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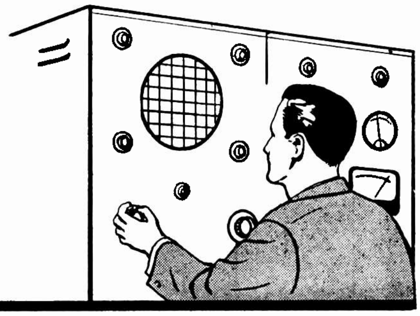

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Transistorized Relay Circuits

By the Engineering Department, Aerovox Corporation

SENSITIVE d-c relays which operate on control currents of a few microamperes usually are of the D'Arsonval (rotating-coil, meter-movement) type. Their construction is similar to that of a microammeter. They are high-priced, often delicate, and sometimes depend upon a permanent-magnetic stationary contact to pull the moving contact "home," thus making a reset operation necessary to open the contacts. Formerly, the only way to sensitize a more rugged, less expensive relay so that it could be operated on tiny currents was to precede it with a tube-type d-c amplifier. But this necessitated a power supply for plate and filament voltages, and the resulting standby-current (and power) requirement had to be taken into account. Furthermore, the reliability of such a combination is poor because of tube and power failures. Battery power could not be employed economically.

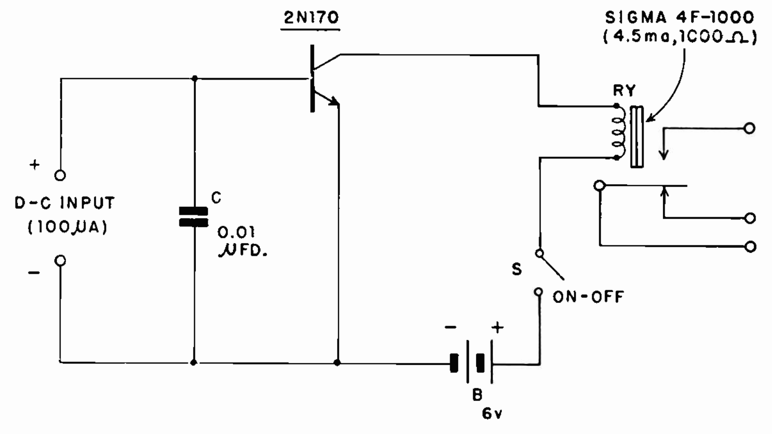
The transistor has removed many of the problems of relay sensitizing. Since the transistor basically is a current amplifier, it is readily applied to d-c relay circuits. Its standby power requirements are negligible and it can be operated economically from a single, small, inexpensive battery. Its life is unlimited, its circuitry simple, it is ready for fast operation (requiring no warmup whatever), and the amplifiers in which it is used may be made small and compact.

This article describes a number of circuits for transistorized relays which have been tested by the Editors. Complete operating data are given so that the reader can set up any one of the circuits at will. These arrangements do not exhaust the possibilities but are typical of certain classes of applications. In addition to being useful, as shown, they will suggest other modes of use.

D-C Relay Circuits

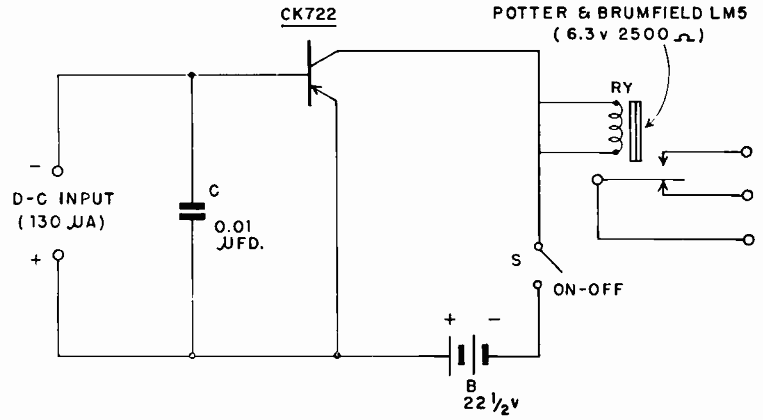
Figures 1 to 6 illustrate basic amplifier-type d-c relay circuits. In each of these arrangements, direct current amplification is provided by a transistorized circuit ahead of the mechanical relay. (Figure 6 dispenses with the relay). The variety of circuits given will enable the designer or technician to select the one best suited to an individual application. The common-emitter configuration is employed in each instance, for maximum current gain. The specified operation current and input resistance will vary somewhat with individual transistors.

Figure 1 shows a simple, single-transistor circuit employing an inexpensive NPN transistor (2N170). An input current of 100 microamperes will close the relay. The latter is a 1000-ohm, 4.5-milliampere unit. (Sigma 4F-1000). The input resistance of the amplifier is ap-



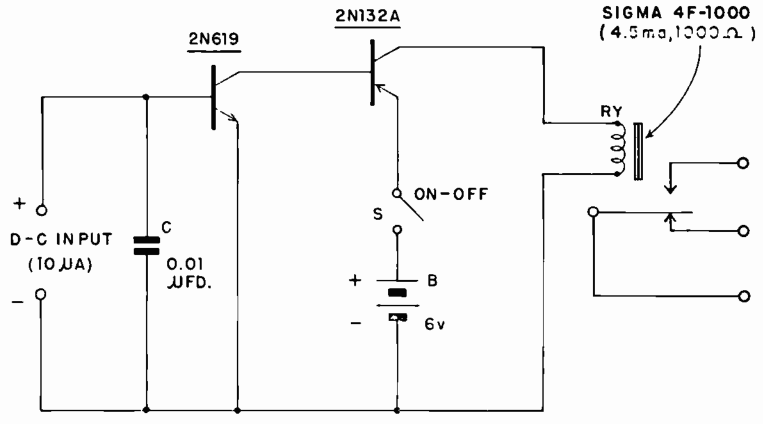
D-C CIRCUIT WITH MILLIAMPERE RELAY

FIGURE 1



D-C CIRCUIT WITH "PLATE CIRCUIT" RELAY

FIGURE 2



ULTRA-SENSITIVE D-C CIRCUIT

FIGURE 3

proximately 5000 ohms. Bypass capacitor C serves to remove any a-c or r-f component which may be present in the input current. Standby current from the 6-volt battery, B, when Switch S is closed but no input current is applied to the circuit is 60 microamperes. If a CK574 transistor is substituted for the 2N170, an input current of only 20 microamperes will close the relay. However, the CK754 is a PNP unit, and its use will require reversing the polarity of Battery B and the two d-c input terminals.

Figure 2 shows a similar circuit for operation of a somewhat heavier, tube-plate-type relay. Here, RY is a 6.3-ma, 2500-ohm unit (Potter & Brumfield LM5). Some designers will have such relays on hand from previous vacuum-tube systems. An inexpensive PNP transistor (CK722) is employed. The relay will close with an amplifier input current of 130 microamperes. The input resistance of the amplifier is approximately 4000 ohms. Standby current from the 22½-volt battery, B, when Switch S is closed but no input current is applied to the circuit is 72 microamperes.

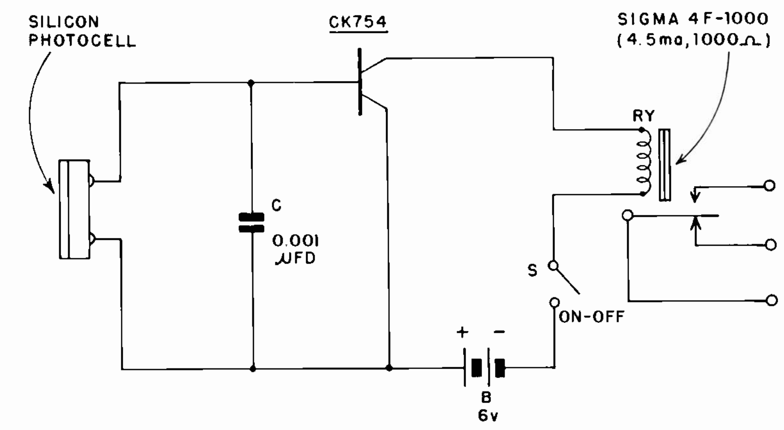
The ultrasensitive circuit in Figure 3 is recommended for operation at very low current levels. Here, a 2-stage direct-coupled amplifier supplies the high gain needed to close the 4.5-ma, 1000-ohm relay, RY (Sigma 4F-1000), from an input current of only 10 microamperes. Standby current from the 6-volt battery, B, is of the order of 100 micro-amperes. The NPN input transistor (2N619) receives its positive collector voltage from Battery B through the internal base-emitter path of the PNP output transistor (2N132A). The collector output current of the 2N169 therefore flows through the base-emitter path of the 2N132A, this arrangement requiring no coupling resistors.

It is clear that the zero-signal static collector current of the 2N619 likewise flows through the input path of the 2N132A and, being amplified by the second transistor, will raise the static current flowing rectifying ac for operation of a d-c meter.

Figure 7 shows several circuits for accomplishing this conversion. In Figure 7 (A), a general-purpose germanium diode, D, is connected in series with the input transistor, V, of the relay amplifier circuit. The diode is poled here to supply a negative output to the base of the PNP transistor. If the input transistor is an NPN type, the diode must be reversed to supply a positive output to the base.

The simple circuit just described is satisfactory only when there is no d-c component in the ac or rf signal. Such direct current reaching the input transistor would cause a spurious signal in the amplifier output circuit and might erroneously close the relay. The circuit shown in Figure 7 (B) provide d-c isolation by means of the blocking capacitor, C. In this instance, however, an additional diode, D_2, is required for the reverse half-cycle of the signal component. The two diodes, D_1 and D_2, are shown as a unit within dotted lines and designated RECT, for the reason that 2-unit meter rectifiers are obtainable in this configuration and are useful efficiently up to about 5 kc. For higher-frequency operation, a pair of general-purpose germanium diodes should be connected as shown in Figure 7(B). The diodes are poled in this illustration so that the d-c output is positive to the base of the NPN input transistor, V, of the relay amplifier. In, instead, a PNP transistor is employed, **both** diodes must be reversed to supply a negative output to the base.

Figure 7 (C) shows an r-f circuit for tuning-in a desired r-f signal which is to actuate the relay. The inductance of Coil L and the capacitance of Tuning Capacitor C are chosen for resonance at the frequency of desired signal. For impedance matching, the tap to which Diode D is connected is placed between ¼ and ⅓ of the way up from the ground end of the coil. The diode is poled to deliver a negative d-c output to the base of the PNP input transistor, V. If, instead, an NPN transistor is employed, the diode must be reversed to supply a positive output to the base.



SENSITIVE, LIGHT-OPERATED RELAY

FIGURE 8

Another rectifier, not shown here, is the bridge-type. The full bridge employs four rectifiers or diodes and is familiar to most readers. While the bridge delivers more d-c output current than single-element rectifiers, and somewhat more than the 2-element unit shown in Figure 7 (B), its disadvantage is that its input and output circuits cannot be grounded simultaneously. This often introduces many operating difficulties in amplifier-relay circuits such as those shown in Figures 1, 2, and 3.

While a bypass capacitor should be connected across the d-c output terminals of each rectifier circuit, it is not shown in Figure 7, since such a capacitor already is present in each of the circuits to which one of these rectifiers might be connected. (See Capacitor C in Figures 1, 2, and 3).

Light-Operated Relay

In Figure 8, the d-c input signal for the transistorized amplifier is obtained from an illuminated, self-generating photocell. A silicon photocell (such as International Rectifier Corporation Type Sa5-M or Hoffman S-1A) is employed for high output. Similarly, a high-gain transistor (CK754) is used. (This transistor has a maximum short-circuit current gain, **beta**, of 300). This combination results in high sensitivity, light from a regulation-size flashlight at a distance of more than 30 feet being sufficient to close the 4.5-ma, 1000-ohm relay, RY (Sigma 4F-1000) in the collector circuit of the single transistor.

Standby current from the 6-volt battery, B, is approximately 200 microamperes when the photocell is darkened.

Further Possibilities

The practical circuits given in this article show some of the ways of using transistor circuits in relay applications. New semiconductor devices and circuits will increase the scope of application. For example, heavy currents can be handled by the new **solid-state thyratron,** a transistor-like power-switching device which might be employed in a circuit of the general type shown in Figure 6.

Another possibility is the use of flip-flop circuits, which have the ability to remain in a conducting state once they are switched-on by a signal pulse and thus simulate electronically the latching relay. Still other possibilities are circuits simulating multipole, multiposition relays but in which the mechanical relay is dispensed with entirely.

current. Assuming that the relay contacts will switch the full, maximum rated current of 15 amperes, this relay circuit will provide an over-all current gain of approximately 7500. In order to handle safely the power involved, the 2N255 power transistor must be provided with a suitable heat sink.

In the 2-stage circuit shown in Figure 6, the mechanical relay has been omitted entirely, the output power transistor (2N255) switching current in the load directly through its collector circuit. This arrangement will be suitable for use with load devices (such as heaters, solenoids, lamps, signal alarms, etc.) of resistance not exceeding 1 ohm. At higher load resistances, the output current change decreases.

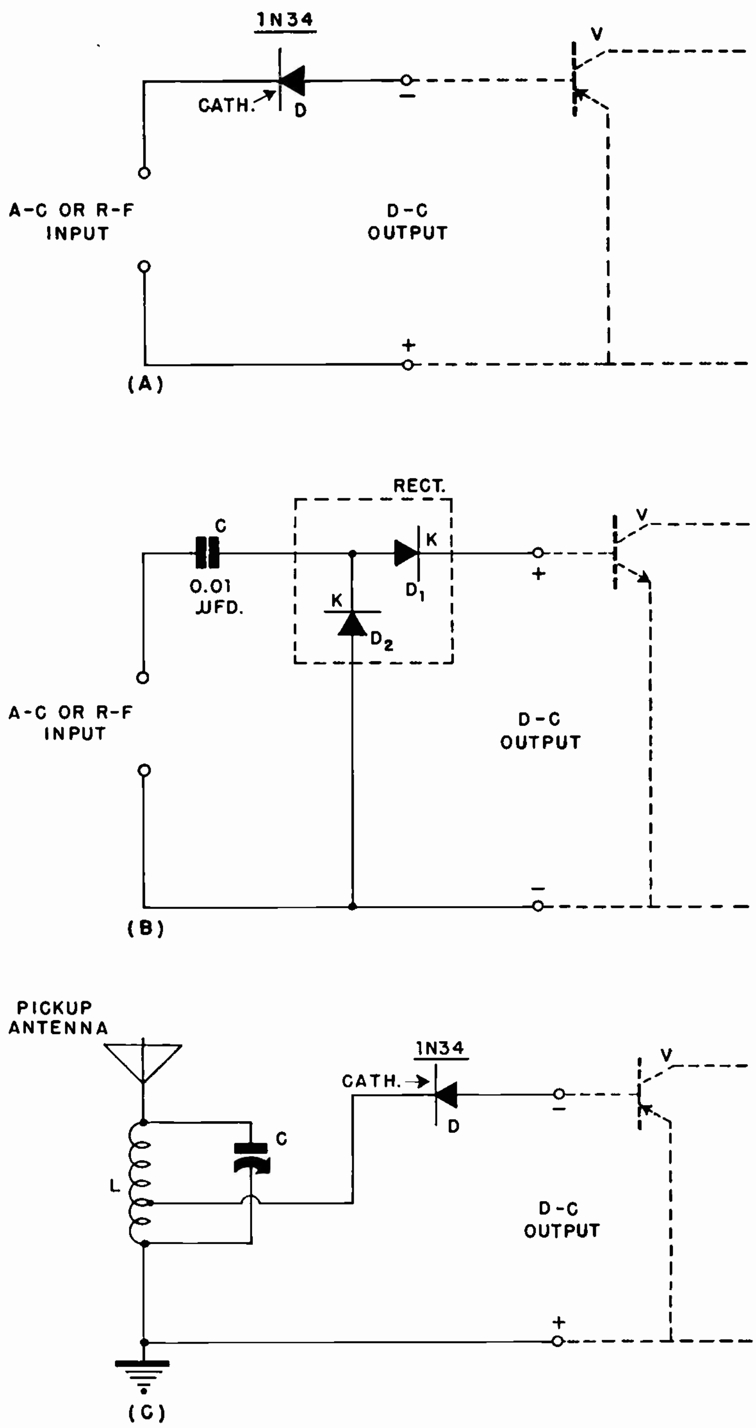
An input current of only 2 milliamperes to the 2N170 transistor will produce a current flow of 1 ampere, through the load. Standby current from the 6-volt battery, B, is approximately 3 milliamperes. In order to handle safely the power involved, the 2N255 transistor must be provided with a suitable heat sink.

As in the circuits given in Figures 3 and 5, a direct-coupled arrangement is employed here, with the collector current change of the input transistor flowing through the internal base-emitter path of the output transistor directly. However, a silicon input transistor is not required (as was the case in Figure 3) since the amplification of the 2N170 leakage current by the 2N255 does not result in enough current to be significant in the external load, in most instances.

Where heavier load currents are to be switched, a larger transistor than the 2N255 may be used. Contemporary high-power transistors handle collector currents up to 15 amperes or more.

A-C and R-F Circuits

The amplifier-relay circuits shown in Figures 1, 2, and 3 may be adapted to a-c and r-f use by connecting suitable rectifiers ahead of them. This is comparable to the process of



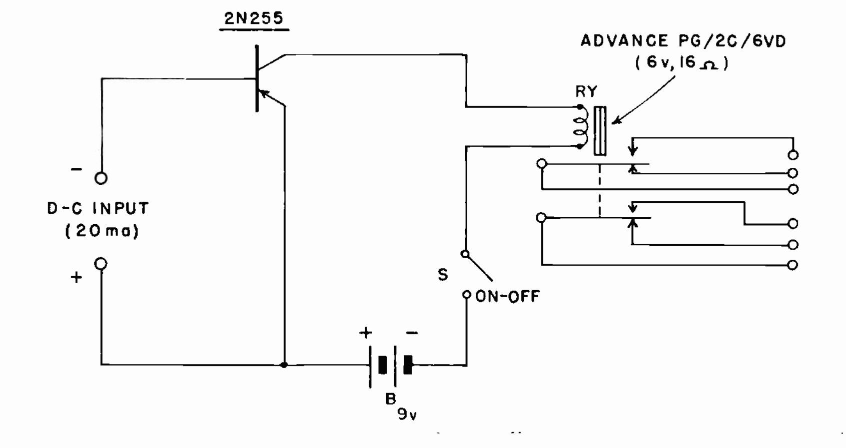
A-C AND R-F INPUT CIRCUITS

FIGURE 7

through the relay. For this reason, a silicon transistor is specified for the input stage because of the extremely low leakage current of such a transistor and the good high-temperature characteristics of this unit. This is done with full realization that silicon transistors presently are high-priced (the 2N619 costing about five times the price of the 2N132A), however there is no alternative if the simplicity and compactness of this high-gain, direct-coupled amplifier are to be obtained.

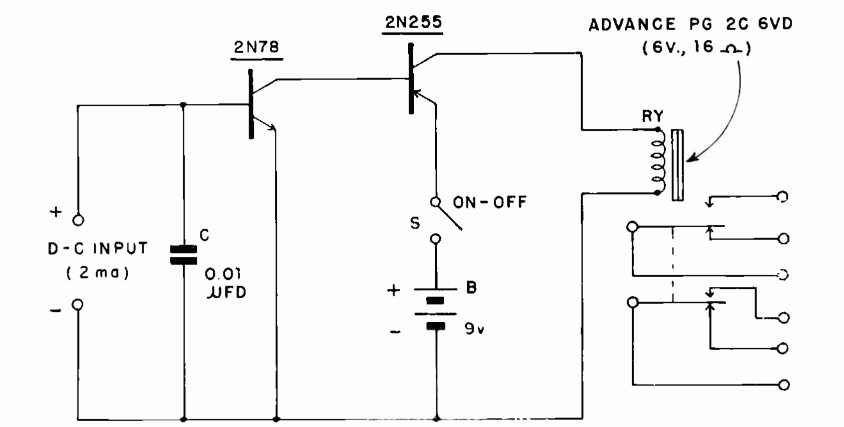
Figure 4 shows the circuit of a power-transistor amplifier for operating a heavy relay, RY (Advance PG/2C/6VD). The latter is a 6-volt, 16-ohm unit requiring approximately 0.4 ampere for closure. The relay contacts will handle 15 amperes at 115 volts. An input current of only 20 milliamperes dc will actuate the relay. Standby current from the 9-volt battery, B, is approximately 1.5 milliamperes. The input resistance of the amplifier is approximately 1 ohm. The power transistor (2N255) must be operated with a suitable heat sink, for safe dissipation of the power of approximately 2½ watts. Assuming that the relay contacts will switch the full, maximum rated current of 15 amperes, this relay circuit will provide an over-all current gain of approximately 750.

When the current sensitivity (20 ma) of the high-power circuit must be increased, a low-level amplifier stage may be added, as shown in Figure 5. Unlike the arrangement given in Figure 3, however, a silicon transistor is not needed in the input stage, since normal leakage current drift in the 2N78 germanium input transistor will not result in sufficient increase in the relay standby current to be detrimental. An input current of only 2 ma to the input transistor (2N78) will result in relay closure. The relay is an Advance PG/2C/6VD unit requiring approximately 0.4 ampere of closing current. Standby current from the 9-volt battery, B, is 3 milliamperes in the absence of an input signal. Capacitor C serves to remove any a-c or r-f component which may be present in the input



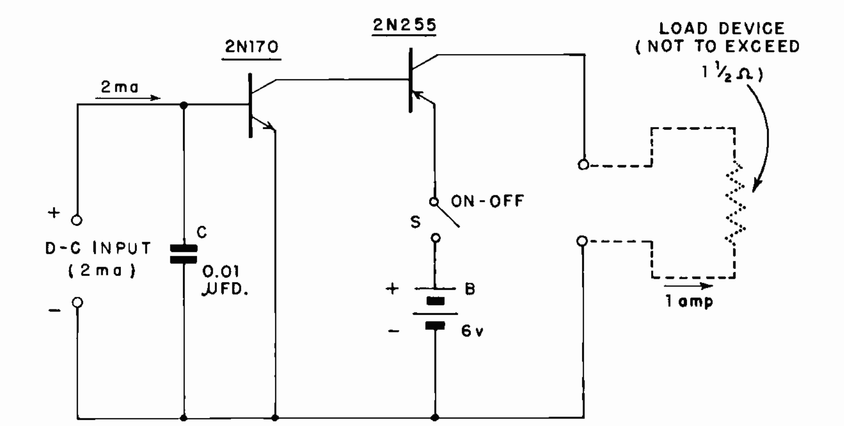
D-C POWER TRANSISTOR CIRCUIT

FIGURE 4



SENSITIVE HEAVY-DUTY D-C CIRCUIT

FIGURE 5



DIRECT USE OF POWER TRANSISTOR AS D-C RELAY

FIGURE 6

- *superior construction*
- *premium performance*
- *conventional prices*

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