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This book is a practical guide to the fascinating new world of Transistors, prepared especially for the interest and enjoyment of engineers, technicians and hobbyists who have been eager to experiment with Transistor circuits. It fills the need for a source of circuits that will help the builder to study the many facets of Transistors — their properties, performance and adaptability.

Emphasis has been placed on practical applications. Basic Transistor theory is discussed in many of the articles, such as the article, “Build This Transistor Receiver” on page 3. It contains a wide variety of circuit diagrams plus detailed procedures and parts lists to assist the builder in every step.

Raytheon Transistors and other components needed for these projects are available through Raytheon tube suppliers who can lend valuable assistance in many ways.

A great deal of information contained in this Raytheon Transistor Book has been made available through the courtesy of two leading publications in the electronics field — RADIO-ELECTRONICS and RADIO AND TELEVISION NEWS. We wish to express our sincere appreciation to them for their cooperation.

Credit is accorded RADIO-ELECTRONICS for the articles originating on pages 7, 9, 11, 22, 25, 29, 31, 35, 37, 43, 52, 56, 61, 65, 71, 75, 77, 91, 95, 97, 99, 100 and the articles “Transistor Dick Maker” on page 85, “Transistor Oscillator Powered by Light” on page 96 and “Noise Generator” on page 100.

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Relevant Data on Raytheon Semiconductor Diodes
inside back cover
BUILD THIS
TRANSISTOR
RECEIVER

ROBERT K. DIXON
Radiotron Tube Division
Raytheon Manufacturing Company

A BOUT four years ago, the transistor was first announced. Since that time, a considerable amount of effort has gone into the design and production of transistors and much has been written about them.

Transistors are semiconductor devices capable of acting as amplifiers, oscillators, and performing other functions now performed by vacuum tubes and with greater efficiency. The basic material in most transistors today is germanium and the devices are made in two different types—the point contact, which was the original, and the junction.

A semiconductor is any material which is neither a good conductor nor a good insulator, thus its name. Germanium has a simple atomic structure with the inter-atomic spacing in the crystals forming relatively straight corridors or paths. The basic unit of the crystal has eight atoms per cell, four of which form the corners of a small cube while the other four are wholly within the cube. There are relatively large spaces between the atoms. In this pure form, germanium is basically a stable material and does not exhibit a surplus or deficiency of electrons.

By the introduction of certain selected elements, the germanium can be made to exhibit an excess of electrons and thus become a negative or “n” type material, or by the introduction of other impurities or chemical elements there may be a deficiency of electrons and the material will be considered a positive or “p” type material.

If electrical pressure is applied to a piece of “n” type germanium material, current flow will exist by virtue of the free electrons existing therein. Similarly, if electrical force is applied to the positive type material, conduction appears by virtue of the phenomenon called hole conduction. The application of electrical potential causes electrons to move from the negative and toward the positive end, the presence of holes facilitating the electron flow.

The point-contact transistor consists of a block or crystal of material such as germanium with two properly spaced pointed electrodes making contact with the surfaces of the germanium. In many respects, it resembles the well-known crystal diode with the exception of the additional electrode. During manufacturing, the position of the two point contact electrodes (including the relative spacing of these elements) is adjusted for proper operation of the transistor as an amplifier device.

The basic block of germanium is normally “n” type in the point-contact device. Small areas of the germanium adjacent to the pointed electrodes are converted to “p” type material during production. (See Fig. 1A.)

Junction transistors consist of a block of material in which “n” and “p” type materials are arranged in alternate layers. The end sections can be either “n” or “p” material with the center zone being the opposite type. (See Fig. 1B.)

The point-contact transistor finds wide application in switching circuits and oscillator circuits at frequencies normally not possible with the junction type units. The point-contact transistor has inherently higher noise output than the junction units.

The junction transistor, on the other hand, is a more efficient amplifier while operating at low voltages. They are extremely rugged and have exceptionally long life. The normal noise voltage generated in a junction type is lower than that of the point-contact type transistor. Since the electrons travel somewhat slower through the germanium material in transistors than in a vacuum and due to the high internal capacities of junction transistors as we know them today, operation is normally limited to the lower frequencies.

This article deals with a “p-n-p” junction transistor recently announced by the Raytheon Manufacturing Com-
The mechanical data for the CE722 are shown in Table 1. It is extremely rugged and when operated at normal ratings has exceptionally long life.

Basicly, the "p-n-p" junction transistor may be compared to the vacuum tube with the emitter resembling the cathode, the base resembling the grid, and the collector resembling the plate. There are several basic differences, however, which are outstanding.

In the "p-n-p" junction transistor, conduction is accomplished in a solid instead of in a vacuum. The collector is operated with a negative bias instead of the customary positive voltage applied to the plate. Another outstanding difference lies in the input impedance. The vacuum tube has almost infinite input impedance over a considerable range of frequencies. The transistor, on the other hand, is a rather low input impedance in the grounded base or grounded emitter connection which is analogous to the grounded grid and grounded cathode types of vacuum tubes.

The electrical data for the CE722 are shown in Table 1. Since the transistor is a three-terminal device, several combinations of connections may be used; namely, the grounded emitter, the grounded base, and the grounded collector.

The CE722 is a small signal, low-voltage amplifier. It is capable of handling a small signal input and producing a high output. The CE722 is used in applications where a small signal is required.

The CE722 is capable of driving a large impedance load and is used in applications where a large signal is required. The CE722 is used in applications where a large signal is required.

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be a small 2 or 3 inch dynamic speaker. Notice that it is directly connected to the transistor without use of an impedance matching transformer. With a voice coil impedance of 4 ohms and with R adjusted for a collector current of 100 microamperes, the necessary voltage would be approximately 2V to a good carbon mile with an 8-ohm battery. The noise of the circuit at Fig. 2B may be used to calculate the need of a tapped battery. With 6V the gain will be slightly less. A 20-ft shielded cable is required, a transformer should be used instead of a tap. A transistor in the collector of the transistor as in Fig. 2B. This will be a small plate-to-line transformer of 2,000 to 100 ohms impedance. Because the operating current is only battery life is good. The supply for the transistor can be obtained from the standard high voltage plate supply of amplifier and in fact the circuit has the advantage of supplying a more constant current to the transistor. The important factors in these circuits are the low input impedance of the emitter, on the order of 200 ohms with the grounded base connection, and the high output impedance of the collector, on the order of 50,000 ohms. With grounded emitter connection, the input impedance of the base is a function of operating parameters so no value can be given for it.

Several stages of transistor amplifiers can be cascaded and the use of matching transformers will assure faithful reproduction of the incoming signal. Transformers can be used with some loss in gain (approximately 6 db). Stage coupling condensers must be used to obtain good low frequency response because of the low impedance levels.

Push-pull operation of transistors is utterly feasible, permitting greater power dissipation with consequent greater output power. Class A operating efficiencies on the order of 50 percent are obtainable while class B operating efficiencies to nearly 80 per cent are possible. Matched units should be used in this application and degeneration can be applied to improve performance.

A simple amplifier type operation lends itself admirably to a simple broadcast receiver. To investigate this application more thoroughly, such a receiver has been built. For those interested in duplicating it, a description follows:

**Translator Receiver**

One or two transistors may be used in this receiver (Fig. 4). The first unit is utilized as a detector/amplifier. The second transistor is connected as a grounded emitter amplifier. The first unit is capable of delivering adequate earphone volume so that the second stage can be eliminated if it is desired to reduce the cost of the receiver. Although the experimental receiver shown has been built on metal, obviously it could be built using a wooden case without affecting performance. In the Boston area where this receiver has been operated, the two tuned circuits have given more than adequate selectivity to separate the local stations. An antenna of 50 feet and a good ground made possible reception of stations over approximately a 15 mile radius. The importance of a good antenna and ground, particularly in an area somewhat remote from high power broadcast stations, cannot be overemphasized.

The two circuits are coupled through mutual coupling existing by physicality placing the coils close together, one inch separation center-to-center is recommended. The detector coil must be modified to connect to the transistor detector/amplifier. The antenna coil part of the Merit 2602 should be carefully removed. It can be slid off the end of the form without damage to the coils after unsoldering the leads. The wire from this antenna coil may be used to scramble wind 50 turns on the 2602 form, tight against the first pin of the tuning coil. (See Fig. 4). This detector coil can be centered in place with a good coil doeb, such as Almaphased 912.

The amplifier is connected in the grounded emitter type circuit. The advantages of this circuit are that only one battery is required and that it has a higher input impedance than the

![Fig. 4. Diagram of transistor receiver. A single unit may be used if desired. See text.](image)

![Fig. 5. E]-/[-1/4 turns for the C972.](image)

Over-all view of the experimental transistor receiver showing accessory headphones,
Transistor Receiver

 grounded base circuit. The value of N should be chosen so that the collector current is about 1 milliampere. The collector current of the detector/amplifier transistor will depend on the strength of the received signal but will average about 200 microamperes with a strong signal.

 Battery life with only one transistor will probably equal the shelf life of the battery. With two transistors, the life will depend on average hourly use but should be at least 200 hours for two penlight type cells.

 If magnetic phones are used, they may be connected directly in the collector of either transistor. Low impedance phones or a speaker will require the use of a matching transformer. A load impedance of 5000 ohms in the output stage is correct for the voltage and current indicated.

 Alignment is perfectly straightforward but should be done carefully in order to realize maximum sensitivity. Any good service oscillator or signals from broadcast stations may be used to accomplish the alignment. The collector current of the first transistor is a good indication of resonance. The parallel trimmers are used to line the set up on the high frequency end and the slug on the low frequency end.

 The output power of this receiver is about 1.5 milliwatts and is sufficient for adequate earphone volume. An efficient speaker can be connected to the output circuit and adequate volume will be obtained in a quiet location.

 However, the addition of a class B output stage to drive the loudspeaker is recommended.

 The receiver, as originally built and as shown in the photos, included a CR702 germanium rectifier and several parts associated with this rectifier. The junction transistors were used as straight audio amplifiers. Tests proved that the diode was not essential and in fact provided no advantage, so the receiver has been modified to the circuit of Fig. 4.

 BIBLIOGRAPHY


This sensitive and selective unit contains regenerative detector and audio amplifier

By DR. WILLIAM H. GRACE, JR.

This compact regenerative receiver has given more than ample earphone volume on broadcast stations located several hundred miles away. When used with a 50-foot outside antenna, stations well beyond 1,000 miles have been repeatedly heard right through the numerous superpowered N.Y. C. locals. This indicates its sensitivity and selectivity. The receiver makes a reliable repeater for emergency use during power failure should a sudden air attack occur. Though built for use with earphones, many of the local broadcasting stations can be received at moderate room volume on a 20-watt PM speaker with a suitable matching transformer.

Construction

A black bakelite meter case was used for the cabinet, the outside dimensions being 3 7/8 x 6 3/8 x 2 inches. The set is built within the cabinet rather than on a separate panel. This construction simplifies the assembly and permits mounting the smaller components on a little shelf directly above the trimmer capacitor. This small variable capacitor is the regeneration control and provides the necessary capacitance feedback for oscillation. The knob is suspended by small-sized L-brackets, very easily attached by hex nuts to the projecting machine screws that hold the dial plates in position on the front of the panel. This idea works nicely and eliminates the drilling of extra holes in the cabinet.

The circuit is a standard grounded-emitter type with the first transistor acting as a regenerative detector and the second as a transformer-coupled audio amplifier (Fig. 1). Both transistors are Raytheon junction type CK 722, that operate satisfactorily on only 4.5 volts.

Crystal triodes are durable and have a long life if reasonable precautions are taken to prevent burnouts. The negative side of the battery must be connected to the collectors as indicated in the diagram.

The antenna requirements of any practical emergency receiver must be flexible. Thus, two separate antenna connections have been provided. On the left side of the cabinet are 3 phone-tip jacks. The two nearest the rear are for antenna connections; the third is for ground. In series with J1 and the main tuning capacitor (C1), is C5, one of the antenna coupling capacitors. The J1 connection is used only with a short, 30- or 25-foot antenna, plus a ground connection. It is often possible to obtain good results with J1 connected to the shell of a floor lamp or table lamp, the shell of a telephone box, or to one side of an a.c. outlet. No ground connection is made if any of the above antenna substitutes are used. This precaution is necessary because of the possibility of a short in C1. There will be only a very slight loss in volume by so doing. Capacitor C2 is in series with J2; this connection is used when a longer outside antenna (60 to 100 feet) is available. Two 3-foot lengths of flexible wire, phone tips at one end and alligator clips at the other, furnish the actual connection from act to antenna and ground. Of course, the greatest volume and best dx will be obtained with an efficient outside antenna as high above ground as possible.

Inductor L1 is a standard Ferri Loop-stick coil; and L2 is approximately 5 turns of No. 30 enamel wire, wound directly over the cardboard covering of the Ferri coil. The constructor should experiment with a greater or lesser number of turns on L2. In general, a few turns more than 5 will give greater volume and less selectivity, while fewer turns result in slightly lessened volume but increased selectivity. Incidentally, if oscillation is not obtained, reverse the leads to L2; this is the same as reversing the leads to the tacker coil in a regenerative tube receiver. The coil is mounted in the upper right-hand corner of the cabinet, rear view. The projecting dial plate screw again becomes useful.

The choke prevents r.f. from entering the audio circuit. Smooth regeneration will not take place if this choke is omitted. I found it convenient to mount the choke on the under side of the shelf just to the right of the trimmer capacitor.

The audio transformer is connected backward; that is, the high impedance winding is in the collector circuit. This is done to satisfy the impedance requirements of the transistors which can be considered to be opposite to tube triodes in respect to input and output impedances. The colored wire leads shown in the diagram are for the UTC type 800-02 subcircuit transformer. In conventional circuits using trans-
Internal view. The transistors are near the ends of the mounting strip.

former coupling with transistors, a base resistor is indicated from the base to the minus side of the battery. But with the particular CK722 used in this case no advantage seemed to be gained. The builder should experiment with this connection. The exact value of this resistor can best be found by test; any value between 320,000 ohms and 2 meg-ohms may prove suitable.

Both transistors C5 and C6, and the audio transformers were mounted di- rectly on the shelf. Capacitor C6 could well be of greater value, but the value suggested does work satisfactorily. If better base response is desired, short this capacitor with one of equal value. The objection to using a larger value may be that the actual physical size of such a capacitor prevents get- ting it into the cabinet.

The switch and phone output jacks are mounted at the right side of the cabinet, front view. Any type of battery switch may be used; a sliding type was chosen because it happened to be at hand. It is a good pre- caution to mount the switch so that the on position is as obvious as possible. In this way there will be less chance of forgetting to turn it off the set.

The battery requirements of this re- ceiver are easily met by 2 pilot cells. The cells are taped together edgewise, connected in series to furnish 1.5 volts. The minus lead from the battery goes to one switch terminal, the positive lead to ground. The cells are soldered, as far as their leads are concerned, directly into the circuit since they will seldom need replacement because of the very low current drain of the two transi- stors. The total drain for both transistors is about 1 ma, hence the cells should last almost their normal shelf life with average use. A conven- ient way to anchor the cells is with two small L brackets fastened again to the two projecting machine screws from the dial plate. Small pieces of folded cardboard wedge the three cells to pre- vent them from slipping sideways.

Capacitor C3 is a miniature 368-pF tuning capacitor. A standard broadcast capacitor could be used, but I found the smaller one easier to mount.

Operation

With only two controls the operation of the receiver is simplicity itself. The left-hand knob controls the frequency; the right-hand knob controls the vol- ume, by varying the degree of feedback. It is comparable to the operation of any other regenerative-type of tuner. No other volume control was used in the circuit. If still greater volume is re- quired it would be an easy matter to add a second stage of audio amplifica- tion. In this case a separate volume control would be necessary, and space on the front of the cabinet has been provided for this control just between the two dial plates.

Regeneration

Failure to obtain regeneration may be due, in the majority of instances, to incorrect coil connections. Fig. 2 shows the exact method of connecting L1 and L2. If there is any doubt as to which is the start of the winding on the Ferri Logopitch and which is the end, the following may prove helpful. Using a sharp knife, remove the cardboard cov- ering protecting the coil winding. The starting and ending lead will now be visible. Care must be taken in doing this, or the coil winding will be dam- aged.

Another common cause of failure to obtain regeneration is due to the actual variation in the transistors themselves. Some CK722s are good oscillators and good rectifiers, others are not so effi- cient as detectors, and still others do not seem to oscillate or regenerate at all. Fortunately, a large percentage of these tested perform very well. We should realize that these transistors were not designed for regenerative pur- poses. CK722 transistors were built as low-power audio amplifiers and are for low-frequency purposes. However, they will work very nicely over most of the broadcast band as r.f. rectifiers. When a particularly good one is found it acts as a very sensitive detector just at the point of oscillation. In fact, when oper- ated under the conditions described the sensitivity is remarkable and regenera- tion is fairly stable.

About the only other common or likely cause for lack of regeneration is a gross error in the circuit hookup. Worn- out dry cells will also produce poor re- sults.

This receiver is very simple to con- struct, using the minimum number of parts and but two transistors. It will prove an interesting introduction to the transistor field for anybody interested.

**Fig. 1—Schematic of the 2-transistor radio. Circuit is grounded-emitter.**

**Fig. 2—Diagram of L1-L2 connection.**

In these modern devices, the perform- ance of this little rig proved ample re- ward for the few hours needed for its assembly.
**Transistor REGENERATIVE Receiver**

By EDWIN BOHR

**NOTE**

Use of a CA705 germanium diode in place of the IN14 is recommended.

REGENERATION "sucks up" the performance of transistor receivers. Simple transistor radios with

regeneration are just crystal circuits followed by audio amplifica-

tion. There is no r.f. amplification, and sensitivity and selectivity are always poor. In contrast, the regenerator has

high gain and sharp selectivity.

Visit your friends may have at-

tributed to build a transistor regenera-

tor and found it did not work. Several

factors make the design of a workable

transistor regenerative different from

the vacuum-tube equivalent.

First, the transistor must be able to

sustain r.f. oscillation throughout the entire broadcast band. Whether or not this can be done successfully depends upon the design of the feedback and tuning circuits. Unlike vacuum-tube oscil-

lators, transistor oscillators are not unusually self-starting. Tubes draw heavy current, when they are first turned on and shock their circuits into oscillation. The transistor circuit must have starting features built into it. Furthermore, the transistor must be made d.c. stable or it may unk itself into a condition of oscillation.

Fig. 1 is the successful regenerative

transistor circuit. Feedback is from em-

itter to emitter. The emitter circuit

impedance is very low, unsuitable for a

parallel-tuned circuit. This is the rea-

son the tuning capacitor and coil are

placed in the collector circuit. Here the

impedance is moderately high. The triode winding feeds the emitter.

With tubes, detection or demodula-

tion takes place in the tube. The grid

rectifies the r.f., charging a grid-leak

capacitor. The voltage across the grid-

leak follows the modulation, placing an

audio signal on the grid. Unfortunately,

this scheme of things will not work with the junction transistor.

The reason it does not work is simple.

To obtain enough collector current to

flow for r.f. oscillation, the emitter

must have a constant bias current flow-

ning through it. This emitter-current

flow ruins the emitter's effectiveness as

a detector-rectifier. This means the sig-

nal must be detected by something other

than the transistor. The problem of at-

tuning the transistor is overcome and

still detect the signal can be solved by

using a separate rectifier (a22N44).

**Fig. 1—Regenerative transistor circuit.**
Let us get a complete picture of the circuit operation by following an r.f. signal through the detector. The signal, arriving from the antenna, is fed into L2 by transformer action from L1. The signal then passes through C4. This capacitor prevents the emitter bias from shorting to ground through the tickler coil (L2). It also blocks the audio signal that will be developed by the 1N34A. C4 and R1 provide an action without which resistors should not oscillate past a frequency of 600 or 700 kilocycles.

From C4 the r.f. flows both to the 1N34A and to the emitter. The r.f. choke RFC prevents the r.f. signal from bypassing to ground. The r.f. that reaches the emitter is amplified in the transistor and is fed back into L1. This feedback gives r.f. amplification by reducing the r.f. resistance of the tuning circuit.

A part of the r.f. signal reaches the 1N34A and is rectified by it and charges C3. The charge on C3 now varies with the modulating frequency and amplitude. This audio voltage flows through the r.f. choke (RFC) and varies the emitter current. From here, it is amplified in the transistor, flows through the tuned circuit and into the earphones.

Some will ask why the 25-ohm capacitor (C5) does not shunt all the audio to ground. The answer is the low impedance of the emitter. For all but the very lowest audio frequencies, the emitter impedance is lower than the shunt resistance. The 25-ohm capacitor absorbs the audio power. Experiment will bear this out. Try low values for C5 — say .05 to 0.6 — and the audio output will be very low. The same thing results if the 1N34A is disconnected. Without the 1N34A rectifier, detection will take place only with the regeneration control rotated all the way to the ground. Then the set will not regerate.

Potentiometer, R2, in the base circuit, controls the emitter bias and r.f. gain. Capacitor C8 bypasses audio and r.f. around the potentiometer. Here 20 ohf is a good bypass value because of the higher impedance of the base.

Capacitor C9 isolates the battery voltage from the tuning-coupling plates.

Construction

The small size of the transistor and its accompanying parts make it possible to set up the whole circuit on one small piece of board. The leads to the battery terminal strips, the transistor terminals and the terminals on the board are all that can be soldered to the tiny terminals on the socket. This makes it necessary to mount the receiver components and feed all of the lead wires onto which the many connections can be soldered. These lead wires and wires are run up to the transistor socket. None of the lead lengths are critical.

A metal front panel is very necessary. Without the panel, hand capacitance effects make tuning extremely difficult.

The electrolytic capacitors may have a tendency to limit the charging rate of the electrolytic. Two commonly used voltage rating will do for the paper and ceramic capacitors. Capacitor values may vary 5% from those specified. The resistors may be 5% or better.

The tuning coil is a modified Ferrite core. The extra-high Q of the loopstick is responsible to a large extent for the easy oscillation of the circuit through the entire broadcast band. The 1/4-turn coil (L2) has been used satisfactorily on the 10-meter band. None of the other coils experimented with worked nearly as well.

To modify the loopstick, first remove the cardboard sleeve that covers the winding. The short antenna coil with the coil is discarded. Remove 5 turns of wire from the far end of the coil. The remaining 30 or 35 turns of the coil. When this is done, L2 is wound directly over the loopstick winding. L2 is 7 turns of about No. 22 wire (the resistance of the wire is not important). A single twist of the free ends nears the coil from unwinding. Push the iron core into the coil until it extends an equal distance from each end of the coil.

When the receiver is put in operation it will be necessary to slide the core sightly to adjust the tuning range. The length of antenna connected to the receiver also changes the tuning range. The slug will compensate for this too.

Operation

After the set is wired, check off all parts and connections against the diagram. Make sure that the electrolytics are wired properly — positive side to ground. Plug in the CT822 in the transistor holder. The transistor is inserted in the battery holder. A connecting wire is inserted in the battery holder. Be sure the negative battery terminal is fastened to the earphones and 100,000-ohm resistor, R3.

With the earphones and battery connected, a "rushing" sound should be heard in the phone. The lack of this sound does not indicate a bad transistor. The only possible reason for the sound not being heard is that something is wired wrong. This sound is the noise generated by all transistors.

For a voltage check of the circuit, typical voltages are shown on the diagram. These measurements were made using a 10,000-ohm-per-volt meter with the regeneration control in the middle position.

The rushing sound is heard at any setting of the control regardless of the setting of the regeneration control. However, the loudness of the rushing sound will increase slightly with clockwise rotation of the regeneration control.

Connect an antenna 25 feet or longer to the stator terminal of the tuning capacitor. When tuning, have the regeneration control advanced as far as possible. This does not give best reception, but it is the best that is possible. One too weak to be heard — will sound the best.

At some settings — usually near the exact size of the wire is an important factor. Weaken stations come in better just below critical regeneration; strong stations, above this point.

A good antenna and ground reduce the tendency to motorboat; and the detector will pass over critical regeneration with a single "plop" sound.

The regeneration control setting affects the tuning slightly. On the high end of the dial, the receiver may defte the station, making a tuning readjustment necessary. If it is impossible to pick up a station at either extreme of the tuning capacitor, the iron core can be adjusted in the coil to bring in the station.

Power supply

A small a.c. power supply for the receiver is shown in Fig. 2. Do not use a direct earth ground with the power supply. Two 12-volt lead accumulators

Fig. 2 — Schematic of a.c. power supply. Power supply is shown in the diagram are not shown in the picture — they were added later. Any ordinary regulating type selenium rectifier will work. A 100-ohm rectifier was in the original circuit because of the large unit pictured. The resistors can be any wattage. We made the 6,000-ohm resistor from two smaller ones because they were at hand, not for better power.

The reader can make a much safer supply with a 12-volt filament transformer and a small germanium rectifier. The present job — if used — should be enclosed and treated with caution — (Editor)

From a small country town, in two weeks of listening with a 25-foot anten-

na, 12 stations were recorded. The nearest powerful station was more than 100 miles away. No ground was used.

The regenerative circuit is good starting point for experimentation. With a hearing-aid battery, inaddition tuning capacitor, and a smaller re-
generation control, the circuit will shrill to shirt-pocket size.

The radio is a real performer considering its very small power consumption. The audio gain is much better than any vacuum-tube circuits operat-
ing on this low voltage. In the same location mentioned, a transistor radio without regeneration was able to pick up just two stations — and it was almost impossible to separate them. With re-
geneneration many more stations were received, all with good selectivity.

Parts list for receiver

<table>
<thead>
<tr>
<th>Part</th>
<th>Description</th>
<th>Qty</th>
<th>Each</th>
<th>Remarks</th>
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</thead>
<tbody>
<tr>
<td>L1</td>
<td>1N34A</td>
<td>1</td>
<td>100</td>
<td>10.5 mm, 15 volt</td>
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<tr>
<td>L2</td>
<td>loopstick</td>
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<td>20</td>
<td>1.5 turns, 100 ohm</td>
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<tr>
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<td>2</td>
<td>20</td>
<td>1-250</td>
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<tr>
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<td>1</td>
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<td>10000-ohm, 1%</td>
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<td>2200-ohm, 1%</td>
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<tr>
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<tr>
<td>M11-M12</td>
<td>200-ohm-inductor</td>
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<td>200</td>
<td>200-ohm-inductor</td>
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</tbody>
</table>

Parts list for a.c. power supply

<table>
<thead>
<tr>
<th>Part</th>
<th>Description</th>
<th>Qty</th>
<th>Each</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1-C10</td>
<td>25-ohm, varible</td>
<td>10</td>
<td>25</td>
<td>1-250</td>
</tr>
<tr>
<td>C11-C20</td>
<td>25-ohm, varible</td>
<td>10</td>
<td>25</td>
<td>1-250</td>
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<tr>
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<td>2200-ohm, 1%</td>
<td>1</td>
<td>2200</td>
<td>2200-ohm, 1%</td>
</tr>
<tr>
<td>M1-M10</td>
<td>200-ohm-inductor</td>
<td>10</td>
<td>200</td>
<td>200-ohm-inductor</td>
</tr>
</tbody>
</table>

END
TRANSISTOR RADIO

uses NO
POWER
SUPPLY

Here's what many have looked for—nothing for nothing

By WILLIAM H. GRACE, JR.

RECENT statistics on the sales of
transistor parts for such sets as hobby-
ists indicate that there may be as many
as a quarter of a million such
receivers in use throughout the
world. One manufacturer reports sales
of 50,000 crystal sets during 1954. The
sets are cheap and dependable
radio, good fidelity, low initial cost
offset to no upkeep expense. The
chief disadvantage of crystal receivers
is low sound volume in the head-
phones or speaker. This defect could
be remedied by a stage of tube or
transistor audio amplification but this
requires some external source of power.
The circuit described in this article
avoids a stage of transistor audio
amplification of moderate gain without
receiving any external source of power of
a conventional type whatever. I
constructed the circuit several years ago
by experimenting with standard line
circuits and it has proven itself
tactical and effective.

This circuit comes as close to giving
nothing for nothing as you are apt
to come in a long time. Because of
this characteristic, it seemed to be a
natural for a battery-less transistor am-
plifier. If you live in a house where a
radio receiver will provide a good
supply of current, this battery-less transistor am-
plifier will almost double the volume.

The crystal tuner (see diagram) is the
indication of a tuned-primaries-tuned-
secondary affair used for years by
some manufacturers and before that by
ship-to-shore stations in the days
of shipboard transmitters. A 1N40
germanium diode is used as a detector-
.....

Schematic of the battery-less amplifier.

Parts for battery-less amplifier
1—100-ohm decade potentiometer; 2—C313 transistor (2); 3—R828 transistor pair; 4—32 µfd. electrolytic (or 3 47 µfd. electrolytic); 5—1.5 volt battery; 6—2N107 diode; 7—R828 transistor (base); 8—1N40 germanium diode (2); 12 turns, 20-mil wire, tapped at 20th turn from the top end.
Another interesting application for transistors. Details for constructing several amplifiers are also included.

Fig. 1. Typical transistor circuit. (A) grounded base; (B) grounded collector; (C) common-base; (D) common-emitter. [Image]
A voltage at the collector because of the voltage drop in $R_c$, resulting from collector current. 10,000 ohms is about right for CK722.

Note that in each of these circuits (Figs. 2A and 2B) a decoupling filter comprised of $R_a$ and $C_a$ is shown. This is necessary for unless the battery is of extremely low impedance there will be positive feedback resulting from the fact that the battery impedance is common to all stages. It may even be found necessary to add decoupling filters in other stages depending upon the total number in the amplifier, the total gain, etc. Experience has shown that most batteries will cause feedback in a high-gain transistor amplifier for even though the battery impedance is low, it is appreciable compared to the relatively low impedances of the transistors. $C_a$ must be a fairly high capacity if $R_a$ is to be kept small enough to not drop the operating voltages too greatly. For example $R_a$ of 500 ohms and $C_a$ of 40 $\mu$F or more might be satisfactory but final values can be determined by trial and will depend upon the frequency range of the amplifier as well as the gain, number of stages, etc. In general, the time constant $C_a R_a$ should be greater than 1/$f$ for the lowest frequency passed by the amplifier. (In computing this time constant $C_a$ must be expressed in $\mu$F, $R_a$ in ohms, and $f$ in cycles per second.)

Now we come to the output stage where we wish to operate a small earphone requiring 2 or 3 milliwatts for suitable output. Because we are dealing with a power amplifier operated from a low voltage supply, the output signal will have a voltage swing of only a few volts, never more than the theoretical limit of twice the supply voltage. Crystal phones are of high impedance and depend on larger voltage swings so are not desirable because they require a matching transformer. Magnetic phones are readily available with impedances of a few thousand ohms and may be used without transformer.
coupling as indicated in Fig. 4A. Of course, the d.c. resistance should not be too high or the voltage drop will reduce the output voltage to too low a value. Low impedance power sources are satisfactory if there is no objection to using a matching transformer as in Fig. 4B. The approximate load impedance to match the output transistor is found with sufficient accuracy for experimental use by dividing the d.c. voltage at the collector by the d.c. collector current.

A word about transformers. There are many types of transformers with a variety of impedance combinations suitable for use in the circuits discussed. However, a small tapped transformer such as UTC types R-27, R-28, R-30, R-36A, R-59, Transformer types S62, S86, S87, S88, and similar universal types are relatively inexpensive, small, and provide impedance ratios from a few hundred to several thousand times so that optimum coupling can usually be obtained for inter-stage use as well as for input and output requirements. A monolith of two to one in the lower level stages may be used without appreciable loss of gain.

The next item in designing this amplifier is the battery voltage. Three volts is a desirable supply voltage although 1.5 will suffice in many cases. Even higher voltage may be used when larger output power is required. The maximum collector current rating for type CK722 is 5 ma, so with 3 volts supply less the drop in the output transformer or earphone, we can still put 5 or 10 milliwatts in and easily obtain several milliwatts of audio output power. The input resistor in the final stage should be adjusted to give the lowest collector current which will result in sufficient output power to drive the phone for there is no need for using more battery current than necessary. The CK722 transistor has a maximum collector dissipation rating at room temperature of 30 milliwatts which means that with obtainable efficiencies you can if you desire more power output (up to about 20 or 25 milliwatts), operate the final stage at its maximum collector current rating of 5 ma, and a collector voltage of about 10 volts. If this is done, it will save battery power if the stages preceding the output stage are operated on a separate 1.5 or 3 volt battery rather than through a dropping resistor connected to the total available supply voltage.

Although some amplifiers may be usable without a volume control, it is usually necessary that means be provided to adjust the volume to accommodate variations in signal input, changes resulting from battery aging, etc. The volume control problem is not quite as simple as with tubes but one good method for resistance-coupled circuits is illustrated in Fig. 5 where the resistance portion of the control becomes the load for the transistor and the arm of the control supplies the signal to the following stage. The control may be used in any convenient amplifier stage but ordinarily it is best to put it at the “front” of the circuit to aid in preventing overloading of following stages on strong signals. Fig. 5B shows a volume control circuit suitable for use with transformer coupling. In this circuit, the resistance of the control should be at least 10 times (more if possible) the impedance of the transformer secondary.

The volume control cannot be connected in a manner which would vary the bias base, and thus the collector current, so Fig. 5C is a volume control circuit which is not satisfactory. Fig. 5D shows another method which is not satisfactory because it would vary both collector current and load impedance. Even the insertion of a condenser between volume control arm and transformer primary would not make the circuit desirable because the load impedance would vary with changes in the volume control setting.

Although we assumed that we were designing a transistor amplifier for a particular purpose the reader should understand that this was to give some indication of how to proceed with the design of an amplifier for a typical application. There are infinite combinations of components which may be used and after one has gained some experience in building transistor amplifiers he can readily work out variations such as the use of loudspeakers for both pickup and reproduction as in intimate combinations of different transistor circuits such as a first stage using a crystal mike directly coupled to the high input impedance grounded-collector circuit, followed by grounded-emitter stages for maximum gain, and other combinations designed to meet particular ideas and requirements.

Also, transistors may be used in push-pull class A, class B, and other conventional circuits for greater output so there is no end to the possibilities which may be investigated and employed by those interested in the advantages in small size, lightweight, and low battery drain obtained by using transistors. Negative feedback in a grounded-emitter circuit may be obtained by an unbypassed resistor in the emitter lead and offers another line of investigation for the experimenter. Negative feedback over more than one stage is possible, as with tubes, but not always as easily accomplished. For example, tertiary windings on transformers appear most promising in transistor-coupled amplifiers for which negative feedback is desired. It is very desirable that the investigator have available an audio signal generator and oscilloscope for use in observing the effect of changes in transistor circuits and operating conditions.

REFERENCES

A TRANSISTOR VIBRATION AMPLIFIER

By LOUIS E. GARNER, JR.

A transistorized and simplified version of a circuit first described in Jan. 1953 issue.

The extremely small power requirements of transistors make it quite attractive to "transistorize" portable equipment wherever practicable. This is true not only of hearing aids and portable radios, but also of most types of portable test and measuring equipment.

In an earlier article, the author described a small vibration pickup amplifier "Tilt-A-Tone" around a used hearing aid ("A Transistor-Pickup Amplifier," January, 1953, Radio & Television News). A "transistorized" version of a vibration pickup and amplifier is shown in Fig. 3, together with the headphones used as an accessory.

The attempt made was, in designing the transistor version, to exactly duplicate the performance of the earlier circuit. Rather, the instrument shown in Fig. 3 was designed for somewhat different application. Where the earlier circuit was used primarily to check mechanical movements and vibrations of a clock, this instrument is designed for checking sounds in |nuitor mechanics.

The instrument is designed for a suitable mechanism in diagnosing troubles. Because of this, only one frequency is used (two tubes were used in the earlier version), and less gain is provided.

Circuit Description

The circuit used in the transistor vibration amplifier is quite simple and straightforward, as can be easily seen by reference to the schematic diagram given in Fig. 2. (The conventional single-ended grounded-emitter amplifier circuit is used.)

In operation, mechanical vibrations picked up by the probe are converted into electrical signals by a piezoelectric-crystal (an ordinary phonograph crystal cartridge). These signals are, in turn, applied to the primary winding of T1.

A piezoelectric crystal has a high input impedance. The transistor amplifier stage has a low input impedance. Hence, in order to match these two impedances to insure maximum signal transfer, a transformer (T1) having a stepdown turns ratio is employed.

The signal appearing across the secondary winding of T1 is applied to the base-emitter circuit of the transistor through coupling condenser C1. A fairly large capacity condenser is used here to prevent loss of signal level at medium and lower frequencies, which might otherwise occur due to introducing a comparatively high impedance in series with the low input impedance of the transistor.

F1 serves as the "base return" resistor, and, by providing a d.e. path between the power source and the base, establishes the base "bias" current. The value of this resistor determines the "bias" current flow and hence the operating characteristics of the stage. The collector current also varies with the size of R1, as collector current is directly proportional to base current.

The audio signal is amplified by the transistor stage and the amplified signal appearing in the collector circuit is applied to the headphones. Since magnetic headphones are used, they also serve to complete the d.c. path for collector current flow.

A hearing-aid type battery, B1, serves as the power supply, and a s.p.s.t. slide switch, S1, as the power switch.

No provision has been made for a gain control, as it is not needed with a single stage of amplification.

Construction Hints

Both the pickup probe and the amplifier itself are assembled in a small Bud "Minibox." These small aluminum boxes may be obtained with either a gray hammerhead or an etched aluminum finish.

The general parts arrangement used by the author is apparent from the interior photograph given in Fig. 4. Layout is not critical, however, and a somewhat different arrangement may be used by the builder, if desired.

In the author's model, the small transformer and the battery are held in place by two "Z" brackets, fastened in place by a single machine screw and nut. Connections to the battery are made by soldering leads directly to the terminals. Scotch electrical tape is used over the battery terminals to prevent accidental shorts.

Another builder might prefer to devote a small socket arrangement so that the battery may be installed and removed without soldering. The transistor has been wired directly into the circuit in the model shown. Where this is done, special care must be taken to avoid overstressing the transistor leads. Like most semiconductors, the transistor is particularly sensitive to heat, and may be easily damaged by excessive high temperatures.

As an alternative, a socket might well be used for the transistor. Transistor leads are long enough to fit in the socket employed (only three of the pin positions are required).

Once the unit is completed, labels may be made up by using standard decals, obtainable through most wholesale parts distributors. In the author's model, black decals were used. After the decals were attached, three coats of clear plastic were applied to protect both the decals and the finish of the case.

Some builders may prefer to omit the labels, however, since they add nothing to the performance of the unit.

Assembling the Probe: A detailed cross-sectional view of the probe assembly is given in Fig. 3 and this sketch is, in some extent, self-explanatory. A few comments are appropriate, however.

The probe itself is made up from an ice pick. The metal point is removed from the handle and the blunt end heated in a gas flame until it changes.
color. This process removes the temper and permits a standard die to be used for threading the end.

Choose a die size that is appropriate for the diameter of the job pick point used. This will vary somewhat with different job picks. A 10-32 die was used by the author.

The sharp end of the job pick should be rounded slightly by using a grinding wheel. This is done to prevent the point from digging into or scratching the surfaces against which it is held. Do not remove the temper from the point by heat-treating, however.

Only that portion of the probe which is to be treated should be re-ground. For best results, the rest of the probe should be kept in its original state. When assembling the phonograph cartridge and probe as shown in Fig. 3, note that the probe point and its mounting nut bear against the case of the crystal cartridge, not against the needle Shank.

In operation, the case tends to vibrate around and against the crystal, with the inertia of the crystal resisting this movement. This provides the necessary bending and twisting action to operate the crystal so that an electrical signal is produced.

Parts Substitutions: Since so few parts are required for this unit, and these are all standard, the prospective builder should not find it necessary to make substitutions. A number of substitutions are permissible, however.

First, a case different from the one employed by the author might well be used. In choosing another case, keep in mind that it should be fairly rigid—for this reason, a plastic case is not generally recommended.

Another transformer might well be substituted for Tn. Use any transformer capable of matching a high impedance to the low input impedance of the transistor. A certain amount of mismatch will not cause difficulty. In choosing another transformer, make sure that its physical size is such that it will fit easily into the case chosen.

If preferred, a somewhat smaller condenser may be used in place of C2, The author used a 10 µfd. condenser because of its ready availability. An 8, 4, or even a 2 µfd. condenser should give equally satisfactory results.

A toggle or rotary switch might be substituted for the slide switch used in the author's model.

Either an open or a closed circuit jack may be used as J, although an open circuit jack will prevent accidental current drain when the headphones are disconnected. If the switch is to be in the "on" position as an alternative, the closed circuit jack should be wired permanently in place and no jack provided.

Circuit Modification

Only a moderate amount of gain is provided by the single amplifier stage used in the author's model. This is sufficient, however, where the circuit is used on equipment having vibrations of large amplitude.

For some types of work, the builder may prefer an amplifier providing more gain.

One simple technique for increasing the gain of the unit is to substitute a Bayoune type C2721 transistor ("p-n-p" type) for the C2722 shown in the schematic diagram (Fig. 2). The connections are the same, and it should not be necessary to change any parts values.

Where even greater gain is desired, a two- or even three-stage amplifier may be used. In such cases, it will be necessary to provide a gain control to prevent overload on strong input signals.

For general information on multi-stage transistor amplifiers, as well as suggested gain control circuits, refer to Charles W. Martel's article "Transistorize Your Audio Amplifiers" (March, 1953, Radio & Television News).

The builder may find that a tone control will be desirable for some applications. Such a control may be added by connecting a 10 kΩ, condenser in series with a 20,000 ohm resistor, and connecting the entire assembly between the collector and emitter leads of the transistor. This forms a simple, but effective, "tapered" type tone control circuit.

Using the Unit

To use the transistor vibration pickup, plug a pair of magnetic headphones into the output jack (4) and turn the unit "on".

The case is held in the hand and the pointed probe held firmly, lightly, and gently, against the machinery or equipment being checked. Experiment with both the angle at which the probe touches the machinery as well as the exact point at which contact is made.

This technique often enables the user to distinguish between different types of vibration sounds and to pick out those sounds of particular interest.

If the builder has assembled a unit using two or more amplifier stages, and has provided a gain control, this control should be set for minimum gain when the probe is first placed in position. The gain is then gradually

increased, without moving the probe, until the desired signal level is finally reached.

This last technique is used for two reasons. (1) To prevent "blasting" due to high signal levels, and (2) to prevent accidental signal overload, with resulting distortion and changes in signal quality. A distorted signal is difficult to properly interpret.

Applications

Although primarily designed for in-
(Continued on page 101)
TRANSISTOR GUITAR AMPLIFIER

By LOUIS E. GARNER, JR.

This multistage unit uses four transistors, operates from a single 6-volt battery, and will withstand heavy portable use.

A GUITAR amplifier provides an interesting construction project for the experimenter or technician who wants to "try his hand" at building a multistage, transistor-operated audio amplifier. Such an amplifier is shown in Fig. 1, together with the guitar from which it is used and the pickup microphone and cable. Interior top and bottom chassis views of the amplifier itself are given in Figs. 3 and 4, respectively.

Although the amplifier shown can be considered as a substitute or replacement for a conventional vacuum-tube amplifier because of its low power output (a fraction of a watt), it does offer several advantages over conventional amplifiers for some applications. First, its small size and light weight make it an ideal instrument for portable use—even a small child can carry it about without difficulty. Secondly, since the power supply is self-contained (a battery), the instrument may be used wherever desired—at picnics, lawn parties, weiner roasts, or at similar outdoor functions. Another advantage is its low maintenance cost. Except for an occasional battery replacement, the amplifier should seldom, if ever, require any adjustment or servicing. It certainly will never require replacement tubes. Further, since less expensive "toy" transistors are used, the amplifier is its over-all ruggedness. With no tubes to shake out of their sockets, or tube elements to loosen and become microphonically allergic, the amplifier can withstand a considerable amount of "jouncing" in the trunk of an automobile or on the floor of a station wagon.

The transistor guitar amplifier is fairly easy to assemble and wire. The average technician will find that it makes an excellent "weekend" construction project.

Circuit Description

As can be seen by reference to the schematic diagram of Fig. 2, the complete amplifier consists of a two-stage "voltage amplifier" followed by a push-pull output stage.

A Brush "Vibromike" vibration microphone is used on the guitar, with a shielded cable connected between the mike and the input jack (X, Y) of the amplifier. The signal obtained from this mike appears across R, which serves as the "gain" or "volume" control.

In designing transistor-operated audio amplifiers, it is important that the signal level be controlled in such a fashion as to avoid changing either the base "bias" current or the collector current of any transistor stage. C, serves as a blocking condenser to prevent the comparatively low d.c. resistance of the primary of T, acting as a shunt across R. In turn, is used to match the high microphone and "gain" contra impedance to the low input impedance of the transistor amplifier. Thus, a stepdown turns ratio is used in this transformer.

The a.c. signal appearing across the secondary of T, is coupled through d.c. blocking condenser C, to the base of the first CK721 transistor amplifier stage. R serves as the "bias" resistor and establishes the "bias" current for this stage, being returned to the negative terminal of the power source, B.

An amplified signal appears across the primary of transformer T. This transformer is used to perform a function similar to that of T. Where T serves to match the high microphone impedance to the low input impedance of the transistor amplifier stage, T, is used to match the comparatively high output impedance of one amplifier stage to the low input impedance of the succeeding stage. Because of the differences in impedances, different turns ratios are required, and hence different transformer types are used for T and T. Condenser C, and resistor R, perform functions similar to C, and R, respectively.

The second CK722 transistor stage provides additional amplification, with the output signal appearing across the primary of T.

Transformer T, performs two jobs. It acts to match the high output impedance of the second CK722 stage to the low input impedances of the push-pull output stage, and at the same time, provides two signals having 180° difference in phase to properly drive the two output transistors.

Another advantage is the low noise level, since the cathodes of the push-pull output transistors, R and R, are connected across condensers C, and C, respectively, while resistors R, and R, are the "base return" resistors for the CK722 transistors used in the output stage.

A conventional push-pull audio-output transformer, T, is used to match the output stage to the 8-ohm loudspeaker used.

The volume control is conventional and consists of R, and C, connected across the primary winding of T. As the resistance of R, is reduced, C, becomes more and more effective in bypassing the higher frequency components of the amplified audio signal. This type of tone control circuit is commonly called a "loser" tone control.

The 6-cell radio battery is used as the power source for the entire circuit. A rotary type switch, S, is used in the "A" lead as the "Power" switch. The 6-ohm guitar amplifier circuit points up an important feature of transistor
amplifier circuits in general. Although "grounded-emitter" amplifier stages are used throughout, the common " chassis" ground is to "X." Thus the "type" of transistor amplifier circuit (grounded base, grounded emitter, and grounded collector) is determined by the method of applying the input signal and the location of the output, rather than the location of chassis ground. In general, chassis or circuit ground may be made at any one in a transistor amplifier stage, regardless of type.

In this respect, the guitar amplifier may be considered analogous to a vacuum-tube amplifier in which "R plus" plate return leads are connected to ground, with "R minus" and the tube cathodes above ground potential.

Construction Hints

A sloping front speaker wall baffle has been used as the "chassis" of the guitar amplifier. Rubber tack feet have been added to the "top" of the baffle, which then becomes the base of the cabinet. A small handel was also added to facilitate carrying the unit. These modifications are readily visible in the photographs.

Both the loudspeaker and the battery power supply are mounted directly in the baffle, with a small clamp provided for holding the battery in place. The rest of the amplifier circuit is contained within a small aluminum chassis visible in Figs. 3 and 4.

Layout and parts location are not too critical, although standard good wiring practice should be followed. The input and output signal leads should be kept well separated. No provision is made by the manufacturer for mounting the "Sub-Omber" transformers (T1 and T2) and it becomes necessary for the builder to use his ingenuity in mounting these units. The author employed small T2 brackets, clearly visible in Fig. 5.

Both the primary and secondary leads of transformers T1 and T2, as well as the primary leads of transformer T3, are identified by color-coded leads. All other transformer connections are identified by numbered terminals. The proper connections to use in each case are indicated in the schematic diagram (Fig. 2).

As far as the output transformer is concerned, however, the proper secondary leads to use should be chosen for the specific loudspeaker employed. Although the author used terminals 3 and 5 (as shown in Fig. 2), some other pair of terminals might give better results with a different speaker.

Either an "open" or a "closed" circuit jack may be used for the input (J1), at the discretion of the builder. For many applications, a closed circuit jack is preferred, as it reduces the possibility of noise and hum pickup. The "Gains" control is turned up with the "mike" unplugged.

In the author's model, the transistors have been soldered directly in place, but sockets may be provided if desired. Ordinary 5-pin subminiature tube sockets are suitable, with only three of the pins being used.

Should the builder prefer to solder the transistors in place, special care should be taken to avoid overheating the leads. Transistors are, in many respects, more susceptible to heat damage than are conventional germanium diodes, and many technicians have probably, at one time or another, damaged at least one germanium diode while removing it or installing it in a circuit.

Do not cut the transistor leads too short. Use a clean, well-tinned hot soldering iron and complete each joint quickly.

(Continued on page 105.)
A new and interesting application of transistors in the instrumentation field. Increased sensitivity is obtained.

It should not be particularly difficult to obtain full-scale deflection on a 20 microamperes meter for a temperature change of one degree Centigrade with operating collector currents on the order of 100 or 200 microamperes. In the case at hand, however, it is desired to make the temperature response as low as possible because here temperature response is the same as zero drift. In a d.c. amplifier using transistors in a grounded emitter circuit necessary here because the grounded base circuit has current amplification less than unity) the direct first-order cause of collector current drift is the temperature coefficient of the cut-off current and the two are related according to:

\[ I_C = I_{ne} \times e^{(\beta/2)(1/1-A)} \]

where:

- \( I_C \) = collector current
- \( I_{ne} \) = cut-off current (the collector-to-base current with open emitter)
- \( \beta \) = most-circuit current amplification (grounded base).

The foregoing points immediately, of course, to a balanced circuit which allows us to proceed at once to an examination of second- and third-order effects upon zero drift and response. In the circuit of Fig. 2, if the transistors can be matched for cut-off current, temperature coefficient of the cut-off current, and alpha, the residual zero-drift over the ordinary range of "room temperature" (28 °C) should be negligible. In addition, it is quite likely that a transistor of higher-than-average cut-off current can be paired with one of lower-than-average temperature coefficient and vice versa. This latter technique could resolve itself into a simple matching of collector currents (at either a fixed or zero base current) with a maximum permissible mis-di- vision of the collector-to-collector load as the sole criterion of temperature behavior, although the effectiveness of the test would be greatly increased if the original balance were followed by checking the shift in zero caused by shorting the input (base-to-base). This, in turn, results in the elimina-
tion of the electrical zero adjustment as shown in Fig. 3 which, as a design feature, would be somewhat more practicable with a meter having a greater range of adjustment of the mechanical zero.

The choice of battery capacity, collector current, and load resistors are all interrelated. If these are chosen with an eye to convenience in the matter of battery replacements, the use of the Mallory RM-12 (also RM-1200) with collector currents of 75 to 100 microamperes will result in operation requiring a new battery only once a week without the inclusion of an "on-off" switch. Collector currents below 100 microamperes, on the other hand, will show some increase in sensitivity with rising temperature. This can be circumvented by at least two methods: (1) Choose an operating collector current high enough (about 200 microamperes) so that any small further increase in current amplification is largely offset by compensating changes in other transistor parameters or (2) use a temperature-sensitive meter shunt as shown in Fig. 6. Proper proportion of R and F will allow the use of rather low collector currents without causing an unduly large response error over a reasonable range of operating temperatures.

Since some degree of matching appears to be inevitable, it seems logical to use only those transistors whose open-base collector currents fall within the desired range. This leads to the elimination of the base resistors entirely; while the circuit of Fig. 3 seems al- most too good to be true, high performance may be seen in Fig. 5 which shows voltage gain, current gain, and power gain as functions of source impedance. These plots, which are typical for the CK721, point out immediately the chief operational defect of the circuit: it cannot measure either current or voltage accurately unless the source impedance is much higher (for current) or much lower (for voltages) than the base-to-base impedance at the transistor input. This means (oddly enough) that the meter is virtually useless for quantitative measurements at the point which gives maximum power gain. This involves an operational concept which is somewhat unusual and it should not trouble us too much if we recall that the original objective was to realize a substantial increase in the current sensitivity of a microammeter with an absolute minimum of components.

Although the meter is of some potential value as a millivoltmeter for use with thermocouples, bolometers, and other low impedance sources, an extra word of caution may be interjected at this point. If the designer elects to use the same meter for current and voltage measurements, the most careful matching of transistor characteristics will be necessary; otherwise there may be a substantial zero shift in going from a high source impedance (0.1 or 1 megohm) to a low impedance (10 or 100 ohms) and vice versa.

The curves shown in Fig. 5 are intended to illustrate only one particular operating point using typical CK721's, which were matched in sil- paks. With a battery current of 150 microamperes (in the open-base cir- cuit) the corresponding collector cur- rent of 75 microamperes to each tran- sistor yielded characteristics as indi- cated in Table 1.

The resulting high input impedance leads, in this case, to rather serious errors if the current source impedance falls very much below 1 megohm. If this is too high for the application at hand, the only remedy is to operate at higher collector current with the im-
pedance scaling to the right by a factor of ten for approximately a doubling of current. The power curve is not the product of the voltage gain and current gain curves because the signal voltages and currents were computed from 8/360, while the power input was computed from 8/36. All points were for constant output power at full-scale meter deflection: 26 microamperes, 1800 ohms, 37 millivolts, 674 microwatt. This treatment may appear rather unorthodox but is more indicative of circuit performance in the face of a basic concept of good instrumentation (which postulates that the power expended in the measuring system must be small compared to the total power in the circuit being measured) than other presentations that could be used.

The parenthesis remark indicates more clearly why the circuit fails (in a usage sense) at maximum power gain because at this point the impedances are matched and the two powers are equal.

In the early months of transistor history, much was made of the fact that here, for the first time, was a device that could be regarded as a current amplifier. In the intervening years, however, very little has appeared in the form of practical devices making use of this important and interesting property. This being so, it may be permissible to emphasize the current-amplifying properties of the present device and gloss over its role as a voltage amplifier in proportion.

If the current amplification is, then, on the order of 20,000 ohms or more (depending upon the operating point chosen) the current gain of the circuit is approximately the grounded-emitter current amplification of the transistor multiplied by the shunting effect of the voltage divider across the meter: 

\[ CG = \frac{a vt-1}{a vt} \times \frac{R}{R} \times \frac{1}{R} \]

This is the current gain (expressed as a factor)

\[ R_v = \text{rare resistance.} \]

This factor neglects the further shunting effect of the collector resistor because this will be at least several hundred thousand ohms.

Inverting and informative comparisons may be made between the d.c. transistor amplifier and its vacuum-tube counterpart. In a d.c. vacuum-tube voltmeter of the balanced cathode-follower variety, the "bottom" tube usually functions mainly as a balancing tube, to stabilize zero in the face of changes in contact potential and input signals with changes in cathode temperature. While the balancing transistor is even more necessary in the transistor amplifier (although for a different reason) the second transistor is active dynamically and does not "shunt down" circuit sensitivity as does the case with balanced tube circuits. Also, it is usually the prac-

tice to ground the lower grid of the tube circuit because of troublesome ground capacitances and currents while the transistor circuit, being a relatively low impedance circuit containing very little in addition to the meter movement, need not be grounded and can therefore be operated at a considerable impedance to ground. The "bottom" transistor, then, is at the bottom only on paper and actually there is no necessity to designate "high" or "low" terminals at the input nor to provide a polarity-reversing switch (except as a convenience) at the indicating meter.

Certain types of laboratory and service instruments would appear to be logical candidates for improvement, through transistorization, in one or more of the following particulars: Instrument size and weight; number of components; manufacturing costs; performance; etc. For example, the voltmeter-milliammeter class of instrument (as exemplified by the Simpson, Model 260 and the Triplet Model 630-A) which at present uses a 50 microamperemeter movement can offer 200,000 ohms-per-volt and 1.5 to 5 megohms at meter-scale in the same instrument at slightly higher cost. For this purpose, the C-T202 with a current gain of 10 or 12 should be adequate.

Or, conversely, the performance of the d.c. vacuum-tube instrument (of the balanced cathode-follower type referred to before) can be approximately equaled in a smaller instrument of the same or possibly lower cost.

While much of the foregoing also applies in an abstract sense to a-c amplifiers and instruments, it will be understood that the presence of alternating current to d.c. is this is partly because there is such a glaringly obvious discrepancy between the power supply and inputs of d.c. instruments (particularly battery-operated instruments) and what may and should be possible with transistors. In this class of instrument with its plethora of batteries, including separate "A" and "B" battery, "C" battery, coupling batteries and backup battery, it is not unusual (for the weight and size of the instrument) for the voltage supply to exceed 75% of the total). Further, if the user attempts to reduce this proportion substantially, the unusual result, on meters used widely, intermittently, is a considerable loss of time in servicing operations. To this may be added the difficulty of maintaining fresh stocks of several types of batteries in the usual hospital and office, where most of the available instruments require different battery types.

Among the d.c. instruments which are often battery operated may be mentioned: photometers, densitometers, pH meters, spectrophotometers, infrared amplifiers, strain gauge amplifiers, mass spectrophotograph leak detectors, etc. While the ability to obtain the sort of input impedance which can only be realized from electron-tube amplifiers, there appears to be no reason why the remaining stages cannot be taken over by transistors. In fact, in the type of circuit using a large negative feedback, it is possible that the transistor stages can be operated single-ended because the temperature drift of the first transistor, i.e., the second stage, will be reduced in proportion to the gain of the electrometer input stage. This type of hybrid (tube and transistor) operation, coupling batteries, where required, and the meter stage battery will be single cells, one of which is already present in the form of the electrometer tube filament battery.

A fair example of a simple conversion to a combination circuit may be seen in Figs. 8 and 9. The former is a simplified schematic of the familiar "Suns" type of radiation meter with a full-scale sensitivity of 25 milliamperegons per hour and using five batteries (not counting the ion chamber battery which is not part of the amplifier proper). The addition of two transistors not only reduces the number of batteries to two but also increases over-all sensitivity at lower plate current to the electrometer tubes. The temperature characteristics of the transistors are not particularly important in this application since there is an inherent current-mirror action and instruments of this type are frequently checked by this setting.
The new CKT27 inures
both quiet operation
and high voltage gain

By RUFUS P. TURNER*

low-noise
transistor
preamplifier

Although the junction transistor in the common-emitter circuit always has offered attractive possibilities as a high-gain, single-stage, monomicrophonc, single-battery, voltage preamplifier, there has been some objection to its use because of the inherent high noise level of the transistor. When operated ahead of a main amplifier having high voltage gain, this noise voltage has appeared

as an annoying hiss in the final output.

The new Raytheon CKT27 p-n-p transistor has a lower noise factor (18 db) maximum in the common-emitter circuit with 6.5 volts collector potential than previous high-alpha units. In other respects, the room-temperature characteristics of this new transistor are similar to those of the CKT21 in the 1.5-volt common-emitter circuit, except for a collector resistance in the CKT27 of 1 megohm, base resistance of 800 ohms, and cutoff current of 2 ma.

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Fig. 1 shows a common-emitter preamplifier circuit which I found optimum for my particular requirements. This resistance-capacitance-coupled arrangement is designed to operate into a high impedance, such as an a.c. vacuum-tube voltmeter or the grid circuit of an amplifier, which will allow full use of the preamplifier voltage gain.

For the transistor tested, voltage gain at 1,000 cycles is 35. The maximum 1,000-cycle input-output voltage before rounding of the positive peaks of the output signal is 18 millivolts. Output voltage is 0.05 volt across 1 megohm connected to the amplifier output terminals. The input impedance at 1,000 cycles is 7,500 ohms (output impedance of the signal generator used was 600 ohms, resistive). The noise voltage measured with a vacuum-tube a.c. millivoltmeter at the amplifier output terminals, was 3 millivolts with the input terminals short-circuited. This is 49.8 db below maximum signal-voltage output.

Fig. 2 shows the frequency response of the single-stage amplifier when worked into a 1-megohm load resistor connected to the output terminals. Response is constant from 500 to 5,000 cycles, and is 10.66 db down at 50 cycles and 3.15 db down at 50 kc. This curve was plotted with a constant 10-mv input signal and with the amplifier gain control set at maximum output.

A single 4.5-volt battery powers the amplifier. Since the current drain is only 100 microamperes d.c., this can be a miniature battery, for example three 1.5-volt penlight cells connected in series. The battery switch can be operated by the volume-control potentiometer. I used small nonalluminized paper 1-at coupling capacitors for C1 and C2. For compact installations, however, these components may be miniature tantalum electrolytic capacitors.

If the latter are used, the positive terminal of C1 must be connected to the top a.c. input terminal, and the positive terminal of C2 to the top a.c. output terminal.

It is a comparatively simple matter to build this preamplifier into a test probe, microphone case, stethoscope pick-up, or similar accessory requiring high voltage gain with few components, freedom from the power line, and a simple circuit. Its low power drain (around 50 microwatts d.c.) makes it economical to operate for long periods and prevents the mortal sin of forgetting to turn it off.
TRANSISTOR CLIPPER AMPLIFIER

By

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The advantage of clipper filter units in the speech circuits of transmitters has been pretty well accepted by the amateur fraternity as a means of overmodulation prevention together with increased communication range. Prior to the advent of the transistor these advantages could be attained only at the expense of one or two tubes, a duo-diode, the bias for the diodes, as well as the extra plate and filament power required to supply the additional load. The transistor, however, has an exceptionally sharp cut-off as compared to vacuum tubes, together with high gain at reasonably low values of load resistance.

In this transistor clipper amplifier it was desired to use a carbon microphone input to the clipper amplifier and to use this one stage of gain to drive a 6LQ6 to more than 2 watts output. A grounded emitter circuit was chosen together with a collector voltage of 20 volts. This voltage being generally unavailable in either boxed or mobile installations was obtained by means of a bleeder from the 300 volt supply at a cost of only 1 mil including the losses in the bleeder and the electrolytic condenser. A bleeder rather than a simple dropping resistor was deemed necessary due to the relatively low and not particularly stable resistance of the electrolytic condenser. The d.e. base bias current was obtained by use of a 1.2 megohm resistor which established the collector current of the amplifier and was sufficiently high compared to the base impedance to have only negligible effect on the input signal. The clipping action was obtained by the sharp cut-off characteristic of the transistor which in itself gives better clipping than the usual combination of duo-diode and triode without their additional circuitry and biasing requirements. The use of a clipper amplifier requires the use of a filter to avoid generation of high frequency harmonics when the signal exceeds the clipping level. Iron core chokes were used to permit a reasonably high value of load resistor at a cut-off frequency of 3000 cycles. The input of this amplifier may be coupled by means of a .1 mil condenser for a low frequency cut-off of 400 cycles. This is usually considered to be most satisfactory for this type of amplifier. No volume control was considered for the output of the transmitter since negative feedback should be used in the driver stage and may be readily adjusted to limit the modulator output to just under 100% modulation. For those who prefer unclipped high fidelity speech, a larger coupling condenser together with a higher frequency cut-off low pass filter may be used. This will provide the performance of a straight unclipped amplifier with the exception that regardless of errors in loudness of speech or gain control setting the operator will find it impossible to overmodulate the transmitter. The only precaution necessary are that the negative feedback of the driver be adjusted to that no stage subsequent to the low pass filter be overdriven and that the input to the clipper stage be adjusted to provide the desired degree of clipping. This amplifier has a maximum output of 20 volts peak to peak and may, if desired be used with a transistor output to drive anything up to push pull 6LQ6's in class "A". The stage gain of this transistor amplifier is 80 so that only 25 millivolts peak to peak are required to drive this amplifier to full output although 75 millivolts are desirable for moderate clipping.

If it is desired to use other than a carbon microphone, a preamplifier stage should be used. In design of a preamplifier, consideration must be given to the fact that the clipper stage has an input impedance of about 5000 ohms which will probably rate a second transistor as the most acceptable choice.

The use of this transistor circuit will provide the advantage of a clipper amplifier together with marked circuit economy and simplicity. In addition, the basic circuit without filter may also be adapted to such other drivers as noise clipping audio amplifiers, and FM limiting i.f. amplifiers.
A TRANSISTOR PHASE INVERTER

A PHASE inverter is a circuit which provides coupling between the output of a single-ended stage and the input to a push-pull stage. A phase inverter provides two outputs which are 180 degrees out-of-phase, so that when one stage is driven positive, the other is driven negative.

Phase inverter coupling can be provided by a transformer, a vacuum-tube stage, or by a transistor stage.

The Transformer stage is the simplest to design and requires no power for operation, and provides a voltage gain. There are several disadvantages to the transformer, however. It has a limited frequency response, and is sensitive to hum pickup from the magnetic fields of power transformers. In some applications the weight of the transformer is a serious disadvantage.

These difficulties led to the development of the vacuum-tube phase-inverter circuit. The vacuum-tube stage is insensitive to power transformer hum fields, has an excellent frequency response, and is lighter in weight than most transformers. Its disadvantage lies in the requirement of heater and plate power, and, in some designs, in hum pickup from the heater of the tube.

These drawbacks led to the transistor phase-inverter development. The transistor stage has the same advantages as the tube stage, with respect to frequency response and immunity to power fields, with the further advantage of lighter weight. In addition, the transistor stage needs no heater power, so there is no hum pickup from this source.

The Transistor circuit uses a base input, with an emitter-follower output to provide isolation, and a collector output for phase reversal. The equivalent circuit is given in Fig. 1A.

The two loop equations are:

1. \( R_1/1 = R_2 \) 
2. \( 1/(R_2 + r_e) = -R_2 - R_1 \)

Solving equation (1) for \( I_1 \) gives:

3. \( I_1 = E/R_1 \)

Substituting in (2):

4. \( E = -R_2 (I_1 + I) \)

Equation (5) must equal minus one to give the desired phase shift of 180 degrees in the collector branch of the circuit.

Therefore:

5. \( R_2 (I_1 + I) = -R_2 (I_1 + I) \)

Choosing \( R_2 = 72,000 \) ohms from d.c. considerations, and using a CK722 transistor with collector resistance, \( R_c = 500,000 \) ohms and mutual resist ance, \( R_{

Two views of the transistor phase inverter is used in an audio amplifier. Terminal board mounting is used.

Details on a novel application of transistors of interest to experimenters. It may be used in audio amplifier circuits.

Add a dropping resistor for operating from 250 volts, add coupling and bias resistors, connecting and bypass condensers, and the circuit of Fig. 1B is derived.

The transistors provide a compact terminal-board mounting of the circuit. The phase inverter serves to drive push-pull 68V tubes in an audio amplifier. The unit serves as a good project to introduce the experimenter to transistor techniques. The design was discussed in some detail to show how it can be adapted to other transistor circuits.

The variations in the gain of the circuit, especially in the collector branch, with different CK722 transistors are dependent on how close the tolerances the manufacturer holds on the characteristics of the transistor. There are, however, two aspects of this circuit which favor uniformity of performance. One is the use of the transistor to provide unity gain, so that there is no multiplication of variations. The other feature is the large amount of degeneration introduced in the emitter branch of the circuit. Of five CK722 transistors used in the circuit, the maximum variation was found to be less than ten per cent.

The gain in the emitter branch is constant to within two per cent for various CK722 transistors. The balance between collector and emitter is quite good, and can be made as close to unity as desired by adjusting the collector load resistor, although this is not necessary for most applications.

The maximum signal level that the (Continued on page 104)
COMMERCIAL transistor hearing aids employ type CK728 junction transistors. The CK728 is special type supplied to manufacturers of hearing aids. The simple hearing aid described in this article uses type CK728 transistors which are available to the experimenter.

The task of developing a transistor hearing aid that might be duplicated by any electronic technician proved intriguing, but this author met obstacles at every turn. First, no amount of experimenting with the CK728 in resistance-coupled circuits seemed to give the required gain and power output with tolerable noise level, even when four 6-C-6 stages were cascaded. Transformer coupling finally was used. Also, the much desired operation on a single 1¾ volt cell did not pan out. We had to go to 15 volts. Undoubtedly, the CK728, with its higher power gain and different coefficients, would furnish the required drive. But this is an expensive type, and is not as readily available to the private experimenter as the CK722. And finally, most of the subminiature circuit components we wanted to use just were not to be had. So we used the smallest parts available to the general radio public and made them work in a small space.

The finished hearing aid is shown in photo. It is built into a du Maurier cigarette tin. Many types of inexpensive boxes were considered, but preference finally was given to this extra-light, attractively colored aluminum box with hinged lid. Overall dimensions are 3¾ inches high, 2 inches wide, and ¾ inch thick. As Fig. 1 shows, the instrument is just slightly larger than the standard cigarette package beside which it is posed. In fact, it is only cubic inches larger and it weighs only approximately 3 times as much as the full pack of cigarette.

This hearing aid will fit easily into a man's shirt pocket. It is entirely self-contained except for the mini-ear phone. Operating current is supplied by a single 15-volt Burgess U10 bear-
of fixed resistances. Finally, try it in place of the single collector resistor, and adjust for highest undistorted output with low collector current.

To facilitate these tests, the reader may start with the author's values as given in the schematic, then substitute the variable resistor progressively in each position. In this way, the entire system will be in operation while one stage is being "ganged." During this test, the microphone may be disconnecting temporarily a 1:000-cycle signal fed into transformer T1 from a low-distortion audio oscillator. An a.c. vacuum-tube voltmeter or radiofrequency may be connected in parallel with the earphone for quantitative observations of output while listening to the signal.

In general, it is a good procedure to minimize the noise level by making adjustments in the input stage, and to maximize output by means of adjustments in the output stage, although some compromise necessarily must be reached between adjustments in each of the three stages.

Once the fixed resistors have been installed, avoiding transitions between stages will not be practical. But no inconvenience should arise from having to keep such transistor in the same stage, since their life is said to be 70,000 hours (approximately 8 years if you run the hearing aid 24 hours continuously each day).

Speech at a comfortable conversational level originating about 4 feet from the microphone will produce a 1-volt swing across the crystal earphone when the V.O.I. control is set for maximum volume. At this setting, the residual noise level varies from 0.08 to 0.1 volt and is a gentle rushing sound. The noise level may be higher or lower with other transistors.

The volume control is a Centralab type B10-218 subminiature potentiometer with ganged switch S. This unit is smaller than a dime, and is in the lower right-hand corner of the case in Fig. 1. The back of the control, showing the three potentiometer lugs and the two switch lugs, can be seen to the lower left-hand corner of the opened lid in one of the other photographs.

Construction

Construction details are shown in the photographs.

The microphone is mounted in the upper center portion of the lined lid of the cigarette case. A 0.001-inch diameter hole is cut with a pocket punch. This hole is then covered with a square of waxed cloth which serves as a grill when Bues-creamoid inside the lid back of the hole. A square washer of thin spring copper is then riveted around the hole, over the cloth, and the micro- phone is cemented to this rubber. This makes a good shock mount.

The volume control is mounted through another 0.015-inch-diameter hole in the lower right-hand corner of the lid. One switch lug must be bent temporarily slightly perpendicularly to allow passage of both lugs through the hole. The control is held by small springs (riveted) which pass through holes in the switch lugs. One of these sets (and the corresponding switch lug) accordingly must be insulated from the metal lid. This is the lug connected to the positive terminal of the battery. Carborundum (Scotch) tape was used for this insulation in the author's instrument.

One photo (Fig. 4) shows how the circuit components are mounted on a thin plastic card. The three trans-

Fig. 3, left, and Fig. 4, right, show the interior of the case and the way the parts are mounted on a plastic card. The transistors are mounted on the card between the cylindrical capacitors. The one fastened to the right is amplifier V1.

Very thin plastic-covered flexible wire is used for the connections from the volume control, switch, microphone, and battery. Note that the transistors have been mounted with their cores at right angles to minimize undesired coupling. The transformer lead coloring is indicated in the schematic, to permit proper connections to be made with less confusion. If insulation should become excessive, replacing the leads of one of the transformer windings usually will correct it.

Howling due to acoustic feedback will vary whenever the earphone is held close to, and pointed at, the microphone. With the plastic ear plug attached, the earphone must be placed within 1 inch of the microphone to start the howl. The plug's narrow canal introduces some attenuation of sound, and without it whistling occurs when the earphone faces the microphone from 1 foot away.

Conclusion

Without apology, it should be pointed out that this instrument does not represent the ultimate in subminiaturization and low power drain that may be possible to obtain in transistorized hearing aids. Rather, it is an answer to a challenge to develop the smallest practical instrument that can be built from parts obtainable, which would use the readily available CK722 transistor, and which might reasonably expect a radian to duplicate with ordinary tools.
A miniature test unit which requires neither batteries nor power lines. It has several unique service applications.

M GET electronic and electrical devices have one circuit in common—the power supply. In some cases, the power supply consists of one or more batteries, and may include additional components such as a vibrator, transformer, rectifier, and filter components. In other cases, the equipment is "line-operated," and the power supply may include a power transformer, rectifier (whether a vacuum tube or "dry diode"), and filter components.

But the audio oscillator shown in Fig. 1 (together with its small earphone) is completely self-contained and requires neither batteries nor "line plug-in" for operation! All that is required for operation is a reasonable amount of light to fall on its face. While not quite "something for nothing," it is a close approach.

The unit shown is not an expensive "laboratory device" but a practical piece of equipment that can be easily duplicated by almost any technician or experimenter.

Its design and construction has been made possible by utilizing two semiconductor devices—a self-generating selenium photocell and a Fairchild type CK722 junction transistor.

Circuit Description

The complete schematic diagram for the light-powered oscillator is given in Fig. 2, while an interior view of the unit is shown in Fig. 3.

Referring to the schematic diagram, the transistor collector is connected to the primary of a small "Sub-Owner" transformer, T. The return load is connected to the "negative" terminal of the self-generating photocell, P9.

The transformer secondary winding is connected between the transistor emitter and, through coupling condenser C5, to the transistor base. R5 serves as a "base return" resistor and is connected to the negative terminal of the photocell.

An output signal is obtained through coupling condenser C9 and applied to a standard crystal earphone, the lower lead of which connects directly to the transistor emitter. The "positive" terminal of the photocell is also connected to the transistor emitter.

In operation, light striking the photocell generates sufficient voltage to drive a small current through a low impedance load (the maximum current obtained with the photocell shown does not exceed a few hundred micromicroamperes).

This current flows over two paths. Part of the current flows through the R5 and base-emitter path, establishing the "bias current" for the transistor. Another part of the current flows through the primary of T; and the collector-emitter path.

As is readily apparent, the transistor itself is connected in a modified "todler feedback" grounded-emitter oscillator circuit, with feedback obtained through the primary and secondary winding of T. Current variations in the primary winding cause a.c. variations in the secondary winding through magnetic coupling. The signal thus developed in the secondary is applied to the base-emitter circuit of the transistor, where amplification takes place, resulting in further variations in the primary current (since this is equal to the collector current).

The oscillation obtained continues as long as sufficient light falls on the photocell.

With the parts values shown, there is a certain amount of "blocking oscillation" action, with the result that the frequency of operation varies with large changes in the amplitude of light falling on the photocell (and hence with changes in the amount of generated current). When the model shown is held in sunlight and gradually turned so that greater amounts of light strike the photocell, the tone gradually increases in pitch, then suddenly changes over to a low frequency "buzz."

Good results can be obtained under incandescent lights, but when the unit is used under fluorescent lamps, the 60-cycle line buzz modulates the normal signal, with the result that a "buzz" is heard in the earphone.

Construction is fairly straightforward and no particular difficulty should be encountered by the skilled technician. However, a few special suggestions appear to be in order.

The author's model has been assembled and wired in a small plastic box (an old "pill box"). As is evident in the interior view, Fig. 3, the inside of the box is mostly "empty space."

A smaller plastic box had been available at the time of construction, the entire unit could have really been "miniaturized."
Either a larger or smaller case may be used by the builder, as he prefers. However, two points should be kept in mind when selecting the case—first, it should be large enough so that the photocell used can be easily mounted. Secondly, if the builder plans to mount the photocell inside the case (as the author did), the case should be of clear (transparent) plastic.

This brings up an important point—obtaining the photocell. All parts used in constructing the small unit are commercially available and can be obtained from the majority of wholesale electronics parts distributors—except the photocell. Two possible sources of supply are open to the experimenter, (a) he can salvag e a unit from a discarded or used photographic exposure meter, and (b) he can watch for "surplus" sale ads, where these units are sometimes offered at low prices. (Concord Radio, of New York, recently offered similar photocells at less than one dollar each.)

Once the photocell has been obtained, the polarity of lead connections must be identified. If these connections are not already marked on the photocell, a 0.1 ma. or 0.500 microammeter should be connected to the photocell and the unit held under a reasonably strong light. By noting whether the meter "walks" or "trends," the lead polarity can be quickly determined.

In the unit used by the author, the rear surface was positive and two narrow slits were cut in the front (or light-sensitive) surface formed the negative terminals.

When mounting the photocell, make sure that the light-sensitive surface faces in the proper direction. Also make sure that positive contact is made to the photocell terminals. This contact is preferably made through spring surfaces (phosphor bronze is good material to use for this). No attempt should be made to solder directly to the photocell unless special terminals are provided for this on the unit itself.

Although the transistor could be wired directly into the circuit, using its leads, it is suggested that a standard 5-pin subminiature tube socket be used (as shown in the model). This step is necessary because the short lead lengths used in subminiature wiring might result in the transistor being overheated during soldering.

However, if the builder does not have the proper socket available, and cannot easily obtain one, the transistor may be soldered into the circuit if special care is taken to hold each transistor lead during soldering with a pair of flat-nosed pliers (the pliers should be held on the "transistor side" of the soldered joint).

Both the transistor socket (where used) and the "Sub-Quint" transformer may be mounted simply by cementing them to the plastic case using either "Duro" cement or any general-purpose radio service cement. Other parts are supported on their own leads.

Adjustment

Once the wiring is completed, the unit should be checked for operation by placing the earphone in the ear and holding the completed oscillator near a reasonably strong light source so that light falls directly on the photocell.

If oscillation is not obtained, try varying the size of R1. If necessary, a 250,000 ohm potentiometer may be temporarily connected in place of this resistor and an adjustment made. The value is then checked and a fixed resistor of approximately the same value permanently connected in place.

Should it be impossible to obtain oscillation, even by varying the size of R1, reverse the transformer secondary leads (the two black leads, Fig. 2) and again check for oscillation. If necessary, again try varying the size of R1.

Where the last step does not permit oscillation to be obtained, it may indicate that the photocell is defective or "weak." Check this unit for operation by connecting a 0.1 ma. or a 0-500 microammeter across it and holding the unit under a strong light source; a current of at least 50 to 100 microamperes should be obtained, with as high as several hundred microamperes obtained from a readily sensitive cell.

In an extreme case it may be necessary to try another transistor; but, in general, this should not prove necessary. The author tried this circuit with a number of different transistors (of the same type) and obtained satisfactory results in every case.

Applications

While the light-powered audio oscillator, as shown in the photographs, is basically an experimental "gadget," the unit does offer a number of practical applications. For example, by providing a hand-key in the emitter circuit, the unit could be used as an extremely compact and inexpensive to-operate code-practice oscillator. The unit could also be used by a blind person to determine if a room is lighted or dark. Since the tone pitch varies somewhat with light intensity, this would provide some indication as to the amount of light in a room and as to the light source.

In addition to the applications of the audio oscillator, the use of "light-power" suggests many other possibilities. The author plans to eventually construct a small light-powered transmitter, a receiver, and possibly a small audio amplifier.

The reader can undoubtedly think of many additional applications of the light-powered audio oscillator, as well as other more general applications of light-powered "electronic" equipment.

Fig. 1. Schematic of audio oscillator unit.

Fig. 2. Internal view. Unit can be constructed in even smaller cabinet if desired.
JUNCTION TRANSISTORS FOR HIGH-FREQUENCY OSCILLATORS

By I. QUEEN

JUNCTION TYPE transistors are made and sold as low-frequency, low-power units. Catalog specs usually call for a certain minimum gain at 1 kc or perhaps 5 kc. No high-frequency specifications are given, but it is known that frequency response begins to drop early. Therefore it may surprise many readers to find that the junction transistor is efficient as an i.f. and r.f. oscillator. I have carried on many experiments with the CK722. Of several tested, all oscillated easily in the i.f. range near 400 and 500 kc. For most transistors tried, less than 1 volt was sufficient power supply. About half could oscillate above 1 mc. Those active units required about 3 volts at this high frequency.

Transistors cannot be made as uniform as vacuum tubes. All transistors are efficient at audio frequencies, but even then it is usual to choose a bias resistor for the particular unit in the circuit. At intermediate and radio frequencies the nonuniformity is even more important. Substituting one transistor for another may call for retuning, changing the applied voltage, or even redesigning the circuit. Often, the circuit must be designed around the transistor.

If you plan high-frequency experiments and if you have access to several units, determine which are most active at r.f. If the more sluggish transistors may be set aside for a.f. circuits. Fig. 1 is a typical circuit for a crystal oscillator. Fig. 2 is a self-controlled oscillator. The values shown were found to work well for the particular transistors used. The base resistor, voltage supply, and base capacitor may need adjustment for best operation of your particular transistor.

In Fig. 1, if no collector coil has to be tuned to approximately the crystal frequency. Due to transistor loading, the adjustment may vary with the transistor used. I obtained good results using a slug-tuned coil rather than a conventional capacitance-tuned tank.

The tank in Fig. 2 may be a single winding with an intermediate tap, or it may have two separate windings. The collector portion may be 3 or 5 times as large as the base winding. The windings must be correctly polarized. Connect them so that an electron starting out at the base will travel in the same direction around both coils to reach the collector. In other words, the windings should have the same effect as a single coil with an intermediate tap. Often, the collector tuning is desired instead of slug tuning, connect as shown by dotted lines in Fig. 2.

A broadcast oscillator coil is not suitable for a junction-transistor oscillator. Its frequency range is too high. Instead, use an antenna coil with primary. If you want a broadcast-band oscillator, a coil of the i.f. transformer also makes a good tank. If used as is, it generates a signal near 300 kc. By retuning this tank and reducing the coil turns, you can reach the broadcast band with it. For the same reason, i.e., the frequency is too high, core loss becomes too great. For example, if you hear signals at 600, 900 kc, etc., your frequency is 300 kc. This is a good idea to keep a milliammeter or microammeter in series with the battery during experiments on the transistor oscillator. It offers a means of measuring the input to the transistor, and can indicate if the circuit is oscillating. Maximum input to a CK722 is 5 ma, which is normally sufficient for a low-power oscillator. I obtained ample output in most circuits with an input of only 100 ma. In any case, the current is controlled by the base resistance and the applied voltage, and depends on the individual transistor. A lower base resistance increases the current input and the power output. An ideally, one amount of oscillating current differs from the nonoscillating flow. In a typical case, a current of 44 ma flowed when the circuit was oscillating. In the nonoscillating condition, the same circuit did not draw more than 2 ma. This circuit used a 470,000-ohm base resistance and 3 volts input. With a small base resistance, the oscillating value will be less than the nonoscillating current. For example, in the above circuit a 40,000-ohm resistor raised the oscillating current to 0.5 ma. When not oscillating, it climbed to 0.65 ma. In any circuit the oscillations may be killed by simply shorting out one or both tank coils.

Knowing the oscillating and the nonoscillating current values will save much time. For example, if you are trying to increase frequency by lowering the base current, you can have a better idea of whether oscillations are still present, which will tell you whether the frequency is between oscillating and nonoscillating. This shows that you are approaching the frequency limit at which the signal is just barely maintained. It is a most valuable thing to know about a self-oscillating tube oscillator. This is evidently due to the loading of the transistor itself. The base current variations are on the verge of dying out that the tone would disappear if you use too low a voltage on the transistor, or if you operate it too close to its frequency limit. It happened here during an experiment when I was using 50 volts on a transistor oscillating near 700 kc, and the r.f. signal was modulated by sputtering whistles and hum. The trouble was that I had my meter on the 40-40 range to measure the very low input current. On this range the meter has a resistance of 2,500 ohms. When I switched to the 1-ma range (100 ohms) the signal was strong. I was able to use pure unmodulated r.f. again.

The base resistance of a self-controlled oscillator has considerable effect on frequency. With one circuit I obtained a Frequency of 780 kc. The base resistor was 470,000 ohms and the base capacitor 500 μf. Changing the (Continued on page 106)
TRANSISTOR TOY OSCILLATOR

By G. E. KNAUSENBERGER

This is a simple device with a Raytheon CK722 pnp-junction transistor in an R. F. oscillator circuit. It can be used in conjunction with a home radio for monitoring any motion which involves capacity changes and thereafter shift in oscillating frequency of the transistor transmitter.

The oscillator, operated from a hearing aid battery, is enclosed in a rubber toy. A lead, acting as antenna, and sensing probe, extends from it. The device may be used for monitoring a baby’s rest. The toy is suspended from the rails of the crib, the lead with a pacifier at its end extended within Baby’s easy reach.

The home radio in a neighboring room tuned to give an audible beat with the transistor oscillator. As long as Baby rests, the beat frequency will not change. If Baby drops the pacifier or starts playing, rapid tone changes occur.

When the child plays with the toy itself and listens to the tuned in radio, “birdie-whistling” emerges from the loudspeaker, giving great enchantment to the child.

There is no danger connected with the operation; the device is rugged and of long operation time.

Circuit:
A junction transistor CK722 circuit in grounded collector amplifier connection is destabilized by a parallel tuned circuit in the base. Emitter bias is provided by a resistor, shunted a.c. wise in the base, therefore allowing one battery operation. Output is taken off on emitter side, where a capacitor-resistor combination contributes to a.c. destabilization and d.c. stabilization.

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TRANSISTOR PHONO OSCILLATOR

By EDWIN BOHR

The small transistor phone oscillator in actual operation.

Music and conversation can be broadcast over short distances with this tiny transistor oscillator. The basic circuit uses one transistor plus a few inexpensive components. An extra audio stage may be added for more amplification.

The idea that junction transistors are useful only at audio and low radio frequencies is fading away. Practically all 2N2422 transistors will oscillate in the broadcast band. Some will go as far as 3 megacycles. All of the transistors I’ve been able to get my hands on have worked in the phone oscillator circuit.

The first experimental circuits with transistor phone oscillators used a separate transistor amplifier to collecter-modulate another transistor oscillator. At least two transistors were necessary plus some sort of modulation transformer. The circuit evolved into a simpler one-transistor layout that performed better than the two-transistor circuit.

The circuit makes a single transistor do double duty as an audio amplifier and oscillator. The oscillator is grounded base and the audio amplifier is grounded emitter. Let us see how it works.

Fig 1—The basic oscillator circuit.

Despite small size, there is ample room for wiring.

All major components are neatly laid out for maximum compactness.
Circuit

Fig. 1 shows the oscillator alone. Except for resistors R1, R2, and R3 which stabilize the a.c. operating points of the transistor, the circuit is a simple type where feedback is tapped from the tuning capacitor rather than from the coil. This is a matter of convenience as permanency tuning can be used. Capacitors C1 and C2 bypass the r.f. around the battery and base resistor.

To also function as an audio amplifier, several extra components are necessary. (See Fig. 2.) The microphone is connected in the base circuit from the bias resistor R2. This resistor and also R1 must be bypassed for audio, as we must keep the r.f. feedback from going to ground too. The choke labeled ARC prevents this.

Resistor R4 stops a periodic blocking of the r.f. oscillator by the voltage developed across R1, R2. Two hundred ohms for R4 kills instability for all transistors, but 100 ohms is usually enough. The lowest value that prevents mistracking of the carrier is the most desirable since high values of R1 reduce audio gain.

Fig. 2—Diagram of transistor photo oscillator showing component values.

Some of the battery voltage is lost in the stabilizing resistors, so, up to 50 volts can be used without exceeding the transistor ratings. Thirty volts of course gives the greatest power output, but the circuit oscillates down to 12 volts, with 12 volts to 16 volts (subject to variations in individual transistors).

Construction

The oscillator chassis is a 2 1/2 x 1 inch piece of insulating board. The components are mounted by binding their leads through holes drilled in the board. As shown in the photographs, the electrolytics and coils take up the greatest amount of space.

The tuning coil and choke are both outside Fenn-Resist look units. Take off the cardboard sleeve over the looped winding and cut off the mounting bracket plus most of the form. The coil and coil form are then mounted to the chassis by pushing them into a block of fiber board. The block has a hole drilled in it the same size as the outside of the coil form.

Push the iron core all the way into the choke, otherwise the oscillator may not work at the lowest end of the tuning range. The iron core in the tuning coil is pushed in and out to adjust the carrier frequency. This way the oscillator can be tuned from about 600 kc to over 1 mc.

The transistor plugs into a hearing-aid tube socket. It is made into a three-socket by using one for the battery contacts.

Some switching of the on-off control switches was necessary to find the smallest inexpensive capacitors. Transistors C1 and C2 are 200-volt miniature units made by Arovec (type PHZ62). They cost about the same as regular capacitors. The electrolytics are Cornell Dubilier 15 mcfd.

A few precautions are necessary. Most of the transistor circuit polarities are just opposite to those of vacuum tubes. Note that positive sides of the electrolytics and battery go to ground. Disconnect the battery before the transistor is removed from its socket.

One end of the socket for the transistor has a raised identifying dot. The socket pin nearest the dot is wired to the collector circuit. This corresponds with the red dot on the transistor case. It certainly will not do the transistor any good to plug it in backward.

The antenna is a whip type, two feet long, mounted by a banana plug and jack. Any short wire can be connected directly to the collector. Longer antennas, plus those connected to the base through a 100 microfarad trimmer. With this trimmer, long antennas load the circuit a little heavily, but usually it will oscillate.

The complete photo-oscillator—batteries and all—is mounted in a 1/4 x 2 1/2-inch aluminum case.

Operation

To test, connect an earphone to the audio input and slide the iron core about halfway into the tuning coil. Next place a radio within a few feet of the oscillator and tune across the broadcast band. A "whistling" or "hissing" will be heard as the transistor carrier is passed over. If a whistle is heard, the carrier is heterodyning with a broadcast station. To cure this, find a quiet spot on the dial and tune the transistor oscillator to that frequency by moving the core. The oscillator will drift for the first few minutes, so let it operate a while before the frequency is set.

If the carrier motorboats, increase the value of R4. To get an idea of the tuning range of the oscillator, follow the carrier with an a.m. radio dial as you move the tuning plug 5/16 moved in and out of the coil. The two 300-microfarad capacitors may be changed to other values. If each capacitor is changed to 100 µf, the oscillator will tune from 1 mc to about 1.5 mc.

Tap on or talk into the earphone and the sound should come through the radio. There will be feedback unless the microphone is too close to the speaker of the radio. The microphone gives a pretty good impedance match to the transistor input, but it overloads and distorts easily on loud sounds. A 3-inch speaker connected through an output transformer to the oscillator makes a better microphone. Carbon microphones are suitable and much more sensitive. Carbon microphones must have a coupling transformer. A small flat-plate transformer will do. Fig. 5 shows a type.

Carbon microphone

3

Fig. 3—Circuit for carbon mike input.

Here the full side goes in how it is connected. The 6-volt side goes in the battery and battery and the 110-volt winding goes to the transistor.

Clarkson or Plaxton VR cartridges can be connected directly to the oscillator, but the modulation will be very low. An A.G. cartridge, because of its lower output, can just barely be heard. Crystal pickups are not satisfactory, even with matching transformers.

Parts for oscillator

Resistors:

1 10,000—1.0; 10,000—1.5; 100—50.

Capacitors:

1 .05 uf, midget; 2—2 uf, electrolytic; 1—.001 uf, midget; 1—2 uf, midget.

Mica capacitors 500—1 uf, 1—3 mf, 3—20 Microsoft, 3—100 uf, 3—1 mf, 1—30 uf, 10—20 uf; 2—50-uf, 2—25-uf, 2—15-uf, 2—10 mf; 2—3-uf, 2—2-uf, 2—1-uf, 2—0.1-uf, 2—0.01-uf, 2—0.001-uf, 2—0.0001-uf.

Chokes:

1—1200 microhi; 1—200 microhi. (Copper base.)

Amplifier

Once the oscillator is built you may want to add an extra stage of audio amplification which gives satisfactory operation with VR cartridges. An amplifier is shown in Fig. 4. Like the oscillator, the amplifier is d.c. stabilized. There is no need to make any circuit adjustments for individual transistors. The output of the amplifier is connected directly to the audio input terminals of the oscillator.

Conclusions

The photo-oscillator makes a very good experimental transistor project. The range is limited because of the low power, yet it can transmit a signal from room to room.
A SUBMINIATURE CODE PRACTICE OSCILLATOR

by LOUIS E. GARNER, JR.

In an earlier article, the author described the construction and use of a compact "pocket" sized code practice oscillator (1/2" Transistor Code Practice Oscillator, April, 1955, Bano & Teivision News). Although the unit described in the earlier article was quite compact, no real attempt was made to "miniaturize" it, except for a wearing aid type battery and the transmitter. All components were standard-sized, and the unit was intended to be used with a regulation hand-key and standard earphone.

Nonetheless, the author received a good deal of good-natured kidding from friends about the size of the oscillator. Such remarks as "why not build a vest-pocket sized oscillator" and "sure the oscillator is small, but the key and headphone take up too much space" were not uncommon.

Being human, a decision was quickly reached to build a code practice oscillator that was really small. On in which every part would be so compact that the entire practice set-up, oscillator, power source, key and headphones, could be easily fitted not only in a vest-pocket, but even in a watch pocket... and yet one which could be used for serious code practice, rather than a tiny "museum piece" destined to collect dust in a forgotten corner. It was also decided to design a unit which could be easily duplicated by any competent technician, using parts available through most of the larger mail-order electronic parts distributors.

The diagram shown in Fig. 1 along side a standard matchbox and a king-size cigarette. The entire code practice set-up is shown here, including the "key," the oscillator, the power source, and the headphone. The key, oscillator, and power supply are all within the small plastic box, with the hearing aid type headphone (and its cord) shown alongside.

As can be seen by reference to the schematic diagram of Fig. 2, the transis tor and amplifier are connected in a modified "topc" feedback grounded-emitter audio oscillator circuit, with feedback provided through the transformer T1. In operation, no current flows until the key is depressed... this eliminates the need for a separate "on-off" switch.

When the key is depressed, d.c. can flow over two paths. Part of the current flows over the base-emitter path, establishing the "bias" base current for the transistor. Another part of the current flows over the path consisting of the primary of T1 and the collector-emitter circuit of the transistor. The current drain on the power source depends primarily on the size of R1, not only because this resistor is in series with the base-emitter current path, but also because the amount of base current flow, in turn, determines the d.c. collector current flow. By keeping R1 large (10 megohms in the author's model) the current drain is kept small and long battery life is insured. The actual battery life, in normal use, should approach the "shelf" life of the cell.

Variations in the primary current of T1 are coupled through magnetic lines of force, to the secondary winding, where they appear as an a.c. voltage. This signal, in turn, is applied through the d.c. blocking condenser C1 to the base-emitter circuit of the transistor. The step-down turns ratio between the primary and secondary windings of T1 permits matching the low input impedance of the transistor amplifier stage.

The signal is amplified by the transistor and applied to the primary of T1. In this fashion, the basic condition of signal amplification with positive feedback is set up, and oscillation occurs. The output audio signal is obtained through coupling condenser C1 and applied to the Fash crystal earphone.

Construction Hints

All the electrical and mechanical components for this unit, except the earphone and its cord, are assembled in a small plastic box measuring 1/2" x 3/8" x 3/4". A somewhat larger case may be employed, if desired, and will make the wiring easier.

Although a metal case may be used in place of the plastic box, plastic is preferred as it simplifies insulation problems.

The general parts arrangement used by the author is apparent from the exterior and interior views of the oscillator. Figs. 2 and 4, respectively. Layout is not critical, however, and the builder may use any layout that will permit fitting the various parts compactly in the particular case used.

Mounting Parts: Only the two major components, the "Topc-SubTransistor" transformer and the Mallory RM-1000 mercury cell are actually "mounted." The other parts, i.e., the transistor, the two condensers, and the resistor are allowed to move or less "hang free." Actually, the wiring is sufficiently compact so that the pressure between parts when the case is closed is adequate to hold them immobile. The transformer is mounted by
emounting it to the case, using either Duro cement or general purpose radio engineer cement.
A small "L" bracket is used to hold the mercury cell in place, pressing it against the side of the case. This bracket also serves to make electrical contact to the outer shell (positive terminal) of the cell.

Wiring: Secure care must be exercised when wiring the oscillator unit, both to prevent damage to the transistor and to the plastic case. Because so little space is available for components, it was not found practicable to use a socket for the transistor; and soldered connections had to be made directly to the transistor leads.

If the builder uses a somewhat larger case, so that a little "extra" space is available, it is suggested that a socket be used for the transistor, and that the transistor not be installed until all wiring is completed. A standard 2-pin subminiature tube socket is suitable for the C6722 transistor (only three pins are used.)

For best results, a small "pencil" type iron should be used. Keep the iron well-tinned and clean. Tie each wire or component lead prior to making the final connection, and use quickly soldered lap joints.

The transformer secondary leads (black) should be arranged so they can be easily interchanged should such a step prove necessary during final testing of the completed unit. Once the oscillator wiring has been completed, and the unit tested, exposed connections may be effectively insulated by applying two or three coats of fingernail polish. Do not coat the negative terminal of the mercury cell, or the contact of the "key", however.

Assembling the "key": The construction of the miniature "key" is clearly visible in the photographs and in the side view sketch given in Fig. 3. Required parts are a small machine screw (preferably one having a smooth head), a small compression spring, and a nut to fit the machine screw used.

A small hole is drilled in the plastic case directly above the location of the mercury cell, and the key assembled so that contact is made with the negative terminal of the cell when the key is depressed.

Contact to the key is made by tapping a wire to the side of the machine nut. This connection should be made before assembling the key to avoid melting the plastic case.

For best results the threads of the machine screw above the section where the nut fits on should be filed smooth. Otherwise, there is a tendency to catch on either the spring or the sides of the hole (in the case).

The side of the nut facing the battery should be filed smooth to insure good positive contact each time the key is depressed as well as to reduce the thickness of the nut.

Testing And Adjustment

Once all wiring is completed, carefully check each connection to make sure there are no errors in wiring and that all joints are secure. Holding the earphone close to the ear, depress and release the "key" a few times.

If oscillation does not take place, try reversing the secondary (black) leads of the transformer (P1). It is important that these leads be connected correctly to insure proper phase of the feedback signal if oscillation is to take place.

Should it still be impossible to obtain operation, it may indicate that good electrical contact to the battery is not made when the "key" is depressed, or that the battery, transistor, transformer, or some other part is defective. Check each part in turn. Since it may prove somewhat difficult to properly check the transistor, all tests may be concentrated on other parts, excluding the earphone and cord.

In some instances it may be necessary to change the value of R8. Should this be the case, temporarily connect a potentiometer or resistance substitution box in place of R8, adjusting the value until oscillation takes place. Then install a fixed resistor having the appropriate value.

Because of the small size and construction of the "key" used this unit should not be used exclusively in learning the radiotelegraph code. A standard hand-key (which, if desired, may be connected in place of the mini- ature key) should be used for regular practice sessions in order to develop a good "Stix." Use the miniature key only for supplementary practice.

When using the miniature key, try to simulate, as far as is practicable, the normal hand movements used with a standard hand-key. One technique is illustrated in Fig. 4.

The oscillator is held lightly between the thumb and middle finger, with the forefinger pressing on the "key." Code is sent using a normal wrist motion, not the motion of the forefinger alone. In order to do this, the thumb and middle finger (holding the oscillator) are allowed to flex slightly so the key is depressed. A little practice will enable almost anyone to acquire this technique.
If you like to experiment with new, unconventional circuits, try this one. It is a subharmonic crystal oscillator using a junction transistor. It acts just like an oscillator with a crystal frequency between 75-125 kc. Crystals in this range are very expensive and not generally available. I am the same results with a surplus crystal in the 400-4000 kc range. The cost of transis- tor plate surplus crystal is actually less than that of a standard low-fre- quency crystal.

The circuit uses a 6CT7A transistor. This is the low-cast junction unit now available at most parts distributors. The crystal is connected between emitter and collector as shown in the dia- gram. If desired, it may be connected between emitter and base instead, re- sults being about the same.

The two coils are part of a 302-ke. I.F. transformer with about 30% of the turns removed from the primary (red-blue) winding. Without the crys- tal, this circuit looks and acts like a conventional Hartley (tapped coil) circuit. It generates a low-frequency signal with strong harmonics through the broadband circuit. The oscillator fre- quency is approximately 140 kc, and harmonics can be heard at 500 kc, 700 kc, 840 kc, etc. One or both trimmers may be used to vary the fundamental over a small range. Those self-excited signals will sound about 77 or 78. Those from any low-C oscillator will be shaky and susceptible to harmonics and other external effects.

To use this as a subharmonic oscillator, tune the circuit (still without crystal) so that the 77 is as low as possible. To use the 302 coil, you may make a low-frequency oscillator. For exam- ple, if you use a 315-crystal and want to use a 302-base subharmonic, set the oscillator to about 150 kc. You will hear harmonics at 500 kc, 700 kc, etc., etc.

When you insert the crystal into its socket, you will hear a faint or pur- sure "tuh" tone. It will suddenly be- come a much louder tone, regardless of hand capacitance.

If you insert either or both trimmers for maximum stability and output. A good test is to turn the battery on and off several times to see if the oscillations start each time. If you have a 400-kc crystal, and wish to build a 100-ke crystal oscillator, tune the I.F. trans- former to about 100 ke or slightly be- low. If 100 ke is too low for your transformer, you may need additional capacitance across the secondary for black-feeding (see dotted lines in diagram).

A single 1.5-volt penlight cell sup- plies sufficient power for the transistor. Its drain is low, so battery life should approach six months.

A few different transistors were tried, with the following results and some rather surprising results. All were good subhar- monic oscillators, and in each case the complete subharmonic oscillator harmonics were strong—well into the high-frequency region. For example, a 315-ke subharmonic generator (using a 3000-kc crystal) provided harmonics beyond 20 mc. For greatest output, connect the antenna lead of the oscil- lator to the receiver antenna post.

I arrived at this unusual circuit while experimenting with transistor crystal oscillators. I am not sure what the theory is, but the following may come close to the truth. Evidently the two coils in series act like a Hartley tank, tapped near the middle. The tank resonates near 125 ke, and may be adjusted over a narrow range by tuning either trimmer of the trans- former. This is the frequency which I have observed when the crystal is re- moved from its circuit. Now, one of the

Diagram of the subharmonic generator.\n
\[\text{[Diagram image]}\]

\[\text{[Diagram description]}\]

This case, at a subharmonic of the the crystal appears that the lower frequency oscillator is in a Colpitts oscillator field in the upper tuned circuit, and its feedback is set by emitter-base bias and base-emitter capacitance within the transistor. We think that the crystal oscillator is a Hartley oscillator with feedback due to the inductive coupling between the coils and only able to oscillate at 400 ke because of higher frequencies.

Not all transistors tried in the cir- cuit set alike. I tried three and all gave unsatisfactory results. However, one transistor generated much lower fre- quencies than the other two. For exam- ple, with the crystal removed from its socket, we have a self-controlled oscillator as already explained. Now with the tank values we have we would expect a fundamental frequency near 140 kc. This is what I observed when two of our transistors were used. The third generated only a frequency as much as 70 kc, and without changing the tuning of the transformer. Possibly this particular transistor is more active than the others. Evidently it acts as a "half-wave" as well as subharmonic generator. Other tests show that this transistor performs better than the others in high-frequency circuits.

The transistors which generate oscil- lators near 100 kc are used to gen- erate 200 kc from a 737-kc crystal. With a small coil in series with the transformer winding (black-green), we can reach 100 kc. This gives the equiv- alent of a 100-kc crystal oscillator when the 200-kc crystal is used. As for the transistors which oscillate near 70 kc, I am using this in a 135-kc crys- tal oscillator by plugging in a 737-kc crystal. With slight change in trimmer tuning, I have a 135-kc output. A few experi- ments with oscillators when I insert a 625-ke crystal near 70 kc.

If your transistor does not generate a fundamental frequency in which you can find the desired frequency, it's probably not capable of oscillating on the frequency at all.

Regardless of what actually makes one crystal "natural," there are many useful applications for it. A low-fre- quency 135-kc oscillator provides nu- merous stable clock points over the entire band. It generates standard frequencies on the amateur bands, and can be useful-metering. There's nothing to plug in and nothing to tune (since the transistor need not be matched). Also, if your oscillator does not start each time you switch it on (due to slugger effect), try the battery on and off a few times or simply disconnect and reconnect the transistor oscillator antenna lead.
The high efficiency of the Junction transistor and its ability to operate on extremely low d.c. voltages make possible many interesting low-powered devices hitherto unattainable in the electronic field.

A typical example is the miniature audio oscillator shown in the accompanying illustrations. It receives all its d.c. operating voltage from a self-generating photocell. An interesting fact to note is that both the active units in this circuit are semiconductor devices—the triode is a germanium transistor (CR722) and the power supply is a selenium photocell (International Rectifier Corporation Type DP-5 or equivalent).

In subdued room light, 0.02 millivolt r.m.s. is developed across 2,000-ohm magnetic headphones. A 100-watt lamp, 1 foot from the cell, gives a signal of 0.3 millivolt. From 1 to 3 millivolts can be obtained when the cell is illuminated by direct sunlight. All these signals can be heard easily in the headphones.

With the UTC type SO-3 Omcer transformer shown, the signal frequency is approximately 900 cycles and the waveform good. The frequency can be lowered by means of suitable capaci-

The oscillator has very little circuitry. Tuning values in parallel with the high-impedance winding of the transformer. If the reader does not have a sub-
microphone transformer available, any microphone transformer or line trans-
former (200 or 500 ohms to single or push-pull grid) will do the job. Con-
nect the high- and low-impedance wind-
ings as shown in the figure. Polarity of the windings is important, since the phasing must be correct for oscillation. If the device does not oscillate readily when the photocell is illuminated, re-
verse the connections of one of the transformer windings.

While this oscillator is a novel gadget, it is not as much of a toy as it might appear at first. For example, in one very practical application, the output signal (which is proportional to the amount of light falling upon the photo-
cell) may be amplified directly without the need for a conventional amplifier, and the amplified output may be rectified and caused to operate a d.c. relay or high-current meter. For this purpose, the headphones may be replaced with a 2,000-ohm re-
sister across which the input terminals of the amplifier are connected. In this way, one of the knottiest problems connected with self-generating photocells is solved—that of amplifying the low d.c. output of these devices. Stable d.c. amplifiers which might be used for the purpose are complicated, bulky, and expensive. The only previous alternative has been to chop the light beam to obtain from the photocell an "a.c." output which might be handled by a conventional amplifier, or to feed the d.c. from the cell into some sort of modulator whose a.c. output would be proportional to the applied d.c. This transistor oscillator converts the direct current from the photocell immediately into a.c. without light-chopping or modulation in bulky preamplifier equip-

A SIMPLE transistor oscillator circuit is shown in the accompanying dia-
grame. The constants given are for operation at approximately 1 ke. The wave-
form is excellent.

Resistor R1 determines the emitter current, hence the collector current. If the oscillator output is heavily loaded, R1 will have to be made a lower value than that specified. If it is lightly loaded, the value can be made higher.

Resistor R3 is used to limit the reverse collector current which flows when the collector end of the tuned circuit swings positive. If its value is too low, flat-tops appear on the positive peak of the wave.

If the value is too high, oscillation stops. The waveform is better at high values. The value of R4, depends on the load and on the "Q" of the coil. Use from 10,000 to 20,000 ohms with a high-Q toroid coil and from 0 to 1000 ohms with a low-Q choke.

The battery voltage is not critical. The drain is about .1 ma. with the values shown. The peak output voltage is about equal to the collector battery voltage. A crystal diode, with its "anode" po-
larized toward the collector, can be used to replace R4, but its performance is just about on a par with the resistor.

Operation is class C.

By RUFUS P. TURNER

By LOUIS CARCANO
I.F.-R.F. CRYSTAL OSCILLATOR USES JUNCTION TRANSISTOR

By I. QUEEN

I.F.-R.F. crystals are mounted on top

M

AY experiments have shown that junction transistors are effective only at audio frequencies, so they don't try to use them in high-frequency circuits. Actually most junction transistors have I.F. range, often beyond 1 mc. This crystal oscillator uses a CK722 junction transistor, and oscil- lates in the intermediate-frequency and radio-frequency range. It is equipped with an output control and is suitable for measuring, aligning, and calibrat- ing.

Fig. 1 shows the hookup. The trans-istor is powered by a pair of penlight cells that will last a long time. Provi- sion is made for two different frequen- cies: I used a 1-mc crystal (looks like a metal tube in the photo) and a 935-kc crystal (surplus type). Both crystals are left in the circuit at all times. Only the cells are switched. The circuit oscil- lates when the collector cell is tuned close to either one of the crystal fre- quencies.

Fig. 1 shows the layout. The output is to a pair of penlight cells that will last a long time. Provision is made for two different frequencies: I used a 1-mc crystal (looks like a metal tube in the photo) and a 935-kc crystal (surplus type). Both crystals are left in the circuit at all times. Only the cells are switched. The circuit oscillates when the collector cell is tuned close to either one of the crystal frequencies.

Materials for I.F.-R.F. oscillator

1—200-ohm, 1-watt resistor; 1—935-kc par- sul crystal; 1—435-kc crystal; 1—CK722 transis- tor (available by special order from radio parts outlets); 1—4-mc crystal; 1—435-kc crystal; 1—penlight cell; 1—5-volt battery; 1—penlight cells.

A single penlight cell is sufficient for the I.F. band. However, I found it ad- visable to use at least two cells for the 1-mc range; otherwise the oscillator does not start each time and the output is weak. Since transistors are not uni- form, you may find that still greater voltage is necessary for the r.f. oscillator. You may have to use 8 volts or more. However, on quick trial here, I found all frequencies satisfactorily. One even oscillated at 1 mc with less than 3.6 volts.

MINIATURE AUDIO-FREQUENCY TEST OSCILLATOR

By I. QUEEN

This tiny oscillator is self-contained except for lead) and is mounted inside a plastic box only 2 1/4 x 1 1/2 x 1/4 inches. The heart of the circuit is a 2N27 transistor, type CK722. It is powered by one A-4 dry cell. Output is strong enough to provide a good head- phone signal.

Audio feedback is maintained by a "Sub-Oscillator" 5:1 ratio audio transformer. Any other transformer may be used but will require considerably more space. If the "Sub-Oscillator" is used, fol- low the terminal connections specified. If another type is used, connect the low-impedance winding in the base circuit, the high-impedance winding in the collector circuit. If no oscillations are heard, try reversing connections to one of the windings.

The frequency is determined by the particular transformer used and the capacitor in series with the base. With

the circuit and constants shown in the figure the frequency is 1,500 cycles. To change the tone one uses a different value of capacitor. The frequency will vary (upwards) to some extent when the oscillator is used near a strong inac- customed lamp. For example, the fre- quency will rise to about 2 kc if a di- ward lamp is brought a few inches from the oscillator. A fluorescent lamp does not cause a perceptible change. Sun- light, even indirect, makes a consider- able difference in the frequency. Evi- dently the transistor is slightly photo- sensitive.

The oscillator was constructed to see how compact a reliable instrument could be. It is more than a mere toy. It may be used to test a.f. amplifiers or for long-distance "CW" communication by wire. It may be used as a source of known frequency (if shielded from light). It is easily carried about in a pocket to permit checking in code prac- tice during lunch hours or recess, or other spare periods. The efficiency of the CK722 transistor is astounding. In this circuit it con- sumes 5 microamperes. This is about .006 of 1% as much power as required by a sensitive high-frequency buzzer, or a low-power tube oscillator.

This oscillator contains an unusual degree of miniaturization. With an essentially small cell for power, the CK722 transistor, and the U.V.D. suboscillator 20-3 transformer (10,000-ohm primary, 90- ohm secondary), the unit can be easily handled.
Fig. 1. Over-all view of the home-built counter with its unconnected accessories (from left to right: coil, relay, push-button switch, "Microswitch", and push-button switch.

By LOUIS E. GARBER, JR.

Details on a versatile unit of many applications which features a compact, battery-powered transistor amplifier

Fig. 2. Rear view of the counter with the terminals and controls labeled.

There is probably not an industry or business in the nation that has not, at one time or another, been confronted with a "counting" problem of some sort. Manufacturing firms may wish to count the items passing a given point in a production line, department stores may wish to count the number of customers entering a certain door, a real estate firm may wish to count the persons visiting a model home, and almost every merchant has a good-sized counting job at inventory time. Although there are numerous commercial counters on the market, most units are designed to perform limited types of counting operations. In some instances, these limitations so restrict the applications of particular units that it is very often necessary to rely on "custom-built" counting devices. However, the counter and accessories shown in Fig. 1 combine to provide so many different types of counting operations as to be considered an almost "universal" counter. Not only will the instrument handle routine counting operations, where the closure of a simple switch is involved, but it will also "count" where the actuating signal is a small current, as might be obtained from a photocell or thermopile.

This extreme versatility has been made possible by combining the characteristics of a direct-coupled transistor amplifier, a sensitive relay, and an electromagnetic counter in one compact assembly.

The basic design is straightforward and fairly simple, so the average technician should have little or no difficulty in assembling a similar unit in less than a day's time. Once assembled, the technician may keep the counter for his own use, or sell it to firms requiring such an instrument.

Circuit Description
Reference to the schematic diagram given in Fig. 3 will show that the counter consists of three related but independent sections: a sensitive "electronic" relay featuring a transistor amplifier, a low voltage a.c. supply (F1), and an electromagnetic counter. The connections from each section are
brought out to separate terminals on screw-type terminal strips, permitting maximum flexibility in choosing a particular combination.

The "electrostatic" relay consists of a type CTKZ 5-p-s-p junction transistor connected in a grounded-emitter amplifier. A sensitive relay, $RL$, serves as the collector "load." Power is supplied by a 6 volt battery, $B$, controlled by power switch $S$.

Two modes of operation are possible, depending on whether the control signal is furnished through the closed circuit jack $J_s$ or "control line" terminals $A_s$. Closed circuit jack $J_s$ is used where the control signal consists of a small current (from 0 to 100 microamperes), such as might be furnished by a telephone. The "A" terminals are used where the activating signal is a simple closing (or opening) of a circuit.

Let us first consider the operation of the circuit where the "A" terminals are used, and where a simple push-button switch is used to close the circuit.

With power switch $S$ closed, a voltage is applied between the collector and emitter of the transistor. However, there is little or no current flow in this circuit since the base-emitter circuit is open (at the "A" terminals) and base current flow cannot take place. Thus, relay $RL$, remains open.

Let us discuss each section push-button is depressed, shutting the "A" terminals together, base current can flow over the path consisting of the negative terminal of the battery, switch $B$, and through the shorter "A" terminals, $R_s$ through jack $J_s$ (now closed), the base-emitter of the transistor, and back to the positive terminal of the battery. This base current flow permits a corresponding collector current flow. Relay $RL$ is then closed and held in until the push-button is released and a biasing base-collector current is applied to the collector current flow.

Relay $R_s$ is used to limit the maximum base current flow, while $R_s$ is used to set the current flow to a fixed value within this maximum limit.

If the external switch is normally closed ("A" terminals shorted together), the action is just the reverse. Relay $RL$ is normally held closed, and "drops out" when the external circuit is opened.

Let us now consider the action of the circuit when a current generating device is plugged into the "control line" jack $J_s$. Since this is a closed-circuit jack, inserting a phone plug immediately disconnects $R_s$, "A" terminals, and the $R_s$ circuit.

Two conditions may exist. The external current generating device may supply a current only when the "counting" operation is to take place, or it can supply a current at all times, with the current dropping sharply or ceasing to flow when "counting" occurs.

In the first case, the relay will normally remain open, closing only when current is supplied to the base-emitter circuit of the transistor through $J_s$. In the second case, the relay will close and "hold in" until the current supplied through $J_s$ is appreciable.

Since the base-emitter current of the transistor is supplied solely by the external circuit, the source should be capable of supplying at least 250 microamperes, and should not supply more than 5 ma. If there is a possibility of the current supplied by the external source exceeding 5 ma, an external current limiting resistor should be provided.

A "typical" current generating device that might be plugged into $J_s$ in an ordinary self-generating (harrier type) selenium photo-cell. Another such device could be a heat-operated thermocouple in series (parallel connection of several thermocouples to obtain greater current).

In any case, the connection of the external device to the photo plug should be such as to apply the negative terminal to the base of the transistor. See Fig. 5.

The low voltage a-c, supply is the next version of the "universal" counter to consider. This consists simply of a 6.3 volt transformer (22), a line cord, a power switch (part of $S$), and a pilot light.

The electromagnetic counter is a commercial unit having "reset" provision and operation in 6 units.

An a-c-operated supply was not provided for the transistor amplifier circuit for several reasons. First, there is no real need for such a supply, with normal use, battery life is quite long (due to the small power required of the thyatron). Secondly, the battery supply permits completely independent operation of the transistor amplifier and relay circuit. This allows the circuit to be used alone or for control purposes without requiring line connections. Finally, providing an a-c supply would needless overdrow on already well-filled cabinet.

Construction Hints

The general layout used in the author's model is clear from the exterior, back, and interior views of the instrument, given in Figs. 1, 2, and 4, respectively. The entire counter circuit has been assembled within a standard bud sloping panel utility box. The electro- magnetic counter, the 6.3 volt transformer (22), the power switch ($S$), and the pilot lamp socket and jewel are all mounted in the "cabinet." All other parts, including the relay, transistor, phone jack ($J_s$), and battery are mounted on the back panel. The Mul-

![Fig. 5. Schematic diagram of the counter.](image)

![Fig. 6. Interior view of the instrument showing components mounted on panel.](image)
Adaptation and Operation

Correct the wiring is completed and checked, the counter may be tested for proper operation. The first step, however, is to identify the various screw terminals on the back panel. The connections used in the author's model are apparent when Figs. 2, 3, and 6 are compared.

Without plugging the line-cord into a wall socket, turn the instrument "on." Next, with Rs set in its maximum resistance position, temporarily short out the "A" terminals (Fig. 3). Gradually adjust Rs until the relay (RL) clicks as it is pulled in. Remove the short from the "A" terminals and the relay should drop out. If the outlined action is not obtained as each step is carried out, it indicates either a defective part in the normally to be held closed, and to open for each count, the armature (Arm.) and "normally closed" (NC) contacts are used. This connection is shown in Fig. 6B.

A minor circuit modification: The electromagnetic counter used is also available with a 115-volt coil. If the builder prefers to use the 115-volt unit, the transformer (T) may be omitted from the circuit. The pilot light may then either be left out or a 115-volt unit used instead.

Should the builder decide to use a 115-volt coil, a cover should be arranged for the back panel of the instrument to avoid accidental short circuits or electrical shock from the exposed terminals.

Applications

As mentioned previously, the position of the various accessories may be altered to suit his own requirements. The "universal" counter is not limited only by the imagination and requirements of the individual user, but the group of four shown with the counter in Fig. 1 should give the reader some idea of the possibilities.

Fig. 5. How the photocell, one of the accessories, can be connected to count.

By rearranging the various control units, the circuit or an error in wiring. Carefully review all connections and parts.

Once the relay circuit is operating properly, the rest of the counter may be checked. This will require connecting the electromagnetics counter, 6-volt a.c. power source, and the relay circuit together properly. Use the relay contacts to switch the a.c. voltage so that it is applied to the electromagnetics counter whenever a counting operation is to take place.

Two connections are possible, and both are illustrated in Fig. 6. If the relay is normally to be held open, and to close for each count, the armature (Arm.) and "normally open" (NO) contacts are used. This connection is shown in Figs. 2 and 6A.

A typical example where this connection might be employed is where a push-button switch is across the "control line" ("A" terminals), with a count being registered each time the button is depressed and released.

On the other hand, if the relay is

Assembling the Accessories

The versatility of the "universal" counter depends not only on the counter circuit proper, but on the choice and use of various accessory "control" units. While the number of possible accessory control units is limited only by the imagination and requirements of the individual user, the group of four shown with the counter in Fig. 1 should give the reader some idea of the possibilities.

Reading from left-to-right, the accessories shown in Fig. 2 are as follows: (a) selenium photocell, (b) mercury switch, (c) "Microswitch," and (d) pin-button switch.

The photocell is typical of a current generating type of accessory and is equipped with a phone plug to fit in the proper "control line" jack (A). The selenium cell used is of the type employed in exposure meters. It has been mounted in a small plastic box. The connections for the photocell are given in Fig. 5.

The other three accessories are typical of "simple switch" controls. Each has been equipped with a short flexible line and spade lugs, for easy connection to the screw-type "A" terminals (see Fig. 3).

Typical applications of these accessories will be discussed later.
TRANSISTOR-OPERATED PHOTOCELL RELAY

By LOUIS E. GARNER, JR.

Construction details on a simple unit which has many uses in the home or shop. Power requirements are low and cheap.

Fig. 1. Overall view of author’s unit. A discarded exposure meter cell was used.

While battery-operated, self-contained photocell relays are certainly not new (see “A Photocell Index” by R. J. Vangelos-sang, Popular Science MONTHLY, August, 1953), the unit shown in Fig. 1 does possess several unique features. First, no resistors, coils, transformers, condensers, or vacuum tubes are used in its construction. Secondly, a single inexpensive, comparatively low voltage battery is all that is required for its operation and this is contained within the small housing shown. The battery life is fairly long, due to the low current drain.

All these features are made possible by the use of a self-generating photocell, together with a direct current transistor amplifier. Only a few parts are required for the device, as can be seen in the schematic diagram (Fig. 2), and the interior view given, Fig. 8.

Circuit Description

The operation of the circuit may be easily followed by reference to the schematic diagram of Fig. 2. The Raytheon DG11 transistor (“pnp” type) is the “heart” of the device, and is connected as a direct-coupled grounded emitter amplifier. This serves to amplify the weak current obtained from the photocell sufficiently to operate the relay.

As long as no light falls on the photocell, the base current of the transistor is essentially zero and negligible collector current flows through R2, which remains open. When light is allowed to fall on the photocell, a small base current starts to flow, permitting a corresponding increase in the flow of collector current through the relay. The collector current is several times greater than the base current, with a current amplification of ten comparatively easy to achieve.

As the light intensity increases, base current and collector current also increase, until the current through the relay is sufficient to close it.

If the light intensity falls off, a corresponding decrease in base and collector current is obtained. However, the relay does not open until the light level drops appreciably, since less current is required to hold the relay closed than is needed to close it. Under normal conditions, the base current does not exceed the collector current and does not exceed a few milliamperes, while the collector current must not exceed a few milliamperes.

The collector voltage is supplied by battery B4, with switch S provided to open the collector circuit when operation of the unit is desired.

Thus, only five electrical components are used in the entire device—a photocell, a transistor, a relay, a switch, and a battery.

Construction Hints

With the simple exception of the photocell, all the parts used in building the device are easily obtained from radio-electronic wholesale parts distributors. A “self-generating” photo-cell may or may not be available at a particular distributor, depending on local demand. Although this item is commercially manufactured, not all supply houses have sufficient demand for the item to warrant stocking it. The photocell used by the author in building the model shown is a seleniunm cell salvaged from a defective exposure meter of the type used in amateur photographic work. These meters consist of the basic photocell together with a microammeter. Since the meter movement is most susceptible to mechanical damage than the photocell, it is sometimes possible to pick up a “defective” unit in which only the meter movements is damaged—the photocell is virtually in perfect condition. In most cases, the cost is negligible. Even where it is necessary to purchase an exposure meter in “operating” condition, the price of a used unit is likely to be quite low. A used but operating unit offers the further advantage of supplying the experimenter with a sensitive microammeter for other work.

A certain amount of ingenuity may have to be exercised by the builder in mounting the photocell, depending upon its actual shape and size—some are round, others square, and still others rectangular. The one used by the author is shown in Fig. 5. In mounting the photocell properly, it is best not to attempt to solder leads to it. Use spring contacts made from phosphor bronze or similar material. If a commercial unit is used, it will generally have leads or terminals provided.

No special precautions are necessary when assembling and wiring the circuit, and the builder may follow his own inclinations as far as layout is concerned. The unit shown in the photographs was housed in an old shield box, but almost any type of housing may be used—a plastic or wooden box, a small metal utility box, or even a small chassis, with a bottom plate used as a “cover.” A hole must be provided for the leads, of course, to permit access to the inside.
strike the photocell. Generally, no lens will be required unless the builder wishes to increase the over-all sensitivity somewhat by concentrating light from a large area on the cell, using a good quality lens.

The effect of light striking the unit from a side angle can be reduced either by using a lens ahead of the photocell or by mounting a closed tube in front of the cell, as shown in Fig. 3. The curvature of the tube should be finished in dull black to reduce interior reflections. The tube has not been used in the model shown in the photographs.

For Substitutions: A toggle, lever, rotary, or almost any type of switch may be used in place of the slide switch employed in the model. A lock switch is particularly good for this application, as it permits the owner to turn the unit "on" or "off."

Other relays may be used in place of the one specified in the parts list. When choosing a substitute relay, pick one having good sensitivity. The relay should have a reasonably high coil resistance and should draw on less than 5 ma. However, the so-called "plate" relays are not suitable for use here due to their high coil resistance, requiring much higher supply voltages for proper operation. Best results will be obtained with sensitive relays having a coil resistance of 3000 ohms or less.

In general, the more sensitive the relay, the more sensitive will be the complete device (requiring less light for operation). If other relays are used, they may be found possible to use a supply voltage of less than 15 volts.

In any case, the choice of a battery should depend on the intended operation of the unit. A hearing aid type battery (Burgess U10) was used in the model and is given in the parts list. This particular battery was chosen because of its low cost, ready availability, and reasonable life under the low current drain required by the device.

Where the unit is to be used in an application requiring extreme battery life, a larger battery might well be employed.

Adjustment and Operation

Once the wiring has been completed, a milliammeter should be connected in series with the relay and the unit turned "on. Light should then be permitted to fall on the photocell. A marked increase in collector current should occur, as indicated by the milliammeter reading. If this increase does not occur, reverse the connections to the photocell. Base current must have the correct polarity.

Next, the relay's sensitivity must be adjusted so that the relay closes when light is falling on the photocell and opens when the light source is interrupted. Use a focused light source supplying the same amount of light as will later be used in the intended application. The relay's sensitivity can be changed by tightening or loosening the tension on the armature spring and by adjusting the armature's position relative to the core piece.

Be sure sufficient light is employed, the sensitivity of the completed unit may vary considerably, depending on the photocell used, the relay used, the adjustment of the relay, and other factors.

In the model built by the author, the light obtained from a 3-cell flashlight held two to three feet away from the opening in the housing was sufficient to operate the relay. This light fell through a 1/4" diameter round hole in the housing to strike the photocell. Because of this, only about half the photocell's area was used. Greater sensitivity could have been obtained by using all of the photocell's active area. The set-up employed in this test is shown in Fig. 4.

Applications

The applications of the photocell relay described in this article parallel the applications of photoelectric relay units in general, although there is somewhat greater versatility because operation is possible anywhere (special power is not required) and because of the small size possible in assembling a complete unit. However, a number of possible applications might be of interest to the reader, and may aid him in selecting or devising similar applications of his own.

In considering applications for the photocell relay, the device can be considered as a switch that performs any one of the following functions, depending on how the connections to the relay contacts are made:

1. To open a circuit when light strikes the photocell.
2. To open a circuit when light striking the photocell is interrupted.
3. To close a circuit when light strikes the photocell.
4. To close a circuit when light striking the photocell is interrupted.

Irrespective of the connections chosen, it is best to supply power to operate the external device from a separate power source, rather than to attempt to use the small battery in the photocell relay circuit proper.

A few possible applications follow, but these should, by no means, be considered a complete list.

Brighter Lights: The light source and photocell relay may be arranged...
TRANSISTOR CONTROL RELAY

A tubeless gadget for remote switching with radio, light-beam, or magnetic-field control

By EDWIN BOHR

NOTE
Use of a CK-705 germanium diode in place of the EN-34 is recommended

THE HEART of this tubeless remote-control relay is the new Raytheon CK-722 junction transistor. It will operate garage-door openers, lighting circuits, or alarms, or will perform almost any type of switching operation. The relay can be operated by a photo-cell, radio signal, thermocouple, or any device that will furnish 0.0025 watt of power.

Many transistor-operated circuits have been more novel than practical. We assure you this one is entirely practical—for two reasons. First, this transistor relay fills some honest-to-goodness everyday applications. Second, it costs only a little more than most vacuum-tube operated circuits.

Fig. 1—Basic P-N-P junction-transistor relay circuit. Relay operates only when a positive signal or pulse is applied to the emitter electrode of the transistor.

The total cost of the unit—including the transistor—was only $13.15.

When you consider that the transistor will probably give years of service without attention, with negligible power consumption, also its ruggedness and small size, the transistor-operated circuit in this instance is a real buy.

Basic circuit

The basic circuit is shown by Fig. 1. Note that no bias is applied to the emitter circuit. Under these conditions only a few microamperes of collector hole current will flow through the relay. This type of operation is similar to heating a vacuum tube to cutoff. With this P-N-P transistor, however, zero bias cuts off the emitter current and any further negative bias produces no effect.

The transistor will pass only the positive half-cycle of an a.c. input signal or a positive-polarity d.c. signal. These are desirable features in a relay circuit.

Since the current amplification of a junction transistor is a little less than 1 (see "Transistors," by John R. Pierce, in the June Radio-Electronics), the power gain of the unit depends on the resistance of the relay in the collector circuit. For a given current change through the transistor, the voltage change across the relay coil depends on the coil resistance.

A relay with a high-resistance winding will operate on a much lower current than a low-resistance relay. But a 10,000-ohm relay, for example, that will operate on one milliampere of current, requires 10 volts across the winding, or a power input of 10 milliwatts. It is difficult to get this much voltage and power from a radio control signal, but it is entirely practical with low-frequency magnetic fields.

The transistor will amplify a signal current with a small voltage change to a much larger voltage change across the relay coil. A 10,000-ohm relay in the collector circuit will give a power gain of about 10. As the relay resistance is increased, the supply voltage

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A TRANSISTOR TIMER

By LOUIS E. GARNER, JR.

A "natural" for the photo lab, this timer requires no external power source and offers a wide selection of timing intervals.

MOST electronic timers suffer from two disadvantages—they require a source of line voltage and they become extremely warm when left on for any length of time. Both disadvantages result from the necessity of using vacuum tubes and comparatively high voltages.

Although the necessity of having line voltage available seems like a small problem, occasions do arise when it is desired to control (turn "off" or "on") battery-operated or portable equipment over pre-determined time intervals.

The second disadvantage mentioned is of real importance in some applications. Anyone who has worked in a darkroom in summer soon realizes that any heat is too much! Yet it is in the photographic darkroom that a large percentage of electronic timers are employed.

With these problems in mind, an effort was made to design a timer that would meet the following specifications:

(a) Simple in construction and wiring;
(b) Easy to operate;
(c) Completely self-contained, using no line power;
(d) Generating as little heat as possible;
(e) Rugged, yet compact.

The result is shown in Fig. 1.

The timer shown in Fig. 1 is reasonably small (over-all dimensions of the case are 5" x 4" x 3") and lightweight, requires no line voltage, is easy to operate (only three transistors—"Power" switch, "Reset" button, and "Time Control"), generates virtually no heat in its operation, and yet is fairly simple to wire (refer to the schematic diagram of Fig. 2).

All of these features have been made possible by employing a Raytheon Type C8722 Junction transistor as a control element in place of the usual vacuum tube and providing for battery operation. Battery life is unusually long, since the maximum current drain is only slightly over a milliampere, and this only for short periods. In fact, the battery life should equal the normal "shelf life" of the units.

Circuit Description

The operation of the circuit is not at all complex, as can be readily observed by reference to the schematic diagram of Fig. 2.

In operation, when the "Power" switch, S1, is closed, current can flow through R5 and R9, charging condenser C9, and permitting a momentary surge of base current. The base current flow, in turn, permits collector current to flow, closing the relay.

As soon as condenser C9 is charged, the current flow over the R5, R9, C9, and the base-emitter path ceases. The drop in base current flow to virtually zero results in a correspondingly drop in collector current flow, permitting the relay to open or "drop out."

The time period in which the relay "holds in" depends on the period of collector current flow, which, in turn, depends on the period of base current flow, and hence on the time it takes condenser C9 to charge. This, in turn, depends on the time constant of C9, R9, and the base-emitter impedance.

If any of the parameters in the RC charging circuit thus formed are changed, then the time interval may be changed. In practice, an adjustable time interval is obtained by using a rheostat for R9, keeping R5 at a small value simply to limit base current flow and hence to protect the transistor. However, if fixed time intervals are desired instead of a continuously adjustable control, a single fixed resistor may be used in place of R9. R5, and different values of C9 chosen by using a conventional selector switch.

Once the unit is "set-up" for operation as described, the desired "timing interval" is selected by adjusting R9. The "Reset" switch, S2, is then depressed, shorting out and discharging C9. When the "Reset" switch is released, C9 starts to charge again and the relay closes, opening again after C9 is charged. The timing interval may be repeated as often as desired simply by depressing and releasing the "Reset" button.

The layout and parts arrangement used by the author are readily seen by referring to the interior and exterior photographs of the model, given in Figs. 3 and 1, respectively. As is easily seen, no attempt was made to create a "pretty-looking" model and hence there is no crowding of parts. Because of this, wiring the unit should be simple, even if the builder is not highly skilled:

Leads can be any length desired, and the builder may use either "point to point" or "right-angle" wired, or a combination of both, as he prefers.

Although the author wired the transistors directly into the circuit soldering the leads, the builder might prefer to use a socket. An ordinary 5-pin flat subminiature tube socket is employed. The builder may follow the author's practice, however, take care to keep the transistor leads at least an inch long and do the soldering as quickly as possible to avoid overheating and damaging the transistor. Use the same "safety rules."
that are followed when working with germanium diodes.

The author’s model was assembled in a standard box “Mini-box” (2” x 4” x 3”), but the unit may be built in any way preferred by the reader. A plastic box, given a wooden box, might well be employed.

Should the reader wish to incorporate the timer circuit in some other piece of equipment, the entire assembly may be easily wired on a flat mother board or on a small sub-chassis.

Inexpensive “rubber feet” were provided in the model shown by using thick rubber geomets, mounted in holes drilled in the back of the “Mini-box”.

The batteries were mounted by using a flat metal strap and two long 6-32 machine screws.

Parts Substitution

Although the relay used by the author is moderately expensive, it is positive-acting, quite rugged, and can handle currents up to 5 amperes at 117 volts a.c. (ample for almost all uses). A less expensive or a more expensive relay may be substituted by the builder if desired; however, the following considerations should be kept in mind:

The relay should be positive acting. Among relays tried by the author, none, such as a spring that the armature moved slowly from the “front” to the “back”, lacked in the collector current dropped. Where a reasonable load is connected to the contacts, such slow movement would cause excessive arcing and plating of the contacts.

The relay should be reasonably sensitive. A “very sensitive” relay is not required in this application. However, the relay should be capable of closing on five milliamperes or less, since 5 ma. is the maximum rated collector current for the CK72 transistor.

Battery voltage should be adjusted for the relay coil resistance and sensitivity. The relay used by the author has a 500 ohm coil, requiring 5.3 volts d.c. to operate, hence the six volts provided by the battery is ample (there is little drop in the transistor when conducting). However, if a different relay is used, it may be necessary to use either greater or less battery voltage.

Resistor R, is used primarily to limit base current and hence, size is not too critical. As little as 500 ohms may be used here, although the larger resistor is preferred.

With the components specified in the parts list, the timing range is from slightly less than three to slightly less than ten seconds, ample for most photographic enlargers, timing, when using a 15 psi regulator. Shorter time intervals may be obtained by using a small condenser in place of C1, while longer intervals may be obtained by increasing the value of C1.

The timing range of another model, even with different parts values as given, may be found to vary somewhat from the values given due to tolerances in components. Such variation should be considered normal and not as an indication that any part is defective or that writing mistakes have been made.

Black decals were used to label the model. “Factory-built” appearance was obtained by spraying three coats of plastic on the front panel after applying the decal labels.

Operation and Adjustment

No attempt was made to calibrate the main “Timing Control” in the model. However, the average luidjer will undoubtedly wish to calibrate the control soings. This may be done accurately by using a step within which the relay clicks and marking the dial settings accordingly.

If a step watch is not available, reasonably accurate calibration may be obtained by using a "one-second" countdown—one-pause—two-pause—three—pause—four—pause—five, etc.

To use the unit, the following procedure may be employed:

1. Connect the switch leads of the equipment to be turned "on" or "off", to the proper relay contacts.
2. Turn on the “Timer” and wait until the relay drops out.
3. Set the “Time Control” (R,) to the desired time interval and press the “Reset” button. If another time interval is desired, press the “Reset” button a second after the relay has dropped out. The interval may be repeated as often as desired simply by pressing the “Reset” button each time operation is desired.
4. If a different time interval is desired, wait until the relay “drops out” (that is, until the unit is ready for recycling) and set the “Time Control” to the new time, pressing the “Reset” button to initiate operation. If the setting is from a longer to a shorter time interval, the “Time Control” should be moved slowly back, to prevent a current surge that may cause the relay to close.

If the relay specified in the parts list is employed, it should not be necessary to change the manufacturer’s adjustment. If another relay is employed, however, some change either in spring tension or in armature position might prove necessary.

In general, the armature spring tension should be adjusted so that really positive action is obtained. If it is necessary to increase the spring tension to accomplish this, it may also be found necessary to change the armature spacing with respect to the pole piece in order to regain sensitivity.

The relay’s sensitivity may be increased by adjusting the “front” and “back” contacts until the armature is moved closer to the pole piece. Sensitivity is reduced by moving the armature away from the pole piece (increasing spring tension, or both).

Applications

One major application of a timer is in photographic work. In this field, the timer is especially valuable when making a series of identical prints. Once the proper time interval has been determined (using test prints or an enlarging meter), the timer may be set to this interval, and any number of additional prints made, almost "automatically".

The relay contacts are simply used as a switch to turn the enlarger or printing box "on" and "off". Still another application of the timer is in scientific work and in chemistry, where it is desired to turn a heater (Continued on page 118).
RADIO CONTROL CIRCUIT

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With the development of the RK61 thyratron, Raytheon made a tube available to radio control hobbyists, which would operate reliably with a very simple superregenerative circuit. This tube has seen rather extensive use in the radio control field. The useful life of the tube is governed principally by the amount of plate current drawn during operation. This indicates the desirability of a D.C. Amplifier following the RK61 circuit, permitting the thyratron to idle at a lower value of plate current and yet retain sufficient relay current change for reliable operation. Several such circuits have been developed in the past using vacuum tubes. These circuits increase considerably the size of the radio control receiver and require increased battery weight due to the filament current requirements of two tubes.

The CK722 transistor seemed a very logical choice for a much improved D.C. Amplifier which would overcome these disadvantages. Exhibiting a current gain on the order of ten, it would permit the RK61 to idle with a plate current of less than 0.5 ma.

The next task was to apply the CK722 to the basic RK61 circuit with a minimum of additional components, for such a receiver when used in a model plane or boat must be compact and require a minimum of batteries.

The final circuit is shown in figure 1 and requires only the addition of one electrical component other than the CK722, to the basic circuit. The base of the transistor is connected through R7 to the plate circuit of the RK61 and the emitter is returned to B+, resulting in the plate current of the RK61 serving as bias current for the transistor.

The relay is located in the collector circuit and is returned to the mid-point of the two 22½ volt batteries, thereby supplying the necessary negative potential for the collector. It is necessary that Ry have a resistance of at least 5000 ohms in order that collector current of the transistor be held below its maximum rated value. J4 facilitates metering this circuit for tuning and relay adjustment. Adjustment of R6 results in a reduction of the RK61 plate current such that its idling value is on the order of 0.4 ma.

The CK722, exhibiting a current gain on the order of ten, produces a collector current, under these circumstances, of approximately 4.4 ma. Upon receipt of a signal the plate current of the RK61 drops to 0.1 ma and the transistor collector current is now down in the vicinity of 1.4 ma.

We now have a current change available for
relay operation which varies from 4.4 ma (signal off) to 1.4 ma (signal on), a difference of 3 ma.

This compares with a current difference of 1.4 ma for the RK61 circuit alone. The idling current of the RK61 has been reduced from 1.5 ma to 0.4 ma which will extend its useful life many times. In order to accomplish this it is only necessary to add the CK722 transistor and R2 to the basic RK61 circuit.

**PARTS LIST**

C1—4-30 mmf ceramic trimmer capacitor
C2—18 mmf ceramic capacitor
C3—100 mmf ceramic capacitor
C4—0.05 mf 200V paper capacitor
R—3 megohm 1/4 watt
R—25,000 ohm subminiature pot.

L—8 turns #14 wire 1/8 inch dia.
3/4 inch long-tapped 2 1/2 turns
from plate end. (6 meter band)

J—subminiature phone jack
Ry—5000 ohm sensitive relay
RFC—3/16" dia. 3/8 long form wound full
#36 wire close spaced

S—D.P. S.T. Switch
A SELF-POWERED TRANSISTOR

C. W. MONITOR

One of the salient features of transistors that make their use attractive for radio transmitter control and auxiliary equipment is the extremely low power requirement for their efficient operation. It is this attribute that has made possible the compact, reliable instrument described in this paper. The unit should prove especially interesting to the amateur radio C W operator, and is intended to augment a growing number of monitoring schemes which use vacuum tubes and power supplies. One popular device is currently described in the Radio Amateurs Handbook, 30th Edition, p. 237-238; and utilizes a power supply, type 6J5 swapping tube, a NE-2 saw-tooth generator, and 6SL7 mixer-amplifier.

The unit described here is simple and effective. A Raytheon type CK-705 or 1N66 Germanium crystal diode provides the necessary d. c. voltage from the R. F. pick-up line for the proper operation of the CK-722 transistor A. F. oscillator. The oscillator is capable of driving a 3" PM loud-speaker to comfortable volume. A length of 5" pick-up line placed within ¾" of the 4D32 power amplifier in the author's transmitter (a Viking 1), and fed through shielded line to the unit serves to drive the oscillator to full output. A gratifying observation made of the transistor oscillator in action is its clean make-break characteristics which make it a pleasure to listen to the unit. This is in sharp contrast to the inferior keying characteristics of the V/T sidetone oscillator which it has replaced.

CONSTRUCTION DETAILS

The transistor monitor is self-contained in an ICA sectional box, 1½" x 2" x 4". The layout is straightforward and requires nothing more than good wiring practice. Before mounting the output transformer, the mounting lugs must be filed in close to the mounting holes to allow it to be installed as shown. There is just sufficient clearance for size 6/40 hex nuts between the transformer and sides of the chassis. Be sure, also, to solder a 3" lead to the #3 terminal (bottom) of the secondary winding before mounting the transformer.

A common ground tie point for all return circuits is essential. The first model of the monitor depended upon the box for ground returns for the coax connectors, R. F. choke, and the transformer. Operation of the unit was quite erratic, and the oscillator was affected by hand-capacity. However, all grounds were brought to a common tie-point in the final model, and the unit is now completely stable.

The base resistor used with the transistor is 15,000 ohms, ⅛ watt. With the
transformer used, this value proved to be optimum, combining usable output, a tone frequency for minimum listening fatigue (870cps), and excellent starting characteristics. However, a transformer of different characteristics from that shown may require a base resistor of higher or lower value best determined by trial. In any case, the value should not exceed 30,000 ohms, or be less than 8,500 ohms. A miniature 25,000 ohms variable resistor in series with a 8,500 ohm fixed resistor would provide continual adjustment if desired. However, this unit is installed inside the TVI enclosure of the Viking transmitter, and is therefore fixed.

It is recommended that the 2.5-mh R. F. choke shown be used in duplicating the unit. A 1-mh R. F. choke was used in the development model to conserve space, but the developed d.c. voltage from the germanium diode dropped appreciably on the V4 and 28-nc frequency bands. Replacing the choke with the 2.5-mh value shown provided uniform d.c. voltage throughout the range of the transmitter.

INSTALLATION AND ADJUSTMENT

The monitor may be conveniently mounted with transmitter enclosures provided ambient temperatures do not exceed recommended upper limits for the transistor. Sufficient R. F. pick-up may be derived from a 300-ohm twin lead by coupling a length of lead to the monitor. Scotch electrical tape provides a neat and effective means of fixing the pick-up to the twin lead.

Adjustment of pick-up should be made carefully, since permanent injury to the transistor is possible by over-coupling. First, a pair of head-phones is connected to the output jack. The R. F. pick-up, consisting of shielded single conductor cable, or coax (RG-59/U) of suitable length with the shield braid stripped back about 5" from the end is fitted to the input jack. With the transmitter loaded to rated output, the pick-up is carefully moved into the R. F. field of the power amplifier. The oscillator will operate as the final tank or tube is approached, and volume will increase as the pick-up is moved closer to the final tube or tank. It is here that care should be exercised. If head-phone operation, or coupling to the receiver A. F., is desired, adjust the distance of the pick-up from the final tank for the desired volume level. For loud-speaker operation with the unit shown, coupling is adjusted until the d.c. current to the emitter reaches 0.5 ma. This is adequate for the output connections shown, and is ample volume. For the Viking I, a ¾" cone insulator is mounted at one of the 4D32 socket mounting holes, a ¾" x 5" threaded rod is screwed into the top of the insulator, and connected to the monitor by shielded line. The output of the unit drives a Utah 3" PM speaker.

This device performs a most useful function without the penalty of supplying additional power to the unit.
DIAGRAM OF SELF-POWERED TRANSISTOR MONITOR

![Diagram of Self-Powered Transistor Monitor]

PARTS LIST

R1 - 15,000 ohm, 1/4 watt, comp. res. (IRC)
C1 - .01 uf, 300-v, disc. ceramic fixed cond. (Erie)
C2 - .02 uf, 200-v, paper cond. (Sprague)
X1 - CK505 Germanium Diode (Raytheon)
Rfe - 2.5 mh rf. Choke (National R-100 S)
T1 - Output Transformer (Hallidarnson HVAT-4)

I1 - Phone tip jack, ceramic insulated, (ICA)
I2 - Single conductor mike connector (ICA)
I - Sectional box, 1 1/2"X2"X1" (ICA)
I - Terminal strip, 5-point (Cinch)
I - CK722 Junction transistor (Raytheon)
TRANSISTOR KEYING MONITOR

Easy to construct, and easy to use, the monitor makes for clean keying

By I. QUEEN

ANY c.w. operators monitor their keying by listening to the blocking of the receiver or to the clicks of the key. These methods are O.K. when sending at slow speeds but are definitely no good when sending at 15 words per minute and higher speeds. Receivers often block for periods long enough to convert a dot into a dash and make the operator stumble over his own feet. Using a bug without a keying monitor is one sure way to make the other fellow break off the contact with some weak expanse like QRM, QRN, or gots QRT for chow.

This keying monitor makes it possible for you to follow your own keying with ease so you are more relaxed and can really enjoy the contact. Your keying will be cleaner and the follow on the other end will find it easier to copy and won't be so easy to run off and work someone else. It is so easy to construct and use that no c.w. man should be without one.

The circuit is essentially an a.f. oscillator with trigger characteristics. No positive emitter bias is used, so the transistor tends to remain blocked. If a positive signal energizes the emitter, the transistor begins to conduct. Current flows in the high-resistance base circuit. Due to the voltage drop in this circuit, a positive bias is placed on the emitter. The transistor, once conducting, tends to remain that way.

The base resistor is adjustable. It may be set to a minimum value, so that triggering is only temporary. Then the circuit oscillates only for an instant after its emitter is energized. Removing the external signal permits oscillations to die out at once and the transistor blocks again. This is the correct adjustment for a keying oscillator. The monitor is coupled very loosely to a transmitter-antenna or final tank. When the key is pushed down, the strong i.f. field triggers the transistor and a tone is heard. Retaining the key stops the tone. I didn't need a crystal to rectify the r.f. field. Evidently the periodic disturbance of the r.f. keeps the circuit triggered and operates the oscillator. This circuit will follow dots up to any speed Macay can transmit.

Few adjustments or controls are needed. Finding the proper resistance between switch and ground may require a little experimenting. I found 350,000 ohm O.K. If it is too high, oscillations will continue with the key up. If too low, the circuit may not oscillate.

The base resistor varies tone. It also determines trigger conditions. Near zero, the transistor will be too critical. It will oscillate at the slightest touch of the headphones. Results are best with about 4,000 ohms in the base circuit.

The transformer is the type used in a TV vertical blocking oscillator. It measures 220 turns across the palmway (between GE and BR) and 1,600 ohms across the secondary. There is no reason why high-quality audio transformers should not work in this circuit.

I have used this monitor on all bands with a low-power (50-watt input) transmitter. The only coupling procedure required is to wrap the short insulated lead from the emitter once or twice around the antenna. Placing it near the final tank also works fine.

Schematic of transistor keying monitor.

Materials for Keying Monitor

Resistors: 1-220 ohm; 4½ watt; 1-4,000 ohm; 1½ watt

Capacitors: 1000p cap, 500p cap

Miscellaneous: 1-500,000 blocking oscillator type G.E.S; 1 long A.G. tube, 6-216 or 6-256; 1 short A.G. tube, 6-262; 1 fixedunity transformer; 1-300,000 unity transformer

This instrument can also serve as an excellent a.f. oscillator. The base resis-
tor varies tone over a fairly wide range, almost 3 octaves. With a larger resistor, the variation is even greater. If much use is to be made of this unit as a generator, it might be better to add a switch to disconnect the high resistance. This will do away with the trigger characteristics and permit the transmitter to oscillate at all times.

This circuit has another curious characteristic, mentioned earlier. When used as a trigger circuit, you will find that the instrument is sensitive to mechanical shock as well as acoustical and r.f. signals. For this reason, turn the tone control as near to zero as you can without oscillations. Now, if you tap the headphones over so lightly, the circuit will be tripped and oscillations will be heard. Speaking or whistling into the phone will do the same thing. Once oscillations begin, they may be stopped by turning the tone control. Or, by returning the tone control to maximum. This resets the trigger.

Most c.w. men take pride in their sig-
nal quality, and this transistor keying monitor will enable them to hear themselves as others hear them. Its compactness and ease of installation make it a valuable instrument.
A TRANSISTORIZED AUDIO FILTER
FOR AMATEUR RECEPTION

An audio filter which will select or reject one audio frequency is a handy accessory to a receiver which is to be used in today's crowded amateur bands. On CW it will boost a desired signal or reject an undesired signal. On phone it will reject heterodynes which will be present until all amateurs switch to single sideband suppressed carrier. The audio filter takes the place of the crystal filter in a receiver which does not have one and supplements it in a receiver which does have one.

A vacuum tube circuit, popularly known as the select-o-ject, which will select or reject one audio frequency has been described in the literature, 1,2,3 and the circuit described here uses the same basic principle with Raytheon CK-722 transistors as the active circuit element. The transistorized version has the advantage that it will run for a long time on its self contained battery and therefore the only connection necessary to the receiver is to plug the filter into the headphone jack.

A UTC SSO-1 is used as an input transformer in case the filter is to be employed with a receiver where the headphone jack is connected to the output of the first audio stage. The transformer steps down the high impedance of the audio stage to the low impedance of the input of a transistor stage. One volt on the high impedance side of the transformer gives good volume in the headphones. The transformer can be omitted if the receiver has a low impedance output feeding the headphone jack. In this case padding will probably be needed between the receiver and the filter.

The amplifier consisting of JT1, JT2, and JT3 includes a variable phase shift network and will give a phase shift of 0° at one selected frequency and a different phase shift but relatively constant gain at all other frequencies. When the switch is in the reject position the output of this amplifier is combined with the output of the stage consisting of JT4 which gives 180° phase shift and constant gain at all frequencies. When the reject control is set so that both channels give the same gain at the selected frequency, that frequency will be canceled out in the load. In the boost position the stage consisting of JT4 gives regenerative feedback which will be maximum at the selected frequency. The selectivity can be varied by the boost control and is greatest at the point where the circuit is about to break into oscillation.

JT1 is a split load phase inverter. It should be noted that when this circuit is used with a transistor it will not give perfect balance because there is a finite input current into the base and most of this current will flow in the emitter circuit because the emitter resistance is much lower than the collector resistance. This balance is not as...
important as some authors think; if the balance were perfect and the frequency response of the amplifiers were completely flat, the boost or reject control would not have to be readjusted when the frequency control was changed. The author has found that these controls do have to be readjusted even in the vacuum tube version in which precision resistors are used in the phase inverters.

JT2 is another split load phase inverter but here the input is returned to the emitter to increase the gain of the stage and to improve the balance by preventing the input current from flowing through either of the load resistances. Transformers are used between each phase shift network and the next transistor to present a high impedance to the output of the network and to match the input of the transistor.

JT3 drives the headphones and also provides an output of phase voltage for JT4 when the switch is in the boost position. In the boost position, JT4 gives another 180° phase shift so that the output of JT4 will be in phase with the input and therefore give regenerative feedback at the selected frequency. In the reject position, JT4 drives the headphones in addition to JT3.

It is important in the boost position that the stages have sufficient gain so that the device can be made to oscillate and in the reject position it is necessary that all stages have low distortion so that harmonics of the undesired frequency will not be produced. Such harmonics will not be filtered out when the fundamental is filtered out and the usefulness of the device will be reduced.

The transistorized audio filter is a useful accessory to an amateur receiver and is a good starting place for the amateur who wants an introduction to the newest active circuit element.

REFERENCES

Any amateur can now have a transistor frequency standard at low cost. Simple, stable, with no warmup drift, this unit runs continuously off its internal flashlight cell.

THE availability of "p-n-p" junction transistors has opened many interesting possibilities in the field of compact test equipment. One example of such equipment is the small frequency standard to be described here. Although compactness is in itself a virtue in the crowded ham shack or service shop, the low power consumption of the transistor provides an additional benefit, of value in the fixed station as well as for portable operation.

Consider a typical a.c.-powered frequency standard used for locating band edges, calibrating receivers and v.f.o.'s, and for checking service-type signal generators. It contains a recifier tube, a 100-kc crystal oscillator, and perhaps a multivibrator to produce markers at 10-kc. intervals. It consumes about 30 watts, and runs hot because it is built in a small box. As a result, its frequency drifts as it warms up, and its multivibrator may have to be readjusted to compensate for circuit-element changes during the heating cycle. A better design with a sufficient provision for heat dissipation would improve matters.

This transistor frequency standard is powered by a 1.5-volt cell. The unit is compact and portable. COMPRESSED AIR-TO-HEAT SINK

Notice that the transistor band spotter has no power cord and needs no ventilation holes. The terminal posts, junctions, transistor, etc., give an idea of its size.

The Band Spotter

By PETER G. SULZER, W3HPW

should operate the unit for years, and therefore an "on-off" switch is not required. Since the band spotter operates at all times there is no warmup problem, and an accurate frequency calibration is available at all times, particularly if there is no hot equipment nearby. An additional point worth mentioning is the lack of a power cord to add up to that ever-growing "tree" at the power outlet.

The band spotter contains a 100-kc crystal oscillator and a 10-kc synchronized bucking oscillator, each using a "p-n-p" junction transistor. Two outputs are provided at 100 kc: a clipped sine wave at Terminal 1, which provides usable recover-calibration markers, up to 30 mc, and a sine wave at Terminal 2 for oscillator frequency comparison. The 10-kc output at Terminal 3 is a 1-microsecond pulse having strong harmonics beyond 20 megacycles.

The "P-N-P" Transistor

In order to discuss the circuits used in the band spotter, a brief and much simplified description of the "p-n-p" junction transistor is in order. This type of transistor contains a small (0.08 inch by 0.12 inch) by 0.005 inch thick) wafer of "p-type" germanium. It will be recalled that most of the conduction in an "n"-type semiconductor takes place via electron flow, in contrast to the "p"-type, in which conduction effects occur through the flow of holes (where electrons are missing in the crystal structure). A small dot of indium is placed on the two opposite faces of the wafer, which is then heated, permitting a portion of the indium to diffuse into the germanium. In this manner the diffused portions of the germanium are converted to the "p"-type. The heating process is continued until the thickness of the remaining "n"-type ger-
The diagram shows the construction of the crystal oscillator and the associated electronic components.

The text, however, is not legible and cannot be accurately transcribed.
piller of higher input impedance is obtained. The current, which depends critically upon the value of v, may be 10 or more, while drift values for the input and output impedance are 1000 ohms and 100,000 ohms respectively.

It should be pointed out that the basic circuit is identical to the phase reverse, as does the grounded-cathode circuit. The properties of a small voltage-amplifier are the same. The current of 1000 ohms connected between grid and cathode resemble those of the high -powered transistor, although the transistor will operate with a much smaller power supply.

The base-driven connection is used in the crystal oscillator and blocking oscillator in the band spotter.

Considering the crystal oscillator, one might be tempted to "borrow" the conventional Miller vacuum-tube oscillator, connecting the crystal, considered as a parallel- resonant circuit between the base (grid) and ground, and tuning the collector (plate) with a parallel-resonant circuit. Perhaps a small feedback condenser might have to be connected between the collector and base to make it oscillate. It will not oscillate, though, because of the high-Q resonant circuit, which shorted the high parallel-resonant impedance of the crystal. Fortunately here the design engineer has recourse to the useful concept of duality, which suggests that grid voltages should be required by emitter (or base) currents, and parallel-resonant circuits should be replaced by series-resonant circuits. This is easy here because the crystal can set as a series-resonant circuit, and therefore it is simply connected in series with the transistor base and the rest of the circuit. The maximum feedback is obtained at the series-resonant frequency, where the crystal impedance is minimum, and the base current is maximum.

The rest of the circuit could consist simply of a phase-reversing transformer, which could have a one-to-one ratio. Such a transformer was not readily available and, therefore, a collector choke L, condensers C1, C2, and parallel circuit LC, were used to obtain a practical circuit necessary for positive feedback. The voltage across C is nearly sinusoidal because of the filtering effect of the tuned circuit LC. The small condensers C1, C2, and parallel circuit LC, were used to couple to Terminal 1 through a similar arrangement of series and parallel tuned circuits. These condensers have strong harmonics throughout the high-frequency range.

The operation of the blocking oscillator is analogous to that of a vacuum-tube blocking oscillator, and can be understood by the following factors. For the inductor, collector current flows when the emitter is positive with respect to the base or, since the grounded-emitter connection is used, collector current flows when the base is negative with respect to the emitter (providing, of course, that the collector is also negative with respect to the base).

Suppose now that C is charged so that the base is positive with respect to the emitter. The collector current will be cut off (or nearly so, if it is a good transistor), and C will discharge through R and R, until the base goes slightly negative with respect to the emitter. Emitter and collector current will then flow, and a regenerative action will take place through the blocking-oscillator transformer T, which is connected to produce a phase reversal. A heavy collector current flows, and the voltage across C builds up very nearly equally to that of the supply voltage. At this point the charging current must decrease since the change in C, has reached its maximum value. The transistor is soon cut off and the conditions existing at the start of the cycle have been restored. Since the charging cycle is much shorter than the discharging cycle, the voltage across C, is of saw-tooth form. A sinusoidal synchronizing current is coupled to the emitter by C, and it is the purpose of one of the half-cycles of this current to initiate the regenerative charging action slightly in advance of its normal time, thus effecting synchronization.

The small condenser C isolates the blocking oscillator from load changes at Terminal 3.

Conclusions

The details of parts layout and mounting are shown in the photograph. The box is 2½" by 3" by 4" deep. The depth could have been decreased by ½" inches by using a tunneling aid mercury cell in place of the flashlight cell and by removing the blocking-oscillator transformer from its case.

The transistors were mounted by means of bolt and retaining lug. Although some transistors should last as long as the rest of the equipment, and therefore do not require any change.

The holder was hanged in a piece of sponge rubber to decrease the effects of shock, and mounted by means of a metal "strap."

Looking at the internal-view photograph, the crystal oscillator, using a CK721 transistor, is toward the far edge, although the top of the crystal holder is visible at the lower right. The crystal Oscillating factor may be determined in this unit. It will be noted that several leads are soldered together on the edge of one of the chokes, L, in the foreground. This is the junction of C, C, R, and the transistor base. It is not one of the connections of L itself. It so happened that an extra bolt in the choke base made a convenient pivot for the stop positions.

Adjustment

In setting up the crystal oscillator, the crystal and L and C, should be disconnected, and the current through L should be measured. If it is much less than the normal value of 100 microamperes a resistor R, (shown dashed in Fig. 1) should be connected and adjusted to obtain 100 microamperes. Next, the crystal should be connected directly between the base and the emitter, a large variable condenser substituted for C1, and C2 adjusted to produce the maximum output as observed at Terminal 2. The frequency should then be checked, and if it is high an inductor, L should be connected in series with the crystal and the frequency adjusted to zero beat with WIV. For this test the receiver antenna terminal should be connected to Terminal 1. A small condenser C across L will facilitate the initial adjustments while C is used for the final (external) frequency trim.
Transistor–Varistor Modulator for low-level audio

Semiconductor unit gives excellent results

By ALBERT H. TAYLOR

The pickup is applied in push-pull between the two secondaries and bypassed for r.f. The bypass capacitors are essential to carry the r.f. current of the rectifiers. If they reduce the audio fidelity, try in their place series-resonant circuits with smaller capacities, tuned to the carrier frequency.

To provide the necessary d.c. path for the rectifiers, the primary of an Output type push-pull output transformer from a BC-347-A interphone amplifier serves as a center-tapped audio choke. It has a resistance of 600 ohms. A pair of resistors would probably do if they did not load the pickup nor throttle the rectifiers. The output load resistor is not critical and satisfactory modulation with little change in level takes place with anything from wide open to a direct short through the receiver's antenna coil or an r.f. choke. Too low a resistance probably loads the pickup but I can't say I missed any highs in a broadcast receiver.

I generally use a 10,000-ohm resistor and a 200-mfd coupling capacitor to avoid misalignment. A d.c. voltmeter across the output conveniently indicates oscillation and reads about 0.5 volt with the coil turns I am using. The output impedance is so low that if I make another unit I shall use more turns on the twin secondaries for a high-carrier-to-sound ratio in the diodes.

Construction

Any small metal box will make a good chassis — I found that of the BC-347-A single-family. Simple wiring keeps the transistor oscillator signal where it belongs and no shielding is necessary between oscillator and modulating sections. The only critical job is making and mounting the r.f. transformer, but it can be done very nearly without special tools. If you are afraid of it, try Fig. 2 instead of Fig. 1. You may get away with using an unshielded, stock receiver antenna transformer if you trimmers from the bridge corners to the live side of the secondary.
spaced from this mark. They are wound with the Litz wire that comes with the Loopstick, which is just enough for the two 5-turn coils with a little over for leads. I wove them as Turk's heads to hold them in place till they could be lipped. Then I plugged the open end of the form with a wad of cotton and then-dipped the completed coils into the wax, also dipping the butt of the Loopstick to hold it onto its dowel.

The Loopstick primary L1 and the twin secondaries are held to their brackets at identical heights by wood screws in the dowels. They must fit accurately and squarely so as not to bind when the secondaries travel back and forth.

In the assembled modulator (see photo) the transformer takes up a great deal of room because the Loopstick must be kept away from large pieces of metal. If it gets too close, the oscillator coils. A single screw holds the bracket of the Loopstick at one end of the case, while the long-footed bracket of the secondaries at the other end has two 10/32 screws tapped into it which travel in slots in the case, parallel to the axis of the coil. A 1-inch 10/32 adjusting screw through the end of the case is tapped into the moving bracket and is turned from the outside to move the secondaries gradually. A rubber band between the brackets pulls against the screws to take up backlash, and the moving bracket may have to be centered by a pinjig unless the guide screws are set up hard after it has been set. The oscillator stops and starts if the bracket makes intermittent contact. To the coil leads to convenient points and have slack for motion. Match the polarity.

Band Conversion
This modulator can be used as a frequency changer or converter if the r.f. input, suitably filtered against spurious responses, is applied in place of the audio. The by-passes would then be tuned to the local oscillator frequency. Fig. 2 appears a little better suited for this job.

Both this and the tube modulator save tuning elements and radiation varies by connecting directly to receivers. Both may be used readily by tuning the outputs. The low-inductance transistor-varistor modulator should be tapped down on the tank circuit. In the tube modulator the tank circuit would replace the plate lead varistor, with small c.f. chokes in place of the extra resistors if finer balance is needed. But be careful! My father worked New Zealand from Washington, D.C., way back then, with just two 201-A's.

References

Fig. 3—Cross-section of transformer.
Transistor AM Test Oscillator

An extremely small and portable instrument for servicing radio receivers

By EDWIN BOHR

This pocket-size, battery-operated, transistor-oscillator generates four spot frequencies for testing and servicing AM receivers. The frequencies are 60 kc, 300 kc, 1 mc, and 1.4 mc. These signals may be modulated or unmodulated. In addition, the oscillator will supply an audio signal for testing audio stages. The oscillator, in combination with a volt-ohmmeter, will link just about any AM service job.

The oscillator is fine for L.F. alignment, testing front-ends, and trouble-shooting by signal injection. In contrast to signal tracing, signal injection makes the receiver under test supply all the amplification. Where a signal tracer must have many stages of amplification and a loud speaker, the signal injector may be a one-stage oscillator.

For signal-injection testing, hold the oscillator in one hand and move it from stage to stage, starting from the output tube and moving forward into the L.F. and R.F. stages. The troubles is located immediately behind or in the stage where the signal disappears.

Intermediate-frequency stages can be aligned with the 455-kc signal. Tracking is checked at the standard test frequencies of 600 kc, 1 mc, and 1.4 mc. And remember, the entire oscillator fits easily into a pocket watch pocket.

Test Oscillator

The instrument (Fig. 1) uses a single CL722 junction transistor. At audio frequencies this transistor operates on even less than 1 volt. However, at broadcast frequencies, most CL722 transistors require at least 15 volts. They are not designed to operate on the broadcast band at this voltage, the operation is sometime erratic, so a 22.5-volt battery is used for the collector supply. This voltage assures easy oscillation and larger interchangeability of transistors.

The four test frequencies are obtained by switching capacitors across the collector tuning coil L1. Coil L2 is a tickler that feeds energy back into the emitter where it is reamplified by the transistor.

Fixed micro capacitors shunt the tuning trimmers for the two lowest frequencies. This "handshakes" the trimmer tuning and makes the calibration adjustment easier.

Switching C3 across R1 produces audio modulation of the r.f. carrier and the audio test signal. The frequency of this modulation varies with individual transistors and may vary from a slow shift to several hundred cycles. The more actively the transistor oscillates, the lower the frequency of the modulation. If the frequency is too low, the oscillator will put harmonics all across the broadcast band when switch S2 is in stop position. This is not always desirable. The modulation frequency in this case may be raised by decreasing the value of C3. The 1-kc choke prevents the r.f. signal from bypassing to ground when C3 is switched in.

An oscilloscope of the oscillator's AM carrier is shown in Fig. 2. The output of the AM carrier, greatly in excess of 100 µv, the r.f. is periodically blocked off completely. A. D. oscillations do not appear on the microphone until the oscillations stop. The oscillator is then biased to return to a higher positive bias as C3 recharges. When this bias reaches a safe enough value, the r.f. oscillations begin again. The positive emitter bias comes from a divider network R2 and R3. Capacitor C6 has appreciable reactance compared to the emitter input impedance. Therefore, should you wish to operate the oscillator at frequencies lower than 450 kc, the value of C6 must be increased accordingly.

When the frequency selector is rotated to any of the four spot frequencies, the unit is turned on. A fifth contact in the circuit. With this arrangement, the operator is more likely to turn the oscillator off and not run down the battery.

A simple jack serves for both the audio and r.f. test signals. The jack is isolated from the transistor circuit by C5. Since the output is taken from the low-impedance emitter circuit, the oscillator is virtually immune to loading effects. No ground jack is included to ground the oscillator to the circuit being tested. The reason is this: If the oscillator case were grounded and the oscillator output jack were accidently connected to a high-voltage a.c. line in the receiver, there might be enough signal coupled to the emitter, through C5, to damage the transistor.

Construction

The design of a good layout for small pieces of electronic equipment is more difficult than seems obvious. A 1 1/2 x 2 1/2 x 3 1/2-inch aluminum case houses the oscillator. Volume-wise there is adequate space, but the size and shape of the parts is such as to oppose arrangement. If the oscillator is built in the same size box that I used, follow the drilling details of Fig. 3; this is the only way the parts will fit. Some aluminum cases are made from 1/16-inch stock; others are made of less rigid stuff.

The measurements of Fig. 3 are based on a 1/16-inch wall thickness. Other boxes may require a slight revision of these measurements to compensate for a different thickness.

The largest component is the selector
Several of the parts are mounted to the case under the chassis board (Fig. 5). The loose wires from these parts are soldered to appropriate tie points on the chassis board once it is in place and mounted to the switch.

Calibration and use
An easy way to calibrate the oscillator is to tune it with a communications receiver. Ordinary broadcast receivers are usually too poorly calibrated. The 455-kc spot could be set by adjusting it until the second harmonic is picked up at 910 kc. Another way to set the 455-kc trimmer is to feed the oscillator output directly into the I.F. stages of a receiver and adjust the oscillator until it generates a 455-kc signal. If this procedure is followed it is advisable to short out the oscillator section of the receiver beforehand.

There are many stations on 600 kc, 1 mc, and 1.4 mc and at least one station can be received on each of these frequencies. These stations can be used for calibration. For example, tune in a 1400-kc station, turn the transistor oscillator knob to the 1.4 position, and turn the 1.4 trimmer all the way in. Now back off the trimmer about 1/4 to 1/2 turns. The oscillator should be heard as it passes 1400 kc. Place the modulation switch in the on position and slowly adjust the oscillator trimmer until it zero-beats with the station. All the trimmers will be adjusted within a turn or so of complete closure when they have been tuned to their proper frequency.

The accuracy of the 600-kc adjustment can be ascertained by checking the 600-kc harmonic at 1200 kc. Also, the third harmonic of 455 kc falls in the broadcast band at 1355 kc. For most work with the oscillator, the calibration (Continued on page 106)

Fig. 5—Components mounted to case.

Fig. 6—Front-panel view of test oscillator.
Heterodyne Frequency Meter
uses pair of Transistors

A frequency meter using junction transistors has none of those disadvantageous features that have led to the following desirable advantages: (1) Complete isolation and portability. (2) Small size. (3) Light weight. (4) Practically zero drift. (5) Low-frequency operation from a single battery. (6) Instant operation. (7) No microphonics. (8) Long battery life with small loss during accidental left-on periods. (9) Infraror “tube” replacements, since the transistors are believed to have a life of tens of thousands of hours. (10) Ability of the instrument to take rough handling without damage.

The basic instrument

The heterodyne frequency meter is well known to commercial radio operators who use it to measure transmitter carrier frequency. Having used this instrument for many years, I am aware of the benefits and drawbacks. The heterodyne frequency meter is a simple instrument used in radio-frequency laboratories where it is used to check the frequency of crystal oscillators and signal generators and as a frequency divider. It is a simple instrument used in radio-frequency laboratories where it is used to check the frequency of crystal oscillators and signal generators and as a frequency divider.

The block diagram in Fig. 1 shows the basic arrangement of a heterodyne frequency meter. The r.f. oscillator and an inherently stable circuit tunable over a single frequency band. Its output is fed into an audio-frequency detector or mixer together with the test signal to be measured. The oscillator and test signals (or some harmonics of one or both) produce a beat note whose frequency is amplified by the audio amplifier and monitored with headphones or a visual indicator. The r.f. oscillator is tuned to zero beat with the reference signal and the frequency is read off the oscillator dial. The dial may be directly calibrated in Hz.

The test signal frequency may be lower than the fundamental frequency range of the oscillator. Its harmonic, then, beats with the oscillator. Or the alien frequency may be higher than that of the oscillator, in which case an oscillator harmonic will beat with the signal. In this way, we use the instrument over a wide frequency range extending from f/2 to f, where f is the oscillator fundamental frequency at some suitable setting, and n is a multiplier or divisor representing the most remote useful harmonic or subharmonic which will give a sufficiently strong beat note.

Thus, in our commercial heterodyne frequency meter, the oscillator is tunable from 100 to 200 Mc, and the useful measurement range (from f/2 to f) is 10 to 2,000 Mc. (In this instance, the factor n is 10.)

(Continued on page 102)
A GENERAL-PURPOSE TRANSISTOR VOLTOMETER

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ABSTRACT
A compact and rugged voltmeter of moderate accuracy and high sensitivity has been designed using two junction transistors. Full-scale ranges are 1, 10, 100, and 1000 volts d.c. at 100,000 ohms per volt and 10, 100, and 1000 volts a.c. at 10,000 ohms per volt. The instrument is based on a one-milliampere meter movement and is powered by a single 1.5-volt flashlight cell.

INTRODUCTION
Vacuum-tube voltmeters have become very popular for electronic test and service purposes. In general, these instruments are highly sensitive and are of reasonable size for portable work but usually require external a.c. power. Those that are battery-powered are limited in usefulness by the size and relatively short life of the battery supply. In contrast to vacuum-tube instruments, the portable multirange type of voltmeter that needs no supply but whose sensitivity is limited to that of its basic movement, generally not exceeding 20,000 ohms per volt. The current-amplifying ability of junction transistors provides the means for increasing the sensitivity of a basic movement more rugged than that ordinarily used in either of the first two types of instrument to produce a voltmeter intermediate in sensitivity and powered by a small battery of long life.

DESIGN
The capabilities of the CK.722 are such that a properly designed d.c. amplifier using two in cascade to operate a one-milliampere movement should provide a sensitivity of about 100,000 ohms per volt, which is useful for most test functions. The junction transistor exhibits current amplifications in two amplifier connections, giving a choice of four basic circuits for an amplifier of two transistors in cascade. Of these four possibilities, only two — the grounded-emitter to grounded-collector, and the grounded-emitter to grounded-emitter — have the advantage that the output current tends to be independent of temperature-induced current changes in the two transistors. In addition, when operated from a low-voltage supply where the bias currents for the transistors are fed through relatively small resistances, the short-circuit current amplification of each transistor is most nearly approached if each works into as low a load resistance as possible. Accordingly, the grounded-emitter to grounded-emitter connection was chosen for the amplifiers, the basic circuit for which is given in Figure 1.

Feedback seems desirable for ensuring a linear relation between meter indication and input current, but since the transistor is a current-amplifying device indeed, as opposed to a voltage-current transducer such as the vacuum tube, the application of inverse feedback inevitably reduces the amplifier current sensitivity; it is therefore not used in the present application. Adequate d.c. linearity has been achieved by proper choice of transistor operating points, although inverse feedback, if it were used, would have the additional advantage of tending to maintain a given absolute sensitivity.

THE TRANSISTOR VOLTMETER
The complete circuit diagram of the instrument is given in Figure 2. Resistor R, in conjunction with the setting of the METER control R,
determines the base bias current of JT. The bias current for JT is determined by R3, R9, and the zero-input collector current of JT. Because of the variability of different transistors, adjustment of the values of R1, R8, and R2 will usually be required in setting up the circuit initially. In making this adjustment, R2 and R7 should be chosen so that R7 is from five to ten times R1.

Variation of R1 provides a convenient adjustment of the absolute sensitivity. Because of the connection of the lower end of R1 to the meter terminal, a small fraction of the output current is fed back in positive sense to the input through R1. Meter zero can be attained by setting R1 for a large range of R1, the positive feedback being smaller as R1 is increased. The overall gain of the amplifier can thus be standardized for a considerable variation in transistor current amplification factor. For transistors that give excessive gain with no feedback, the absolute sensitivity can be lowered by reducing the ratio of R7 to R1. Accuracy of the completed instrument for d.c. is within five percent of full scale and depends mainly upon the care taken in selecting precise resistance values for the multiplier and in selecting R1.

A.c. rectification is provided by the germanium diode, D. Since the diode operates at a low voltage level, its d.c. output is not linear with a.c. input, and the non-linearity results in calibration inaccuracies of about ten percent of full scale. The inaccuracy could be reduced, of course, by providing a non-linear scale for a.c. readings. Resistors R7 and R8 determine the absolute sensitivity for a.c. and have been adjusted in the completed instrument to provide accurate readings (sinusoidal r.m.s. values) at about mid-scale. Calibration is constant over the frequency range from 50 cps to 150 kc.

As shown in the photographs, the instrument is housed in a 3x4x5-inch utility box. In use, the meter is first zeroed with the METER control, R1. The test leads are then shorted, and the meter is zeroed again with the SHORT control, R9. The second zeroing adjustment is usually necessary only on the lowest two d.c. ranges; for a.c. or high-range d.c. measurements, any necessary adjustment can be made with the METER control only. Note that if a.c. measurements are to be taken in a circuit containing a steady d.c. potential in addition to the a.c. term, a series capacitor should be added externally. Battery drain is about four milliampere, so that a size D flashlight cell should give either intermittent or continuous service for 500 hours or more.
FIGURE 1 (Basic current amplifier)

FIGURE 2 (Volmeter circuit diagram)

VOMETER PARTS LIST

B—1.5-volt dry cell, size D.
C—0.5 µF paper capacitor, 200 volts.
D—germanium diode, Raytheon CK705.
JT, JT—junction transistor, Raytheon CK722.
M—0.1 milliamperc meter.
R—330K, ½w (see text).
R—4.7K, ½w (see text).
R—470, ½w (see text).
R—470, ½w.
R—1000 wirewound potentiometer.
R—200 wirewound potentiometer.
R—82K, ½w (see text).
R—15K, ½w (see text).
R, R, R, R—3.3M, ½w.
R—1M, ½w.
R—100K, ½w.
R—10K, ½w.
S—s.p.s.t. slide switch.
S—d.p.d.t. slide switch.
S—double-pole, four-position wafer switch.

66
MINIATURE AUDIO FREQUENCY METER

by ROBERT T. BAYNE

As usually constructed, the Audio Frequency Meter is rather large and is dependent on 110 volts, 60 cycles for a source of power. One popular model weighs 12 lbs. and occupies just slightly less than a cubic foot of space.

Since the advent of Transistors and Germanium Diodes, a very small and light-weight Audio Frequency Meter may be constructed which has the further advantage of operating entirely from self-contained batteries. The Audio Frequency Meter then gains all the portability enjoyed by the indispensable Volt-Ohm-Milliammeter and becomes just as convenient to use.

The Audio Frequency Meter to be described is the portable type and uses two CK722 Raytheon Transistors and four CK706 Raytheon Germanium Diodes. The overall characteristics are, as follows:

- **Total Current**: 2.5 Milliamperes
- **Drain**: Internal calibration of battery voltage before measurement.
- **Calibration**: Range Selector Switch, Calibration Adjust Rheostat, On-Off Switch, Cal. — Read Switch
- **Controls**: Range Selector Switch, Calibration Adjust Rheostat, On-Off Switch, Cal. — Read Switch

**CIRCUIT OPERATION**

As shown in the schematic Fig. 1, the input signal is fed to a clipping circuit composed of W1 and diodes D1 and D2. Since there are 1.5 volt cells in the diode ground return, the output of the clipper cannot exceed 3 volts peak to peak over a wide range of signal input. The primary purpose of the clipper is to provide overload protection for the limiting transistor P2. Needless to say, it also assists in limiting the input signal.

The output of the clipper is connected to the base of transistor P3 by means of R7. The emitter of P3 is grounded, and the entire stage functions as a limiter-amplifier. A small amount of negative "bias" current is supplied to the base of P2 by means of R6. The Collector of P2 is capacitively coupled to the base of transistor P3 through C3.

Transistor P3 is used both as a second limiter and as a switch to provide pulses of charging current to one of the condensers C6, C7 or C8, depending upon the position of the Range Switch, SW1.

With no signal impressed on the base, P1 has approximately 140 Microamperes of base cur-
rent supplied through $R_c$. The corresponding collector current is about 2 Milliamperes so that a large voltage drop occurs across $R_c$. This drop is almost equal to the total Emitter-Collector Potential, 7.0 volts. Under these conditions, the only potential across the condenser (for example $C_2$) is the difference between the supply (7.0 volts) and the drop across $R_c$ (6.6 volts) or 0.4 volts.

When a signal is impressed, a positive pulse appearing at the Base of $P_t$ effectively "cuts-off" $P_t$ so that the potential at point A becomes that of the supply, $C_t$ is then able to charge through $R_c$, Diode $D_t$, and Meter $M_t$ to approximately 7.0 volts. When a negative cycle of signal reverses the potential of the Base at $P_t$, the potential at point A falls to a low value and $C_t$ discharges through Diode $D_t$.

The long time constant of the meter movement integrates the uni-directional charging pulses to provide a steady meter reading which is a linear function of the input signal frequency according to the equation:

$$I_{m} = fCE_t$$

$$I_{b} = fCE_t$$

Since Capacity and $E_t$ (amplitude of the charging current pulse) are fixed by choice of capacity and the action of the limiting circuit, $I_{m}$ becomes a function of frequency only. The Meter Scale can thus be calibrated directly in cycles.

The single Meter Scale is marked 0-30 and frequency readings are multiplied by 10, 100 or 1,000, according to the position of the Range Selector Switch. This necessitates capacity ratios of 1:10:100 between $C_t$, $C_r$, and $C_s$ respectively. Since the accuracy of the entire device depends upon the accuracy of the 1:10:100 ratio, $C_t$, $C_r$, and $C_s$ should be selected using a bridge to determine their exact capacity. If desired, small trimmer condensers may be placed in parallel with $C_t$ and $C_r$ and adjusted for the proper capacity ratio with respect to $C_s$.

The amplitude of the charging current pulse depends on the Collector Voltage. This potential must therefore be of constant value to insure accuracy. To accomplish this, a Calibrate-Read Switch $SW_t$ and Calibrate Adjust Rheostat are included. When $SW_t$ is in the Calibrate position, $M_t$ becomes a voltmeter due to $R_t$ which is in series with its negative terminal and the battery supply. The supply potential can then
be set to the proper magnitude by adjusting the series Rheostat R. The exact point to which the voltage is set is indicated by a small arrow on the meter scale.

The On-Off Switch SW₃ short circuits the meter terminals in the “Off” position. This dampes the movement heavily, protecting it from damage due to shock or vibration.

**MINIATURE AUDIO FREQUENCY METER**

**PARTS LIST**

<table>
<thead>
<tr>
<th>Chassis</th>
<th>“Channel-Lock” Box, 5x4 x3 inches</th>
</tr>
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<tbody>
<tr>
<td>J</td>
<td>Amphenol 75-PCIM</td>
</tr>
<tr>
<td>D₁, D₂</td>
<td>Raytheon Germanium Diodes</td>
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<td>P₁, P₂</td>
<td>CK722 Raytheon Junction Transistors</td>
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<tr>
<td>M</td>
<td>0-100 Microammeter, Trilett type 321-T</td>
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<tr>
<td>SW₁</td>
<td>Centralab S.P. 3 Pos. Type 1461</td>
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<td>C₁</td>
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<tr>
<td>R₂</td>
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<td>C₂</td>
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<td>R₁₁</td>
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</table>
TRANSPORT AUDIO FREQUENCY AND VOLTAGE STANDARD

by
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There is a need for a miniature, self-powered source of accurate audio frequency and voltage suitable for voltmeter and oscilloscope calibration, signal tracing in radio and television sets, and frequency comparison. The oscillator to be described fills such a need, since it provides 1 volt, 1/10 volt, 10 millivolts, and 1 millivolt with an accuracy of ±2% at one kilocycle. The frequency is accurate to better than 1/4% over the normal range of room temperature. Although it is little larger than a cigarette package it will operate for more than two years on its self-contained mercury battery. The current required is but 50 microamperes, and therefore an on-off switch is not necessary. Because of its small size and lack of power cord the oscillator should readily find a place in the service kit or on the laboratory bench.

A very interesting feature of the circuit is that, as explained below, an accurate audio-frequency voltage is obtained automatically without requiring calibration from any other standard.

Consider the simplified circuit of Fig. 1(a), which is a form of the Colpitts oscillator with the emitter of the junction transistor receiving its drive from a portion of the voltage across the tuned circuit. The base is held at ground potential. Assuming that oscillation will start, an alternating voltage will build up across the tuned circuit until limiting takes place somewhere in the circuit. It will be recalled that, in a pnp transistor, the collector is biased negatively with respect to the base. This is in the non-conducting direction, and therefore the signal current flowing in the collector results from "holes" injected through the base by the emitter. However, a large collector current will flow if the collector goes positive with respect to the base. This is the form of limiting obtained here, and it takes place when the peak voltage across the tuned circuit exceeds the supply voltage. When the collector clips it does so in a very abrupt manner, because it now functions as a part of a high-conductance junction diode.

Consequently, if the feedback and the amplitude are increased, the onset of the clipping is readily observed with an oscilloscope or a voltmeter, and, if the feedback is adjusted so that clipping is just detectable, the peak voltage across the tuned circuit is almost exactly equal to the supply voltage E. An accurate voltage E can be obtained with mercury hearing-aid cells, which provide 1.34 volts to better than 0.5%.

The actual circuit used is shown in Fig. 1(b), in which two mallory type RM-1 cells in series provide 2.68 volts. As a matter of convenience the negative battery terminal has been grounded. The feedback voltage appears across C3, while C1 is used to adjust the frequency. The inductance L is a small, uncased, powdered-fermalloy toroid, which is available from any one of several transformer manufacturers. The capacitors C1, C2, and C3 are paper-tubular units. The resistor in the voltage divider should have an accuracy of ±1% if possible.
In setting up the circuit, the resistor R should be omitted, and the presence of oscillation should be checked with an oscilloscope or a high-impedance voltmeter. If the circuit does not oscillate, the dashed-line connection of R should be used, and R should be decreased from 1 megohm until oscillation starts and clipping commences.

This will be observed with the oscilloscope or, if a voltmeter is used, the output will increase but very slowly as the resistance is decreased past a given point. If oscillation is obtained with R disconnected, the solid-line connection of R should be used, and R should be decreased until the clipping almost stops. One connection or the other will be required depending upon the condition of the transistor and the Q of the tuned circuit.

The final frequency adjustment can then be made by adjusting C₂. It is convenient to use the 600-cycle modulation from WWV as a standard, employing Lissajous figures for frequency comparison. The output across the tuned circuit was found to be 1.83 volts rms., which is about 3% lower than the battery voltage would indicate. The difference results from the fact that the base of the transistor is not held exactly 2.86 volts positive with respect to ground. The resistances in the voltage divider have been chosen to compensate for this difference, which has been found consistent in the three breadboard oscillators constructed. The distortion is about 1% with the proper circuit adjustment. The source impedance of the oscillator must be considered when making a calibration. The impedance at the 1-volt tap is approximately 30,000 ohms with loads greater than 100,000 ohms. Thus, if a meter with a resistance of 1 megohm is connected to the 1-volt tap, it will read about 3% low. The impedances at the other taps are approximately 5,000, 500, and 50 ohms respectively.

The oscillator is constructed in a brass tube 3 inches long and 1¾ inches in diameter. Bakelite end caps are used, and the mercury battery is held in a small bakelite tube running down the center of the brass tube. The negative terminal of the battery, which is ground, is located at the center of the four audio-frequency-output terminals. The positive terminal of the battery, which is recessed to prevent shorts, is available at the other end of the oscillator for battery checks and also to permit the calibration of dc voltmeters.
Fig. 1 Transistor Audio Frequency and Voltage Standard

PARTS LIST
1—Raytheon CK722
1—0.3 μf toroid
1—0.1 μf capacitor (see text)
1—2 μf capacitor
1—0.5 μf capacitor
1—1K ½w resistor
1—43.3K ½w 1 percent resistor
1—47K ½w 1 percent resistor
1—4.7K ½w 1 percent resistor
1—470 ohms ½w 1 percent resistor
1—52.2 ohms ½w 1 percent resistor
1—½w resistor R (see text)
2—Mallory type RM-1 cell
TRANSISTORIZED VOLTOMETER

Operating from a single cell, instrument has an input resistance of 0.1 v.v.m.

By RUFUS P. TURNER

HIGH values of current amplification are obtained in the grounded-emitter junction transistor circuit by using the base as the input electrode. A small change in base current produces a rather large change in collector current. Such base-to-collector current amplification is designated by the Greek \( \beta \) (beta), and in commercial transistors has a value many times higher than the familiar anode-to-cathode amplification \( a \) (alpha). \( \beta \) is equal approximately to \( a^2 \) or \( \alpha^2 \). From this relationship, we see how a junction transistor having an alpha of only 0.009 can give current amplification of 10 in the grounded-emitter circuit. It is clear also that junction transistors with the highest alphas, approaching 1, also show the highest betas.

High-beta performance permits operating the grounded-emitter circuit as a d.c. amplifier with low power drain. The amplifier has a current gain of 10 when alpha is 0.009 and can have a gain of approximately 100 when alpha is very slightly greater than 0.009. Taking advantage of this gain, a d.c. milliammeter in the collector circuit will respond to millivolts applied to the base-input circuit.

Fig. 1a shows such a simple amplifier type milliammeter. Input current of 100 microamperes will deflect the 0-1 d.c. milliammeter full scale. For simplicity, zero-setting circuits for bucking the static collector current out of the meter have been omitted from each circuit in Fig. 1. In Fig. 1b, a second common-emitter amplifier stage has been added in cascade for 10-microampere operation of the meter. Note that transistor V2 has been turned over so that current flows through its base in the correct direction to increase collector current. The collector current of transistor V1 flows directly through the base-emitter input circuit of V2, so no load resistors are required and interstage impedance-matching problems disappear. Likewise as current from both batteries flows in the same direction through lead X, a single battery may be inserted in this lead to supply both transistor stages. This has been done in the final circuit shown in the Fig. 1c diagram.

It is entirely possible to use low-priced junction transistors, such as the C282, in this d.c. amplifier circuit. However, for a total current gain of 100, the transistors would have to be selected for a minimum alpha of 0.009 each. There is gain to spare when using a combination of one C272 and one higher-alpha unit, such as the C273, in cascade. This combination requires no special picking of transistors.

An interesting and useful application of the transistorized milliammeter is as the basis of an electronic d.c. voltmeter—the transistor equivalent of the v.v.m.—by adding suitable multiplier resistors to the input of the d.c. amplifier circuit. Since the two junction transistors require only about 2 ma from a 1.5-volt cell for complete circuit operation, the result is a completely portable electronic voltmeter having operating economy not obtainable with conventional battery-operated v.v.m.'s.

A 0-10 microampere meter has been shown before as the basis of a d.c. voltmeter having 100,000 ohms-per-volt sensitivity. A 10-microampere d.c. meter is expensive, however, and not obtainable except as special order. The transistorized d.c. amplifier permits use of the meter ranges, inexpensive, and readily obtainable 0-1 d.c. milliammeter. To render the meter capable of a sensitivity of 100,000 ohms per volt unfavourably with the input resistance of the conventional v.v.m., we would like to point out that the 100-volt range has an input resistance equal to that of many v.v.m.'s, and on all higher ranges the transistor voltmeter has a higher input resistance than the v.v.m.!

Instrument circuit

The complete circuit of the transistorized electronic voltmeter is shown in...
Fig. 2. To the simple two-stage tran-
sistor microammeter circuit of Fig. 1a have been added the input multiplies resistors (R1 to R6) and the zero-set-
ting meter circuit (R7 to R10). The zero-set
circuit is that of the four-arm-bridge
type common in V.U.M.'s.
Resistors R1 to R6 must be selected to the
exact specified values. The 50-
megohm value required for the 500-volt
range is obtained by series-con
tecting one 10- and two 20-megohm resistors.
For highest accuracy on the 1-volt range, the
input resistance of the CK722 (approximately 2,000 ohms)
should be subtracted from the normal 100,000-ohm
value of R1, making it 99,000 ohms. If this is not done, the
1-volt range will read 5% low. To check the input resist-
ance of the first transistor in the com-
plete circuit, feed in an input current
of 10 microamperes and measure the voltage drop between base and emitter. Determine the resistance by dividing the voltage by 100,001.
On all but the last range, the 0-1
scale of the milliammeter can be used by
merely adding zero mentally where necessary.
The author found the 1-, 10-, 100-, and 500-volt ranges suitable for his purposes. Other ranges may be
included if these are undesirable. The table shows multiplier values for common voltage ranges other than those shown in Fig. 2.

### ADDITIONAL VOLTAGE RANGES

<table>
<thead>
<tr>
<th>Range (vols)</th>
<th>Multiplier</th>
<th>Resistance [megohms]</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.5</td>
<td>0.25</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>0.5</td>
<td>60</td>
</tr>
<tr>
<td>7.5</td>
<td>0.75</td>
<td>150</td>
</tr>
<tr>
<td>15</td>
<td>1.5</td>
<td>750</td>
</tr>
<tr>
<td>25</td>
<td>2.5</td>
<td>750</td>
</tr>
<tr>
<td>50</td>
<td>5</td>
<td>750</td>
</tr>
<tr>
<td>250</td>
<td>25</td>
<td>75</td>
</tr>
<tr>
<td>500</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>1000</td>
<td>1,000</td>
<td>10</td>
</tr>
</tbody>
</table>

One pole of the range selector switch disconnects the battery. For protection of the instrument, the off position is placed after the highest voltage range. Phone Jack 21 is provided for the "high" d.c. input lead which in this circuit is connected to the negative pole of the voltage source under test. A conventional shielded input lead and probes are advantageous when working around strong fields. The "zero" (positive) lead is connected to pin Jack 22.
The calibration control R6 permits the instrument to be standardized ini-
tially and for its periodic recalibration. This control has a slotted shaft for screwdriver adjustment and is mounted inside the instrument case for protection from disturbance.

Adjusting the ZERO ARCTIC rheostat R7 allows the meter to be set to zero against the effects of steady collector current through both transistors. Static collector current in the CK722 is am-
plicated and increases the static collector current of the CK722.

### Construction

Being a straight d.c. instrument, the problems of stray coupling and fre-
quency dependence are absent. The model shown in the photos is built in an aluminum utility box 6 inches high, 4 inches wide, and 2 inches deep. The two transistors and components R5, R9, and R10 are mounted on a 1/4-
inch x 4-inch balsa wood board attached to an inner wall of the case with long 0.02 screws. Transistor and resistor leads are pulled through small holes in the board and connections are made under-
neath.

Resistors R1 to R6 are soldered di-
crectly to the range switch. The flash-
light circuit is held to an inner wall by a
curved bracket which does not appear
in the photo.

Leads from the meter, battery, zero-
set rheostat and battery section of the
range switch are cabled together and run to the component board, underneath
which connections are made.

The instrument can be built much
smaller than shown here. Smaller meter,
components, battery and case are en-
tirely feasible.

### Initial Adjustment

After the wiring has been inspected, make the initial adjustment in the fol-
lowing manner: 1. Set the range switch to the 10-volt position and set R8 about halfway between its minimum and maxi-
 mum rotations. 2. Zero the meter by adjusting R7. 3. Apply an accurately
known 10-volt d.c. potential to the input terminals. 4. Adjust R8 for exact full-
scale deflection of the meter. 5. Remove the voltage. If the meter does not read exactly zero, reset by adjusting R7.

6. Reappraise the voltage and readjust R8, if necessary, until the full-scale reading is correct. 7. Repeat steps 4, 5, and 6 until the meter reads full scale when the voltage is applied and falls back to zero when the voltage is removed.

Even when substituting transistors, the author found the circuit response surprisingly close to true linearity. This had made it possible to obtain good accuracy with the regular meter scale. Such operation was not anticipated and it is believed that beta would vary greatly with input current. How-
 ever, where highest possible accuracy must be insured, the builder should calibrate as many scale points as pos-
 sible during the initial adjustment. Suggested points would be 1-Volt apart from 1 to 10 volts. They should be checked after completing the full-scale adjustment. If the calibration then did not follow the millimeter scale, a special meter card might be drawn or a calibration chart prepared.

### Performance

The transistorized electronic volt-
 meter will give a good account of itself as a completely portable instrument having high input impedance and excel-
 lent economy of operation.

It can be used in place of the V.U.M.,
which it usually will supplement, especi-
 ally in tests involving voltages which are not over the 100-volt and higher
ranges. The input resistance on these ranges equal, or better than, that of the tube type d.c. instrument.

### Ports for electronic voltmeter

These are:- 1. Input terminals (100,000 ohms line last); 2. Input mag-
tometer (100,000 ohms last); 3. Input mag-
etometer (100,000 ohms last); 4. Input mag-
etrometer (100,000 ohms last); 5. Input mag-
etrometer (100,000 ohms last); 6. Input mag-
etrometer (100,000 ohms last).

All operating power is furnished by
a 1.5-volt cell. Total current drain, at full deflection of the milliammeter, is approximately 2 ma. A jumbo-size flash-
light cell will give long life even when the instrument is accidentally left running.
A penlight cell will give some-
what shorter service, while a mercury
 cell will very nearly give its shelf life of several years continuous operation.
Operation is instantaneous, without warm-up periods, as a result of battery and transistor operation.

With good transistors, zero-setting
drift is negligible except during wide
changes in temperature, whereas the static col-
lector-current increases rather slowly with temperature. However, the author finds that the usual precautions for this drift. The instrument was kept in continuous operation for 6 hours at a controlled temperature of 30° C with no zero drift.

Other operational features, such as current range and voltage scales, may be added in the conven-
tional manner, borrowing from V.U.M. techniques.
PISTOL-GRIP SIGNAL TRACER

This small and compact transistorized instrument features a unique design, and yet is easy to construct.

By HOMER L. DAVIDSON

The pistol-grip tracer in operation.

This little transistorized signal tracer resembles the pistol type soldering iron used by many experimenters and service technicians. It is compact and has only one outside lead—an alligator ground clip. The nozzle or pointer of the tracer is touched to the circuit being tested; the signal is rectified and amplified, then reproduced through a 3-inch speaker.

A 6001-dc type capacitor couples the incoming signal to the amplifier. A 1N34 crystal rectifies any r.f. signal picked up and feeds it to a volume control. This control is used to reduce signal strength when necessary. It is a standard type but a midget unit could have been used. Had that been done, the 6.p.n.t. switch could have been placed in the control instead of at the top of the unit.

A midget electrolytic capacitor couples the incoming signal to transistor V1. Both transistors used in this signal tracer are C572F’s. They are mounted in hearing-aid tube sockets that were lying around, although regular sockets can be used. Be careful when wiring the leads because heat from a soldering iron can easily damage transistors. A good trick is to let long-nose pliers absorb the heat. This also applies to the 1N34.

Resistor R1 is a base return and develops bias for the stage. Since transistor characteristics vary, R2 should be chosen for the value that provides maximum volume. Within the applied current limits. To find the correct value, use a 500,000-ohm potentiometer in place of R1 and vary it for maximum signal. At the same time, connect a milliammeter in series—the current should not rise higher than 5 ma. The audio amplifier stage is
transformer-coupled to the output stage. This little transformer is a Buxton IM-123. Primary impedance 25,000 ohms, secondaries 1,000 ohms. It was designed primarily for transistor-empowering stages. A standard percentage coupling transformer could be used if the signal tracer is constructed on a chassis where space is not limited. A 10-uf electrolytic capacitor couples the signal to the base of V2. The base-return resistor R2 was measured before being placed in the circuit as R1 was. A small output transformer steps down the amplified signal and feeds it into a 2-inch speaker.

Wiring the unit

When wiring the signal tracer be sure the transistors are properly connected—and be sure neither one draws more than 5 ma. The wiring is not critical but all leads and components must be closely spaced with the leads as short as possible. There isn’t any separate chassis, the two transistor sockets being soldered to the speaker frame. Pins 5, 4, and 3 of the hearing aid sockets are soldered together. A heavy piece of brass wire is soldered to both sockets and then anchored to the 2-inch speaker frame. Also, the positive lug on the small 32-volt hearing aid battery is soldered directly to the 1-inch bolt fastened directly to the speaker frame.

The transistor sockets are soldered directly together. When plugging the C722 transistors into their sockets, be sure both red dots or pins are plugged in properly. A d.p.t. push type switch is mounted on top.

Construction of the gun holder is easy. Get a few scraps of three-ply wood and draw a gun on each piece. On two of the pieces cut off the handle. Place the other piece between these handleless pieces and glue and nail them together. After the assembly dries, round the edges, carve and sand, giving it the appearance of a pistol. The middle section of the pistol is not nailed or cut out until the plastic is formed around it.

A small piece of Lucite is used as a cover for the pistol signal tracer. It is fitted around the pistol assembly while heat is applied from a gas flame. Be sure to hold the plastic away from the flame. Then the plastic can be formed around the gun assembly and held there until it sets. The speaker holder can be drilled before or after the plastic is in. All protruding corners are then cut and rounded off to fit snugly around the wooden assembly.

At this point the center of the gun assembly is sawed out. Only a narrow border is left and the plastic piece is screwed to it. A 3/8-inch hole is drilled into the bottom for the volume control, which resembles a trigger. A 1-inch hole is then drilled for the pistol barrel. The barrel consists of a 1-inch piece of round plastic tubing with a plastic bottle cap and 2-inch bolt fastened into the end as the test probe. To save mounting space the small "isolating" capacitor and the 1N54 can be mounted in the plastic tube.

The results obtained from the small transmit signal tracer were surprising. T-coils were easily located in small radios, TV sets and amplifiers.

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Parts for signal tracer
- 1 each: 12-volt, 3-cells, 1/2 ampere, 1/2 watt radio battery
- 1 each: 2.2 uf, 50 volt, electrolytic capacitor [soldered on chassis]
- 1 each: 2.2 uf, 60 volt, electrolytic capacitor [soldered on chassis]
- 1 each: 2.2 uf, 100 volt, electrolytic capacitor [soldered on chassis]
- 1 each: 2.2 uf, 200 volt, electrolytic capacitor [soldered on chassis]
- 1 each: 2.2 uf, 1000 volt, electrolytic capacitor [soldered on chassis]
- 1 each: 1N54, Zener diode [soldered on chassis]
- 1 each: 7805, 5 volt adjustable regulator [soldered on chassis]
- 1 each: 7812, 12 volt adjustable regulator [soldered on chassis]
- 1 each: 2N2222, transistor [soldered on chassis]
- 1 each: 2N2907, transistor [soldered on chassis]
- 1 each: Buxton transformer, primary impedance 25,000 ohms, secondaries 1,000 ohms [soldered on chassis]
- 1 each: 32 volt, hearing aid battery [soldered on chassis]
- 1 each: sheet of plastic, 3 pieces of 3/8 inch plywood [soldered on chassis]
- 1 each: 3/8 inch, plastic tube
- 1 each: 3/8 inch, plastic tube
- 1 each: 3/8 inch, plastic tube

Schematic pistol-grip signal tracer.

Assembly of the signal tracer—unit is compact; completed plastic cover at right.
DEMONSTRATION TRANSISTOR CIRCUITS

By EDWIN BOHR

Kit for the transistor experiment...

BY all of these circuits and really get the feel of transistorized equipment. Experiment for personal pleasure or for an audience—the layouts are ideal for club demonstrations. A single transistor is used in each circuit. Other parts are standard and easily obtained—if not available from the junkbox. Every circuit has been checked out with several OKT22 production transistors and found to be foolproof. (A demonstration circuit must work without embarrassing tinkering and fumbling.)

Components are mounted breadboard style, allowing the individual circuits to be connected or torn down quickly. Since a single transistor is involved in all the circuits, it should be especially protected from continuous handling and soldering.

Two types of breadboard mountings for the transistor are used. In one layout, the leads are run to breadboard clips held to a heavy base of clothboard or masonite by #6-32 screws. This base should be heavy and large enough to prevent accidental upsets. The other breadboard model sports a small five-prong hearing-aid tube socket into which the transistor can be plugged. Only the first, third and fifth pins of this socket are used. The other two pins are given a slight twist and pushed out. It is a good idea to mark clearly which lead is the emitter, base and collector. Another suggestion: Slip spaghetti over all wires that might touch or short.

Microwatt oscillator

The most remarkable feature of the transistor is its ability to perform useful electronic tasks with a minimum of power consumption. The first project is an audio oscillator requiring a total power of 0.002 watt. A perfect example of low power consumption! A simple electrolytic cell, constructed from a dime and a piece of absorbent paper, supplies the energy.

The circuit (Fig. 1-a) must use trans- former feedback to operate at this low power level. For this purpose, and in keeping with the size of the transistor, a tiny U.T.C. SO-3 or SSO-3 subwoofer Transformer is used. Larger transformers will do, but the data given in this article is for the SO-3.

![Figure 1-a](image)

The exact connections for the SO-3, with the correct feedback polarity, are shown in Fig. 1-b. One wire from the "plate" side of the transformer goes to the collector and the other wire is connected to one side of the headphones. The two low-impedance wires from the transformer are connected to the base and emitter.

Either grounded-emitter (point 2) or grounded-base (point 1) operation is available by switching the wet-cell connection. Operation of the two circuits is essentially the same, but the grounded-base circuit gives a tone of slightly higher pitch. The frequency of the oscillator changes with the voltage of the wet cell. Increasing the voltage lowers the tone.

Make the wet cell (Fig. 1-c) by placing a piece of absorbent paper moistened with saliva against a dime. The dime forms the positive electrode and a wire lead held against the other side of the moist paper provides the second electrode. A few drops of soft drink also make an excellent electrolyte.

Several of these dime-saliva cells were checked on a potentiometer and the voltage was always around 6.7. When the cell is connected to the transistor oscillator, the voltage drops to about 5.5. With this voltage, the oscillator draws 8 microamps of collector current—a total input power of 0.00004 watt.

By making a megaphone out of paper and placing it to one of the earphones, the tone can be heard several feet away. For larger groups, an audio amplifier input can be connected directly across the earphones for room volume. The microwatt oscillator operates from other flea-power sources. Replace the saliva cell with a self-generating photocell and the oscillator will "sing" from the power produced by ordinary room illumination. Automobile headlights at night as far as 30 feet away will give enough light for oscillation. The listener changes the intensity. This could possibly be used as a blind man's light meter or in a steering device to bring an electronic animal to its nest. A peak a.c. output voltage greater than the applied d.c. voltage can be obtained from transistor oscillators. This offers some novel transistor uses. For example, it is often necessary to send small d.c. signals over long-wire distances from remote locations. The microwatt oscillator can operate from these small voltages and, at the point of origin, change them to a.c. for more

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Microwatt oscillator with saliva cell.

High-gain radio

Astounding! Is the only way to describe the findings of most people when they first hear this set (Fig. 2) in operation. Only a single tuned circuit, transistor, SO-3 transformer and a battery are used.

The tuned circuit is coupled to the emitter by a tap on the coil, a 6847 oscillator type—only here it is used as an antenna coil. A broadcast tuning capacitor (410 μF) covers the band with perhaps only a few stations missing on the low end of the dial. The tuning is broad enough so these stations will be picked up anyway.

Fig. 2—High-gain transistor radio.

Simply connect the set as shown in the diagram. The grid connection of the 6847 coil goes to the tuning capacitor rotor plates, the ground side of the coil goes to the frame (motor) and the cathode tap to the emitter.

The emitter conducts only on the positive half of the carrier swing, like an ordinary diode detector; therefore, the instantaneous emitter current follows the modulation pattern. The emitter thus controls the current in the high-impedance collector circuit, producing amplification.

The secret of the receiver's performance is the 56-3 matching transformer. Ordinary medium-impedance earphones connected directly to the collector circuit do not realize the full gain possible from the transistor. But, with the circuit of Fig. 2, much higher gain is possible. Even Army type moving-coil (low-impedance) earphones connected across the output winding give very good performance.

A small 0.100-microamp meter connected in series with the collector makes a very good tuning indicator. With a single dry cell for current, and no signal, the collector draws about 10 microamps. As a signal is tuned in, the current increases. A signal producing 20 microamps of collector current is loud enough to be heard fairly 3 or 4 inches from the earphones, while 15-microamp signals are exceedingly loud. Generally, a ground is not needed, but it does eliminate hum-capacitance tuning effects. For demonstrations, just touch the tip of a transformer type instant heat-soldering iron (plugged in but not turned on) to the antenna terminal of the receiver. This makes a very effective antenna with a whopping big signal of over 20 microamps. For even more volume, simply increase the collector supply to 5 volts.

Audio amplifier

The grounded-emitter circuit has become the established transistor audio circuit. There are two reasons for this: First, the gain is highest and, second, the proper bias voltage can be obtained most easily and with the least unwanted power by grounding the emitter.

The transistor emitter is basically a rectifier circuit and a bias voltage must be placed on it to cause forward current to flow. For the CE722 this voltage must be positive. Without this bias, any negative swing of the emitter signal would drive the emitter into its "backward" region and produce collector cutoff distortion. In the grounded-emitter circuit, the base is made slightly negative by a series-dropping resistor from the negative collector supply, which is equal to making the emitter positive.

Fig. 3 is a typical amplifier circuit of this type. The input impedance being roughly 1,000 ohms, it can be fed from a single magnetic headpiece used as a microphone, the transistor radio or a variable-reistance cartridge.

To try out the circuits, connect a single-earphone to the input and another to the output. Place the input earphone (microphone) in one room and the output one in another room. Sounds near the microphone can be heard clearly. The transistor amplifier can be built complete with a mercury-cell power supply in a volume as small as that of the earphones. You can't do this with a vacuum tube! On the debit side, the transistor amplifier has a noise level higher than an equivalent vacuum-tube circuit. This noise, heard as a soft hissing sound in the earphones, is not objectionable.

Utility oscillators

The utility oscillator is a demonstration circuit operating from a single-
cell. It is useful as a self-contained signal source for Wheatstone bridge circuits, toy musical instruments or as an audio test generator. When operating at very low frequencies (40 cycles or less), the output is sufficiently rich in harmonics to radiate signals into the lower end of the broadcast band. The circuit of Fig. 4 is the same as Fig. 1, except for the power source and a variable resister inserted in the emitter circuit to vary the frequency. Figs. 5-a, b, c and d give the waveforms and frequencies obtained as the resistance is varied from zero to 7,000 ohms. Notice that the waveform improves and the harmonic content decreases as the emitter resistance is increased.

Output is sufficient to operate headphones or a speaker at very low volume. Either earphones or the speaker output transformer may be connected to the output terminals of the oscillator shown in Fig. 4.

A short antenna can be connected to the collector for signal radiation. The audible tone generated by the oscillator can be heard all across the low end of the band where it is strongest. Just turn on any radio within a few feet of the antenna.

Another utility oscillator circuit is shown in Fig. 6. This is an "easy starting" circuit than that of Fig. 4. Some circuit disturbances is always necessary to start an oscillatory circuit in operation. A pendulum or tuning fork, for example, must be given that first push or impact to start it oscillating at its natural frequency. Vacuum tubes receive this push the instant the plate voltage is applied. When the plate voltage is switched on, the grids has zero bias and heavy plate current flows. This heavy surge of current quickly establishes the tuned circuit which oscillates and in turn builds up a grid-leak bias that limits the plate current to a lesser value.

With the transistor, this same situation is not obtained. Like the vacuum-tube grid, the emitter also has zero bias at the instant the collector voltage is switched on. But, conversely, zero emitter bias allows very little collector current to flow, since a positive emitter bias is needed to increase the collector current to a point higher than the normal back current.

The Fig. 4 oscillator develops a starting bias across the variable base resister. As the collector starting current flows through this resistor, it places a positive bias on the emitter.

Oscillator of Fig. 4 using mercury cell.

Fig. 6—An "easy start" oscillator.

Loading the circuit with an antenna or hand capacitance changes the waveshape considerably but causes little if any frequency variation. These circuits will provide plenty of new entertainment and experimental material. You will have to disassemble some of them—especially the radio.

Parts for transistor demonstration
1-5979 transistor; 1-5963 (2SC1) transformer; 1-6AL4 oscillator tube; 1-5963 (2SC1) transformer; 1-6AL4 oscillator tube; 1-2N26 transistor; 1-2N37 transistor; 1-0.1 uf condenser; 1-25 ohm carbon resistor; 25 pf or greater; 1-0.1 uf condenser or dry cell; several full-wave bridge clips.

However, even one transistor is too expensive to limit to any single circuit. Furthermore, the clip-boardboard technique makes it possible to set up any of the other circuits in short order.

Fig. 5—Waveforms of Fig. 4 oscillator for variations in emitter resistance.

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A n ENTERTAINING gadget of durable
A popularity is the "wireless mike," a
tactile modulated r.f. oscillator which can
be plugged in a standard broadcast re-
er昼夜 distances up to 20 or 30 feet.
In common with "wireless" photograph
oscillators and the radio remote-tuning
devices sold some years back, these units
are not transistors in the FCC sense of
the term as long as their range is small
compared to the wavelength at the oper-
ating frequency.

The transistor circuit shown operates
in the low-frequency half of the broad-
cast band, where the wavelength is up-
wards of 9000 feet. V is the r.f. oscillator.
The Colpitts-type circuit is tuned by
means of a powdered-iron slug to an
empty spot in the broadcast band, some-
where in the vicinity of 700 kc. This
oscillator is "plate" modulated in the
regular wiring style by a second transis-
tor V. The microphone was a balanced-
armature magnetic unit having a d.c.
impedance of 200 ohms, obtained from a
surplus collection. Since the input
impedance of V is on the order of 1000
ohms, a low-impedance microphone is re-
quired.
Crystal microphones will not work.
It was found that the tank capaci-
tances in the r.f. oscillator circuit shown
must be small, or the circuit will not
oscillate at frequencies as high as the
lower edge of the broadcast band. Hence
an inductance some-hat larger than the
usual broadcast coil (0.5 millihenry) is
needed. The one used here is a com-
mercial surplus item. However, it should
be effective to rewind a broadcast-band
coil to about twice the original number
of turns. Experimentation is easy be-
cause no tap is required, and the "Q"
need not be particularly high. In the
present state of the transistor art there
is, of course, no assurance that all in-
dividual transistors of one particular type
will have the same upper frequency limit
of oscillation. Broadcast band frequen-
cies are definitely at the high limit, for
junction transistors, apparently, and all
that can be said is that two transistors
worked in this circuit.
The battery drain for the oscillator
should be between 0.4 milliampere and
1 milliampere. Before operating the cir-
cuit, this must be checked. Proper bias
will vary with different transistors. Bias
is adjusted by selecting the value of re-
sistor R. The lower it is, the higher the
collector current. Bias for the modulator
transistor V is determined by resistor R,
which should be selected to give a col-
lector current of 0.8 to 1.5 milliamperes.

TRANSISTOR "WIRELESS MIKE"
By A. H. HELLMERS

\[ R = \frac{31000 \text{ ohms}}{12 \text{ V}, \text{ cc}} \]
\[ R = \frac{22000 \text{ ohms}}{15 \text{ V}, \text{ cc}} \]
\[ C = 3 \mu \text{fd}, 100 \text{ v.c.c.} \]
\[ C = 0.05 \mu \text{fd}, 100 \text{ v.c.c.} \]
\[ C = 0.01 \mu \text{fd}, 100 \text{ v.c.c.} \]
\[ C = 0.03 \mu \text{fd}, 100 \text{ v.c.c.} \]
\[ C = 0.05 \mu \text{fd}, 100 \text{ v.c.c.} \]
\[ C = 0.10 \mu \text{fd}, 100 \text{ v.c.c.} \]
\[ C = 0.10 \mu \text{fd}, 100 \text{ v.c.c.} \]
\[ C = 0.20 \mu \text{fd}, 100 \text{ v.c.c.} \]
\[ C = 0.30 \mu \text{fd}, 100 \text{ v.c.c.} \]

Miller-Variable resistance mike or sound pow-
erated crystal unit (not tested)

V= -12 v.d.c. junction type "pnp" transis-
tor (latter)

TRANSISTOR DOT MAKER

A series of dots gets more attention
and is less tiresome than a continuous
line. It can be used to modulate a
signal generator or as a stand-by signal
while adjusting a phone transmitter,
wireless phone attachment, or inter-
com. A dot generator can also be used
as a signal source for remotely control-
ing a model plane or for speed key
practice without a Vibroplex or other
automatic key. One of the simplest
possible dot generators can be made
with a junction type transistor and an
audio transformer. (See diagram.

The transmitter is connected in a
conventional feedback circuit. If it has
a third winding (as in a transceiver
transformer) the added coil may be
used as the output winding. The tran-
sistor base is biased by a capacitor.
Thus the oscillations build up, are
blocked, and so on. With values shown,
the dot rate is 2.5 second. The power
supply may be a 5-volt battery.

When the voltage is increased, the
sound level increases, and the dots
become more crisp. They become
shorter with respect to the space be-
tween them. The rapidity of dots
increases when a high resistance shunts
the collector and base. For example,
an 8.2-megohm resistor doubles the dot
rate.

80
A TRANSISTOR METRONOME

By LOUIS E. GARNER, JR.

MECHANICAL metronomes are known to almost every musician and have been in use for perhaps two centuries or more. In their simplest form they consist of a pivoted pendulum with one fixed and one movable weight. The position of the movable weight determines the number of oscillations or "beats" per minute when the pendulum is set in motion. More complicated versions employ a clockwork mechanism to drive the pendulum, and it is this version that is perhaps the best known.

In modern times, electrical and, later, electronic metronomes have been wider use. Today, electronic metronomes are probably most widely used than the mechanical versions because of their lower cost, ease of setting, and ready availability. A number of articles have appeared giving construction information on such units. Most electronic metronomes suffer from a disadvantage not shared by the mechanical units—they require a line power source. Power may not always be available or convenient to the musician in his "working" location. Battery operated metronomes have, in the past, proven too satisfactory because of the large and heavy batteries required to deliver reasonable "loudspeaker" volume from vacuum tube operated equipment, as well as the comparatively short battery life gained.

Today, however, with the ready availability of the highly efficient transistor, it is now possible to design and build a battery operated electronic metronome that is simple, compact, light in weight, and comparatively low in cost, yet delivers sufficient power to give a distinct "beat" of sufficient loudspeaker volume for all normal use.

The "Transistor Metronome" designed and built by the author is shown in Fig. 1. Standard, easily available components are used throughout. The average technician should have little or no difficulty in assembling and wiring a similar or duplicate unit for his own use.

Circuit Description

A double neon CKT22 junction transistor is used as a modified grounded emitter "tickler (feedback) oscillator circuit, as can be easily seen by reference to the schematic diagram, Fig. 2. A standard "universal" audio output transformer, T1, serves both to provide the feedback necessary to maintain oscillation and to drive the small 3⁄4" PM loudspeaker.

In operation, the start of a current flow in the collector circuit and through the primary of T1 induces a signal across the secondary winding of the transformer. This signal, in turn, causes C, to charge rapidly through the base-emitter circuit of the transistor and the secondary winding of T1.

As C starts to charge, the resulting base current flow permits an increase in the collector current flow, thus increasing the signal amplitude in the secondary winding of T1. The net effect is cumulative, with both base and collector currents reaching a peak as C charges.

The voltage across C soon reaches its maximum value and the charging current starts to decrease. This means that the base current drops, with a resulting drop in collector current. The drop in collector current reverses the polarity of the voltage induced in the secondary winding of T1.

If the base-emitter of the transistor was a bilateral conductor, this reversal of signal polarity across the secondary of T1 would simply result in the rapid discharge of C. However, since the base-emitter passes current in only one direction (that is, acts like a diode), C cannot discharge over its charging path and must, instead, discharge through R, and R2.

The result is a sudden pulse of current flow across C; changes rapidly, with a comparatively long period of virtually no current flow as C, discharges slowly through R, and R3. The charging time depends on the value of C, and upon the combined impedances of the base-emitter circuit of the transistor and the secondary winding of T1. The discharge time depends on the value of C, and upon the values of R, and R, that is, upon the resulting RC time constant of these components.

Once C, has discharged sufficiently to permit the start of base current flow again (over a path consisting of the battery, R, R1, R2, and the base-emitter of the transistor), the charging cycle is repeated.

This action then continues, with the pulses repeated at intervals determined primarily by the RC time constant (R, C) and by the battery voltage, and with each pulse giving a "tick" of fairly good volume in the loudspeaker. Adjusting R, permits the repetition rate ("beats" per minute, or "frequency") to be varied.

Since appreciable current flow occurs only during the short time interval of the pulses, the average current drain from the battery is small, and battery life is long, even though a small "heating aid" type battery is employed. The average current drain will depend, however, upon the number of "beats" per minute, with high repetition rates requiring considerably more power.

A stepped-down turns-ratio is used in the transformer (T1) to match the
high-impedance collector circuit to the low-impedance impedance of the base-emitter circuit. A still greater (40:1) step-down ratio (resulting from the second-ary winding) is used to match the even lower-impedance of the loud-speaker voice coil.

A toggle switch S, is provided to turn the unit "on" and "off.

Construction Hints
The entire "Transistor Metronome" has been designed to fit comfortably in the available 8" meter case, with the small transistor mounted behind the meter opening. Fusible flange "clotb" was used by the author to cover the space opening but this may be left uncovered, if desired, or plain screening or foil-covered screening used instead.

In assembling the unit, a small aluminum chassis was used to mount the transformer, battery, transistor, and condenser (C), with the control (R) and power switch (S) mounted as the cabinet.

The location of all major components except the transistor itself is clearly visible in the interior view of the unit, Fig. 1. Note that the condenser (C) is mounted below the chassis. The transistor is mounted on a terminal strip directly behind the small battery compartment.

When installing the transistor, the author recommends using a socket, however, a small pin subminiature tube socket is available, with only 3 of the pins being needed.

Should the builder decide to follow the author's example and wire the transistor into the circuit, he should exercise special care when soldering the connections. Transistors are easily damaged by excessive heat. Each connection should be made as quickly as possible, using a very hot, clean, well-fluxed iron. The transistor leads should not be cut short.

A small "E" bracket was used to hold the battery in place. The author found that small size paper clips made almost perfect connection clips for the battery, slipping over the projecting terminals. However, if the builder prefers, the battery can be made by soldering the leads directly to the battery cell, provided the leads are thin enough to be folded back and held in place by the battery case. The bracket should be taken out to overhear the battery if this technique is used.

Parts Substitutions
A number of parts substitutions are possible, depending on the needs and requirements of the individual builder. For example, a larger speaker and dif-

The prospective builder may prefer to use a different battery in place of the 15-volt hearing aid type battery used by the author. The circuit is not at all critical and will operate with comparatively low voltages, although the operating frequency as well as the output amplitude (voltage) may change. Other suggested batteries are the Mallory 32824 (a 6.5 volt battery designed specifically for transistor applications), the Ricco type 431 (another 3.5 volt bat-
tery), and the RCA type VS08B (a 6.3 volt "A" battery).

Any standard "universal" audio out-
put transformers should give satisfactory results, although the builder may have to experiment somewhat with the tapped secondary connections. The terminal connections and color-coding given in the schematic diagram (Fig. 2) refer specifically to the主播 unit.

A slide or rotary switch might be used in place of the toggle switch em-
ployed in the author's model, or, if preferred, a control type switch on R5, may be used as a power switch. This would reduce the number of controls from two to one.

Substitutions for C, R, and R5 will depend on the operation desired.

Circuit Modifications
A fairly wide range of "beat" sig-
als is provided by the component values given in the parts list. In the author's model, the range is from 1 beat per second to 5 beats per second. The range is divided into a number of steps, which can be achieved by varying C, R5, and R.

Fig. 2. Complete schematic of the metronome which uses one "p-p" transistor.

The fixed resistor, R5, is chosen to give a particular maximum (or mini-
mum) repetition rate for specific val-
ues of C and R.

All three component values may vary, with different transistors and supply voltages, and hence it is difficult to determine these components in advance. Rather, the circuit is built up and an easily available value chosen for C (50, 100, 150, 200, or 250 µF). As the designer begins to close in on the circuit, and a resistance substitution is made in place of R and R5, the resistance is then adjusted until the desired minimum repetition rate is obtained. This value is equal to C. R5 is a potentiometer having a stand-

ard value most closely approaching the difference of the two values determined experimentally, that is, R5 = R - C.

Where the value of R does not even closely approach a commercially avail-
able potentiometer, a different value of C, may be used.

If several ranges are desired, a se-
lector switch may be provided to in-
sert different values of C, into the circuit.

Further circuit modification is to dispense with a continuously adjust-
able control entirely and to provide a selector switch inserting fixed val-
es of R5 (Fig. 3). In this way, two or three more fixed beat rates may be obtained for a given size of control (number of switch positions available).

Still another circuit modification is to provide a phone, rather than loud-

speaker, output. Simply connect a pair of low-impedance magnetic ear-
phones in place of the loudspeaker voice coil.

Calibration
No effort was made by the author to accurately calibrate the settings of R, in terms of "beats-per-second" (or per minute), since this was not necessary in the application in which the author's model was used.

Furthermore, for many applications a calibrated control will be desirable.

A variable control may be used for calibrating the completed instrument, depending on the repetition rate desired. Where a slide switch is used, however, a scale and a pointer knob should be provided for the control. For maxi-
mum accuracy, a large scale is desir-
able, and it may be found best to mount the control on the side of the meter case, where it is more visible.

For a more accurate calibration, the desired, the builder may borrow another metronome (either a mechan-
ical or electronic model) that is ac-

(Continued on page 104)
A TRANSISTORIZED APPLAUSE METER

Build this compact unit for rental or "loan." It can be used as an output meter or for sound-work tasks.

WITH the increasing general interest in square-dance competitions, amateur shows, and similar contests, the radio-TV service shop is frequently in a position to pick up extra money or to obtain good publicity by renting or lending and installing p.a. systems, record players, and juke boxes. General practice is to rent the systems or equipment to clubs and money-raising groups, and to "lend" the systems to churches and similar charitable organizations.

At such contests, prizes are often awarded on the basis of "audience reaction." The only fair way to determine audience reaction to a particular act is by means of the impartial judgment of an electronic applause meter. In this way, there is no possibility of favoritism on the part of the examiner, nor any question as to the fairness of decisions.

Since the radio-TV service shop may be called on to furnish or operate the p.a. system, it is only natural that it also be requested to supply or obtain an applause meter or similar device. Commercial applause meters may not only be difficult to obtain locally but quite expensive, so the service organization handling such work may find it worthwhile to consider building its own instrument.

In choosing the design for such an instrument, several features are desirable. The applause meter should be self-contained, compact, light weight, sensitive, easy to use, and, preferably, independent of both the power line and the p.a. system. These last two features are important because the instrument may sometimes be used outdoors where power is not available or in small groups where a p.a. system is not needed.

The instrument shown in Fig. 1 comes close to meeting all of these requirements. It is completely self-contained. No extra "hike" or other pickup is required. It is compact as the over-all dimensions are only 4" X 4" X 4 1/4". It is quite sensitive, yet easy to operate and use—only a simple control is provided. It is battery operated and no power-line connections are necessary!

These features have been made possible by utilizing p-n-p transistors in the design of the instrument.

Circuit Descriptions

The complete schematic diagram for the transistorized applause meter is given in Fig. 2. The basic circuit consists of a two-stage transistor-coupled transistor amplifier followed by a single stage combiner, amplifier-detector. A built-in crystal microphone (Mic.) serves as the pickup.

In operation, audio signals picked up by the microphone are applied to the primary of transformer T1, a step-down unit used to match the high impedance of the crystal microphone to the low input impedance of the first transistor amplifier stage.

In order to adjust the gain of the instrument for different sized audiences, a simple step-type attenuator consisting of rotary switch S, and resistors R1, R2, R3, and R4 is provided between the secondary winding of T1 and the input of the CR721 amplifier stage.

The audio signal obtained from the "arm" of S is applied through coupling condenser C1 to the base of the transistor, connected as a conventional "grounded-emitter" amplifier. This basic circuit has been used throughout the instrument as it provides good gain and permits a single battery power source to be employed.

Resistor R7 serves as the "bias" resistor. Connected to the negative terminal of the power supply, it establishes the base current "bias" for the first stage.

Transformer T2 is used to match the high output impedance of the first stage to the low input impedance of the second stage, a CR722 "grounded-emitter" amplifier. The primary winding of this transformer serves as the collector load for the CR721 stage.

Coupling condenser C2 offers a low impedance path for the audio signal to the base of the CR722 amplifier. It prevents the secondary winding of T2 from acting as a d.c. short from base to ground. R2 is the base return resistor for the second stage; again, the value of this resistor determines the base "bias" current.

Connecting C3 in parallel with the coupling transformer, C2, to bypass the higher frequency components of the audio signal, reduces the effects of high-pitched whistles on the final meter reading. This condenser also reduces, to some extent, the amplitude of the noise "buzz" generated by transistor amplifier stages.

If desired, crystal headphones may be inserted in the microphone jack, C4, coupled to the second amplifier stage through condenser C5. This provision permits the operator to hear the signal as picked up by the applause meter.

Transformer T3 serves to perform a function similar to that of T2; that is, its primary winding serves as the collector "load" for the second amplifier stage, and it is used to match the high output impedance of one stage to the low input impedance of the next stage.

C6 serves as the coupling capacitor to the last stage, a CR722 transistor operated without base bias "bias" current. Note that base resistor R3 is returned directly to ground rather than to "GND." When a transistor amplifier is op-
erated without base "bias" current, it acts to rectify as well as to amplify the applied signal. Thus, collector cur- rent depends directly on the amplitude of the applied audio signal and this current is indicated on the microammeter, M.

Provisions are made for "smoothing out" the peaks of audio signals by means of a large capacity bypass con- denser, C4, across the meter. The use of this filter is optional with the op- erator, since it may be thrown out of the circuit by means of switch S.

Power for the entire instrument is obtained from a single 6-volt storage battery, B1, controlled by a s.p.e.t. power switch, S.

Construction Hints

The assembly and wiring of the instrument are straightforward and should present no problem to the skilled technician. The placement of major parts is apparent from the in- terior view of the instrument given in Fig. 3. The microphone cartridge and the input transformer (T1) are mounted on the back panel.

A small chassis is used for the transistor circuits. An under chassis view is shown not shown because the panel view, with the operator's layout, must be left open to this change in location. The subminiature transformers are field in place by small "Z" brackets. Wiring and layout are not especially critical, but the builder may find it convenient to lay out on paper a "rough" drawing and to use one to suit his own requirements. Care should be taken to follow good audio practice; that is, leads should be kept reasonably short and the "input" and "output" portions of the instrument should be kept well separated.

Although the author's model has been assembled in a standard snap-in panel utility box, another type cabinet may be preferred by the builder. Al- most any small metal box will serve well in this capacity; a Budd "Minibox" is a good choice.

The transformer leads are identified by color-coded wires—the proper con- nections are shown in Fig. 2 for the transformers specified in the parts list.

In rare instances it may be found necessary to readjust the values of the "base return" resistors R4 and R5 for optimum results with a particular transistor. To do this experimentally, connect an audio sine-wave generator to the input and an oscilloscope to the output of the stage to be checked. Adjust the value of the resistor for best gain with minimum distortion, but in no case choose a value which permits the oscillations to rise above 5 ma.

The builder can use one of two methods when installing the transla- tors. He may either use resistors or wire the transistors directly into the circuit. Should sockets be preferred, standard 3-pin subminiature tube sockets are suitable.

If the transistors are to be soldered in position, however, special care should be exercised to complete the soldering as quickly as possible to avoid possible damage by overheating these expensive components.

Circuit Modifications

A considerable number of modifica- tions in the basic amplifier circuit are possible to meet the special needs of the individual builder. How- ever, because the number of possibilities is so large, only a few suggestions are outlined here.

First, the monitor circuit may be eliminated entirely if desired. Simply remove C5 and J. No other circuit changes are necessary.

Another meter may be substituted for the 0-500 microammeter unit speci- fied in the parts list without making any other circuit changes. An 0-100 microammeter will provide increased sensitivity, while less sensitivity will be obtained with a 0-1 ma. unit. Irre- spective of the meter chosen, however, care must be taken to set the attenu- ator so that serious overload will not occur. The exact setting will vary with different sized audiences.

In the author's model, the resistors in the attenuation network (R, R4, R5, R6, and R7) were chosen arbitrarily and no attempt was made to provide a precise degree of attenuation at each switch position. This method was employed since the instrument is used only to indicate relative peaks and exact meter readings are unimportant.

Some builders might prefer that the attenuator switch provide precise steps of attenuation, either in terms
Construction details on a compact unit which can be used to warn the householder of unusual or dangerous leakage.

Electronic experimenters and technicians occasionally find it necessary to devise and build some type of simple moisture or rain detector. The unit may be destined for their own use, or it may be built at the request of a friend, relative, or neighbor. There is no doubt that the applications of a reliable moisture detector are quite varied... from closing a window with the first few drops of rain to protecting the family washing (by sounding an alarm so clothes may be removed from the line), or from detecting leaks and excessive condensation, to giving a signal when "bed-wetting" occurs.

Unfortunately, many of the "rain detector" designs suggested and used in the past required vacuum tubes or thermistors for their operation... making high voltage operation almost mandatory, and battery operation, at the best, expensive and cumbersome. Line voltage operation restricts the possible applications of a moisture detector considerably—outdoor use is limited, and applications involving possible body contact may be dangerous.

By transistorizing a moisture detector, however, low voltage battery operation becomes economically feasible, and such an instrument has virtually unlimited application. A typical transistorized moisture detector, suitable for construction by the home builder, is illustrated in Fig. 1, with the complete schematic diagram given in Fig. 3.

Since only a few components are required, the cost of the completed device is reasonable and compares favorably with vacuum-tube operated units. Wiring and assembly is straightforward and simple, and the average technician should have little or no difficulty in assembling a similar unit in an evening's time.

Circuit Description

As can be seen by reference to Fig. 2, the basic device consists of a moisture sensing element ("sensor"), a p-p-n junction transistor connected as a grounded-emitter "direct-coupled" amplifier, and a relay, used for controlling an external circuit.

The "sensor" consists of two pieces of aluminum foil connected to a piece of plastic, with a very narrow separation between the conductors (from 1/36" to 1/48/"). In operation, the base-emitter circuit of the transistor is normally open, and little or no collector current can flow through the relay. The relay thus remains open.

Should a drop of moisture fall on the "sensor" plate so as to conduct both pieces of foil simultaneously, the base-emitter circuit is closed, and base current may flow. The electron path in the base circuit is from the negative terminal of the battery, through the power switch, through one resistor, through the drop of moisture on the "sensor" plate, and through the base-emitter of the transistor back to the positive terminal of the battery.

This basic current flow permits a corresponding collector current flow to take place, though of much larger amplitude due to the current amplification of the transistor stage. The collector current flow closes the relay which may be used to switch on some external circuit.

A single battery, B, supplies both base and collector. A power switch, A, is provided to turn the unit "off" when operation is not desired. Series resistor R serves to limit base current to a safe value, even if the "sensor" elements are accidentally short-circuited. The high d.c. resistance of the relay coil satisfactorily limits collector current well within the maximum ratings of the transistor.

Construction Hints

The author's model of the moisture detector has been assembled on a small standard aluminum chassis. Parts layout and wiring are clearly visible in the over-all (Fig. 1) and side-chassis (Fig. 4) views. However, this type of assembly need not be followed by another builder since the circuit is completely non-critical—parts may be made as short or as long as may be desired.

However, if the builder decides to solder the transistor directly into the circuit, as in the author's model, he should exercise care to avoid overheating the transistor leads. The transistor is quite susceptible to heat damage. Allow the transistor leads to remain reasonably long, covering them with insulting tubing, and complete the wiring as quickly as possible, using hot-dip, tin-lead solder.

As an alternative, a socket may be provided for the transistor. Use a standard five-pin subminiature tube socket. Only three of the socket terminals are needed. The moisture detector might easily be assembled in a standard metal utility box or Bud "Minibox" to provide a completely enclosed unit.

Parts Substitutions: Although comparatively few parts are required for the construction of this device, it is still possible to make a number of parts substitutions to utilize components that may already be available in the builder's "junk box."

A slide, toggle, or even key-operated switch may be substituted for the toggle switch (S) used in the model. A key-operated switch is an especially good selection as it permits one or two persons to exercise complete control over the operation of the unit.
A type CK21 interaction transistor may be directly substituted for the type CK22 shown in the schematic diagram, and will provide somewhat greater sensitivity. No other component changes are necessary.

Another relay may be substituted for the unit specified in the parts list. Choose a relay which will require more than about 2 milliamperes coil current for operation, and with a moderately high d.c. resistance. In a few instances it may be necessary to use a higher voltage battery should a different relay be employed.

Since very little current is drawn from the battery until the moisture detector actually operates (relay closes), battery life is quite long. In some instances the battery life in the detector may approach the normal "shelf life." Because of this, the builder may exercise wide latitude in his choice of a battery. A conventional zinc-carbon dry battery, a "wet-cell" storage battery, or a mercury battery may be used as the power supply for the unit.

Assembling "Sensor" Plate

The "sensor" plate consists, basically, of two conducting elements separated by a narrow strip of insulating material. It may be made up in any one of several ways, depending on the inclination of the individual builder and the facilities available to him. The "saw-tooth" design, shown in Fig. 4 and described, is probably the simplest and most satisfactory. The "saw-tooth" pattern may be used in place of the "saw-tooth" employed by the author, provided the foil is cleanly divided into two separate conducting elements. A few possible patterns are illustrated in Fig. 3.

A "sensor" plate may also be made up by means of two pieces of copper or brass screening, separated by a piece of plastic screening. Over-all dimensions may be as large or as small as desired.

However, irrespective of the method chosen for assembling the "sensor" plate, care should be taken that the two conducting elements are not so close together that accidental short-circuits may easily occur (resulting in "false" alarm conditions). It is recommended that a single drop of moisture cannot contact both plates.

Once the wiring is completed, the moisture detector should be carefully checked for operation by closing the power switch and pressing the finger, and touching the "sensor" plate in the gap between the two conducting elements (there is no danger of shock). The relay should close. Remove the finger and allow the damp spot to dry, the relay should then open.

If satisfactory operation is not obtained, carefully check all connections. Look out especially for "cold-soldered" joints and errors in wiring. Make sure that the battery has been connected with the correct polarity.

If a different relay has been used in place of the unit specified in the parts list, it may be that insufficient current flows to operate the relay. This may call for a larger battery.

When using a larger battery, take care that the maximum ratings of the transistor are not exceeded. The collector voltage should not exceed 20 volts and collector current should not exceed 5 ma. In addition, a new value should be chosen for RC. Using Ohm's law, calculate a resistance value which will not allow more than 5 ma base current flow, even if the "sensor" elements are separated together.

Once the moisture detector is operating properly, it may be set up to perform the desired function. Let us discuss a few typical applications:

Rain Alarm: To use the moisture detector as a rain alarm, connect the relay contacts to operate an alarm bell, buzzer, or signal light. Place the "sensor" plate on a window sill or in a similar exposed location.

For maximum response two or more "sensors" plates should be provided, simply connect the additional plates in parallel. A separate "sensor" plate may be placed on each window sill if desired.

If the builder prefers, the relay may be used to activate a small electric motor (set up to close the open window) instead of sounding an alarm signal. Should this arrangement be employed, a small "limit switch" should be placed on the window frame to shut off the motor after the window is closed.

Such a "limit switch" may be inserted quite easily by using either a Micro-switch or small push-button switch in series with the motor leads, arranged to open the motor circuit when the window is fully closed.

Condensation or Leakage Detector:

Fig. 3. Complete schematic of moisture detector. Parts variations are possible.

Fig. 4. Underneath view of detector. Any place convenient is suitable as circuit connections are for low voltage, non-critical. See article...
An interesting project for the experimenter, this battery operated unit requires few parts for its construction.

A TRANSISOR "ELECTRIC ORGAN"

Fig. 1. Overall view of "organ." Both hands are used to operate instrument.

A THOUGH the device shown in Fig. 1 is not an "organ" in the strict sense of the word, it is capable of producing tunes when operated by a person of moderate skill. In fact, the operator need not be a skilled musician. The average person, with a little practice, can "pick out" tunes, playing one note at a time.

As a toy, the "electric organ" shown is of real value. The author has several times turned his model over to his children, who enjoy playing with it in preference to their more conventional toy pianos, toy xylophones, toy guitars, and other toy musical "instruments." But the value of the device as a toy is not limited to its appeal to children. Although the output is obtained through a loudspeaker, the volume is not so high as to prove distracting to the parents. The children can "make music" to their little hearts' content while the parents, in an adjoining room, can watch television, listen to the radio, or even read, without distraction.

Another real advantage of the "electric organ" shown is its independence from the power line, and the fact that there is relatively no danger of electric shock. Nor is the design such that the battery used has to be replaced every day or so. With average use, the battery should last its normal shelf life.

These desirable characteristics, for a toy, have all been made possible by utilizing a Kaydexus junction transistor in a simple oscillator circuit. As illustrated by reference to the schematic diagram, Fig. 2, relatively few other parts are required for the construction of the unit.

Referring to the schematic diagram, Fig. 2, a type CKB22 transistor is connected as a modified grounded-emitter "Hartley" oscillator. The emitter is connected through push-button switch B to the positive terminal of a small hearing-aid type battery, and the collector is connected through one-half of the transformer T1, primary winding to the negative terminal of the battery.

The necessary feedback signal for operation is obtained from the other half of the transformer primary winding, which is connected through coupling condenser C1, to the base of the transistor.

Resistors R1 to R6 serve as "base return" resistors, with the desired resistance selected by depressing the proper push-button 16, to 61. If toggle switch S1, is thrown, the "base return" resistor bypasses R1 and R2 in series. Since R3 is variable, the total resistance value can be adjusted from the value of R3, to the sum of R1 and R6, or from 800 ohms to more than 2 megohms.

The S1 FM loudspeaker is connected to the proper taps on the secondary winding of T1. Transformer T1, serves both as an "oscillator coil" and as an "output transformer." In operation, one of the resistor switches, S5 to S9, and the power switch, S10, are thrown simultaneously. Battery current can then flow over two paths.

Part of the current flows through the "base return" resistor and the base-emitter of the transistor, establishing the bias current for the transistor. The amount of current so established depends on the battery voltage and the total impedance of the resistor plus the internal base-emitter impedance of the transistor. Since the external resistor generally has a greater value than the internal impedance of the transistor base-emitter circuit, the base current, for practical purposes, can be said to depend primarily on the size of the "base return" resistor.

Current also flows over the path including half of the transformer primary winding and the collector-emitter circuit of the transistor. This is the collector-current and its value depends primarily on the amount of base current flow (as well as on the battery voltage).

Any changes in collector current in- duce an a-c voltage in the primary of transformer T1. This voltage is coupled through condenser C2 to the base of the transistor, adding an a-c component to the d-c base current, and causing corresponding changes in collector current. Thus, the basic conditions for oscillation are set up - positive feedback from output to input circuit, coupled with stage gain.

The frequency of operation depends on the transistor characteristics, on the transformer used, on the value of coupling condenser C2, and on the size of the "base return" resistor. Varying any of these factors permits the frequency to be varied continuously from about 20 cps to about 10 kc, simply by adjusting R3.

The "organ" operation bears an inverse relationship to the size of the "base return" resistor, that is, as the resistor value is reduced, the frequency of operation increases. At the same time, the base current (and hence the collector current) increases. The fact is also that the battery current drain is several times greater than at lower frequencies. It is this characteristic that makes it necessary to provide a feedback resistor R8 in series with the continuously variable control. Thus, R8, although limiting the maximum frequency of operation when the variable control is wide open, also limits the maximum base and collector current and thus serves to protect the transistor.

Since oscillation is obtained by means of "positive" feedback rather than by employing a tuned cir-
cult, the signal emanated is not a sine wave. Rather, it is extremely rich in harmonics. The sound charac-
teristics vary with frequency, and also with the characteristics of the tran-
sistor and transformer used.

Construction Hints

Because of the simplicity of the circ-
cuit, duplication of the model should not prove at all difficult for the aver-
gee radio technician. Practice must be exercised when installing the transformer. If the transistor is sold-
directly into the circuit (i.e., of a socket using resistor, care must be taken that the transistor leads are not unevened.

Circuit layout, lead length, and lead arrangement all are completely non-
critical. It is suggested, however, that standard good wiring practice be fol-
lowed.

The author's model has been assem-
bled in a standard 1/4" sloping front cabinet, and easily obtained push-butt-
ton switches were used for the various "keys." A different color push-button (black) was used for the "power" key (R.) than for the "tone" keys (S. to R.)—red push-buttons were used here.
Six notes were provided, plus a continuously variable control (E.).

Since the range of keys and case which he feels is desirable. An ingen-
tious technician should have no diffi-
culty in modifying the keys of a top-
plane to serve as switches for the "electric organ," assembling the rest of the components within the case of the piano. If space permits, the loud-
speaker could be mounted within the toy piano case, otherwise it could be mounted separately (a sloping panel motor case makes an excellent "baffle" for a 2" or 3" speaker).

If preferred, # 5, 6, 8" or larger speaker may be used in place of the 3" speaker used by the author.

The transformer used by the au-
ther is of the "universal replacement" type with a multi-tapped secondary wind-
ing. If the builder uses a similar transformer, he should experiment with loudspeaker connections on the different taps, choosing the pair giv-
ing the best results.

Although only six "keys" (and hence six notes) are provided in the model shown, any number of keys may be used, simply by adding more switches and different value resistors. Thus, if a child's toy piano is used as the basic unit, a different note can be supplied by every key on the board.

Since the frequency (tone of the note obtained as each key is depressed depends upon the size of the "base return" resistor (R. to E.) but also on the unique characteristics of the transistor and transformer used, there are no restrictions com-
limiting the size of these resistors in advance. Rather, they are determined experimentally after the unit is wired and tested.

Two methods may be employed for choosing these resistors. If the com-

plished unit is to be used primarily as a toy, the resistor values may be chosen arbitrarily without regard to the notes obtained. This method was used in the author's model. A series of resistors having values of 150,000, 270,000, 390,000, 210,000, and 260,000 ohms were used.

On the other hand, if the builder intends to use the completed unit to play actual tunes, each key should be adjusted to give the desired musical note. This can be done either by using a potentiometer to determine the proper resistor value, later perma-
nently installing a fixed resistor, or by using a rheostat for each resistor. The second method is the most flexi-
ble as it permits readjustment at any time, but is also the more expensive, requiring a separate potentiometer for each note to be sounded.

(Note: For the frequency of various musical notes, refer to "Fun with a Home-Built Electronic Organ," by Jim Kirk, Radio & Television News, March 1963.)

The continuously variable control was included in the author's model more as a novelty than for any serious purpose. However, it does permit un-
usual tonal effects to be obtained, or may be either retained or omitted, as desired by the builder. Some builders may even wish to provide several such controls.

Operation

In the author's model a separate power switch, as such, has not been provided. Rather, the power switch (E.) becomes one of the "playing keys."

To sound a particular note, the de-

lected "tone key" (S. to E.) and the "power key" (E.) are depressed simulta-

aneously. They are held down long enough to sound the desired interval (quarter note, half note, full note, etc.) and then released together.

Either one finger of each hand may be used; in approved "hunt and peck" typewriter style, or the fingers of both hands may be employed to cover all the operating "keys." The latter tech-

Fig. 3. Schematic of transistor "orga-
This useful test accessory can be used alone or built into an existing audio oscillator. It is compact and reliable.

The instrument shown in Fig. 3, although small enough to be held comfortably in the palm of the hand, is, nonetheless, capable of producing good-quality rectangular waves when driven by a sine-wave signal of moderate amplitude. A further feature of the instrument is that the level of the output signal can be easily controlled, from zero to an amplitude several times greater than the input signal. The instrument is completely self-contained! No external power source or batteries are required for its operation.

These features have been made possible in the compact instrument shown by utilizing the new Raytheon CK722 PNP transistor in a clipper circuit requiring a minimum of additional components. This is apparent from the interior view, Fig. 5, and from the schematic diagram, Fig. 2.

Circuit Description

Referring to the schematic diagram of Fig. 2, the CK722 transistor has been connected in a conventional grounded emitter amplifier circuit, but without "bias" voltage between the base and emitter. C serves as the input blocking condenser, R as the input resistor, R as the load resistor, and battery B as the power source.

When a transistor amplifier is operated without "bias," and a sine wave is applied to its input, the output consists of a series of fairly narrow rounded pulses. This effect has been noted previously (see The Transistor in Simple Circuits) by W. H. J.

The output waveform is also relatively unaffected by the setting of the output control, R, except as far as amplitude is concerned, due to the low value of this potentiometer. An output "blocking condenser" has not been included in the model.

In order to prevent even a minute current flow when the unit is not in use, a switch has been provided in the collector circuit (R) and is mounted on control R. When in use, the current drains average only a fraction of a milliampere (the peak is about 1.5 ma. drains) and, therefore, the battery life
should approach the normal "shelf life." 

Construction Hints

The entire circuit is easily assembled in the small size of the Bud "Mini-boxes" (CU-3000, 2½"x2½"x1½") if reasonable care is taken and the components specified in the parts list are used. The use of a metalized tubular paper condenser in the input is particularly important as it is virtually impossible to find a paper condenser of large capacity (1.5 mfd.) in a box of this size and still have room for the remaining components.

Leads should be kept reasonably short and direct to avoid stray capacitance to ground with resultant deterioration of the output waveform. This should not prove too difficult as short leads are almost naturally used in a circuit wired as compactly as is shown in the photographs (Figs. 1 and 5).

The arrangement of parts used by the author is apparent from the illustrations, but the reader need not follow this layout exactly. As long as excessively long leads are avoided, the layout is non-critical.

For best results, it is essential that a cerfex potentiometer be used for $R_b$, although a linear taper is not absolutely necessary. If a wirewound pot is used, however, deterioration of the signal waveform at high frequencies (due to residual inductances) is likely.

In the model shown, connections to the battery have been made by soldering leads directly to the battery terminals and wrapping with 60/40 electrolytic tape to prevent accidental shorts. The battery is held in place by a simple bracket found in a commercial "hardware assortments."

The "panel" of the instrument has been labeled by using standard black decals and then spraying with clear plastic to provide additional protection.

The transistor has been wired directly into the circuit by its tinned leads. Although there are special sockets available for the CK722, the author feels that their use would only be justified in equipment designed for continuous 24-hour-per-day operation, due to the inherent long life of transistors.

Circuit Modification

The 15 volt hearing aid battery, $B_b$, may be replaced by batteries of lower voltage without affecting signal waveform or the action of the circuit—the only difference will be in the amplitude of the output signal. The lower the supply voltage, the lower the maximum output signal. Voltages as low as 3 volts have been tried experimentally without deterioration of output waveform quality.

If a fixed output signal level is preferred or an adjustable output, $B_b$ may be a fixed carbon resistor, the 1½ watt size is satisfactory for use here.

An output d.c. blocking condenser, similar to $C_b$, but connected between the circuit output and the output terminal or binding post, may be used if desired, and will make it unnecessary to check for a blocking condenser in the circuit to which the clipper is connected for test purposes (or to use an external blocking condenser).

The switch on the output control may be replaced by any suitable a.p.s. switch—a toggle, lever, rotary, or slide switch may be used.

If both input and output blocking condensers are used, and a battery of larger size than the one given in the parts list is used, it may be necessary to assemble the unit in a larger container. The next largest size Bud "Mini-box" should be suitable unless regular paper condensers and an extremely large battery are employed.

Where preferred, the circuit may be assembled as part of an existing audio oscillator rather than as a separate accessory. If this alternative is adopted, a switch should be provided so that a choice of either "Sine" or "Rectangular" waves may be made by the operator, or separate output terminals should be provided so that both sine and rectangular waves are available on the front panel simultaneously.

Fig. 4. Waveforms from clipper. (A) 45 cps. (B) 3 kc. (C) 25 kc. (D) Output when 10 kc. sine-wave signal of low amplitude is applied. (E) Overdamped unit.

Fig. 5. Interior view of clipper. All hookup leads should be kept as short as possible.

Operation: Once the wiring is completed, the builder should become familiar with the basic operation of the clipper before attempting to use it in practical test and experimental work. The best way to do this is to connect the output terminals of the clipper to the "Vertical Input" terminals of an oscilloscope. An audio sine-

(e) 

(continued on page 101)
TWO TRANSISTORIZED METAL LOCATORS

By EDWIN BOHR

Two lightweight units—one small and one large—feature stable oscillators, simple construction and low cost

Both transistorized r.f. and audio circuits are used. The oscillators are extremely stable, using a separate battery bias circuit for oscillator stabilization. Battery life is long and standard easily obtained components are used throughout.

Circuit description
Small circulating eddy currents are generated in metals placed in a radio-frequency field. These currents oppose the back e.m.f. of the coil producing the field, lowering its inductance. If the coil is part of an oscillator circuit, the frequency of oscillation is increased as metals are approached.

Parts for small metal locator
Components: 1—280 pf, paper, capacitor; 2—0.01 mf, 1,000 volt, paper; 1—250 pf, variable (ECCO G7-16). Capacitors: 1—220 pf, paper. 1—100 pf, paper, 1—8 pf, paper. 7—2.5 mfd, 1,000 volt, paper. 1—2.5 mfd, 400 volt, paper. 1—1.25 mfd, 400 volt, paper. 1—0.1 mf, 1,000 volt, paper.
Miscellaneous: 6—C32272 capacitors; 6—spring-loaded knife switch; 3—2200 ohm 1/2-watt resistors; 2—battery clips; 1—4-wire radio plug; 1—4-channel jack; 8—1/4 in. nuts; 1—sheet metal.

Parts for large metal locator
Components: 1—1,000 pf, 1,000 volt, paper; 1—100 df, variable (ECCO G7-16). Capacitors: 1—220 pf, paper. 1—100 pf, paper, 1—8 pf, paper. 7—2.5 mfd, 1,000 volt, paper. 1—2.5 mfd, 400 volt, paper. 1—1.25 mfd, 400 volt, paper. 1—0.1 mf, 1,000 volt, paper.
Miscellaneous: 6—C32272 capacitors; 6—spring-loaded knife switch; 3—2200 ohm 1/2-watt resistors; 2—battery clips; 1—4-wire radio plug; 1—4-channel jack; 8—1/4 in. nuts; 1—sheet metal.

Fig. 1—The transistorized metal detector uses two beat-frequency oscillators.

Fig. 2—Schematic of metal detector using additional two-stage amplifier.
Of several ways for detecting metals, this inductance change method is the most simple and requires very little in the way of complicated circuits.

The change in inductance must be translated into some sort of signal that can be detected by the human mechanism. This might seem difficult, since the change in inductance is small. But, the problem is easily solved by beating two oscillators, producing an audible indication.

The two oscillators, in Fig. 1, are labeled Reference and Detection. The reference oscillator operates at a fixed frequency, adjustable by an iron core. However, the detection oscillator changes frequency when the exciting coil comes near metal. The oscillators are coupled to headphones where their outputs combine to form a different beat. The locator in Fig. 2 has an additional two-stage amplifier between the oscillators and the headphones. This requires very stable oscillators.

Two features increase the stability of the transistorized circuit. First, the oscillators are similar electrically. Thus, their drift rates are similar—the beat note change is not so pronounced if there is a shift in the oscillator frequencies. Second, the separate-battery bias stabilization reduces—as much as possible—the drift troubles produced by the transistors.

Why bias stabilization is necessary may not be too clear. The problem is unique with the transistor and very interesting. To clear up the picture, special characteristics of semiconductors must be known.

Stabilization

Germanium diodes and transistors do not perform well at high temperatures. Neither should allow current to flow in the reverse direction; but they do, and that is a fact we have to live with. The amount of back-current increases with junction temperature and, in the case of transistors at a given temperature, may vary from one unit to the next by a factor of 10.

Because there is resistance within the transistor base, part of the back current takes a path to ground through the emitter, generating positive emitter bias. The “hole” current thus generated causes a further increase in collector current. The resistance within the transistor base, alone, causes instability. But, many of the published circuits add fuel to the fire by placing large biasing resistance (perhaps a megohm) in the base circuit.

With very high performance transistors, high resistance in the base can cause this temperature plus back current plus bias effect to become cumulative and destroy the transistor. For standard-gain transistors, however, resistance in the base usually does not produce anything as drastic. But, it does result in a circuit undeniably sensitive to transistor variations and temperature changes.

Stabilization is obtained by putting as much resistance as possible in the emitter circuit and as little as possible in the base circuit. One way to do this is to place a voltage divider across the collector supply. The base is then returned to the divider, and enough resistance inserted in the emitter circuit to bring the bias current to the correct value.

A better way, and the one used in the locator, returns the base directly to ground. The bias, then, is supplied by a separate emitter battery and resistor.

The small locator

A capacitance type dividing network across the tuning coil provides the feedback and proper impedance match between the collector and emitter. There is a further advantage in that a simple two-terminal coil, without taps or tickler...
winding, can be used. The value of the capacitor for the emitter tap in Fig. 1 is 1,000 μF but it is correct for the lower emitter impedance of the transitor.

Positive emitter bias flows through the headphones and the 1,000-ohm emitter resistance. This current is necessary to start the transistors into oscillation. After the oscillations have begun, the emitters are self-biased, class C.

The values of the components are rather delicately balanced. For example, two 0-100 μF capacitors bypass the collector supply. More capacitance than this will reduce pulling between the oscillators, but it will also reduce the loudness of the beat note. Less capacitance produces severe pulling. If the headphones have too much internal resistance, the oscillators will not start. The headphones resistance should be limited to 1,000 ohms. For higher resistances an extra emitter bias cell, connected in series, could be used, but the oscillators may lock together more readily.

The circuit operates at about 500 ke. Most transistors will operate to this frequency with a suit of collector supply. The poorest transistor tested in the circuit was able to make it to 600 ke before it quit oscillating.

Also, at this frequency an ordinary radio can be used to check the heater. And the frequency is low enough for the locator coil to be used without a Faraday shield being absolutely necessary.

Small locator construction

The exploring coil for Fig. 1 is an ordinary loop antenna salvaged from an abandoned portable radio. The loop is mounted, with polyethylene coil dope, to a Lucite panel. Saw off one end of a 6-inch length of Lucite rod, at a 60° angle, and weld it to the Lucite loop panel. A 75% ethyl ether solution is excellent for welding plastic surfaces. Cover each surface with the solution and press them together, pushing out all air bubbles. The resulting weld will be almost as strong as the plastic material.

Tap the other end of the rod for two 6-32 screws, which mount the aluminum case. The switch, coil, and headphone jacks are mounted on the case. The transformer, power supply, and relay parts are mounted by support leads to these three components.

The transistor chassis is a section of plastic from the lid of a small radio hardware assortment box. Rectangular holes for hearing-aid sockets are made with the end of an instant-hard soldering iron. While the plastic is still warm and soft, the sockets are pushed into place. Support and connection wires to the chassis are treated in the same way. The wire is heated and pushed through the chassis.

Mercury cells, type RN-35RT, power the locator. Because of their long life, they are wired into the circuit. Three cells are wired in series to form the collector battery. The tab is bent upward at a right angle, near its tip, and soldered to the side of the next cell. Tin each surface first, and be quick with the soldering iron. The cell is small and quickly becomes overheated, with possible damage from an internal short. After the cells are soldered together, give them several coats of TV corona dope for insulation. A small piece of cloth, pressed into the wet dope, improves the insulation.

To fit a knob to the variable loopstick, wind a single piece of solid hookup wire, in two layers, near the end of the adjusting screw. The solder is then flowed into the wire and screw for a solid mass.
Small locator operation

Turn on the power switch and rotate the pushbutton until a suitable audio signal is heard in the phones. If no audio signal is detected, either the oscillators are not operating; or, they are working at too low a frequency to be brought to zero beat. A few tests will indicate what is happening. Short out the earphone terminals and bring the locator near a radio tuned to the low end of the broadcast band. At some point on the radio dial a strong carrier from the detection oscillator should be received. The reference oscillator should also be received, but it will be weaker. It can be identified since its frequency changes when the locator tuning knob is turned. If the loopstick cannot bring the reference oscillator to the same frequency as the detector oscillator, it may be necessary to add capacitance across either the loop or loopstick. I had to add a 100-pf micro capacitor across the loopstick. It can be seen in the photograph.

Plug the phones in again. This may shift the frequency slightly, but the oscillators should continue to work. If they do not, the headphone resistance is too high. I used a single phone and had no trouble. If high-resistance phones must be used, short out the regular headphone terminals and connect the phones in series with the collector battery. As an alternative I use an additional emitter bias cell. But, to repeat, the oscillator should give no trouble with 1,000 ohms in the headphone circuit.

Best performance is obtained with the reference oscillator tuned to the lowest possible beat note, just before the oscillators lock together. When the exploring coil comes near metal, the pitch will rise. The reference oscillator can be set for a constant high pitch note that goes down to zero beat as metal is approached, but the sensitivity is less.

The operator must practice with the locator until the "feel" of operation is acquired. Practice first with objects that can be seen.

Maximum range for the locator is about a foot in the case of relatively large-surfaced metals. The boundaries of the magnetic field are typically within an inch at a distance of 6 inches. Signal is detected either at zero beat, at a low beat note in the lowest value position, or at zero beat, with the object being approached closely, or out of range, will be not too high for the ear to easily distinguish small pitch variations.

Large locator

The larger locator varies in several respects with the smaller locator. The oscillator frequency is 3 mc and the search coil is electronically shielded by a length of insulated wire. A two-stage a.f. amplifier is included. These modifications (in the r.f. circuit) tend to increase the range of the locator. Larger search coils spread out the magnetic lines of force (the target varies roughly as the radius of the coil) and the higher operating frequency gives an increased frequency change for a given inductance change of the search coil.

When a coil approaches a large mass of metal, the eddy currents tend to reduce the inductance of the coil and increase the oscillation frequency. But, the increased circuit capacitance, caused by the nearness of the metal, tends to reduce the frequency. (The capacitance effect is more pronounced at higher frequencies.) This opposing capacitance effect is removed by shielding the coil with an open loop of copper or aluminum tubing called a Faraday shield. Without the shield—because of the increased capacitance—the best note goes down as nonmetallics are approached. The shield almost completely eliminates this and the locator responds only to metals.

Large locator construction

Assemble the locator circuit on a strip of insulating board. Use a No. 20 drill to cut out holes for the transistor sockets. Just drill two of these holes side by side and square them to fit, with a small file. The 50-3 transistor is held down with a solid wire harness that is pulled through and soldered to the terminal board eylets. Take care in soldering to the negative center pole of the mercury cell. It is more delicate than the cell used in the small locator, since it has no metal tab. Check the cell with the ohmmeter after the leads have been soldered.

The entire loop-and-handle assembly is detachable. Wing nuts hold the handle to the locator box and a small photograph jack is used as a disconnected loop coil. Both leads to the coil are above ground. Thus, the jack must not be mounted directly to the box. Cut out a plate washer and place it between the outside of the box and the jack. The current path of the r.f. circuit consists of a small length of coaxial cable which should be used as the coil lead to the collector batteries. A 1-foot loop of 0.1-inch copper tubing encloses the detecting coil. This tubing is wound on the ferrite and mounted in the alo- minum handle. The two free ends of the tube are left dangling electrically and cramped mechanically to a Lucite insulating block. If the loop ends were brought together, they would form a shorted turn in the r.f. field.

The coil is made by pulling six strands of wire through the tubing. The ends are then soldered together to form a single six-turn loop. I used fine wire (Belden 8817), but any almost small wire will do.

Other side coils can be built by winding 88 feet of wire into the loop. For this length of wire the smaller loops will have larger inductances, but this can be adjusted by decreasing the tuning capacitance slightly. Use the same methods of checking the oscillators as outlined for the smaller locator.

Try all four transistors in the oscillator circuits. The most active transistor should be used in the detection oscillator, the second most active in the reference oscillator, and the other two in the audio amplifiers. If there is any trouble in obtaining oscillation (if none of the transistors have good r.f. characteristics), the collector supply should be increased to 15 volts. The small-localizer operating procedure is used with the larger locator, with one exception. The variable 250-ohm resistor can be used as a combination volume control and fine frequency adjustment. The bias current varies the collector capacitance, changing the oscillator frequency. There is plenty of audio gain and power output—enough for the signal to be heard with the headphones hanging about the operator's neck. The range of detection is around 3 feet.

Metal locators in many ways are very limited. They do not tell what has been detected or located, how deep it lies, or very much about its exact size—if it is very small or deeply buried. Most metal-detecting operators are surprised at first by the amount of trash material that has been dug up before they find the item in which they are interested. The locator has spoiled feeling, but it certainly does not have eyes.

To go beyond 3 feet in detection depth, it requires more technical skill and more elaborate equipment. A few of these have been outlined in the Handbook of Industrial Eletrode Circuits (McGraw-Hill),
A novel approach for eliminating the sponsor's message

TRANISTORIZED COMMERCIAL KILLER

By HAROLD REED

EXPERIMENTERS often use transistors in many applications, which although neither practical nor profitable on a commercial basis, prove interesting and satisfying to the hobbyist. These experimental applications contribute to familiarization and greater knowledge of transistor theory and circuitry. One such application is the transistorized commercial killer described in this article.

The unit is essentially a transistorized photovoltaic relay that opens or closes the volume control of the TV receiver's speaker. When the unit is connected and operating, no longer have to get up and turn down the volume during commercials, or while the phone rings. I simply turn on a small table lamp beside my favorite chair and the relay does the rest. I glance at the screen occasionally while the set is silenced to ascertain when the commercial is over.

The commercial killer can be used also with a radio receiver but the listener is at a disadvantage because he has no indication when the undesired part of the program has ended. In this application, however, the relay may be used to connect a resistor across the speaker voice coil to reduce the volume to a level where the program is barely audible when the table lamp is on.

This photosensitive relay (see Fig. 1) is built around the Raytheon CK722 p-n-p junction transistor connected in a grounded-emitter circuit. Two self-generating photovoltaic cells are wired in series and connected between the base and emitter of the CK722. A sensitive relay is connected in the output, or collector, circuit, along with a 59,000-ohm variable control for adjusting the negative voltage to the collector. All component parts are mounted in a 4 x 4 x 2-inch metal box with room to spare.

Construction

There is no critical arrangement in the mounting of the parts of the unit, except of course that the photocells be in proper position to allow light to strike the active surfaces. The relay, a surplus BK-7-B, has an adjustable slider and scale for adjusting its sensitivity. With the sliding arm at zero on the scale, the relay operates with a current flow of 100 μA at 0.4 volts. The switch disconnects the battery and also prevents base-current flow which would occur when light strikes the active surface of the photocells.

The photocells are mounted on a strip of bakelite in which holes were cut, the exact diameter of the active portion of the cell surfaces. A larger cut, equivalent to the overall diameter of the cell, is made halfway (counter sunk) through the back of the bakelite. Allowing the cell to be recessed into the back of the strip. There is a small metallic ring deposited at the outer edge of the cell plate. I placed a strip of tinfoil under this ring and fastened it to a lug for the negative connection of the cell. Each plate and tinfoil is then held in place by the pressure from a spring leaf of a discarded phone jack or switch, which also provides contact with the back or positive connection of the cell, as shown in Fig. 2. Observe polarity and take care to prevent shorting between the tinfoil and positive coating on the back and edges of the plate.

After wiring the unit as in Fig. 1, experiment to obtain positive relay action when the control light source strikes the photovoltaic. Several variable factors must be considered: the setting of the relay slider arm, the battery voltage applied through the variable control, the ambient room illumination, and the distance between the photocell, relay and the table lamp.

The following operating characteristics were obtained with the unit described here: With a 25-watt lamp in the center of the room 15 feet from the TV set (this lamp is normally turned on during a TV program), the collector voltage is adjusted to minus 12 and the relay sensitivity control.
set to 13 on the scale. Collector current is 540 μA and the base current is 4 μA.

The relay is not energized.

The controlling light source is a 100-watt bulb, 10 feet from the TV set. When the lamp is on, the base current drops to 3 μA and the collector current increases to 575 μA. This operates the relay and short-circuits or opens the speaker voice-coil leads. At 5 feet, the device can be operated with just one photocell. Also, using the two cells, a 15-watt lamp gives satisfactory operation at 6 feet. With less illumination and for

![Fig. 1](image)

Photo of all parts used in the relay. The transistor, used in other experiments, is cemented to a small plastic block which supports its fragile leads.

![Fig. 2](image)

Fig. 2—Rear view of photocells countersunk into the bakelite mounting strip.

40. However, the cost will increase considerably.

A miniature radio tube could be made to function in this device, but the great advantage of the transistor in this application is its ability to operate without filament or plate voltages which would require a power supply.

![Fig. 3](image)

Fig. 3—Connections for opening voice coil at a or shorting it out at b.

or a means of obtaining these voltages from the TV chassis. The unit is small and completely self-contained, with just two wires to be attached to the TV speakers. Fig. 3 shows connection between the relay contacts and the speaker voice-coil leads. The life of the small 15-volt battery in this circuit will probably be equivalent to its normal shelf life.

The cost of the unit is minimized by using surplus photocells and relay. I purchased the photocells for 25¢ each and the relay for $1.50 from Burstein-Applebee Co., in Kansas City, Missouri. Olson Radio Warehouse, of Akron, Ohio, has rectangular-shaped selenium cells which give the same output as the round ones used in this instrument. Advance Type 850 or Porter and Brumfield series L6-5, 2.568-ohm relays can be used with a 7X721 transistor. The components listed in the parts list are the least expensive.

While the immediate purpose of this unit is as a commercial killer, the basic circuit arrangement lends itself to many applications. Making use of the sensitive relay in the collector circuit, this unit can be used to energize or de-energize many types of electrical equipment.

Raytheon Transistors are available through all leading parts suppliers.
ELECTRONIC HEADPHONE

Baby tending and actor cueing are but two of many uses for this vest-pocket transistor receiver and midget transmitter

By JOHN A. IRWIN and L. QUEEN

There are times when some way of transmitting a radio signal a short distance to a small or inconspicuous receiver may be very useful. The first application that comes to mind is a cueing or prompting device for actors. Such apparatus (which can be very costly) is often used by magicians or "mentalists."

In the home such equipment may be used to hear radio or phonograph music without disturbing other persons in a room. (True, the listener could wear headphones, but they would limit his movements and the long leads would be

Top, the one-tube transmitter—unit tuned between 1.5 and 1.8 mc.
Center, underchassis view of transmitter. A single 117L7 is used.
Right, the receiver, containing a single audio frequency stage.
a safety hazard.) In some cases this transmitter-receiver combination might even be used as a radio "murmur," with the advantage that the mother could more freqy room to room without getting out of the "noise" range.

Fig. 1.—One-tube transmitter. Isolation transformer reduces shock hazard.

A 117L7 tube (actually called a 117L7/6M-8T) makes a fine oscillator for the transmitting end. Its filament requires 117 volts which may be supplied directly from the line, avoiding the need for a 6.3-shot transformer. This tube has, in one envelope, a diode and a triode, and the diode is used as a line rectifier (Fig. 1). The pentode is the oscillator tuned to the high end of the broadcast band or slightly above. The oscillator will work without isolation transformer TI, but its use is definitely recommended. It prevents a shock hazard when the chassis (or any other normally grounded points) is touched. The transformer may be any shock hazard when the chassis (or any other normally grounded points) is touched. The transformer may be any

The pentode screen is not returned to B plus as might be expected, but to ground. It is varied about 1 volt above and below ground potential by the modulation input.

Typical modulation sources are: speaker voice coil (working out of a radio, phone, or tape machine amplifiers), P.M. or A.M. tuner, crystal pickup, high output mike. In any case the signal amplitude should be about 1 volt or more.

The oscillator tunes between 1.5 and 1.8 mc. The front core of oscillator coil T3 controls the frequency. Adjust it while listening in on a near-by broadcast or all-wave receiver. Any unoccupied channel is recommended. Use as short an antenna as possible for the receiver used. If the antenna is too long, you may create radio interference over a wide area. With a 6.3-shot transformer on an ordinary home type radio receiver, you should be able to hear the oscillator signal 20 or 30 feet away.

A simple portable receiver is shown in Fig. 2. It is a crystal set followed by an audio-frequency stage. The detector is a CK729; it was found more efficient than the usual 1N24. The amplifier uses a CK722 function transis-

Raytheon Transistors are available through all leading parts suppliers.
A transistorized GEIGER COUNTER

By NATHAN O. SOKAL* and IRS L. RESNICK* 

ToURIST gets $10,000 for Uranium claim staked with Geiger counter.* Occasional headlines like this dramatize the fact that many vacationers now carry Geiger counters with them wherever they go.

If you don't plan to go in for modern-style treasure-hunting, this Geiger-Müller counter (see photo) will at least make a pleasant project good for an evening's recreation in ionizing radiation physics, Geiger-Müller tubes, and transistors, all in one fall swing. And you might discover uranium in your own back yard.

Geiger-Müller tubes

A Geiger-Müller (G-M) tube is a metal cylinder with a wire running along its axis, as shown in Fig. 1. The tube is filled with gas, and a high-voltage d.c. source, usually about 900 volts, is connected between the cylinder and the wire, the wire being positive. Ordinarily, there is no current flow in the tube.

I onizing radiation—alpha rays (helium nuclei), beta rays (fast-moving electrons), gamma rays (electromagnetic radiation similar to light, but of much shorter wavelength), and cosmic rays (very fast-moving nuclei of hydrogen or other elements, or their by-products after passing through the atmosphere) — passing through the tube ionizes a gas molecule. The electron in the outer shell of the atom is knocked out with the ionizing particle and travels to the center wire, and the new positive charged gas molecule travels more slowly toward the negative cylinder. The moving electron collides with gas molecules along its path, knocking electrons off these molecules; these electrons in turn knock out others: within a few microseconds an electron "avalanche" has built up. The electrons and ions flowing inside the tube show up as a pulse of current drawn from the high-voltage source. The pulse for a typical G-M tube is shown in Fig. 2.

If an earphone is connected in series with the tube and the voltage source, as in Fig. 3, a faint click will be heard in the earphone each time a current pulse flows. The 1-megohm resistor in Fig. 3 is to limit the current drawn from the battery in case of an accidental short-circuit.

A G-M tube can be used to trigger a Geiger-Müller counter, for example, to trigger a Geiger-Müller counter, for example, to light a Geiger-Müller (G-M) tube with a high-voltage source, a typical G-M tube is shown in Fig. 4.

The transistor amplifier

A transistor amplifier can be added to the basic circuit of Fig. 3; the clicks will then be louder, making for easier listening. A circuit using a grounded-emitter amplifier is shown in Fig. 4. In this circuit, the current pulse from the G-M tube is drawn out of the transistor base. A similar pulse, amplified by the transistor, flows through the speaker in the receiver circuit. The amount of amplification depends on the characteristics of the particular transistor, and on the pulse rise-time and duration. In the authors' equipment, the amplification was about seven or eight, using a 1N3417 transistor.

High-voltage sources

The authors used batteries for their high-voltage source. Three Remington U200 or Eveready 400 800-volt batteries in series give the 900 volts required for most G-M tubes.

A way to get the 900 volts without an

(continued on page 110)

Parts for Geiger counter

1. G-M tube (transistor): 2. Raytheon CK1028 tube; 3. 1-1/2" diameter, 1" long, 1/8" hole; 2. 1000-volt U200 or Eveready 400 battery, each 400 volt; 4. 5000-ohm resistor; 5. 1-megohm resistor; 6. 10-megohm resistor; 7. 1-megohm resistor; 8. 10-megohm resistor; 9. 1000-volt battery; 10. 1000-volt battery; 11. 1000-volt battery; 12. 1000-volt battery; 13. 1000-volt battery; 14. 1000-volt battery; 15. 1000-volt battery; 16. 1000-volt battery; 17. 1000-volt battery; 18. 1000-volt battery; 19. 1000-volt battery; 20. 1000-volt battery; 21. 1000-volt battery; 22. 1000-volt battery; 23. 1000-volt battery; 24. 1000-volt battery; 25. 1000-volt battery; 26. 1000-volt battery; 27. 1000-volt battery; 28. 1000-volt battery; 29. 1000-volt battery; 30. 1000-volt battery; 31. 1000-volt battery; 32. 1000-volt battery; 33. 1000-volt battery; 34. 1000-volt battery; 35. 1000-volt battery; 36. 1000-volt battery; 37. 1000-volt battery; 38. 1000-volt battery; 39. 1000-volt battery; 40. 1000-volt battery; 41. 1000-volt battery; 42. 1000-volt battery; 43. 1000-volt battery; 44. 1000-volt battery; 45. 1000-volt battery; 46. 1000-volt battery; 47. 1000-volt battery; 48. 1000-volt battery; 49. 1000-volt battery; 50. 1000-volt battery; 51. 1000-volt battery; 52. 1000-volt battery; 53. 1000-volt battery; 54. 1000-volt battery; 55. 1000-volt battery; 56. 1000-volt battery; 57. 1000-volt battery; 58. 1000-volt battery; 59. 1000-volt battery; 60. 1000-volt battery; 61. 1000-volt battery; 62. 1000-volt battery; 63. 1000-volt battery; 64. 1000-volt battery; 65. 1000-volt battery; 66. 1000-volt battery; 67. 1000-volt battery; 68. 1000-volt battery; 69. 1000-volt battery; 70. 1000-volt battery; 71. 1000-volt battery; 72. 1000-volt battery; 73. 1000-volt battery; 74. 1000-volt battery; 75. 1000-volt battery; 76. 1000-volt battery; 77. 1000-volt battery; 78. 1000-volt battery; 79. 1000-volt battery; 80. 1000-volt battery; 81. 1000-volt battery; 82. 1000-volt battery; 83. 1000-volt battery; 84. 1000-volt battery; 85. 1000-volt battery; 86. 1000-volt battery; 87. 1000-volt battery; 88. 1000-volt battery; 89. 1000-volt battery; 90. 1000-volt battery; 91. 1000-volt battery; 92. 1000-volt battery; 93. 1000-volt battery; 94. 1000-volt battery; 95. 1000-volt battery; 96. 1000-volt battery; 97. 1000-volt battery; 98. 1000-volt battery; 99. 1000-volt battery; 100. 1000-volt battery.
A TRANSISTOR BRIDGE NULL DETECTOR

By LOUIS D. CARCANO

IMPEDANCE bridges and capacitance bridges which employ headphones for null detectors, offer good opportunity for transistorization. A visual null indicator is more convenient than a pair of "ears." Null detector circuits using vacuum tubes, however, are inconvenient because of long warm-up time, and require a separate power supply.

The transistor circuit shown requires no waiting after it is turned on and takes all its power from the 6-volt battery usually included in the impedance bridge.

The circuit consists of two grounded-cue-plate stages using junction transistors, and a rectifier and a microammeter. Noise level is not quite as great as with headphones, but was found to be adequate.

The input impedance is about 20,000 ohms. Ordinary microamp output transformers make satisfactory interface-coupling units. Transformer T1 is tuned to 1,000 cycles with a condensor C. The value of C will vary with the particular model of transformer, but should be around 0.002 to 0.005 ufd.

The second stage should overload just before the meter goes off scale. Overload level depends on the emitter-base current, which is determined by resistor R7, for a particular battery voltage. R7 may require adjustment for the particular transistor used. A more sensitive microammeter can be used if R7 is increased accordingly.

NOISE GENERATOR

The junction type CK722 transistor may be used as a noise generator to provide signals over a wide spectrum (see diagram). The circuit, a Hartley type, uses a high base resistance and small capacitor. Obviously it superregenerates and sets up standing waves on either side of the carrier. This carrier is determined by the tank coils. In this case I have chosen 900 kc. The tank is slug-tuned and a shunt capacitor is added. On either side of 900 kc numerous sidebands may be heard. They are spaced approximately 10 kc, and extend to about 200 to 250 kc on either side of the carrier. In the broadcast band, the individual sidebands may be distinguished from each other. As we tune, one sideband after another comes and goes. On the higher frequencies, the sidebands tend to merge or blend. For example, signals are heard at 1,800 kc, 2,700 kc, etc. On each side of these harmonic carriers, the sidebands generate a veritable bedlam. It is like a half dozen air-raid sirens wailing at once, each with a different pitch. Of course, these tones do not change unless the tuning is varied. On the short-wave bands, the noise appears at every 900 kc. A turning meter shown an increase in noise until a maxi- mum is reached at the harmonic of 900 kc, then there is a gradual decrease down to zero. At any point within this range, there are many simultaneous whistles, and the receiver may be tuned, adjusted, or aligned. No other modulation is needed from the generator.

With a more sluggish transistor, it may not be possible to use a carrier frequency as high as 900 kc. Then the circuit should be set for some lower frequency. Some transistors may also require a higher voltage, but I found that satisfactory results are obtained with as little as 3 volts.

The connection to the emitter seems to be necessary. It may be either a direct connection to the receiver antenna post or a long lead left floating near it. —J. Queen.
wave generator is connected to the input terminals of the instrument. The setup used is shown in Fig. 6.

Turn on all the equipment, allow sufficient time for "warm-up" of the scope and generator, then adjust the scope controls until three or four cycles of the signal can be easily observed. The frequency is not too important, and the generator may be set to deliver a sine wave from 30 to 30,000 cycles.

Gradually turn "up" the amplitude or output control of the sine-wave generator. The output signal should first appear as shown in Fig. 4(b); then the pulse peak should flatten, as the signal level is increased, until a pattern similar to those shown in Figs. 4(a) and 5 is obtained. The output of the sine-wave generator should be between 3 and 5 volts when the proper pattern is obtained.

If too much signal is applied, a pattern similar to the one shown in Fig. 4(e) will be obtained. Under these conditions there is some danger of damaging the transistor.

After the output signal level of the sine-wave generator has been set, the frequency of the generator should be varied and "spit checks" made at different frequencies over the audio range. The scope should be readjusted at each point as may be necessary to obtain a complete and steady pattern of two or three cycles. In a few instances it may be found that the output of the sine-wave generator is affected by the readjustment of its amplitude control to a new frequency, or by the substitution of different frequencies. In such a case, in order to select a signal which will insure a good rectangular output signal from the clipper at any frequency, but without distortion at any point, as shown in Fig. 4(e). If such a signal is not available, the output signal will be found, it will save considerable time and effort if output test is to be made at different frequencies.

A few tests were made; the major applications of the output signal obtained from the sine-wave clipper. It may be used for gain measurements, for rapidly checking frequency and transient response characteristics of an amplifier, or as a source of pulse signals. Let us discuss each application separately.

Gain measurements: When proper clipping occurs, the output signal level of the sine-wave clipper remains constant, irrespective of input variations in the input signal level. To this, the output signal is ideally suited for gain measurements at different frequencies.

The basic instrument setup illustrated in Fig. 4(e) was used. The scope is first used to check the output from the sine-wave clipper so that the sine-wave generator can be adjusted to supply sufficient signal for proper clipping. Once this is done, the output control of the sine-wave clipper (R6, Fig. 2) is adjusted to deliver the desired input signal to the clipper.

The input signal amplitude to the amplifier will now remain constant at the predetermined level, even if the frequency of the sine-wave generator is changed (provided, of course, that the signal supplied to the sine-wave clipper by the generator does not drop below the point of clipping action. Should this occur, however, it is only a small change in the waveform of the signal observed on the scope.

Gain measurements now become merely a matter of determining the output signal level. Since the input signal is of known amplitude and unvarying, actual gain is a matter of simple calculation.

Frequency and transient response checks: The rectangular wave signal obtained from the sine-wave clipper can be used in a fashion similar to square waves for rapidly checking the over-all frequency response of an amplifier, attenuator, or filter network (see "Wide Frequency Range Square-Wave Clipper," March, 1950, Roto and Transistors News). The high frequency response of a circuit or network is determined by applying a high frequency rectangular wave to its input and observing the output signal wave shape on the screen of an oscilloscope. Higher frequency response will cause excessive rounding at the peak of the "leading edge" of the sharper rectangular pulse (see Fig. 7). Poor transient response or "ringing" will cause a signal overshoot at this point.

At low frequencies, signal is used to check the low frequency response of the circuit. By selecting the correct "flat top" (again, refer to Fig. 7), it is observed that the signal is somewhat "sloping" at the flat top indicates phase shift at lower frequencies.

Using the rectangular wave in checking a circuit's response, it must be remembered that the rectangular wave's narrow pulse is representative of a square wave of somewhat higher frequency than the actual repetition rate of the signal.

In a similar fashion, the wider portion of the signal represents that of a square wave of somewhat lower frequency.

If an analysis of the signal wave shapes is qualified with these facts in mind, then the techniques of square wave testing may be applied directly to the use of rectangular waves in circuit analysis.

Pulse signal source: Since a pulse is basically a rectangular waveform, the output of the sine-wave clipper may be used in the same fashion as the signal obtained from a pulse generator. If narrower pulses are desired, an RC or RL differentiation network may be used as the clipper.

Conclusion
The sine-wave clipper circuit described, although designed for a specific application, is basically nothing more than an overdriven transistor amplifier, operated without bias. Because of this, the basic circuit given should offer the experimenter ample opportunity to become familiar with the operation of the basic resistance-coupled transistor amplifier.

However, those experimenters who have not previously worked with transistor circuits should exercise reasonable care when experimenting with modifications of the basic circuit given. Be sure the maximum ratings of the transistor are not exceeded. Transistors are both relatively expensive and easily damaged.

Vibration Amplifier
(Continued from page 16)

Vibrtion calming and interpreting vibrational movement in machinery. The transistor vibration amplifier has been found to have a valuable application.

When the point of the probe is moved lightly across a material surface, a sound is produced in which the frequency depends on the number of surface irregularities encountered and the speed of movement, and in which the amplitude depends on the degree of surface irregularity.

Used in this fashion, the instrument is produced in the optical field as very small differences in the surface samples of various materials.

Best results are obtained when the probe is held at a slight angle, with the axis facing away from the direction of movement. The probe tip should produce firm, but light, contact with the surface of the material being checked.

When comparing the surface roughness of two different materials or objects, special care must be taken to move probe across each surface at exactly the same speed. Otherwise, the results are somewhat difficult to interpret.

The same will soon discover additional applications for the transistor vibration amplifier; he works with it.

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of voltage gain at db level. In such a case new react will vary as shown in this network. Refer to Pedersen’s "Ref-
ence Data for Radio Engineer" for the
necessary design formulas.
A continuously variable attenuator control may be provided if desired. Simply use a standard 1000 ohm po-
meter in place of R8, and its as-
sociated resistances.
If the completed instrument is to be used in other than "applause meter" applications, the builder may wish
to provide frequency selective filter net-
works so the frequency response of the amplifier can be adjusted for spe-
cial measurements. Again, filter net-
work design data will be found in the
handbook mentioned previously.
Calibration: As long as the instru-
ment is used only as a peak-reading
device, there is no need for meter scale calibration, either in db or in other terms, and none is provided in the model. Should the builder wish to use the instrument for absolute
sound level measurements, however,
not only will scale calibration be necessary, but the attenuator switch will have to provide precisely known amounts of attenuation.
Meter reading is best carried out by burrowing a standard sound-survey meter or similar instrument and ob-
taining a comparative test. The final calibration may either be a chart of the chart or a device may be prepared for the meter itself.
Applications
To use the completed instrument as an applause meter, place it on a small stand or table with the microphone facing the audience. Set the attenuator
switch (E) in the maximum at-
tenuation (minimum signal) position. The meter switch (E9) may be set either in the "filler" or "peaks" posi-
tion, as preferred by the individual operator, but the switch position should be left fixed during any series of tests.
The power switch should now be turned "on." The meter reading should be noted during the program and the attenuator switch adjusted for a one-
third to one-half full-scale reading during a particularly good "hand" and below the maximum level during a poor one. As an alternative, the audience may be asked for a "radio engineer" type program starts, and the attenuator switch left in position.
Once set, the switch is left in posi-
tion and all subsequent "voting" is completed.
In some cases it may be desirable to have two or three "judges" to note
the meter reading during voting to
avoid any possibilities of error.
In addition to its use as an applause
meter, the completed instrument has
many other possible applications. For
example, when placed in front of a
receiver's loudspeaker, it may be used as a "no controllable" output meter. Good results can be obtained in this application if the background noise level is not too high. When calibrated, the instrument may be used as a sound-survey meter and, in this application, is useful for checking noise levels in offices, stores, schools, and factories. In many cases, the background noise level has a defini-
tive effect on workers' efficiency.
When used in conjunction with a
dispersed audio signal source, the instru-
ment will permit measurement of the compara-
tive sound absorption qualities of differ-
ent types of draperies, acoustic tile, and other covering materials.
Installers of p.a. systems should use such an instrument for measuring sound distribution in a particular installa-
tion, both to insure adequacy of coverage and to prevent "sided" spots.
These suggestions cover only the more obvious applications; however, the reader will undoubtedly think of many additional applications both in regard to his own work and of a gen-
eral nature.

Moisture Detector
(Continued from page 96)
level in a tank. The "sensor" plate is not used in this application. Instead, a special "sensor" unit is made up by connecting two stainless-steel rods or tubes a short distance apart (1/4" to 15/16") in an insulating base.
The "sensor" is then mounted on the side of the tank so that the rods pro-
ject downward to the desired level. The insulating block, to which termi-
nal connections are made, should be located as not to be dampened by the
inlet pipe. A solenoid-operated valve is placed in the inlet pipe, with the solenoid connected in series with the "normally-
closed" terminals of the moisture de-
tector relay.
As long as the water level stays below
the two rods, the relay is open and the solenoid valve is actuated, per-
mitting water to flow through the inlet pipe and into the tank. As soon as the water level reaches the predetermined point and makes contact wire the "sensor" rods, the relay is pulled closed, opening the solenoid circuit and permitting the inlet valve to close.
When the water level drops below
the two rods, as when water is drawn from the tank, the moisture detector
relay again opens out, permitting the valve to operate in the opposite direction.
Note that this application differs from those previously discussed in that the relay is normally held closed. This places a small, but constant, current drain on the battery.
Because of this, and in any applica-
tion where a current drain may exist (or comparatively long periods of time), a periodic "battery inspection and test" schedule should be set up and followed.

Bump Pump Control: In this appli-
cation the rod supervisor's "sensor" is also employed. Mount the rods in the bump at the desired level (slightly above the top of the pump).
Connect the moisture detector relay output to operate a pump pump motor when the relay is closed.
There is very little current drain from the battery unless water enters in the bump to a sufficiently high level to make contact with the "sensor" rods. When this happens, the moisture detector relay closes, turning on the pump motor. The relay will stay closed, and the motor will continue to operate, until the water level drops below that of the "sensor" rods.
If desired, a 1000 ohm rheostat may be connected in series with R8. This rheostat may be used as a sensi-
tivity control and will permit some de-
gree of operational adjustment.

Heterodyne Frequency Meter
(Continued from page 63)
When using a junction transistor in the r.f. oscillator section of a heterodyne frequency meter, the designer is limited by the fact that this type of transistor ordinarily will not oscillate beyond the top of the standard broadcast band. However, by tuning the transistor oscil-
lator from 500 to 1,500 kc, the practical

Fig. 1—Block diagram of the meter.
measurement range is found to be 50
kc or less to 30 mc. Response at the high frequencies is dependent to a great extent upon the strength of the test signal.
Fig. 2 shows the complete circuit of the transistorized heterodyne frequency meter. Type CXT22 transistors are used in the r.f. oscillator and a.f. amplifier stages, and a CG705 germanium diode is used in the mixer stage. The r.f. oscillator is a high-gain grounded-emit-
ter amplifier provided with inductive
feedback through the tickler coil L1. The r.f. output from the oscillator is coupled to the diode mixer circuit through pickup coil L2. Coil L2 is a Miller type 206A 4-pole coil (113 turns of No. 32 wire closely wound on a 1-inch-diameter form) with the slip-
ya, 0.0005". Inductor L1 consists of 40 turns of No. 30 enameled wire closely wound on a 1-inch-diameter core made of same material as L2. L3 is 15 turns of No. 28 enameled wire closely wound and cemented inside the form on which L1 is wound. So that the reader may
see the circuit for oscillator, the diode L1 and L2 have been labeled X and Y respectively in Fig. 2. X and Y are the beginnings or ends of each coil. It is immaterial which is chosen as long as they correspond.
Construction

The photographs show construction details of the heterodyne frequency meter. The entire instrument is built into an aluminum alloy case measuring 10 inches long, 5 inches high, and 3 inches deep. Considerable reduction in size is possible by the use of smaller components.

The tuning capacitor C3, calibration trimer C2, and the r.f. coil assembly are mounted directly to the box (see rear-view photo). The meter and a.f. amplifier components are mounted between the two terminals of a Uscanf 2 x 2 inch terminal board. Placement of these parts will be seen in the photo of the audio subcabinet. Oscillator transformer T2, capacitor C1, and re- sistor R1 are mounted on a small baffle- plate terminal strip attached to the front of the main tuning capacitor C3, and are not visible in the rear-view photo.

Base resistors R1 and R2 are the only critical components. Their values vary with individual transistors and must be selected for the particular transistors used. The resistance values given in Fig. 2 worked satisfactorily in the author's instrument and will be of good starting values from which to begin tests. Resistor R1 should be selected for lowest collector current which will permit strong oscillation over the entire range of the tuning capacitor. For this test, connect a multimeter d-c. milliam- permeter temporarily in the lead from 1.1 to the negative terminal of the battery. Note the indicated collector current for each experimental value of R1. To test for multichip action, put a 7 inches of the transistor with the finger. The multimeter should read several amperes. A slight change shows weak oscillation. If there is no change, make this check at each setting of C3. To adjust R2, insert a pair of 2000- 3000-ohm headphones into the jack. Feed in an r.f. test oscillator signal (1000 to 1000 kc) at the SIGNAL INPUT terminals, and obtain a beat note by tuning. Increase the battery voltage and the value of R2 for lowest undistorted signal. The value of R2 should be adjusted to equal the value of R3 for maximum output. Place a d-c. milliammeter into the jack. The current should not exceed 1 ma. Choose R2 for the lowest current which gives a loud signal with low background noise.

Calibrations

The best final calibration will be obtained with a 100-kc frequency stan- dard. However, follow these steps for the initial calibration:

1. Feed a 50- kc signal to the a.f. input terminals.

2. Set the main tuning capacitor to its full-capacitance position. (3) Plug headphones into the jack and adjust the CALIBRATION trimmer C2 for zero beat. The C2 dial now may be marked 500 kc at this point. (4) Substitute a 100-kc frequency standard for the signal gen- erator. (5) Reset C2, if necessary, to establish an accurate zero-beat with the standard. (6) Tune C2 slowly from this setting until another standard f requency point is brought in on zero-beat. If test signal is applied to the meter through coupling capacitor C4, Audio output from the mixer is coupled through transformer T (a UTC type 62-00) to the grounded-emitter a.f. ampli- fier. Note that the interstage transformer is connected backward to match the low input impedance of transistor V2.

The entire instrument is powered by a miniature 15-volt battery. The 15- volt potential is necessary for high- frequency oscillation because with 1.5- 6 volt cells, all CKE12 transistors will operate up to and including the broadcast band. While for size consider- ations, a hearing-aid-type battery is shown here, a larger-battery size can be used and may be more desirable, from a life standpoint, to individual buyers. Total current in the circuit is 440 microamperes d-c. in this instru- ment, though this may vary in different directions with individual transistors.

Mark this point 600 kc on the dial. (7) Repeat at each standard spot fre- quency, marking the 10-, 200- and 1000-kc points on four accurately. If the frequency standard is calibrated to 1000 kc above a 10-kc multivibrator, 10-kc points may be obtained and marked between the 1000-kc graduations on the dial. It is advisable to check against a standard-frequency source before be- ging use of the heterodyne frequency meter at any subsequent time. A single- spot check will suffice. A rapid method is to set the dial to 1000 kc (F 11) and, with the 10-kc standard feeding into the signal input terminals, adjust trimmer C2, if necessary, to re-establish exact zero-beat. This compensates for any frequency shift due to transistor temperature characteristics or to battery variation.

Application

Always use high-resistance magnetic headphones (minimum 2000 ohms). Crystal phones will not work, because transistor V2 relies upon the d-c. path through the phone for its collector current. When using a visual zero-beat indicator, such as an oscilloscope or meter, complete the d-c. collector path by connecting a 2000-ohm resistor in parallel with the jack.

When checking a transistor (anode and cathode terminal) or oscillator, satisfactory coupling into the frequency meter is obtained by using 1 or 2 feet of stiff wire. Longer ones may cause interference on nearby broadcast receivers. Ordinarily, such interference is not created by the low power output of the transis- tor oscillator stage.

Remember that a relatively low input impedance appears at the SIGNAL INPUT terminal. This is an important factor when the meter is used to calibrate an r.f. oscillator or signal gen- erator connected to these terminals. Usually, the only hitch is the re- requirement of a high-impedance meter. In such cases, hook up the meter generator into the antenna coil of a receiver.

Transistor Timer

(Continued from page 68)

on for a specific short interval (1 to 60 seconds). Where a heating element or other piles of equipment requiring large current is used, care must be taken that the maximum current rating of the relay contacts is not exceeded.

Still another application is in con- trolling a tape machine or record player so that a specific commercial message or advertisement is heard, when the "Reset" button is pressed. A typical example would be in the display room of a convention or show. When a passenger presses the button, a tape playback machine operates for a spe- cific period of time, giving an ad or desired message or "sales talk." A similar application is in the oper- ation of mechanical displays.

The reader can undoubtedly list many other, worthwhile applications of the timer. Then, too, once the builder has achieved satisfactory operation of the completed unit, other possibilities will occur to him.
Phase Inverter

(Continued from page 24)

phase inverter will handle ten volts peak, which is sufficient for push-pull 6V6 tubes in class A operation. The minimum signal level is determined by the noise factor of the transistor. The transistor phase inverter may be excessively noisy, if used directly from a low-output microphone; a minimum signal level of about 40 db should be obtained, by a vacuum-tube stage, if necessary.

For good frequency response the phase inverter should be used with high-impedance input and output circuits, and the signal capacity should be kept low. Short, direct wiring to other stages should be used. If the phase inverter must be used with an input circuit or output circuit of low impedance, the input or output coupling condensers may be increased, if it is desired to improve the low-frequency response.

A voltmeter of 20,000 ohms-per-volt or better, or a v.i.m. should be used in measuring the voltages. The input voltage, measured at the junction of R. and C, is 70 volts above ground. Output voltage, at the junction of R. and G, is 72 volts. Collector voltage, at the junction of R. and C, is 30 volts.

E.C. forms a demodulating and voltage-dropping network to supply 90 volts at the junction of R. and C. The input signal is fed through R. to the transistor base at the junction of base resistors R. and R. The emitter current flowing through the base resistor R. develops the in-phase output voltage, which is coupled through the blocking-condenser C. to one grid G. Collector current flowing through R. gives the phase-reversed output, which is coupled through blocking-condenser C. to the other grid G, of the push-pull stage.

It would appear that the transistor will find increasing use as a phase inverter in audio amplifiers of the push-pull class, provided that transistors are available at a price competitive with the triode.

When this happy day dawns, we may expect to see not only smaller and more compact amplifiers, but units of unparalleled reliability.

Transistor Phase Inverter

(Continued from page 24)

Door Opener: The photocell relay may be arranged in a garage so that light striking the unit from an auto's headlights actuates a motor to operate a garage door opening motor. In this application, a long tube (Fig. 3) should be used to prevent operation due to extraneous light from passing cars, street lamps, etc.

Counter: A light source may be arranged to fail across a ball or area way so that anyone passing interrupts the light beam. An electromechanical counter can be used to keep a record of the number of persons passing given a spot in a day or for any other period of time.

Light Switch: The photocell relay may be arranged so that daylight falls on it, and connected so that when the light level falls, due to clouds or the approach of evening, room lights are automatically switched on.

Smoke Alarm: If the light source and photocell relay are arranged across the top of a room, smoke from a beginning fire will interrupt the beam and operate the unit. An alarm signal could be afforded if such an arrangement seems desirable.

The Transistor DC Amplifier

(Continued from page 21)

Such d.c. amplifiers working from low-impedance thermal and mechanical transducers and not requiring the electrometer input stage will undoubtedly pose rather severe problems in relation to temperature drift at the input transducers—the severity of the problem varying according to the over-all gain required and the maximum drift that can be tolerated. In applications where these requirements are particularly stringent, the most careful attention must be paid to the complete thermal circuit associated with the input transducer. In the extreme case where temperature control appears to be impossible, the separate transistor amplifier associated with each control would be a relatively simple and straightforward affair since, as already remarked, a transistor amplifier intended to amplify a temperature signal is much easier to design, circuit-wise, and construct than one which must produce nearly zero output for the same kind of signal.

The long-term stability of the temperature characteristics of junction transistors has yet to be determined. However, to judge by our present knowledge of this subject, it appears likely that the "zero adjust" control commonly found in d.c. amplifiers should not have overly serious or insensitively low range in a transistor amplifier until the vacuum-tube instrument it replaces.

To those who have not yet certified their eyes, the more similar, described earlier in this article may be recommended as a relatively painless introduction; while the design engineers, interested in the particular locality—whether it be microfilm reproduction, or computers—should not have too much difficulty in mastering the intricacies of the circuit illustrated in the diagram of Fig. 3.

Transistor Metronome

(Continued from page 82)

currently calibrated. The "Transistor Metronome" is adjusted until it is in step with known settings of the other instrument, and the settings of the clock, so marked.

Finally, for higher repetition rates, the output of the "Transistor Metronome" is connected to an oscilloscope and the calibration points are obtained by means of兰kienius figures. These figures obtained will still be displaced, since a pulse is obtained from the clock, but the operator will have little difficulty in distinguishing 1:1 ratios.

Applications

Although the "obvious" use of the "Transistor Metronome" is in music, there are numerous other applications, depending on the individual needs and requirements of the operator, and upon his ingenuity in adapting the instrument to his use.

One application, for example, is in the photographic darkroom, where the metronome may be used to audibly "tick" off seconds for timing printers, enlargers, and chemical processes. In this application, a "switch" type unit is adjusted to deliver either 1-second or 1-second "ticks" would be valuable.

Still another application is in timing mechanical processes or work movements where the eye cannot be transferred to a stop watch or, similarly, in timing chemical or biological processes. Such an instrument might be easily operated, it is especially valuable in these applications in that it could be easily carried to the job—outdoors, even.

Photocell Relay

(Continued from page 42)

source may be arranged to fall across A, B, or C, the operator entering the proper loop in iin 2. The first loop may turn a check, doornot, or buzzer to sound. Such an arrangement is particularly useful for small stores, small offices, etc.

105
Junction Transistors For High Frequency Oscillators

(Continued from page 29)

resistance to 40,000 ohms dropped the frequency to 700 kc. The lower base resistance also increased current input from 2 µ to 600 µ from the 1.5-volt battery.

Battery voltage affects frequency to a great extent. The following table illustrated this. The tank was a slug-tuned pair of coils wound over the same half-inch core. The collector winding had about 75 turns No. 28 enamelled wire and the base winding about 30. Each was wound with 7 turns per layer. The coils were about 7 1/2 inches across.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 5</td>
<td>700 µ</td>
</tr>
<tr>
<td>2</td>
<td>770 µ</td>
</tr>
<tr>
<td>3</td>
<td>800 µ</td>
</tr>
<tr>
<td>4</td>
<td>830 µ</td>
</tr>
</tbody>
</table>

The frequency control can be operated at a distance. For example, I used a remote 1,000,000-ohm potentiometer across a battery (Fig. 3). A 0.1 uf. capacitor bypassed the leads where they connect to the oscillator itself. Thus the remote network (potentiometer and battery) are bypassed. Of course, the power increases as we raise the frequency. If the circuit is to be used as a frequency modulator (to input may be fed into a limiter to keep the power constant. Frequency may also be controlled by a resistance in series with the battery. A 1,000,000-ohm resistor from 610 to 600 k. This method is not suitable for remote control. It seems that the capacitance between leads cancels out some of the resistive effect. Unless the resistor is right at the circuit, much of its effect is lost through this capacitance.

The combination of an active transis-
tor and a high base resistor gives rise to a frequency control. The circuit goes into multiple oscillations like a superregener-
cator or multivibrator. The output is composed of a strong carrier (at the frequency of the tank coil) and numer-
ous sidebands. These frequencies may be spaced by about 3 kc or less. Thus, as the band is tuned, one signal comes in just as the next is leaving, so there is a more or less continuous signal. With a certain adjustment here, we ob-
tained the carrier at 800 kc. The side-
bands occupied a width of about 200 kc on either side of the carrier.

Of course the multiple signal appears on the short-wave bands as harmonics. Thus we have a maximum signal at 1.6 me, 2.4 me, etc. In each case the noise signal is maximum just before each harmonic, but drops off to zero on either side. For a good noise signal, adjust the cir-
cuit so that the individual side fre-
quencies merge or blend to become con-
tinuous. Such a noise is fine for align-
ment or adjustment of a receiver, and for many test purposes.

Guitar Amplifier

(Continued from page 18)

Because 'battery life is long, due to the small current requirements of the transistors, the Skin-Binder soldering connections directly to the battery termi-
nals. Some points may be soldered to a simple socket, however, so that the battery could be easily re-
moved and replaced without using a soldering iron.

No attempt was made to obtain either maximum gain, maximum over-
load, or maximum power output in the model assembled by the author but, rather, parts values were chosen experimentally to give a good com-
mromise between these factors con-
sistent with the characteristics of the transistors and speaker employed. Because of this, the builder may ex-
perience wide latitude in making circuit modifications to obtain especially desired characteristics.

For example, the 10 pf. coupling con-
densers used in the model (C1, C2, C3, and C4) were chosen because of ready availability. Smaller coupling condensers will do as well, and values as low as 4 pf. or even 2 pf. may be used without changing the low fre-
quency response appreciably.

The low frequency response of the model is limited primarily by the low frequency response of the miniature interstage transformers employed (7, 7', and 7"), rather than by the size of the coupling condensers. This does not indicate that the transformers are of poor quality. The small transform-
ers employed are "bullets" or "pico-
formers" but are simply not designed as "hi-fi" transformers. Their small size pre-
cludes using enough iron in their cores to insure good low frequency response.

Should the builder have, or be able to obtain, precision interstage trans-
formers having a wider frequency re-
sponse, he should probably replace them.

The builder may also find it worth-
while to experiment somewhat with the sizes of those resistors affecting "base" currents to get any individual stage characteristics (R1, R3, R5, R6). The following technique may be used:

(a) Connect an 0.10-milliammeter in the collector circuit of the stage to be checked.
(b) Connect the "Vet. Input" termi-

nals of an oscilloscope to observe the signal appearing across the out-

put load of the stage (generally the primary or secondary winding of a trans-
former).
(c) Connect a variable resistor or a resistance substitution box in place of the "base return" resistor.
(d) Connect a radio-sounder interstage generator to supply a signal to the stage being checked. While con-
necting the generator, use a blocking con-
denser if necessary to avoid a change in the d.c. value of the input circuit.

Whether or not a blocking con-
denser will be required will depend on the output circuit of the generator.

1) Applying a sine-wave signal to the stage, and observing the output signal on the scope, adjust the value of the "base return" resistor for the desired characteristics; maximum gain, minimum distortion, etc. When the graph lines are as close as possible to the input signal level constant. When checking distortion, be sure the input signal is not overloaded.

2) Do not use any value of "base return" resistor that permits more than maximum collector current to flow. For the 15 ma. for the CR72 and CR722, the number of possible parts substi-
tutions have already been mentioned but several others are possible. Let us review a few of these.

The Mollison "7225" is a 6-7 volt mercury cell unit. A larger speaker might well be used instead of the 6-7/8" speaker used by the author. If a large speaker is employed, it will be necessary to use a larger case, of course.

If the builder prefers, any other type of cabinet might be substituted for the wall speaker baffle. A standard speaker cabinet, an old receiver cabinet, or even a small "overnight" case might well be used.

The rotary power switch may be left out and a control type switch used for the wall speaker baffle. All stand-
and speaker cabinet, an old receiver cabinet, may be used instead.

In addition, the guitar amplifier has been designed to permit use with a standard crystal micro-
phone, perhaps too far from the mouth of the speaker, that is provided a reasonably strong output signal is obtained from the "micro" used in this application, it permits the beginner to perform a number of interesting experiments. Still another application of the guitar amplifier is to provide loud-
speaker output from a crystal or transistor receiver (resistor load is connected in place of the usual mag-
netic headphones, and the audio sig-
nal appearing across this resistor connected to the input of the am-
pifier). The where the amplifier is not assembled for a specific application, it is perhaps the best single project for the student, technician, or engineer desiring greater familiarity with transistor circuits.
Transistorized Gasig Counter
(continued from page 91)

many batteries is to use a single battery to charge two capacitors in parallel. If the capacitors are connected in series with each other and with the battery, you have a high-voltage source which decays slightly each time the G-M tube drives current. The larger the battery, the unit operates between recharge. The capacitors in this circuit can be connected as a 3-pole, 3-way, nonshorting switch as shown in Fig. 3, giving the equivalent of a 550-volt battery from only a 350-volt battery and two capacitors. One switch position is used for charging the capacitors, the other for operation. Of course, the switches must be capable of withstand-

ng the voltages placed on them.

High voltage can be obtained from the low-voltage transistor battery using a vibrator, a step-up transformer, and a rectifier.

(Note that 900 volts—especially from batteries—can be dangerous. Be careful.)—Rexnor

A transistor oscillator can be used instead of the vibrator; full details on such a unit are given by W. G. Bryan in an article in the Proceedings of the I.R.E., November, 1932. A high-voltage power supply of this type is manufactured by Technical Operations, Inc., Arlington, Mass.

The CK1085 tube can be mounted in a T-pin miniature tube socket by pushing the center wire through the hole in the center of the socket. A tall tube shield (such as for the 6A8G) holds the G-M tube in the socket. (Drill holes in shield to pass radiation.) A strip of spring copper can be fitted inside the shield to contact the shield (and thus the chassis) to the outside of the tube envelope, the negative connection for the tube. The negative side of the high-
voltage source is also connected to chassis, thus completing the high-voltage circuit. Provide insulation between chassis and the headphones and transformer adequate for 900 volts, also connect the positive side of the high voltage to chassis and insulate the negative connection of the G-M tube from chassis.

When soldering the transistor into the circuit, hold the lead with pliers between the transistor and the soldering iron to prevent damaging the transistor by excessive heat from the iron.

The headphones used in the authors unit were 2,000 ohm impedance. Better results can probably be obtained with 500-ohm headphones, or they are available. If the utmost in portability is desired, a hearing-aid earphone can be used instead of the larger headphones shown in the photograph. END

AH Test Oscillator
(continued from page 62)

many batteries is to use a single battery to charge two capacitors in parallel. If the capacitors are connected in series with each other and with the battery, you have a high-voltage source which decays slightly each time the G-M tube drives current. The larger the battery, the unit operates between recharge. The capacitors in this circuit can be connected as a 3-pole, 3-way, nonshorting switch as shown in Fig. 3, giving the equivalent of a 550-volt battery from only a 350-volt battery and two capacitors. One switch position is used for charging the capacitors, the other for operation. Of course, the switches must be capable of withstand-}

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voltage source is also connected to chassis, thus completing the high-voltage circuit. Provide insulation between chassis and the headphones and transformer adequate for 900 volts, also connect the positive side of the high voltage to chassis and insulate the negative connection of the G-M tube from chassis.

When soldering the transistor into the circuit, hold the lead with pliers between the transistor and the soldering iron to prevent damaging the transistor by excessive heat from the iron.

The headphones used in the authors unit were 2,000 ohm impedance. Better results can probably be obtained with 500-ohm headphones, or they are available. If the utmost in portability is desired, a hearing-aid earphone can be used instead of the larger headphones shown in the photograph. END

A strong inductive field is created around the test oscillator by the Ferri-Loopstik. Receivers with loop antennas are very sensitive to this field and can pick up the oscillator many feet away, even though it has no probe or antenna plugged into the output jack. As the oscillator is slowly related in one hand, the signal strength from the inductive coupling to the loop-antenna will change tremendously. In some positions a com-
plete null will be reached and in others the signal will be terrific. A dial-loc sig-
nal can be fed into some I.f. transform-

ers this way.

Parts list for AH test oscillator

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-4820 4uf, 200 volts, max.</td>
<td>1</td>
</tr>
<tr>
<td>1-35 uf 450 volts, max.</td>
<td>1</td>
</tr>
<tr>
<td>1-450 ma coil, 400 ma, max.</td>
<td>1</td>
</tr>
<tr>
<td>1-9 volt, 2 ma, max.</td>
<td>1</td>
</tr>
<tr>
<td>1-450 ma coil, 400 ma, max.</td>
<td>1</td>
</tr>
<tr>
<td>1-9 volt, 2 ma, max.</td>
<td>1</td>
</tr>
<tr>
<td>1-4820 4uf, 200 volts, max.</td>
<td>1</td>
</tr>
<tr>
<td>1-35 uf 450 volts, max.</td>
<td>1</td>
</tr>
<tr>
<td>1-450 ma coil, 400 ma, max.</td>
<td>1</td>
</tr>
<tr>
<td>1-9 volt, 2 ma, max.</td>
<td>1</td>
</tr>
</tbody>
</table>

There are other uses for the oscillator. You can make a wireless code-practice oscillator out of the test unit by substituting a telegraph key for S2 and reducing the value of C8 for a sharp practice tone.

106
The CK721 is a PNP junction transistor intended primarily for use in audio or low radio frequency applications. The tinned flexible leads may be soldered or welded directly to the terminals of circuit components without the use of sockets. Standard inline subminiture sockets may be used by cutting the leads to a suitable length.

**MECHANICAL DATA**

**CASE:** Plastic and Glass  
**BASE:** None (0.016" tinned flexible leads. Length: 1.5" min.  
**Spacing: 0.08" center-to-center)  
**TERMINAL CONNECTIONS:** (Red Dot is adjacent to Lead 1)  
- Lead 1: Collector  
- Lead 2: Base  
- Lead 3: Emitter  
**MOUNTING POSITION:** Any

### ELECTRICAL DATA

**RATINGS - ABSOLUTE MAXIMUM VALUES:**
- Collector Current \( I_{C} \): 15 mA  
- Emitter Current \( I_{E} \): 10 mA  
- Collector Dissipation \( P_{D} \): 100 mW  
- Ambient Temperature \( T_{a} \): 70 °C  

**AVERAGE CHARACTERISTICS:** (at 27°C)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector Voltage ( V_{C} )</td>
<td>-1.5 volts</td>
</tr>
<tr>
<td>Emitter Current ( I_{E} )</td>
<td>1.0 mA</td>
</tr>
<tr>
<td>Collector Resistance</td>
<td>500 ohms</td>
</tr>
<tr>
<td>Base Resistance</td>
<td>1000 ohms</td>
</tr>
<tr>
<td>Emitter Resistance</td>
<td>25 ohms</td>
</tr>
<tr>
<td>Base Current Amplification Factor</td>
<td>45</td>
</tr>
<tr>
<td>Cut-off Current (approx.)</td>
<td>6 µA</td>
</tr>
<tr>
<td>Noise Factor (max.)</td>
<td>22 dB</td>
</tr>
</tbody>
</table>

**AVERAGE CHARACTERISTICS - COMMON Emitter:** (at 27°C)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector Voltage ( V_{C} )</td>
<td>-1.5 volts</td>
</tr>
<tr>
<td>Emitter Current ( I_{E} )</td>
<td>1.0 mA</td>
</tr>
<tr>
<td>Input Resistance ( r_{ie} )</td>
<td>1500 ohms</td>
</tr>
<tr>
<td>Output Resistance ( r_{o} )</td>
<td>20,000 ohms</td>
</tr>
<tr>
<td>Power Gain (Matched Input)</td>
<td>39 db</td>
</tr>
</tbody>
</table>

**AVERAGE CHARACTERISTICS - COMMON Collector:** (at 27°C)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector Voltage ( V_{C} )</td>
<td>-1.5 volts</td>
</tr>
<tr>
<td>Emitter Current ( I_{E} )</td>
<td>1.0 mA</td>
</tr>
<tr>
<td>Input Resistance ( r_{ie} )</td>
<td>0.6 ohms</td>
</tr>
<tr>
<td>Load Resistance</td>
<td>20,000 ohms</td>
</tr>
<tr>
<td>Power Gain (Matched Input)</td>
<td>13 db</td>
</tr>
</tbody>
</table>

**AVERAGE CHARACTERISTICS - COMMON Base:** (at 27°C)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector Voltage ( V_{C} )</td>
<td>-1.5 volts</td>
</tr>
<tr>
<td>Emitter Current ( I_{E} )</td>
<td>1.0 mA</td>
</tr>
<tr>
<td>Input Resistance ( r_{ie} )</td>
<td>70 ohms</td>
</tr>
<tr>
<td>Load Resistance</td>
<td>0.1 ohms</td>
</tr>
<tr>
<td>Power Gain (Matched Input)</td>
<td>31 db</td>
</tr>
</tbody>
</table>

**Notes:**
- \( I_{E} \) is the maximum operating or storage temperature recommended.
- \( I_{E} \) is the maximum voltage for a 1 cycle bend test at 1000 cycles.
- Higher input impedances, without appreciably less in gain, can be achieved by operating at lowered emitter current.
- \( I_{E} \) is a function of maximum ambient temperature \( T_{a} \) expected. It is approximately equal to \( 4(T_{a} - 70) \) milliwatts.
- In circuits stabilized for \( I_{E} \) or \( I_{C} \) and which do not have linear distortion requirements, absolute maximum peak voltage is 60 volts.
- Collector voltage \( V_{CE} \) at which \( I_{E} \) drops to 2 ma. in common emitter circuit with base lead connected directly to emitter lead. Ambient temperature \( T_{a} \) = 70 °C.

Tentative Data

<table>
<thead>
<tr>
<th>Tentative Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>107</td>
</tr>
</tbody>
</table>
GROUND BASE
Typical Collector Characteristics

GROUNDED EMITTER
* Typical Collector Characteristics

* This family is a function of ε and changes appreciably with small changes in ε.
TYPICAL CHARACTERISTICS AS A FUNCTION OF JUNCTION TEMPERATURE

Temperature - Degrees Centigrade

Emittor \( \rightarrow \) Collector

Base \( \rightarrow \) Collector

Arrows refer to positive electrode current flow.
The CK722 is a PNP junction transistor intended primarily for use in audio or low radio frequency applications. The tin-coated flexible leads may be soldered or welded directly to the terminals of circuit components within solder-socketed or socketless circuits. Standard inline substrates sockets may be used by cutting the leads to a suitable length.

### Mechanical Data
**Case:** Plastic and Glass  
**Base:** None (0.060" tin-coated flexible leads. Length: 1.5" min.  
**Spacing: 0.08" center-to-center**  
**Terminal Connections:** (Red Dot is adjacent to Lead 1)  
Lead 1 Collector  
Lead 2 Base  
Lead 3 Emitter  
**Mounting Position:** Any

### Electrical Data

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector Voltage (Vc)</td>
<td>±22 volts</td>
</tr>
<tr>
<td>Peak Collector Voltage (Vce)</td>
<td>±48 volts</td>
</tr>
<tr>
<td>Collector Current</td>
<td>±10 ma.</td>
</tr>
<tr>
<td>Collector Dissipation</td>
<td>10 ma.</td>
</tr>
<tr>
<td>Emitter Current</td>
<td>70 °C</td>
</tr>
</tbody>
</table>

**Average Characteristics:** (at 27°C)

- Collector Voltage
- Emitter Current
- Collector Resistance
- Base Resistance
- Emitter Resistance
- Base Emitter Amplification Factor
- Collector Power Gain (Total)
- Noise Power Gain (Input)

**Average Characteristics - Common Emitter:** (at 27°C)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector Voltage</td>
<td>-6 volts</td>
</tr>
<tr>
<td>Emitter Current</td>
<td>1.0 ma.</td>
</tr>
<tr>
<td>Input Resistance</td>
<td>1600 ohms</td>
</tr>
<tr>
<td>Load Resistance</td>
<td>20000 ohms</td>
</tr>
<tr>
<td>Power Gain (Matched Input)</td>
<td>37 db.</td>
</tr>
</tbody>
</table>

**Average Characteristics - Common Collector:** (at 27°C)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector Voltage</td>
<td>1.5 volts</td>
</tr>
<tr>
<td>Emitter Current</td>
<td>1.0 ma.</td>
</tr>
<tr>
<td>Input Resistance</td>
<td>1600 ohms</td>
</tr>
<tr>
<td>Load Resistance</td>
<td>20000 ohms</td>
</tr>
<tr>
<td>Power Gain (Matched Input)</td>
<td>39 db.</td>
</tr>
</tbody>
</table>

**Average Characteristics - Common Base:** (at 27°C)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector Voltage</td>
<td>-6 volts</td>
</tr>
<tr>
<td>Emitter Current</td>
<td>1.0 ma.</td>
</tr>
<tr>
<td>Input Resistance</td>
<td>1600 ohms</td>
</tr>
<tr>
<td>Load Resistance</td>
<td>20000 ohms</td>
</tr>
<tr>
<td>Power Gain (Matched Input)</td>
<td>32 db.</td>
</tr>
</tbody>
</table>

- This is the maximum operating or storage temperature recommended.
- Measured under conditions for grounded emitter operation at 10mA. ±2.5 volts for a 1 cycle bandwidth at 1000 cycles.
- Higher input impedances, without appreciable loss in gain, can be achieved by operating at lowered collector current.
- This is a function of maximum ambient temperature (T_A) expected. It is approximately equal to 4 (100°C - T_A) milliwatts.
- Collector voltage V_C at which in series to 2 ma. in common emitter circuit with base lead connected directly to emitter lead.
- Ambient Temperature: 25°C.
- In circuits stabilized for le or le and which do not have critical distortion requirements, absolute maximum peak voltage is 70 volts.

Tentative Data
GROUNDING BASE
Typical Collector Characteristics

GROUNDING EMMITTER
Typical Collector Characteristics

This family is a function of 1 - α and thus changes appreciably with small changes in α.

111
The CK727 is a PNP junction transistor intended for use in low level audio applications where low noise factors are of prime importance. The threaded flexible leads may be soldered or wired directly to the terminals of circuit components without the use of sockets. Standard inline subminature sockets may be used by cutting the leads to a suitable length.

MECHANICAL DATA
CASE: Plastic and Glass
BASE: None (0.016" threaded flexible leads. Length: 1.5" min. 
Screwing: 0.08" center-to-center)
TERMINAL CONNECTIONS: (Red Dot is adjacent to lead 1)
Lead 1 Collector
Lead 2 Base
Lead 3 Emitter
WEIGHT: 0.025 ounces
MOUNTING POSITION: Any

ELECTRICAL DATA
RATING - ABSOLUTE MAXIMUM VALUES:
Collector Voltage 6 volts
Collector Current -10 ma.
Collector Dissipation 10 mw.
Ambient Temperature 70°C
CHARACTERISTICS: (at 27°C)
Collector Voltage -1.5 volts
Collector Current -0.3 ma.
Current Amplification Factor (min.) 25
Collector Resistance (min.) 12 meg.
Collector-Cutoff Current (max.) 12 ma.
Noise Factor (max.) 10 db.
AVERAGE CHARACTERISTICS - COMMON EMITTER CIRCUIT: (at 27°C)
Collector Voltage -1.5 volts
Collector Current -0.3 ma.
Collector Resistance 1000 ohms
Lead Resistance 10,000 ohms
Gain 20 db.
Noise Factor 10 db.
AVERAGE CHARACTERISTICS - COMMON BASE CIRCUIT: (at 27°C)
Collector Voltage -1.5 volts
Collector Current -0.3 ma.
Generator Resistance 100 ohms
Lead Resistance 10,000 ohms
Gain 20 db.
Noise Factor 20 db.

- With zero emitter current in grounded base connection.
- In a one-cycle bandwidth of 2000 cycles.
+ Measured under conditions described in "Common Emitter Circuit.
* This is a function of maximum ambient temperature (T_a) expected. It is approximately equal to 4 (°C - T_a) in watts.

Tentative Data

113
AVERAGE NOISE CHARACTERISTICS

Common Collector

- Collector Voltage (Vc)
- Emitter Voltage (Ve)
- Base Current (Ib)
- Generator Resistance (Rg)
- Load Resistance - 10,000 ohms

Noise Factor - db

Generator Res. 1 2 3 4 5 6 ohms
Emitter Voltage 0.2 0.4 0.6 0.8 1.0 volts
Emitter Current 1 0.6 0.4 0.2 mA
# Raytheon Germanium PNP Junction Transistors

**Characteristics Measured at 27°C**

<table>
<thead>
<tr>
<th>Type</th>
<th>Typical Application</th>
<th>Collector Voltage (V)</th>
<th>Emitter Current (mA)</th>
<th>Average Collector Resist. (MΩ)</th>
<th>Average Base Resist. (kΩ)</th>
<th>Average Emitter Resist. (kΩ)</th>
<th>Average Base Current (μA)</th>
<th>Average Collector Current (mA)</th>
<th>Max. Power Factor</th>
<th>Alpha</th>
<th>Cut-Off Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZN63</td>
<td>BF AMPLIFIER</td>
<td>-6</td>
<td>1.0 2.0</td>
<td>350 25 22</td>
<td>6</td>
<td>25</td>
<td>0.6</td>
<td>*ZN63</td>
<td></td>
<td></td>
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<tr>
<td>ZN64</td>
<td>BF AMPLIFIER</td>
<td>-6</td>
<td>1.0 2.0</td>
<td>700 25 45</td>
<td>6</td>
<td>22</td>
<td>0.8</td>
<td>*ZN64</td>
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<tr>
<td>ZN65</td>
<td>BF AMPLIFIER</td>
<td>-6</td>
<td>1.0 2.0</td>
<td>1500 90 60</td>
<td>20</td>
<td>1.2</td>
<td>*ZN65</td>
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<td></td>
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<tr>
<td>ZN106</td>
<td>LOW NOISE BF AMPLIFIER</td>
<td>2.5 0.5 1.0</td>
<td>700 25 45</td>
<td>6</td>
<td>12</td>
<td>0.8</td>
<td>*ZN106</td>
<td></td>
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<tr>
<td>ZN112</td>
<td>(CK760)</td>
<td>-6</td>
<td>1.0</td>
<td>75 25 10</td>
<td>5</td>
<td>2</td>
<td>*ZN112 (CK760)</td>
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<tr>
<td>ZN113</td>
<td>(CK761)</td>
<td>-6</td>
<td>1.0</td>
<td>75 25 45</td>
<td>10</td>
<td>*ZN113 (CK761)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>ZN114</td>
<td>(CK762)</td>
<td>-6</td>
<td>1.0</td>
<td>75 25 65</td>
<td>20</td>
<td>*ZN114 (CK762)</td>
<td></td>
<td></td>
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<tr>
<td>ZN130</td>
<td>BF AMPLIFIER</td>
<td>-6</td>
<td>1.0 2.0</td>
<td>350 25 22</td>
<td>6</td>
<td>25</td>
<td>0.6</td>
<td>ZN130</td>
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<tr>
<td>ZN131</td>
<td>BF AMPLIFIER</td>
<td>-6</td>
<td>1.0 2.0</td>
<td>700 25 45</td>
<td>6</td>
<td>22</td>
<td>0.8</td>
<td>ZN131</td>
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<tr>
<td>ZN132</td>
<td>BF AMPLIFIER</td>
<td>-6</td>
<td>1.0 2.0</td>
<td>1500 90 60</td>
<td>20</td>
<td>1.2</td>
<td>ZN132</td>
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<td></td>
<td></td>
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<tr>
<td>ZN133</td>
<td>LOW NOISE BF AMPLIFIER</td>
<td>2.5 0.5 1.0</td>
<td>700 25 45</td>
<td>6</td>
<td>12</td>
<td>0.8</td>
<td>ZN133</td>
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<tr>
<td>CK721</td>
<td>BF AMPLIFIER</td>
<td>-6</td>
<td>1.0 2.0</td>
<td>700 25 45</td>
<td>6</td>
<td>22</td>
<td>0.8</td>
<td>CK721</td>
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</tr>
<tr>
<td>CK722</td>
<td>BF AMPLIFIER</td>
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<td>1.0 2.0</td>
<td>350 25 22</td>
<td>6</td>
<td>25</td>
<td>0.6</td>
<td>CK722</td>
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<td>CK725</td>
<td>BF AMPLIFIER</td>
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<td>1.0 2.0</td>
<td>1500 90 60</td>
<td>20</td>
<td>1.2</td>
<td>CK725</td>
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<tr>
<td>CK727</td>
<td>LOW NOISE BF AMPLIFIER</td>
<td>2.5 0.5 1.0</td>
<td>700 25 45</td>
<td>6</td>
<td>10</td>
<td>0.8</td>
<td>CK727</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes**
- *Hermetically Sealed.
- + Measured under conditions for grounded emitter operation at V_{CE} = -2.5 Volts for a 1 cycle bandwidth at 1000 cycles.

## Mechanical Data

- **2N63, 2N64, 2N65, 2N106, 2N112, 2N113, 2N114**
- **2N130, 2N131, 2N132, 2N133**
- **CK721, CK722, CK725, CK727**

![Mechanical Diagram](image-url)
RAYSIN POINT CONTACT GERMANIUM DIODES

These diodes combine good forward response, high frequency capability with low cost and dependability. Ambient temperature range —50 to 150°C.

<table>
<thead>
<tr>
<th>Type</th>
<th>Maximum Forward Current (mA)</th>
<th>Maximum Reverse Voltage (V)</th>
<th>Maximum Reverse Current (μA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYPE 46</td>
<td>20</td>
<td>20</td>
<td>200</td>
</tr>
<tr>
<td>TYPE 47</td>
<td>50</td>
<td>50</td>
<td>500</td>
</tr>
<tr>
<td>TYPE 48</td>
<td>100</td>
<td>100</td>
<td>1000</td>
</tr>
</tbody>
</table>

**Note:** Branching and bonding connections should be made to the leads only. Connections between leads will cause damage to the device.

RAYSIN GOLD BONDED GERMANIUM DIODES

This group of diodes features small size, high forward conduction, high bias stability, and good temperature characteristics. Because junction area is increased over that of point contact types, leakage is slightly higher, transient response slightly slower.

<table>
<thead>
<tr>
<th>Type</th>
<th>Maximum Forward Current (mA)</th>
<th>Maximum Reverse Voltage (V)</th>
<th>Maximum Reverse Current (μA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYPE 50</td>
<td>10</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>TYPE 51</td>
<td>30</td>
<td>30</td>
<td>300</td>
</tr>
<tr>
<td>TYPE 52</td>
<td>50</td>
<td>50</td>
<td>500</td>
</tr>
</tbody>
</table>

**Note:** Instantaneous reverse voltage limit is 150 V. Maximum forward current limitation is 2 A. Maximum reverse bias limitation is 100 V.

RAYSIN BONDED SILICON DIODES

Raysin Bonded Silicon Diodes provide high reverse resistance, a sharp Zener characteristic and a good transient response with no forward resistance.

<table>
<thead>
<tr>
<th>Type</th>
<th>Maximum Reverse Current (mA)</th>
<th>Maximum Reverse Voltage (V)</th>
<th>Maximum Forward Current (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYPE 53</td>
<td>10</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>TYPE 54</td>
<td>30</td>
<td>30</td>
<td>300</td>
</tr>
<tr>
<td>TYPE 55</td>
<td>50</td>
<td>50</td>
<td>500</td>
</tr>
</tbody>
</table>

**Note:** All ratings at 25°C unless otherwise indicated.

RAYSIN SILICON POWER RECTIFIERS

This new Raysin silicon rectifier is the first to give high current rectifying capacity in extremely small volume. The rectifiers deliver to 750°C, to 200 volts max and to over 95% efficiency, start forward resistance ratio is over 100,000.

<table>
<thead>
<tr>
<th>Type</th>
<th>Maximum Forward Current (mA)</th>
<th>Maximum Reverse Current (μA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C675</td>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td>C676</td>
<td>225</td>
<td>225</td>
</tr>
</tbody>
</table>

**Note:** Both C675 and C676 have maximum voltage of 500 volts. C675 has maximum reverse current of 60 mA. C676 has maximum reverse current of 120 mA.

*Recommended by external heat sink.*

ADDITIONAL RATINGS (25°C)

<table>
<thead>
<tr>
<th>Type</th>
<th>Recommended Max Current (mA)</th>
<th>Max Reverse Voltage (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C675</td>
<td>60</td>
<td>250</td>
</tr>
<tr>
<td>C676</td>
<td>80</td>
<td>100</td>
</tr>
</tbody>
</table>

*Recommended by external heat sink.*