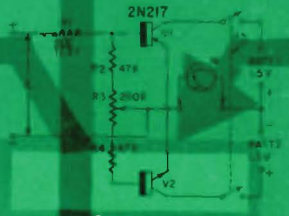
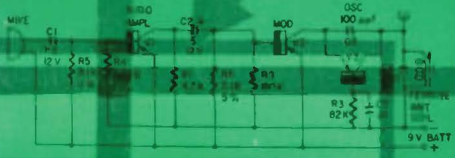
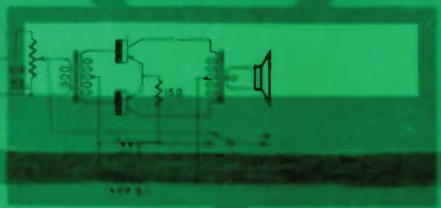
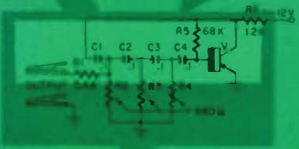
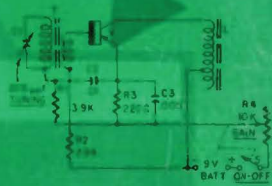


T TRANSISTOR PROJECTS



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*Transistor
Projects*

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introduction

SOMETIME back in 1920, midget tubes became very popular in radio receivers. Resembling modern miniatures somewhat, the midget was popularly known as the "peanut". It was microphonic, had small gain and was soon swept into limbo by the advent of larger and sturdier tubes. Tubes were fairly substantial in size until modern technology permitted the construction of miniatures more rugged than the ancestral "peanut" tube.

No Nostradamus was needed to spot the forces making for a trend toward smallness. Early portable receivers required a sturdy right arm. The "power packs" alone used by these receivers were larger than several modern transistor sets combined. But portable receivers were soon designed to work around miniature tubes. Batteries came down in size. Even so, the current requirements of tubes seemed to impose a limit below which batteries could not go.

The transistor provided a breakthrough to miniaturization. That it took so long to arrive in its modern form is very surprising since the semiconductor, in the form of an iron pyrites detector, was a contemporary of the "peanut" tube. However, both vacuum tubes and semiconductors began their existence as diodes. The introduction of the control grid in vacuum tubes was such a momentous leap forward for tubes that it is small wonder "crystals" were considered almost solely as signal rectifiers.

That the transistor has made such tremendous progress in the last decade must be credited in part to the vacuum tube. All the knowledge of signal detection and amplification gained in working with vacuum tubes was brought to bear on transistors. Early

transistor circuits were "duals" of tube circuits, but today transistor circuitry is quite capable of standing on its own.

The transistor is unique. If you calculate efficiency on the basis of battery-power input vs. signal-power output, there is no doubt that the transistor is superior to the tube. Part of the power fed into a vacuum tube is lost in the form of filament power. Part of it is lost as power dissipated at the plate. The transistor has neither problem and, because it requires no heating, is instantaneous in operation.

At the time this book was compiled, all the transistors used in the various projects were readily available for purchase from radio parts jobbers or through most radio parts catalogs. New transistors are being developed so rapidly, though, that it is entirely possible you may experience some small difficulty in obtaining a particular type. Fortunately, there are many equivalent transistors that can be substituted for those used in these projects.

Although this book has been divided into sections, no attempt has been made in any of the sections to have the projects arranged in any order of ascending difficulty. Originally appearing in RADIO-ELECTRONICS Magazine, the articles are those which the editors feel will have greatest interest for the hobbyist. The authors, and the articles for which they are credited, are listed in the Table of Contents.

MARTIN CLIFFORD

SECTION 1

TRANSISTOR
HINTS

WHETHER you work with transistors as a hobby or as a profession, and whether your approach is at the design or the practical level, your job will become easier (or your hobby more enjoyable) if you dispel any misconceptions you may now have about transistors and start to think in terms of semi-conductor rather than vacuum-tube operation when dealing with transistor circuits.

Common misconceptions

Let's take a look at the more common present-day misconceptions regarding transistor operation.

Transistors are noisy

True enough at one time, and true today as far as some types are concerned. However, a properly designed and selected transistor may have a lower noise figure than a vacuum tube of comparable quality. An important factor here is the absence of excessive thermal agitation (which contributes to noise generation in vacuum tubes) since most transistors operate at relatively low temperatures.

Transistors are unstable

The first transistors were point-contact units. These transistors,

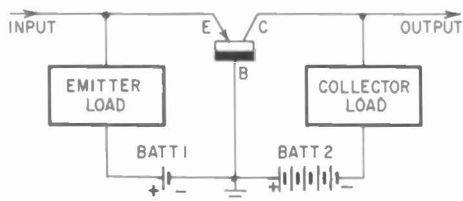


Fig. 101. The common-base circuit is a typical arrangement for point-contact transistors. These units are not as stable as more modern transistors.

by their very nature, had very high gain — so high, that they exhibited a negative resistance characteristic in some circuit con-

figurations. As a result, amplifier circuits using these components had a tendency to oscillate and oscillators would often change their mode of operation. To combat this tendency, the common-base circuit configuration (see Fig. 101) was almost mandatory when point-contact units were used in practical equipment. Modern transistors, on the other hand, are very stable, and a properly designed transistor amplifier may have superior stability characteristics when compared to a vacuum-tube amplifier with similar performance specifications.

Transistors are low-frequency devices

This is one of those odd misconceptions that persist and are difficult to trace. The first (point-contact) transistors *were not* low-frequency devices. Many point-contact units could be used as amplifiers and oscillators well into the amateur radio bands. True, the first low-cost (junction) transistors were essentially audio devices, but high-frequency transistors have been available commercially for several years. Today, units can be purchased across the counter which may be used as oscillators and amplifiers into the hundreds of megacycles, and experimental transistors have been developed which operate into the thousands of megacycles.

Transistors are low-power devices

Another of those hard-to-dispel misunderstandings. Transistors are highly efficient because they require only microwatts of power when handling micro-watt signal levels. This, plus the fact that early transistors were limited to milliwatt ratings, has led many to feel that the transistor is basically a low-power device. However, today we have transistors capable of handling kilowatt loads, and multikilowatt transistors are in the works. Especially interesting is that the first large-scale commercial application of transistors was as power amplifiers in auto radio receivers. Today, transistors are often preferred to vibrators, vacuum tubes and rotary motor generators, as power inverters and converters.

Transistor bias voltages are critical

This statement becomes true if we replace the word "voltages" with "currents," and is easy to understand if we think of the transistor as a current- (rather than voltage-) amplifying device.

Adherence to this misconception has resulted in many authors suggesting that transistor batteries should be replaced if their voltage measures 10% low. In practice, a transistor power supply battery's internal impedance is much more important than its

terminal voltage in determining circuit operation. A battery with high internal impedance may cause interstage coupling in distortion, oscillation and other equipment defects.¹

Transistors are similar to vacuum tubes

A common misconception resulting from attempts to explain transistor behavior in terms of vacuum-tube operation, this statement is completely wrong unless modified to read: *Transistors are similar to vacuum tubes only in the respect that both are amplifying devices.*

Aside from differences in construction, physical shape, size,

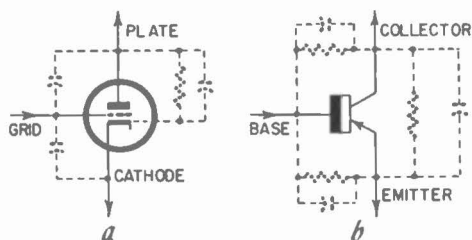


Fig. 102. Important internal impedances in the vacuum tube (a) and in the transistor (b).

basic principles of operation, internal impedances and methods of application, these two devices perform almost in opposite fashion.

Except at uhf, where lead inductances become important, a vacuum tube's important internal impedances are its interelectrode capacitances and its cathode-plate resistance, as shown in Fig. 102-a. There is no direct connection between any pair of electrodes. The cathode-plate resistance is actually a consequence of a unidirectional stream of electrons in a vacuum — they can flow from cathode to plate but not vice versa.

In a transistor, on the other hand, there is a direct resistive connection between each pair of electrodes in addition to the

¹The internal impedance of a battery is important in both tube and transistor-operated receivers, but assumes much greater significance in transistor sets since we are dealing with a current (low-impedance) device rather than voltage (higher-impedance) unit. Howling, squealing, oscillation and distortion, when caused by feedback across the internal impedance of the battery, can be cured either by replacing the battery with a fresh one, or often by shunting the battery with a high-capacitance electrolytic. The dc working voltage of the capacitor should exceed the battery potential by at least several volts, preferably more. Connect the positive terminals of the capacitor and the battery; similarly the negative terminals. Using a capacitor in this manner may help you squeeze just a little more work out of a battery which otherwise would have to be discarded.

interelectrode capacitances, as shown in Fig. 102-b. And these resistances are bi-directional — current can flow in either direction (although a higher resistance may be offered to current flow in one direction than in the other).

There are other differences. In a vacuum tube, plate current is at a maximum with zero grid bias, and decreases as bias voltage is increased. In a transistor, collector current is at a minimum with zero base bias, and increases as bias current is increased.

In a vacuum tube, in general, an increase in bias voltage reduces stage gain. In a transistor amplifier, on the other hand, an increase in base bias current increases stage gain. This characteristic is important in understanding AVC action in transistor receivers.

A class-B vacuum-tube amplifier is operated with a moderately high grid bias. A class-B transistor amplifier is operated with close to zero base bias current.

As a general rule, most vacuum-tube oscillators are class-C amplifiers. Transistor oscillators are generally class-A amplifiers. This is important in determining whether a local oscillator is functioning properly.

Half-truths

A couple of statements about transistors are part true and part untrue. Some did apply in the early days of transistors, but today are meaningless.

Transistors are temperature sensitive

This is one of those half-true half-false conceptions often used as an argument for vacuum tubes and against transistors. Actually, the vacuum tube is *more* temperature-sensitive than the transistor, but is equipped with a built-in oven to help maintain its temperature.

Transistor operating characteristics do vary with their temperature. And since most transistors are used under ambient temperature variations, the circuit design must compensate for possible temperature variations if optimum circuit operation is to be maintained. Now in the development stage are semiconductor devices capable of operating between 2° Kelvin and 1,500°C.

Reversing battery voltage will ruin transistors

This is the most common misconception of all, mainly because it is sometimes true. It is repeated frequently in books and magazine articles. To understand how this came about, we have to

go back to the old point-contact transistor and to its almost mandatory common-base circuit configuration (see Fig. 101).

When a transistor is used in the common-base circuit, its emitter-base junction is generally biased in its forward or low-resistance direction. In Fig. 101, this bias is furnished by Batt 1, with emitter-base current limited only by Batt 1's value, the emitter load's dc resistance and the very low, emitter-base impedance. The collector-base junction, on the other hand, is biased in its reverse or high-resistance direction by Batt 2. Here, collector-base current is determined by Batt 2's value (which is relatively high compared to Batt 1), by the collector load's dc resistance and by the relatively high collector-base impedance.

Under these conditions, if the collector bias battery (Batt 2)

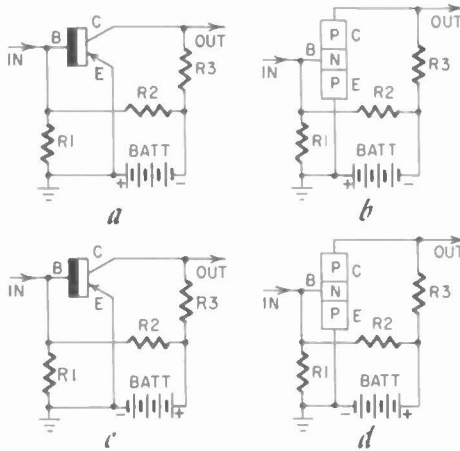


Fig. 103. How reversing battery polarity affects circuit operation. Typical common-emitter amplifier (a) using a p-n-p transistor; the first drawing is put in block form (b) to emphasize junction biasing. The remaining circuits (c and d) correspond to the first two, but with battery polarity reversed.

is reversed, the collector-base junction will be biased in its forward or low-resistance direction, and collector current will rise to a value determined primarily by Batt 2's voltage and the collector load's dc resistance. If the collector load has a low dc resistance, the collector current may rise to the point where the transistor is damaged.

Today, however, the common-base circuit is seldom used in practical equipment. The common-emitter configuration, shown in Fig. 103-a, is by far the most popular. With this circuit ar-

rangement, reversing the battery polarity will not damage the transistor. In rare instances, the circuit may even perform better with reversed battery polarity.

Referring to Fig. 103-a, a p-n-p transistor is used as a common-emitter amplifier. A single battery furnishes base bias current through voltage divider R1-R2 and collector bias through collector load R3. Base bias current is determined primarily by the battery voltage and R1-R2's ratio. Collector current is determined by the battery voltage, by R3's value and by the transistor's base bias.

The basic circuit has been redrawn in Fig. 103-b to better illustrate interelectrode junction biasing. Note that the base-emitter (n-p) junction is biased in its forward direction. There are two junctions between the emitter and collector electrodes. Thus, the positive side of the battery (Batt) connects to a p-type electrode (emitter) while the negative terminal connects to another p-type electrode (collector).

Let's suppose, now, that Batt's polarity is reversed. This condition is illustrated in Figs. 103-c and 103-d, corresponding to Figs. 103-a and 103-b, respectively.

With Batt reversed, the base-emitter (n-p) junction is now biased in its reverse or high-resistance direction. As a result, base bias current will drop to a very low value.

Referring to the collector circuit, we find that the positive side of the battery still connects to a p-type electrode (collector in this case), while Batt's negative terminal is still connected to a p-type electrode (emitter). Thus, there is virtually no change as far as collector-emitter impedances are concerned, except for the drop in base bias current which, in itself, tends to reduce collector current.

In other words, reversing the battery polarity in this circuit reduces (rather than increases) both base and collector currents. In most cases, collector current will be reduced almost to cut-off and the circuit will no longer operate, but the transistor will not be damaged. In fact, transistor damage due to overload is less likely to occur with reversed than with normal biasing.

Under rare conditions, however, circuit operation may be improved by reverse biasing—a circumstance which has caused much scratching of heads among experimenters and engineers who have accidentally connected a battery to a test circuit with reverse polarity.

To see how this can happen, refer again to Fig. 103. Suppose,

now, that the transistor is very leaky. Under these conditions, considerable collector current may flow even without base bias, and a small bias may take the transistor to saturation. In this case, applying a small reverse base bias might well reduce the collector current to the point where linear circuit operation is possible. The fact that collector voltage polarity is reversed at the same time may be relatively unimportant.

At this point, you may wonder why one outer electrode is called an emitter and the other a collector, if they can be used interchangeably. It's a matter of convention, coupled with the fact that the emitter is generally designed to perform this role better.

Several firms manufacture symmetrical transistors in which the collector and emitter electrodes have almost identical characteristics. Here, either can be used as an emitter collector.

Leaky coupling capacitors will ruin transistors

This is another of those half-truths deriving from vacuum-tube circuit operation.

The effect of a leaky coupling capacitor in a R-C-coupled amplifier can be determined by an examination of the basic circuit shown in Fig. 104.

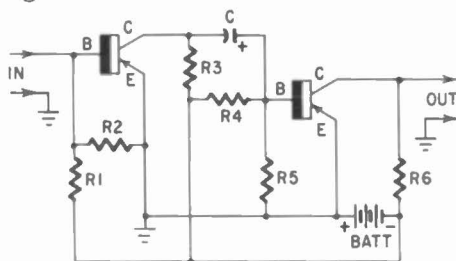


Fig. 104. Typical two-stage resistance-coupled amplifier. P-n-p transistors in the common-emitter configuration are used in both stages.

In this circuit, two p-n-p transistors are used as common-emitter amplifiers. A single battery supplies all operating currents. Base bias for the first stage is supplied by voltage divider R1–R2; for the second, by R4–R5. R3 and R6 serve as collector loads for the first and second stages, respectively. Capacitor C couples the two stages.

In a typical circuit, R1 and R4 will be about 47,000 ohms, R2 and R5 about 3,900 ohms, and R3 and R6 about 4,700 ohms. C is generally an electrolytic with a value between 2 and 20 μf . The battery may range from 1.5 to 9 volts.

Referring to Fig. 104, suppose that C became leaky, or even shorted, what happens?

If C is shorted, R3 and R4 are connected in parallel and their total resistance drops to a value somewhat under that of the lower unit (for example, a little under 4,700 ohms). The second stage's base bias current will increase somewhat, but not enough to damage the transistor, since bias current is limited by the dc resistance (R3 and R4 in parallel) in series with the base electrode.

What about collector current? It can increase, too, due to the increase in base bias, but its maximum value is limited by the collector load resistance (R6) and Batt's voltage. If this supplies 9 volts the maximum collector current that can flow is less than 2 ma, well within the maximum ratings of commercially available transistors.

Thus, a leaky coupling capacitor in a circuit similar to that shown in Fig. 104 may introduce distortion and clipping, but will not damage the transistors unless the collector loads have very low dc resistances.

Transistor hints

When working with transistors you will often have to resort to many tricks and kinks to solve various problems. Here are some ideas you will find helpful and time-saving.

Mercury batteries

To prolong the life and facilitate the use of mercury or other transistor batteries, try this trick. Clean the ends of the battery and strip the end of a piece of red wire and a piece of black wire (any colors will do so long as you know which is plus and which is minus). Now place these ends alongside the ends of the battery and tie them tightly with enameled wire or heavy thread. Check with a meter to see that the leads are making contact. Next, holding the wires, dip the whole battery in In-sulex or a similar heavy plastic tool dip. Remove the battery and let the plastic harden. When it does, the battery will be sealed in a moisture-proof case with handy color-coded leads. This is especially useful for the tiniest mercury batteries which are easily ruined by the heat of soldering.

Transistor sockets

If bent properly, transistor sockets fit into each other to form excellent subminiature plugs and jacks. The jack is wired exactly as an ordinary socket. The plug is another transistor socket with leads soldered carefully in place. These sockets are sold with as

many as eight leads. They can also be used as subminiature switches by bringing the switch leads to the socket and shorting the corresponding pins (see Fig. 105). Here, plugging in the headphones turned on the unit. A little improvising could probably devise many other uses for these little sockets.

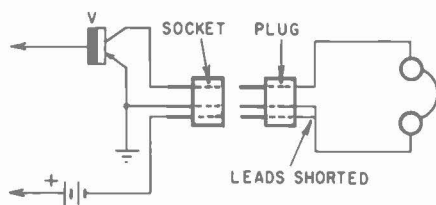


Fig. 105. A pair of transistor sockets can be used as an on-off switch, at the same time connecting the earphones to the receiver.

Saving transistor leads

If you have a transistor with fragile leads (this includes most of them) which you frequently push in and pull out of its socket, here's how to save yourself worry, money and trouble caused by broken leads. Using the previous kink, you can insert the transistor in a socket and tape it in place. Now the socket becomes the bottom of the transistor, and you can unplug and plug the unit to your heart's content without worrying about breaking the transistor leads.

Another way to protect transistor leads is to shape a small wooden block to the same size as the bottom of the transistor and about $\frac{1}{4}$ inch thick. Next drill three thin holes spaced as the transistor leads are spaced. Place the leads through the holes and glue the block in place with a nonpermanent glue such as rubber cement. Now if a lead breaks, it will break flush with the wood instead of the transistor. If this happens, remove the block and trim all the leads to the length of the shortest one. The transistor leads are still long enough for use in a socket.

Current measurements

Measuring the current on each transistor electrode in a circuit is done quickly and conveniently with the gadget shown in Fig. 106. You will need two transistor sockets, six tip jacks and three toggle or slide switches. One socket is used as a plug and the other holds the transistor. The latter socket along with the jacks and switches is placed on a panel. The switch of the lead whose current is being measured is left open while the other two are

closed. The current meter is plugged into the jacks going to the lead under test. It is best to use a multimeter with this instrument since transistor current ranges from microamps to over an ampere for power transistors.

Broken leads

Once in a while, despite precautions, a transistor lead will break off flush with the case. It is usually possible to remedy this. Take a piece of thin copper or brass about 1/16 inch wide and put a small dimple in it near one end. Lightly file the bottom

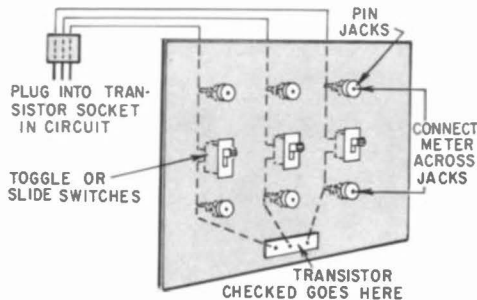


Fig. 106. Use this test jig for making current measurements in transistor receivers.

of the transistor. Now press the dimple on the tiny dot of metal showing at the bottom of the broken lead and tie the strip tightly to the transistor. Then test it to see if it has made contact with the exposed metal. If it has, cover the whole bottom with a thick coating of glue or tool-dip plastic. If it does not make contact, keep untying and tying until it does. The new lead will not be as sturdy as the original lead, but at least it will render the transistor usable. Unfortunately this method will not always work, but it is certainly worth a try. It will not work on metal-bottom transistors. If all attempts at fastening a new lead fail, you still may be able to use the two remaining leads as a diode.

Wire for transistor circuitry

A good supply of wire for miniature transistor circuitry can be obtained by purchasing several feet of No. 22 conductor telephone cable. This will give you many short lengths of strong, thin wire. You will also have wire of many colors to allow for color-coded leads.

Saving resistor space

When building one of the tiny transistor items described later

in this book you will often find it annoying to have resistors take up so much space. You can solve this problem by standing them on end in groups. For instance, there are usually several resistors in a circuit which have a common meeting point. With all of them standing up and attached as a group, a lot of space can be saved. This will not complicate wiring too much if the unit is centralized. The same idea can sometimes be applied to the miniature capacitors in these devices. Just remember when miniaturizing that any empty space above a part is wasted space, so don't hesitate to stack components.

Transistor radio signal tracer

Have you ever realized that the amplifier of your six- (or more)

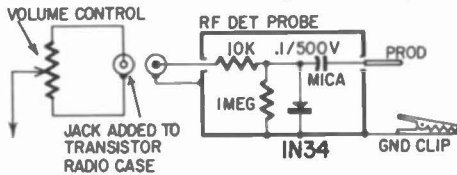


Fig. 107. With the help of this adapter, your transistor receiver can be made into an audio or rf signal tracer.

transistor radio will also make a handy signal tracer? Just run two leads from the amplifier input (usually the volume control) to a new jack. Make a simple probe with a capacitor and a diode, and you are all set (see Fig. 107). Of course, by leaving out the diode it becomes a general-purpose speaker amplifier or audio signal tracer.

Mica for power transistors

Most manufacturers recommend using a thin sheet of mica to insulate a power transistor from its heat sink. You can get a good supply of these sheets by taking apart a large (0.1 μ f or larger) mica capacitor. These usually consist of several dozen sheets coated with a metallic substance. Thin slices may be easily cut with a sharp razor blade, and the same tool will scrape off the metallic coating.

Transformer leads

The loss of a lead on a tiny transformer can sometimes be even more disastrous than a broken transistor. The leads are usually not attached very firmly and you can lose good transformers by accidentally pulling out the leads. This simple method puts an end to this. Just take the leads of the new transformer and fold

them back along the sides. Next tape them down (Fig. 108). This takes the pressure off the delicate connection and almost nullifies the chance of breakage. An even better way might be to mount the transformer on a tiny terminal board with lugs, but this might waste some of the precious room in a miniature project.

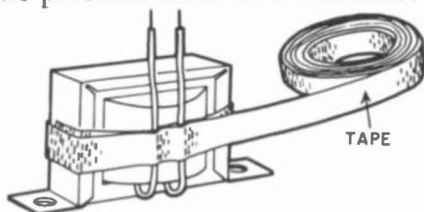


Fig. 108. To secure transformer leads, fasten them with tape. Use either Scotch tape or electrician's tape.

Subminiaturizing

There is a simple way to subminiaturize the popular Raytheon CK722. Just slowly chip away the case of the transistor (filing is safer, but don't let friction generate too much heat) until you get to the inner metal shell. A careful job will yield a transistor almost 75% smaller, perfect for ultra-miniature work. Remember to keep track of the collector lead, since there is no red indicator dot on the inner metal case.

Regeneration controls

The builder of a transistor radio often finds that using subminiature pots as regeneration controls leaves something to be desired. Their range is crowded and it is often difficult to get that critical setting for maximum sensitivity. You will find that one of the small industrial types do a much better job. These tiny, multi-turn potentiometers are ideal when you need very accurate settings.

Dual variable capacitor

Many transistor superhet circuits specify a dual 365- μf variable. Unfortunately, this value has not yet come out in a dual unit of the really miniature type. You can make one out of two individual 365- μf miniature units (such as Argonne AR-274). Place them side by side and glue them together. Now attach a tiny pulley to each shaft and string them together with dial cord. Make the cord tight to prevent slippage. Then cut one shaft short and put the knob on the other (Fig. 109). The one knob will control both units and you will have a very small dual 365- μf variable.

Heat sinks

To get maximum efficiency from heat sinks used for power transistors, paint them dull black. Black is a much better radiator

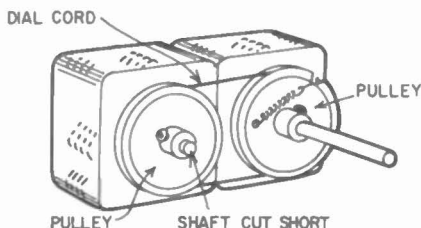


Fig. 109. A two-gang variable capacitor can be made by joining two single units. To make certain that the capacitors will give best tracking and to avoid damaging the plates, make sure that the plates of both units are fully meshed when making the change.

of heat, so that a small black heat sink will be much better than a larger shiny one. You can also use this principle for ordinary transistors. If a transistor is going to be near something warm, paint it with a shiny aluminum paint. If you are worried about the transistor itself heating, paint it dull black so it can easily radiate its excess heat.

Color-code transistors

After a time, experimenters build up a supply of transistors. A handy way to identify them quickly would be to color-code them in a manner similar to the resistor color code. The first two (or three) numbers could show the transistor's beta or current gain. The next band could be gold or silver for n-p-n and p-n-p, respectively. You could use another notation for function, so you could easily spot an audio, rf or any other kind of unit. About 10 colors of 10-cent bottles of paint such as Testor's Pla (available at a hobby store) will code hundreds of transistors for rapid identification.

Holding thin wires

Sometimes it is difficult to hold very thin wires in ordinary alligator clips, since the wire slips through the teeth. The problem can be easily remedied by filing off the teeth. Now the jaws will be flush and the tiny wire will be gripped easily, putting an end to the slipping.

Another way of handling this problem is to fill the jaws with solder. Heat the clip until solder flows into the jaw readily. Then

turn the clip upside down and fill the other jaw in the same way. If the solder surface isn't flat, file it. Use a file having fine teeth. A coarse file will make the surface too rough.

Substituting and replacing transistors

In working with transistor projects you may have the problem of making transistor substitutions. Manufacturers make recommendations for such substitutions, but these are based upon similarities between operating characteristics. This means that the substitution of one transistor type for another does not necessarily indicate that the transistor will work. Generally, though, these recommendations are safe to follow, but there will always be cases in which some adjustment may be necessary.

Neither do you have any assurance that a transistor, replaced by one of identical number, will work immediately. You may have to experiment with the bias current, either by changing the values of the resistors shunting the battery, or by using a battery having a higher or lower voltage.

SECTION 2

TRANSISTOR
RADIOS

solar-powered radio

JUST think of it! As long as the sun shines — even a very cloudy day will do — this radio operates from a solar power supply. When there is no sunlight, an auxiliary mercury cell can be switched into operation.

Anyone can build this solar-powered radio. The solar energy converter is a modified self-generating selenium photocell. Generally, solar radios and transmitters have been laboratory-built devices, very expensive and next to impossible for the hobbyist to reproduce. This solar radio, however, uses only standard components and can be built for around \$15.

A high-gain transistor (Fig. 201) provides plenty of amplification; a loopstick gives souped-up sensitivity and selectivity. Actually the circuit is a crystal set followed by a stage of transistor amplification, but the sensitivity and selectivity are very much better than usually associated with this type of radio.

A fabulously high Q (about 350) is the hallmark of the “energized” loopstick. Detector loading of the tuned circuit can quickly degrade this figure. Nevertheless, by using loose coupling between coil and detector, we retain a single tuned circuit with exceptionally sharp selectivity.

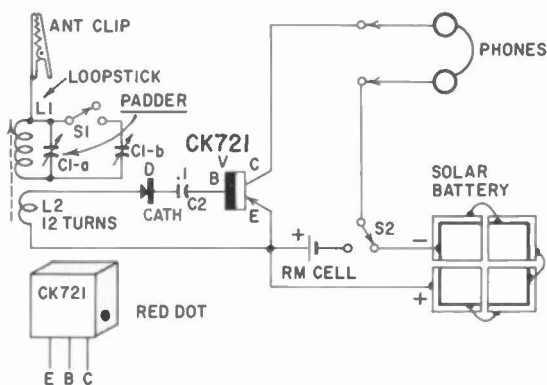
One end of L1 connects directly to the antenna. The opposite end seems to float without any electrical connection to the remainder of the circuit. Coupling does exist though in the form of stray capacitance between L1 and L2. There is also mutual coupling between the two coils, aided by the loopstick core.

A padder type variable capacitor with an attached knob is used for station tuning but does not have sufficient range to cover the lower end of the broadcast band. Thus, an extra capacitance is used to permit low-end tuning. (The diagram shows a variable unit, but a 200- μf fixed capacitor may be used.) This capacitor parallels the tuned circuit through S1 and effectively splits the broadcast band in two.

L2 is a winding added to the loopstick. Nominally, this coil should be 12 turns wound at one end of L1 as shown in Fig. 202. Increasing the number of turns gives increased sensitivity or loudness, accompanied by some loss in selectivity, and, of course, decreasing the turns of L2 gives better selectivity at the expense of signal volume. The size of the wire used to wind L2 is not critical, but space the turns slightly apart.

The detector is a germanium diode. Any of the many available types are satisfactory. (Surplus silicon "radar" crystals, however, are *not* suitable). Typical crystals that can be used are the Raytheon CK705, Sylvania or Radio Receptor 1N34 and the G-E 1N69.

Crystal-detector receivers operate the diode in the low millivolt



parts list for solar-powered radio

Capacitors: C1-a, C1-b—padder (each section 200 μf or more). C1-b can be a fixed unit. C2—.1 μf , 200-volt miniature.

Transistor: V—CK721.

Diode: D—CK705 (or 1N34, 1N69).

Coils: L1—5-inch loopstick (Superex-Allied Radio 51CO38); L2—see text.

Batteries: B-15 photocell; RM cell—1.345-volt mercury cell.

Switches: S1, S2—spdt.

Miscellaneous: antenna clip; transistor socket; non-metallic case; knob for padder capacitor; $\frac{1}{4}$ -inch dia. brass shaft; phenolic base; 2,000-ohm earphones; hardware.

Fig. 201. The solar-powered radio has a crystal detector and a single transistor audio amplifier stage. For sunless days, use the mercury cell.

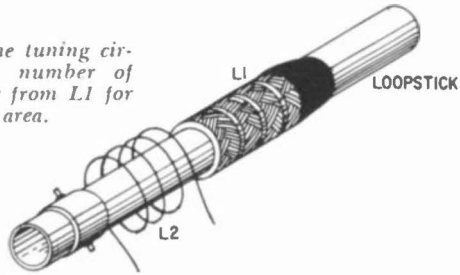
region. In this low-level signal range no diode is a really good rectifier. Detection takes place because the diode is a nonlinear resistance element passing more current in one direction than the other. This is termed "square-law detection," the name being derived from the diode characteristics at low signal levels.

Crystal detectors, with no exceptions, operate on this principle.

And despite what you may have heard, they are not distortion-free. All produce some second-harmonic distortion.

Audio output from the detector is coupled to the transistor by

Fig. 202. *L1* forms part of the tuning circuit. Experiment with the number of turns for *L2* and its spacing from *L1* for best results in your area.



a 0.1- μ f capacitor. This can be one of the miniature 200- or 120-volt units commonly found in personal radios. Since the capacitor can discharge back through the nonlinear diode resistance, there is no need for a diode load resistor between the diode and capacitor — they are connected directly together.

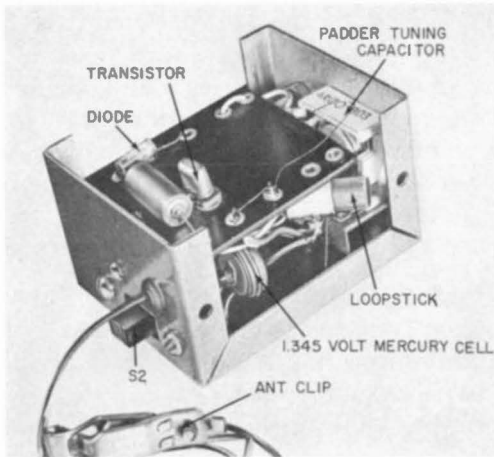


Fig. 203. *The solar-powered radio is a compact little unit.*

The transistor should be a high-gain type, the CK721 for example. Using the CK722 results in a considerable lowering of performance. With a CK721 and 2,000-ohm earphones, the power gain of the transistor stage should be at least 160. A hermetically sealed type of high-gain transistor was used in the original receiver and is visible in the photograph, Fig. 203. Except for the metal case, it is almost identical to the CK721.

Solar power supply

A type B-15 self-generating photocell forms the basis for the solar power supply. The B-15 cell is unmounted. A rectangular silver band around the perimeter of the cell is the negative or front electrode. The solid silver backing is the positive terminal.

For our purpose, the cell must be cut into four equal-area sections. A small hacksaw is suitable for the cutting operation. To avoid overheating the edges, cut slowly. If the cell is clamped in a vise, use cardboard buffers to avoid mutilation of the cell's surface.

Check each of the four photocells by connecting a milliammeter — 0-1 ma will do — across its terminals. The four cells should all give approximately the same output. For checking, each cell can be held near a 100-watt light bulb. If any cell gives appreciably lower output, the edge formed by the cut may be partially shorted. This can be corrected by scraping the edge with a screwdriver or knife blade until the cell delivers normal current.

Pieces of small, flexible, stranded wire connect the cells in series. The wiring arrangement is given in Fig. 204. Tin the wires first and then solder *quickly* to the appropriate silver band or back; otherwise, the silver may melt away from the solder connection. When the cells are soldered together, check them again by connecting a voltmeter across the two output wires. In sunlight, the meter reading should be in excess of 1.5 volts. After the final check, place the cells face down on a square piece of clear plastic and bind them to the plastic with cloth adhesive tape. The modified cell is then ready for installation in the receiver.

Construction and operation

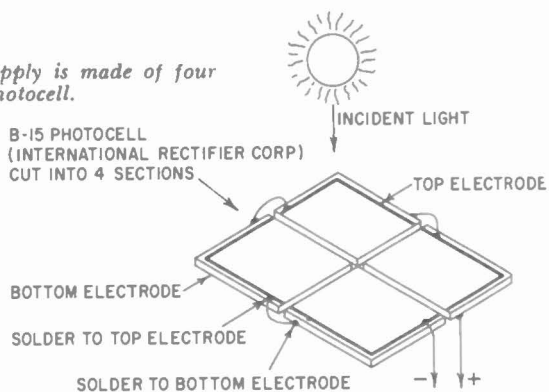
The original receiver was mounted in a small aluminum case but the closed aluminum box reduced the Q of the loopstick. A non-metallic case is recommended.

To attach a tuning knob to the padder, take a piece of 1/4-inch brass shaft and drill a hole in its center very slightly smaller than the padder shaft. Then heat the 1/4-inch shaft until the hole enlarges enough to be pushed onto the padder. When the shaft cools, it will be solidly mounted to the tuning capacitor.

The remaining mechanical details are simple and the parts may be placed wherever most convenient. An easy way to mount the mercury cells is simply to solder the metal extension tab (negative terminal) to the S2 terminal. To avoid damage, soldering to any part of the mercury cell must be done quickly and the cell should be checked afterward with a voltmeter.

For an operational check, clip the antenna lead to something metallic. A screen door, clothesline or short length of wire, say

Fig. 204. The solar power supply is made of four sections of a photocell.



15 feet long, should do. By tuning the receiver, stations should be heard with the power switch in the mercury cell position. Hold the receiver facing through an open window and flip the switch

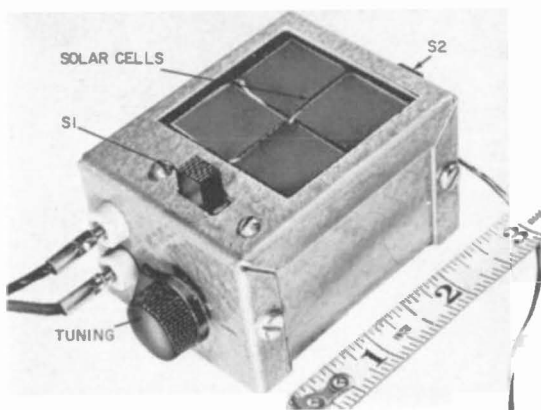


Fig. 205. The solar-powered radio with the solar cells in position.

to the solar cell position. The station should come in just as loudly as with the RM cell. Direct sunlight can have an intensity of 10,000 foot-candles; yet the radio operates satisfactorily with only 100 foot-candles. (The complete receiver, with solar cells in position, appears in Fig. 205.)

The volume and selectivity obtainable from such a simple circuit is amazing. Strong stations are loud enough to be heard with

the phones pushed back from the ears. Selectivity is good enough to separate three stations located at 1550, 1450 and 1230 kc and it "takes some going" to do this with only one tuned circuit. Full credit for this achievement goes jointly to the super loopstick and the high-gain transistor.

shirt-pocket radio

WITH the help of transistors, experimenters and hobbyists can construct their personal all-transistor radio — one that can fit into a *shirt pocket*.

This receiver requires only 4.5 volts, supplied by 3 penlight cells. These should last more than 600 hours of normal use, so the

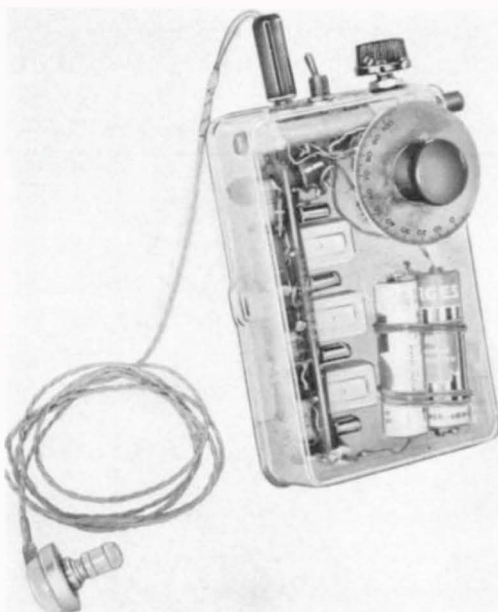


Fig. 206. *The shirt-pocket radio, completed and ready to go with you.*

operating cost is about 1 cent for 24 hours. Fidelity is very good because of the reduced sideband cutting of a transistor amplifier. The entire set is housed in a transparent plastic box (see Figs. 206 and 207) with a hinged cover. This is a $4\frac{1}{2} \times 2\frac{3}{4} \times 1\frac{1}{8}$ -inch box and can be bought at many hardware and department stores for

about 20 cents. The set weighs less than 7 ounces. It delivers a strong signal to its earpiece. Actually, the receiver will operate well with as little as 2 volts at less than 1 ma. Perhaps this is a good chore for a group of sun batteries!

Tested in many localities and under different conditions, the set seems to work anywhere. Carrying it in a shirt pocket, you can walk along the street, in a steel building . . . even in a cellar, yet pick up stations loud and clear. Unlike some other "self-contained"

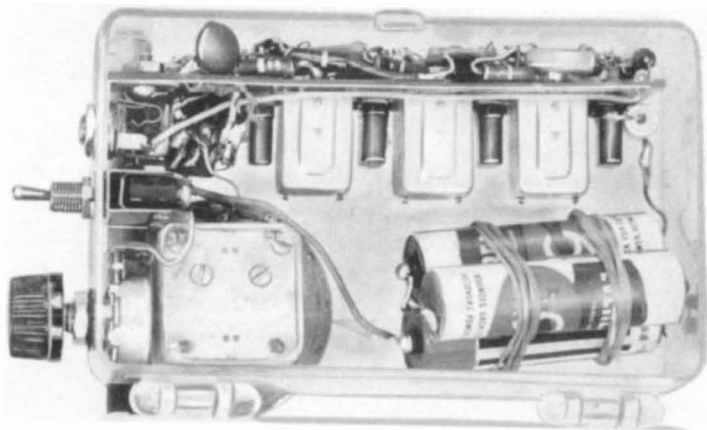


Fig. 207. *The shirt-pocket radio inside its plastic case.*

sets which may also work well but require a 10- or 20-foot antenna, this radio depends entirely on its own.

Two important problems had to be worked out—the converter stage and the if amplifier. In each case the result was completely successful, providing a very efficient and sensitive radio. Full earpiece volume is obtained without a separate audio stage.

Six separate units make up this receiver: the antenna loop, battery control, variable capacitor, converter-if amplifier, battery and switch.

Constructing the receiver

The first component to be mounted in the box is the loop antenna. It is Lafayette part MS-272, slightly modified. Remove 25 turns from the larger winding of the loop, that is, starting with the white lead. Then tape or cement the ends so that there will be no further unwinding.

Saw off part of the form which is nearly $3\frac{1}{2}$ inches long—the plastic box is only $2\frac{3}{4}$ inches wide. Saw the form (preferably a little from each end) until its total length is about 3 inches. This

will leave some of the form extending from each side of the box for support. A hacksaw will do the job nicely.

The words "horizontal," "top," "side," etc., refer to directions with the box standing on ends as when placed within a shirt pocket.

Holes for the loop should be only slightly larger than $\frac{1}{4}$ inch in diameter. Drill them with a $\frac{1}{4}$ -inch drill, then file a little. These holes should be as near the *top* and *front* of the box as possible. (The front is the side opposite the hinged cover and is farthest from the person wearing it in his shirt pocket.) To insert the loop, open the box cover and push one end of the core into one of the holes until the other end can pass through the hole in the opposite side.

Next mount the battery control. This is Lafayette part VC-32, a 1,000-ohm potentiometer. It requires a $\frac{1}{4}$ -inch hole through the top of the box and as far to the left as possible. This unit has a diameter of $\frac{3}{4}$ inch so there is plenty of space for it and the loop, also. Before mounting this control cut off part of its long shaft (to less than $\frac{5}{16}$ inch) and solder leads to its terminals — soldering is more difficult later.

The variable capacitor is mounted just below the battery control and also to the left as far as possible. This capacitor is Lafayette part MS-270, one of the most unusual items made available to experimenters in recent years. Only $\frac{11}{16}$ inches square and $\frac{5}{8}$ inch deep behind the panel, it is a complete two-gang capacitor with a cut-plate type oscillator section and built-in trimmers. The two columns in the center of the table show the capacitance of the tuning sections as the shaft is rotated through 180 degrees from its maximum-capacitance (plates fully meshed) position. The column at the extreme right shows corresponding frequencies tuned in when using an antenna coil with an inductance of 327 μ h and an oscillator coil of 221 μ h.

dial (%)	ant (μ mf)	osc (μ mf)	freq (kc)
0	211.0	101.0	535.00
10	189.4	94.8	562.35
20	168.9	88.2	594.03
30	148.0	81.1	631.70
40	126.9	73.3	678.15
50	105.4	64.6	737.71
60	83.8	54.9	816.66
70	61.8	43.7	930.76
80	41.6	31.8	1093.59
90	23.9	19.7	1336.73
97	13.0	11.0	1605.00

You can use a dial calibrated like the one in the photograph

ing and joining them with a file, until the socket fits through. The oscillator transformer requires a $\frac{1}{4}$ -inch mounting hole. It is held in place (with terminals upward) by its own leads passing through the Bakelite strip.

Mounting dimensions

Here are some dimensions for mounting the parts: The oscillator transformer hole is located $\frac{3}{4}$ inch from one end of the Bakelite strip. The if transformers are spaced $\frac{7}{8}$ inch apart (center-to-center), the last one being $\frac{3}{4}$ inch from the other end of the

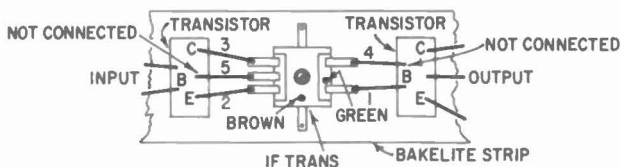


Fig. 210. Bottom view of if transformer showing connection details.

Bakelite strip. A small portion of the strip must be cut away where it interferes with the antenna loop.

Fig. 210 shows typical connections to an if stage. It is a bottom view of the Bakelite strip with the converter stage (not shown) at the left. Each if transformer is mounted with its brown dot on the bottom. This places three of its terminals on the left, two on the right. Each transistor socket is mounted with its collector terminal at the top. Remember: Fig. 210 is a *bottom* view. Note the coding dots.

The transformer terminal numbers are marked in the diagram. Terminal 3 connects *directly* to the collector of the previous transistor. This is made possible by carefully bending the terminals of the transformer and transistor until they meet! Likewise, terminal 1 is soldered directly to the base of the following transistor. Terminal 4 is not connected electrically but is soldered to a dummy terminal of the following transistor for support and to keep it from moving. In the same way, terminal 5 is soldered to a dummy terminal of the preceding transistor. Terminals 5 and 2 are connected to other components as indicated in Fig. 209.

To make this convenient wiring (or rather, lack of wiring) possible, the transistor sockets must be mounted just as shown in Fig. 210. If the socket is turned around, wiring becomes more difficult.

Neutralization

Neutralization is generally required in a transistor if amplifier

because transistors are triodes with no shielding between input and output. Without neutralization the amplifier may oscillate and generate whistles as each station is tuned in. A 56- μf capacitor was found necessary between the bases of V3 and V4. Strangely enough, none was found necessary between V2 and V3.

One other component is needed on the amplifier assembly. It is a miniature earpiece jack, such as made by Telex. Either a *closed*- or *open*-circuit jack may be used. This jack should come out of the box at the *top* for easy plug-in. A small aluminum angle bracket can be made up for this. It may be $\frac{1}{2}$ inch on each side and $\frac{1}{2}$ inch wide. A $\frac{1}{4}$ -inch hole at one end takes the jack. Two small screws mount the other end (of the bracket) onto the Bakelite sheet.

Testing

Before mounting the amplifier you may wish to test it. With the power on you should hear a buzz when the amplifier is brought near a fluorescent lamp. This shows that the amplifier is working. The oscillator may be checked by listening to its signal in a nearby receiver. Connect a capacitor temporarily, across the coil for tuning. You should be able to cover from approximately 1 to 2 mc; that is, 455 kc higher than the broadcast band limits.

To mount the amplifier, remove the screw from the earpiece jack and insert the jack into a hole drilled for it in the box top. Tightening the screw on the jack is sufficient to hold the entire amplifier unit in place. If desired, the unit may also be supported near the bottom of the box.

The power supply for this receiver is composed of three pen-light cells held together by a rubber band. Connections are soldered directly to the cells as required.

The battery switch problem is more difficult than might be supposed. The only satisfactory solution is a tiny toggle switch made by Milliswitch of Los Angeles, a very expensive item costing nearly \$4. Unfortunately, there is no miniature earpiece jack that can close a battery circuit when the earpiece is plugged in. This would solve the problem nicely. Other substitutes might be a miniature four-position switch (sold by Lafayette) or a potentiometer with switch instead of the battery control used here.

Alignment

After all parts are mounted and connected in the plastic box, align the receiver. If you have no signal generator, try using the fluorescent buzz mentioned before. This buzz will grow in strength as you approach correct alignment. Also, you may use a loud

station to help your alignment. Alignment with a signal generator is much better, of course, and in some cases will make the difference between excellent and erratic operation.

Adjust the oscillator core for maximum pickup at low broadcast frequencies. Tune the antenna trimmer of the dual capacitor for maximum pickup at high frequencies.

The battery control has only slight control over gain. Actually, it is useful for reducing drain from the battery and also acts as a filter in conjunction with the 16- μ f capacitor. As batteries grow old, it may be necessary to turn this control up to compensate for added resistance in the battery. With full resistance in the circuit, the battery drain should be about 2.5 ma. This control also prevents overloading on the more powerful local stations.

Don't hesitate to build this transistor radio. You will find plenty of use for it since you can keep in touch with the ball games, news flashes, your favorite concerts, etc. When carried in a shirt pocket, everything remains hidden except for the hearing-aid earpiece. The sound fidelity is far better than provided by most tube radios and the tuning is much less critical. Yet there remains sufficient selectivity to separate even the closest locals. As for volume, the stronger stations may be heard as much as a foot or two from the earpiece!

adding a speaker

If you constructed the shirt-pocket radio (or similar transistor tuner) you can make a simple modification and adapt it for speaker operation. With few additional parts, the signal is boosted and

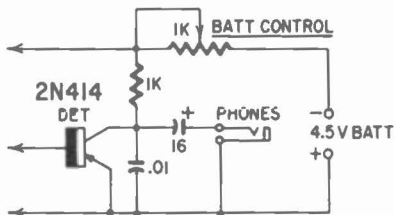


Fig. 211, Circuit of the class-B detector used in the shirt-pocket radio.

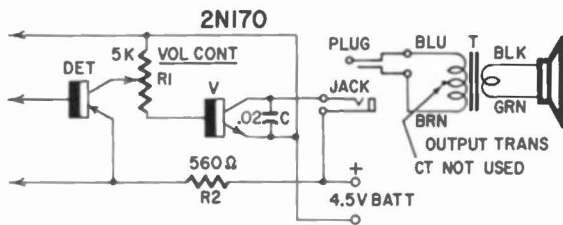
made audible several feet from a speaker in a quiet location. The output stage is coupled directly to the transistor detector, thus simplifying construction. The amplifier is similar to that used in G-E receiver models 675-676.

Fig. 211 shows the class-B detector used in the shirt-pocket

radio. When modified for an additional audio stage, the circuit looks like Fig. 212. Note that an n-p-n transistor audio stage must be used when the detector transistor is p-n-p. The direction of current through the p-n-p collector is correct for biasing the n-p-n base.

In Fig. 212, variable resistor R1 acts as the detector load as well as a volume control. It replaces the 1,000-ohm fixed resistor, originally part of the shirt-pocket radio. It may be a dime-size potentiometer (for example, Lafayette VC-33) and it occupies the hole originally drilled for the battery control which is no longer used. A 560-ohm resistor is added for isolation and filtering.

A tiny speaker assembly can be made up with an Argonne



parts list for single-ended speaker stage

Resistors: R1—5,000-ohm midget potentiometer (Lafayette VC-33 or equivalent); R2—560 ohms, ½ watt.

Capacitor: C—.02 μf.

Transistor: V—2N170.

Miscellaneous: T—output transformer, pri-

mary impedance 500 ohms, secondary impedance 3.2 ohms (Argonne AR-119); speaker (Argonne SK-61); perforated plastic board; subminiature plug and jack (Telex); Batt—4.5 volts; battery holder; transistor socket; knob for R1; mounting board; hardware.

Fig. 212. This modification adds a single-ended speaker stage to the shirt-pocket radio.

SK-61 speaker and Argonne AR-119 transformer. This speaker is only 1½ inches square and 1⅞ inches deep. The transformer has a 500-ohm primary (the center tap is not used) and a 3.2-ohm secondary. This speaker fits into the hinged plastic box in which the transformer is sold. Slight filing down of the speaker sides may be needed for a neat fit.

To increase the baffling action and to strengthen the assembly, use a piece of perforated plastic board (Lafayette Radio part MS-304) between speaker and plastic box. (See Fig. 213.) The perforated board permits sound to pass out of the speaker. Of course corresponding holes must be drilled through the front of the plastic box. Only 6 rows of holes are needed through the box, because the speaker is 1½ inches square. One of the speaker screws holds the transformer inside the box. Leads from the transformer pri-

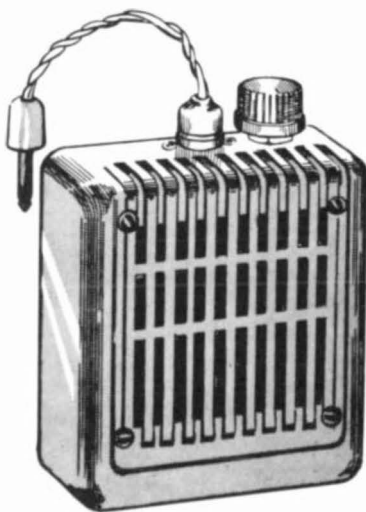
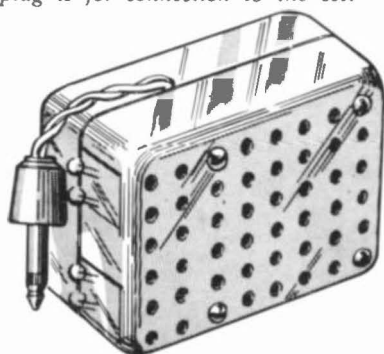
mary should end in a Telex or similar subminiature plug for insertion into the jack on the set. The completed amplifier is shown in Fig. 214.

With this amplifier, most stations come in too loudly on an earpiece and the volume will have to be lowered. With a speaker, the signals are audible up to 5 or 6 feet away. The last stage requires about 0.5 to 5 ma, depending on signal strength.

If you want a full-power signal from your pocket radio, add the direct-coupled stage but use a class-B amplifier before the speaker.

Fig. 213. (below) Insert a piece of perforated plastic board between the speaker and the box.

Fig. 214. (right) The completed amplifier is a compact unit. The plug is for connection to the set.



The class-B stage (Fig. 215) is small enough to be placed within the speaker case along with its battery supply. The output will be sufficient to be loud and clear many feet from the speaker, yet power consumption is low.

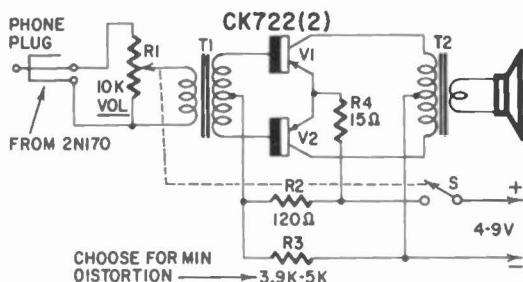
The class-B circuit can be operated from any voltage from 4 to 9. All parts are mounted on a piece of perforated board measuring about $2\frac{1}{2} \times \frac{7}{8}$ inches. When completed, the board may be wedged at one side of the speaker.

The speaker and Sound Box are designed for each other. The speaker is a $2\frac{1}{2}$ -inch unit (Lafayette SK 65). The sound box or speaker case is already fitted with a beautifully styled grill, and a two-pin socket at the top. Incidentally, this case machines very well. It can be drilled or filed without fear of the cracking or chipping that we expect from most plastic materials.

The battery used in this particular device is an RCA VS 308 which gives 4 volts. The voltage can be boosted up to about 9 with a proportional increase in output power.

The volume control (with switch) is mounted on top of the speaker case. It is single-hole mounted.

This Sound Box makes a very attractive and useful addition to the shirt-pocket radio. It permits listening in at comfortable sound



parts list for push-pull amplifier

Resistors: R1—10,000 ohm potentiometer; R2—120 ohms; R3—3,900–5,000 ohms (experiment with resistors in this range for minimum distortion); R4—15 ohms (all resistors ½ watt, 10%).

Transistors: V1, V2—CK722.

Transformers: T1—driver transformer, primary impedance 10,000 ohms, secondary impedance 2,000 ohms center-tapped; T2—

output transformer, primary impedance 500 ohms center-tapped, secondary impedance 3.2 ohms.

Switch: S—spsst (mounted on R1).

Battery: 4 volts (RCA VS 308).

Miscellaneous: 2½-inch speaker and sound box (Lafayette SK 65); phone plug (Telex); phenolic board; battery holder; knob for R1; transistor sockets (2); hardware.

Fig. 215. Push-pull class-B amplifier that can be added to the shirt-pocket radio. Experiment with different values of R3 for minimum distortion.

levels and can be attached to the radio with a flexible cable. Some constructors prefer to use the same power source for both the radio and the class-B amplifier. This is easily arranged since they both require approximately the same voltage. Alternatively, both units may be built into the same box, and energized from the same battery. This will give you a high-performance device with all desirable features: two stages of high-gain if, power detector, class-B audio and low drain from an inexpensive battery.

regenerative receiver

Two distinctive features make this transistor detector really new. First, without sacrificing any audio gain, all long time constants have been completely eliminated from the detector. This, for all practical purposes, does away with audio bypass capacitors and the familiar regenerator squeal, growl or motorboat sounds. Second, but also of first-order importance, we have used the surface-barrier transistor which performs circles around conventional diffused-, alloy- or grown-junction transistors.

The SB (surface-barrier) transistor is a hot-performing detector at radio frequencies. It is worth while to the reader to know why this is true. So let us start with some explanatory background. The cutoff frequency of a transistor is the frequency at which the transistor gain is 3 db below its low-frequency value. This cutoff frequency is measured *with the transistor in the grounded-base connection*. You should also know that beta is the transistor's ground-emitter current gain.

Current gain

The grounded-base transistor connection does not give current gain. However, the grounded-emitter connection provides plenty of current gain at low frequencies. This is because the base circuit must be supplied with only enough current to make up for the small difference between emitter and collector currents. Current gains of a hundred or more are common in the grounded-emitter connection.

But, this current gain can be realized only when the emitter and collector currents are in phase. As the frequency is increased, the emitter and collector currents get further and further out of phase. This phase difference causes the emitter current to have a much different value from the collector current at any given instant. This results in a lowered current gain at high frequencies. And the higher the beta gain of the transistor, the more this effect is magnified at high frequencies.

The high-frequency gain of a grounded-emitter stage begins to roll off at a frequency equal to the quotient of the transistor cutoff frequency divided by the beta gain.

Suppose we have a transistor with a beta of 40 and a 10-mc cut-off. With these conditions, the performance of a grounded-emitter stage will begin to drop at 250 kc (10 mc divided by 40), well below the broadcast band. Usually, high-frequency transistors also have very high betas. This makes conditions, usually, somewhat more unfavorable than those just presented.

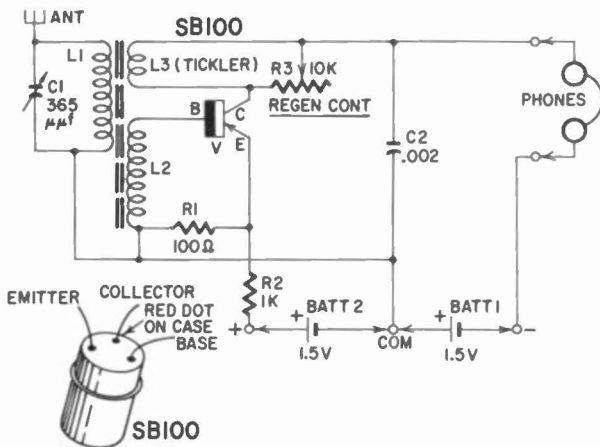
For the reasons just presented, low-frequency transistors (the 2N107 or CK722, for example) are most useful in the broadcast band as grounded-base-connected amplifiers or detectors. High-frequency units like the 2N136, however, are suitable in the grounded-emitter connection.

Surface-barrier transistor

In contrast to junction types, with their degraded high-frequency performance, the surface-barrier transistor just begins to

show its clear-cut superiority at radio frequencies. It is designed to give optimum performance at high frequencies.

Typically, an SB transistor may have a *cutoff frequency at 50 mc and a beta of 10!* This means performance is excellent through the broadcast band and far into the shortwave bands. The SB transistor gives this type of performance with only a volt of col-



parts list for regenerative receiver

Resistors: R1—100 ohms, ½ watt; R2—1,000 ohms, ½ watt; R3—10,000-ohm potentiometer.

Capacitors: C1—variable capacitor, 365 μf ; C2—.002 μf ; ceramic or paper.

Transistor: V—Philco SB100.

Coils: L1—ferrite-rod antenna; L2,L3—special windings (see text.)

Miscellaneous: Batt 1, Batt 2—1.5-volt dry cells; pegboard; Fahnestock clips, wire, knobs, solder, screws, terminal strip.

Fig. 216. The surface-barrier transistor performs well at broadcast frequencies in this regenerative circuit. R3 controls the amount of feedback, hence the volume indirectly.

lector supply and a power consumption only one-tenth that of a junction transistor.

SB detector circuit

Fig. 216 shows the regenerator circuit employing the SB100 surface-barrier transistor. Notice the emitter is biased from the drop across a 100-ohm resistor (R1). This value of resistance is low enough to obviate the need for a bypass capacitor. Because the bypass capacitors are eliminated, the usual audio howls are gone. Admittedly, there is a bypass capacitor (C2) across the headphones, but this has little effect at audio frequencies.

The usual emitter or base bypass capacitor has been dispensed with at the expense of some power loss in the 1,000- and 100-ohm

resistors (R2 and R1). Even then the resulting power consumption is still far less than for a junction-transistor stage.

An interesting facet of this circuit points up the marvelous characteristics of the SB transistor. Once the detector has gone into oscillation, the emitter bias can be reduced to zero and the circuit will continue to oscillate strongly! As many experimenters will know, this just can't be done ordinarily. It is indicative of the circuit's high gain and merit.

This was the reason we had to control regeneration with a shunt resistor (R3) across the tickler coil. If a bias type regeneration control had been used, it would have lost control immediately with the beginning of oscillation. The only way to stop oscillation under these conditions would be to turn off the battery supply.

Construction

The original circuit was built on a pegboard (Fig. 217) allowing the circuit to be quickly modified without the confusion that usually rules the breadboard layout. This arrangement is very con-

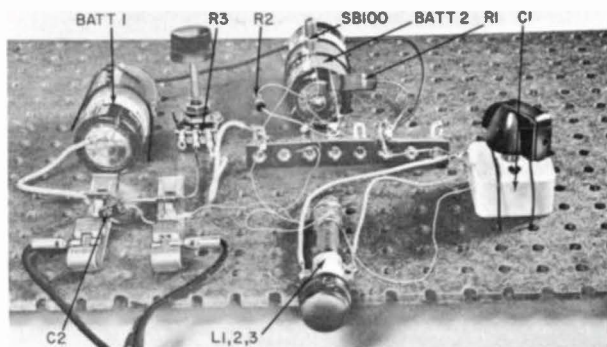


Fig. 217. A pegboard can be used as the chassis for the regenerative receiver.

venient. Otherwise hard-to-mount components are easily attached to the board with wire harness running over the components and through the pegboard holes. As the photo in Fig. 217 shows, the tuning capacitor, antenna and dry cells were all attached that way. Almost any component can be jockeyed around on the board's surface until its mounting holes coincide with those punched in the board.

As a design rule of thumb, any regenerator tuned circuit should have the highest possible Q. This is the reason a ferrite-

rod antenna, or loopstick, is used. It must have two additional windings — one for the transistor base circuit and the other to provide feedback from the collector. Winding L2 is seven turns and L3 two turns of flexible wire wound over the main winding. The wire size is not too important. It is advisable, though, to wind tickler L3 on a small paper sleeve so it can be slid on or off the ferrite rod. This provides a rough regeneration control that can be adjusted to account for changes in antenna length and loading.

Some of the newer ferrite-rod antennas are tapped for transistor use. The Lafayette MS-299 is the latest example. If this type is used, simply connect the transistor base to the tap and add only the tickler coil L3.

Connect the emitter and collector cells, observing the proper polarities, which are exactly the same as for a junction p-n-p transistor. The emitter is biased with a positive current and the collector operated with a negative voltage.

Operation

Now, connect a short antenna — say 10 feet — to the detector and rotate the regeneration control back and forth. The detector should go into oscillation with a popping sound or a click. If it does not oscillate, reverse the leads to the tickler coil.

Adjust the tickler position so the detector goes in and out of oscillation near mid-position of the control. With these adjustments made, stations should be picked up easily. Local stations will be loud and clear with plenty of volume. Some can even be picked up without an antenna. Distant stations can be received in the daytime but the audio level will be too low to hear comfortably. Two stages of additional transistor audio amplification can be added if desired for distant reception.

The tuning capacitor

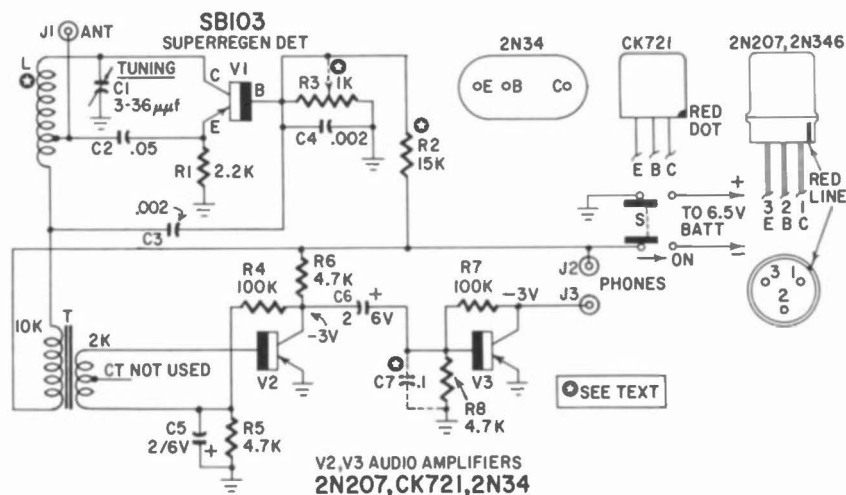
The new solid-dielectric type of tuning capacitor was used on this model. It does not produce the annoying swish during rotation that earlier models had exhibited. As shown in Fig. 217, the tuning screw on the antenna coil has a knob attached and is used for fine tuning. Knobs are now available that exactly fit the diameter of this tuning screw.

If you are interested in transistor regenerators, try this circuit. We believe it will outperform anything you've seen yet.

pocket police receiver

THE idea of owning a police radio receiver is always intriguing. Interest spans all age groups from children to grandparents. There is a thrilling vicarious experience; listening to emergency broadcasts is exciting to all but the victims.

Added to this, we have an extra-special police receiver. It is hand- or pocket-size and completely transistorized. Its operating frequency range is about 30 to 45 mc.



parts list for pocket police receiver

Resistors: R1—2,200 ohms; R2—15,000 ohms (see text); R3—1,000 ohms (see text); R4, R7—100,000 ohms; R5, R6, R8—4,700 ohms (all resistors ½-watt 10%.)

Capacitors: C1—3-36- μ f trimmer (Bud MT-833 or equivalent) C2—.05 μ f ceramic, sub-miniature type; C3, C4—.002 μ f, disc ceramic; C5, C6—2 μ f, 6 volts, miniature electrolytic; C7—0.1 μ f ceramic (see text.)

Transistors: V1—SB103 (Philco); V2, V3—

2N34 (CK721 or 2N207 may be substituted.)
Jacks: J1, J2, J3—pin jacks.

Miscellaneous: L—7 turns, tap at 2¼ turns (Barker & Williamson type 3003 Miniductor); S—dpst slide switch; T—driver transformer, primary impedance 10,000 ohms; secondary impedance 2,000 ohms center tapped (Argonne AR-109 or equivalent); battery—6.5 volts (Mallory TR-165R or equivalent); terminal board; case; miscellaneous hardware.

Fig. 218. This superregenerative receiver has a high-frequency detector and two stages of audio amplification. The circuit is designed to eliminate practically all controls.

The small size makes it ideal for auxiliary police, Civil Defense workers, merchant police, ambulance crews and the like. Also, it is just the thing for those who like to know what is going on.

The circuit (Fig. 218) is simple and there are few parts. One of the transistors is a surface-barrier type. It is used just like a

p-n-p fused-junction type. However, SB units can operate at very high frequencies.

The SB transistor is used as a high-frequency superregenerative detector. The other two transistors are audio amplifiers.

The receiver, as illustrated, is a fixed-frequency type. Tuning can be changed only by adjusting C1 through a hole in the case, and even the amount of *superregeneration is set at a fixed value*. These are desirable features, since they eliminate controls.

Receiver sensitivity

To appraise its performance, here is a report on the receiver in use. However, bear in mind that signal strengths vary tremendously in this type of service.

From experience, the audio output is strong and clear 5 miles from a central police transmitter. Reception is usually good, even without an antenna. Reception of patrol cars or utility truck transmissions is another matter. Unless the vehicle is very close, audio is weak and garbled.

This circuit has been used with a third audio stage and a small speaker. Still, earphone operation seems preferable for one-man listening. If a third stage is added for speaker operation, considerable audio decoupling is necessary to eliminate motorboating.

Detector circuit

The superregenerative detector is the receiver's nerve center. Superregeneration develops tremendous amplification in a single stage.

Inherently, the superregenerative detector is not very selective. Also, it has a natural automatic volume control action.

With rare exceptions, the stations in the 30-60 mc band are narrow-band frequency-modulated. The pocket police receiver picks up these stations by slope detection.

Because the detector is broadly tuned and the frequency swing is very small, audio output from the detector is low. This makes the two medium-gain audio stages necessary.

The superregenerative detector's selectivity can be sharpened somewhat by setting the value of superregeneration carefully. In fact, it *must* be set for greatest selectivity for really good performance. This procedure requires a signal generator and is explained later.

The maximum frequency at which the detector will superregenerate depends upon the Q of the coil, transistor characteristics, the value of C2, the position of the coil tap and transistor bias.

To operate the receiver at 40 mc or higher, you may have to juggle or vary all of these values for maximum superregeneration.

High-frequency performance is particularly dependent upon coil L. For this reason, we will give it special mention. First, the coil must be kept away from the sides of the case, transformers and other metal parts. If at all possible, use a larger metal case, a plastic case or no case at all. Test the circuit before placing it in a case.

The receiver (Fig. 219) operated up to 45 mc before placed in its case. In the case, it works to about 39 mc using a selected, hot-performing 2N346/SB103 transistor. Other units may not perform as well.

A lot of experiments were carried out with some of the completely shielded miniature iron-core coil forms now available. These would do away with effects caused by nearby components. But, because their performance was lower initially, they made no improvement.

The Miniductor type coil (Barker & Williamson No. 3003) gave the best results. Coil L consists of 7 turns tapped at $2\frac{1}{4}$ turns. This coil is $\frac{1}{2}$ inch in diameter, with a pitch of 16 turns per inch.

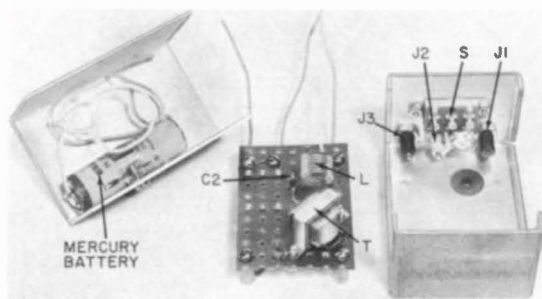


Fig. 219. A metal case will lower the limit of the receiver's high-frequency operation.

Resistors R2 and R3 control superregeneration. With fixed frequency operation, fixed values of resistance can be used. For each individual receiver and frequency, however, these values will have to be changed for best performance. Either decrease R3 or R2. (Decreasing R2 has an opposite effect from decreasing R3.)

To make superregeneration variable, substitute a 1,000-ohm potentiometer for R3 and connect the center terminal of the control as indicated by the dotted lines in the schematic. Also, decrease R2 to 10,000 ohms.

Capacitor C2 should be a subminiature ceramic. The rather large value for C2 is necessary for superregenerative action.

Another essential is transformer coupling. The transformer characteristics have an effect on the detector's quench action. The Argonne AR-109 or something very similar should be used.

Only surface-barrier transistors will work properly in the detector circuit. The 2N346/SB103 is satisfactory (so is the 2N128).

Audio amplification

The two audio transistors have medium beta (current-gain) figures — about 40 to 45. Any other p-n-p transistor with about the same gain is suitable.

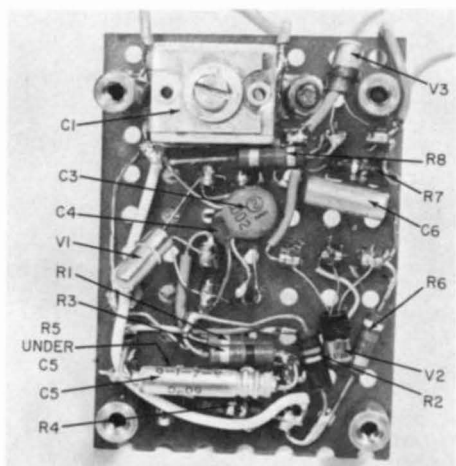


Fig. 220. This underside view of the pegboard shows the placement of the parts.

Direct-current feedback stabilization is used. While this is not as good as having emitter stabilization, it is sufficient and saves the space occupied by two emitter bypass capacitors.

The feedback does not compensate for individual transistor variations, but it does hold temperature changes of the collector current to a reasonable amount. The circuit works like this: If collector current tends to increase because of temperature effects, collector voltage decreases because of the drop across the collector load resistor. This, in turn, tends to decrease the base bias current and reduces the total change considerably. This bias method is infinitely better than just a single resistor from the base to the supply voltage.

Collector voltage of transistors V2 and V3 should read -3 volts (± 0.5 volt) using a 20,000-ohms-per-volt meter. If higher, *decrease* the value of R4 or R7, as the case may be, to *decrease* the collector voltage and vice versa.

If a 2,000-ohm earphone is used, R7 may have to be reduced to about 47,000 ohms.

You may find that listening is more comfortable when the optional capacitor C7 is added. Capacitor C7 suppresses the ultra-

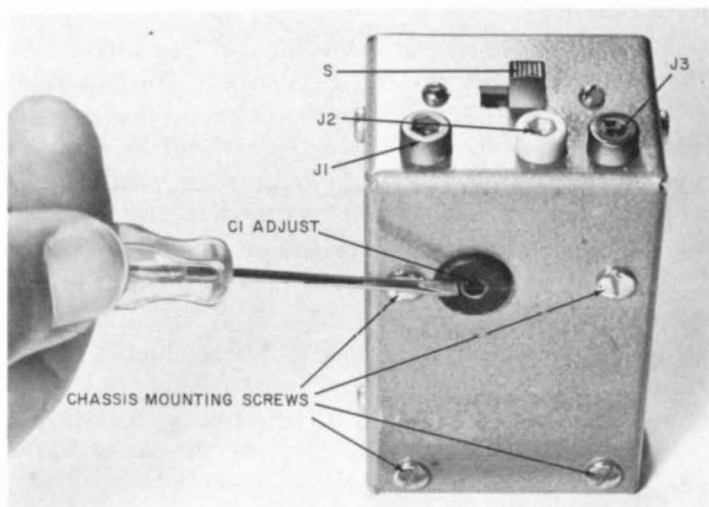


Fig. 221. The tuning capacitor, C1, is reached through a hole in the case.

sonic quench frequency before it reaches the earphones or overloads V3.

A small terminal card (Fig. 220) simplifies construction. The components are wired to the card. Then the card (pegboard or terminal board) is bolted into the case with four brass standoff spacers.

The mercury cell is clamped to the case cover with a piece of strapping material. Of course, a capacitor clip or battery holder could also be used.

The antenna can be a heavy piece of Copperweld wire, about 12 inches long, that plugs into the antenna jack. Increasing the antenna length does not seem to improve reception very much. Too much antenna length will load the oscillator and reduce the maximum working frequency.

Final check

For reception of narrow-band FM, detector superregeneration must be set for maximum selectivity. To do this, a signal generator is necessary. Assuming the set is working, a hiss or frying sound is heard when the detector is superregenerating. With the antenna connected, tune the receiver to the carrier frequency. (See Fig. 221.) This is found by setting the generator at the carrier with tone modulation. Now, rock the tuning capacitor C1 back and forth and adjust the value of R3 until the sharpest selectivity is obtained.

Turn off the generator and listen for a police carrier. The instant the carrier is heard, *turn C1 very slightly* for best reception. This is necessary to account for inaccuracies in the signal generator's calibration and *because the detector must be tuned to one side of the carrier for slope detection*. In other words, best audio *will not* be obtained with the detector tuned exactly to the carrier.

If the detector does not superregenerate, check the connections to the surface barrier transistor. It is easy to confuse the emitter with the base lead.

Next, check the transistor voltages. There should be about 6 volts from ground to collector and, very roughly 0.1 volt from emitter to base. The base should be negative with respect to the emitter. Also, check to see that none of the parts have been omitted.

When the receiver is first connected to the battery, set R3 at maximum resistance. This protects V1 if the battery is inadvertently connected with wrong polarity.

carrier-power receiver

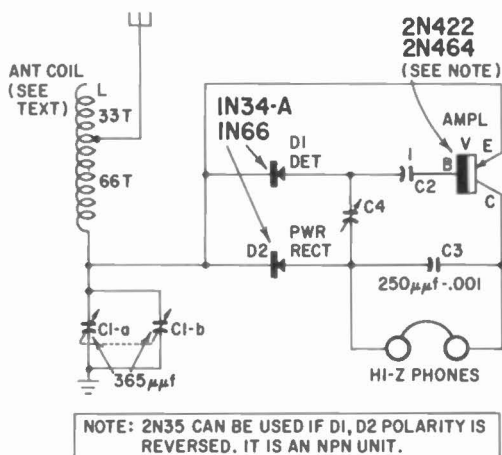
If you live within 10 miles or so of a broadcasting transmitter, the circuit shown in Fig. 222 is a way to get something for nothing. The field created by the nearby transmitter can supply the power you need to operate a 1-transistor receiver.

In this receiver only one antenna is needed and the detector, amplifier and power supply are connected by only one lead to the rf or tuned section. No ground return is used as it is not needed. At first glance the circuit may appear unworkable, but it does work, and very efficiently at that.

Check for power

Before building any free-power receiver you should determine if your location, plus a suitable antenna system, will deliver enough power to operate the amplifier. One important factor that affects the strength of a receiver's signal is the height of the receiving antenna. In practice, antenna height contributes as much as its effective length to signal strength, so place the receiving antenna as high as you can possibly get it.

A good way to determine the amount of available power is



parts list for carrier-power receiver

Capacitors: C1—2 gang variable capacitor, 365 μmf each section. C2—1 μf ; C3—250 μmf -.001 μf ; C4—small tuning capacitor.
Diodes: D1, D2—1N34A, 1N66.
Coil: L—antenna coil, 99 turns No. 22 or 24

dcc on 2-inch diameter form, tapped at 33 turns.

Miscellaneous: M—dc milliammeter (1 ma full scale or more, as required) rfc—2.5 mh (optional, see text); hardware.

Fig. 222. The power supplied by a strong transmitting carrier will operate this receiver. Select the most powerful station. The length and height of the antenna are important factors.

empirical — erect the longest and highest single-wire antenna possible in your location and connect it to the simple crystal set shown in Fig. 223. The tuner and the two diodes are connected with clip leads as these components will be used in the receiver. Place a milliammeter between the diodes and, if you get a reading of 500 μa or better, you should have enough power for a batteryless transistor radio. If you get a reading between 1 and 2 ma, you have enough dc to operate an efficient speaker. Of course, a good ground such as a waterpipe will contribute to the power received.

Sometimes multiple ground connections to separate grounds produce even greater current.

In making your tests, be certain you have tuned in your strongest station because this is the frequency you will use later. In short, if you live within reasonable distance of a strong transmitting station, have an antenna at least 100 or 150 feet long and 35 to 45 feet high, you should have no power shortage. Some antenna systems only 75 feet in length at an average height of 35 feet are capable of delivering better than 1 ma when located in a favorable spot.

The receiver circuit

While the few components required are familiar to all radio men and need no description, the unconventional circuit does require some discussion. Its operation is similar to that of the double-diode arrangement in the power-checking circuit of Fig. 223 with detector diode D1 working in conjunction with the

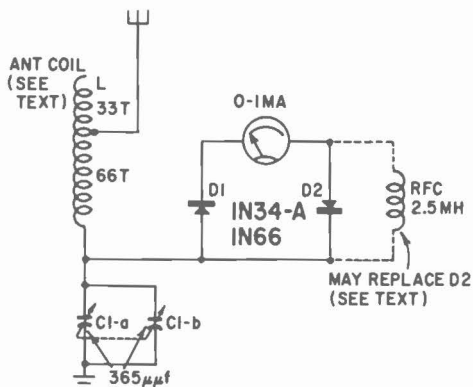


Fig. 223. This circuit will give you an idea of the relative strengths of carrier power in your vicinity.

emitter to the base element of the transistor. Diode D2 is set up so the rectified carrier dc is supplied to the collector in the proper direction. While the circuit appears freakish upon casual inspection, its operation is entirely conventional.

It may interest readers to know that in the power-checking circuit, one of the diodes may be replaced with an rf choke with equal efficiency.

Of the many types of diodes, the 1N34A and 1N66 will be found suitable. Various types of junction transistors can be tried and some will perform better than others. Among these will be

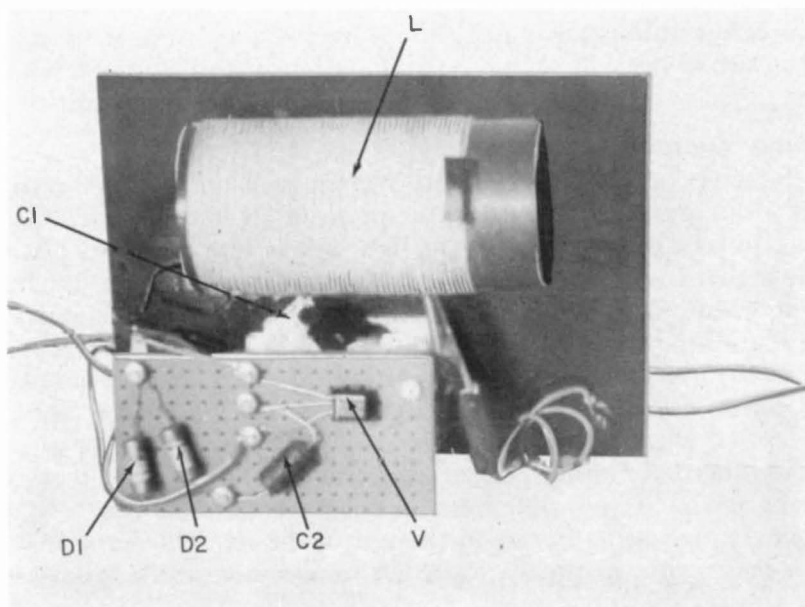


Fig. 224. This is a rear-view photo of the carrier-power receiver. The coil is tapped at the 33d turn for an antenna connection.

the 2N422, 2N464, 2N107 and the 2N35. The last is a n-p-n type and, if used, the polarity of both diodes must be reversed. The circuit works just as well with either type of transistor if proper current direction is insured. The value of the base capacitor is not critical and values from 0.1 to 1 μf were suitable. A base-bias resistor did not add to the circuit's efficiency. Try several diodes and transistors, using the ones that perform best in your final circuit. Many inexpensive types are suitable.

Almost any type of coil may be used in the antenna circuit (Fig. 224). A single-layer coil of 99 turns of No. 22 or 24 dcc wire, tapped at the 33d turn allowed for adjusting the total inductance used, so you can adjust for the most favorable ratio of L to C in the series-tuned circuit. For best power response C1 should be the largest value that will let the circuit be resonant at a given frequency in respect to the value of L — more current is passed when the ratio of C to L is large. Naturally, a series-tuned tank is not the most selective type of tuning element, but selectivity is not too important with this receiver. Both the signal frequency and the power or carrier frequency are the same. A station has to be on frequency for the power circuit to function, hence the amplifier

works only when there is sufficient power to activate it. Furthermore, it is unlikely that any builder lives at a location where more than two or three local transmitting stations furnish enough power for signal overlapping. So selectivity is sacrificed for simplicity.

Some operating notes

Receiver operation is exactly the same as that of a simple crystal set — the one dial is moved to the point of greatest volume. With certain transistors, a heterodyne-like whistle may be heard just to the higher-frequency side of the station resonant point on the dial. The whistle is caused by feedback, but does not interfere with reception if the dial is turned a slight bit toward the lower-frequency side. By adjusting C4, a small tuning capacitor or medium-sized trimmer, the whistle can be eliminated. The point of clearest reception is easily noted, and once adjusted need not be changed.

Another interesting point noted was that it does not seem to make much, if any, difference how long a conductor is used to connect the tuning circuit to the rest of the set. One experiment was made with the tuner proper left in one room while the rest of

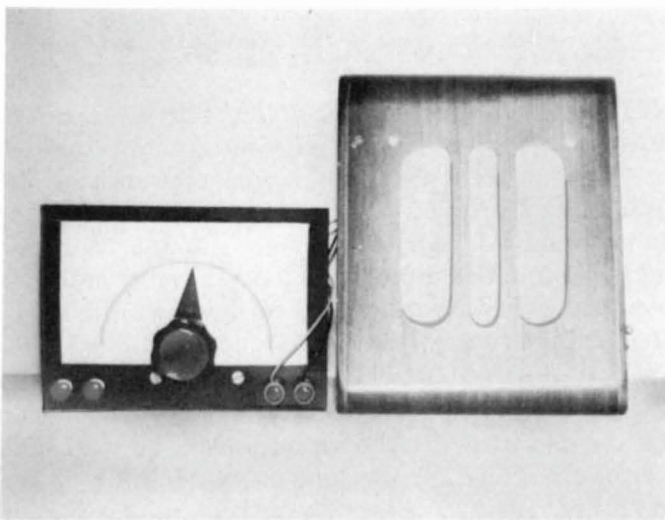


Fig. 225. *If the station carrier is strong enough, the carrier-power receiver will operate a speaker.*

the unit was placed 40 feet away in another part of the house. There was no reduction in volume.

If the receiver is operating correctly, its output is in the order of four to eight times that of a plain crystal set. Exact measurements cannot be given because the volume always depends on the

actual power delivered by the antenna. In some places the volume level is surprisingly strong — enough to drive a sensitive PM (Fig. 225) or an old magnetic type speaker, should one be at hand. Signals from a pair of headphones should be audible 10 or 15 feet away. The whistle effect will be absent and the quality ragged if power is borderline. A longer antenna will usually end this problem.

The percentage of modulation of the transmitter can also affect reception on a receiver of this type. If the modulation is less than 100%, the quality of the receiver's output will be far better than otherwise. There must always be more carrier power to the collector than voice signal.

The experimental receiver described here uses the same station to furnish both the signal and power but somewhat more advanced circuitry will lead to a batteryless receiver which uses the carrier frequency of a very strong transmitting station to amplify the signals from a low-level or weaker station on another frequency. The receiver in Fig. 222, though, serves as an interesting introduction to the construction of more complicated receivers using the free-power principle. And we all like to get something for nothing.

transitube pocket radio

This radio is designed around a subminiature hearing-aid tube and two transistor amplifier stages. The subminiature tube is a 2E31 used as a regenerative detector. Of course, a 2E35, CK503AX or CK506AX could also be used.

Building the receiver

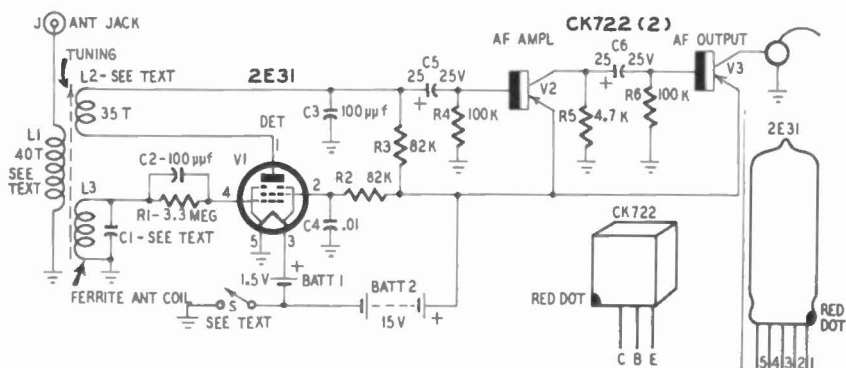
The ferrite antenna coil (L3) is a high-gain unit with a long core. Two windings are added to the coil. The first (L1) consists of 40 turns of No. 28 enameled wire closewound over the existing coil. See Fig. 226. Secure this winding with cellophane tape. The other winding (L2) is 35 turns of No. 28 wire closewound about 1/2 inch away from L3.

The whole broadcast band may be covered by placing a 220- μ f capacitor (C1) across L3.

A 25- μ f electrolytic (C5) couples the signal from the plate of the detector to the base input of the first transistor amplifier. The transistor stages are conventional R-C-coupled amplifiers with base and collector resistors connected to ground. Their emitters are

connected to the positive end of the B-supply. The last stage drives a hearing-aid earpiece.

A miniature 1.5-volt battery is used for the B-supply and a 1.5-volt penlight cell for the detector's filament. Filament leads must be connected as shown. The on-off switch is home-made. Two small



parts list for transitube pocket radio

Resistors: R1—3.3 megohms; R2,R3—82,000 ohms; R4,R6—100,000 ohms; R5—4,700 ohms (all resistors 1/2-watt, 10%.)

Capacitors: C1—see text; C2,C3—100 μ f, ceramic; C4—.01 μ f, ceramic; C5,C6—25 μ f, 25 volts, electrolytic.

Transistors and Tube: V1—2E31; V2,V3—CK722.

Coils: L1—40 turns No. 28 enameled wire closewound, 1/2-inch from L3; L3—ferrite antenna coil (Superex Ferri-Loopstick; Lafayette MS-11; Allied No. 51 C 036, or equivalent.)

Batteries: Batt 1—1.5 volts, penlight cell; Batt 2—15 volts, hearing-aid type.

Miscellaneous: J—tip jack; S—see text; plywood boards, 6x3 1/2 inches (for case); hearing-aid earpiece; hardware.

Fig. 226. Tubes and transistors form a good working combination in this three-stage receiver. Regeneration can be controlled by making C3 variable, but this will add another control.

brads are nailed through the bottom of the set's wooden case, and a soldering lug is bolted to the case. Turning this lug connects the brads, completing the battery circuit.

The case (see Fig. 227) is made from two pieces of 1/4-inch and one piece of 1/2-inch plywood. First, cut the three pieces to size, place a small brad through each corner and sand all sides evenly. Next, the center of the 1/2-inch board is removed, leaving a 1/2-inch border. At the top of the case a 1/4-inch hole is drilled for the antenna coil's core. Another 1/4-inch hole is drilled for the antenna jack. The earpiece leads run through a hole in the opposite end of the case.

There is no special way of mounting the parts, although they must be kept as close together as possible. Be very careful to prevent parts from touching and leads from shorting. Generous use of spaghetti will help. (The finished receiver is shown in Fig. 228.)

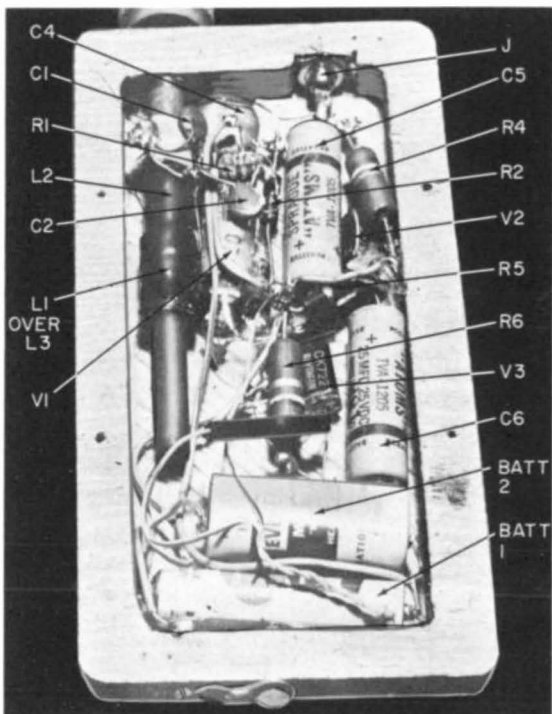


Fig. 227. A wooden case forms the housing for the transitube pocket radio.

Using the receiver

Operation is simple. Just turn on the power, plug an outdoor antenna into the antenna jack and you are ready to listen. The antenna coil's core is a combination tuning and volume control. Tuning is critical for distant stations, but for local stations some detuning may be necessary to reduce volume. Outdoors, you can

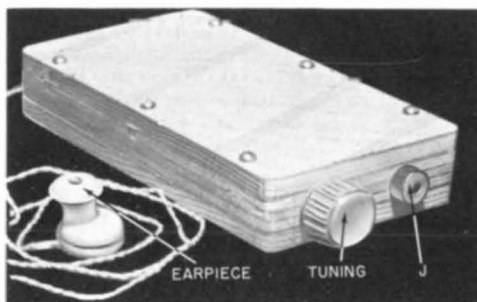


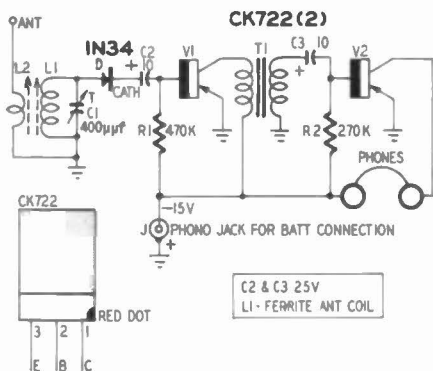
Fig. 228. The regenerative receiver is a fairly compact, flat unit.

use a flexible antenna wire run up your coat sleeve to receive local stations.

If the set's gain and sensitivity seem poor, reverse the L1 winding connections. Varying the value of the detector's plate-load resistor (R3) may give sharper tuning.

headphone radio

THIS two-stage transistor radio is a simple one for training the beginner. Designed around a sensitive ferrite coil and two CK722 transistors it fits into a small plastic box. The ferrite coil (L1 in Fig. 229) used in this simple circuit is the adjustable powdered-iron slug type, commonly used for replacing bad or worn-out an-



parts list for headphone radio

Resistors: R1—470,000 ohms; R2—270,000 ohms (both ½ watt.)

Capacitors: C1—400- μ f trimmer; C2 and C3—10- μ f, 25-volt electrolytic.

Transistors: V1, V2—CK722.

Diode: D—1N34.

Miscellaneous: J—phono jack; L1—ferrite antenna coil; T1—interstage transformer (Stancor U113 or equivalent); midget battery, 15 volts; alligator clip; phono plug; headphones.

Fig. 229. This easy-to-build receiver uses a diode detector and two transistors as audio amplifiers. Any large metal area, such as a window screen, can act as the antenna.

tenna coils in small table radios. Adjusting the slug controls the volume of strong stations and increases the volume of distant ones.

Around the coil wind 25 turns of No. 28 enameled wire (L2). Tape these windings to the coil. One side of L2 is grounded and the other end fastened to a 3-foot length of flexible wire with an alligator clip soldered to it. With this setup you can easily clip to

the bed springs, outside antenna or over the insulated telephone cord for an outside antenna connection.

Capacitor C1, a 400- μf trimmer, is used to tune in the broadcast stations. A $\frac{1}{4} \times \frac{1}{2}$ -inch brass rod is soldered to the original adjustment screw so a knob can be used for convenient tuning.

A 1N34 crystal diode detects the incoming signal. From here the rectified signal is fed to the base of V1 through capacitor C2. The

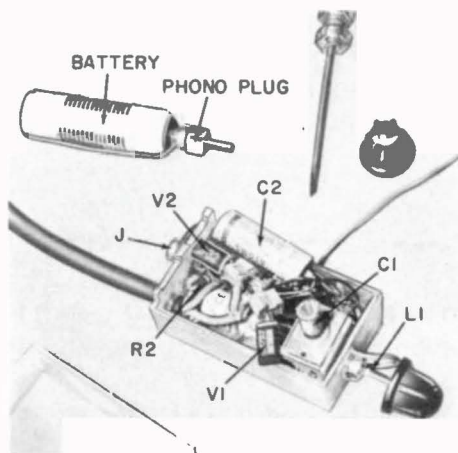


Fig. 230. The headphone radio is a tiny unit.

emitter is grounded and the collector coupled to a transistor inter-stage transformer.

Capacitor C3 couples the signal to the base of V2. The output of this transistor is fed to the headphones. On local stations volume is so great that the phones can be set down and the program easily heard 2 feet away.

There is only one battery, a 15-volt Eveready hearing-aid type. The shell of a male phone plug is soldered to the positive end of the battery. Drill a small hole through the plug's shell. A length of wire is slipped through this hole and soldered to the center prong. The other end of the wire goes to the negative terminal of the battery. With this arrangement the battery plugs into the radio and serves as an on-off switch.

The radio is built to fit a 2 x 2 x 3-inch plastic case (Fig. 230). Although any type of container can be used, plastic is about the easiest material to work with. Place the ferrite coil in one corner of the case. The 1N34 diode is placed next to the coil. Then the inter-stage transformer is put on the opposite side of the coil with capaci-

tor C3 mounted directly above it. Capacitor C1 is soldered as closely as possible to the terminals of the ferrite coil.

Solder a brass wire to the grounded side of the trimmer to be used as a support for mounting the transistor sockets. Plug in the transistors, making sure that the red dot is on the proper end of the socket. A phono jack is mounted on the case. On the same end drill a hole for the headphone cord. It should be a tight fit so the small unit will not slide off the cable.

The radio is easy to operate. Be sure to check the wiring before trying it out. Place the earphones over your head and plug in the battery. Hook the alligator clip to an outdoor antenna and tune in the station you want. Adjusting the ferrite coil's slug will vary the volume of the receiver.

transistors for 10 meters

AFTER being confined to the laboratory, audio and broadcast radio, for the first few years of its life, the transistor is finding its way into the hamshack. Because it is a fairly new device to the ham, many have hesitated to make full use of transistors in their gear.

This section describes a 10-meter receiver that uses low-cost readily available transistors. The set's performance is not equal to

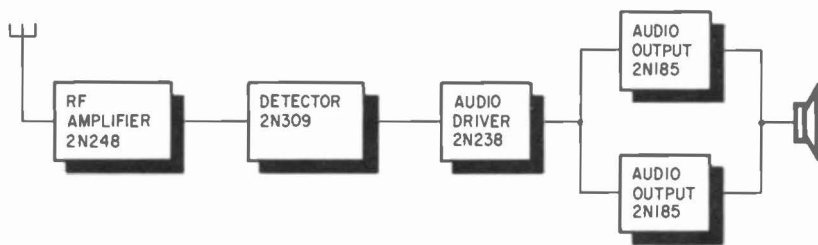
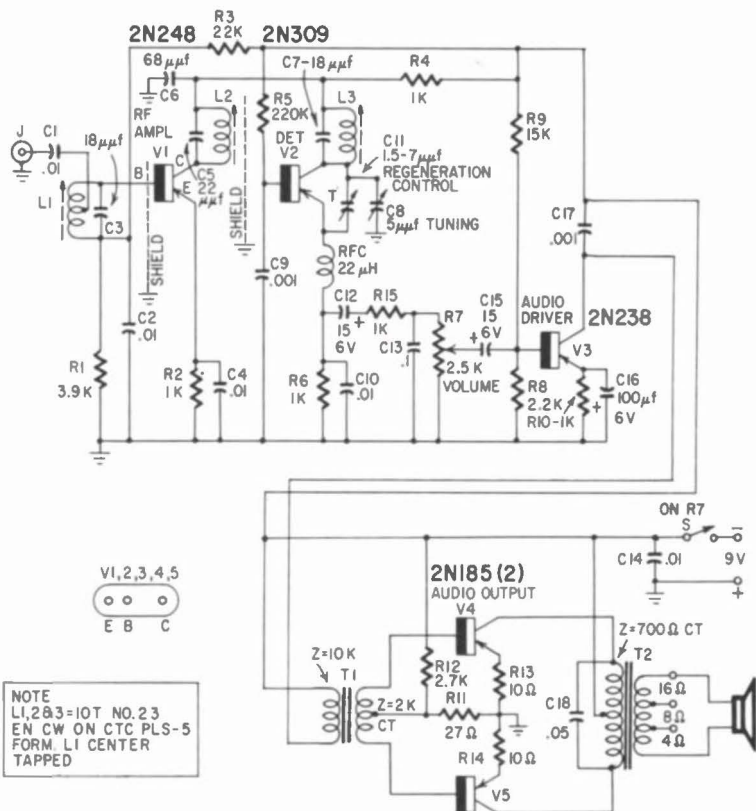


Fig. 231. Block diagram of the 10-meter receiver. The receiver has a tuned *rf* stage and push-pull audio output.

that of a large communications receiver, but is good enough to provide the builder with a useful unit. A 5- μ v signal is plainly audible, and the inherent limiting action of the superregenerative detector keeps the output constant over a wide range of input signals. Noncritical circuitry and ease of adjustment make this receiver ideal for the ham just getting started with transistors.

Receiver circuit

A block diagram of the receiver is shown in Fig. 231. Func-



parts list — transistors for 10 meters

Resistors: R1—3,900 ohms; R2, R4, R6, R10, R15—1,000 ohms; R3—22,000 ohms; R5—220,000 ohms; R7—2,500 ohm potentiometer, audio taper, with spst switch; R8—2,200 ohms; R9—15,000 ohms; R11—27 ohms; R12—2,700 ohms; R13, R14—10 ohms (all fixed resistors ½-watt, 10%.)

Capacitors: C1, C2, C4, C10, C14—.01 μ f, ceramic; C3, C7—18 μ f, mica or ceramic; C5—22 μ f, mica or ceramic; C6—68 μ f, mica or ceramic; C8—5 μ f, variable; C9, C17—.001 μ f, ceramic; C11—1.5–7 μ f trimmer; C12, C15—15 μ f, 6 volts, electrolytic; C13—.01 μ f paper; C16—100 μ f, 6 volts, electrolytic; C18—.05 μ f ceramic.

Transistors: V1—2N248; V2—2N309; V3—2N238; V4, V5—2N185 (all Texas Instruments.)

Coils: L1—10 turns No. 23 enameled wire, close-wound, tapped at 5 turns, on Cambridge Thermionic PLS-5 form with green slug; L2, L3—10 turns No. 23 enameled wire, close-wound on Cambridge Thermionic PLS-5 form with green slug.

Transformers: T1—driver transformer: primary, 10,000 ohms impedance; secondary, 2,000 ohms, center tapped; T2—output transformer: primary, 700 ohms impedance, center tapped; secondary 4, 8 or 16 ohms (Gramer-Halldorson GH6 or equivalent.)

Miscellaneous: J—coaxial connector; speaker; metal shields (2); transistor sockets (5); 9-volt battery (Burgess 2N6 or equivalent); hardware.

Fig. 232. Circuit diagram of the 10-meter receiver. A shield, connected to the common ground bus, prevents coupling between L2 and L3. Capacitor C13 has a fairly low reactance to the quench frequency, bypassing most of it around the volume control. Capacitor C17, shunted across the primary of the interstage transformer, T1, acts as an additional quench filter.

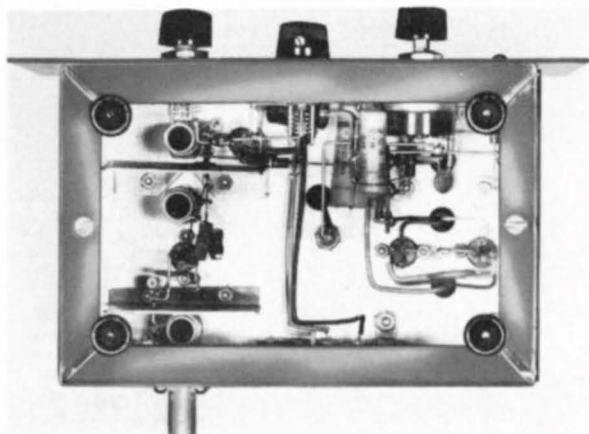
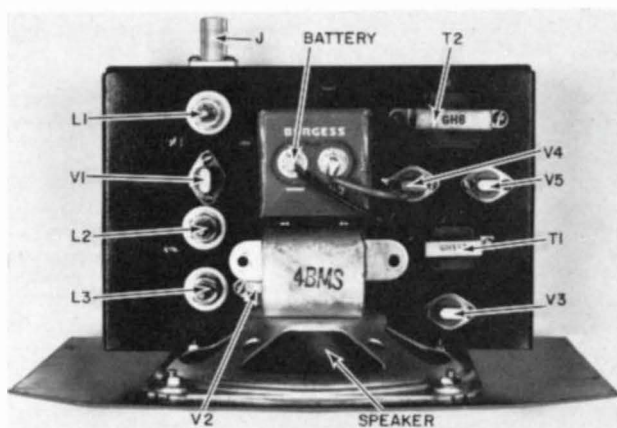


Fig. 233. Placement of most of the components can be seen in this under-chassis view.

tionally, it is no different than a comparable vacuum-tube set. The receiver consists of an rf amplifier, superregenerative detector, audio driver and push-pull audio output stages.

Fig. 232 shows the receiver's circuit. The rf stage uses a 2N248 in a common-emitter amplifier circuit. The input from the antenna is connected to a tap on the coil (L1) in the base circuit. The coil's tuning is very broad because of the base circuit's input resistance. Resistors R1 and R3 set the base-bias voltage. R2 maintains the desired emitter current. The collector tuned circuit consists of L2 and C5.

Fig. 234. The positioning of the coils, transistors and speaker is shown in this photo.



Coils L2 and L3 are not inductively coupled. The shield shown in the schematic helps insure this. Capacitor C6 acts as a coupling between the two coils. As its value goes up, the coupling decreases.

The superregenerative detector uses an easily adjusted circuit that is very tolerant of transistors. A 2N309 is used here. Though intended for 455-kc if amplifier circuits, it works well as an oscillator in the 10-meter range. A 2N248 may also be used here if desired, but is more expensive. The circuit is basically a grounded-base oscillator with an R-C timing network (R5 and C9) provid-

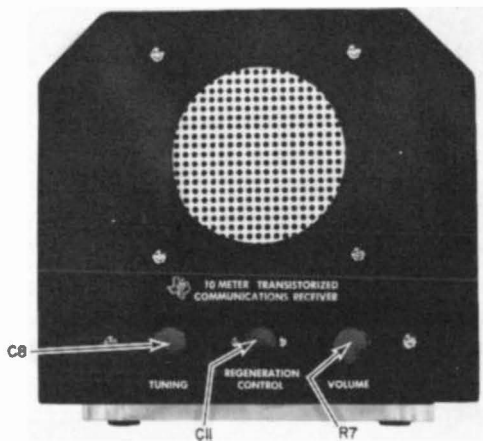


Fig. 235. This is a front view of the 10-meter receiver and shows the position of the controls.

ing the quench frequency for superregenerative operation. The capacitor from collector to emitter, C11, controls the feedback. It is adjusted to insure oscillation over the entire band. Audio output from this stage is taken across the emitter resistor R6. (Most of these components are shown in the under-chassis view in Fig. 233.)

The audio signal contains a large amount of the quench frequency, which would tend to overload the following audio stages. A simple filter consisting of R15 and C13 removes most of the quench voltage and allows the desired audio to pass on to the volume control.

The audio driver stage uses a 2N238. Biasing network R8, R9 and R10 operates in the same manner as its counterpart in the rf stage. A transformer couples this stage to the push-pull output. Capacitor C17 helps to attenuate any quench-frequency signal which was not eliminated at the stage's input.

The output stage is operated class B to provide plenty of power

when needed, while keeping the average battery drain low. Any size speaker may be used. The maximum audio output is 250 milliwatts, more than adequate for good room volume. A small speaker may be used, but will not be as efficient as somewhat larger ones. (The speaker is shown in the top view of Fig. 234.)

The TUNING, REGENERATION and VOLUME controls are mounted on the front panel. The REGENERATION control could be made a small trimmer capacitor since it is seldom touched in normal operation.

Final steps

Adjusting of the receiver is simple. With power on, a hiss should be heard from the speaker. If not, vary the REGENERATION control until you hear the hiss indicating the detector is operating. Apply a 28-mc signal from either a grid-dip meter or other signal source to the antenna input. With C8 set for maximum capacitance, adjust the slug in L3 until the signal is heard. While tuning C8 through its entire range, the hiss should continue, indicating detector operation over the whole band. The positioning of the controls on the front panel of the receiver is shown in Fig. 235.

Apply a 29-mc signal and tune it in. Adjust the slugs in L1 and L2 for maximum signal. This completes the alignment, making the receiver ready to use. A couple of details might be mentioned at this point. Varying the regeneration control will change the detector's frequency, but once this control is set it need not be changed. The tuning of L1, as mentioned previously, is very broad.

The set's performance is quite startling, considering its size and power consumption. Several types of antennas have been used, ranging from a mobile whip to a pair of TV rabbit ears. Good signals have been heard with all of them. The input is designed for a 50-ohm unbalanced line and the receiver works best with a good antenna.¹

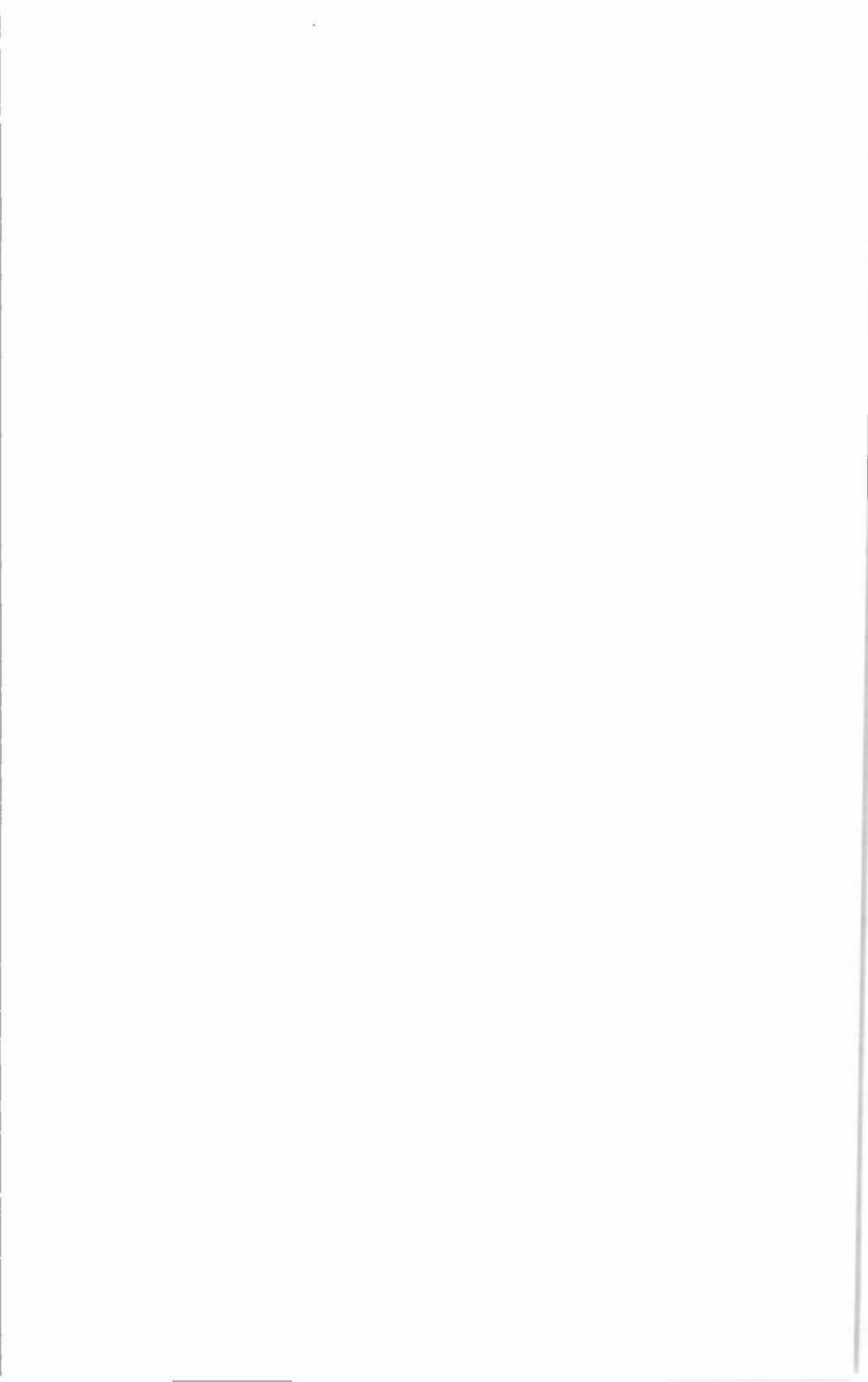
¹When conditions are right, there is no limit to the distance possible on the 10-meter band. Listening tests show that this little set can really reach out. Within a short time after turning it on, phone hams had been picked up coast to coast and from South America.

Selectivity is less favorable. A single strong station can completely blot out several weak ones on other frequencies. Also, the regeneration control affects frequency, so it should not be touched after being set to optimum.

During the tests, a noiselike kind of distortion made it impossible to understand strong stations. It was cured by placing a large electrolytic (250 μ f at 25 volts) across the battery.

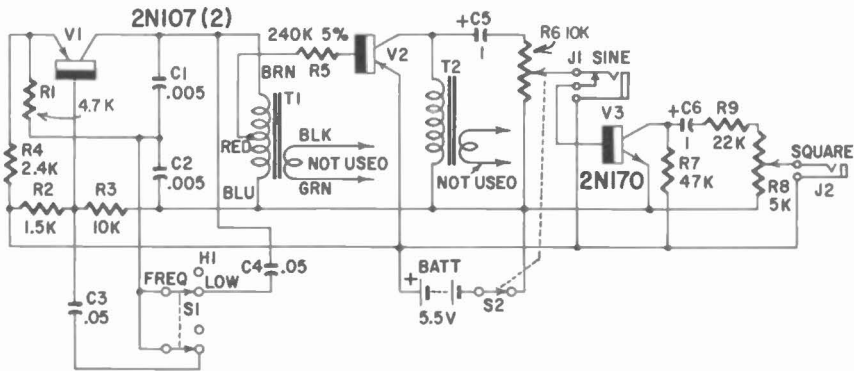
SECTION 3

INSTRUMENTS
AND
ACCESSORIES



sine-square-wave generator

VOLTAGES that vary and repeat themselves at regular intervals are often needed in electronics. Sine, square, sawtooth and pulse are among the recurrent waveforms most useful. Of these, the sine and square wave are especially important for testing audio amplifiers and networks. This compact transistorized unit



parts list for sine-square-wave generator

Resistors: R1—4,700 ohms; R2—1,500 ohms; R3—10,000 ohms; R4—2,400 ohms; R5—240,000 ohms, 5%; R6—10,000 ohm potentiometer with switch (Lafayette VC-28); R7—47,000 ohms; R8—5,000 ohm potentiometer (Lafayette VC-33); R9—22,000 ohms (all resistors ½ watt.)

Capacitors: C1, C2—.005 μ f disc; C3, C4—.05 μ f disc or tiny tubular; C5, C6—1 μ f, 6-volt electrolytic.

Transistors: V1, V2—2N107; V3—2N170.

Jacks: J1—subminiature jack (Lafayette MS-282); J2—may be same as J1 with one un-

used contact.

Transformers: T1—primary impedance 4,000 ohms center-tapped, secondary impedance 3.2 ohms; T2—primary of output transformer approximately 30,000 ohms to speaker. Switches: S1—dpdt or dpst slide type switch; S2—spst switch ganged to R6.

Miscellaneous: Batt—5.5 volts, holder and terminal contacts; sockets for transistors; perforated board (Lafayette MS-304) cut as required; metal box 4x2½x1½ inches; knobs (2) for controls; screws and separators (see text.)

Fig. 301. Either sine or square waves, both highly useful waveforms, can be obtained from this dual output generator. The oscillator is a Colpitts.

generates both waves. Furthermore, there is a choice of frequency — 420 or 2,100 cycles. The instrument has three transistors and a

5½-volt battery supply. It measures 4 x 2½ x 1½ inches and weighs 7 ounces. The battery is contained in the unit.

It is not practical to use a conventional variable Wien-bridge oscillator with transistors due to their low impedance. Therefore many previous transistor generators have been limited to a single fixed audio frequency. Here, by including a choice of *two* (widely separated) frequencies, the device becomes far more practical for testing, calibration and repair work.

Circuitry

The generator provides a sine wave in the first stage, V1 (see Fig. 301). This voltage is amplified by V2 which makes the sine signal available at a subminiature jack, J1. A third stage (V3) amplifies the voltage still more and (due to overloading) flattens the signal and converts it to a square wave. As in tube circuits, this method cannot yield a perfect square wave but, with sufficient gain and clipping, the ideal is approached closely.

V1 is connected as a Colpitts audio oscillator. Series capacitors (C1 and C2) tapped at their junction shunts T1, which is the primary of a subminiature transformer. Its secondary is not used. Feedback from collector to emitter is controlled by R1, a fixed 4,700-ohm resistor. For stability, the transistor base is biased from voltage divider R2-R3. With .005- μ f capacitors (C1 and C2) the output frequency is relatively high. (The frequency is determined by the inductance of the primary of T1 and capacitors C1 and C2.) This is lowered when the .05- μ f capacitors C3 and C4 are switched in. The ratio of the higher to the lower frequency is 5 to 1. For convenience, the lower frequency may be chosen to be an *exact* multiple of the line frequency. In this particular instrument, it is 420 cycles, which you can use as a *standard* frequency. It can be checked periodically (with the aid of a scope) by comparing with the 60-cycle line source. The circuit has high frequency stability, so 420 cycles can be used for calibrating audio oscillators and other networks.

Due to differences in transistors, transformers and other parts, your low frequency may not come out to exactly 420 cycles. If you like the feature of an *exact* multiple of the line frequency, note these pointers: If the frequency is too high, it may be lowered slightly by adding a shunt capacitor across the primary of T1. As a starter, try a variable mica trimmer of about 580 μ mf maximum. On the other hand, if your frequency is lower than the desired value, use less capacitance for C1 and C2. Ceramic

discs are available in such sizes as .0047, .0043, .004, etc. Since the second transistor stage may produce changes in the oscillator frequency, it is better to complete at least the first two stages before making a final frequency measurement.

The sine output of T1 is coupled through resistor R5 to the next transistor. If R5 is too small, the oscillations may cease or become unstable. If too high, the output from V2 will be low. The resistance shown was found correct.

T2, the load for V2, is the primary of any small output trans-

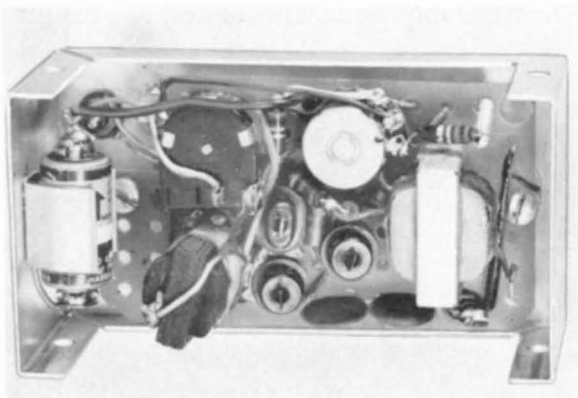


Fig. 302. Inside view of the sine-square-wave generator.

former. C5 keeps dc out of the "sine" jack J1 while passing the af. R6 controls the output voltage from a maximum of about 0.8 volt peak to peak down to zero. The sine waveform is excellent at both frequencies and the amplitude is nearly the same.

When a subminiature plug is inserted into J1 for sine output, the final stage is automatically disconnected. This prevents loading the second stage.

V3, the final transistor, is an n-p-n type that is unbiased. It overloads easily, thus providing the required square wave. The maximum output is about 0.3 volt peak to peak, with excellent waveform at both frequencies of 420 and 2,100 cycles. The waveform is maintained even when relatively low resistors are shunted across the output leads. R6 must be left at its maximum setting for good square waveform.

For convenience, this generator is first mounted on a perforated board. When completed, the board is screwed down to a metal box measuring 4 x 2 $\frac{1}{8}$ x 1 $\frac{1}{2}$ inches. Tapped metal separators keep the board $\frac{3}{8}$ inch away from the metal box so there is plenty

of space for wiring and parts. A mercury battery (Fig. 302) is mounted at one end.

Applications

A sine wave is the only voltage waveform that is unchanged (as to shape) when it is passed through ordinary resistors, capacitors and coils. The wave may, however, be deformed by a nonlinear resistor, overloaded or incorrectly biased tube, saturable coil or other nonlinear element. Thus a sine wave is an ideal test signal. When fed into a hi-fi amplifier, its output will be a sine wave also. Only the amplitude will change, not the general shape.

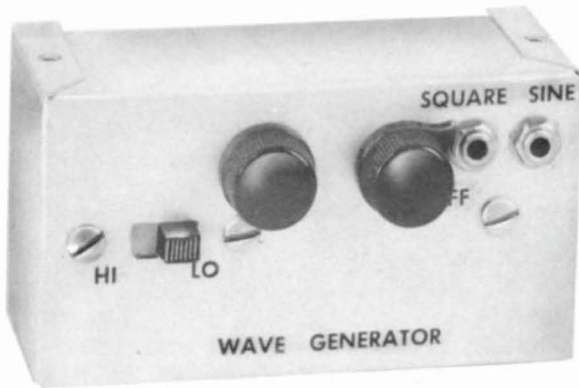


Fig. 303. Simple in appearance, the generator has few controls.

If the wave comes out flattened, peaked or otherwise deformed, there is a defect of some sort in the amplifier or it is not a hi-fi design. Distortion is the introduction of harmonics — multiple frequencies of the original sine wave. The strength of these spurious frequencies indicates the degree of distortion.

Another important application of sine voltages is bridge measurement. If the signal is not a pure sine (single frequency), the bridge detector may not show the desired minimum or sharp null.

A square-wave voltage is a combination of many sine voltages, including a fundamental frequency and very many odd harmonics. Because the square wave is so rich in harmonics, it is an ideal signal for indicating frequency response over a very wide band.

A good hi-fi amplifier should reproduce a 2-kc square-wave signal with little if any deformation.¹ If it is passed with but little

¹ Joseph Marshall, *Maintaining Hi-Fi Equipment*, page 13 (Gernsback Library).

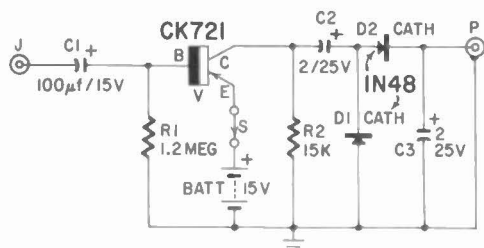
or no change in shape, we may assume that the amplifier has flat response out to 20 kc or more. If it passes a 450-cycle square wave with little distortion, it can be taken to mean flat response down to approximately 40 cycles. With experience, the technician will be able to estimate the amount of amplifier distortion from square-wave tests made with the low- and high-frequency outputs from this square-wave generator.

Fig. 303 is a front view of the completed instrument.

transistor preamp for vtvm's

THE lowest full-scale ac range on the average vacuum-tube voltmeter is in the neighborhood of 1.5 to 3 volts. With this range, readings of as low as 100 to 200 mv are possible, but not too practical. What is needed is an ac vacuum-tube voltmeter with a full-scale range of 100 mv (or less!) or some sort of preamp that can be used with a conventional vtvm to boost its sensitivity. Of the two, the preamp is considerably less expensive.

This preamp is entirely self-contained and self-powered, plugs into a conventional vtvm and boasts a gain of 100, an output in excess of 5 volts and a frequency response sufficiently flat for most



parts list for transistor preamp

Resistors: R1—1.2 megohms; R2—15,000 ohms (both resistors ½-watt.)

Copocitors: C1—100 μf, 15 volts (Sprague Atom TVA—1160 or equivalent); C2, C3—2 μf, 25 volts (Sprague Atom TVA—1201 or equivalent). All capacitors are electrolytics.

Transistor: V—CK721.

Diodes: D1, D2—1N48 crystal.

Miscellaneous: S—spsst switch; Batt—15-volt hearing aid battery (RCA VSO83 or equivalent); J—banana or tip jack; P—phone plug or female microphone connector (see text); S—5-prong hearing aid socket (Cinch-Jones); headset adapter case (or any small metal box.)

Fig. 304. Circuit diagram of the preamplifier for use with a vacuum-tube voltmeter. Completely self-contained, the unit has a gain of 100.

applications. The only fly in the ointment is its rather low input impedance, a characteristic of the junction transistor in a grounded-emitter circuit. This low input impedance is not the drawback that it might seem at first glance. Much of the extremely low-voltage work is done in connection with low-impedance

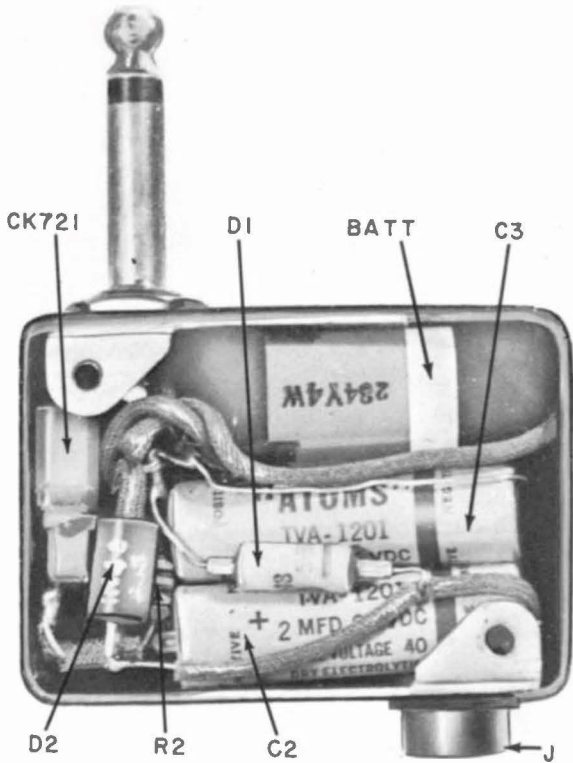


Fig. 305. The parts for the preamplifier fill a headset adapter case.

devices such as magnetic phono pickups or dynamic microphones, and there is a definite advantage in being able to use long, unshielded leads.

The preamp (Fig. 304) is designed around a CK721 junction transistor. It has a gain of around 50 and an undistorted output of about 2.5 volts. The voltage doubler at the output of the preamp doubles both the gain of the amplifier stage and the voltage output. Large electrolytic capacitors insure good low-frequency response and all parts are chosen for minimum size. The total current drain from the 15-volt hearing aid battery is

approximately 500 microamperes, which makes for long battery life.

Construction

The entire preamp is housed in a surplus headset adapter case (Fig. 305). The type of output connector will depend on the



Fig. 306. Outside view of the preamplifier, ready for action.

make of vtm with which the preamp will be used. The standard phone plug (Fig. 306) used on the headset adapter fits most of the kit type instruments. The female microphone connector shown in the photo, Fig. 307, adapts the preamp to most other types of vtm's. To prepare the mike connector for mounting, file the taper off the first $\frac{1}{2}$ inch or so and thread with a 7/16 by 20 die. Then use two flat control nuts to hold the connector to the headset adapter case.

Replace the phone jack on the headset adapter with a banana jack (or tip jack), insulated from the metal case. Cut or file the threaded portion of this jack so that as little as possible projects inside the metal preamp case.

Mount slide switch S directly behind the output connector. (This switch is shown protruding from the case in Fig. 306 and Fig. 307.) Then clip the switch terminals to within $\frac{1}{8}$ inch of the switch, leaving just enough of the terminal projecting to permit soldering a wire to it.

The battery leads and input capacitor C1 are wired first. C1 is directly behind the input jack and under C2 and C3. The re-

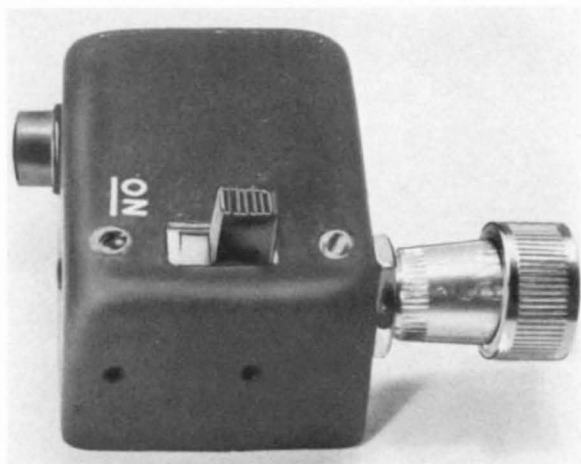


Fig. 307. The type of connector you will need will depend on your vum. Some will require a phone plug; others will need a female microphone connector, as shown here.

mainder of the components can be seen in Fig. 305. The polarity of C2 is opposite to that normally used in a voltage doubler. Its polarity was necessarily reversed to agree with the polarity of the dc voltage on the collector.

Using the specified capacitors and battery, the components fit nicely, although somewhat tightly, into the metal case. Take care during the construction of the preamp to avoid shorts and use fine spaghetti on most of the leads which are not at ground potential. Some space can be saved by using a newer type crystal diode and eliminating the transistor socket. Using a socket for the transistor is safer, however, as heat from the soldering iron can quickly ruin a transistor.

After all wiring is completed and checked, solder the battery to its lead and insert it as shown. Then insulate the inside of the metal lid with plastic electrical tape or anticorona lacquer and screw in place. It will probably be necessary to shorten one or

both of the screws that hold the lid in place to prevent them from shorting to some of the components when they have been tightened.

Connect the preamp to the vtvm and switch both units on. It is a good idea to set the vtvm to one of the higher ranges initially to prevent pegging the meter when the preamp is switched on. Insert the test leads (the vtvm ground lead and the lead from J) and connect them to an audio oscillator or other signal source through a suitable attenuator. With an input of 10 mv the vacuum-tube voltmeter should read approximately 1 volt.

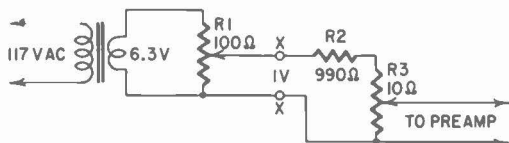


Fig. 308. This circuit can be used to calibrate the vtvm preamp.

Calibration

As maximum gain was desired from the preamp no attempt was made to attain linearity. A calibration card will enable the user to make precise measurements of small voltages. The frequency response of the preamp is within 1 db from 25 cycles to 15 kc, dropping to $-1\frac{1}{2}$ db at 20 cycles and -2 db at 20 kc. Above 20 kc the tapering off is very gradual, and the unit still shows a gain of 10 at 1,000 kilocycles.

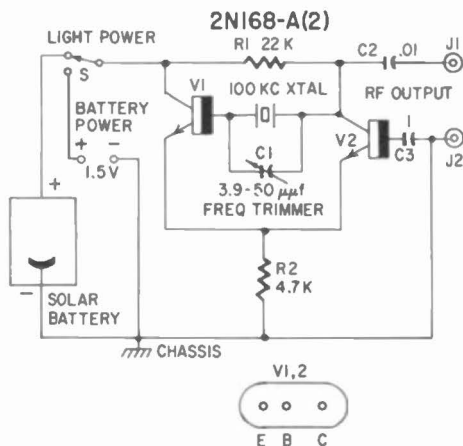
The following procedure (Fig. 308) can be used to calibrate the preamp: Connect the resistors R1, R2 and R3 to a 6.3-volt filament transformer. Set R1 for 1 volt across points X—X. The voltage across R3 will then be very close to 10 mv. By calibrating R3 in 1-ohm divisions with an ohmmeter, the preamp can be calibrated in 1-mv steps to 10 mv. This setup won't be within 1%, but should be accurate enough for all practical purposes. If the overall gain of the preamp is greater than 100 or than desired, insert a resistor of around 100 ohms or so in series with the emitter and battery or try a lower battery voltage.

light-powered frequency standard

Using a 100-kc crystal oscillator you can call on the sun to furnish the dc power for frequency check points. Indoors or at night,

artificial light will do the job. When you must get along in dim light or darkness, the flip of a switch throws an internal battery into the circuit. Thus, this unit is always at your service, and the run-down battery is not as often a problem.

The idea of operating a transistor oscillator from a solar cell is not new. However, the circuit of this instrument (see Fig. 309) is different from most 100-kc crystal oscillators. It is a crystal-



parts list for light-powered frequency standard

Resistors: R1—22,000 ohms; R2—4,700 ohms (both ½ watt.)

Capacitors: C1—3.9–50- μ f trimmer (Hammarlund APC-50 or equivalent) C2—.01 μ f; C3—1 μ f (C2 and C3 are miniature metalized tubular.)

Transistors: V1,V2—2N168-A.

Miscellaneous: J1,J2—binding posts; S—spdt miniature rotary switch; crystal—100 kc; solar battery (International Rectifier SA5-M); case, 4x2x2¼ inches; crystal socket; knob; battery holder; 3-terminal barrier type strips (2 required); 1½-volt battery; miscellaneous hardware.

Fig. 309. Circuit diagram of the light-powered frequency standard. The trimmer across the crystal permits small changes in operating frequency.

controlled multivibrator. No coils are required. The output signal is distorted in shape—it looks like something between a sine wave and square wave. So it is rich in harmonics—always an important point for 100-kc frequency-spotting oscillators, but more so when low dc voltage is used.

Two inexpensive n-p-n rf transistors are used. The circuit is that of an emitter-coupled multivibrator and resembles the cathode-coupled tube circuit. The common-emitter resistor R2 corresponds to the common-cathode resistor in the tube circuit. The 100-kc crystal XTAL forms the transmission path between the output collector and input base and acts as a high-Q, sharply tuned

filter. A 3.9-50 μf air trimmer, C1, connected in parallel with the crystal permits a small amount of frequency variation for setting the oscillator to zero-beat with WWV or standard broadcast stations.

Multivibrator operation

The emitter-coupled multivibrator circuit¹ is a transistor version of the well-known cathode-coupled tube multivibrator. Fig. 310-a shows the tube circuit and Fig. 310-b the transistor circuit. The common-emitter resistor R_E in the transistor circuit corresponds to the common-cathode resistor R_K in the tube circuit. The grid of tube V1 is grounded. The base of transistor V1 is also grounded, but here a large capacitance, C1, is used to ground the transistor for pulses but not for dc. Both circuits differ from the conventional multivibrator only in that one of the capacitance-coupled paths has been replaced by the common-cathode (common-emitter) coupling.

When dc is applied, both transistors start conducting collector current (I_{C1} and I_{C2}). Both collector currents flow through emitter resistor R_E , across which they produce voltage drop V_E , which is

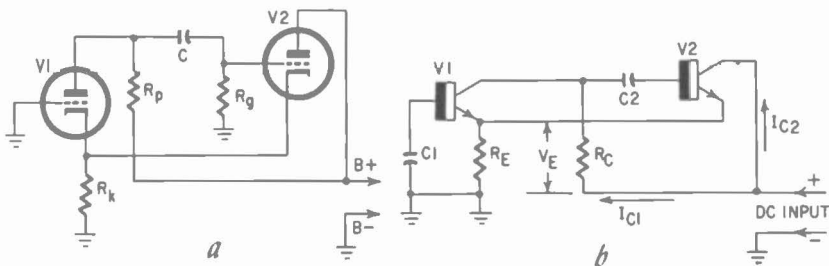


Fig. 310. Cathode-coupled multivibrator; (a) tube circuit; (b) transistor circuit.

applied to both emitters. As collector current flows, the emitter-to-ground voltage increases. Closing the switch of the dc supply transmits a pulse through capacitor C2 to the base of transistor V2. The resulting current flowing through V2's base-emitter circuit causes the amplified collector current of that transistor to increase. This, in turn, causes an increase in V_E which decreases the collector current I_{C1} of V1. This action reduces the voltage drop across R_C , causing the left side of capacitor C2 to receive a still higher voltage. As C2 approaches the supply potential, its charging current flowing through the base-emitter circuit of V2

¹Frank C. Alexander, Jr., "Transistors Use Emitter-Coupled Feedback," *Electronics*, December, 1954, page 188.

increases I_{C2} still further and transistor V1 is emitter-biased higher and higher. This action continues until V1 is cut off and V2 conducts maximum collector current.

At this point C2 is charged and the charging current through the base-emitter path of V1 ceases. The result is that I_{C2} decreases. This lowers the voltage drop across the common-emitter resistor, and transistor V1 draws more collector current. The voltage drop

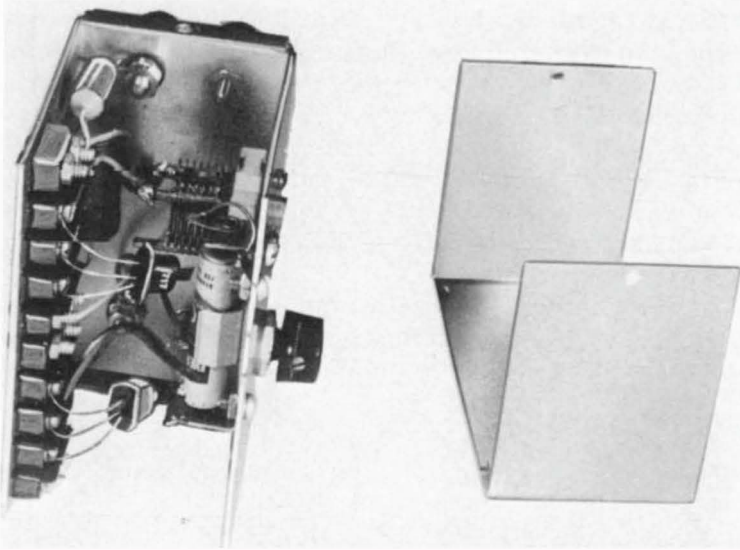


Fig. 311. Positioning of parts in the light-powered frequency standard. Plastic or wood can be used, but a metal case is recommended.

across R_C also increases, lowering V1's collector voltage. Capacitor C2 is now able to discharge and, as it does so, I_{C2} decreases still further as does its effect on the total emitter voltage. This action continues until transistor V2 is cut off and V1 is drawing maximum current. Thus, conduction has been switched from transistor V2 to V1.

Now, capacitor C2 may again begin charging through resistor R_C and the base-emitter path of V2—and the cycle of events is repeated. In the operation of this multivibrator, conduction is switched alternately from V1 to V2 as capacitor C2 charges and discharges. The switching rate is governed by the values of R_C , C2, R_E , V2's internal base-emitter resistance and V1's internal collector-emitter resistance. C1 is made large enough so that this unit is a virtual short circuit to ground at the operating frequency and does not figure into the frequency.

In the frequency standard (Fig. 309), capacitor C2 of the basic circuit has been replaced with the 100-kc crystal. This provides a highly selective coupling path and sets the multivibrator frequency to that of the crystal. Variable capacitor C1, shunting the crystal, has the prime purpose of serving as a frequency trimmer.

Power for the oscillator

When switch S is in the LIGHT POWER position, dc operating voltage is supplied by a silicon solar cell. When switch S is in the BATTERY POWER position, the dc voltage is supplied by an internal 1.5-volt cell. As current drain is low, a penlight cell is used. For longer life and more stable voltage use a mercury cell.

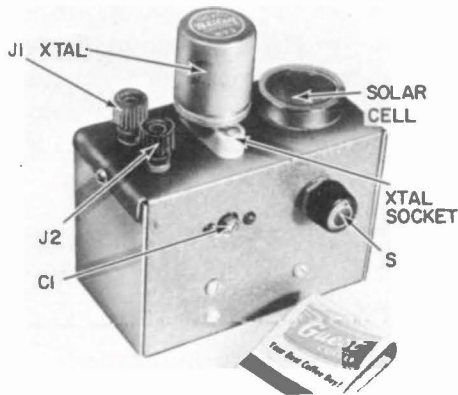


Fig. 312. Outside view of the completed unit.

The solar cell is $1\frac{1}{4}$ inches in diameter and $\frac{5}{16}$ inch thick. It has a clear glass window. The crystal can is 1 inch in diameter and $1\frac{5}{16}$ inches high. The cell has two 6-32 terminal screws. The crystal has a pair of pins that match a standard crystal socket. The completed instrument weighs only 7 ounces.

In bright sunlight, the 100-kc rf output (developed across a 500,000-ohm load) is 0.15 volt rms. This output is the same with a 100-watt incandescent lamp 1 foot above the solar cell. Output when the 1.5-volt battery is used is 0.3 volt rms.

Assembly and wiring

The instrument is built in an aluminum chassis box $4 \times 2 \times 2\frac{3}{4}$ inches. While a plastic or wooden box could be used, metal is recommended to shield against hum pickup from ac power fields.

The photos (Fig. 311 and Fig. 312) show constructional details. The solar cell, crystal socket and output binding posts are mounted on the top of the box. The screwdriver-adjusted trimmer

capacitor and the power changeover switch are mounted on one side.

Use insulated binding posts for the RF OUTPUT terminals. However, only J1 has to be insulated from the box—use a fiber shoulder washer. The ground post is attached directly to the case. A 1/4-inch clearance hole must be drilled for the fiber shoulder washer which insulates the top post. Use a flat fiber washer on the other side.

Similarly, the positive screw terminal of the solar cell must be insulated from the case with a fiber shoulder washer inserted into a 1/4-inch clearance hole. The negative terminal is fastened directly to the box.

A 3/8-inch-diameter clearance hole is required for the tuning screw of trimmer capacitor C1. The ceramic body of this capacitor insulates it from the box. Two 1/4-inch clearance holes are required for the terminal lugs of the ceramic crystal socket. The shank of switch S requires a 3/8-inch clearance hole. A wafer type switch was chosen for its small size. However, a spdt toggle may be used if this type is preferred.

Two three-screw, barrier type terminal strips are used for mounting the transistors. Each transistor pigtail is held by one of the screws. This simple arrangement takes the place of soldering to the pigtails, which can be injurious to the transistor. Solder all connections to the strips before inserting the transistors. These terminal strips are mounted end to end along the lower edge of one inner wall of the box.

A bracket type battery holder is fastened to the opposite inside wall to hold the penlight cell. A solder lug on the wall just in front of the transistor-holding terminal strips receives the ground leads of capacitor C3 and resistor R2. Resistor R1 is soldered directly between the collector terminals of adjacent transistor-holding terminal strips. Coupling capacitor C2 is soldered directly between the output collector terminal and the top output binding post. (The finished unit is shown in Fig. 312.)

Initial testing

Carefully check all wiring before slipping the battery into its holder. Be particularly careful of battery, solar cell and transistor polarity. The crystal has no special polarity and will work whichever way it is plugged into its socket.

Connect an ac vtvm (preferably one with a 0.3-volt full-scale range) to the RF OUTPUT terminals. An oscilloscope may be used in place of this meter. Throw switch S to BATTERY POWER and note the

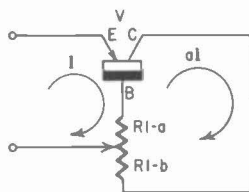
rf output voltage as indicated by the meter or scope. Now, throw the switch to LIGHT POWER, expose the solar cell to the sun or to a nearby lamp, and again note the rf output voltage.

To check the signal tune a non-oscillating receiver to WWV or to a standard broadcast station operating on a frequency (such as 600, 700, 1000 kc) which is an exact multiple of 100 kc. Couple the frequency standard to the receiver by connecting the ground RF OUTPUT terminal to the receiver ground terminal and by loosely coupling the top RF OUTPUT terminal to the receiver antenna terminal. This usually can be done successfully by connecting a wire to the top terminal and winding several turns of its insulated length around the receiver antenna lead. With the switch S set to BATTERY POWER, adjust trimmer capacitor C1 for zero beat with the WWV carrier (or broadcast carrier) during an interval when the signal is not being modulated. Throw switch S to LIGHT POWER and repeat the test, with the solar cell illuminated.

gain checker

Most popular low-priced transistor gain checkers use a dc meter to measure gain, though most transistors are *ac* amplifiers or oscillators. This instrument uses ac and relies on a bridge network to do the measuring. Gain is read from the dial of a potentiometer.

Fig. 313. Basic circuit of the gain checker.



This makes it a rugged, compact and accurate tester. Fig. 313 is the basic circuit. V is the transistor being tested. An ac signal is fed to it.

Amplified current (aI) flows in the collector circuit. Current through R1-a is $(I - aI)$, so the voltage drop across R1-a is $(I - aI)$ times R1-a and the drop across R1-b is $aIR1-b$. (Note that R1-a and R1-b are simply two parts of the potentiometer, and vary with the position of the center arm.) If the resistors can be adjusted for no

voltage across the total resistance (R1-aR1-b), we have

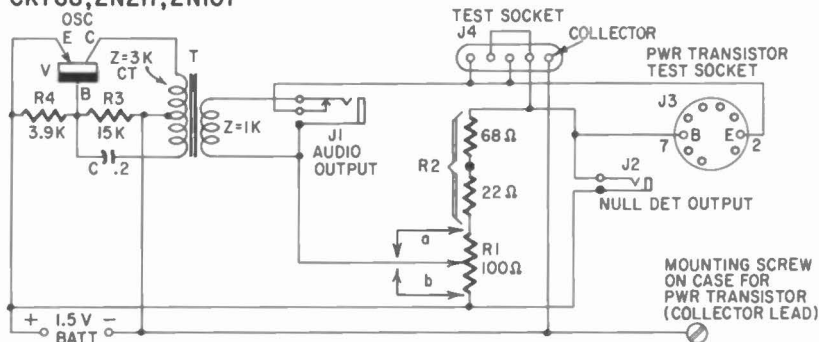
$$(I - aI) R1 - a = aIR1 - b$$

and a little mathematical manipulation shows that

$$\alpha = \frac{R1 - a}{R1 - a + R1 - b}$$

At null, the transistor's alpha gain is known from the resistor values.

CK768, 2N217, 2N107



parts list for gain checker

Resistors: R1—potentiometer, 100 ohms, linear taper; R2—90 ohms (use 68 ohms and 22 ohms in series); R3—15,000 ohms; R4—3,900 ohms; (all fixed resistors, ½-watt 10%.)

Capacitor: C—0.2 μf, disc ceramic, 75 volts.
Transistor: V—CK768, 2N217 or 2N107.

Jacks and Sockets: J1—subminiature phone jack, normally closed; J2—subminiature phone jack; J3—9-pin miniature tube socket;

J4—5-pin in-line tube socket.

Transformer: T—subminiature driver transformer, primary impedance 3,000 ohms, center tapped; secondary impedance 1,000 ohms (Argonne AR-113 or equivalent.)

Miscellaneous: Dial plate, 0-10, see text; penlight battery; holder for battery; case (Lafayette MS-302 or equivalent); mounting board, 1¼x1¾ inches; miscellaneous hardware.

Fig. 314. Schematic diagram of the gain checker. The gain (alpha) of the transistor being checked is read directly from a card mounted on the potentiometer.

Fig. 314 shows a circuit for practical and convenient measurements. Transistor V generates a 1,200-cycle audio signal. Several p-n-p transistors have been tried here and all work well.

Audio for external tests and measurements is at J1. This is another advantage of the ac bridge type tester.

If there is no plug in J1, the signal is fed directly to the transistor under test. Its output appears across the bridge, which consists of R1 and R2 in series. R2 is a fixed 90-ohm resistance made up of a 68- and a 22-ohm resistor. R1 is a 100-ohm potentiometer with a linear taper.

A null is obtained at J2 when the alpha (common-base gain) of the test transistor is equal to

$$\frac{R2 + R1-a}{R2 + R1-a + R1-b}$$

To make a test, the transistor is plugged into the test socket. The circuit is switched on and the potentiometer adjusted for a null. The transistor gain is read from the potentiometer reading.

Testing transistors

For the bridge tester to maintain its advantage over the dc meter, it must be direct-reading. This is easy. Obtain a calibrated dial with linear divisions marked from 0 to 10 for the pot. The dial

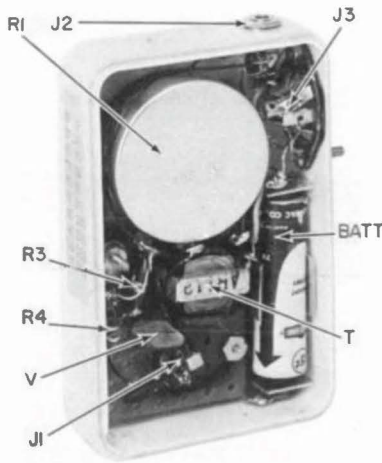


Fig. 315. Interior view of the gain checker. The unit can also be used to test power transistors.

covers the same total angle of rotation as the linear pot (300°). (Dial plates are sometimes marked tone or volume, but as long as the divisions are linear and correspond to the full range of the pot, they are suitable.)

With 0 to 10 aligned with the ends of the pot's rotation you can read alpha gain directly. Simply take the reading off the dial, say 85 (8½), put a decimal point and a 9 in front of it and there it is — alpha equals 0.985. To read beta, you use a chart taped to the side of the instrument. The reading of 85 corresponds to a beta of 65, ($\beta = \alpha / 1 - \alpha$). The dial calibration is shown in the table.

Bridge balance is very good at all settings, and a sharp null is

obtained with a high-impedance earpiece. Use a sensitive earpiece for best results. Transistors with abnormally large leakage may show a broad null.

The tester handles various transistor basings. The common in-line three-pin base is plugged into J4. Transistors with flexible leads around a small circle are plugged into the same socket.

Power transistors are plugged into J3 (see Fig. 315). This nine-pin miniature-tube socket is fastened to the case with its No. 2 and No. 7 pins connected to the emitter and base conductors, respectively. A 4-40 machine screw through the side of the case

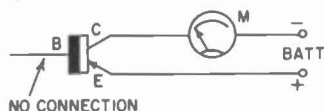


Fig. 316. Simple circuit for measuring leakage.

becomes the collector terminal. The hole in the transistor case fits on the screw. A nut holds the transistor on the screw during the gain test.

Dial Calibration

Dial ¹	Beta
00	9
30	13
50	20
70	32
80	50
85	65
90	100
92	125
94	165
95	200

¹ Note that the dial reading is alpha with the first digit (.9) omitted.

Three questions still need answering.

- Where is the battery switch?
- How are n-p-n transistors tested?
- How about leakage?

To keep the instrument compact and uncomplicated, don't use a switch. Inserting the battery turns the unit on. Take out the battery and you turn the checker off.

Checking n-p-n types

N-p-n transistors are far less common than p-n-p types so there is less need to test them. To do so, remove the penlight cell, substitute an n-p-n transistor for V (2N169, 2N170 or 2N647) and replace the battery, reversing its polarity. Remember to switch V and the battery again the next time you check a p-n-p unit.

If you plan to check n-p-n types often, a separate socket can be added.

There is no provision for measuring leakage. Aging often lowers gain and increases leakage, so a single test may be enough. Besides, an ohmmeter will measure leakage, so you don't need another meter or a separate device.

Take a look at Fig. 316, a typical leakage detector. It is nothing but a series ohmmeter set to measure the reverse conduction

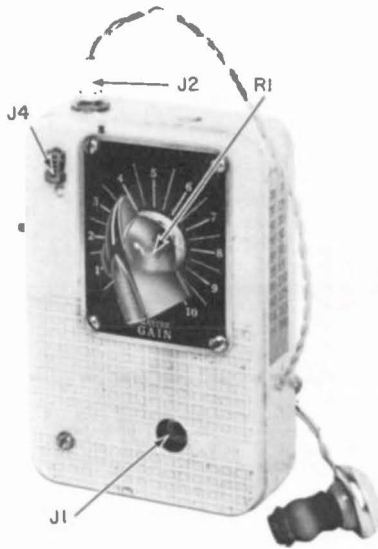


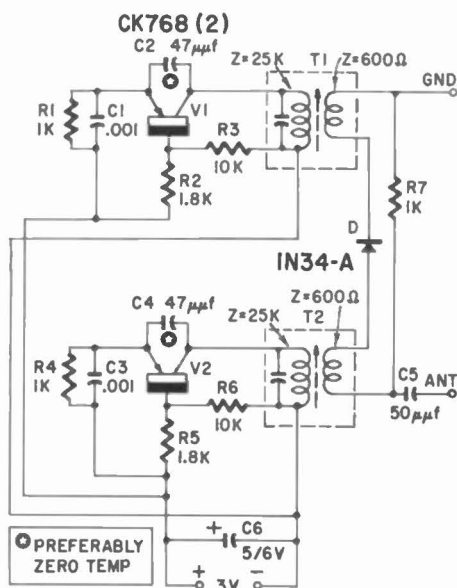
Fig. 317. The completed gain tester. The unit also supplies an audio signal for external use.

of a transistor with its base open. A low-leakage unit measures above 2 megohms while a high-leakage unit usually reads about 100,000 ohms or less.

A comparison between this pocket tester and the dc-meter type of instrument shows it gives accurate results. (The completed unit appears in Fig. 317.) Gain values compare well when low-leakage transistors are tested. High-leakage transistors rate higher on the dc testers, however. This is because the *dc* collector current of a transistor is composed of two parts: one due to the *dc* signal and the other due to leakage. The latter gives a false indication, making the gain seem higher than it actually is. Here only *ac* is the factor and leakage has no effect.

shortwave calibrator

THIS little two-oscillator device helps calibrate shortwave receivers, marks ham bands and checks signal generators. It puts out strong signals at 100-kc intervals. They appear, for example, through the broadcast band at 600, 700, 800 kc. Still higher, they get weaker, but are still useful.



NOTE: TUNE ONE TRANSFORMER TO 400KC, THE OTHER TO 500KC

parts list for shortwave calibrator

Resistors: R1, R4, R7—1,000 ohms; R2, R5—1,800 ohms; R3, R6—10,000 ohms (all resistors ½-watt 10%).

Capacitors: C1, C3—.001μf, disc ceramic; C2, C4—47 μmf, zero temperature coefficient; C5—50 μmf, disc ceramic; C6—5 μf, electrolytic (all capacitors 6 working volts or higher).

Transistors: V1, V2—CK768.

Transformers: T1, T2—subminiature if transformers: primary, 25,000 ohms; secondary, 600 ohms (Lafayette MS-268 or equivalent).

Miscellaneous: Batt—3 volts, penlight cells (2 in series); D—1N34-A diode; battery holder; phenolic chassis board; miscellaneous hardware.

Fig. 318. Circuit diagram of the shortwave calibrator. This is a beat-frequency type of instrument. The crystal diode, D, acts as a mixer.

There is good reason for the strong output. This instrument is *not* a 100-kc generator, with weak rf output because of high harmonic order. Instead, there are two fundamentals and both are at relatively high frequencies. One oscillator is tuned to 400 kc, the other to 500. They are mixed in a diode to generate sum and difference beats.

No claim can be made for lab precision for this device, since it does not use crystals. However, any desired accuracy can be attained by comparing frequency with WWV as standard.

Parts are inexpensive and easy to get. Two penlight cells power the unit whose circuit is shown in Fig. 318. No switch is shown on the schematic; power is shut off by removing one of the batteries from its holder.

Construction

The complete calibrator can be constructed on a perforated phenolic board as shown in Fig. 319. Parts can be mounted on

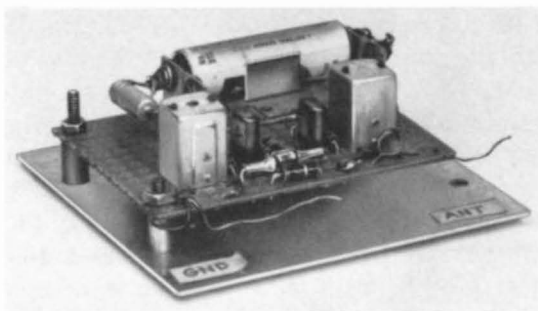


Fig. 319. *The entire calibrator is mounted on a phenolic board.*

both sides of the board, but if this is done, the board should be supported at its corners by mounting studs. Each stud can be a $\frac{1}{2}$ -inch length of metal or insulated sleeving through which a machine screw is passed. A 6-32 machine screw having a length of about 1 inch will do. The studs can then be used to support the perforated board above a small metal plate. Drill through-holes in the plate to pass through the ANT and GND wires. Make these wires sufficiently long so that the calibrator can rest conveniently on the table near the receiver and not have to dangle insecurely in space, supported only by the ANT and GND wires.

No box is shown for the calibrator, but if the unit is to be used only occasionally, it would be better to enclose it in some sort of container, such as an inexpensive plastic box, to protect the components. This would be the situation if the unit is to be used with receivers. If you intend using it with a signal generator, its services may be required somewhat more often, in which case it would be helpful to make it an integral part of the signal generator — if you have the room inside the generator for it. If not, it could be fastened to the side or the top of the generator.

Calibrating the calibrator

It is easy to adjust the calibrator's frequency with the help of an all-wave receiver. Connect the GND and ANT terminals of the calibrator to the corresponding terminals of the receiver. Disconnect the regular antenna. First, tune one of the transformers (in the calibrator) to 500 kc by listening for a harmonic at a WWV frequency: 2.5, 5.0 or 10.0 mc. Do this with your receiver bfo (beat frequency oscillator) shut off. As you adjust the transformer core (either T1 or T2), you will hear a tone when the harmonic beats with WWV.

Now tune the second transformer to 400 kc. Listen in at 2 mc with the bfo off. As the core is adjusted to 400 kc, its fifth harmonic will beat with the fourth harmonic of 500 kc and you will hear the audio beat.

Tuning may also be done with a broadcast receiver if desired. Listen for 500-kc harmonics at 1,000 and 1,500 kc. Harmonics of 400 kc will be heard at 800, 1,200 and 1,600 kc. These signals will make a swish or hissing sound on a receiver without a bfo.

To illustrate the accuracy, suppose you hear a 1-kc beat to indicate that the (10th) harmonic of 500 kc is heterodyning with the WWV carrier at 5 mc. This means you are in error by 1,000 parts in 5,000,000 or .02%! If you tune closer to zero beat, you will obtain even greater precision.

You should now hear beats every 100 kc through the broadcast band and well into the short waves. On a receiver with bfo, they will be clear steady whistles.

500-kc oscillator

You can easily convert this device to a straight 500-kc oscillator by removing the 400-kc transistor. Likewise, you will have a 400-kc oscillator if you remove the other transistor. As a 500-kc oscillator, for example, you will hear signals only at 1,000, 1,500, 2,000 kc, etc.

To adjust a 455-kc transformer to 500 kc you must turn the core (with a small, insulated screwdriver) counter-clockwise nearly all the way. For 400 kc, turn it clockwise nearly all the way. Of several transformers tried, these frequencies were reached in every one. Sometimes you may have to force the core screw slightly to reach the desired frequency. This causes no damage if only a small fraction of a turn is needed past the limiting stop. To lower frequency you can add a small capacitor (about 25 μf) across the transformer primary.

meter sensitivity multiplier

An indication of a voltmeter's quality is its ohms-per-volt input rating—the series resistance needed for a current meter to indicate

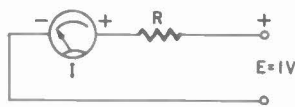
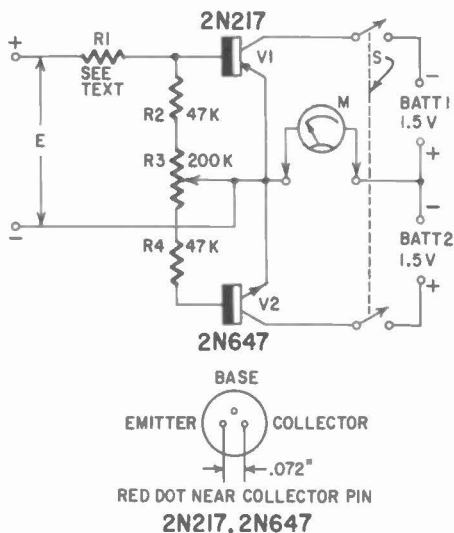


Fig. 320. Method for calculating the sensitivity of a meter in ohms per volt.

$$\begin{aligned} \text{OHMS-PER-VOLT} &= \frac{I}{\text{METER FULL SCALE (AMPS)}} \\ &= \frac{I}{100 \mu\text{A}} \\ &= 10,000 \end{aligned}$$

1 volt. For example, a 100- μA meter is equivalent to 10,000 ohms per volt (see Fig. 320). Using $E = IR$, it is clear that 1 volt will be indicated when 100 μA flows through 10,000 ohms. The meter's resistance is relatively small and may be ignored.

A conventional vtm has nearly 4 megohms per volt on its 3-volt range. This high value accounts for its accuracy even when meas-



parts list for meter sensitivity multiplier

Resistors: R1—see text; R2, R4—47,000 ohms, $\frac{1}{2}$ watt; R3—200,000-ohm potentiometer.

Transistors: V1—2N217; V2—2N647.

Miscellaneous: Batt 1, Batt 2—1.5 volt penlight cells; M—see text; S—dpst toggle switch; 7-pin miniature socket; hardware.

Fig. 321. Circuit diagram of the meter sensitivity multiplier. A pair of complementary-symmetry transistors are used. The value of R1 depends on the meter that is used.

uring a high-resistance voltage source. A 10,000-ohms-per-volt meter would load such a source.

Fig. 321 shows an adapter that multiplies ohms-per-volt by as much as 40 or more. A pair of complementary transistors is used. Actually only one transistor amplifies. The other one *balances* the zero-signal current of the amplifier and *compensates* for temperature variations. To prove this (after you construct the unit) place your finger for a few seconds on one of the transistors and watch the meter deflect because of the higher temperature. Then touch the other transistor and note that the meter deflects in the *opposite* direction. As the 2N217 and 2N647 are nearly equivalent, they make a well-balanced circuit. (Made by RCA they are designed for use in complementary-symmetry circuits such as this one.)

The transistors are plugged into the same seven-pin socket (side by side). This keeps them close together so temperature changes have the same effect on both transistors.

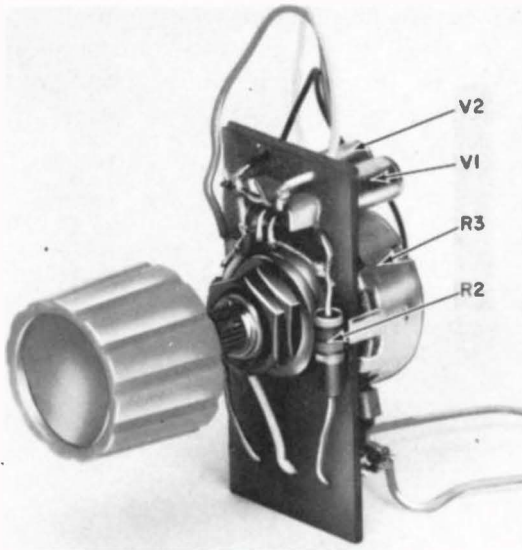


Fig. 322. Complete assembly of the meter sensitivity multiplier.

To use the adapter, zero the no-signal current by adjusting R3 and connect the unit to a dc microammeter. 20- to 200- μ a meters were tried successfully in this project. With a 100- μ a meter, R1 must be approximately 400,000 ohms to reach full-scale deflection with 1 volt. With a 50- μ a meter, R1 should be approximately 800,000 ohms, etc. R1 should be chosen to provide some convenient full-scale meter value, such as 1 volt. Because of variations among transistors of the same type, a little experimenting is usually

needed. Use the transistor that has the higher beta gain for V1, the amplifier.

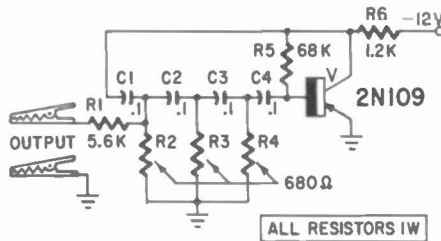
In the assembled unit shown in Fig. 322, V1 is the 2N217 and V2 is the 2N647. The 2N217 that was used had a beta of about 70. The 2N647 measured only about 45.

Each battery is a 1.5-volt penlight cell. A double-pole switch is needed because of the double battery.

The adapter can be built on a plastic board only 1 x 2 inches and added to any meter or chassis. Of course this does not include batteries, switch or meter.

phase shifter

For some reason, transistor phaseshift oscillators have not received the attention they deserve. It is true that the transistor version seems more difficult to design than the vacuum-tube circuit, but this is not due to a defect in the transistor but to an attempt to apply vacuum-tube thinking to an entirely new type of device. Perhaps you can physically replace a vacuum tube with an audio



parts list for phase shifter

Resistors: R1—5,600 ohms; R2, R3, R4—680 ohms; R5—68,000 ohms; R6—1,200 ohms (all resistors ½-watt, 10%.)

Capacitors: C1, C2, C3, C4—.1 μ f, 15 volts

(or higher).

Transistor: V—2N109.

Miscellaneous: two alligator clips; phenolic chassis board; hardware.

Fig. 323. Circuit diagram of the phase-shift oscillator. The frequency can be changed by using capacitors having values other than the ones specified here.

transistor (properly biased) in a standard three-mesh network and have it operate, *if* you make the supply voltage high enough and pick a transistor with a high beta.

The transistor circuit shown in Fig. 323 has definite advantages. When correctly designed, it produces a crisp sine wave, starts easily and continues oscillating until the battery drops down

to about 4 volts. Not to be overlooked is the low cost of the few small parts needed.

The unit described here is the result of painstaking effort to produce a quality circuit that would be reliable, easily started, stable under temperature change, and would allow for unavoidable transistor variations. It oscillates at approximately 1,000 cycles with the components specified. Eleven 2N109 transistors were tested for dc beta to be sure of a proper spread in characteristics. Each variation in the circuit was tested with each of the 11 transistors at five supply voltages from 13 to 4 volts dc. The final circuit is a four-mesh network with voltage feedback from collector to base of the grounded emitter amplifier. The feedback circuit protects the transistor from thermal runaway.

One of the tests given the completed unit (shown in Fig. 324) was a heat run, with a test setup that monitored transistor case temperature, collector current and frequency. At the start of the run, case temperature was 28°C, collector current was 4.4 ma and the frequency was 1,171 cycles per second. The supply voltage was held at 10 volts dc throughout the run. At a case temperature of 63°C, collector current was 7.8 ma and the frequency of oscillation was 2,202 cycles per second. At a case temperature higher than

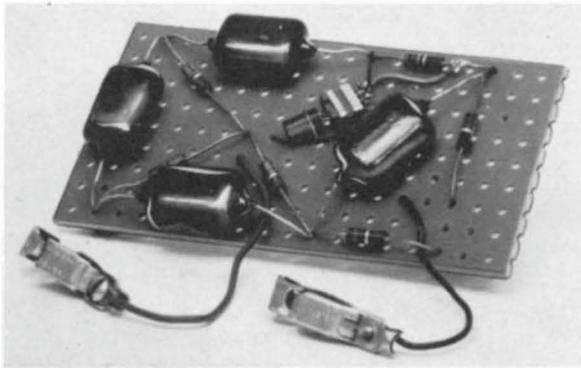


Fig. 324. The phase shifter is easily and quickly mounted on a small section of pegboard.

63°C (149°F), the circuit no longer oscillated, but the transistor was not damaged as its collector current leveled out at about 8.1 ma. The case temperature was taken up to 71°C, which is the manufacturer's specified maximum, and the external heat removed. As the circuit cooled, current drain slowly decreased and the unit resumed oscillating at about 63°C. The phase-shift oscillator was kept operating at normal room temperature for about

24 hours with a Berkeley counter set to record the frequencies on a graph. No failure occurred and the frequency settled down to 1,118 cycles per second, with a 3-cycle variation over the time period.¹

Practical uses

Practical uses for this circuit are numerous. A small probe-type unit can be made up, with a male phono plug on the output end ready to test audio amplifiers. Use the oscillator for musical instruments and toys; it has good stability and is economical to build. In these applications if you wish to vary the frequency, vary the capacitance in the network, not the resistance, to get new and different tones. For example: make each capacitor (C1, C2, etc.) equal to .068 μ f and you will have a frequency of 2,100 cycles per second. In building this circuit, remember, good stability depends on high-grade components. Use impregnated-paper capacitors and 1-watt composition resistors. About 15 or so of these oscillators have been built into receivers, test oscillators and impedance bridges. At no time was any difficulty experienced with this circuit. Use it with utmost confidence.

bridge-type transistor checker

If transistors were made and used under ideal conditions, there would be little or no necessity to test their usefulness and transistor checkers would be unnecessary. Unfortunately this is not so and a transistor checker is more valuable in servicing transistor equipment than a tube checker is for tube circuits.

If a dozen so-called good transistors are tested, a close average of their characteristics is difficult to determine — at best the limits are broad. Transistors rated to oscillate up to 3 mc may do better, or worse. No parameter minimums are given in transistor manuals although maximums are definitely established. Transistor current gain varies considerably, even when the transistors are from the same production line.

Leakage current

Of course, some variations are the result of manufacturing

¹ Tests showed that a better waveform could be obtained by taking the output from the 5.6K resistor and the transistor's collector.—*Editor*

methods. A surgically clean environment is essential for this operation. Impurities or moisture entering the seal during the assembly process will cause excess current flow between emitter and collector, indicating a resistance lower than the usual 20,000–70,000 ohms. With 4.5 volts applied, this means a current flow of not more than 100 μ a, which is known as leakage current or I_{CBO} . It is measured with the base open-circuited to prevent the beta or amplification factor from affecting the measurements.

Temperature effects

Leakage current increases with temperature. If an increase in heat is too great or too rapid, the transistor is usually weakened or ruined. Even heat from your fingers will increase the current flow between emitter and collector. Aging of the unit also decreases the resistance between these elements and increases the current flow.

Beta

The ratio of change of current flowing in the collector (or emitter) to the change of current flowing in the base determines the transistor's gain.

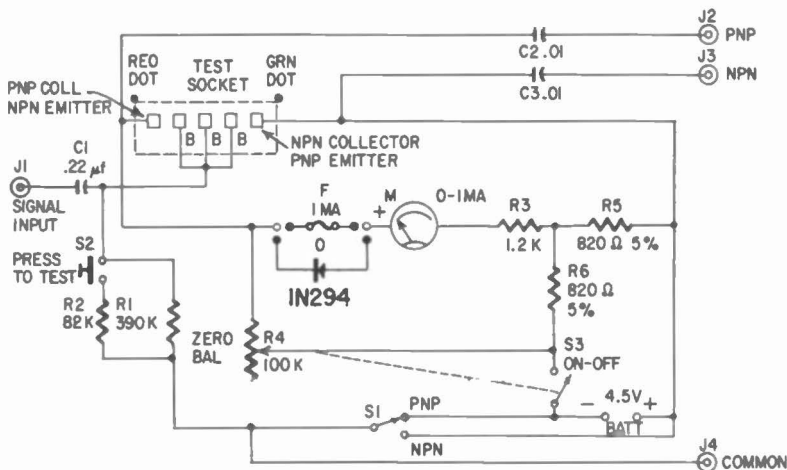
$$\text{Beta} = \frac{\text{change of current in collector}}{\text{change of current in the base}}$$

Base current, of course, is that derived from the input signal or, if the base is coupled to a battery, the bias which is either aiding or opposing the signal current.

The circuit

Fig. 325 is the circuit of the transistor-checker bridge. It uses the resistance between the emitter and collector of the transistor under test as one of the resistance arms. The parts needed to build the unit may be found in your spare parts box or can be purchased from parts jobbers or through catalogs.

The unit is mounted in a 4 x 4 x 2-inch box. The PRESS TO TEST switch (S2) is a single-pole, single-throw, spring-return pushbutton. The values of the two precision resistors (R5 and R6) are not critical, but they must be as nearly equal as possible. These resistors form the standard arms of the bridge and, if exactly equal, zero balance of the meter (M) cancels the resistance between the emitter and collector. The ON-OFF switch (S3) is ganged



parts list for bridge-type transistor checker

Resistors: R1—390,000 ohms; R2—82,000 ohms; R3—1,200 ohms; R4—100,000-ohm potentiometer with spst switch; R5, R6—820 ohms, 5% (all resistors ½ watt, 10% unless otherwise noted).

Capacitors: C1—.22 μf, 200 volts; C2, C3—.01 μf, disc ceramic.

Diode: D—1N294.

Jacks: J1, J2, J3, J4—pin jacks.

Switches: S1—spdt toggle; S2—spst, push-button, momentary contact, normally open; S3—spst on R4.

Miscellaneous: F—1 ma fuse; fuse holder; M—0-1 ma, dc meter; Batt—4.5-volt battery; battery holder; 5-pin in-line subminiature socket; case, 4x4x2 inches; hardware.

Fig. 325. Circuit diagram of the bridge-type transistor checker. An unusual feature of the unit enables you to determine if particular transistors are n-p-n or p-n-p types.

to the 100,000-ohm balancing potentiometer (R4). The meter is a 0-1 dc milliammeter. Fig. 326 shows the bridge circuit.

How it works

In the bridge circuit, if the standard arms are equal, current divides through the standard and nonstandard arms. When the nonstandard arms are balanced, current through the meter is zero. Pressing the pushbutton switch increases current flow from the base to the emitter and collector of the transistor under test, which in effect is the same as changing the resistance between collector and emitter, and current flows through the meter. The amount of current is an indication of the transistor's amplification or beta gain.

Immediately you can see that, since a comparison is made between the change of current in the base and the change of current in the collector, the transistor's beta can be obtained. If the change in base current is 30 μa when the button is pressed, and the change

of current flowing in the collector is $500 \mu\text{a}$, beta is then:

$$\beta = 500/30 = 16.666$$

This value is about right for transistors checked for small-signal beta. (Small-signal beta is always a little more than large-signal beta.)

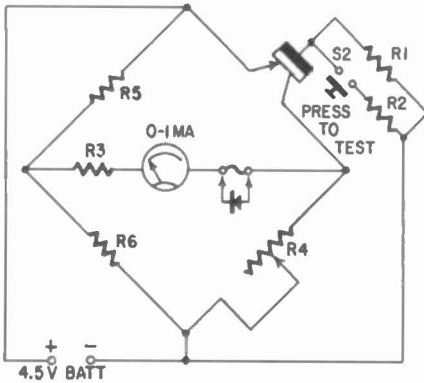


Fig. 326. The rearrangement of the components in Fig. 325 into this form shows that it is a bridge circuit.

Alpha

In circuits where the base is grounded and the signal is applied to the emitter, the alpha or gain between the emitter and collector (usually less than 1) is required.

The formula for beta (β) is given as:

$$\beta = \frac{\alpha}{(1 - \alpha)}$$

We can rearrange this formula in terms of alpha (α) by multiplying both sides of the equation by the denominator on the right-hand side:

$$\beta(1 - \alpha) = \frac{\alpha(1 - \alpha)}{(1 - \alpha)}$$

or

$$\beta(1 - \alpha) = \alpha$$

transposing both sides we get

$$\alpha = \beta(1 - \alpha)$$

In the transistor we just discussed, $\beta = 500/30 = 16$ (approximately). Substituting this value in our equation we will get:

$$\alpha = 16(1 - \alpha)$$

$$\alpha = 16 - 16\alpha$$

transposing:

$$\alpha + 16\alpha = 16$$

$$17\alpha = 16$$

$$\alpha = 16/17 = 0.94$$

Transistors used in computers are not required to amplify, but they must oscillate rapidly as electronic switches. In these applications the transistor is generally turned around or the emitter

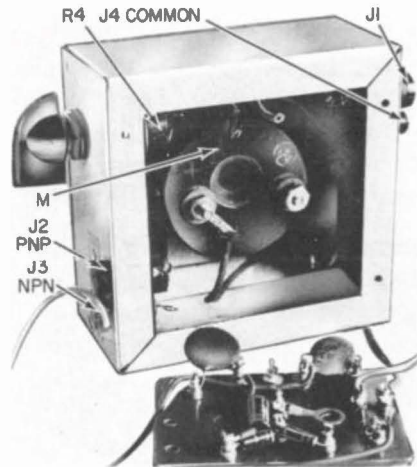


Fig. 327. The checker can be used to learn whether a transistor is a p-n-p or n-p-n type.

placed in the collector socket. When testing these transistors, the reading may be the same whether the transistor is inserted properly in the socket or reversed. These transistors have little if any value in amplifier circuits.

Using the transistor checker

Unless a manual is handy it is difficult to determine whether a particular transistor is a p-n-p or n-p-n type. With the checker bridge, the type is quickly and easily established. For example, if a p-n-p transistor is inserted in the wrong side of the subminiature five-contact test socket (Fig. 327) the reading will be low. Just reverse the transistor in the socket and flip the PNP-NPN switch. The setting that gives the greater reading is correct and the type of transistor is indicated by the switch setting. No damage is caused by these manipulations since the battery voltage is well under the breakthrough value. When the transistor is inserted in the proper socket and is receiving the proper voltage polarity, a zero balance can be obtained and when the pushbutton switch is depressed, maximum reading for the transistor is obtained.

If there is still no balance or indication of current flow, one or more of the transistor's elements are open-circuited. If any element is shorted, there will be a large current flow and no potentiometer adjustment will cause a balance.

To test further, potentiometer R4 is calibrated. (The location of R4 can be seen in the inside and outside views of the tester,

Figs. 327 and 328). Insert various fixed resistors between collector and emitter socket terminals, balance the bridge with each resistor and mark the values on R4's dial. Use resistances from 20,000 to 80,000 ohms. Transistors that attain a balance with less than 20,000 ohms are unsatisfactory since leakage current is excessive and current gain is low. If a transistor has been allowed to overheat and conduct large currents, the same test applies. However, many overheated transistors may still be good. Place them aside to cool and test again in about 15 minutes. If their resistance is still low, discard them.

Dynamic test

This is a most important test for transistors used in if and rf stages, and to conduct it properly a signal generator capable of delivering a good sine wave between 200 and 2,000 kc is needed. If an oscilloscope is not available, a diode must be inserted in the meter circuit.

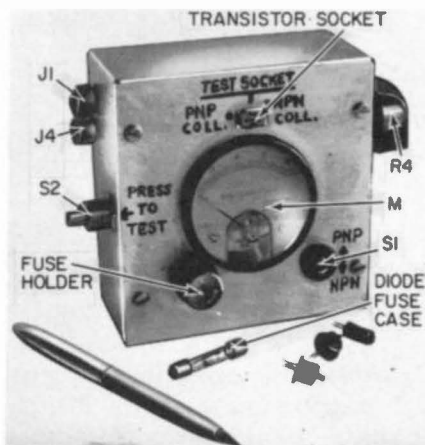


Fig. 328. Because of the greater variation among transistors than among tubes, a transistor checker is more necessary than a tube tester.

If a diode is used, encase it in a glass cartridge (fuse case) after withdrawing the fuse element. Using a minimum of heat, solder the diode leads to the metal ends of the cartridge. When dynamic tests are not being conducted, the diode can be slipped out and a low-current fuse with the same type case inserted. Reverse the diode if the meter gives negative readings, first making certain that the toggle switch (S1) is set for the proper transistor type (n-p-n or p-n-p).

Frequency cutoff

To check for frequency cutoff, insert a transistor in the test socket and balance the bridge. Replace the fuse (F) with the

diode (1N294). Connect a signal generator (set at the frequency at which the transistor normally operates when in the circuit) across the checker's INPUT and COMMON terminals. Slowly increase the generator's output until the meter begins to read. Vary the output frequency a little on either side of the fundamental and watch for lowered readings on the meter. If the results are satisfactory (the meter reading does not vary), increase the frequency until the meter reads zero. Increase the signal output of the generator until the meter reads again. If no amount of increase causes a reading, the frequency indicated on the signal generator is the upper limit of the transistor. (It is usually somewhat less than the rating given in the manual for the transistor.)

If there is no meter reading, determine if the diode's polarity is right by reversing it in the fuse holder. If there is still no reading, make certain that the diode is good by measuring it with an

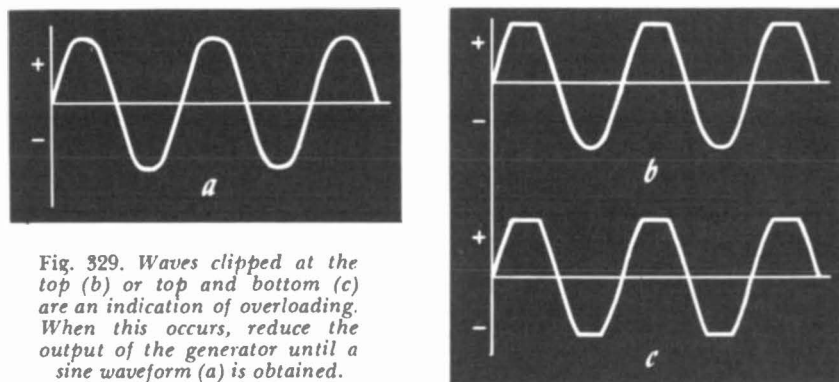


Fig. 329. Waves clipped at the top (b) or top and bottom (c) are an indication of overloading. When this occurs, reduce the output of the generator until a sine waveform (a) is obtained.

ohmmeter (the back resistance should be at least about 10 times the forward resistance). If all components are good and the checker meter still does not register, the transistor cannot be used in if or rf circuits, but may be satisfactory for audio use.

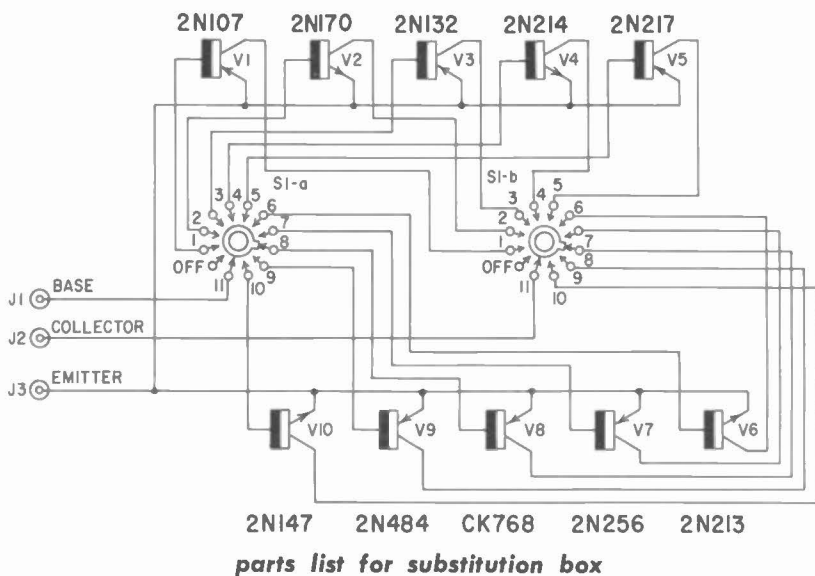
When a scope is used, connect the vertical amplifier to either the PNP or NPN outlet and to the COMMON terminal. Use as little gain as possible at the signal generator. The scope provides the only method of determining the type of wave being amplified by the transistor. Fig. 329-a shows the types of waves to expect.

Clipped waves (Figs. 329-b and 329-c) result from too much input from the generator for the amount of base bias and, since it is difficult to change the bias of the checker, the input signal is reduced. However, if reducing the signal generator output does not produce a sine wave, the transistor is faulty and will cause distortion if used in if and rf circuits.

When using the scope, better results can be obtained if the input signal is maintained at a constant level. Continually switch the scope terminals to the generator output as the frequency is advanced and increase the input signal when required for best results.

substitution box

THIS transistor substitution box has proved to be a pretty valuable piece of equipment on a number of occasions when transistor circuits were being checked. It has a rightful place in your workshop, alongside the resistance, capacitance and inductance substitution boxes.



Transistors: V1—2N107; V2—2N170; V3—2N132; V4—2N214; V5—2N217; V6—2N213; V7—2N256; V8—CK768; V9—2N484; V10—2N147.

Jacks: J1, J2, J3—three-way binding posts

or tip jacks.

Switch: 2-pole, 12-position rotary, non-shorting.

Miscellaneous: chassis box to suit; hardware.

Fig. 330. Circuit diagram of the substitution box. Ten different transistor types are available.

In this unit, there are substitutes for 10 transistors. Included are general-purpose, small-signal audio, large-signal audio, power and

rf types. Selection is for useful characteristics and any combination may be used.

The combination shown in the schematic (Fig. 330) covers most practical applications. These transistors are:

General purpose 2N107, 2N170
Small-signal audio 2N132, 2N214
Large-signal audio 2N217, 2N213
Power 2N256
Rf CK768, 2N484, 2N147

Note that in the first three groups, one transistor is a p-n-p and the other is an n-p-n, while the power transistor is a p-n-p (since most applications use a p-n-p unit.) In the rf group, two transistors are p-n-p's and one is an n-p-n.

A transistor substitution box is, of course, much more expensive than the more usual capacitor or resistor substitute array, at



Fig. 331. Inside view of the transistor substitution box.

first sight so much so as to appear impractical. But until we get a great deal more familiar with transistor receivers and can spot a bad transistor more easily, the positive answers it gives save enough servicing time to pay for it very quickly.

The transistors suggested in the parts list represent the average units used in transistor radios, amplifiers and related equipment. The types that are finally chosen and used should match the particular requirements of the user.

A cigar box or aluminum chassis box can be used to mount

the selector switch and transistors. All wiring must be quite rigid and as short as possible. The power transistor must be mounted on a heat sink and kept as far as possible from other transistors.

An inside view of the transistor substitution box is shown in Fig. 331. The transistors in this photo are not those indicated in the schematic in Fig. 330 (since the unit was originally constructed to meet the author's own special requirements) but the photo still gives you an idea of parts placement. An examination of Fig. 330 shows that the emitters of all the transistors in the



Fig. 332. The switch selects one of ten different transistors.

substitution box are tied together. A good way to do this easily is to fashion a ring of fairly heavy copper wire, preferably wire with a tin coating, for easy soldering. The connection to binding post J3 can then be made by running a wire from this post to the nearest part of the ring.

A front view of the unit is shown in Fig. 332. If you plan to use a 12-position switch, one position should be OFF, while the others should be numbered in sequence from 1 to 11 inclusive. To avoid counting every time you turn the switch, mark each position number on the face of the box. Then, when rotating the knob, you will always know the position number of the switch. This can be made to correspond to an information card pasted on the outside of the box as shown in Fig. 332. The first column on this card gives the position number of the switch. The next column indicates the particular transistor corresponding to that number. The final column shows the general type of use to which the selected transistor can be put.

SECTION 4

MISCELLANEOUS
TRANSISTOR
PROJECTS

remote transistor ear

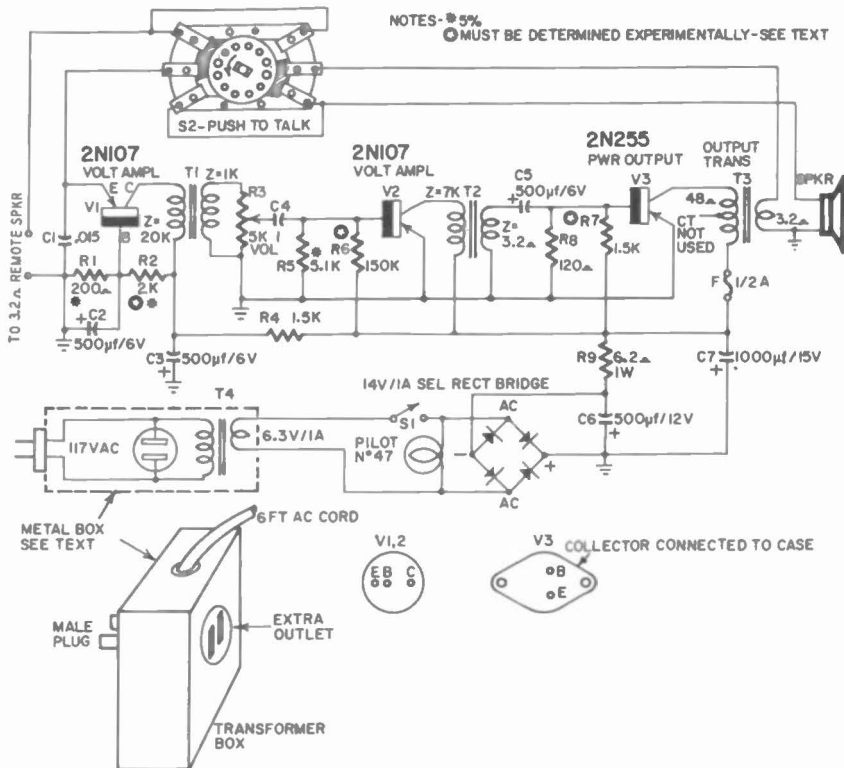
Now that low-priced power transistors are generally available, you can build transistor equipment with power output equal to that obtainable with vacuum tubes. The intercom described here is an all-transistor device which plugs into the 117-volt ac power line. It has an audio output of approximately 1 watt which is instantly available as no warmup time is required.

There are three transistor audio stages, and a selenium bridge rectifier for the power supply. The circuit is simple and conventional except for the input stage, which is connected as a common-base amplifier. This configuration does not require an input transformer since its input impedance is low enough to work directly from speaker voice-coil impedances. Eliminating the input transformer also reduces the possibility of hum pickup by the input stage and results in a quiet, high-gain amplifier. The .015 μ f ceramic disc capacitor (C1 in Fig. 401) connected across the amplifier's input eliminates broadcast-station interference when the intercom is used with a long remote-speaker line. The rest of the amplifier circuit is straightforward, employing transformer-coupled common-emitter stages.

All parts are standard and readily available, with the possible exception of output transformer T3. (The original model used an Acme Electric Corp. T-24041. If you cannot obtain this unit, you can use a Thordarson TR-61.) The primary's ct is not used and only the 3.2-ohm tap on the secondary is shown on the diagram. The power transformer (T4) is a 6.3-volt heater transformer with a 1-ampere rating.

No attempt was made to miniaturize the unit. Plenty of room was available for standard components on the 6½ x 4-inch chassis. Standard components also reduce the cost of parts.

The 2N255 power transistor is plugged into a nine-pin miniature tube socket with no heat sink for the collector. Its case must be insulated from the chassis. A heat sink is not required because the power input to the 2N255 is limited to 1.25 watts, or half the transistor's maximum dissipation rating.



parts list for remote transistor ear

Resistors: R1—200 ohms, 5%; R2—2,000 ohms, 5%; R3—5,000 ohm potentiometer, audio taper; R4—1,500 ohms; R5—5,100 ohms, 5%; R6—150,000 ohms; R7—1,500 ohms; R8—120 ohms; R9—6.2 ohms, 1 watt (All resistors ½-watt 10% unless noted. Proper values for R2, R6 and R7 must be determined experimentally.)

Capacitors: C1—.015 µf, disc ceramic; C2, C3, C5—500 µf, 6 volts, electrolytic; C4—1 µf, metallized paper; C6—500 µf, 12 volts, electrolytic; C7—1,000 µf, 15 volts, electrolytic.

Transistors: V1, V2—2N107; V3—2N255.

Transformers: T1—interstage transformer: primary impedance 20,000 ohms; secondary impedance 1,000 ohms (Argonne AR—104 or equivalent); T2—output transformer for 50L6 or 50C5: primary impedance 7,000 ohms; secondary impedance 3.2 ohms; T3—

output transformer: primary impedance 48 ohms, center tap—not used; secondary impedance 3.2, 8, 16 ohms (Thordarson TR—61 or equivalent); T4—heater transformer: primary 117 volts; secondary, 6.3 volts, 1 ampere (Thordarson 21F08 or equivalent.)

Rectifier: Rect—selenium-bridge, 14 volts dc, 1 amp (Barry Electronics Corp., 512 Broadway, New York 12, N.Y.)

Switches: S1—spst; S2—dpdt, spring-return wafer type (Centralab 1464 or equivalent.)

Miscellaneous: F—0.5 ampere fuse; fuse holder; speaker—impedance 3.2 ohms: 3-, 4- or 5-inch; pilot-lamp assembly and No. 47 bulb; chassis, 6½x4 inches; cabinet, 6½x5½x4 inches; transformer box, 4x2½x1½ inches; male plug; 9-pin miniature tube socket; transistor sockets (2) for V1 and V2; hardware.

Fig. 401. The remote transistor ear is an all-transistor intercom with an audio output of about 1 watt. The unit is always ready for action since no warmup time is needed.

Hints for better construction

The parts layout is not particularly critical. In general, the amplifier follows a logical layout from left to right when viewed from the rear, with low-level components such as the small transistors and interstage transformers mounted at the left end. The output transformer, power transistor and selenium rectifier are mounted at the right end of the chassis, as shown in Fig. 402.

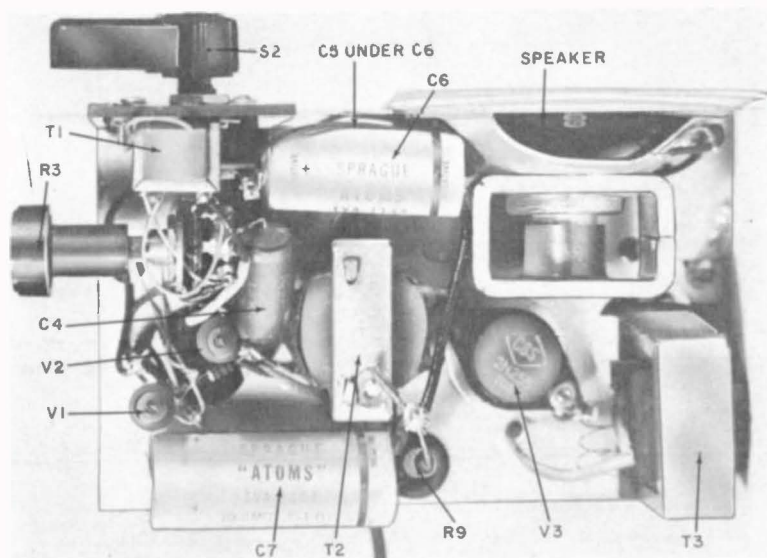


Fig. 402. This photo shows the positioning of the components above the chassis.

When laying out the amplifier, pay particular attention to these items to avoid possible feedback troubles:

A $\frac{1}{2}$ -inch separation between the speaker frame and output transformer core is minimal. If the transformer is too close to the speaker, you'll get audio feedback when the intercom speaker is used as a microphone.

The output transformer's secondary leads must be routed well from the speaker, preferably below the chassis to prevent feedback. Shield the "hot" lead and ground the shield to the chassis.

Do not mount the power transformer on the chassis. The field from the transformer will induce a 60-cycle hum in the speaker when it is used as a microphone, no matter where the transformer is placed on the chassis.

This problem is solved by completely isolating the transformer from the intercom. The transformer is mounted in a small metal

box which plugs directly into the ac outlet. The ac line running from the transformer box to the intercom unit carries 6 volts. During operation, the remote power transformer is left on continuously and the intercom switch is used to turn the unit on and off. The switch merely opens a lead to the bridge rectifier. (Fig. 403). This arrangement is practical since the transformer draws

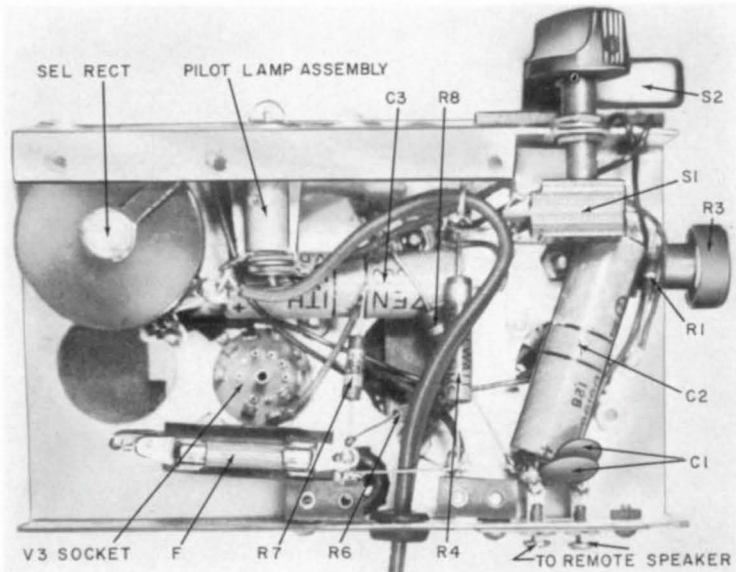


Fig. 403. There is ample room below the chassis for mounting all the components.

negligible power from the line, especially with the intercom switch in the off position.

Mount some of the electrolytic capacitors above the chassis since they are bulky and chassis space is available. Cover the capacitor leads with insulating tubing and route through holes in the chassis as required.

Selecting the bias resistors

The unit should be completely wired except for the base bias resistors (R2, R6 and R7) and the push-to-talk switch (S2). Connect the intercom speaker to the output transformer temporarily and connect a remote speaker to the amplifier input. Be sure the remote speaker is placed so it does not cause acoustic feedback. Connect a 500-ma meter across the fuse holder (F) with no fuse installed. The amplifier is now ready for bias adjustments of the various stages.

Connect a 5,000-ohm potentiometer in the circuit for R7 and make certain that the full potentiometer resistance is in the circuit before the power is turned on. Adjust the potentiometer for a collector current of 250 ma. Allow the 2N255 power transistor to reach full operating temperature by letting it run for about 20 minutes, meanwhile readjusting the potentiometer to keep the collector current at 250 ma. When the output stage has stabilized,



Fig. 404. *The completed intercom makes a fine appearance.*

as evidenced by no further change in collector current, check the potentiometer's resistance on an ohmmeter and install the nearest standard-value resistor permanently. Now check the collector current with the resistor installed and, if all is well, you can disconnect the milliammeter and put the 0.5-amp fuse in its holder.

Follow the same procedure to determine the proper bias resistor for the driver stage, starting with approximately 300,000 ohms for R6. Adjust the 2N107's collector current to 1 ma and again allow sufficient time for the stage to stabilize with respect to collector current.

If collector current cannot be limited to 1 ma, the 2N107 transistor should be replaced with another. Some transistors have a tendency to draw excessive current even with zero bias when operated near maximum ratings of 5 volts or so, due to the lack of uniformity. Such transistors will still perform satisfactorily in low-level low-voltage applications.

When adjusting the bias of the common-base amplifier stage, use a 5,000-ohm potentiometer to determine the value of R2. You will find that the base voltage adjustment for a given transistor is fairly critical. Low emitter-base voltage will result in low collector current and noise with low amplification.

As the emitter-base voltage is increased, the thermal noise heard in the speaker is gradually reduced and amplification increases

noticeably. If the bias adjustment is carried too far, the useful amplification will drop and the amplifier will cease to function. The proper adjustment for maximum gain is just below that point. You will find that the easiest way to make this bias adjustment is to place the remote test speaker in a quiet location and use the ticking of an alarm clock as the signal source.

After adjusting the bias on the various stages and checking the amplifier for stability, wire in the PUSH-TO-TALK switch. If the amplifier tends to oscillate on talk-back, reroute the output transformer lead to minimize feedback. Careful routing of the output transformer's output lead is very important.

The routing of this lead is particularly critical where it connects to the push-to-talk switch, since it is close to the amplifier input at this point. The best procedure is to shield the lead and move it around until there is no feedback on talk-back with the gain nearly wide open. During this test be sure that the remote speaker is far enough from the master unit so you will not be fooled by a case of acoustic feedback.

Most of the time electrical feedback cannot be completely eliminated with the gain wide open on talk-back.

Final steps

It will probably be necessary to treat the cone of the intercom speaker. If the speaker size is less than 5 inches, it tends to produce distortion when used as a microphone because of the thinner cone material used in such a small unit. If distortion is experienced on talk-back, give the speaker cone two coats of shellac to increase the diaphragm stiffness. Shellac the flat conical section only and leave the ribbed outer section near the frame untouched. This will give you a relatively stiff diaphragm with a flexible suspension. This way, performance as a microphone is greatly improved without impairing its performance as a loudspeaker.

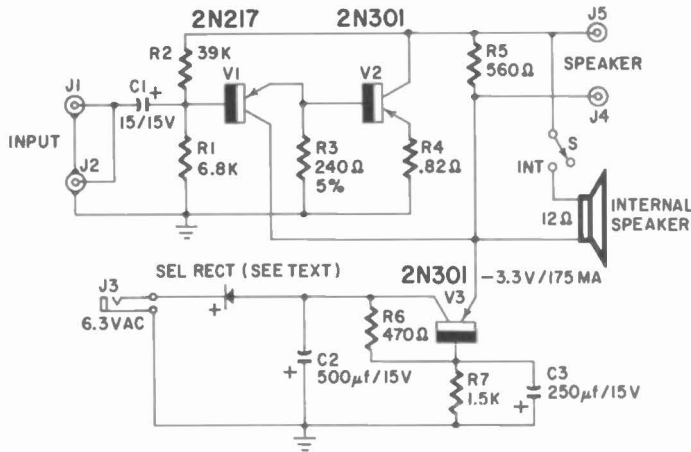
No station-selector switching system was built into the unit because this feature was not desired. However, a regular station-switching system may be added if you want more than one remote station. (The photo in Fig. 404 shows the completed unit installed in its cabinet.)

If excessive thermal hiss develops after the intercom has been in service for a while, it is an indication that the first stage has changed characteristics due to transistor aging. This may be corrected by determining a new value for bias resistor R2. Low-noise transistors are available, so if you feel that the residual amplifier

noise is objectionable, after bias adjustment, try a 2N189 in place of the 2N107 (V1).

the mini-amplifier

HERE is an amplifier with only 200 milliwatts output. In this age of audio amplifiers that deliver 50 and 60 watts, you may feel that 1/5 watt is just a whisper. However, this equals the power of many thousands of people talking at once. Certainly it is far more than most neighbors will stand for! (Average individual voice power in



parts list for mini-amplifier

Resistors: R1—6,800 ohms; R2—39,000 ohms; R3—240 ohms, 5%; R4—0.82 ohm; R5—560 ohms; R6—470 ohms; R7—1,500 ohms (all resistors ½-watt 10% unless noted.)

Capacitors: C1—15 μf; C2—500 μf; C3—250 μf (all capacitors 15-volt electrolytics.)

Transistors: V1—2N217; V2, V3—2N301.

Jacks: J1, J2—phono jacks; J3—phone jack; J4, J5—pin jacks.

Sockets: 3-pin, in-line transistor socket for V1; 9-pin miniature (2) for V2 and V3.

Miscellaneous: S—spdt toggle switch; selenium rectifier (see text); speaker, 12-ohm impedance, 2x3 inches (RCA 214S1 or equivalent); perforated bakelite board, cut to size; case, 5¼x3x2 inches; miscellaneous hardware.

Fig. 405. Circuit diagram of the mini-amplifier. Although the power output is small, it will supply enough volume to fill a room in your home. As shown, the circuit does not have a volume control.

conversation is in the order of 30 μw. 100 mw delivered to an efficient speaker produces all the sound that is needed in an ordinary room.)

The amplifier measures only 5¼ x 3 x 2 inches. This includes a self-contained small speaker. Of course, connections for a good external speaker are provided.

Frequency response is excellent. It is down about 2 db at 12,000 cycles and about 0.8 db at 12 cycles. Undistorted power output is

200 mw — about 1.3 volts across 8 ohms. Maximum input is about 0.1 volt. No volume control is included because the amplifier is used with an FM tuner which has a gain control. An interesting feature is the absence of transformers. Besides improving frequency response, this saves money and space. The two stages are direct-coupled, with the speaker fed directly by a power transistor. A 16-, 12- or 8-ohm speaker is recommended, but 4-ohm units give good results.

The circuit is in Fig. 405. V1 effectively in a grounded-collector

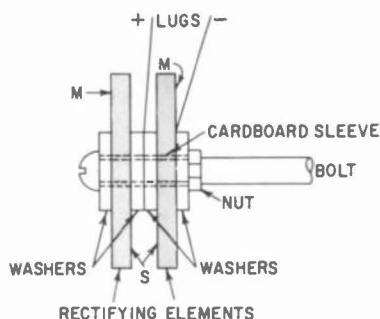


Fig. 406. The selenium rectifier for the mini-amplifier is made by modifying a 117-volt 150-ma unit.

stage is followed by a grounded emitter V2. The output transistor delivers 1/5 watt with about 3.3 volts on its collector. V1, chosen after various tests with other driver transistors, gives maximum power with minimum distortion, at this low voltage.

The power supply

This amplifier operates from an unusual but easy-to-find power source, 6.3 volts ac. This voltage (at less than 0.3 ampere) is found in many electronic instruments. It must be rectified and filtered before being applied to the amplifier. Since the voltage is so low, there is no need for an entire (117-volt) rectifier stack. You can remove two elements from a 150-ma stack and connected them in parallel. See Fig. 406. This permits up to 300-ma drain (at 6.3 volts). The amplifier consumes less than 175 ma.

The rectifier elements are mounted on a long screw which holds the unit to a Bakelite board and serves as the negative terminal. A cardboard sleeve insulates the screw from the elements and washers. One side of each element has a smooth metallic surface. The other side is rough-looking because it is coated with selenium.

These are identified as M and S, respectively, in Fig. 406. Washers are used to make good contact with the surfaces.

After rectification, ripple is smoothed by V3, another 2N301. This is done by supplying the rectified voltage to the transistor

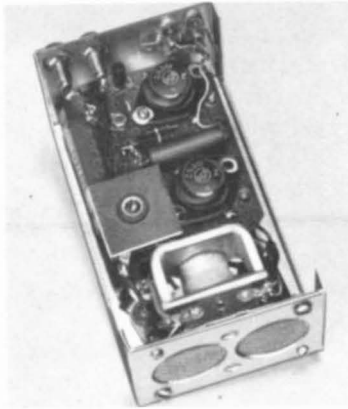


Fig. 407. This photo shows parts layout of the mini-amplifier.

base. The output from this transistor is nearly pure dc. At full gain, the hum is hardly audible even if you place your ear right up against the speaker cone. Neither V2 nor V3 are provided with a

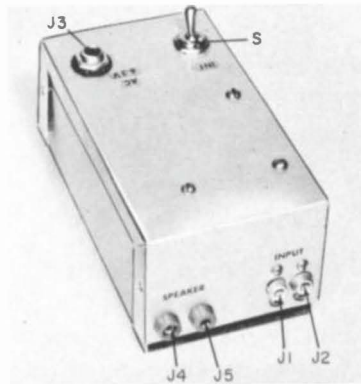


Fig. 408. Outside view of the amplifier. A pair of jacks is provided for external speakers.

heat sink since both are worked far below their maximum ratings.

The amplifier circuit is built on a perforated sheet of Bakelite

held in place by long screws and spacers. A switch cuts the speaker in or out as desired. Resistor R5 closes the power amplifier load circuit should the internal speaker and the external unit be both disconnected at the same time. (The parts layout is shown in Fig. 407.)

Two input terminals (phono jacks) are connected in parallel. One may be used for the incoming signal, the other for connection to a tape recorder. In many recorders the speaker is automatically disconnected during recording (to prevent acoustic feedback into

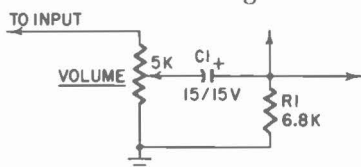


Fig. 409. If your signal source (tuner, etc.) has no volume control, incorporate this circuit with the mini-amplifier

a mike). With this pair of input terminals, the FM tuner feeds the recorder while you monitor it with the amplifier. When you connect the amplifier to an FM tuner, the signal lead shield provides the common ground between tuner and amplifier. The only other lead you need is to the 6.3-volt supply, assuming the other filament lead is grounded. (The completed unit appears in Fig. 408.)

To operate the amplifier from batteries instead of ac, eliminate V3 and its circuitry. Apply 3 or 4 volts to the V1, V2 circuit. A pair of flashlight D cells will last a long time and give plenty of volume when this amplifier is fed from a portable transistor tuner. A single cell supplying less than 25 ma provides ample volume for low-level listening.

If your application calls for a volume control, connect it as shown in the circuit of Fig. 409.

electronic compass

An electronic compass is a worthwhile investment for people interested in outdoor activities such as motorboating, sailing, hunting, trapping, berry picking, camping, hiking or other activity where there is a possibility of getting lost.

The instrument described here was designed especially for uses where portability and ruggedness are important. It is housed in a strong Bakelite case that is easily waterproofed. It is small, light-weight, sensitive; has a sharp null point and incorporates a built-in

magnetic compass. This combination of directional receiver and built-in compass is a true electronic compass and not just a radio homing device. It makes a rapid and accurate determination of actual position possible.

The superhet receiver

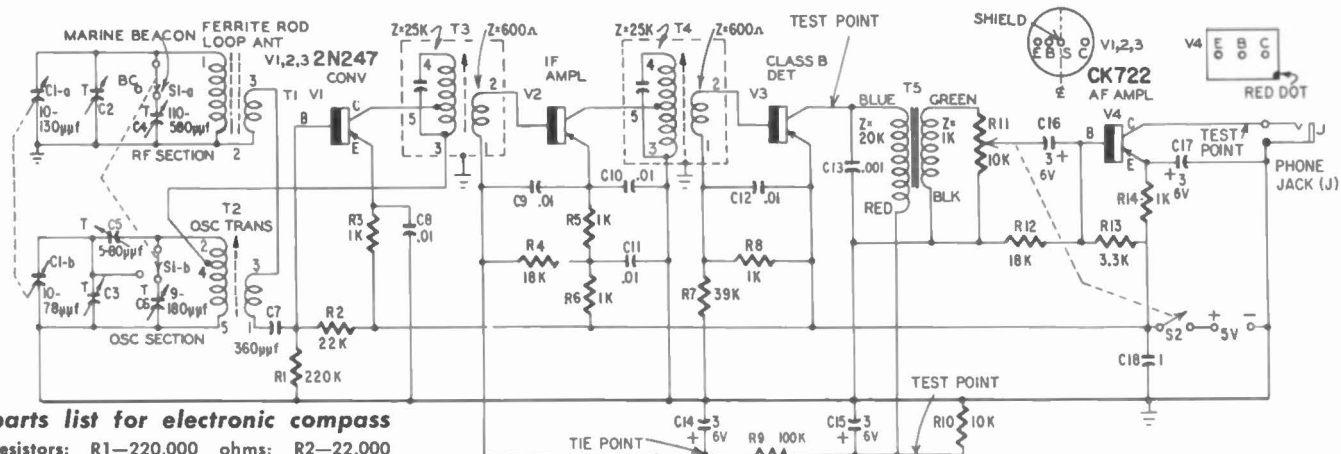
The receiver is a direction-sensitive superheterodyne (Fig. 410) using a type class-B detector and a single audio stage. Two tuning ranges are used: the broadcast band (550 to 1,600 kc) and the marine radio-beacon band (285 to 325 kc). The broadcast band is used so bearings can be taken from nearly any location and to provide entertainment while outdoors.

The radio-beacon band provides an extra degree of usefulness to boat owners. It is a desirable feature because many rivers, canals and harbors have radio beacons located near their entrances. Broadcast stations ordinarily will not permit such close work since they are seldom found in such a desirable location. If the electronic compass is used only for nonboating activities, the marine radio-beacon band can be eliminated.

A compact, flat ferrite loop antenna (T1, shown in Fig. 411) provides the directional properties needed for taking bearings on radio stations. It is mounted parallel to the length of the case to obtain the null point when the long axis of the receiver is in line with the station. The antenna has a high Q (in the region from 450 to 790 kc) for maximum selectivity and sensitivity. A matching two-gang tuning capacitor (T) tunes the antenna and local oscillator coil over the band.

The broadcast band is tuned with the BAND SELECTOR (S1) in position BC. When the switch is thrown to MARINE BEACON, capacitor C4 is shunted across C1-a, C2 and the primary of T1 to lower the resonance range of this circuit to the radio-beacon band and at the same time restrict the tuning range so it fits this narrower band. Similarly C6 is shunted across C1-b, C3 and the primary of T2. C5 is in the circuit to permit more accurate tracking of the oscillator section.

Although its value is not critical, C7 (nominally 360 μf) may have to be changed to a slightly different value in some instances. It must be large enough so the local oscillator functions properly at the lowest frequency in the marine band, but at the same time it must not be so large that feedback is excessive at the highest broadcast frequency. Too much feedback causes the oscillator to generate harmonics and reception of signals above the desired range will result.



parts list for electronic compass

Resistors: R1—220,000 ohms; R2—22,000 ohms; R3,R5,R6,R8,R14—1,000 ohms; R4, R12—18,000 ohms; R7—39,000 ohms; R9—100,000 ohms; R10—10,000 ohms; R11—10,000 ohm miniature potentiometer with spst switch S2 (Lafayette VC-28 or equivalent); R13—3,300 ohms (All resistors $\frac{1}{2}$ watt 10%.)

Capacitors: C1—tuning capacitor; antenna section 10–130 μmf ; oscillator section, 10–78 μmf ; C2,C3—trimmers on C1; C4—110–580 μmf , trimmer (El Menco 467 or equivalent); C5—5–80 μmf trimmer (El Menco 462 or equivalent); C6—9–180 μmf trimmer (El Menco 463 or equivalent); C7—360 μmf , silver mica; C8,C9,C10,C11,C12—.01 μf ; C13—.001 μf ceramic; C14,C15,C16,C17—3 μf , 6

volts, miniature electrolytic; C18—1 μf paper, miniature.

Transistors: V1,V2,V3—2N247 (RCA); V4—CK722 (Raytheon.)

Transformers: T1—ferrite-strip transistor antenna for 130- μmf tuning capacitor (Miller 2005 or equivalent); T2—transistor oscillator coil for 78–100- μmf tuning capacitor (Miller 2022 or equivalent); T3,T4—transistor if transformer, 455 kc; primary impedance 25,000 ohms; secondary impedance, 600 ohms (Miller 2041 or equivalent); T5—transistor audio interstage transformer: primary impedance 20,000 ohms; secondary impedance, 1,000 ohms (Merit A-2741 or

equivalent.)

Switches: S1—dpdt rotary (Centralab 1462 or equivalent); S2—spst on R11.

Miscellaneous: J—miniature phone jack (Lafayette MS-281 or equivalent and matching plug); 5-volt mercury battery (Mallory TR-134R or equivalent); battery holder (Acme type 69 or equivalent); high-impedance magnetic earphone; tuning dial (Lafayette KN-26 or equivalent); knob for $\frac{1}{2}$ -inch shaft; knob for $\frac{1}{4}$ -inch shaft; bakelite instrument case, 2x3 $\frac{1}{4}$ x6 $\frac{1}{4}$ inches (Lafayette MS-216 with matching cover); marching compass (Lafayette F-15 or equivalent); transistor sockets, 5-pin (4 required); hardware.

Fig. 410. Circuit diagram of the electronic compass. The unit is an all-transistor receiver having a class-B detector and a single-ended stage of audio amplification. The front end of the receiver covers two tuning ranges.

Agc Circuitry

The first three stages use 2N247 drift transistors. These transistors have high gain through the highest frequency used and, because of their very low base-to-collector capacitance, do not need neutralization. The converter and if stages are entirely conventional, while the detector is a class-B type instead of the usual diode. This detector provides a worth-while gain and a dc collector voltage that can be used for avc, since its level is determined by the rf signal level.

Resistors R9 and R10 are part of the V2 base-biasing network and R10 is also in V3's collector circuit. The avc voltage developed across R10 is applied to V2's base to regulate its gain with variations in carrier level.

The audio transformer (T5) is a subminiature type well suited for this application. It, as well as all other components, must contain a minimum of iron to minimize errors in the magnetic compass. *A larger transistor audio transformer will not be satisfactory unless it is mounted far from the compass.*

The earphone is a high-impedance magnetic type and is satisfactory where the signal level is high and the noise level low. Sometimes, these conditions may be reversed, making a conventional pair of headphones more desirable.

A 5.0-volt mercury battery powers the unit. It has a 1,000-milli-

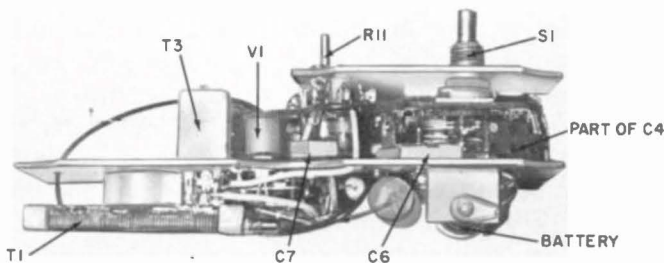


Fig. 411. The electronic compass takes advantage of the sharp directional characteristic of a ferrite loop antenna.

ampere-hour rating and should provide about 500 hours of service since the receiver current drain is only about 2 ma. When near the compass, this battery has a slightly greater influence on needle deflection than conventional flashlight cells but, when mounted as shown in Fig. 412, its effect is not measurable. The battery is easily replaced when the bottom of the case is removed.

All stages use base-bias stabilization to minimize variations in

performance caused by temperature changes since the electronic compass will normally be used outdoors and frequently in the hot sun.

The magnetic compass is a small marching type. It has a rotatable scale for ease and accuracy of bearing determination. A notch and foresight on the compass let you select landmarks (when visible) in line with the desired course.

Let's put it together ●

All parts of the receiver are mounted on a long flat aluminum lower plate and a short flat aluminum upper plate. The unit is fastened into the plastic instrument case with a second hex nut and lockwasher on the threaded switch bushing and with screws that run through the case into two threaded holes along the outer edge of the upper chassis plate.

The compass is mounted near the front end of the case with the needle pivot along the center line of the long dimension. Take your time while aligning the compass to insure the best possible accuracy. The rear mounting screw is a 6-32 flat head in a counter-sunk hole to permit the compass cover to be closed. The front mounting screw can be a round head but *both must be brass with brass nuts*. (Try them with a magnet.)

The aluminum chassis plates are shaped to fit the inside of the case with about 1/16-inch clearance on all sides. Make sure of this clearance after bolting to the tuning capacitor and switch but before the complete assembly of small parts is made. Otherwise, when the receiver is fastened in the case, pressure on one of these plates could upset the alignment by twisting the tuning capacitor.

One of the easiest ways to register the receiver parts with the case is to drill all necessary holes in the upper chassis plate. Then use this plate as a template for drilling the case *from the inside*. Be careful while drilling and avoid chipping. This problem can be minimized by backing each hole with a wood block while drilling and by making each hole somewhat undersize and bringing it to size with a tapered reamer.

The tuning capacitor is mounted with its trimmers facing the outer edge of the chassis for easy adjustment. The adjustment screws should be about 1/8 inch from the outer edge of the chassis to provide adequate spacing between their heads and the plastic case.

One of the mounting holes on the rear of the tuning capacitor matches the corresponding front hole and the top chassis plate can be used as a template to locate this one. The other two must be

located by measurement. If the same tuning dial is used as shown, the capacitor shaft will need to be flattened slightly on one side but its length will be satisfactory.

Final Assembly

The oscillator coil can be fastened to the bottom chassis plate if desired but a better arrangement of terminals is possible if it is mounted on the top plate. To do this, remove the metal mounting

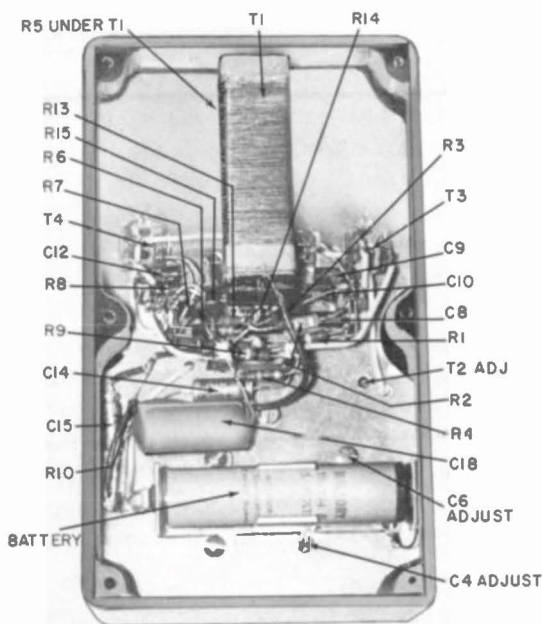


Fig. 412. Interior view of the electronic compass showing placement of parts.

clip and cement a threaded plastic plug in this end. A setscrew in a threaded hole in the top chassis plate is then used to hold the coil. A small hole is drilled in the lower plate directly below the coil for adjustment.

Mount the antenna by first cutting its fiber mounting strip about $\frac{3}{8}$ inch shorter than the antenna. Then retape the antenna to this strip with their front ends flush and apply a small amount of coil dope along the joining edges. The undercut end allows room for some parts underneath. A $\frac{3}{8}$ -inch piece of $\frac{3}{4}$ -inch-diameter polystyrene rod is threaded for two $6/32 \times \frac{1}{4}$ -inch screws, and matching holes are drilled in the lower chassis plate. Mount this piece of rod

on the plate and fasten the antenna to it with polystyrene coil dope, making sure that the antenna is parallel to the long side of the chassis.

Tuning capacitors C4 and C6 (see Fig. 412) are positioned so that their adjustment screws just clear the battery holder. These capacitors are mounted directly under the range switch with their outer plates making contact with the chassis. Their end terminals are soldered to the switch and their grounded terminals are bent over and soldered together for rigidity. Examine the ungrounded plates and rivets to be sure the "hot" ones are not grounded.

Both these capacitors should be set to within one-half to one turn from maximum capacitance before soldering. Capacitor C5 is mounted in the same way as C4 and C6, except that it is insulated from the chassis with a small piece of 1/16- or 1/8-inch insulation.

The if transformers are mounted along the sides of the chassis to reduce their effect on the magnetic compass, and the audio transformer is mounted directly in front of the volume control with a couple of dabs of cement. (See Fig. 413.)

A two-terminal tie point is used for B-plus and for the R9, C14, T3 junction. A ground lug is located under the mounting screw and a No. 20 bare wire connected to it is used as a ground bus. This bus is connected to the shield terminals of the three 2N247's and various small parts are grounded to it along its length. Rubber feet are mounted on each corner of the case to prevent slippage if the weather gets rough.

Steps in weatherproofing

If the electronic compass is to be used in salt-water areas, some weatherproofing will be necessary. Even in fresh-water areas the possibility of wetting by rain, spray and high humidity and falling overboard will make such a step profitable. First obtain some sheet rubber, about 1/32 inch thick, and cut a gasket about 1/8 inch wider on all sides than the bottom cover. Now, with a file, trim the base plate to give a clearance of slightly less than 1/32 inch between all of its edges and the case, and chamfer its inner edge slightly. Glue the rubber gasket to the inner surface of the base plate and allow it to dry thoroughly.

Gaskets made of the same material can be placed under the compass securing nuts, under the switch shaft nut and under the upper chassis securing screws. The tuning control shaft, the switch shaft, the volume control shaft and the phone jack can be gasketed by splitting soft rubber grommets edgewise. Use grommets with a 1/2-inch outside diameter and 1/4-inch hole for the three controls

and $\frac{3}{8}$ -inch outside diameter with a $\frac{3}{16}$ -inch hole for the phone jack. In addition, it is advisable to spray the aluminum chassis and if transformer cans with clear plastic to provide an extra degree of protection. (A front view of the completed unit is shown in Fig. 414.)

Aligning the receiver

The first step is to align the if transformers for maximum output at 455 kc. An output meter or oscilloscope can be connected across the headphones, or attach a high-impedance dc voltmeter between V3's collector and ground or the R10, C15, T5-red junction for an output indicator.

After the if transformers have been peaked, turn the bandswitch (S1) to the broadcast-band position (BC) and adjust T2's core

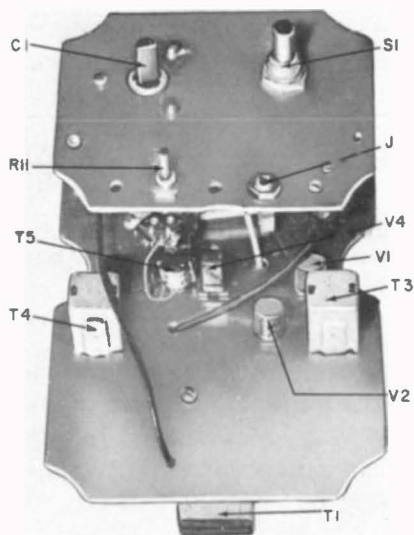


Fig. 413. The if transformers (T3 and T4) are mounted on the side of the chassis to minimize interference with the magnetic compass.

and C3 until the tuning range covers 550–1,600 kc. This is done by alternately adjusting T2's core at 550 kc and C3 at 1,600 kc until both ends of the range fit the dial. Next adjust C2 for maximum output at approximately 600 kc and check for satisfactory tracking at 1,400 kc. If C2 has to be decreased for maximum output at 1,400 kc, bend the slotted plates of C1-a outward and then readjust C2 for maximum output at 1,400 kc. Now adjust for maximum output

at approximately 600 kc by simultaneously varying the tuning capacitor in very small steps and adjusting T2's core until the maximum is found. Alternately repeat the C2 adjustment at 1,400 kc and the T2 core adjustment at 600 kc until maximum output is obtained at both points.

The next step is to align the radio-beacon band. Throw switch S1 to RADIO BEACON and alternately adjust C6 at 285 kc and C5 at 325 kc until this range fits the dial. Next, adjust C4 for maximum output at approximately 290 kc and check for satisfactory tracking at 320 kc. *When aligning this band, do not touch the core of T2, C2, C3 or the slotted C1-a plates, as these parts are adjusted only for the broadcast band.* When alignment is completed, you can calibrate the dial.

How to use it

When the electronic compass is completed, check its accuracy by obtaining the null point on a visible station and at the same time checking to see that the station is directly in line by using the sights on the compass. If possible, check stations at various frequencies in both bands. These checks should be made some distance from the station antenna and well away from any shore line, electric or telephone lines, metal buildings, or automobiles for maximum accuracy. In addition, hold the compass with the hands away from the antenna end of the case.

Accuracy

The overall accuracy of the electronic compass depends on antenna pattern, compass accuracy, compass alignment with respect to antenna, size and proximity of metal objects, and the nearness of a shore line and the station antenna. The compass error including alignment error should be very small. If any sizable error should be present, it can be compensated for by adding or subtracting a correction factor.

To use the electronic compass with the least amount of error and confusion, obtain a map of the area in which you will be operating. First mark a North-South line through the section of the map to be used and locate all the radio broadcast and beacon stations in your area on the map. Now set the North mark on the compass card under the red hairline, align one edge of the electronic compass case with the North-South line on the map, and rotate the map until the compass card North is aligned with the North end of the needle.

This orients the map so its North is pointed North. Now rotate

the electronic compass (but not the map) to obtain a null on a station of known location, place one edge of the electronic compass to intersect with this station as located on the map while maintaining the null and draw a line through the station along the edge of the case. Do the same with a second station. The point where the two lines intersect is *your* location. Now that you know your location, it is a simple matter to get home either by following a plotted course to the desired point or by riding the null straight in if one of the stations is near your destination.

Satisfactory results can be obtained without the map. Simply use

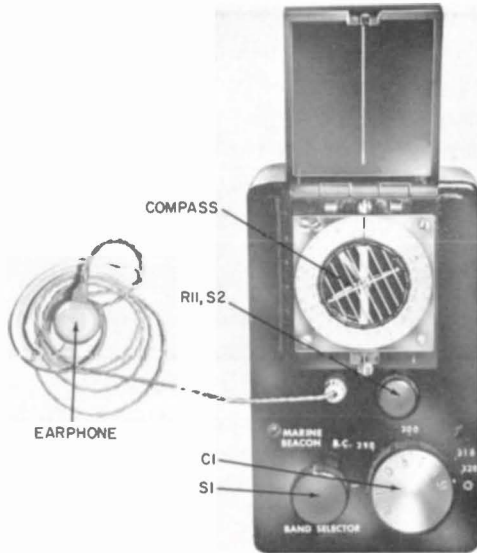


Fig. 414. Front view of the electronic compass.

the compass to orient yourself with respect to North and then take compass readings on the null points of two stations of known location. The compass card is calibrated in degrees (0 to 360) and also has the usual *N*, *E*, *S*, *W* markings. Therefore, the readings on the two null points will immediately show you where you are with respect to the two stations. For greatest accuracy, keep your hands away from the antenna end of the case.

After making several trial runs using both methods, you will be able to decide which you prefer — with or without the map. However, try using the electronic compass each time you are engaging in your favorite outdoor activity, even in clear weather, to become completely familiar with it and to gain confidence in its usefulness.

For those who are interested, the US Coast Guard publishes lists

of lights for the US coastal and Great Lakes areas. These light lists include a chart and tables of the various radio beacons including their frequency, identification code and location. Write to the Superintendent of Documents, Washington 25, D. C., for information and prices.

Final notes

Sensitivity, on the broadcast band, will be adequate for nearly any condition, but the radio-beacon range may need a slight boost if there are no nearby stations. In such cases, try a 5- or 7-inch ferrite antenna instead of the $2\frac{3}{4}$ -inch one used in this model. This longer antenna will also increase the sharpness of the null point. A second if amplifier can also be added if so desired. This stage is identical with the V2 stage, except that the resistor corresponding to R6 should be about 3,300 ohms.

A speaker¹ can be included by adding a pair of CK722's in a conventional push-pull class-B output stage after V4. Also a null-indicating meter can be added to V3's collector circuit to obtain a sharper null reading. All of these changes will require a somewhat larger case and will cause a slight loss of portability.

For some uses it may be desirable to attach a leather or plastic shoulder strap to two *brass* screws mounted on the sides of the case, below the compass but above the receiver chassis.

Where you want to eliminate the radio-beacon band, delete S1, C4, C5 and C6. The tuning capacitor shaft can now be aligned with the center of the chassis, or the extra space can be used for a speaker.

transistor cw tone generator

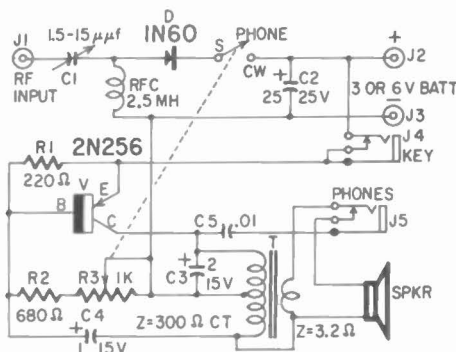
HERE is a versatile transistor CW monitor or code-practice oscillator which can be used by the beginner, novice or full-fledged ham. In fact, the beginner may learn the code with this device and later connect it to a transmitter after getting his ticket.

It is arranged so that versatility does not end with usage as it provides for a number of different connections or hookups. It is powered by a battery or rf and the variable output tone can be heard from either its built-in speaker or a pair of phones plugged into the phone jack.

The unit is connected to a battery for code practice, through a

¹ When adding a speaker or null-indicating meter to the direction finder, be sure to mount them in a place where their magnets will not disturb the magnetic compass. It might be advisable to install the meter and speaker in a separate box connected to the receiver by a cable.—*Editor*

keying relay to a battery for monitoring transmitter output, or to the transmitter's rf output, so when the transmitter is keyed the characters are repeated by the audio tone of the monitor. The lat-



parts list for cw tone generator

Resistors: R1—220 ohms; R2—680 ohms (both $\frac{1}{2}$ watt); R3—miniature potentiometer, 1,000 ohms, with spst switch, S.

Capacitors: C1—1.5-15- μ f trimmer; C2—25 μ f, 25 volts; C3—2 μ f, 15 volts; C4—1 μ f, 15 volts (C2, C3 and C4 are miniature electrolytics); C5—.01 μ f disc ceramic.

Transistor: V—2N256.

Diode: D—1N60.

Jacks: J1, J2, J3—tip jacks; J4, J5—closed-circuit phone jacks.

Transformer: T—output transformer: primary impedance 300 ohms, center tapped; secondary impedance 3.2 ohms (Argonne AR-121 or equivalent.)

Miscellaneous: hardware; 2- $\frac{1}{2}$ -inch speaker, impedance, 3.2 ohms; RFC—2.5 mh choke; S—spst on R3; case—4 $\frac{1}{2}$ x4x4 inches, cut for 2-inch meter; 3- or 6-volt battery; telegraph key; 9-pin miniature socket.

Fig. 415. Circuit diagram of the CW tone generator. The unit can be used to monitor CW transmissions or as a code-practice oscillator. The output transformer supplies the inductance for the oscillator circuit. To change the pitch of the sound, experiment with different values for C3.

ter also checks transmitter operation, as failure of rf output cuts off the monitor.

Power required to operate the oscillator and get a good output from the speaker is very small, in the order of 3 volts at 50 ma or 150 mw. Any size transmitter will provide this power. Just set C1 (Fig. 415) for proper operation. Higher power and higher impedance circuits require less capacitance for C1.

With the value shown for C1, 1.5–15 μ f, full capacitance provides the right monitor power for a 50–100-watt transmitter output into a 52-ohm line with C1 connected directly to this line. For higher impedance and higher powers proceed cautiously. The dc voltage across the monitor's rectifier circuit should not exceed 15 volts under any conditions. Higher voltages may damage components.

For best rf-powered operation the instrument's case is grounded. Of course, the transmitter's rf signal is coupled to the tone generator's RF INPUT jack. (See the photo of the internal view shown in Fig. 416.) If the transmitter uses a coaxial transmission line, attach the rf pickup to the coaxial line on the antenna side of the

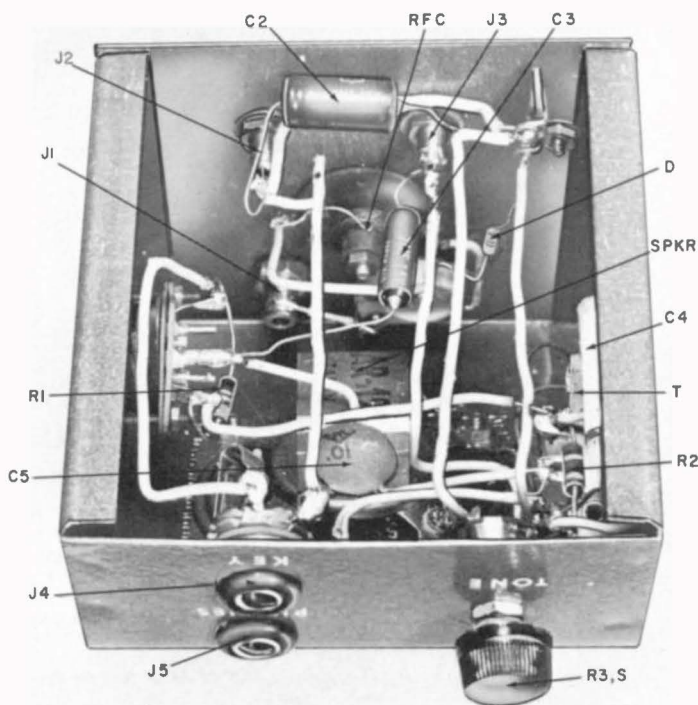


Fig. 416. Inside view of the transistor CW tone generator.

low-pass filter to prevent TVI. A gimmick wire works fine for coupling from an open wire line to the monitor. Sometimes the monitor can be operated from the receiver's antenna input by eliminating capacitor C1 in the monitor proper and placing it across the receiver's antenna-relay contacts, if one is used. This type of hookup is not always entirely satisfactory because it is affected by receiver tuning and factors peculiar to the individual layout.

The well known Hartley oscillator is used. Its frequency is determined primarily by T and C3, but is also affected by the other components.

Capacitor C2 is needed as an audio bypass in rf power operation. Its value is fairly critical as it not only changes frequency but also

turn-off time when the key is opened. Too small a value increases the oscillator frequency; too large a value causes monitor oscillation to hang over, after the radio transmitter is turned off.



Fig. 417. The entire unit can be built into a meter case.

Switch S is purely for convenience. It disables the oscillator during radio-telephone operation. Under battery operation, open the key or disconnect the battery to turn off the oscillator.

There is no volume control in this circuit because it automatically works out right for comfortable listening. An L-pad attenuator could be used to control speaker volume if necessary.

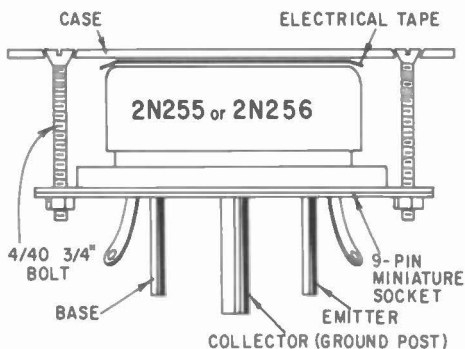


Fig. 418. Method of mounting the transistor.

Construction hints

The transistor CW tone generator is built into a 2-inch meter case (Fig. 417). The 2-inch wide shelf becomes the front panel with the open side of the box downward. A 2½-inch 3.2-ohm speaker is used with a miniature output transformer.

Capacitors C2, C3 and C4 are miniature low-voltage electrolytics.

Be sure that they are polarized according to the schematic or they will be damaged. The transistor can be either a 2N255 or 2N256. Both have the same characteristics, but the 2N256 withstands peaks up to 30 volts while the 2N255 is rated for 15-volt peaks. The transistor has an automobile style case and mounts on the side of the box. (Fig. 418).

A 9-pin miniature socket slips over the transistor leads and holds the transistor in place. If the socket does not have a center ground post to make contact with the transistor case and collector, another method can easily be devised.

Both key and phone jacks are closed-circuit types mounted on the front panel with rubber grommet insulators. A tight fitting 1/2-inch hole will hold the jacks securely without a nut.

simple oscillator

THIS ultra-simple oscillator uses any of the low-cost p-n-p transistors. It is easily constructed and is just about perfect as a first transistor project.

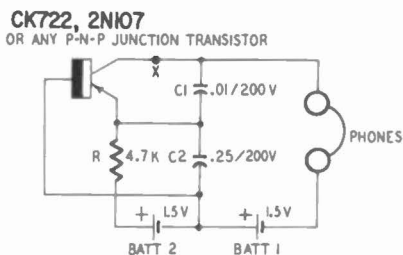
The low-cost transistor, in certain low-power circuits, now completely eclipses the tube. For example, the oscillator described here was built for a *total cost of only \$3.50*. It operates from two tiny mercury or penlight cells and draws less than 1 mw of power. Now look how simple the circuit is. (See Fig. 419.) It contains only one resistor and two capacitors. Compared to this, any vacuum-tube oscillator looks antique!

Low-priced transistors are units that have failed to meet the stringent requirements or production limits set for the higher-grade higher-priced transistors. You can test low-cost p-n-p transistors from several manufacturers and find a unit-to-unit beta gain variation of more than 100%. (Beta is the short-circuit current gain for a grounded-emitter circuit.)

An oscillator using a single junction transistor must usually have either a transformer or a tapped choke as an impedance-matching element. This transformer, however, adds inordinately to the circuit cost. Miniature transformers that are popular for transistor circuits sell for two or three times the price of the transistor. In this circuit, you can eliminate this expensive component by letting the externally connected earphones become the inductive part of the tuned circuit.

Oscillator circuit

The oscillator uses a grounded-base transistor circuit. In this configuration, the collector output impedance is extremely high, while the emitter impedance is very low. Simply explained, this



parts list for simple oscillator

Resistor: R—4,700 ohms, ½ watt.

Capacitors: C1—.01 μ f; C2—0.25 μ f. Both capacitors 200 volts, molded.

Transistor: Any low-cost p-n-p junction (CK722, 2N107, etc.)

Miscellaneous: Batt 1, Batt 2—1.5 volts (penlight or Mallory RM-625RT mercury cells); Bakelite mounting board cut to desired size; headphones, 2,000 ohms impedance.

Fig. 419. Circuit diagram of the transistor oscillator. Excellent as a first project for the novice, it makes clever use of the coils in a pair of 2,000-ohm earphones as part of the tuning section. The oscillator is known as a Colpitts.

is because the emitter-to-base junction is biased in a manner corresponding to a rectifier passing current in the forward or easy-flow direction. Conversely, the collector is biased in the reverse or high-resistance direction.

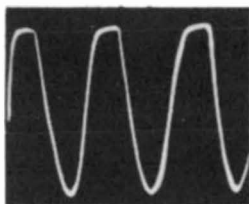


Fig. 420. The waveform of the oscillator is a fairly clean sine wave.

With vacuum tubes, a bias is necessary to *limit* plate current to a safe nondestructive value. The transistor must be provided with an emitter bias to cause *sufficient* collector-current flow for proper operation. Just as it is possible to vary the plate current of a vacuum tube with a grid-bias *voltage*, the transistor collector current is varied with the emitter-bias *current*. Without emitter bias, the only collector current is the result of temperature and leakage effects and is very small, about 5 μ a.

Batt 2 and resistor R provide the oscillator bias current. The value of this circuit bias can, for all practical purposes, be determined quite simply by dividing the bias voltage by the value of R. In this circuit, bias current is 300 μ a.

Under these conditions, we have an amplifier capable of sustaining oscillations. This occurs because a given current change, at low voltage, in the emitter causes an almost equal current change across a very much higher collector impedance, producing a high-voltage output.

However, we must match the high collector impedance to the low emitter impedance in the feedback circuit. The earphones obviously cannot be tapped like a transformer; so the tuning capacitor, made up of C1 and C2, is tapped instead. The values of these two capacitors can be varied, changing the oscillator frequency; their values are not critical. But, to maintain a reasonable impedance match, C2 should be 25–50 times larger than C1. For example, to lower the frequency of oscillation, C1 could be made .02 μ f and C2, 0.5 μ f.

Either a single 1,000-ohm earphone or a 2,000-ohm headset can be used. If you don't want to use the earphones, substitute an iron-core choke or transformer winding. The oscillator frequency, of course, will depend upon the transformer or choke inductance and some experimenting may be necessary to get the proper frequency.

The output waveform across the earphones, as shown in Fig. 420, is reasonably pure for a simple oscillator. The chopped-off positive peak is the result of driving the collector positive into its forward conduction region. This clipping can be reduced, if necessary, by inserting experimental values of resistance at the point marked X on the schematic—try 1,500 ohms first. If a high value of resistance that just maintains oscillation is selected, the sine wave produced will be beautifully clean and free from harmonics.

Construction

The oscillator's parts are small enough to fit into a medium-size thimble. Because of this small size, it is easy to find a small plastic box to accommodate the oscillator circuit and its two cells. The oscillator and two RM-625RT mercury cells fit easily, with room to spare, in a plastic hardware-assortment box. Fig. 421 shows how the parts are mounted on a tiny Bakelite strip.

With a telegraph key or pushbutton in series with either the collector or emitter battery, the oscillator becomes a very compact

and inexpensive code-practice unit. Also, it makes a very handy test-signal source for troubleshooting and servicing audio stages and equipment.

To turn off the oscillator, a spdt switch is needed to interrupt both the emitter and collector cells. Interrupting just the emitter cell leaves a few microamperes of collector current still flowing.

If the transistor is soldered directly into the circuit, grasp the wire leads at a point between the transistor and solder joint with

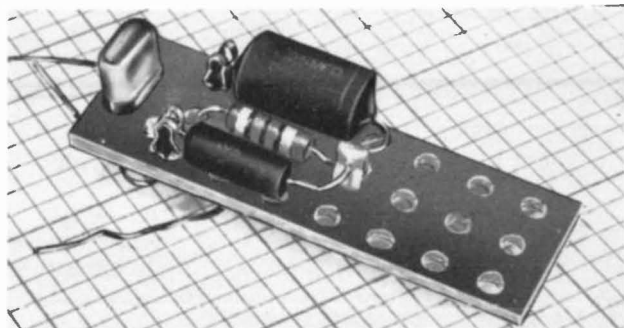


Fig. 421. The parts for the oscillator are mounted on a small Bakelite strip.

long-nose pliers. The pliers then carry away the excess heat before it reaches the transistor. Also be careful when soldering to the capacitors and batteries. They can take very little heat and quickly reach the melting point of the plastic sealing compounds.

This oscillator circuit is simple, inexpensive and just the thing for that first transistor project.

sensitive signaling circuit

A SENSITIVE relay is generally used when a weak electric signal must set off a visual or audible alarm, turn on a motor or accomplish some kind of control. Such a relay is quite expensive. For example, in the 10–20- μ a range, it may cost \$30 or more. If the relay is needed only to set off an audible alarm (to indicate that an electrical signal is being received), it may be replaced by a simple transistor circuit.

This transistor device sounds a warning when an 8- μ a signal is fed to it. Since it is so easy to convert light, sound, temperature

change or rf power into electricity, this unit has unlimited possibilities. For example, a humidity sensor plate can be used to produce the electric signal, turning the signal circuit into a rain detector. When coupled with a lamp and photocell, it can indicate a customer entering the shop, and so on. The instrument will sound off whenever a suitable input is fed to it.

Fig. 422 shows a block diagram of the unit. The electrical signal from a transducer or battery is amplified, after which it

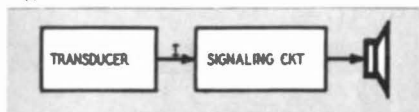


Fig. 422. Block diagram of the sensitive signaling circuit.

triggers a p-n-p power transistor into audio oscillation. The af energizes a small speaker and produces a tone which is audible over a range of 10 feet or more.

The transistor oscillator is many times more efficient than a mechanical buzzer. Besides, its tone is more pleasant. Very little equipment is needed, and the power supply may be any low-voltage battery. You can use 4 volts in this particular unit, but a higher voltage is satisfactory if a louder alarm is needed. Standby current (during absence of the alarm) is but a fraction of a milli-ampere.

The circuit

It is easier to analyze the circuit of Fig. 423 if we assume V1 is temporarily shorted between emitter and collector. Then V2 may be recognized as a conventional Hartley type audio oscillator. Note that the transformer's center tap returns to V2's emitter through the battery. Its base is biased through a voltage-dropping string, R1, R3, R4. This circuit will oscillate at about 3,500 cycles when the battery is switched on. The frequency may be lowered by adding capacitance across the transformer primary, but this may reduce the instrument's sensitivity.

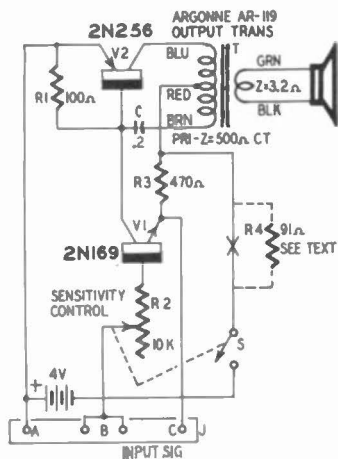
When V1 is added as shown, it affects the oscillator's base bias. Normally the transistor's internal resistance is high. This leaves only a small voltage across R1 to bias V2. Under this condition there is no audio tone. However, when forward bias is fed into V1, its internal resistance is lowered and a greater voltage appears across R1. If the bias is sufficient, V2 will oscillate.

A forward bias of only $8 \mu\text{a}$ starts the oscillator. It may be applied between terminals B and C. B must be connected to the *positive* side of the external signal source since V1 is an n-p-n unit. R2 may

be used to control the signal input. In general, however, an external resistor will need to be added in series to cut down the signal to only a few μa .

The audio tone may be stopped by reducing the input to about $2\ \mu\text{a}$ or less, or by switching off the battery circuit.

The most obvious application of this device is as a sensitive electronic relay which will sound an audio tone when its signal



parts list for sensitive signaling circuit

Resistors: R1—100 ohms; R2—potentiometer, 10,000 ohms with spst switches; R3—470 ohms; R4—91 ohms, 5% (all resistors $\frac{1}{2}$ -watt 10% unless noted.)

Capacitor: C—0.2 μf ceramic.

Transistors: V1—2N169; V2—2N256.

Transformer: T—output transformer; primary, 500 ohms impedance, center tapped; secondary, 3.2 ohms impedance (Argonne

AR-119 or equivalent.)

Miscellaneous: J—4-terminal jack (Lafayette MS-285 or equivalent); S—spst on R2; Batt—4 volts, RCA VS-308; connectors for battery; case, plastic, $4\frac{1}{8} \times 2\frac{1}{2} \times 1\frac{1}{8}$ inches (Lafayette MS-302 or equivalent); bakelite board, cut to size (Lafayette MS-304 or equivalent); knob; miscellaneous hardware.

Sockets: 3-pin, for 2N169; 9-pin miniature for 2N256.

Fig. 423. In this arrangement, the primary of the output transformer is the inductor in a Hartley circuit. This coil helps establish the operating frequency which can be lowered by placing capacitance across the end leads (between the blue and brown leads).

input exceeds $8\ \mu\text{a}$ or so. The signal source may be a sensor plate to detect moisture, for example. Other signal inputs to key the alarm are:

1. A network made up of an rf coil in series with a crystal diode may be connected between terminals B and C. Any rf picked up from a nearby transmitter is detected and fed to V1. The device becomes a CW monitor, giving a loud, pleasant tone every time

the key is depressed. A distance of 2 or 3 feet from a 35-watt-transmitter antenna is about right. The coil need not be tuned — a 2.5-mh choke has been found suitable. The diode must be poled with its cathode toward terminal B (see Fig. 424-a).

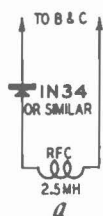


Fig. 424. A simple probe will help detect the presence of rf (a). A photocell can be used to make the signaling circuit sensitive to changes in light (b).



2. The internal battery (4 volts) may be used to supply the control signal. When a resistor is connected between terminals A and B, current flows through it toward the positive battery terminal. Thus VI's base goes positive. The emitter is already tied to the negative terminal through a pair of resistors. If the added resistor (between A and B) is small enough (270,000 ohms or less) oscillation will start.

This added resistance may be a cadmium sulphide or similar photocell, which has a high resistance when no light falls on it. The resistance then drops as light intensity increases. For example, a Clairex CL-2 cell will set off the audio alarm when placed about a foot from a 30-watt fluorescent lamp. Light from a cloudy sky will also work. A thermistor will do the same job for temperature changes (see Fig. 424-b).

3. The alarm may be set off by a combination of signals. If approximately 6 or 7 μa is fed in between terminals B and C, the instrument becomes very sensitive and only 1 or 2 more μa will set off the electronic relay. Under this condition even a slight acoustic shock is sufficient. For example, tapping the speaker or blowing onto its cone will start oscillations.

This instrument has been described as a trigger device that has only two states, on or off. It is also useful as an amplifier as shown below. This is a table of input signal (across B and C) vs. total battery current.

Signal (μa)	Battery (ma)
0	0.3
2.2	0.4
7.0	0.8
8.2	1.0 which triggers to 5.0
25.0	10.0

Note that small changes of input may be measured until about 1 ma when the oscillator is abruptly triggered to 5 ma. Battery currents between these values are not observed. After oscillations

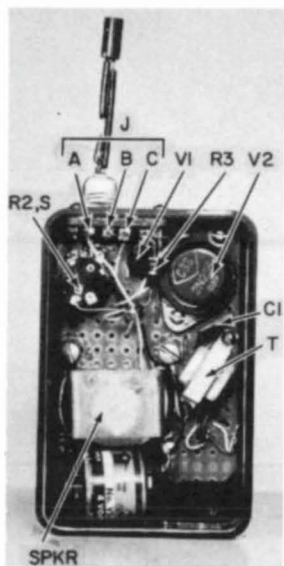


Fig. 425. The components are compactly arranged in this interior view.

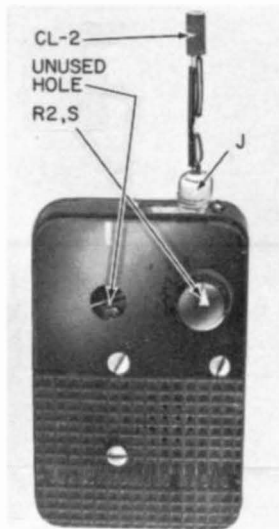


Fig. 426. This photo shows the completed signaling device.

start, increasing the signal increases battery drain still further (and, of course, produces louder sounds).

Resistor R4 has an important job. Although it greatly reduces the circuit's sensitivity, it makes it possible to stop the tone by reducing the input signal. Without R4, the tone can be triggered by as little as $2 \mu\text{a}$, but it will not cease even when the signal is removed. Only switching off the battery will stop the alarm. (R4 was not used in the model shown in Fig. 425.)

Construction kinks

The electronic relay alarm is built into a plastic case (Lafayette MS-302) which has become popular with experimenters. Only one control appears on the front. This is the on-off switch combined with a potentiometer. All parts except the battery are mounted on a perforated Bakelite board.

Jack J (Lafayette MS-285) has four contacts. The inside contacts are tied together. Then a plug (MS-283) can be inserted into the desired pair. The inner contacts (which are connected together)

are shown at B in Fig. 423. Therefore the plug can contact either A—B or C—B, as desired. The photo (Fig. 426) shows a photocell (CL-2) hooked up for a light-operated alarm circuit or for measuring light intensity.

transistor lamp control

THIS simple transistor circuit (see Fig. 427) uses a small dc input to control a filament type lamp between complete darkness and maximum brilliance. The lamp's brightness is proportional to the dc input signal magnitude and control action is smooth.

The device, which takes up little room, can be used wherever the

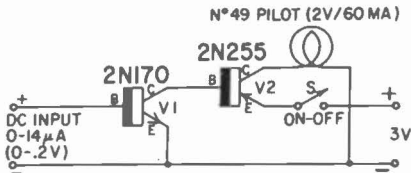


Fig. 427. Varying degrees of light intensity can be had with this circuit.

glow of a conventional lamp must indicate the relative strength of a dc signal which has only 1/40,000 of the power required to light the lamp to full brilliance.

A dc input of only 15 μ a at 0.2 volt will bring the 2-volt 60-ma lamp in Fig. 427 to full brightness. The glow decreases at lower signal levels, and near zero input is extinguished. For greater brilliance than the No. 49 lamp provides, other small lamps (such as the 6–8-volt 150-ma type) can be used but will require correspondingly higher input signal levels. For 6-volt lamps, use a 7.5-volt battery in the control circuit. In one demonstration, the circuit's dc input terminals were connected to the diode output of a simple crystal radio. When the receiver was tuned to a strong local broadcast station, the lamp lighted brightly to indicate resonance. On each side of resonance, the dimming of the lamp was proportional to the detuning, and at some distance on each side, the lamp was extinguished. The circuit has also been used as an AM radio tuning lamp, lighting the dial brightest at resonance, and obtaining the necessary operating voltage by rectifying the filament voltage with a germanium diode. In this setup, the dc signal was derived from the avc circuit. The circuit has also been used as a visual Conelrad alarm — the lamp goes out when the station leaves the air.

A self-generating photocell connected to the dc input terminals will also operate the circuit. The lamp's brightness is proportional

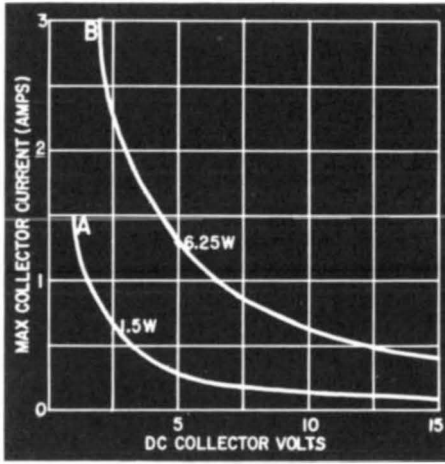


Fig. 428. Collector voltage vs collector current through the lamp.

to the light falling on the photocell. Dimming of the lamp is proportional to the opacity of any object passed between the photocell and its source of illumination. A further use of the circuit is as a lamp type indicator for low-speed flip-flop transistor switching circuits in which the on current and voltage are too low to operate a neon lamp.

The circuit

The circuit is a two-stage dc amplifier using one conventional transistor (V1) and one inexpensive power transistor (V2). Direct coupling between the stages eliminates the need for resistors. By using an n-p-n transistor for V1 and a p-n-p transistor for V2, only one battery is needed. It biases V2's collector negative and V1's collector positive (the latter through V2's emitter-base path). At 30° C, the initial current flowing through the lamp is 0.5 ma. This is only 1/150 of lamp current at full brilliance, and would be only 1/375 of a 6-volt pilot lamp's operating current. With the values shown in Fig. 427, the power transistor (V2) does not need a heat sink.

While battery operation is suggested, it is not mandatory. Dc voltage for operating the circuit may be obtained from a miniature power supply, such as a crystal diode and filter capacitor operated from the secondary winding of a small filament transformer.

You might want to use the circuit with other lamps and voltages. Fig. 428 shows the maximum collector (lamp) current which can be drawn up to the maximum collector voltage of -15 without exceeding V2's power dissipation rating. Curve A is for 1.5 watts constant dissipation in free air, while curve B is for 6.25 watts constant dissipation applying to operation with a heat sink. Curve B stops at the 3-ampere point, since this is the transistor's maximum collector-current rating.

These curves apply to 25°C operation. At higher temperatures, apply a derating factor of .024 watt per degree Centigrade ambient temperature increase to curve A, and 0.1 watt to the 6.25-watt curve B.

broadcast-band booster

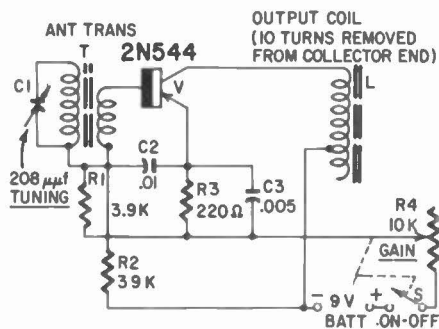
Is your portable radio inadequate when played in some locations? Do you like to stay up late listening to programs from distant cities? Would you like to extend the range of your portable? If the answer to any of these questions is yes, this booster may solve your problem. It is an rf stage inductively coupled to your radio to increase its gain tremendously. *No wired connections are made between the units.*

To use the booster, tune your radio to the desired station and adjust for maximum output. Place the booster output coil L (Fig. 429) near the radio's antenna and tune the booster for maximum signal. Advance the booster's GAIN control as required. Stations normally at whisper strength will come up to full local level.¹ Very often stations that are *inaudible* with the radio alone are brought in extremely well with the booster added!

The circuit is very simple. See the diagram and the photograph, Figs. 429 and 430. T is the booster's antenna transformer. L is the output coil mounted at right angles to T. The output coil is

¹ This booster was tested with both transistor and vacuum-tube receivers. In all cases the sensitivity of the receiver was markedly improved. Stations that were just barely above the noise level came in loudly. Some stations that could not even be heard before the booster was turned on, also came in clearly.

One inherent difficulty—the booster cannot be used with some old radios that have a loop antenna. Some type of ferrite-core antenna must be in the receiver. Otherwise, coupling between the booster and the receiver is too poor to permit the booster to do its job—*Editor.*



parts list for broadcast-band booster

Resistors: R1—3,900 ohms; R2—39,000 ohms; R3—220 ohms; R4—10,000 ohm potentiometer, with spst switch (Lafayette VC-28 or equivalent). All fixed resistors are ½-watt 10%.

Capacitors: C1—208- μmf variable (antenna section of Lafayette MS-270); C2—.01 μf ; C3—.005 μf .

Transistor: V—2N544.

Transformer: T—ferrite-core antenna transformer (Lafayette MS-329 or equivalent).

Coil: L—ferrite-core antenna coil (Lafayette MS-272 or equivalent).

Miscellaneous: Batt—9 volts; battery holder; mounting board, 2¼ x 4¼ inches; hardware.

Fig. 429. Circuit diagram of the broadcast-band booster. The booster is a tuned radio-frequency stage that is inductively coupled to the input of your receiver.

untuned so no neutralization is needed. You can remove 10 turns from it to make sure that it will not resonate in the broadcast

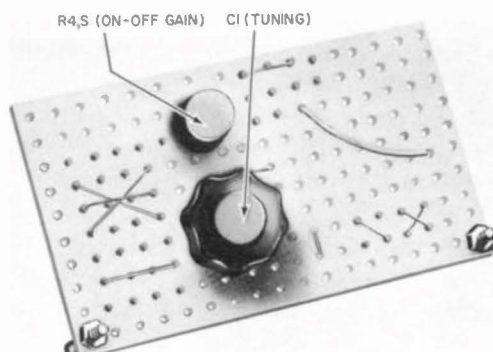


Fig. 430. The connecting wires for the broadcast-band booster are brought up through holes in the mounting board.

band. Note that the *collector end* of this coil is mounted near the transistor and a *short lead* connects the two parts.

L and T are tied to the perforated baseboard with heavy thread.

L acts as primary of a transformer, its secondary being the radio ferrite antenna to which it is coupled.

The antenna transformer covers the entire broadcast band when connected to the antenna section of a two-gang variable capacitor (see the parts list).

A major requirement is that the radio antenna coil be accessible for close coupling to L. This is true of most portable transistor sets. Results are better when L is at right angles or coaxial with either end of the radio's antenna. But experiment to determine relative distances and positions for these units. Of course, T may be oriented for maximum pickup from the desired station.

If oscillations occur with R4 turned up all the way, readjust it until they just cease. This is the most sensitive setting. If no oscillations occur, the resistance may be reduced to zero for maximum gain. The battery drain is approximately 1 ma.

multi-impedance amplifier

EXPERIMENTING with transistors is one of the most fascinating hobbies for the serious-minded electronics worker. Many hobbyists find it so, continually looking for ways to conduct numerous tests and experiments quickly and easily. With this in mind, you will probably realize that, if a flexible amplifier were kept on hand, it could be used in many experimental circuits and test procedures along with other transistor or electron-tube circuitry. The amplifier might also be used as the front end of a permanent audio system using any or all of the input and output arrangements, as required in a specific application. The outcome of this idea is shown in the diagram, Fig. 431.

The circuit provides low-, medium- and high-impedance inputs, low- and high-output impedance. The input circuits can be used for low- or high-impedance microphones, carbon microphone with external battery, magnetic pickups, close match for 500/600-ohm line sources, bridging for terminated 500/600-ohm line and coupling to other transistor apparatus. The output circuits would be suitable for working into the input grid of an electron-tube amplifier, feeding a 500/600-ohm line and working into other transistor equipment. No doubt you will think of many other uses for the device.

The amplifier is built around circuit configurations suggested

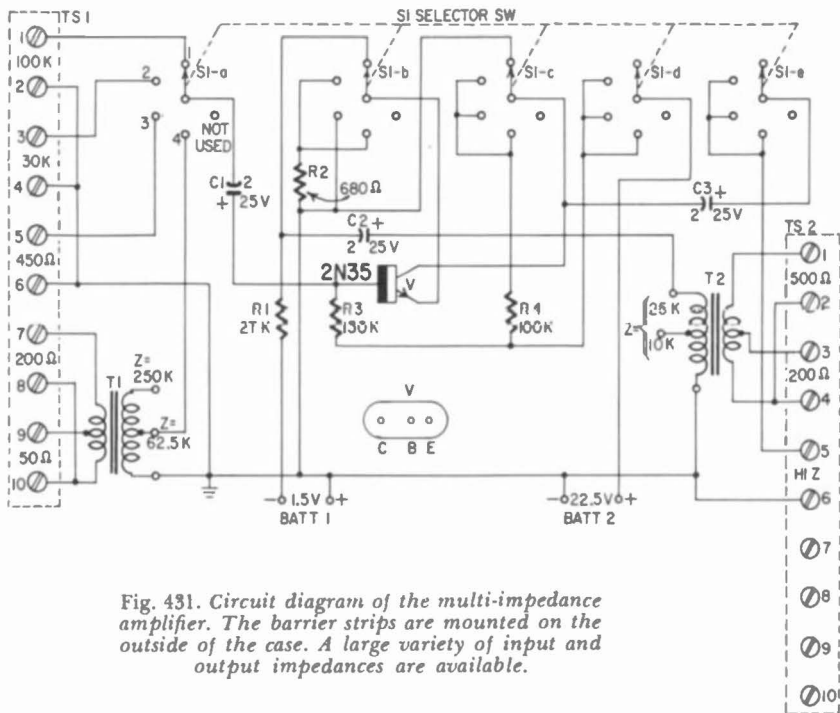


Fig. 431. Circuit diagram of the multi-impedance amplifier. The barrier strips are mounted on the outside of the case. A large variety of input and output impedances are available.

parts list for multi-impedance amplifier

Resistors: R1—27,000 ohms; R2—680 ohms; R3—150,000 ohms; R4—100,000 ohms (all resistors ½-watt, 10%.)

Capacitors: C1, C2, C3—2 μf, 25 volts, miniature electrolytics.

Transistor: V—2N35.

Transformers: T1—input transformer, primary impedances 50 and 200 ohms, secondary impedances 62,500 ohms and 250,000 ohms; T2—plate-to-line transformer, primary impedances 10,000 ohms and 25,000 ohms,

secondary impedances 200 ohms and 500 ohms.

Batteries: Batt 1—1.5 volts (Burgess Type N or equivalent); Batt 2—22.5 volts (Burgess Type U15 or equivalent).

Switch: S—6 poles, 5 positions, miniature rotary, 1 pole not used (Centralab miniature PA-1021 or equivalent).

Miscellaneous: case, 4 x 5 x 6 inches; hardware; TS1, TS2—10 terminal, screw type, barrier strips.

by Sylvania for their 2N35 n-p-n junction transistor. Combining several circuit arrangements, adding switching facilities and including two small tapped transformers produced a one-transistor unit with extreme versatility.

Construction details

The photograph, Fig. 432, shows the unit in its metal cabinet. It is 4 x 5 x 6 inches and was used because it happened to be on hand and would also allow for expansion. Physically, the device could be made much smaller, but this seems to serve no particular

purpose. Also, since the unit was built with convenience and utility in mind rather than appearance, everything necessary for its operation is mounted on the front panel. In this way the unit can be used upright as shown or on its back and all required operating items are conveniently available. A shelf is attached to the rear of the panel for mounting other necessary parts. Parts placement is noncritical except for keeping input and output trans-

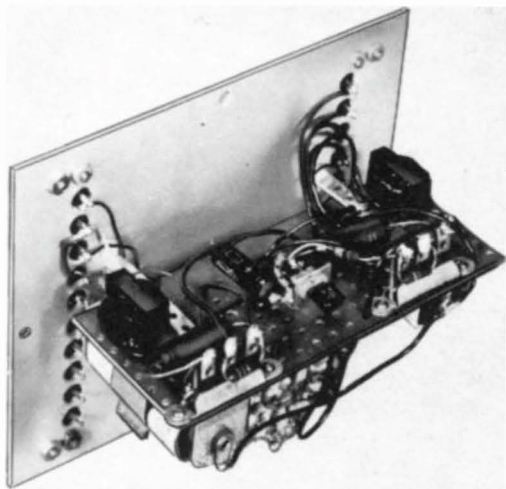


Fig. 432. Inside view of the multi-impedance amplifier.

formers and wiring as far apart as possible. Input and output wiring should be as short as possible and dressed with no closely spaced parallel leads.

Rather than put all the pertinent information on the panel, the selector switch positions and input and output terminals are assigned numbers and a card with data corresponding to these numerals is cemented to the top of the metal cabinet. The information contained on this card is given in the table. The output

Table of Amplifier Characteristics

Input (ohms)	Output (ohms)	Switch Position	Input Terminals	Output Terminals
100,000	500	1	1—2	1—2
100,000	200	1	1—2	3—4
30,000	100,000	2	3—4	5—6
450	100,000	3	5—6	5—6
200	100,000	4	7—8	5—6
50	100,000	4	9—10	5—6

terminal strip has four spare terminals. Both input and output terminals are shown in the outside photo of the case, Fig. 433.

Amplifier circuits

Now for an analysis of the circuit. Position 1 of selector switch S1 provides a common-collector audio amplifier circuit. The common-collector transistor arrangements result in a circuit similar to an electron-tube cathode follower; that is, high input impedance and relatively low output impedance, with voltage gain less

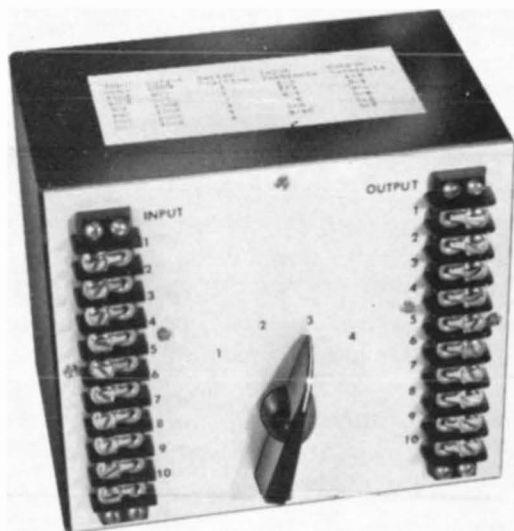


Fig. 433. This photo shows the outside of the case with the barrier strips in position.

than 1 and no signal phase reversal. No dc bias to the base and low collector voltage — Batt 1, 1.5 volts — contribute to high input impedance, which is about 100,000 ohms. The voltage gain is approximately 0.95. The output circuit consists of the 25,000-ohm primary of transformer T2, whose secondary furnishes a 500- or 200-ohm output. T2 also includes a 10,000-ohm tap, not connected in this circuit, which can be useful in experimental work.

Position 2 of the selector switch sets the circuit up for common-emitter operation. In this case, series resistor R2 included in the emitter leg results in degeneration. Degeneration effectively increases the input impedance over the common-emitter circuit without degeneration. Input impedance in this switch position is 30,000 ohms. The output impedance is high, suitable for working into high-Z circuits. Batt 2, 22.5 volts, now supplies the dc potential. The voltage gain is in the order of 100.

With the selector switch thrown to position 3, a common-

emitter circuit without degeneration is provided. Note that the 680-ohm emitter resistor R2 is not included in the circuit. The input impedance is low, about 450 ohms, output impedance is high, 100,000 ohms, and the voltage gain is high, between 300 and 400. Batt 2 is again the dc supply source.

Selector switch position 4 provides the same common-emitter circuit with degeneration as did switch position 2. However, this time transformer T1 comes into the circuit. Its secondary-winding tap of 62,500 ohms works into the medium-impedance input of the transistor. T1's primary provides low-Z inputs of 50 and 200 ohms. Its secondary also offers a 250,000-ohm impedance, not wired in, which will often prove useful. High Z is provided in the output. Gain will be the same in switch position 4 as for position 2, plus the voltage gain provided by the turns ratio of transformer T1, which of course, depends on the winding taps used.

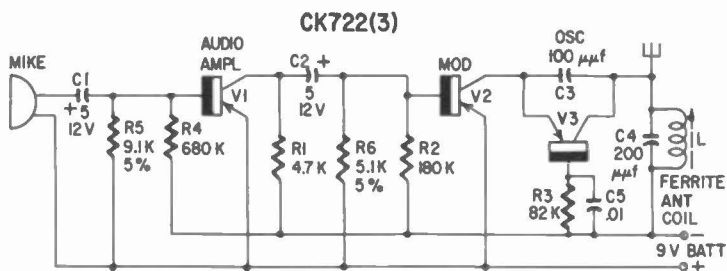
Other wiring arrangements can be visualized and incorporated to suit your personal requirements. The two unused transformer taps are ideal for many transistor circuits and may be used to good advantage. The device, of course, may be expanded further by employing the extra, unused pole and contact position on the switch specified. Also, switches with a greater number of poles and contact positions are available.

the snitcher

THE Snitcher is a voice-modulated three-transistor radio transmitter—a wireless microphone. It is small enough to fit into a rubber ball. In fact that is exactly what was done with this unit.

An unusual modulating system which eliminates the need for a modulation transformer is used. The output of a low-impedance hearing-aid microphone is fed to V1's base through capacitor C1 (see Fig. 434). To use a high-output phono cartridge, connect it to V2's base through C2. V1 is operated as a common-emitter audio amplifier. It is R-C-coupled to V2, the modulator, another common-emitter stage. Current for the oscillator (V3) is delivered by V2's collector and is controlled by the signal applied to V2's base. Thus we get a modulated output signal. What this signal looks like is shown in Fig. 435.

The rf oscillator (V3) radiates its output from a short antenna connected to a tuned rf circuit. This signal can now be picked up



parts list for the snitcher

Resistors: R1—4,700 ohms; R2—180,000 ohms; R3—82,000 ohms; R4—680,000 ohms; R5—9,100 ohms, 5%; R6—5,100 ohms, 5% (all resistors, ½-watt, 10%, unless otherwise noted.)

Capacitors: C1, C2—5 μf, 12 volts, electrolytic; C3—100 μf, tubular ceramic; C4—200 μf, tubular ceramic; C5—.01 μf.

Transistors: V1, V2, V3—CK722.

Coil: ferrite antenna coil, 7/16 x 2 inches (Allied 51C036 or equivalent).

Miscellaneous: microphone (mike) low-impedance, hearing-aid type; Batt—9-volt battery (Eveready 216 or equivalent); micarta sheet, 3/64 x 3 3/8 x 1 1/2 inches; tin sheet—1 1/2 x 1 1/4 inches; miniature eyelets; 1/8-inch eyelets; hardware.

Fig. 434. Circuit diagram of the Snitcher. The oscillator, V3, produces a carrier which is audio-modulated by V2. Do not use an outside antenna with this unit. Radiation beyond your own room limits is illegal.

by broadcast receivers tuned to the same frequency as the Snitcher.

The range is determined by the sensitivity of the receiver used in conjunction with this transmitter. Tests indicate a satisfactory input to a National NC-88 receiver at 20 feet, using a 30-inch antenna on the Snitcher and about the same on the receiver.

Put one together

To make a Snitcher, shape and drill the terminal board first (see Fig. 436). You can use a piece of 3/64-inch Micarta meas-

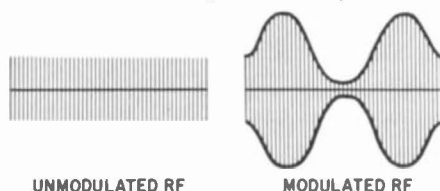


Fig. 435. Appearance of the unmodulated and modulated rf.

uring 1 5/8 x 3 3/8 inches. Drill all holes before folding the ends, to save time later. To bend the battery-holding ends uniformly, make a wood form block 1 x 1 1/2 x 7 7/8 inches. Round the corners so the battery-holding ends will have a radius of about 1/2 inch. The outer portion of the forming tool can be two parallel pieces of

wood, 2 inches apart. Heat the Micarta to about 375° , until it becomes pliable. Now, the ends can be folded at right angles by using the inner form block to hold the Micarta against the outer form blocks for a few minutes.

Next, cut the coil support. Use sheet tin, $1\frac{1}{2} \times 1\frac{1}{4}$ inches. Since it is also connected to the negative battery terminal, drill

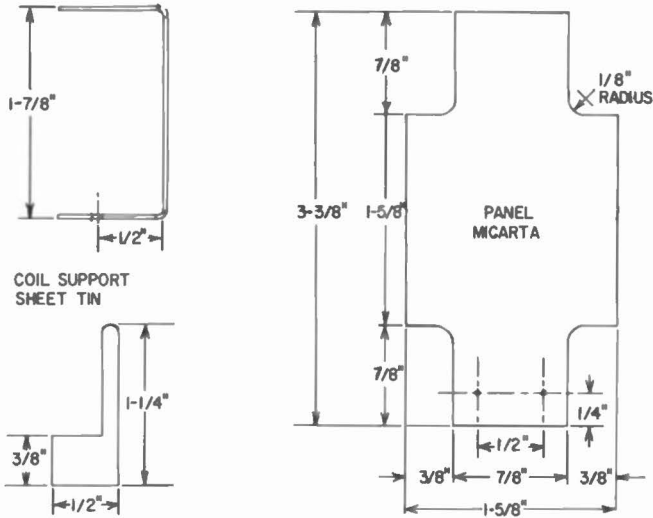


Fig. 436. Template for making the supports for the Snitcher.

holes for the holding rivets and negative terminals before bending. The long narrow part of the coil support fits into the base end of the ferrite antenna coil. If you wish, solder this end of the support to the antenna-coil lug that connects to the negative supply.

Now, mounting resistors and capacitors should be easy. Miniature eyelets let you fasten parts to both sides of the panel (they act as feedthroughs), so keep the capacitors and transistors on the front side and the resistors on the back (under the battery) for a neater layout. You can get an idea of how this is done by examining the photos in Fig. 437.

The $\frac{1}{8}$ -inch eyelets make satisfactory terminals for the battery and also for fastening the support piece to the panel. After the resistors and capacitors are fitted to their positions, rivet the coil support to the panel and complete the soldering operation. Do not solder the transistors in position until all other components have been double-checked. Temporarily insert the battery and

check for proper clearance. In this unit the battery was slightly loose and it was necessary to fasten a piece of clear plastic to one end of the chassis to keep it in place.

While the remaining assembly does not require much time, the procedure is full of do's and don't's.

Be sure that the battery *is not* in position. After you determine which way the transistors go, hold their wire leads with a pair of long-nose pliers to help dissipate some of the soldering heat. Use rosin core solder and only enough heat and time to melt the solder and permit it to flow around the transistor leads. This is a place where a cooling swab of some kind will help keep the heat from traveling up the wire leads to the transistor itself. Make a careful final inspection of all connections, position of the transistors, etc. and you are ready to insert the battery.

What to expect

In a breadboard layout, current averaged about 1.4 ma with an input of 9 volts. This current varies with temperature and with different transistors, but a range of 1 to 2 ma should give satisfactory performance.

After the unit was completed, it was checked with an oscilloscope. The input was a 400-cycle sine wave.

As a portable receiver was moved away from the Snitcher, the signal became weaker and heterodynes from distant broadcast stations prevented reception from the unit. The satisfactory distance was about 10 to 15 feet, even through walls and partitions which contained electrical wires, plumbing pipes, etc.

To find the frequency to use, turn a radio receiver on and tune across the broadcast band. Around the 650-kc mark (± 100 kc), you will probably find a spot where no strong stations are operating. Set your receiver at that place and with the Snitcher battery in position, move coil L's ferrite slug in or out until the radio signal from it can be heard on the broadcast receiver.

A handy way to do this is to place the Snitcher near a clock (a noisy alarm clock is fine) and about 6 feet away from the receiver. Then as the ferrite slug is moved in or out, the tick of the clock will modulate the signal generated by the Snitcher and will be heard on your radio receiver.

When operating positions are changed, you may have to retune the radio receiver a trifle. Any change in antenna length also changes the frequency of the output signal. Adjust the ferrite slug in coil L or retune the radio receiver to get back on frequency.

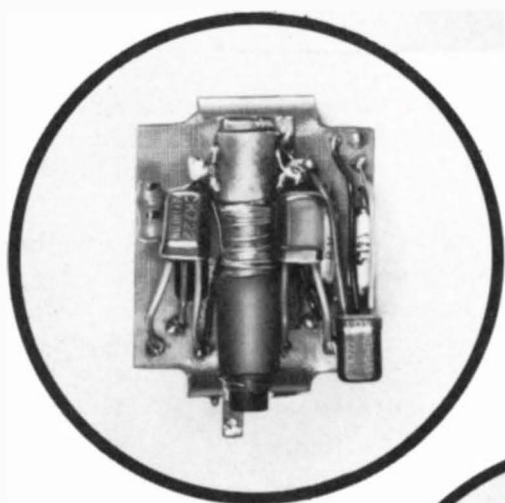
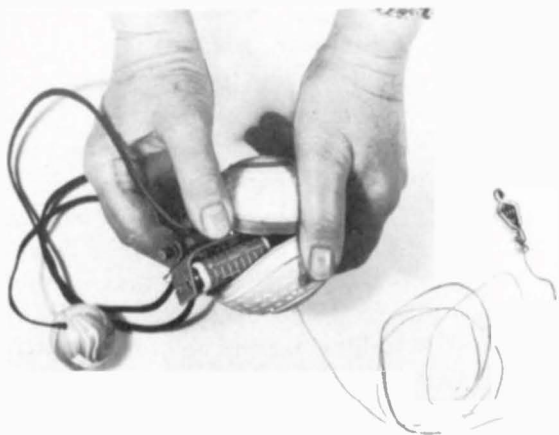
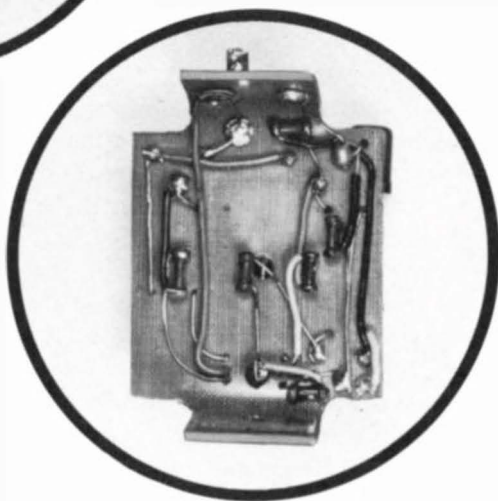


Fig. 437. Transistors, capacitors and ferrite antenna are mounted on one side of the chassis.



With the battery removed, placement of the resistors can be seen.

Performance notes

In the final stage (V3) a CK768 will give about 10% better performance, but the less expensive CK722 is satisfactory.

A low-impedance magnetic pickup gave a performance unit of 5, a small square type capacitor pickup about 2, and a 2,200-ohm earphone only about 1 and with some hum. The low-impedance pickup is a surplus hearing-aid mike which has a dc resistance of 140 ohms.

A 30-inch antenna is recommended. However, longer and shorter lengths may give a better output. Experiment to find out which is best for your Snitcher. Clipping the antenna to a grounded object also improves the output. The change in frequency was about 15 kc when a 10-foot antenna was used.

electronic counter

ELECTRONIC counting devices record a great variety of events: the number of persons viewing displays, the flow of traffic on a city street, objects passing through an assembly line and other occurrences too numerous to mention. The versatility of these devices seems limited only by human imagination.

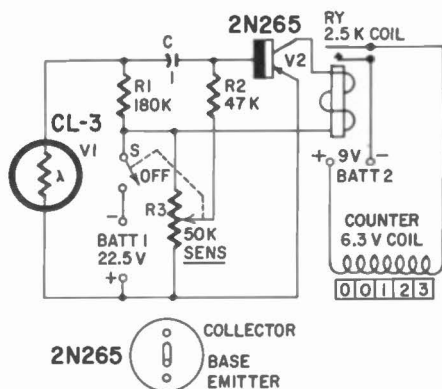
The simplest electronic counter is electromechanical and operates on the same principle as a stepping relay. Each pulse delivered to the counter actuates a ratchet and advances the unit one digit. Such a device requires a rather sizable pulse of current, so the counter is usually operated in conjunction with a sensitive relay. The trigger pulse that keys the sensitive relay (and in turn the counter) may be generated in a number of ways: pressure switches, capacitance relays and photocells to name a few.

The electronic counter described in this article is small (3 x 4 x 5 inches), light (under 2 pounds) and entirely self-contained and self-powered. Sensitivity is so high that the unit need only be aimed toward a window, lamp or light-colored wall. Just about the only auxiliary equipment required is a shelf or box on which to set the thing.

Counter circuitry

The heart of this electronic counter is an extremely sensitive cadmium selenide photocell, the Clairex CL-3. This photocell is so sensitive that a very small, abrupt variation in light intensity

produces a sizable output pulse. This output pulse is amplified many times by a 2N265 transistor (see Fig. 438) which has a beta, or current gain, of 110. To develop maximum gain and



parts list for electronic counter

Resistors: R1—180,000 ohms, ½ watt; R2—47,000 ohms, ½ watt; R3—50,000-ohm potentiometer with spst switch.

Capacitor: C—1 μ f, 200 volts.

Transistor and photocell: V1—photocell, Clairex CL-3; V2—2N265.

Batteries: Batt 1—22.5 volts (Burgess U15 or equivalent); Batt 2—two 9-volt units in parallel (RCA VS305 or equivalent).

Relay: Ry—5-mw sensitivity, 2,500 ohm coil (Sigma 5F-2500-S/SIL or equivalent—see text).

Counter: Electromechanical, 6.3-volt ac coil (Mercury MEA-N5-6A or equivalent).

Miscellaneous: S—spst on R3; chassis box, 3 x 4 x 5 inches; socket for transistor; ⅜-inch threaded control grommet; ⅜-inch Bake-lite control protector cap; hardware.

Fig. 438. Circuit diagram of the electronic counter. The cadmium selenide photocell (CL-3) is sensitive to changes in light intensity.

supply the largest possible bias to the photocell, the transistor is operated at close to its maximum voltage rating. Of course, the photocell could be biased separately with a much higher voltage. However, its sensitivity at 22.5 volts is adequate, and the need for a separate battery and switch is eliminated.

A sensitive relay in the transistor's collector circuit responds to each light pulse at the photocell and operates a standard electric counter.

The instrument's maximum counting rate is determined by the top speed at which the relay and counter will respond, and the time constant of R1-C. The relay and counter operate at about 10 pulses per second. The time constant (R1-C) was purposely made rather long to develop a large pulse at the output of the photocell. This long time constant results in an overall maximum counting rate of approximately five pulses per second. Shortening

the time constant of $R1-C$ by lowering the value of either component will speed the response of the instrument, but results in lower overall sensitivity.

One thing that may seem puzzling is the 6.3-volt ac counter. The reason is that a counter with a dc coil couldn't be found. The

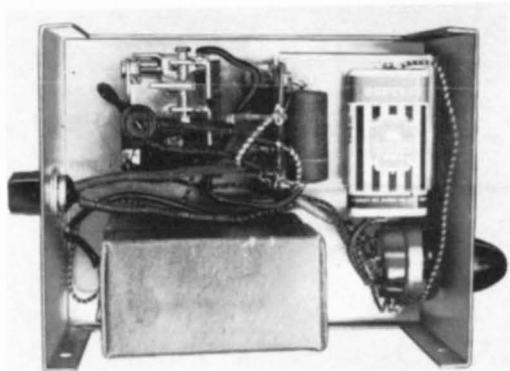


Fig. 439. Interior view of the electronic counter.

ac unit operates very nicely at 9 volts dc. As the counter draws a large amount of current, its power supply (Batt 2) is made up of two fairly large 9-volt batteries, parallel-connected.

Parts substitutions

If you are anything like most hobbyists, you are probably reluctant to buy a new component when you have an almost identical one in the spare-parts box. Here are a few pointers on substituting components used for the counter:

The CL-3 photocell may be replaced with a CL-2 or CL-1, *but sensitivity will suffer*. The CL-3 is about six times as sensitive as either of the other two.

The 2N265 may be replaced with a transistor with like characteristics. One or two hand-picked CK722's will perform almost as well as the 2N265.

When substituting relays, remember several points. The life of Batt 1 depends on the operating current of the relay. For battery economy, use a sensitive relay.

Construction

The unit is housed in a 3 x 4 x 5-inch, two-piece aluminum chassis. All components are mounted on the flanged portion of the chassis. See Fig. 439.

The two metal tabs on the upper surface of the electromechan-

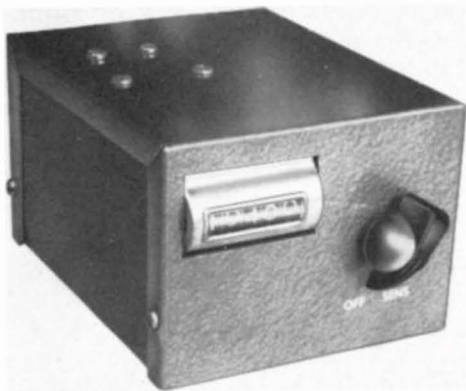


Fig. 440. *The easily read counter appears at the front of the instrument.*

ical counter are bent horizontal and fastened to the case. A $\frac{7}{8}$ x $1\frac{3}{4}$ -inch hole is cut in one end of the chassis for the readout end of the unit.

Batt 1 is cemented to the top inside of the counter with service cement. The two units that make up Batt 2 are cemented together and the entire battery secured to the chassis with more cement. You may prefer to use a clamp, but space is rather limited.

The photocell is cemented inside a $\frac{3}{8}$ -inch threaded control grommet (ICA 1250, E. F. Johnson 115-255 or equivalent) and mounted at the front of the chassis. Saw the solid end off a $\frac{3}{8}$ -inch Bakelite protector cap of the type used to prevent tampering with TV back-of-chassis controls (D&M Control Guards) and screw the remaining portion onto the control grommet. This tube extends $\frac{1}{2}$ inch or so beyond the photocell and limits the field of light.

When wiring sensitivity control R3, make sure that clockwise rotation of the control increases the negative bias at the transistor's base.

A miniature hearing-aid socket is used for the transistor. However, it can be soldered directly into the circuit. Just be careful — don't let heat from the soldering iron do any damage. The photocell can also be damaged by heat, so use a heat sink when soldering to its leads.

Operation

Place the counter so the photocell faces a light source in such a way that objects to be counted will pass between it and the light. As the unit is extremely sensitive, a lamp, window or the light-

colored wall of a well lighted room should be adequate light sources.

Switch the instrument on (one count will register). Advance the sensitivity control (R3) until the counter pulls in. Now back off R3 until the counter releases. The unit is now ready to operate, and objects passing between the photocell and light source should register on the counter.

A little experimenting will quickly determine the maximum distance the counter can be placed from the object to be counted. Factors such as light intensity or area, and the size of the object, will vary the effective distance. In a normally lighted room, the counter will register when a person passes within 6 feet, if the photocell is directed at a shaded lamp 10 to 12 feet away. Small objects must be closer to the counter to register.

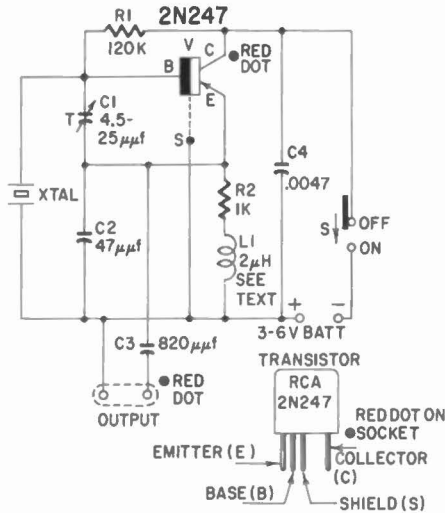
Because the basic electric counter requires a considerable amount of current the largest practical batteries (Batt 2) should be selected to operate the electromechanical counter. After the instrument was completed (see Fig. 440) over 20,000 counts were registered in fairly rapid succession and the batteries were still going strong. This indicates that one set of batteries should be good for quite some time. Batt 1, with only negligible current drain, should approach shelf-life.

multipurpose crystal oscillator

THIS crystal-controlled oscillator (Fig. 441) illustrates the old saying "Good things come in small packages." Here is just such a good thing. Plug in any fundamental crystal in the frequency range of 1.5 to 14 mc and get good sine-wave output, without tuning adjustments of any kind. The parts required are standard, few and inexpensive. An added bonus is the tiny amount of power drawn from the battery supply. In the first model built, battery life equaled shelf life.

The photos (Figs. 442 and 443) give an overall view of the oscillator, but this layout does not have to be followed. Any neat and reasonable mechanical layout of parts will work electrically. The 2N247 is by far the most expensive component in the oscillator. Use a socket for mounting it. All wiring and visual checking is done before inserting the transistor in its socket. In this way the chances of damaging it because of excessive soldering heat or

improper circuit connections are reduced. After the socket is mounted, color-code the collector connection end (a drop of nail polish is fine). The socket has five pin connections in a line; the 2N247 uses four of them. Note the gap between collector and



parts list for multipurpose crystal oscillator

Resistors: R1—120,000 ohms, ½-watt, 10%;
R2—1,000 ohms, ½-watt, 10%.

Capacitors: C1—4.5–25 μμf trimmer; C2—47 μμf, mica; C3—820 μμf, mica; C4—.0047 μf, ceramic.

Transistor: V—2N247.

Miscellaneous: Batt—3–6 volts; L—see text; S—spst slide switch; xtal—1.5–14 mc, as required; xtal socket to match crystal; sub-miniature 5-pin in-line socket for transistor; case, 2½ x 2 x 1 inch (Lafayette MS-158 or equivalent); hardware.

Fig. 441. Circuit diagram of the multipurpose crystal oscillator. The circuit has no tuning controls other than C1, but even this requires but a single adjustment.

shield. Fill the empty hole in the socket with a touch of service cement. It keeps you from inserting the transistor into its socket incorrectly.

The crystal socket is the next component to mount. The one to use depends on the crystal case size and pin spacing. The photo of the model in Fig. 444 shows a Bliley type BH6 crystal. Pin spacing for this type is 0.500 inch. A matching socket is the National type CS-5.

Place the ceramic trimmer adjacent and at right angles to the transistor and crystal sockets. Drill two small holes (No. 26 drill) through the plastic case and mount 4-40 screws in them to serve as the output terminals. The remaining small electrical parts are now soldered point-to-point following the schematic.

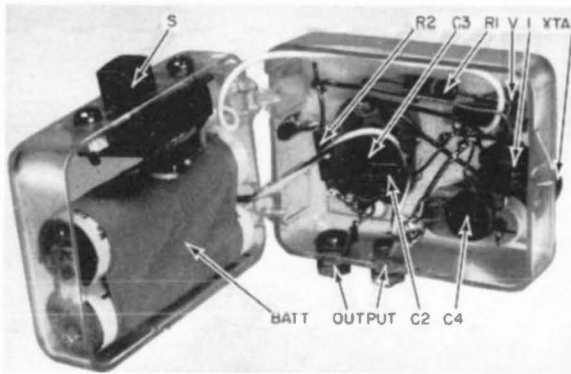


Fig. 442. Overall view of the crystal oscillator.

Final touch-up hints

Electrically, the schematic tells the whole story, except for the miniature choke L. The circuit will oscillate without it, but the output tends to drop with increasing frequency. The choke counteracts the drop in drive current to the transistor's base as the

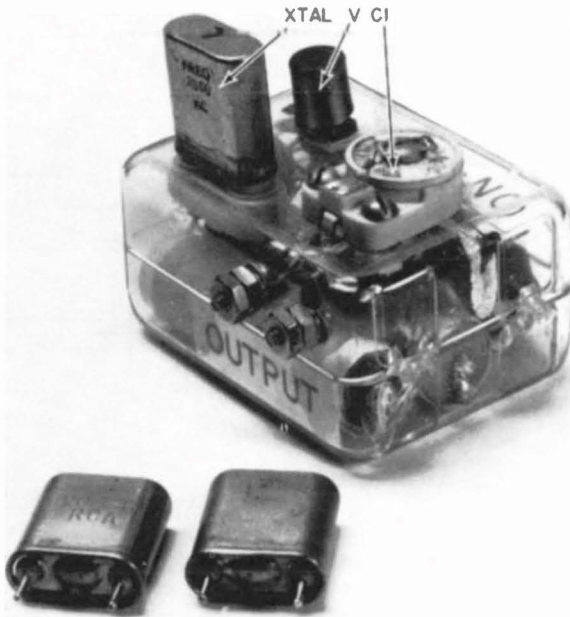


Fig. 443. This photo shows how the crystal, transistor and trimmer capacitor are positioned.

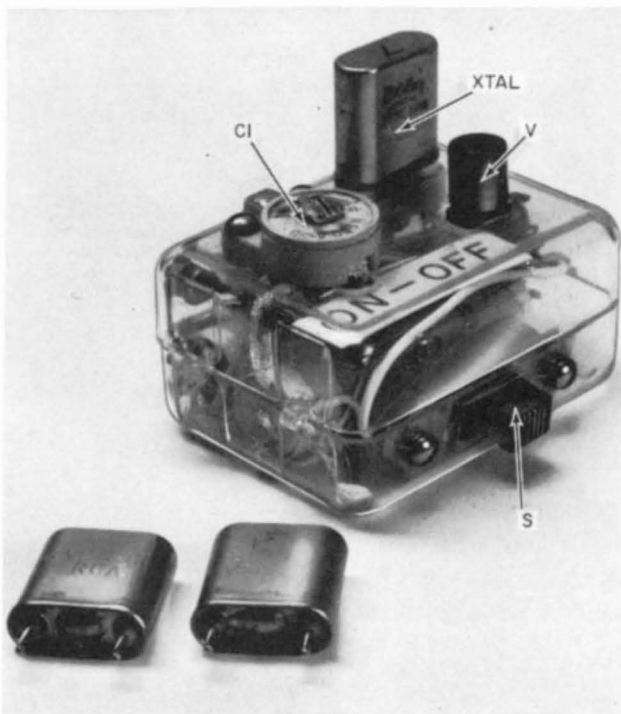


Fig. 444. Additional crystals can be used as required.

operating frequency goes up, by building up the impedance level of the emitter circuit. If, in your application, high-frequency operation is important, two things can be done to insure good results:

- Insert a 2- μ h inductance, shown on the schematic as L.
- Increase the supply voltage to 4.5 or higher.

The second step is particularly important to the efficient use of drift type transistors. RCA application notes show a pronounced knee in the curve that relates collector volts to cutoff frequency.¹ Practically, if we have a collector supply voltage of 4 volts or more, the collector-voltage field extends through the impurity region near the base and the transistor gives the maximum gain of which it is capable. In neutralized amplifier circuits, the 2N247 transistor gives some gain until the frequency gets beyond 50 megacycles. So any fundamental crystal (they range up to about 14 mc) will work in this circuit.

¹ A. Kestenbaum and J. W. Englund, *A Drift Transistor for High Frequency Use*. RCA Laboratories Bulletin LB 1045.

Some applications

When you've built this small convenient oscillator, you will find many uses for it. For example, as a signal source for TV troubleshooting, or for the crystal-controlled oscillator feeding the second mixer in a dual-conversion high-frequency receiver. The oscillator can be used as a known frequency feeding one set of plates on your scope, while an unknown frequency is fed to the other set of plates. Use it for band spotting with your high-frequency receiver. Many times, all you have to do to get a signal into a circuit under test is to place a wire clip lead on the oscillator's hot output terminal, and let this wire rest on the bench close by the trouble spot.

Adjust trimmer capacitor C1 with the aid of a scope at the highest frequency you expect to use. Set it for the cleanest-possible highest-amplitude waveform, and you're done. This will be close to a mid-range setting of the capacitor with a normal variety of crystal.

portable power supply

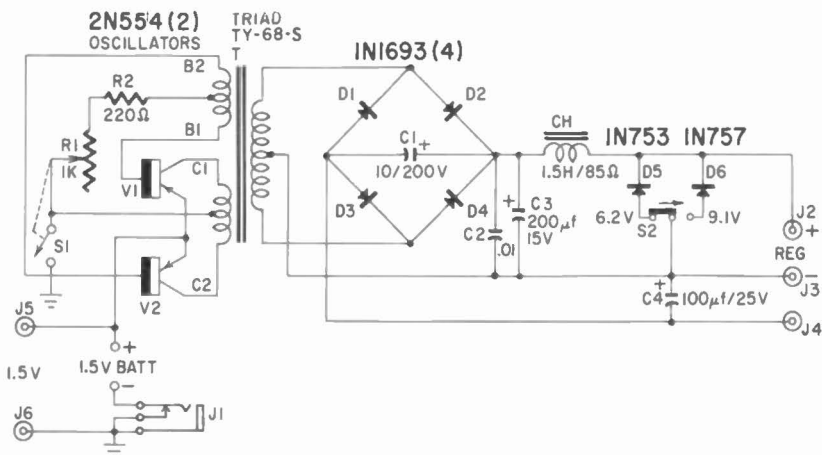
This supply is suitable for transistor circuits. It provides 1.5, 6.2 and 9.1 volts with excellent regulation. There is also a semi-regulated output of about 20 volts. The power source is a size-D flashlight cell which energizes a transistor oscillator. The voltage is stepped up, rectified and then regulated by a Zener diode.

Potentiometer R1 (Fig. 445) controls the input to the oscillator. Its resistance is set as high as possible for the amount of power needed, to save battery power. You can measure the drain by plugging a meter into jack J1.

Four inexpensive diodes make up the bridge rectifier. Each one can handle up to 200 volts peak at high temperature. The choke's resistance must be low. Since ripple frequency is quite high, even a low inductance filters effectively.

There is no direct connection between the 1.5 volts from the D-cell and any of the stepped-up voltages. Thus the 1.5 volts may be combined with any of the others. For example, 6.2 volts minus 1.5 gives 4.7 volts.

The power box measures 5 x 3 x 2 inches. Transistors are mounted at one end, using a Motorola mounting kit available for



parts list for portable power supply

Resistors: R1—1,000-ohm potentiometer with spst switch S1; R2—220 ohms, ½ watt.

Capacitors: C1—10 μ f, 200-volt miniature electrolytic; C2—.01 μ f, 500-volt disc ceramic; C3—200 μ f 15-volt miniature electrolytic; C4—100 μ f, 25-volt miniature electrolytic.

Transistors and diodes: V1, V2—2N554; D1, D2, D3, D4—1N1693; D5—1N753; D6—1N757. D5 and D6 are Zener diodes.

Jacks: J1—miniature phone jack, normally

closed; J2, J3, J4, J5—insulated pin jacks; J6—uninsulated pin jack.

Switches: S1—spst on R1; S2—spdt slide switch.

Transformer: T—transistor power supply transformer, 12 volt dc input, 250 volts, 65 ma from rectifier (Triad TY-68S or equivalent).

Miscellaneous: 1.5-volt size D flashlight cell; battery holder; CH—1.5 henries, 85 ohms; mounting kit for transistor; case, 5 x 3 x 2 inches; hardware.

Fig. 445. Circuit diagram of the portable power supply. A pair of Zener diodes provide excellent regulation for two voltages.

this purpose. Correct polarity of the transformer is important. Base and collector windings are labeled B1, B2, C1, C2. B1 and C1 must connect to the same transistor.

Here are some of the advantages of this power source. It replaces expensive batteries and needs only a common flashlight cell. A maximum of about 20 ma is available from the regulated voltages. An aging D-cell lowers this maximum, but cannot affect the *voltage* set by a Zener diode. Contrast this with direct battery operation where the battery *voltage* begins to drop as soon as it is put to use. Like a TV flyback circuit, this one puts out a limited amount of power, so it has built-in safety. If more than 20 ma is taken from one of the regulated voltage taps, the output drops sharply. The short-circuit current is only about 1 ma. This means greater safety for the power supply itself and for the transistors you energize.

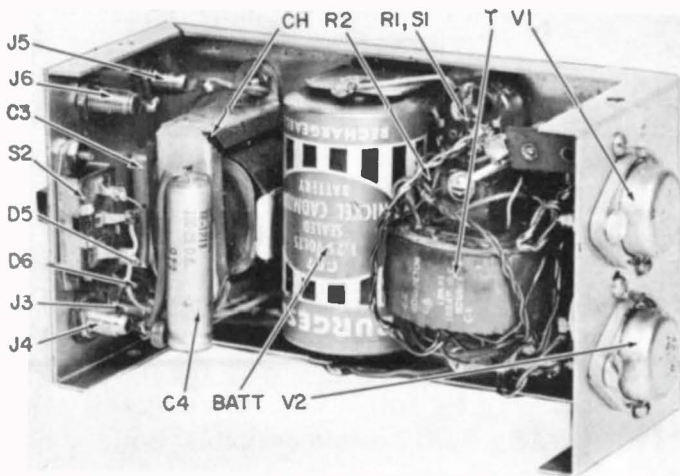


Fig. 446. The case looks crowded, but there is plenty of room for all the parts. Note the power transistors mounted on the side of the case.

At full drain, the D-cell will deliver nearly 250 ma. At light loads, the drain will be about 60 to 100 ma, which extends cell life to 30 hours or more.

If this power supply will be used often and at moderate drains,

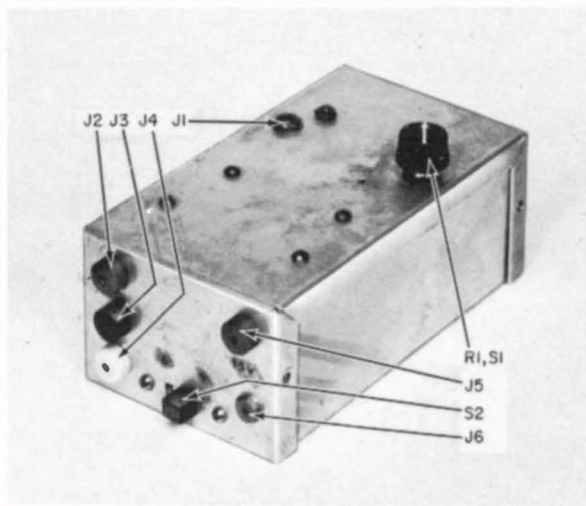


Fig. 447. The finished unit is small enough to fit in the palm of your hand.

your best bet is to use one of the new rechargeable nickel-cadmium cells. A Burgess CD-7 is very satisfactory for this applica-

tion. At 250-ma drain it lasts 10 hours before recharging is needed.

An inside view of the power supply is shown in Fig. 446. The power transistors, V1 and V2, are mounted on the outside of the case. The choke (CH) and the transformer (T) are placed at right angles to each other to minimize the interaction of their magnetic fields. They are separated by the battery.

The completed power supply appears in Fig. 447. The knob for R1, the 1,000-ohm potentiometer, is at the top of the unit. Turning this knob closes switch S1, putting the two 2N554's into action. The other switch, S2, a slide unit at the front of the case, selects either Zener diode, D5 or D6. With the slide switch in one position you can have 6.2 volts. When this switch is moved into its other position, 9.1 volts become available. Both of these voltages are regulated and are taken from jacks J2 and J3.

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