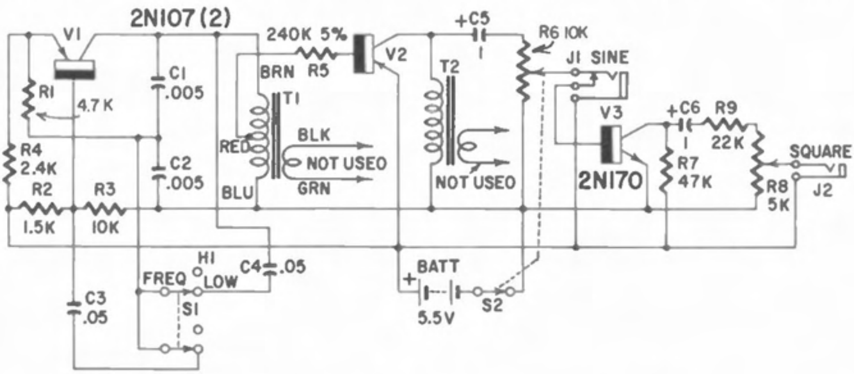
SECTION 3

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 µf disc; C3,C4—.05 µf disc or tiny tubular; C5,C6—1 µf, 6-volt electrolytic.

Transistors: V1,V2—2N107; V3—2N170.

Jacks: J1—subminiature jack (Lafayette MS-282); J2—may be same as J1 with one unused 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 4x2⅛x1½ 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 2⅛ 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-μf 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 and C2.) This is lowered when the .05-μf 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 μμf 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-

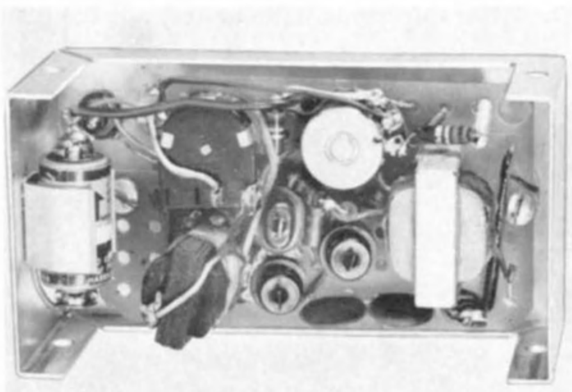


Fig. 302. *Inside view of the sine–square-wave generator.*

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 ouptut 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 2⅛ x 1½ inches. Tapped metal separators keep the board ⅜ 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.

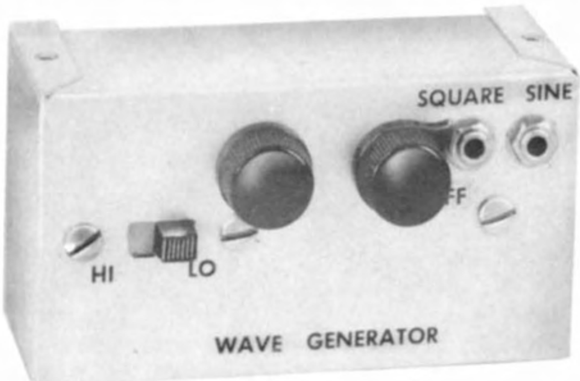


Fig. 303. *Simple in appearance, the generator has few controls.*

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).

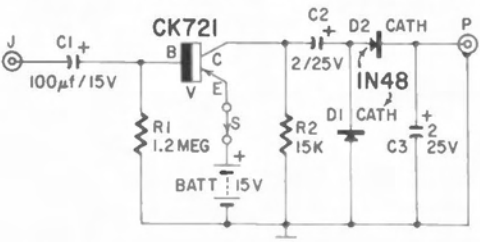
or no change in shape, we may assume that the amplifier has flat response out to 20 kc or more. If it passes a 450-cycle square wave with little distortion, it can be taken to mean flat response down to approximately 40 cycles. With experience, the technician will be able to estimate the amount of amplifier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

Capacitors: 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—spst switch; Batt—15-volt hearing aid battery (RCA VS083 or equivalent); J—banana or tip jack; P—phone plug or female microphone connector (see text); 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

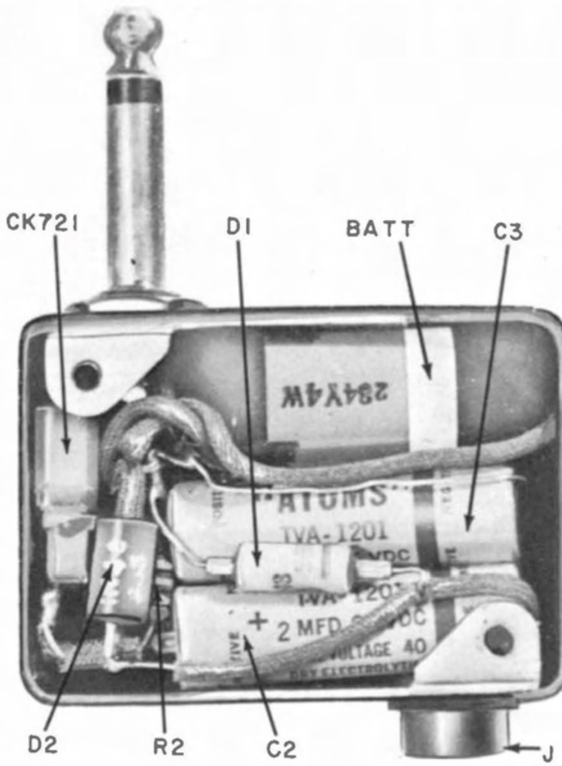


Fig. 305. *The parts for the preamplifier fill a headset adapter case.*

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 vtvm 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 vtvm's. To prepare the mike connector for mounting, file the taper off the first ½ 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 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-

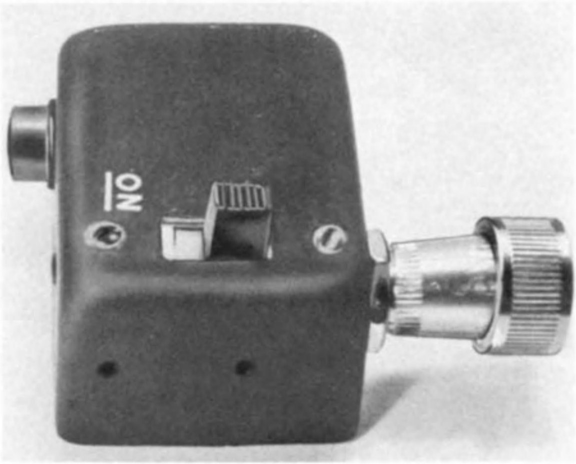


Fig. 307. *The type of connector you will need will depend on your vtvm. Some will require a phone plug; others will need a female microphone connector, as shown here.*

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.

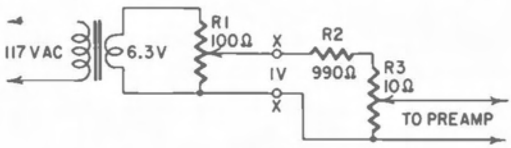


Fig. 308. *This circuit can be used to calibrate the vtvm preamp.*

Calibration

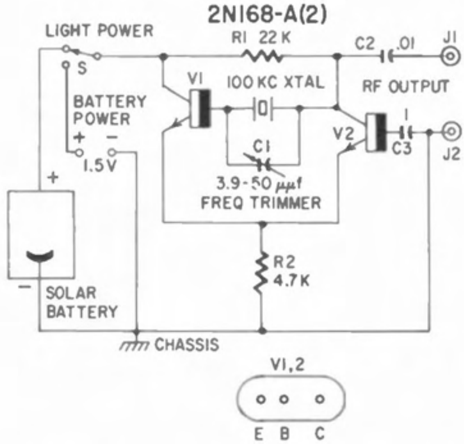
As maximum gain was desired from the preamp no attempt was made to attain linearity. A calibration card will enable the user to make precise measurements of small voltages. The frequency response of the preamp is within 1 db from 25 cycles to 15 kc, dropping to $-1\frac{1}{2}$ db at 20 cycles and -2 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-μμf trimmer (Hammarlund APC-50 or equivalent) C2—.01 μf; C3—1 μf (C2 and C3 are miniature metallized 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, 4x2x2¾ 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 μμf 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 circuit[1] 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

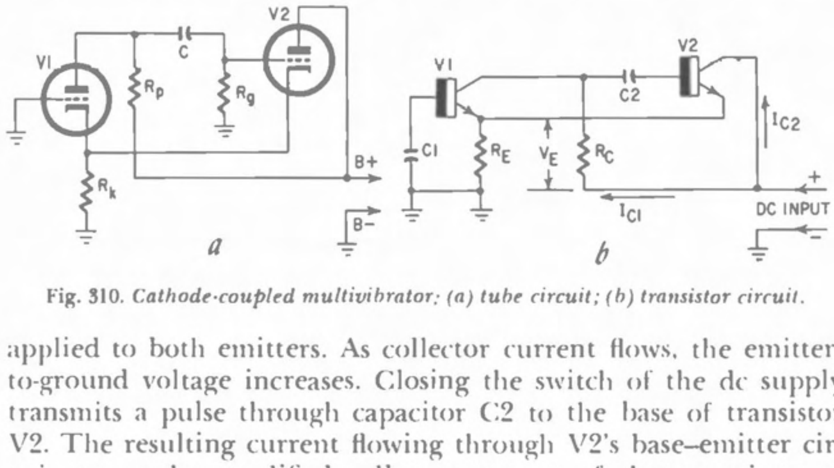


Fig. 310. *Cathode-coupled multivibrator; (a) tube circuit; (b) transistor circuit.*

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

[1]Frank 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

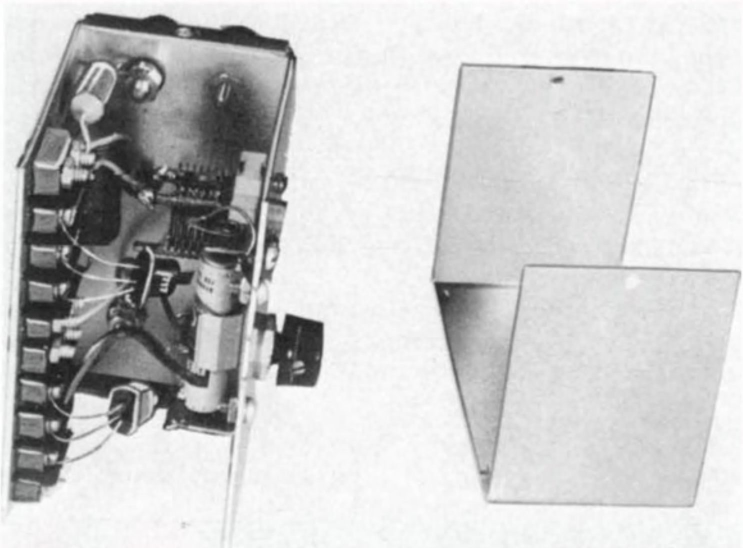


Fig. 311. *Positioning of parts in the light-powered frequency standard. Plastic or wood can be used, but a metal case is recommended.*

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.

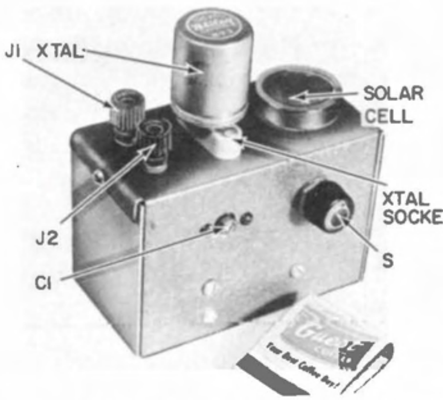


Fig. 312. *Outside view of the completed unit.*

The solar cell is 1¼ inches in diameter and 5/16 inch thick. It has a clear glass window. The crystal can is 1 inch in diameter and 1-5/16 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 x 2 x 2¾ 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 ¼-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 ¼-inch clearance hole. The negative terminal is fastened directly to the box.

A ⅜-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 ¼-inch clearance holes are required for the terminal lugs of the ceramic crystal socket. The shank of switch S requires a ⅜-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.

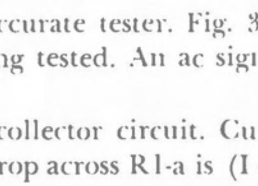


Fig. 313. *Basic circuit of the gain checker.*

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.

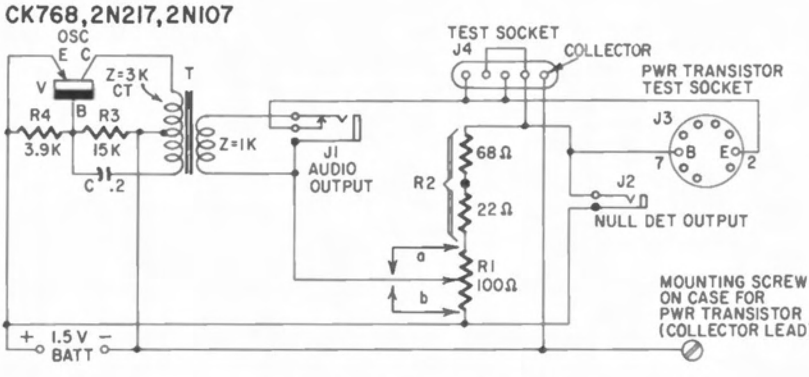
Amplified current (aI) flows in the collector circuit. Current through R1-a is (I − aI), so the voltage drop across R1-a is (I − aI) times R1-a and the drop across R1-b is aIR1-b. (Note that R1-a and R1-b are simply two parts of the potentiometer, and vary with the position of the center arm.) If the resistors can be adjusted for no voltage across the total resistance (R1-aR1-b), we have

$$(I - aI)\ R1\text{-}a = aIR1\text{-}b$$

and a little mathematical manipulation shows that

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

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



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, 1¾x1¾ 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

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

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

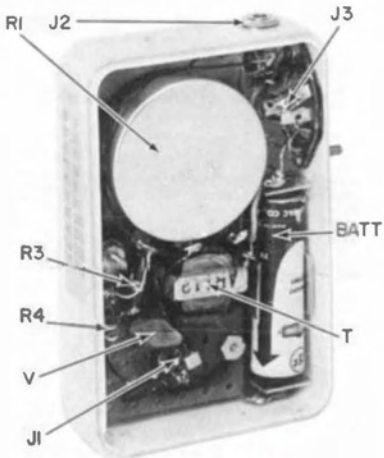


Fig. 315. *Interior view of the gain checker. The unit can also be used to test power transistors.*

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

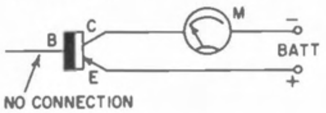


Fig. 316. *Simple circuit for measuring leakage.*

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

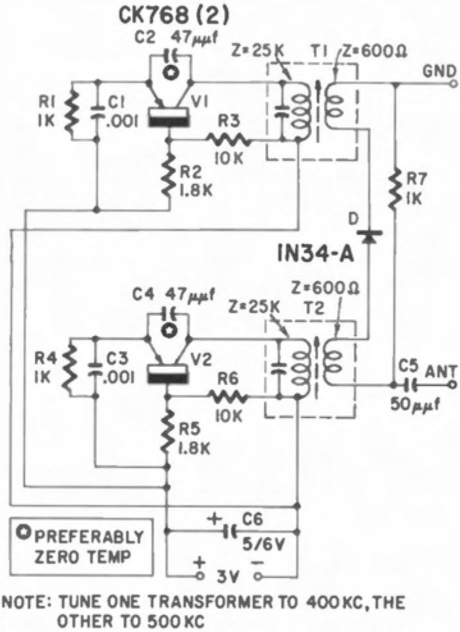
Fig. 317. *The completed gain tester. The unit also supplies an audio signal for external use.*

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.



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 μμf, zero temperature coefficient; C5—50 μμf, 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

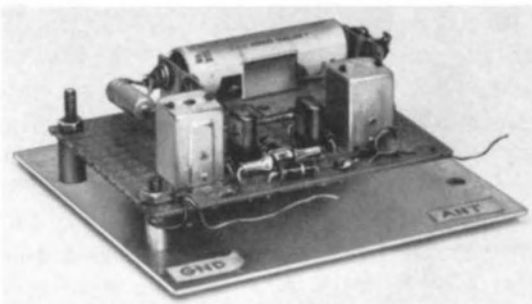


Fig. 319. *The entire calibrator is mounted on a phenolic board.*

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 ½-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 if transformer (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 if 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 μμf) 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

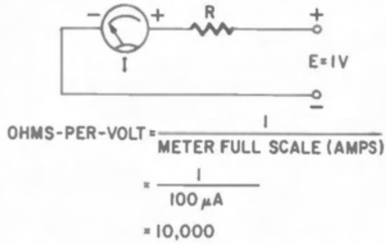
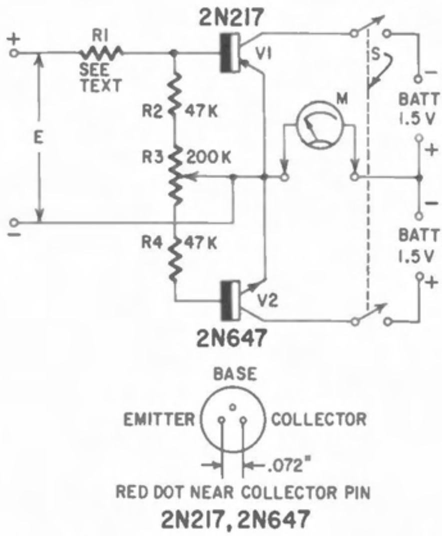


Fig. 320. *Method for calculating the sensitivity of a meter in ohms per volt.*

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 vtvm 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, ½ watt; R3—200,000-ohm potentiometer.
Transistors: V1—2N217; V2—2N647.
Miscellaneous: Batt 1, Batt 2—1.5 volt pen-light 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.

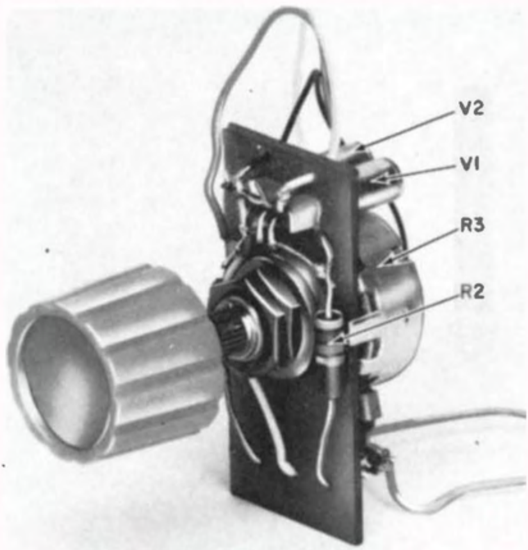


Fig. 322. *Complete assembly of the meter sensitivity multiplier.*

To use the adapter, zero the no-signal current by adjusting R3 and connect the unit to a dc microammeter. 20- to 200-μa meters were tried successfully in this project. With a 100-μa meter, R1 must be approximately 400,000 ohms to reach full-scale deflection with 1 volt. With a 50-μa 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.

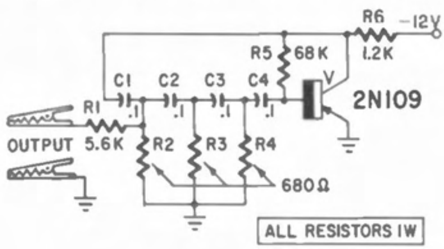
In the assembled unit shown in Fig. 322, V1 is the 2N217 and V2 is the 2N647. The 2N217 that was used had a beta of about 70. The 2N647 measured only about 45.

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 μf, 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

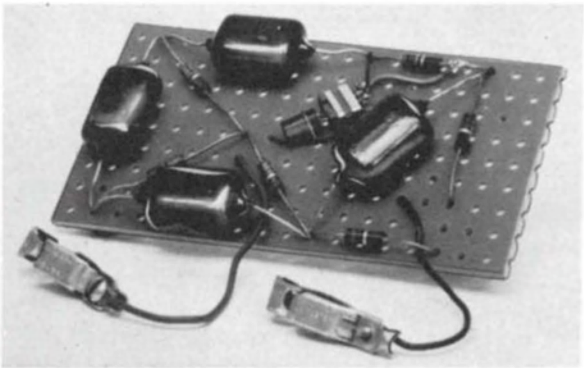


Fig. 324. *The phase shifter is easily and quickly mounted on a small section of pegboard.*

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 μf 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 μa, 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.

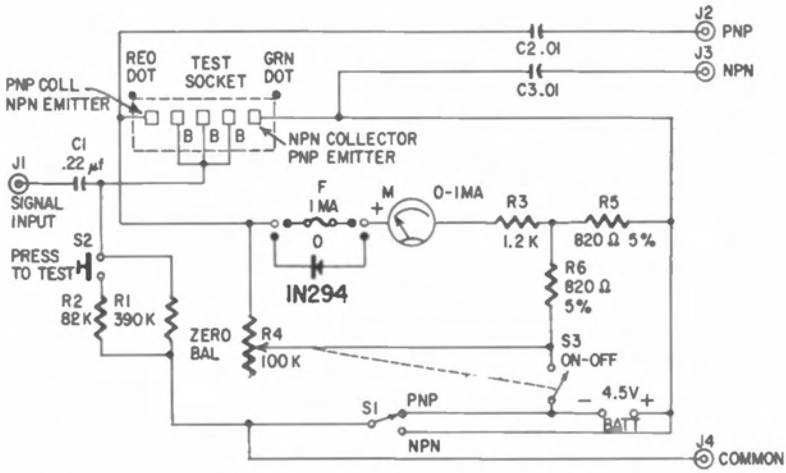
$$\text{Beta} = \frac{\text{change of current in collector}}{\text{change of current in the base}}$$

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, pushbutton, 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 μa, 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.)

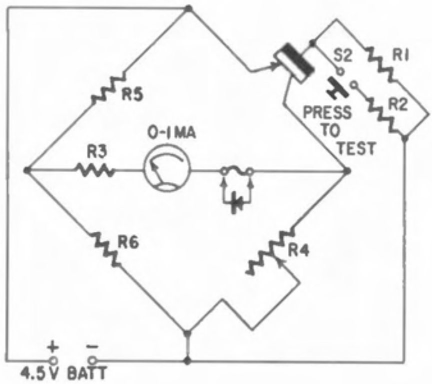


Fig. 326. The rearrangement of the components in Fig. 325 into this form shows that it is a bridge circuit.

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

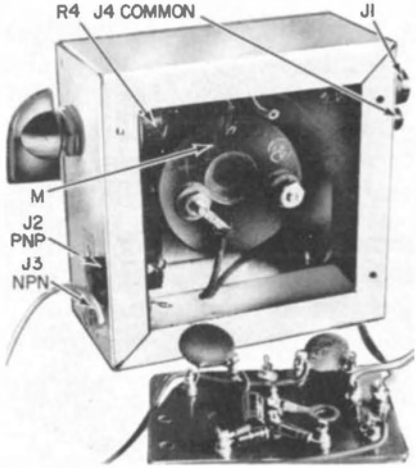


Fig. 327. The checker can be used to learn whether a transistor is a p-n-p or n-p-n type.

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.

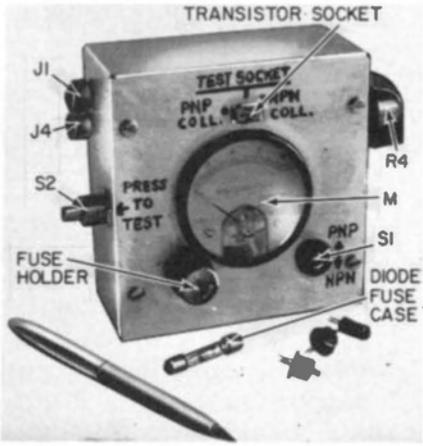


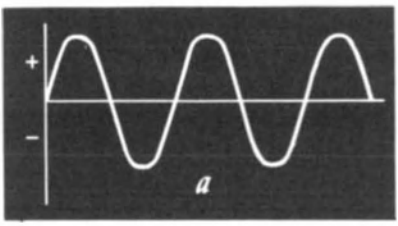
Fig. 328. *Because of the greater variation among transistors than among tubes, a transistor checker is more necessary than a tube tester.*

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



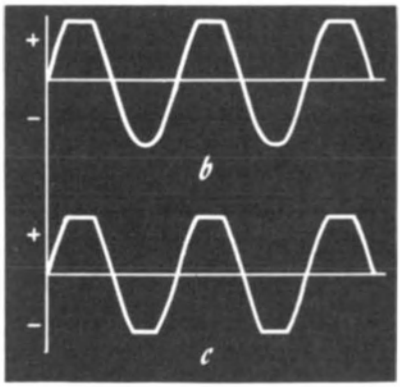


Fig. 329. *Waves clipped at the top (b) or top and bottom (c) are an indication of overloading. When this occurs, reduce the output of the generator until a sine waveform (a) is obtained.*

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.

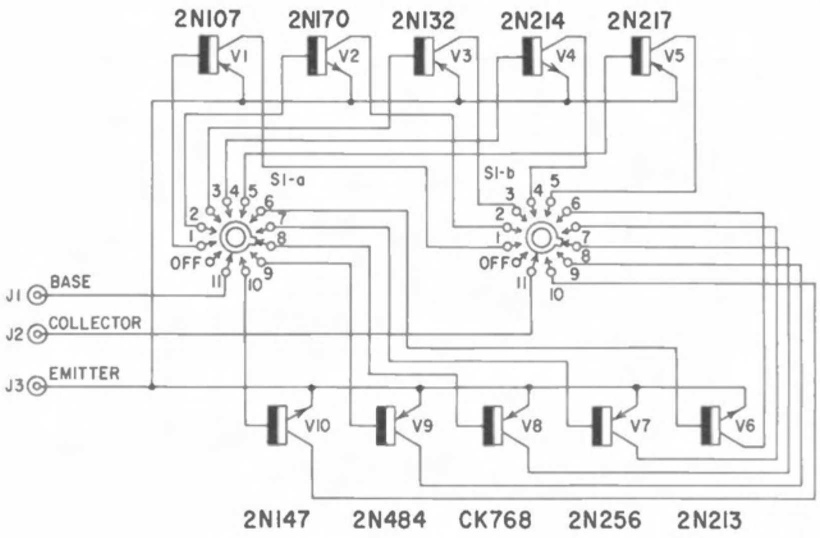
When a scope is used, connect the vertical amplifier to either the PNP or NPN outlet and to the COMMON terminal. Use as little gain as possible at the signal generator. The scope provides the only method of determining the type of wave being amplified by the transistor. Fig. 329-a shows the types of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



parts list for substitution box

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

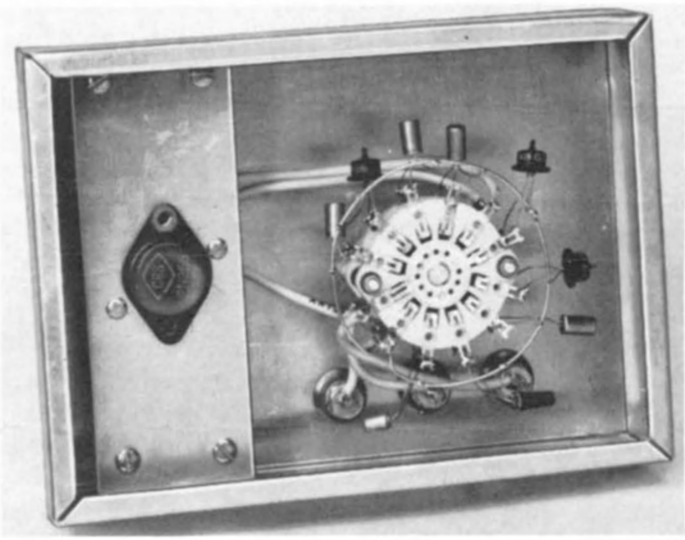


Fig. 331. *Inside view of the transistor substitution box.*

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.