CR3 keeps C1, the filtering capacitor, from discharging back through the lamp circuit, a condition that would increase the ripple voltage output of the supply. Rectifier CR3 also permits the use of a value for C1 that is smaller than would otherwise be possible.

Diodes CR4 through CR7 and resistors R3 and R4 make available the additional voltage values required by the slot-machine circuit. R4 should be adjusted so that there are 5.6 volts across the wiper arm (adjustable tap) and the common terminal.

Construction

Each circuit of the same type in the electronic slot machine uses the same board although the value of one or two of the components may

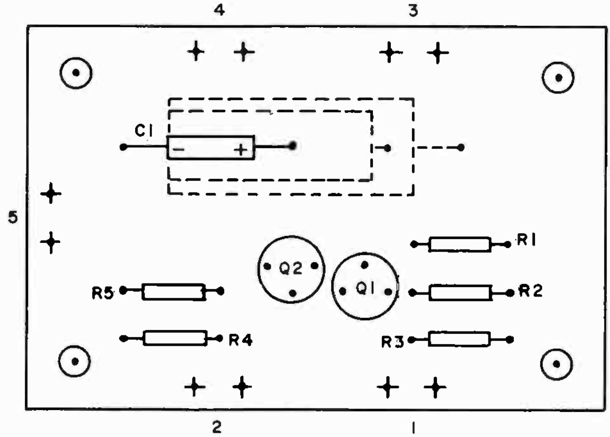


Fig. 290 — Component placement diagram for the running and stop oscillators.

differ. The boards for the same circuit type may be cut and drilled simultaneously; drilling templates are shown at the back of the Manual. Component placement diagrams and photographs of completed circuit boards are shown in Figs. 290 through 299. The list in Table XXXIV indicates how many of each circuit type must be constructed.

The push-button switch used to activate the slot-machine game can be any normally closed type.

The completed slot machine shown in Fig. 279 represents but one method of construction. Many other methods are possible and depend on the material used for the chassis, the lamp socket chosen, etc. If desired, a replica of a conventional slot machine can be used to house the electronic counterpart.

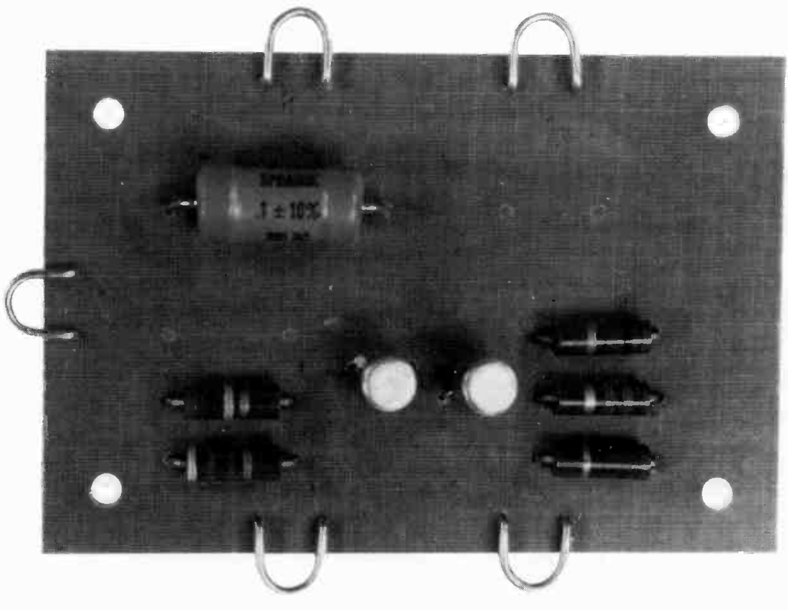


Fig. 291 – Completed circuit board for the running and stop oscillators.

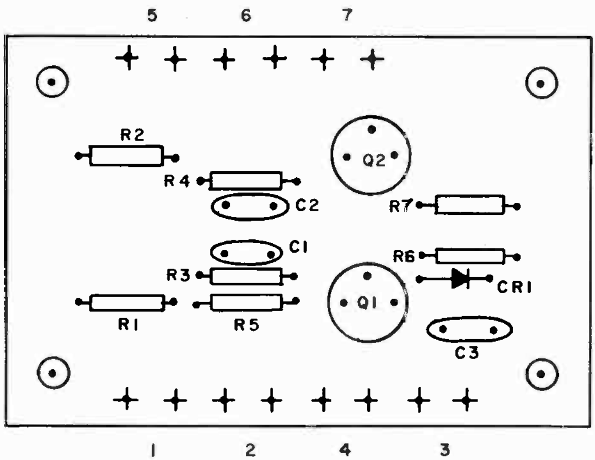


Fig. 292 – Component placement diagram for the flip-flop.

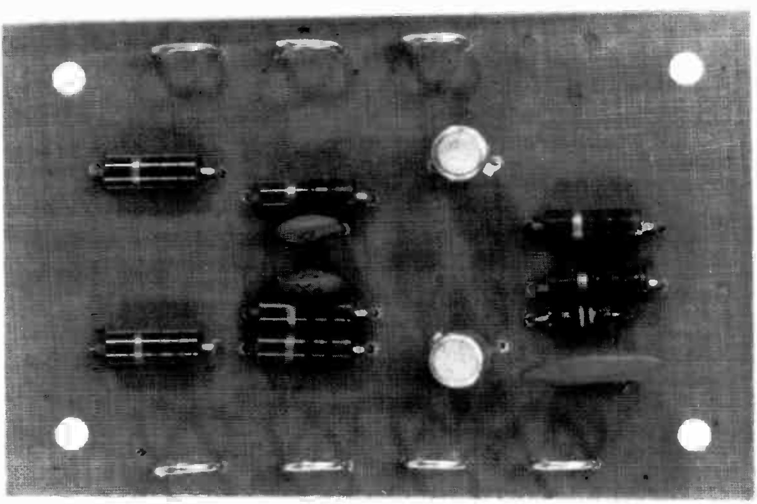


Fig. 293 – Completed circuit board for the flip-flop.

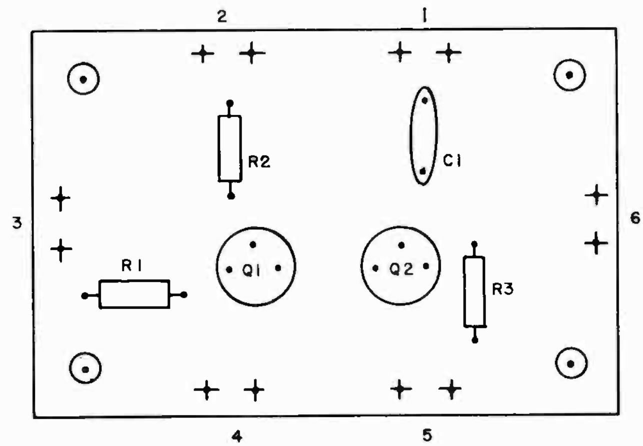


Fig. 294 – Component placement diagram for the NAND gates (A, B, C).

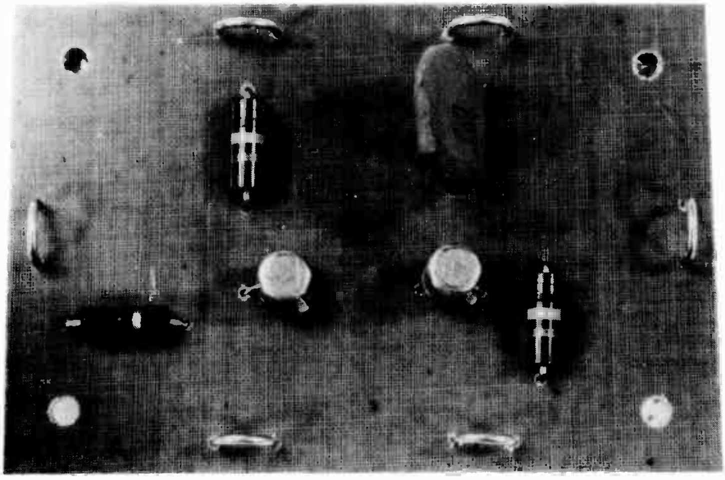


Fig. 295 – Completed circuit board for the NAND gates (A, B, C).

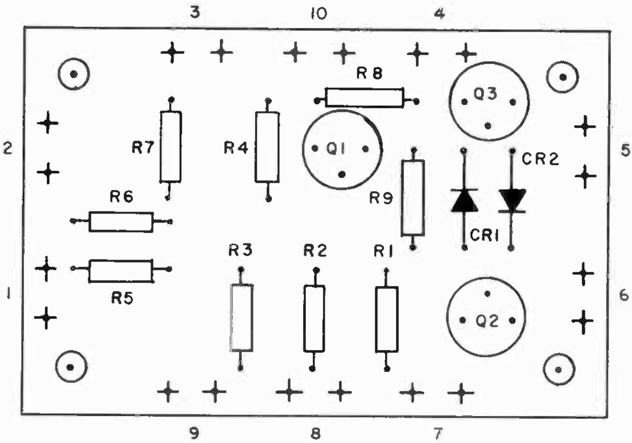


Fig. 296 – Component placement diagram for the NOR gate and lamp driver for score 2.

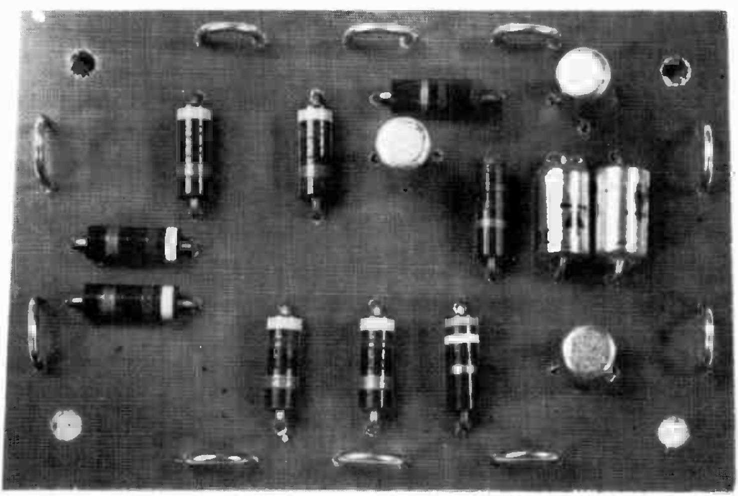


Fig. 297 – Completed circuit board for the NOR gate and lamp driver for score 2.

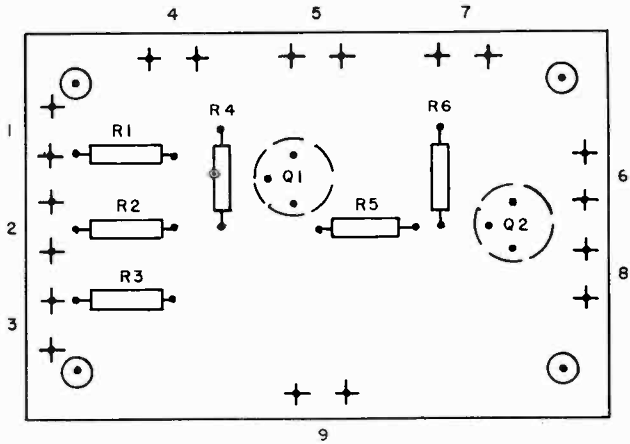


Fig. 298 – Component placement diagram for the NOR gate and lamp drivers for scores 10 through 100.

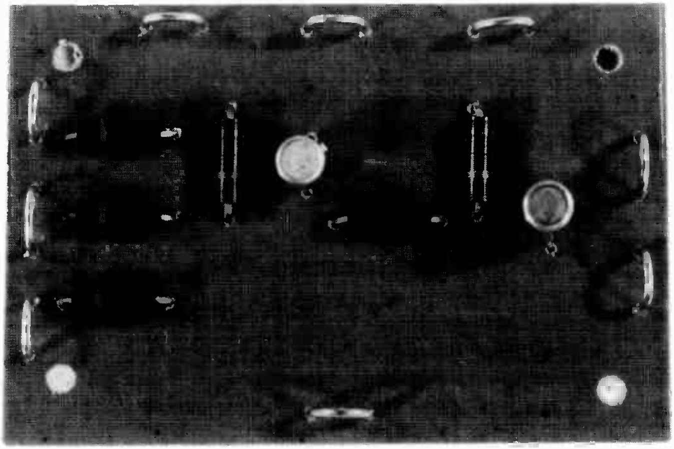


Fig. 299 – Completed circuit board for the NOR gate and lamp drivers for scores 10 through 100.

Table XXXIV.
Circuit Modules Required

	Number Required	Schematic
Running Oscillator	1	Fig. 284
Stop Oscillator	3	Fig. 284
Flip-Flop	3	Fig. 285
Nand Gates	3	Fig. 286
Score Gate (Lamp 16)	1	Fig. 287
Score Gate (Lamps I1 through I5)	5	Fig. 288
Power Supply	1	Fig. 289
Shift Register	3	Circuit No. 7

CIRCUIT NO. 58 – DICE

The dice circuit can display any of the dot patterns that exist on the faces of conventional dice. When the push-button switch is depressed the display lights flash randomly for a few seconds, then stop in a combination representing a number from 1 through 6. If a pair of dice is needed, the circuit described below can be operated twice or a second circuit can be built; one power supply is sufficient to power a pair of electronic dice. A suggested enclosure for the electronic dice is shown in Fig. 300.

Circuit Operation

The schematic diagrams and parts lists for the electronic dice are shown in Fig. 301 and 302.

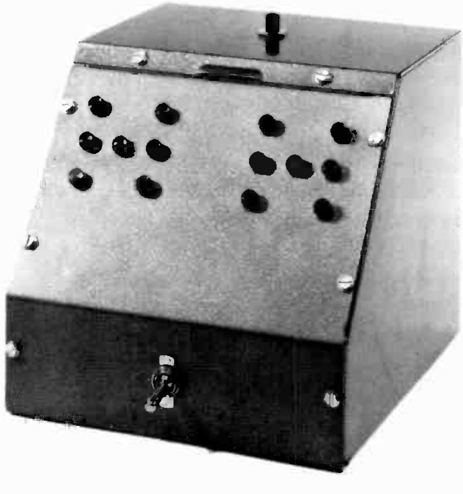
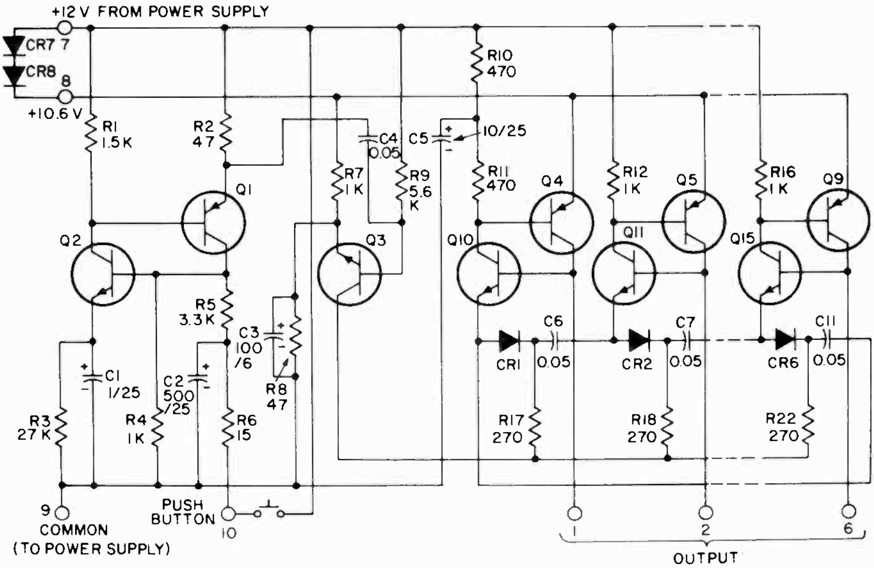


Fig. 300 – Suggested enclosure for the dice circuit.



Parts List

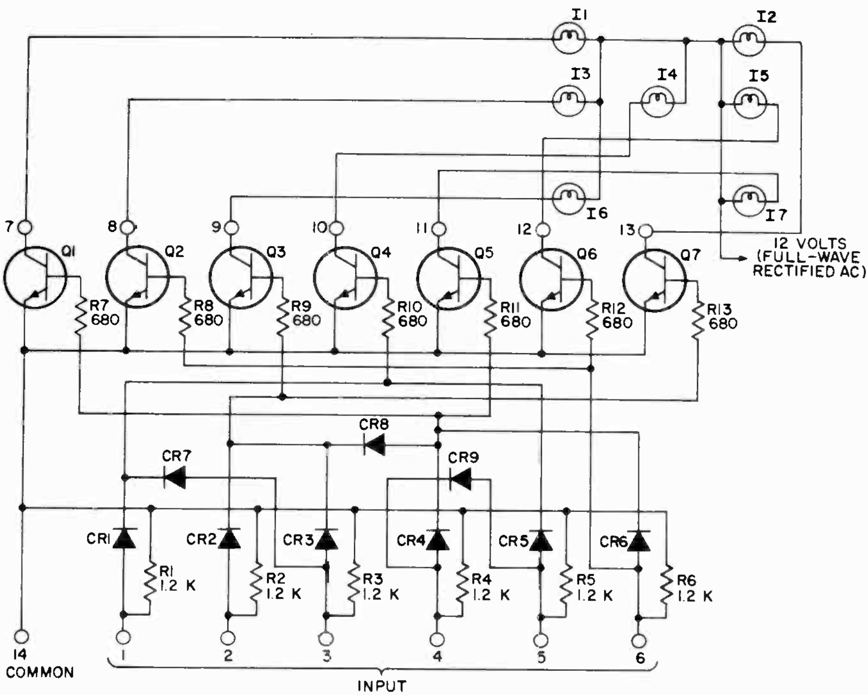
C1 = 1 microfarad, 25 volts, electrolytic
C2 = 500 microfarads, 25 volts, electrolytic
C3 = 100 microfarads, 6 volts, electrolytic
C4 C6 through C11 = 0.05 microfarad, 25 volts or greater, ceramic
C5 = 10 microfarads, 25 volts, electrolytic
CR1 through CR6 = diode, RCA 1N270
CR7 CR8 = rectifier, RCA SK3030
Q1 Q4 through Q9 = transistors, RCA SK3005
Q2 = transistor, RCA SK3020
Q3 Q10 through Q15 = transistor, RCA SK3010
R1 = 1500 ohms, 1/2 watt, 10%
R2 R8 = 47 ohms, 1/2 watt, 10%
R3 = 27,000 ohms, 1/2 watt, 10%
R4 R7 R12 through R16 = 1000 ohms, 1/2 watt, 10%
R5 = 3300 ohms, 1/2 watt, 10%
R6 = 15 ohms, 1/2 watt, 10%
R9 = 5600 ohms, 1/2 watt, 10%
R10 R11 = 470 ohms, 1/2 watt, 10%
R17 through R22 = 270 ohms, 1/2 watt, 10%

Fig. 301 – Schematic diagram and parts list for the digital pulser and six-stage register.

When push-button switch S1 (shown in Fig. 301) is depressed, capacitor C2 charges rapidly to nearly 12 volts; the resultant current through R5 is sufficient to start pulser oscillation. The output pulses from the pulser key the shift register (Circuit No. 7) which is connected as a ring counter; i.e., each stage follows the sequence as if placed around a circle or ring. Stage one in the ring generates the number 1, stage two generates the number 2, and so on. Each pulse input to the ring counter advances the counter one stage.

When the push-button switch S1 is released, C2 discharges slowly through R5 and the pulsation rate decreases until oscillation stops. When oscillation has stopped, the arrangement of illuminated lamps on the face of the electronic dice remains fixed. The nine-diode "OR" gate shown in Fig. 302 gates the output of the shift register to the lamp drivers and assures that the lamps light in proper sequence.

Fig. 303 shows a modification that must be made to the supply (universal series power supply,



Parts List

CR1 through CR9 = diode, RCA 1N270

I1 through I7 = any 12-volt lamp drawing 150 milliamperes or less

Q1 through Q7 = transistor, RCA SK3020

R1 through R6 = 1200 ohms, 1/2 watt, 10%

R7 through R13 = 680 ohms, 1/2 watt, 10%

Fig. 302 – Schematic diagram and parts list for the indicator-lamp gate and driver circuit.

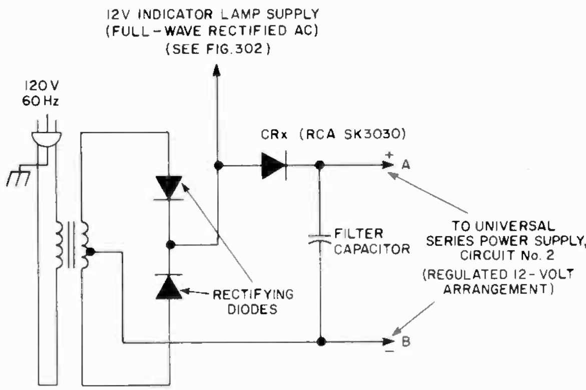


Fig. 303 – Universal series power supply (Circuit No. 2) modified to suit power requirements of the dice circuit.

Circuit No. 2) used to power the electronic dice. The modification consists of the addition of rectifier CRx between the cathodes of the rectifiers and the filter capacitor. Terminal 14 of the dice circuit is connected as shown. The electronic-dice display lamps receive full-wave rectified current through the rectifiers; the lamps do not need regulated voltage that the rest of the circuit requires. CRx in Fig. 303 prevents the filter capacitor from discharging back through the diodes and into the lamp circuit, a condition that would increase the ripple-voltage output of the supply. The presence of CRx also makes possible use of the C1 with a smaller electrical capacitance than would otherwise be suitable.

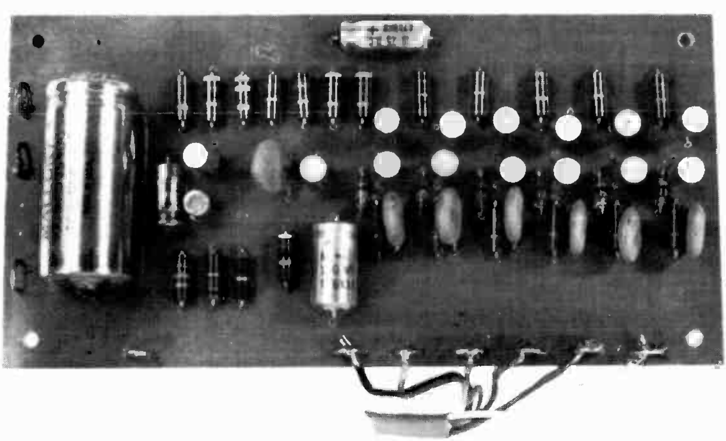


Fig. 304 – Completed circuit board for the digital pulser and six-stage shift register.

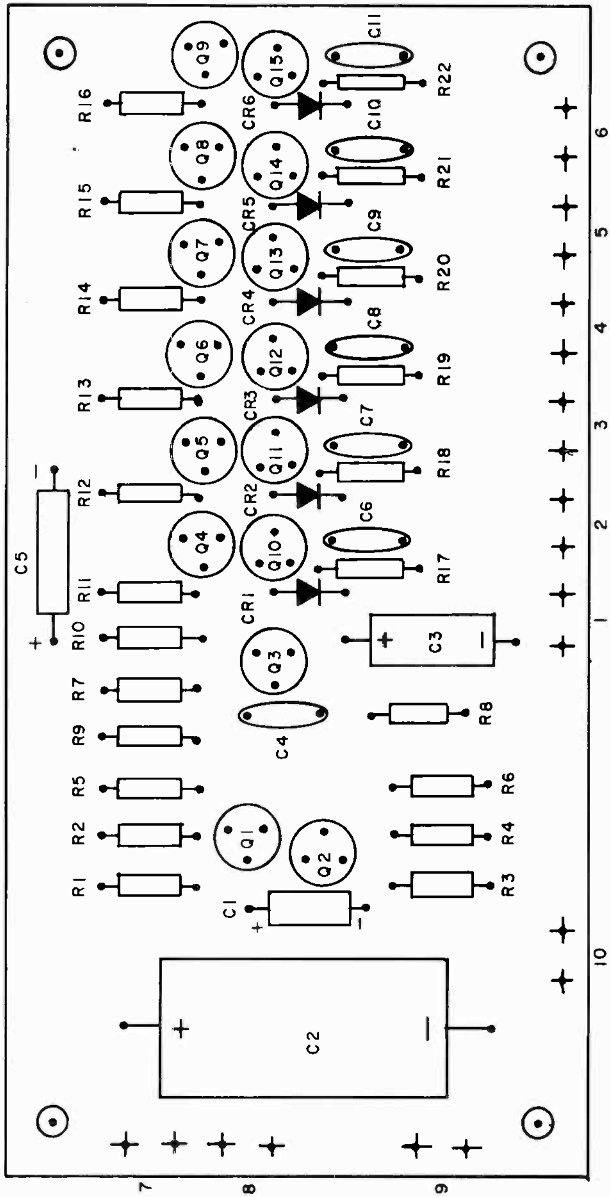


Fig. 305 – Component placement diagram for the digital pulser and six-stage shift register.

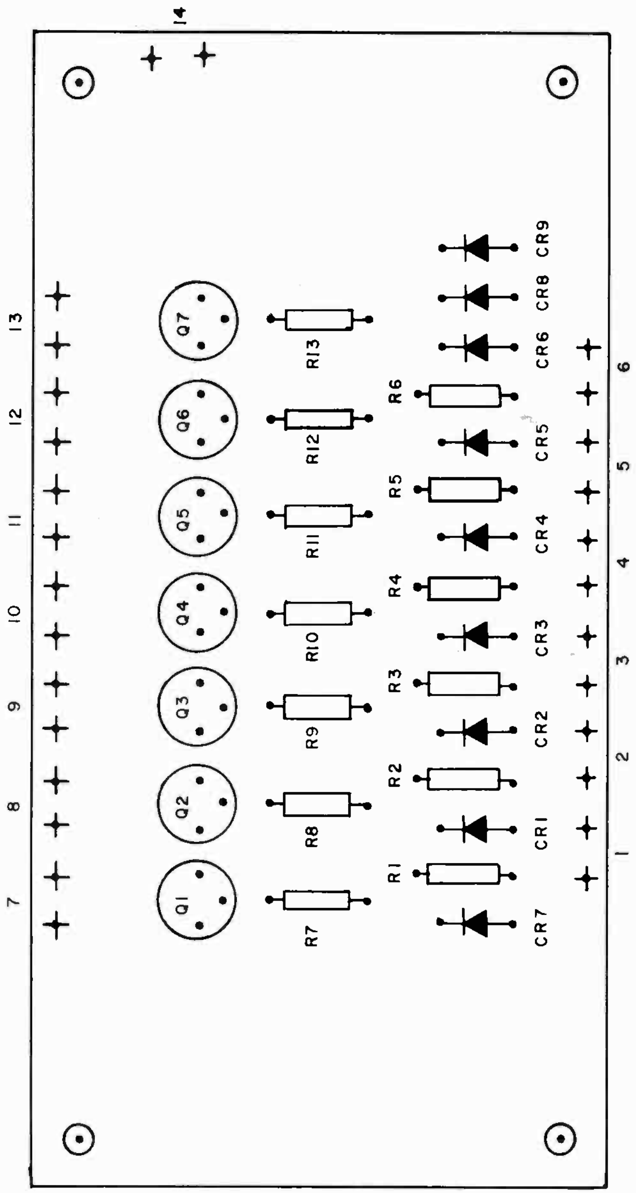


Fig. 306 – Component placement diagram for the indicator-lamp gate and driver circuit.

Construction

The design of the electronic dice incorporates a power supply and three basic modules: the digital pulser, the shift register, and the lamp module. Drilling templates for these circuits are shown at the back of the Manual; photographs of the completed circuit boards and component placement diagrams are shown in Figs. 304 through 307. The arrangement of components is not critical; a circuit layout different from that suggested may be used.

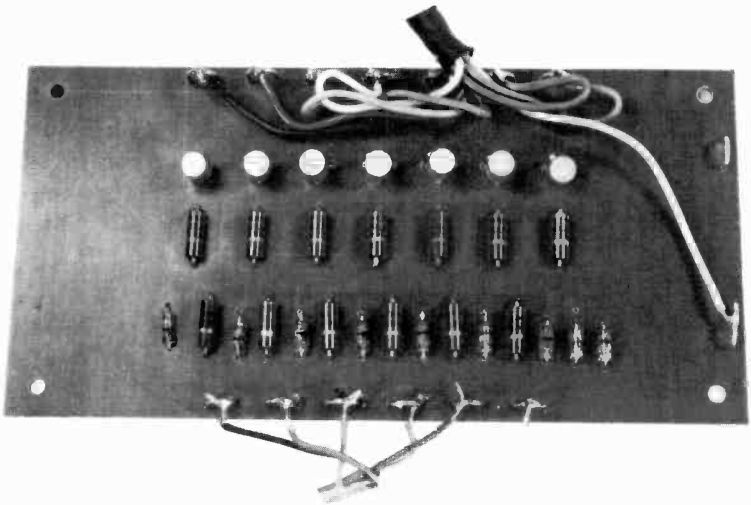


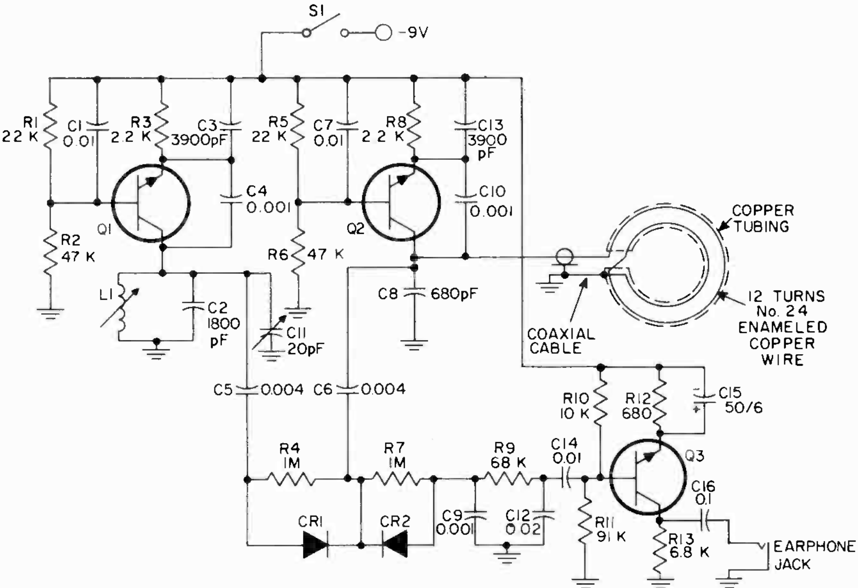
Fig. 307 – Completed circuit board for the indicator-lamp gate and driver circuit.

CIRCUIT NO. 59 – METAL DETECTOR

This circuit can be used to locate buried metal objects, such as water or gas pipes, and metal objects such as coins lost in grass, loose earth, or sand. When no metal is near, a steady tone is heard in the headphones connected to the metal detector. When metal is present, the tone either changes or cuts off completely, depending on how the detector is set. The detector locates metal; it does not determine the size or the depth below the surface of that metal.

Circuit Operation

The schematic diagram and parts list for the metal detector are shown in Fig. 308. The circuit consists of two oscillators. The first oscillator, which includes Q1, operates at approximately 300 kHz, a frequency determined by inductor L1 and capacitors C2 and C11. The second oscillator, which includes Q2, operates at a frequency determined by C8 and the search coil. L1 is adjusted so that its frequency of oscillation is close to that of the



Parts List

C1 C7 C14 = 0.01 microfarad, 25 volts or greater
C2 = 1800 picofarads, 25 volts or greater, silver mica
C3 C13 = 3900 picofarads, silver mica, 100 volts or greater
C4 C9 C10 = 0.001 microfarad, 25 volts or greater, silver mica
C5 C6 = 0.004 microfarad, 25 volts or greater
C8 = 680 picofarads, 25 volts or greater, silver mica
C11 = 20 picofarads, variable type, Johnson type 160-110 or equivalent
C12 = 0.02 microfarad, 25 volts or greater
C15 = 50 microfarads, 6 volts, electrolytic
C16 = 0.1 microfarad, 25 volts or greater
CR1 CR2 = diode, RCA 1N34A
L1 = 50 to 140 microhenries, adjustable, Miller type 4207
Q1 Q2 Q3 = transistor, RCA SK3020
R1 R5 = 22,000 ohms, 1/2 watt, 10%
R2 R6 = 47,000 ohms, 1/2 watt, 10%
R3 R8 = 2200 ohms, 1/2 watt, 10%
R4 R7 = 1 megohm, 1/2 watt, 10%
R9 = 68,000 ohms, 1/2 watt, 10%
R10 = 10,000 ohms, 1/2 watt, 10%
R11 = 91,000 ohms, 1/2 watt, 10%
R12 = 680 ohms, 1/2 watt, 10%
R13 = 6800 ohms, 1/2 watt, 10%
S1 = toggle switch; single-pole, single-throw
Copper tubing: 1/4-inch diameter, 3.14 feet (enough for loop of 1-foot diameter)

Fig. 308 – Schematic diagram and parts list for the metal detector.

Parts List (Cont'd)

No. 24 enameled copper wire: about 40 feet (enough for 12 turns of 1-foot diameter and connections)

Coaxial cable: about 3 feet (exact amount depnds on length of handle)

Earphones = 2000 ohms

search coil. (The procedure for adjusting L1 is described below.) The output of the oscillators is fed into a product detector through C5 and C6. The product detector produces an audio signal when there is a difference in frequency between the outputs of the two oscillators. A difference in frequency occurs when the search coil is brought close to a metal object and its inductance, and therefore its frequency of oscillation, is changed. The audio output from the product detector is applied to the base of Q3, which amplifies the signal to an audible level.

Adjustments and Operation

With the circuit energized, inductance L1 is adjusted until a tone is heard in the headphones. Variable capacitor C11, a fine-tuning control, is used as an aid in achieving maximum sensitivity, a condition signaled by a "motorboating" or "putt-putt" sound in the headphones. The detector is then ready for use. As the search coil is passed slowly over the ground and as close to the ground as possible, a change of tone or the cessation of tone indicates the presence of metal. Damp ground may also cause the tone to change, and may necessitate readjustment of the detector with the search coil held near the ground. The current drain for this circuit is 3 milliamperes.

Construction

The most critical member of the metal detector is the search coil. The coil consists of 12 turns of No. 24 enameled wire enclosed in a 1-foot-diameter loop of 1/4-inch copper tubing. The ends of the loop should be about 2 inches apart at the beginning of search-coil construction and should not be electrically connected. To form the turns within the tubing, one end of the No. 24 wire is fed into one end of the copper tubing and pushed through until it emerges from the other end. The end of the wire that has just emerged is reinserted into the tubing and pushed through as before. This process is repeated until there are 12 turns of wire within the loop. When this task is completed, the loop must be closed so that there is a space of only 1/4 inch between the ends. The loop can be closed by pulling on the ends of the wire within the loop. One end of the wire and the braided conductor of the coaxial cable should then be connected to one end of the copper loop. The other end of the wire should be connected to the center wire of the coaxial cable. Fig. 309 shows a finished search coil.

A handle must then be connected to the search coil as shown in Fig. 309. Metal fasteners should not be used in the area of the coil. The circuit portion of the detector should

Fig. 309 – Completed search coil with handle attached.

be mounted as far as possible from the search coil; a good location is on the upper part of the handle. Layout of the detector circuit is not critical; however, it should be mounted in a metal box as shown in Fig. 310.

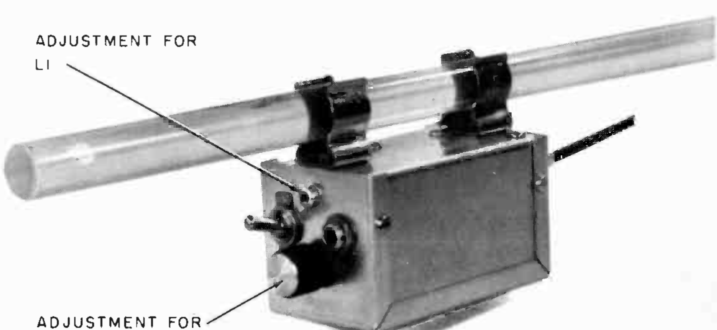


Fig. 310 – Suggested enclosure for the metal-detector circuit.

CIRCUIT NO. 60 – MOTOR-SPEED CONTROL

The motor-speed-control circuit provides both speed control and speed regulation (constant speed under conditions of changing load) for ac/dc universal motors (motors that are series wound). The circuit also provides smooth anti-skip operation at reduced speeds and is useful for adjusting and regulating the speed of power tools, such as drills, buffers, and jigsaws; hair dryers; floor polishers; and commercial food mixers. When the circuit is used with a power drill, the speed of the motor can be made slow enough so that the drill can be used as a screwdriver.

The motor-speed-control circuit is suitable for use with motors that have nameplate ratings up to 6 amperes. Motor speed can be adjusted from complete cutoff to essentially full rated value.

Circuit Operation

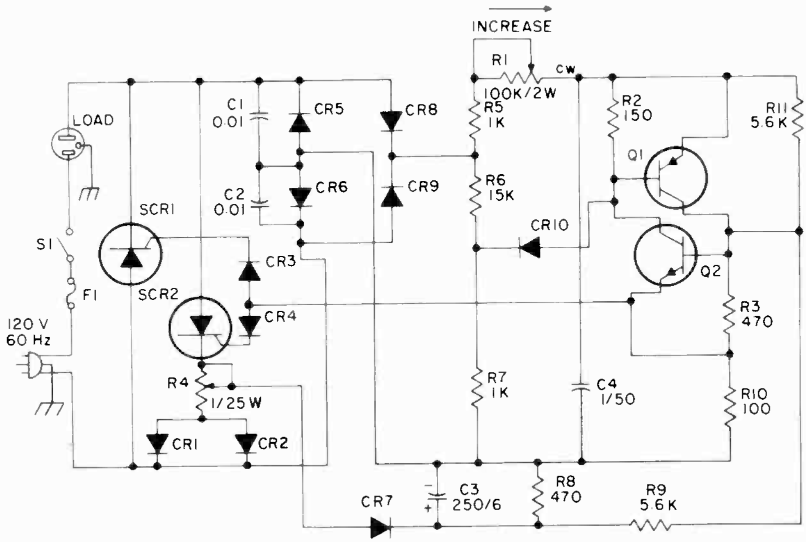
The schematic diagram and parts list for the motor-speed control are shown in Fig. 311. Motor speed is determined by the time that one of the SCR's conducts during each half-cycle of ac input. This time is controlled by adjustment of the potentiometer.

When the potentiometer is set for minimum resistance (control knob in maximum clockwise position), capacitor C4 charges very rapidly and the triggering-voltage level of the two-transistor regenerative switch is reached early in each half-cycle. When the transistors in the regenerative switch start conducting, capacitor C4 discharges rapidly through the series circuit made up of the transistors and resistor R10. The capacitor discharge causes a pulse across the parallel circuit composed of R10 and the gate circuits of the SCR's. If the anode of SCR1 is positive with respect to the cathode, the anodes of rectifier CR5 and CR9 are also positive with respect to their cathodes and the rectifiers conduct. A conduction path then exists between the junction of C4 and R10 and the cathode of SCR1 through CR5. The pulse appearing across the parallel combination of R10 and the SCR1 gate circuit (CR3, the gate, and C4) causes SCR1 to conduct. At the same time, SCR2 is non-conducting because its anode is negative with respect to its cathode; CR6 and CR8 are non-conducting for the same reason. Reverse polarity on SCR2, CR6, and CR8 applies a reverse polarity to CR4 and prevents the pulse from R10 from reaching the SCR2 gate.

During the next half-cycle, the polarity of the power source reverses, and SCR2 becomes the conducting SCR; SCR1 becomes the non-conducting SCR.

As the resistance of the potentiometer is increased, the time required to charge C4 to the triggering potential of the regenerative switch becomes longer, and the pulse is produced later in the half-cycle, or not at all if the charge on C4 does not reach triggering level. Therefore, the speed of the universal motor can be controlled by the position of the potentiometer knob.

When the mechanical load on the motor is increased, the motor demands more current. The increase in current causes an increase in voltage across the 1-ohm adjustable



Parts List

C1 C2 = 0.01 microfarad, 1000 volts, ceramic

C3 = 250 microfarads, 6 volts, electrolytic

C4 = 1 microfarad, 200 volts, paper

CR1 CR2 = rectifier, RCA SK3016 mounted in a fuse clip for heat sinking

CR3 through CR10 = rectifier, RCA SK3030

F1 = fuse, 125 volts, 10 amperes maximum, slow-blow, exact rating depends on intended load

Q1 = transistor, RCA SK3005

Q2 = transistor, RCA SK3020

R1 potentiometer, 100,000 ohms, 2 watts, linear taper

R2 = 150 ohms, 1/2 watt, 10%

R3 R8 = 470 ohms, 1/2 watt, 10%

R4 = adjustable resistor, 1 ohm, 25 watts, Ohmite No. 0360 or equivalent

R5 R7 = 1000 ohms, 1/2 watt, 10%

R6 = 15,000 ohms, 1 watt, 10%

R9 R11 = 5600 ohms, 1/2 watt, 10%

R10 = 100 ohms, 1/2 watt, 10%

S1 = toggle switch, 125 volts, 6 amperes, single-pole, single-throw

SCR1 SCR2 = silicon controlled rectifier RCA KD2100

Fig. 311 – Schematic diagram and parts list for the motor-speed control.

sensing resistor R4. This voltage is fed back through diode CR7 and resistor R9 to the base of Q2, one of the components of the regenerative switch. The application of this voltage to the base of Q2 reduces the triggering voltage required by the regenerative switch and causes it to conduct earlier in the half-cycle. Thus, more power is delivered to the motor so that it can maintain a constant speed. Rectifiers CR1 and

CR2 prevent current from flowing through R4 to the feedback network during the half-cycle in which SCR2 is not conducting. Resistor R4 is set according to motor nameplate rating or load current; the proper setting for this resistor can be determined from the curve shown in Fig. 312.

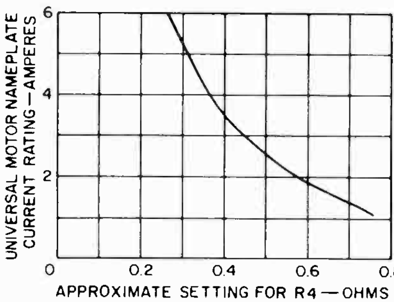


Fig. 312–Approximate setting of R4 for various motor nameplate ratings.

Rectifier CR10 is used to prevent improper timing of the triggering circuit when the potentiometer is set high enough so that C4 does not reach triggering voltage. If the charge on C1 has not reached triggering potential at the end of a half-cycle, this diode triggers the regenerative switch into conduction so that any residual charge on C4 is dissipated. The anti-skip circuit composed of CR10 and R7 ensures that each half-cycle of operation starts under the same conditions and thus provides smooth, continuous motor operation.

Adjustments and Special Considerations

This circuit may produce some radio-frequency interference; such interference can be minimized by the installation of an LC-filter between the circuit and the voltage source and load as shown in Fig. 313. The filter consists of about 18 feet of No. 18E

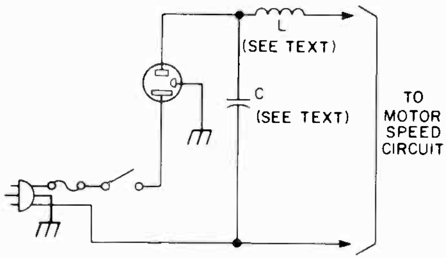


Fig. 313 – Schematic diagram of LC-filter connections.

wire "scramble" or random-wound on a 0.5-inch-diameter rod, and a 0.05-microfarad 200-volt paper capacitor. If desired, the capacitor can be used as the core of the coil instead of the rod. If this method is used, a 600-volt capacitor should be used instead of a 200-volt type. The larger 600-volt capacitor is used only because it provides a better physical core size. Fig. 314 is a photograph of the LC-filter.

Operation of single-speed motors at reduced speeds should be limited to relatively short periods. Most motors intended for single-speed operation depend on the air flow provided by a built-in fan to keep the temperature rise within acceptable limits. When the motor speed is reduced, this air flow also decreases, and the motor may become overheated.

The waveshapes shown in Fig. 315 are typical of those present at various points in the motor-speed-control circuit.

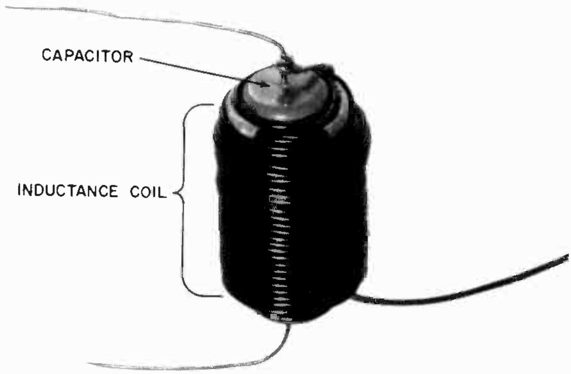


Fig. 314 – LC-filter used to reduce radio-frequency interference.

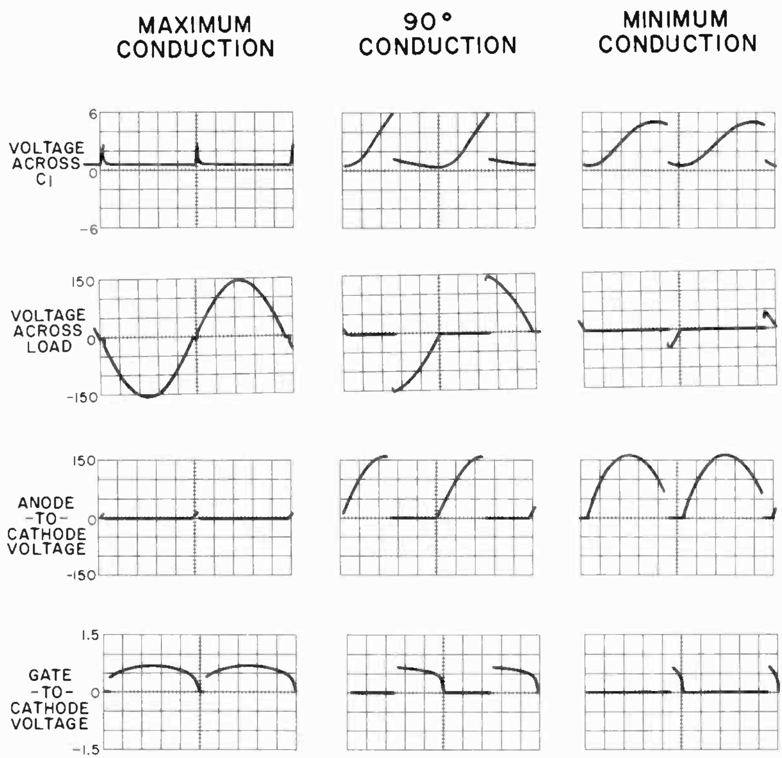


Fig. 315 – Typical waveshapes taken at various points in the motor-speed-control circuit.

Construction

A suggested method of constructing the motor-speed-control in a 3- by 4- by 5-inch chassis is shown in Fig. 316.

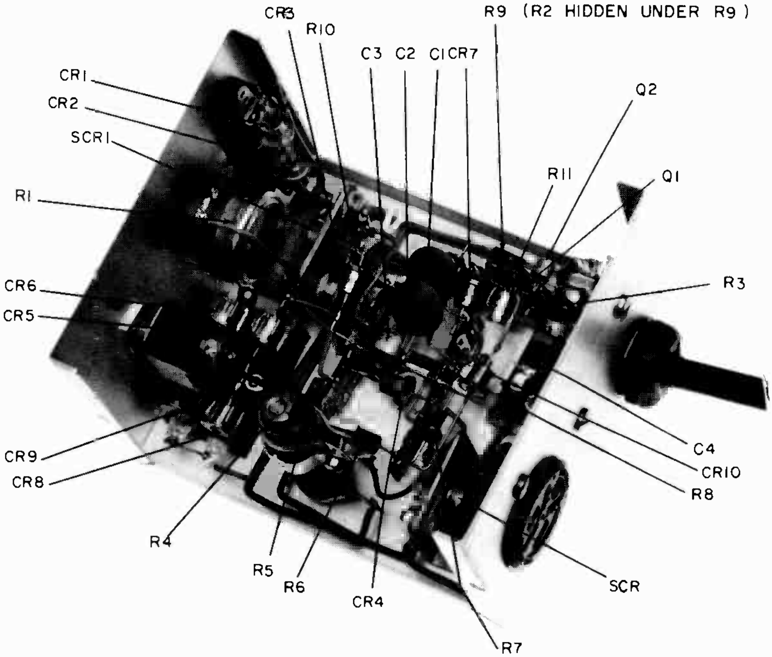


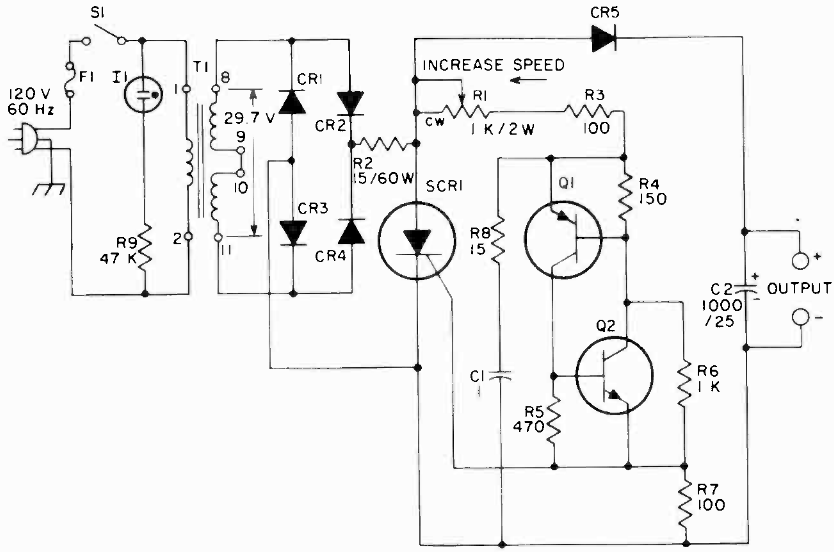
Fig. 316 – Suggested method of construction of the motor-speed control in a 3- by 4- by 5-inch chassis.

CIRCUIT NO. 61 – MODEL TRAIN AND RACE-CAR SPEED CONTROL

The model train and race-car speed control provides continuous and smooth control (from stop to full speed) of most model railroad trains, race cars, and similar "hobby"-type vehicles designed to operate at dc voltage up to 12 volts.

Circuit Operation

The schematic diagram and parts list for the model train and race-car speed control are shown in Fig. 317. The operating speed of the model railroad train or race car with which this circuit is used is determined by the delay involved in triggering the SCR into conduction after the start of each half-cycle of ac input voltage. This delay time, in turn, is controlled by adjustment of the potentiometer R1. Because the load and the SCR are in parallel, output voltage is available at the load only when the SCR is not conducting. When the control knob is set to its maximum clockwise position, therefore, maxi-



Parts List

C1 = 1 microfarad, 200 volts, paper
C2 = 1000 microfarads, 25 volts, electrolytic
CR1 CR2 CR3 CR4 CR5 = rectifier, RCA SK3016, mounted in fuse clips for heat sinking
F1 = fuse, 125 volts, 1 ampere, slow-blow
I1 = lamp, neon, NE-2 or equivalent
Q1 = transistor, RCA SK3005
Q2 = transistor, RCA SK3020
R1 = potentiometer, 1000 ohms, 2 watts, linear taper
R2 = 15 ohms, 60 watts (three 5-ohm 20-watt resistors connected in series)
R3 R7 = 100 ohms, 1/2 watt, 10%
R4 = 150 ohms, 1/2 watt, 10%
R5 = 470 ohms, 1/2 watt, 10%
R6 = 1000 ohms, 1/2 watt, 10%
R8 = 15 ohms, 1/2 watt, 10%
R9 = 47,000 ohms, 1/2 watt, 10%
S1 = toggle switch, 125 volts, 3 ampere, single-pole, single-throw
SCR1 = silicon controlled rectifier, RCA KD2100
T1 = power transformer, Stancor No. RT-202 or equivalent

Fig. 317 – Schematic diagram and parts list for the model train and race-car speed control.

mum delay in triggering the SCR is obtained and maximum speed is attained in the model vehicle.

When switch S1 is closed, the pulsating direct current from the bridge rectifiers charges capacitor C2 through resistor R2 and rectifier CR5, and a voltage appears across the output terminals. Under conditions of minimum conduction of the SCR (approximately 55 per cent of each input half-cycle of voltage), a maximum voltage of approximately 13 volts is present at the output terminals. As the control knob is turned in a counterclockwise direction, the resistance of R1 is decreased and the current through R1, R3, and R8 charges capacitor C1 more quickly to the triggering potential of the two-transistor regenerative switch. The switch, in turn, triggers the SCR into conduction, and the voltage across the output terminals drops to slightly less than one volt when the control knob is in the most counterclockwise position.

Because capacitor C2 performs an integrating function, the output voltage approaches a steady dc level determined by the relative duration of the "ON" and "OFF" periods of the SCR. The rectifier CR5 isolates the anode of the SCR from the potential on C2 so that the capacitor cannot discharge through the SCR when it is triggered into conduction and so that the anode voltage falls to zero and turns off the SCR at the end of each input half-cycle. Resistor R7 helps to stabilize the operation of the SCR, and also provides a parallel path for discharge of C1 after the SCR is triggered into conduction. Resistor R2 limits the current through the bridge rectifier circuit to the maximum allowable value of two amperes in the event of a short circuit across the output terminals.

The parallel arrangement of the load and the SCR in this circuit provides superior control and speed regulation at the operating voltages of model vehicles. The circuit is inherently self-regulating, i.e., it maintains essentially constant speed under varying load conditions. When the mechanical load increases, (e.g., when the vehicle travels on an inclined portion of the track or road), the vehicle motor tends to slow down. The motor current then increases, and the voltage across capacitor C2 decreases. However, because this voltage is also the potential for the timing circuit (R1, R3, R8, and C1), the capacitor C1 charges more slowly and the delay in triggering the SCR is increased. As a result, the output voltage is also increased and the speed is maintained essentially constant.

Fig. 318 shows the waveshapes across the SCR (from anode to cathode) for one cycle of input voltage at (a) full speed, (b) half speed, and (c) zero speed. At the start of each half-cycle (point 1), the SCR is off. The anode voltage then follows the increasing sine wave until it equals the voltage on capacitor C2 (point 2). Rectifier CR5 then starts to conduct, and C2 charges until the SCR is triggered into conduction (point 3) by the timing portion of the circuit. At the start of conduction, the anode drops to 0.6 volt (point 4), rectifier CR5 stops conducting, and capacitor C2 discharges into the load until point 2 of the next half-cycle.

The SCR stops conducting when the input voltage drops to zero at the end of the half-cycle (point 5). The load-voltage waveshape is described by the charge and discharge paths of capacitor C2.

Construction

Fig. 319 shows a model train and race-car speed control assembled in a 3- by 4- by 5-inch aluminum box.

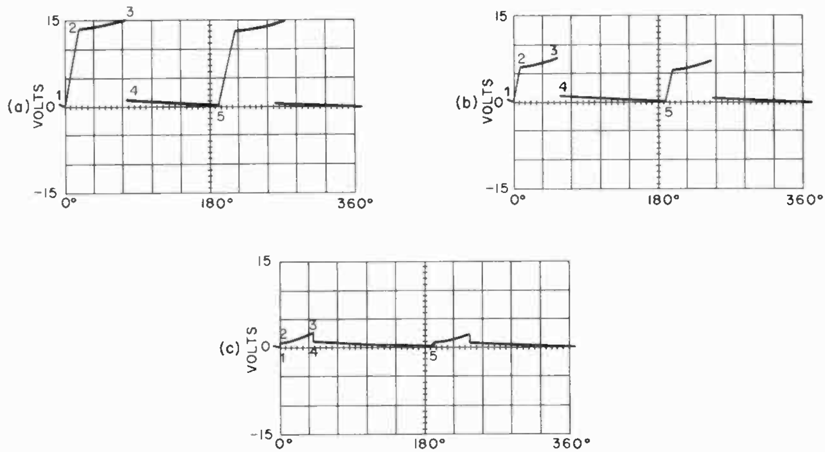


Fig. 318 – Typical waveshapes across the SCR in the model train and race-car speed control at (a) full speed, (b) half speed, and (c) zero speed.

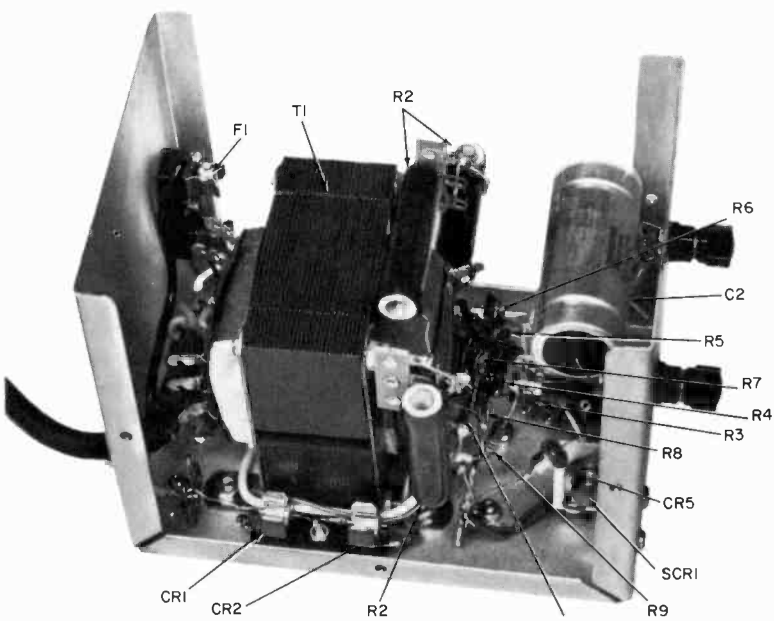


Fig. 319 – Model train and race-car speed control assembled in a 3- by 4- by 5-inch chassis.

CIRCUIT NO. 62 – TIME DELAY

The time delay circuit is useful for actuating an auditory device to signal the end of a time interval (e.g., to limit card or chess players to one minute of "thinking time"), or for making another device "wait" for a short time until some action can be accomplished (e.g., getting into the picture before the camera clicks).

The circuit is used to delay the application of power to a load for a predetermined period after the control switch is turned on and can be used with ac/dc devices that do not use the frame of the device as a ground and that have total power ratings up to 240 watts (nameplate current ratings up to two amperes). The delay time can be adjusted from five seconds to approximately two minutes.

Circuit Operation

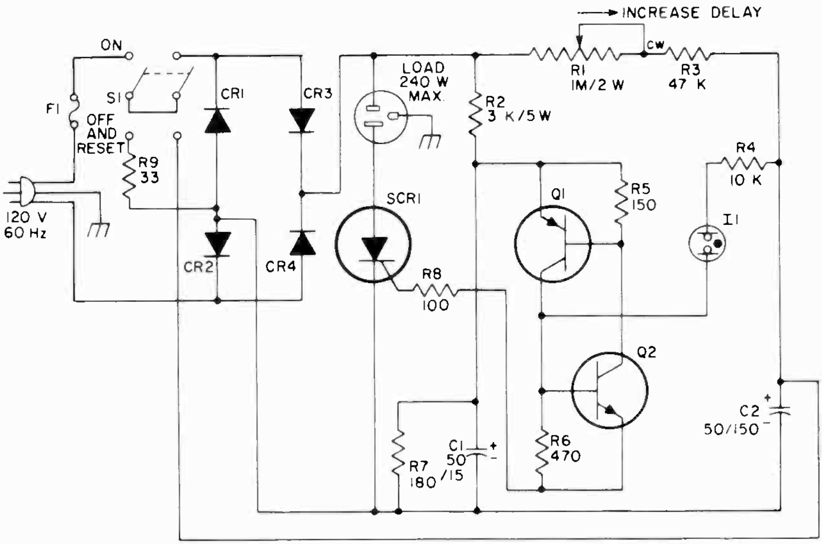
The schematic diagram and parts list for the electronic time delay are shown in Fig. 320. The delay in turn-on time of the equipment with which this circuit is used is determined by the length of time required for the timing capacitor C2 to charge to the value required to turn on the neon lamp NE-83 and trigger the two-transistor switch. This time, in turn, is controlled by adjustment of the resistance of potentiometer R1.

When switch S1 is ON, the full-wave rectified current from the rectifier bridge circuit charges capacitor C1 through resistor R2. The charge on C1 is held to a peak potential of less than seven volts by the voltage divider formed by resistors R2 and R7. At the same time, the timing capacitor C2 starts to charge through series resistors R1 and R3. When the charge on C2 reaches a value of about 80 volts, the neon lamp fires and triggers the two-transistor regenerative switch. The conducting regenerative switch completes the gate circuit through resistor R8 and triggers the SCR into conduction. The fixed charge on C1 then maintains conduction in the regenerative switch through the gate of the SCR, and load current continues to flow for the duration (practically 180 degrees) of each succeeding half-cycle of input voltage until S1 is turned OFF. (The SCR is actually cut off near the end of each half-cycle and retriggered shortly after the beginning of each succeeding half-cycle by the current applied as a result of the steady potential on C1.) In the OFF position, S1 discharges C2 through resistor R9 and prepares the circuit for the next time-delay application.

Adjustments and Special Considerations

With the values shown in the parts list for R1, R3, and C2, this circuit can be set for time delays from five seconds to approximately two minutes by adjustment of potentiometer R1. Although longer time delays can be obtained by the use of a larger value for the timing capacitor C2, it is not economically feasible to obtain delays of much more than five minutes with this circuit.

The exact length of the time delay depends on the capacitance of C2. Most electrolytic capacitors are rated on the basis of minimum guaranteed value (MGV), and the capacitor used may have a value



Parts List

C1 = 50 microfarads, 15 volts, electrolytic
C2 = 50 microfarads, 150 volts, electrolytic
CR1 CR2 CR3 CR4 = rectifier, RCA SK3016 mounted in fuse clip for heat sinking
F1 = fuse, 125 volts, 3 amperes
I1 = lamp, neon, NE-83 or equivalent
Q1 = transistor, RCA SK3004
Q2 = transistor, RCA SK3020
R1 = potentiometer, 1 megohm, 2 watts, linear taper
R2 = 3000 ohms, 5 watts, 10%
R3 = 47,000 ohms, 1/2 watt, 10%
R4 = 10,000 ohms, 1/2 watt, 10%
R5 = 150 ohms, 1/2 watt, 10%
R6 = 470 ohms, 1/2 watt, 10%
R7 = 180 ohms, 1/2 watt, 10%
R8 = 100 ohms, 1/2 watt, 10%
R9 = 33 ohms, 1/2 watt, 10%
S1 = toggle switch, 125 volts, 3 amperes, double-pole, double-throw
SCR1 = silicon controlled rectifier, RCA KD2100

Fig. 320 – Schematic diagram and parts list for the time delay.

much higher than its rating. The circuit should be calibrated for various positions of the control knob after the timing capacitor has had a chance to age.

Fig. 321 shows the electronic time delay assembled in a 3- by 4- by 5-inch aluminum box.

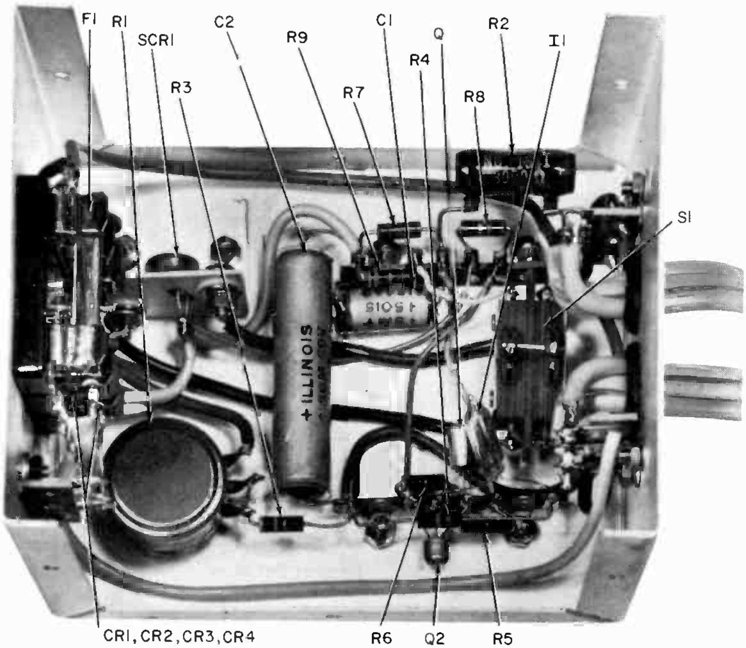


Fig. 321 – Time-delay circuit assembled in a 3- by 4- by 5-inch chassis.

Printed-Circuit-Board and Drilling Templates

THE FOLLOWING pages contain full-size drilling templates or printed-circuit-board templates for most of the circuits in the Manual. It is a good idea to mount each drilling template on cardboard before it is used so that it will not tear readily and become unsatisfactory for repeated use. Drilling templates should be securely fastened to the circuit board before holes are drilled through it. A key to the symbols used on the templates is given below. A list of templates follows the key to symbols.

Where no symbols are given, the following list will serve as a guide.

No. 60 drill (0.040 inch)
Used for 1/2-watt resistors, all capacitors, transistors, rectifiers, diodes.

No. 58 drill (0.042 inch)
Used for 1-watt resistors.

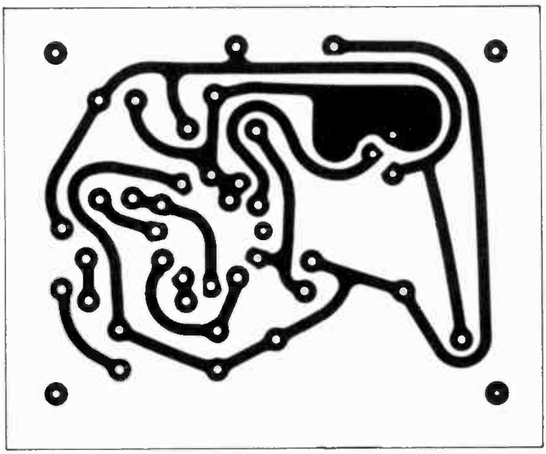
No. 55 drill (0.052 inch)
Used for 2-watt resistors.

No. 50 drill (0.070 inch)
Used for numbered terminals, trimpots, coils.

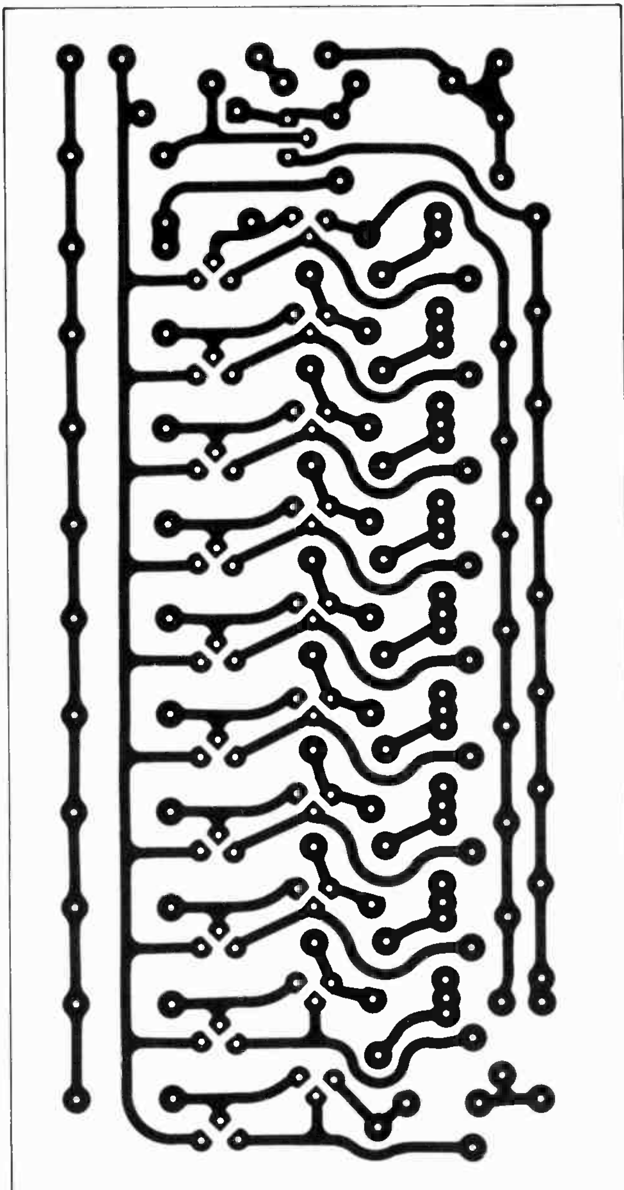
No. 32 drill (0.116 inch)
Used for mounting holes.

KEY TO DRILLING SYMBOLS

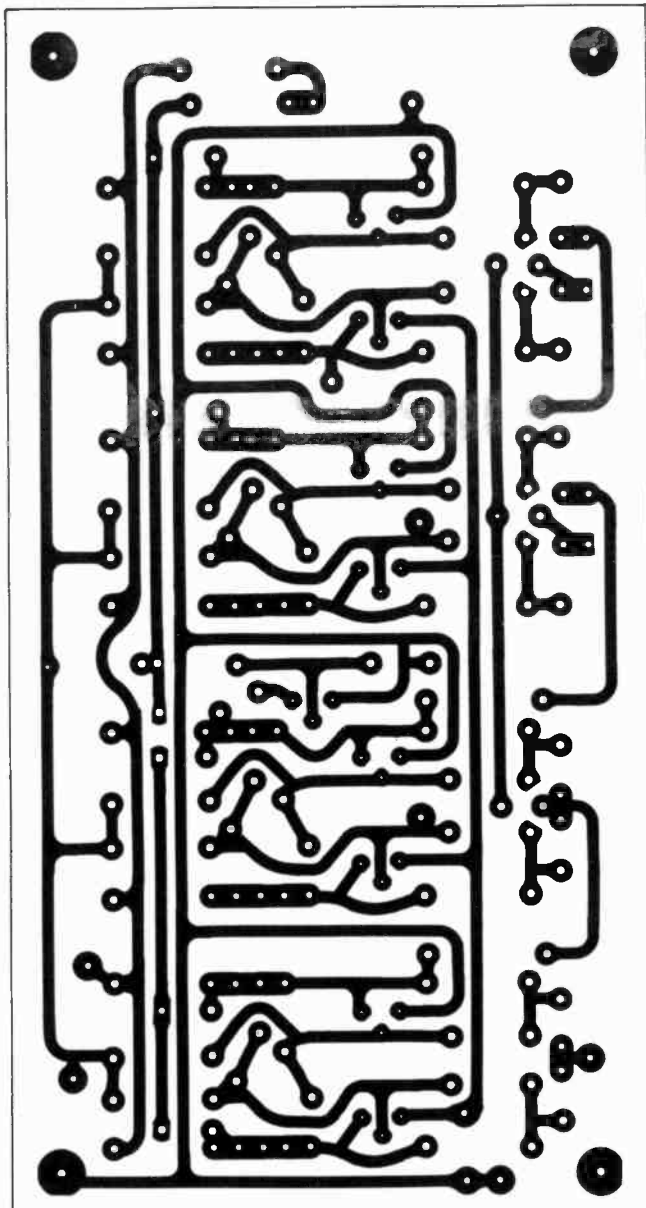
No. 60 drill (0.040 inch)
+ No. 58 drill (0.042 inch)
⊙ No. 32 drill (0.116 inch)



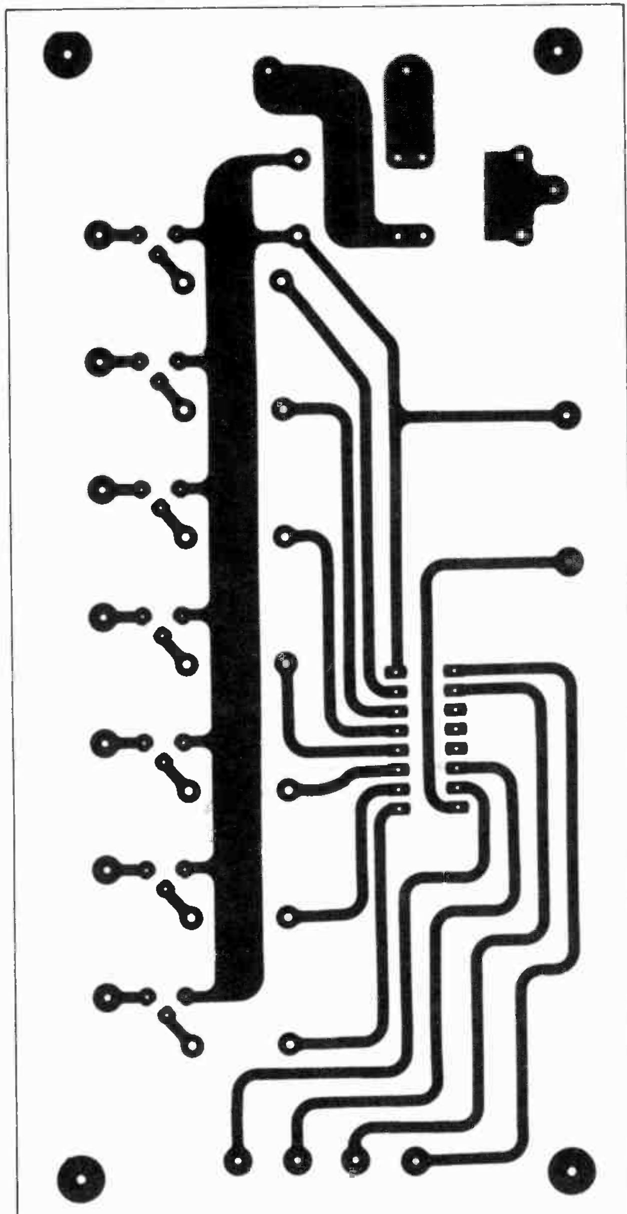
IC 9-Volt Regulated Power Supply



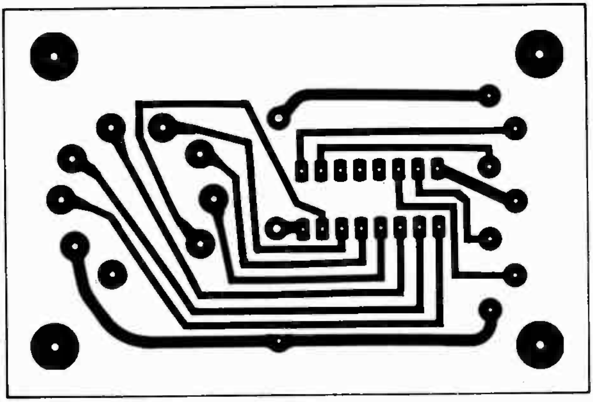
Ten-Stage Shift Register



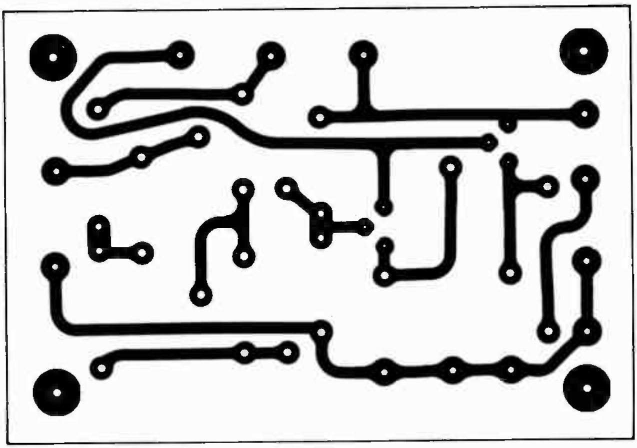
Count-by-Ten or Decade



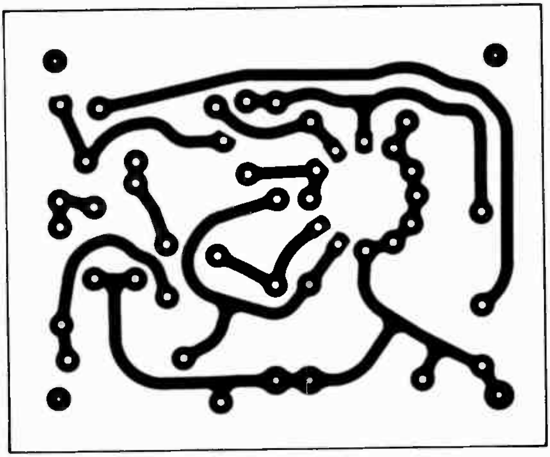
Large-Scale Lamp Display



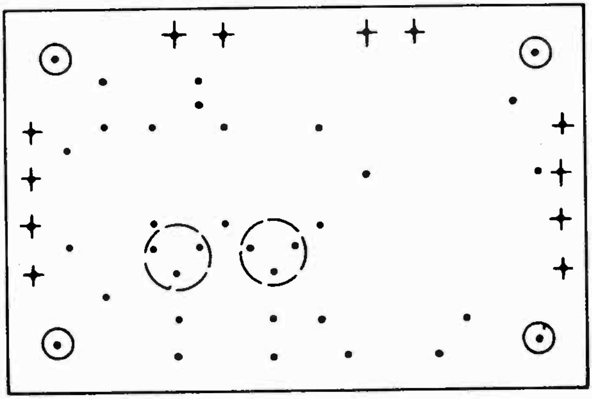
Numitron Display



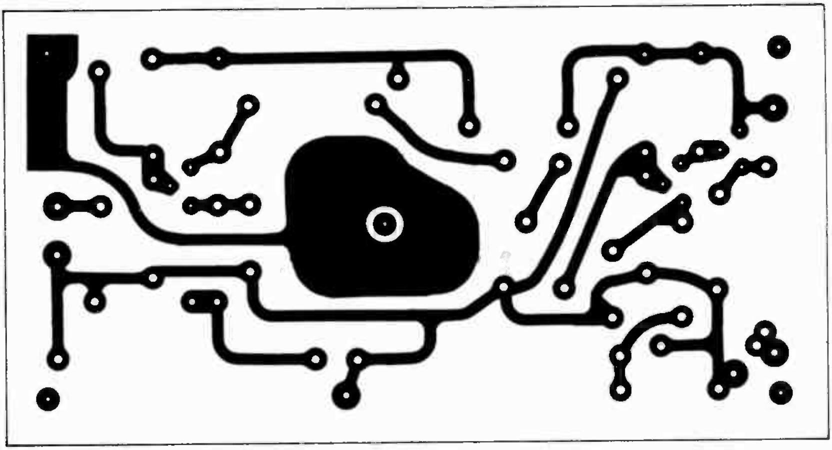
Audio and Code-Practice Oscillator



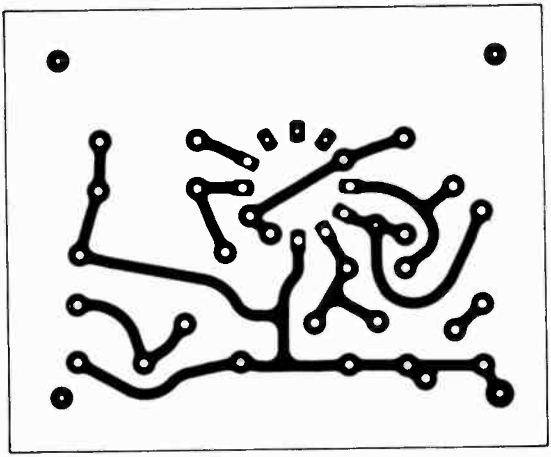
IC Audio Oscillator



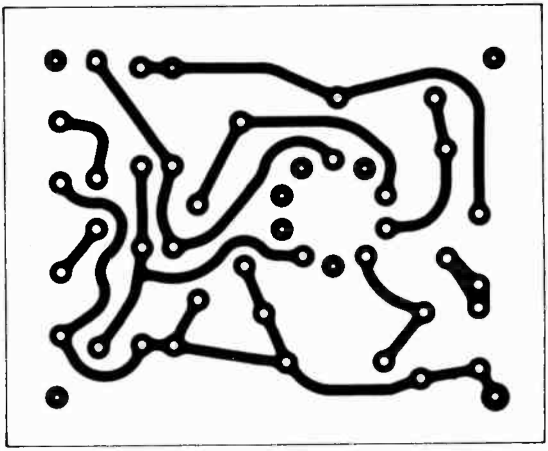
All-Purpose Microphone Preamplifier



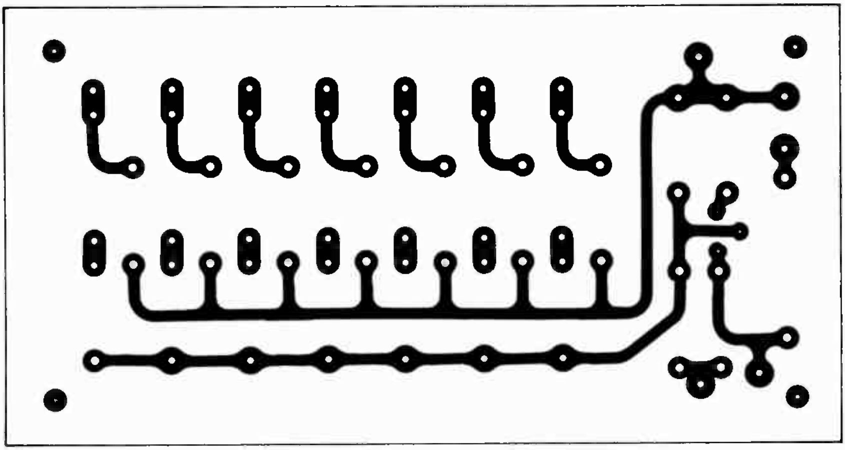
High-Dynamic-Range Microphone Preamplifier



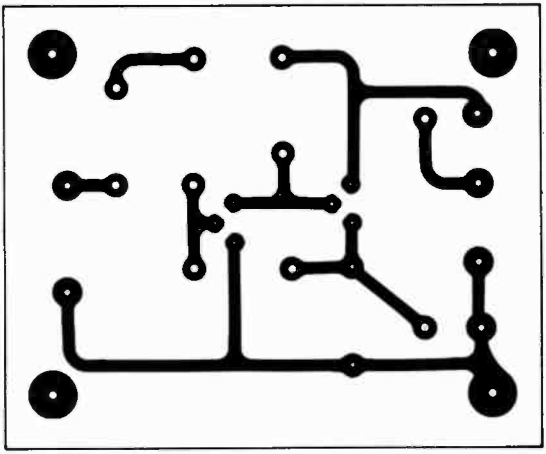
IC Microphone Preamplifier



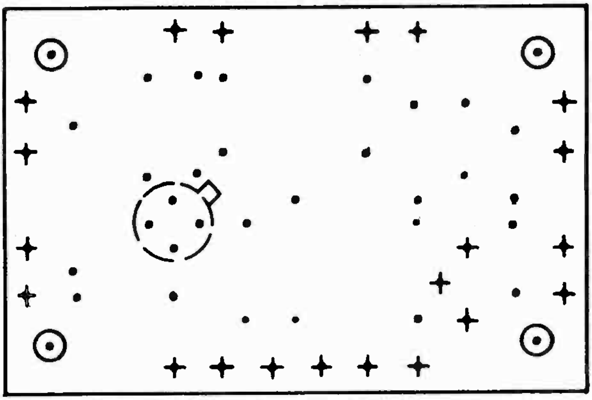
IC Two-Channel Mixer



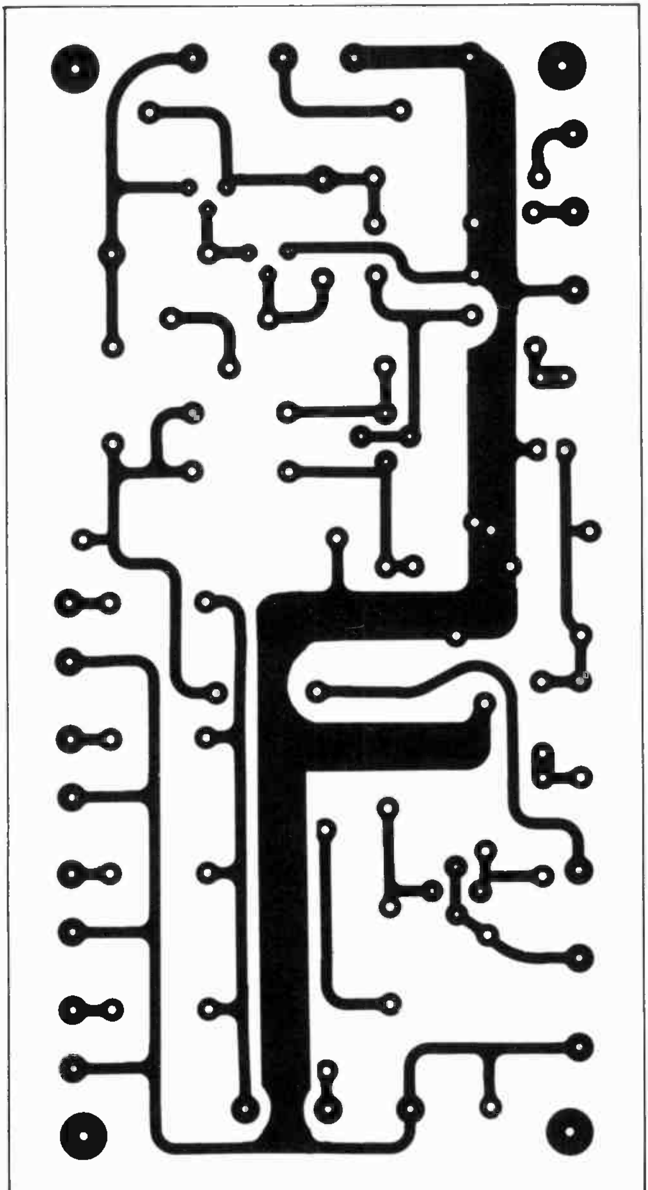
Multi-Input Mixer



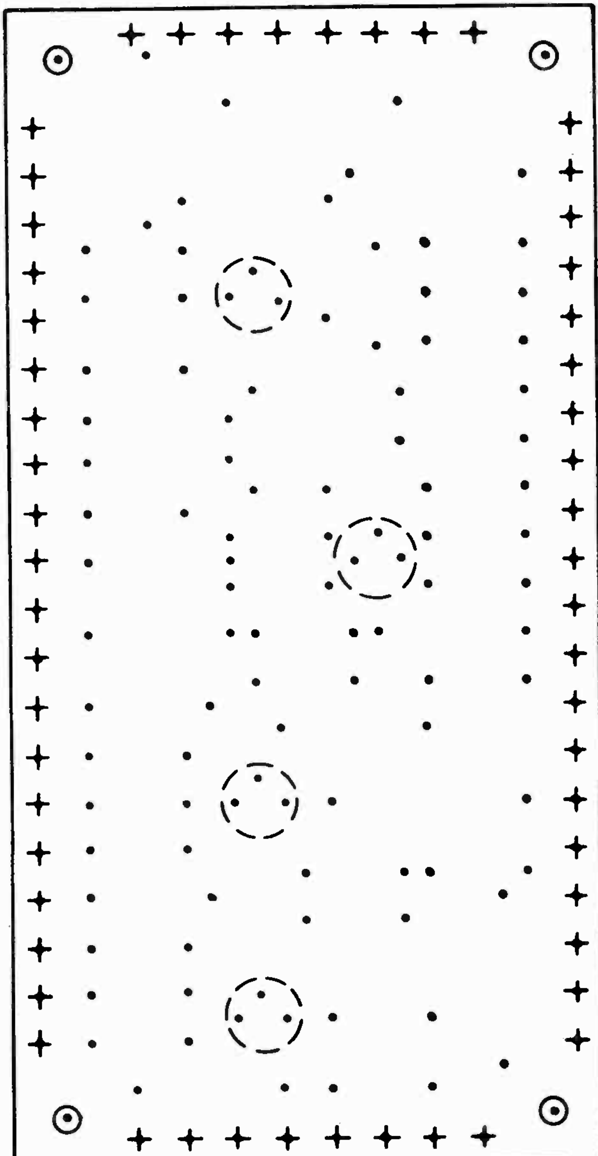
Headphone or Line Amplifier



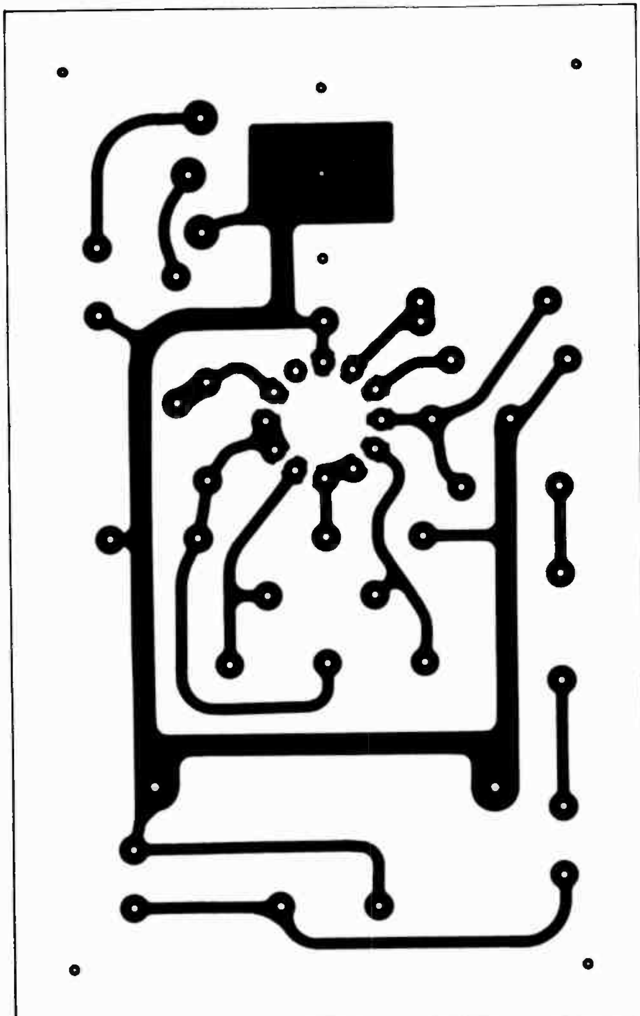
Frequency-Selective AF Amplifier



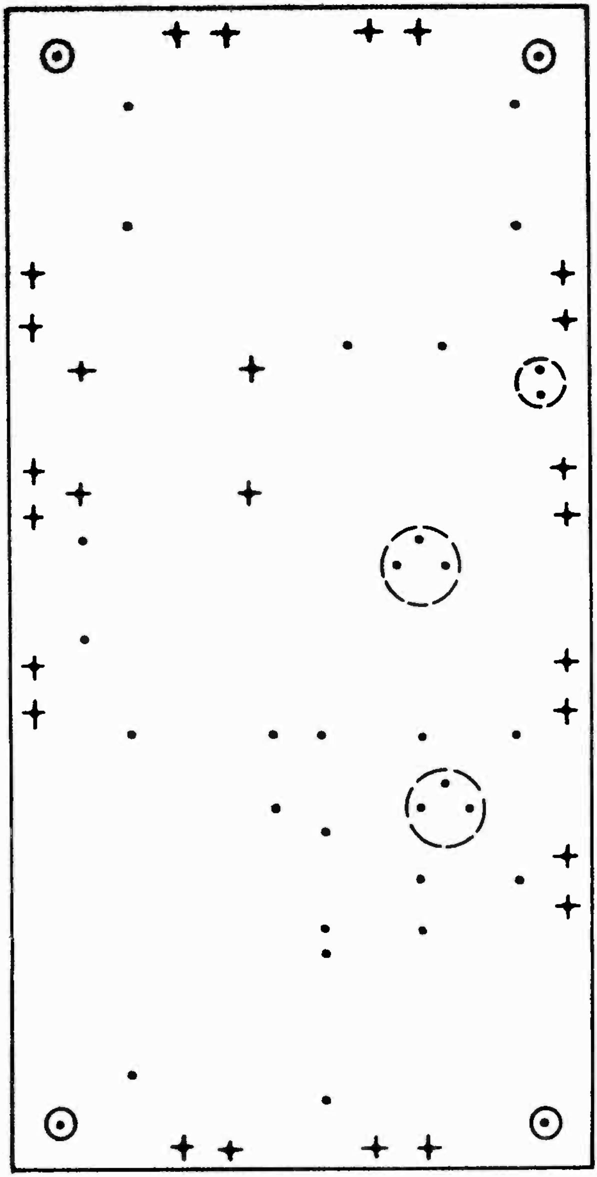
Mixer, Compressor, and Line Amplifier



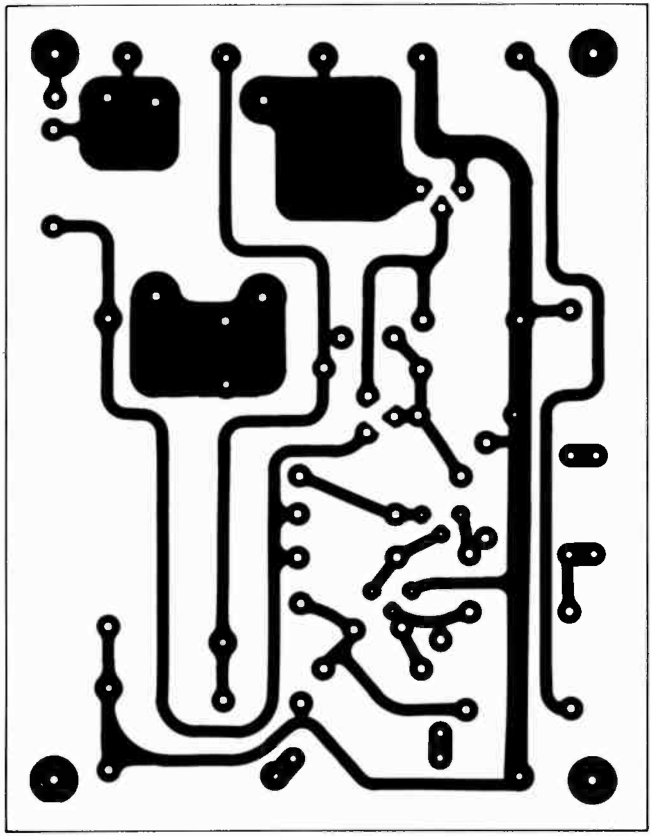
Phonograph Preamplifier



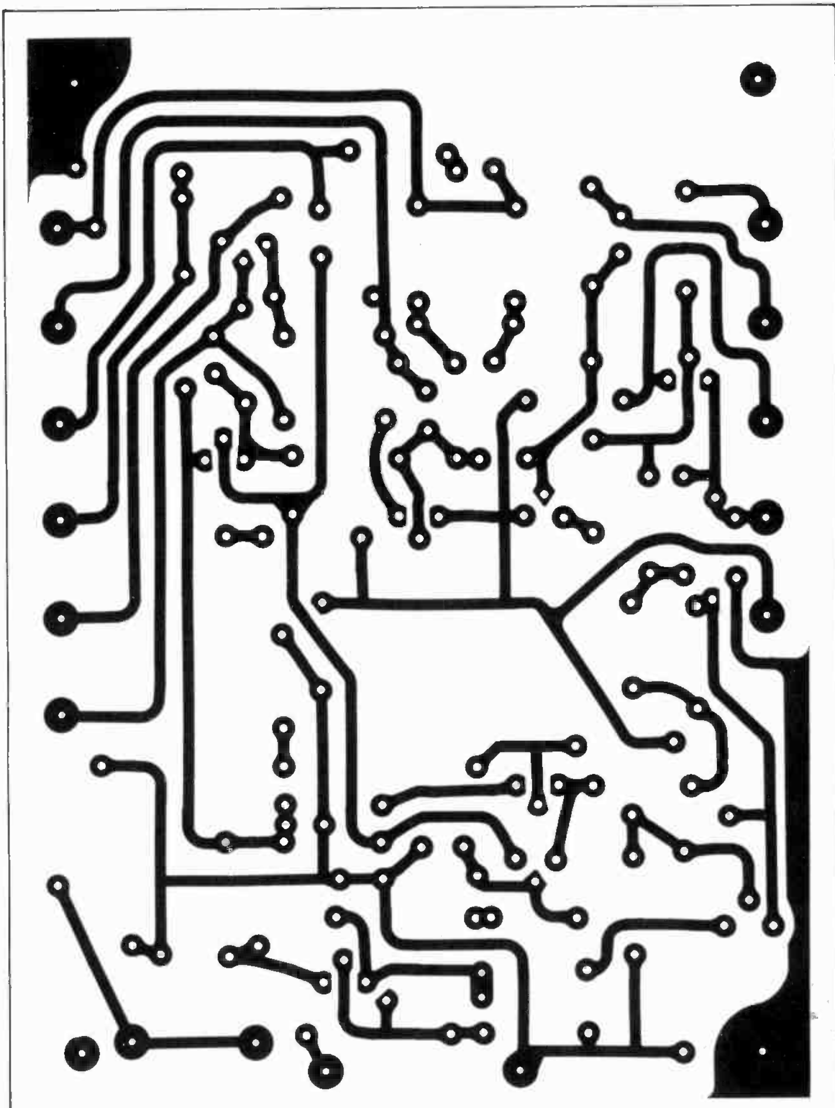
IC Audio Amplifier-Oscillator



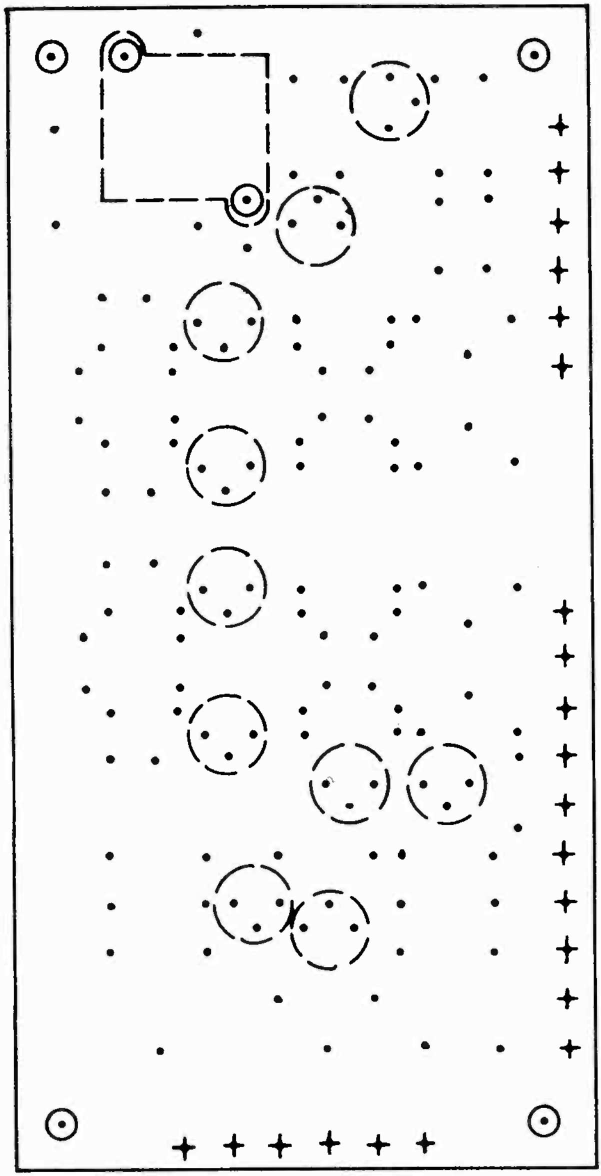
7.5-Watt Audio Amplifier



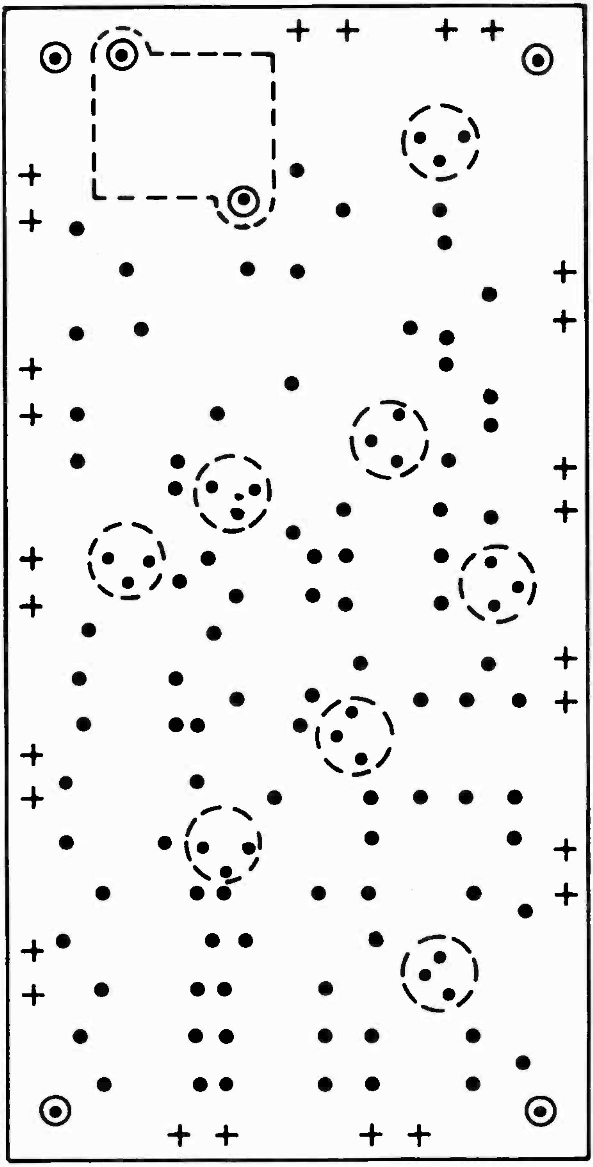
15-Watt Stereo Amplifier



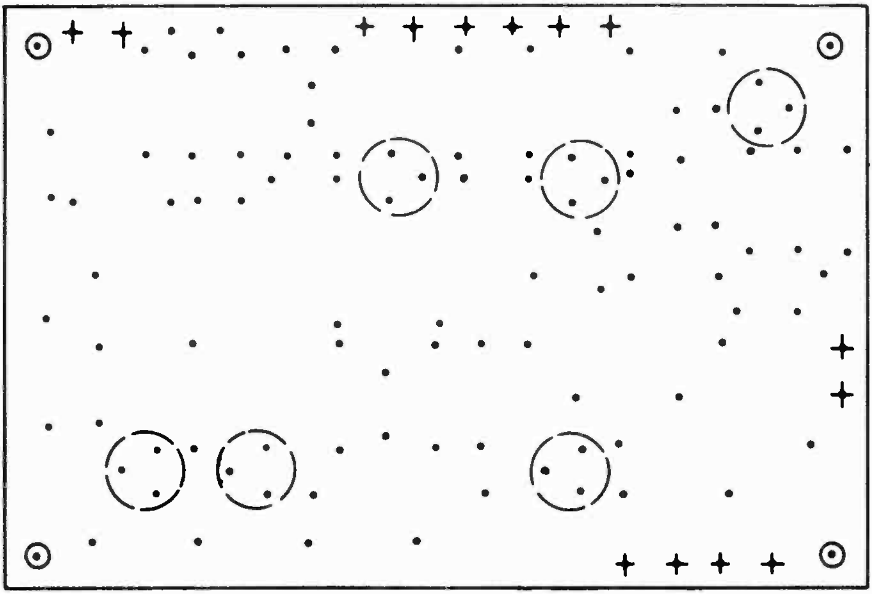
30-Watt Audio Amplifier



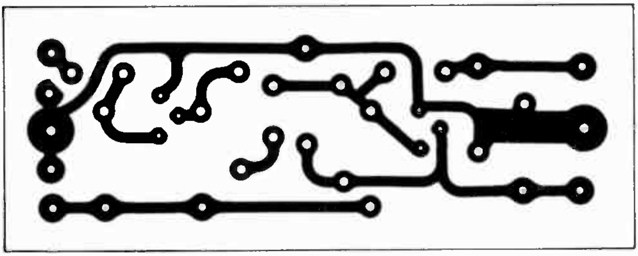
Automatic Keyer



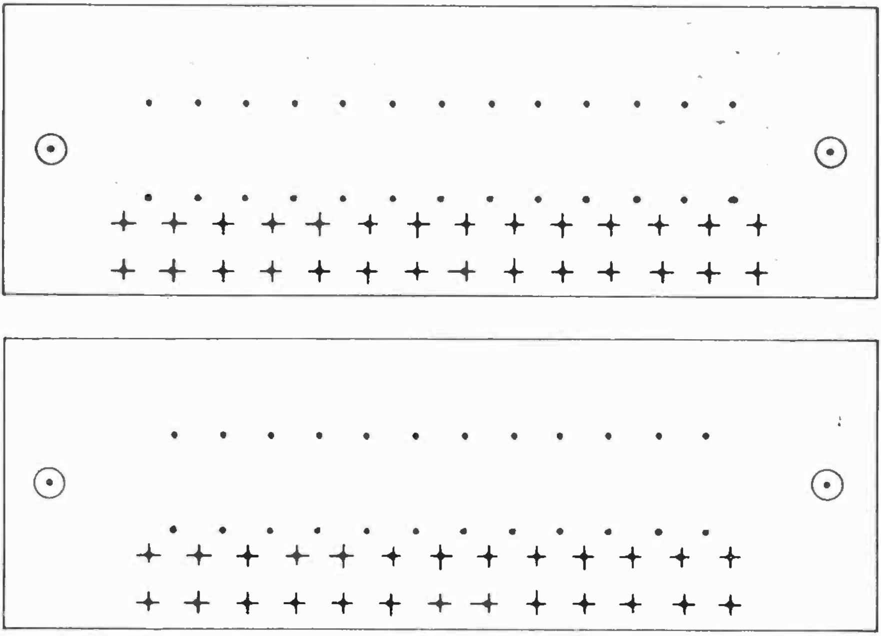
Audio Tape Keyer



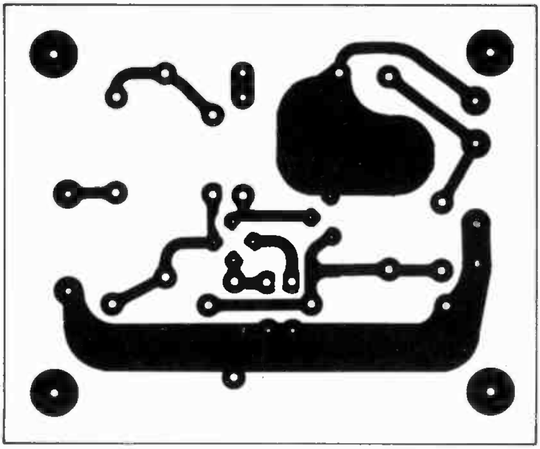
VFO Calibrator



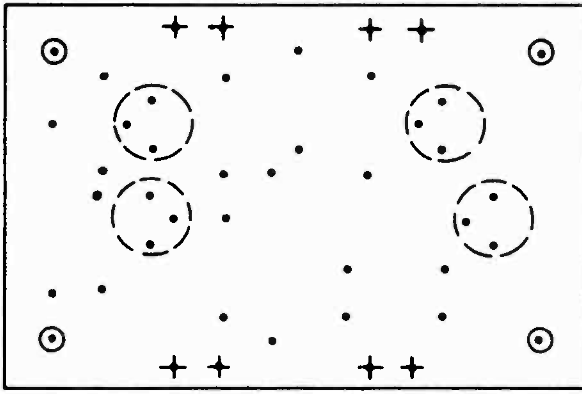
100-KHz Crystal Oscillator



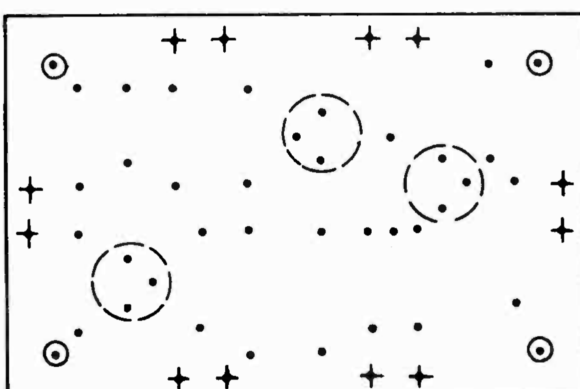
Organ Resistor Board



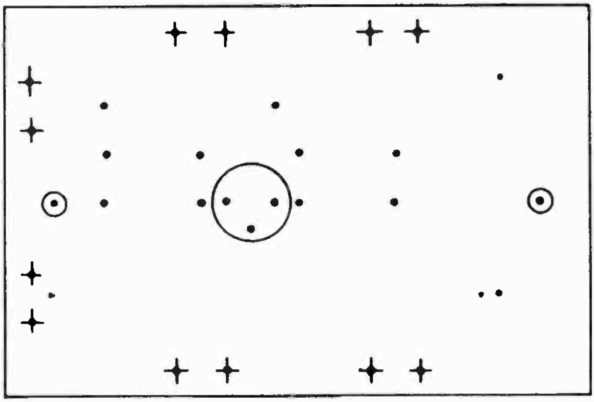
Video Line Amplifier



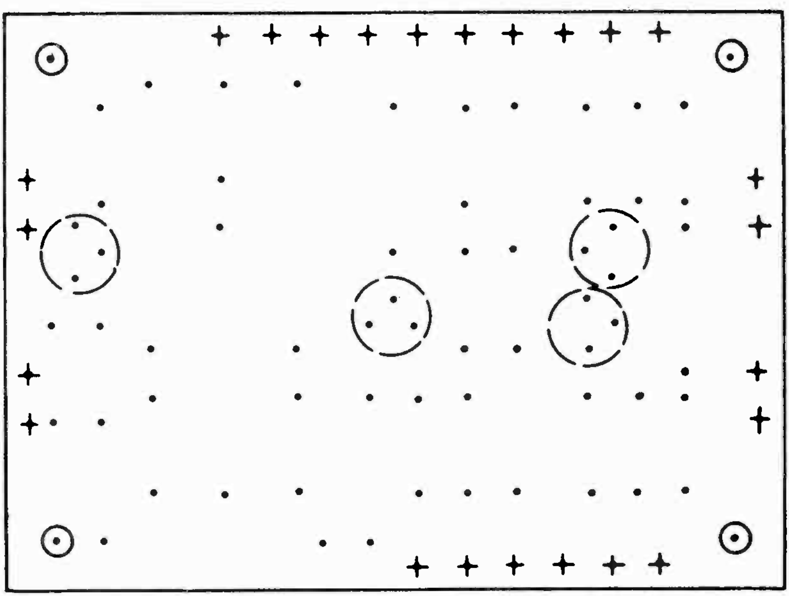
Metronome



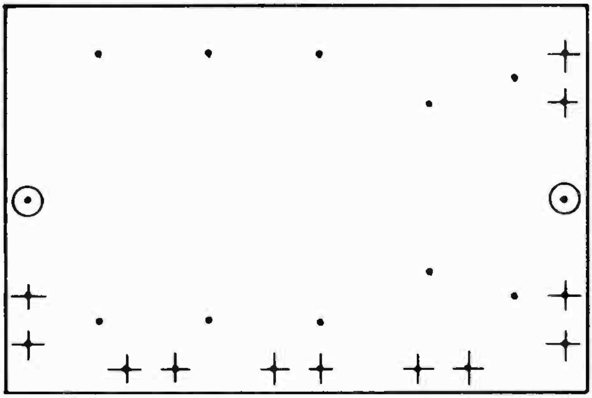
Fuzz Box



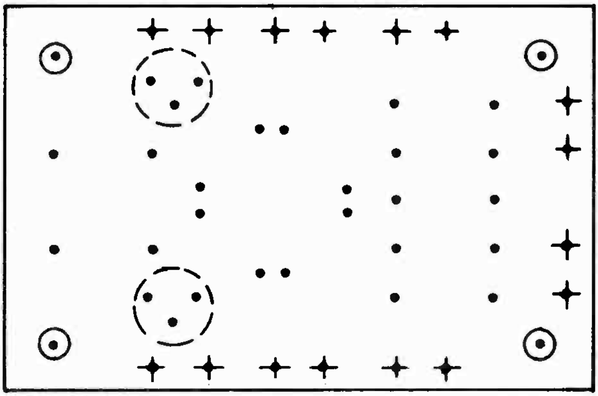
Organ Amplifier



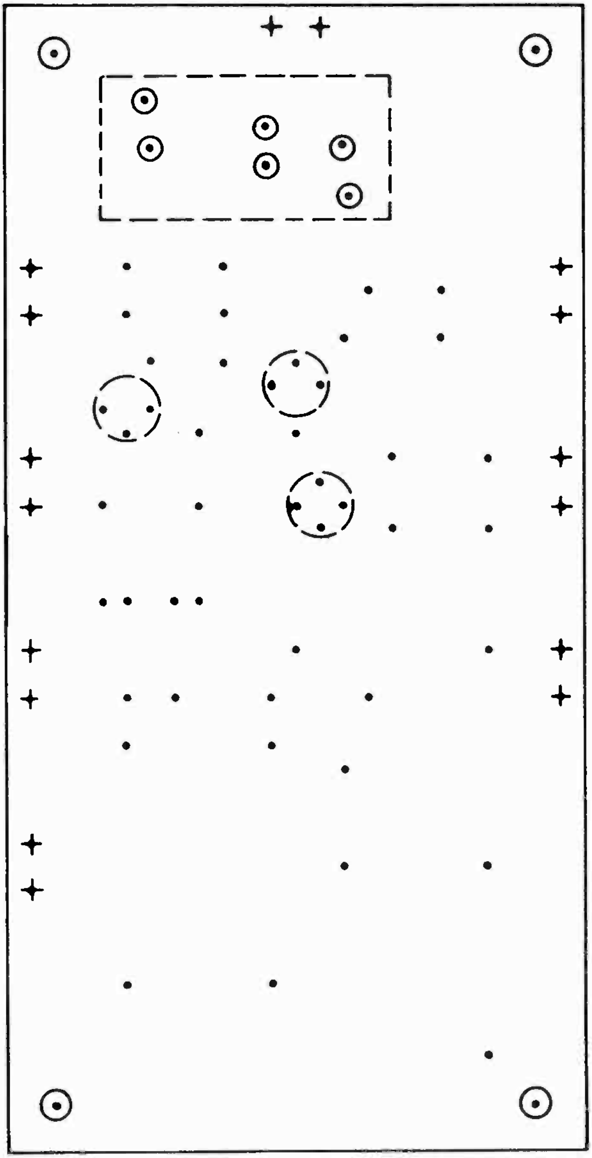
Organ Tremolo and Tone Oscillator



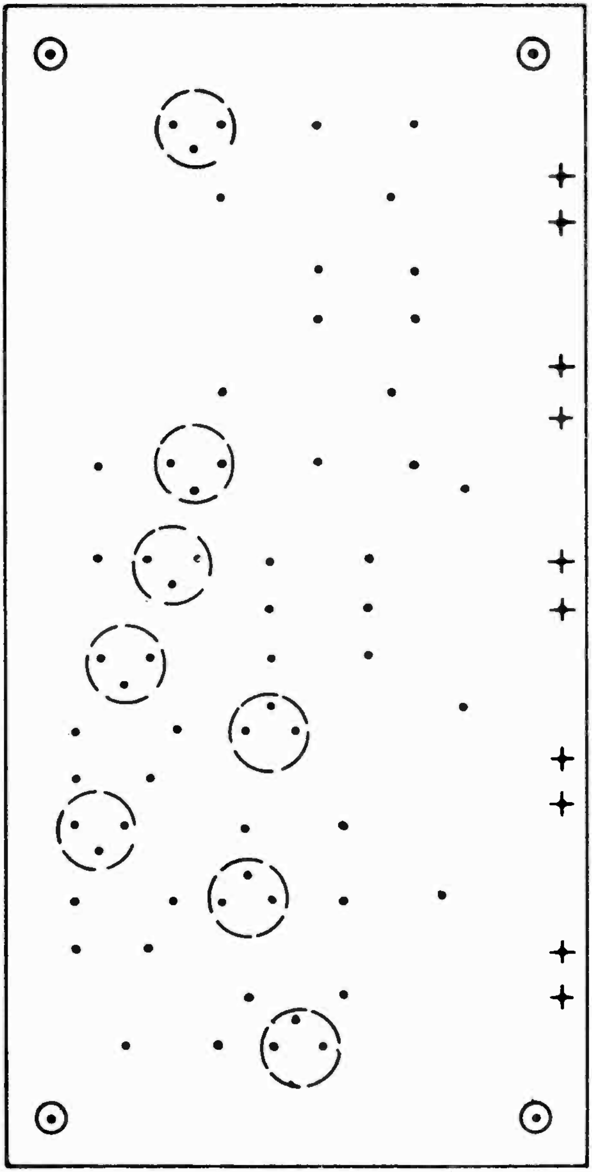
Organ Capacitor Board



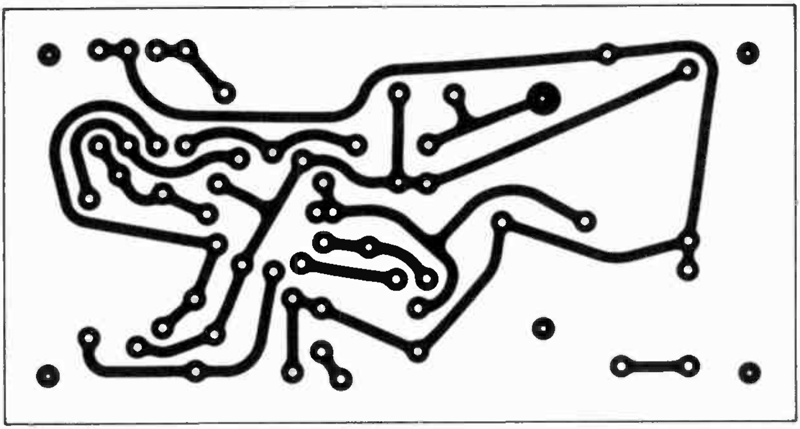
Enlarger Exposure Meter



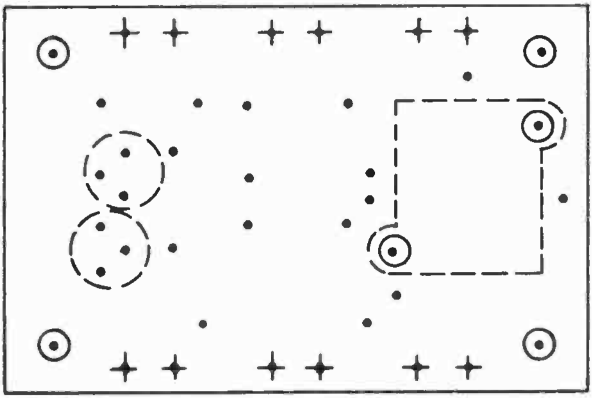
Universal Timer



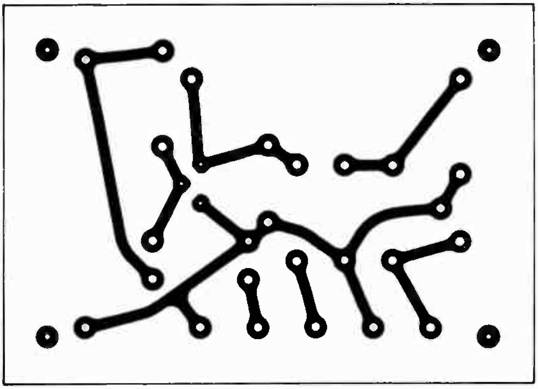
Temperature Alarm



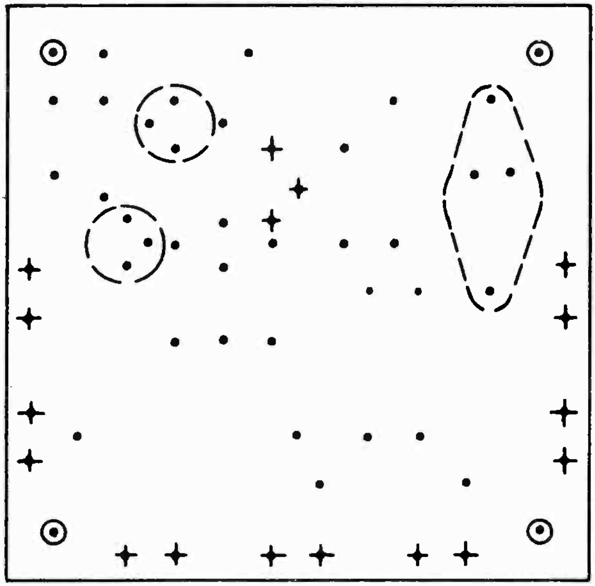
IC Alarm



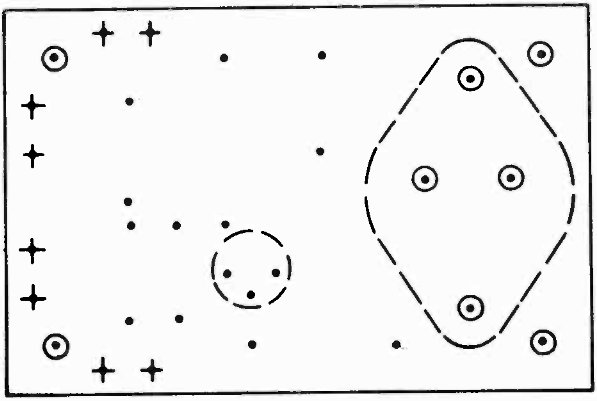
Positive-Action-Light Operated Switch



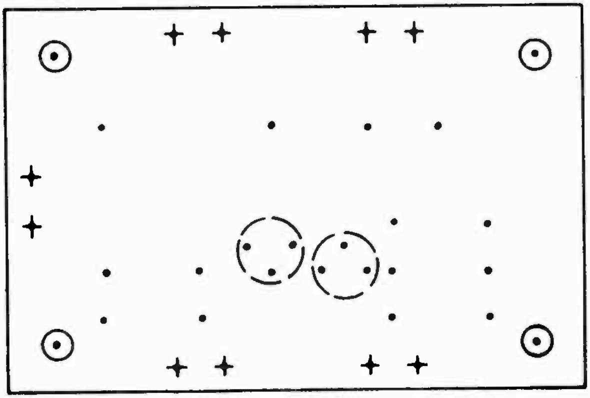
Automobile Tachometer



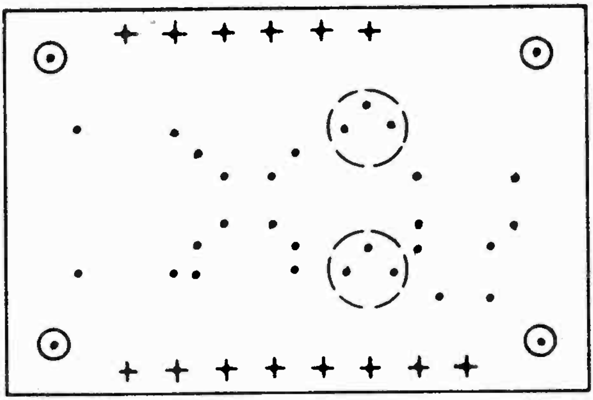
6-volt Battery Charger



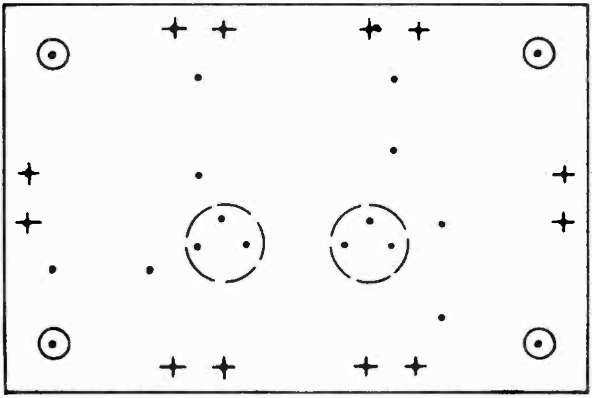
Siren



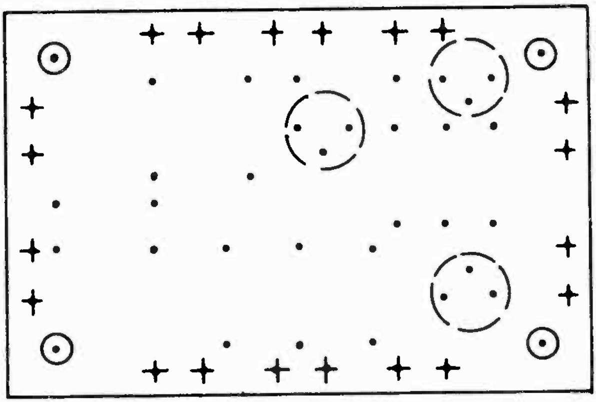
Slot Machine Running and Stop Oscillator



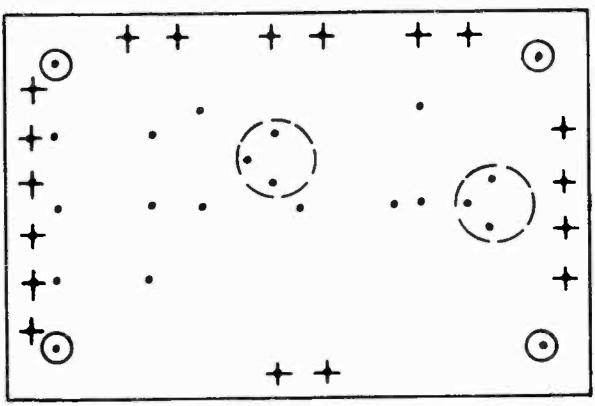
Slot Machine Flip-Flop



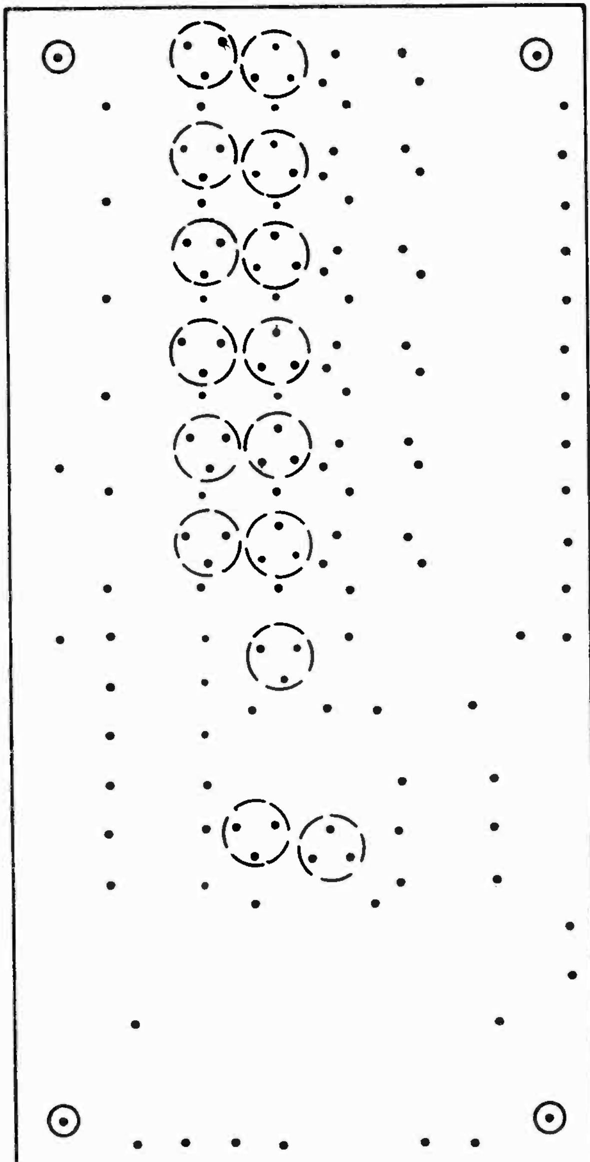
Slot Machine NAND Gates (Gates A, B, C)



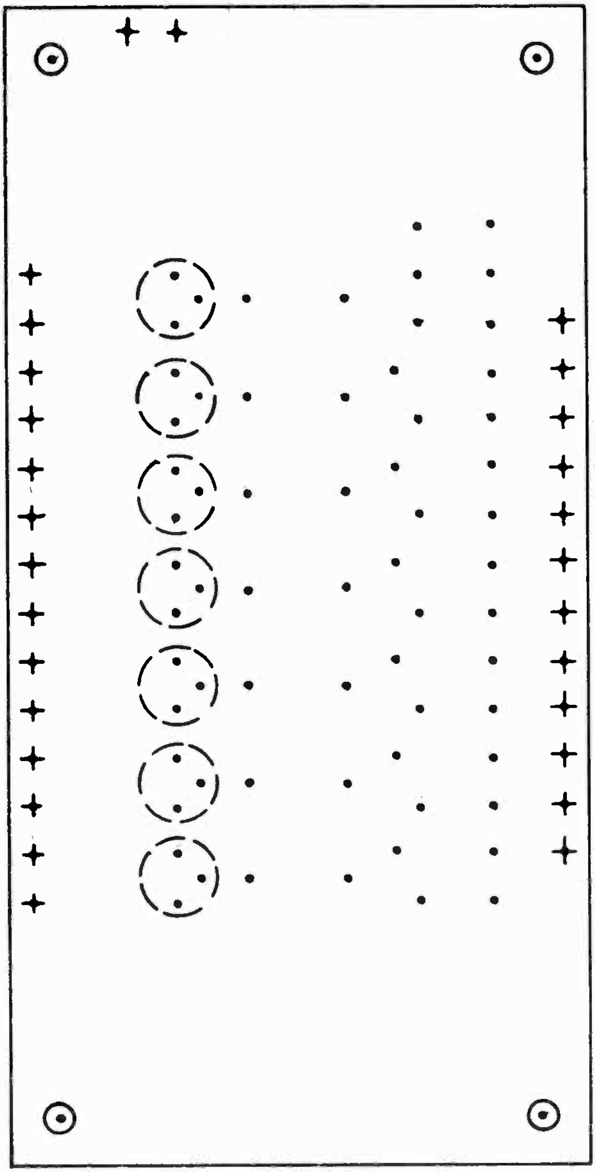
Slot Machine NOR Gate (2 Score)



Slot Machine NOR Gate (Scores 10 through 100)



Dice Digital Pulser and Six-Stage Shift Register



Dice Indicator-Lamp Gate and Driver

Index of Component Manufacturers

The following is a list of the manufacturers of special components and materials referred to in the parts list.

Amphenol Connector Division
Amphenol-Borg Electronics Corp.
1830 South 54th Street
Chicago, Ill.

Anderson Electronics, Inc.
P. O. Box 1589
Hollidaysburg, Pa.

E. F. Johnson Co.
1923 Tenth Avenue SW
Waseca, Minn.

Hammarlund Manufacturing Co.
Hammarlund Drive
Mars Hill, N. C.

Herman H. Smith, Inc.
812 Snediker Avenue
Brooklyn, N. Y.

J. W. Miller Co.
5917 South Main Street
Los Angeles, California

Ohmite Manufacturing Co.
3635 Howard Street
Skokie, Ill.

P. R. Mallory and Co., Inc.
3029 E. Washington Street
Indianapolis, Ind.

Potter and Brumfield
Division of American Machine
and Foundry Co.
1200 East Broadway
Princeton, Ind.

Sprague Electric Co.
481 Marshall Street
North Adams, Mass.

Stancor (Chicago-Stancor)
3501 West Addison Street
Chicago, Ill.

Thordarson-Meissner
7th and Belmont
Mt. Carmel, Ill.

Triad
305 North Briant Street
Huntington, Ind.

United Transformer Co.
Division of TRW, Inc.
150 Varick Street
New York, N.Y.

Wakefield Engineering, Inc.
139 Foundry Street
Wakefield, Mass.

General Index

OTHER RCA TECHNICAL MANUALS

RCA Transistor, Thyristor and Diode Manual (SC-14) $2.50
RCA Power Circuits (SP-51) $2.00
RCA Linear Integrated Circuits (IC-42) $2.50
RCA Silicon Controlled Rectifier Experimenter's Manual (KM-71) . $0.95
RCA Tunnel Diode Manual (TD-30) $1.50
RCA Receiving-Tube Manual (RC-27) $2.00
RCA Phototubes and Photocells (PT-60) $1.50
RCA Transmitting Tube Manual (TT-5) $1.00
RCA Transistor Servicing Guide (1A1673) $3.50
High-Speed, High-Voltage, High-Current
Power Transistors (PM-80) $2.00

Copies of these publications may be obtained from your RCA distributor or from Commercial Engineering, RCA Electronic Components, Harrison, N.J. 07029.

List of Circuits

RCA

Solid-State Hobby Circuits Manual

RCA | Distributor Products | Harrison, NJ 07029