radio test instruments

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Radio Test Instruments

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electronic voltmeters

preface

FOR RELIABILITY, compactness and ruggedness, the radio man always will rely chiefly on commercial test apparatus. The individual experimenter seldom will achieve more effective design or execution than the engineering staffs of the larger and more reputable instrument concerns. Yet there remain many cases where he may wish to supplement his test instruments with self-constructed apparatus. A stand-by instrument may be required for use in the shop while the regular one is out on a job, or conversely, a small portable instrument may be needed for outside use, permitting the commercial equipment to remain on the bench. Old equipment may be available, from which a piece of modern apparatus may be built for a minimum of cost. The serious experimenter may wish to construct a complete line of instruments, as much for the experience and instruction their building will give him as for the instruments themselves.

A selection of test instruments suitable to cover all the above requirements is presented in this book. It ranges from small portable volt-ohm-milliammeters to bench-type tube testers.

Building test equipment is a job for the skilled man, therefore detailed construction information has been abridged or omitted in many cases. The reader who would require such instructions probably would not achieve notable success even should he follow them absolutely. Material on the operational theory of the instruments included in a few of the descriptive items probably will be more interesting to the advanced experimenter than to the practical serviceman.

A VERSATILE TESTER

MUCH ROUTINE laboratory work consists of making d.c. and a.c. voltage and current measurements, rough checks of resistance, and measuring r.f. and a.f. voltage. The instrument to be described is a single unit covering all these requirements.

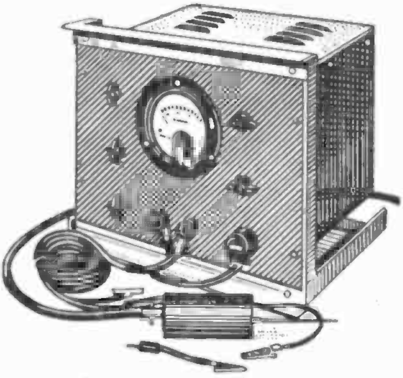
The ranges covered are:

Voltage, d.c. and a.c.: 0-1, 0-100, 0-500, 0-1,000.
Current, d.c.: 0-1, 0-10, 0-100 ma, 0-1, 0-10 amp.
Current, a.c.: 0-10, 0-100 ma, 0-1 amp.
Resistance: 0-10,000 ohms, 0-1 megohm.
Electronic Voltmeter, r.f. and a.f.: 0-1, 0-10, 0-100 volts.
Electronic Voltmeter, d.c.: 0-5, 0-50, 0-500 volts.

A 0-1 ma meter is used for all measurements. There are two scales, the lower graduated for resistance ranges and the upper divided linearly and numbered 0-5 and 0-10 for all other ranges.

Two twelve-position switches are used for selecting all ranges (see Fig. 1). The other controls are two zero-setters for the resistance ranges and one for the tube voltmeter.

As a 1-ma movement is used, all ranges have a resistance of 1,000 ohms per volt. In Fig 3-a, if V volts produce full-scale deflection, and the resistance of the meter movement is *r* ohms, the required series resistance, R ohms, is given by R = 1,000 V — *r*.



Complete versatile tester.

In the meter used, *r* is 118 ohms and can be neglected on all ranges except perhaps the lowest.

The meter movement alone is used for the 1-ma range; for 10 ma a shunt resistance of value $\frac{r}{9}$ ohms is switched across the meter and on the 100-ma and higher ranges a tapped shunt is used. See Fig. 3-b. The advantage of this method is that on the high-current ranges, accuracy of calibration is not affected by variations in switch contact resistance.

Resistance values in Fig. 3-b are given by:

$$R1 = \frac{r}{9{,}900};\ R2 = \frac{r}{1{,}100};\ R3 = \frac{r}{110}.$$

In this case $r = 118$ ohms, hence, R1 = 0.012 ohms; R2 = 0.108 ohms; R3 = 1.08 ohms. The formulas above will give the correct values for other meter resistances.

Details of tapped shunt resistors

The 10-ma range shunt resistance has a value of 13.1 ohms, and is made up of double-silk-covered resistance wire of suitable size. Fig. 2-a gives dimensions of a suggested form, and shows the method of twisting the tinned copper wire terminal tags.

The tapped shunt resistor R1 consists of two 5-inch lengths of No. 14 AWG bare resistance wire in parallel, mounted on the switch wafer. The resistance is adjusted by running solder along the wire. R2 and R3 were made of No. 21 wire, cut to the correct lengths, and are mounted on the same form. Fig. 2-b. These resistors should be adjusted by comparing the meter reading with that of an instrument that is known to be accurate, rather than adjusting to calculated values.

A 1-ma meter rectifier is used. See Fig. 3-d. The d.c. output from this type of meter rectifier is proportional to the mean value of a.c. input. for a sinusoidal wave form, on which most measurements are made, r.m.s. value = 1.11 × mean value. From the manufacturer's data, the potential drop across the a.c. terminals of a 1-ma rectifier is 0.9 volt, for a meter current of 1 ma. Hence, the series resistance R ohms required for V volts r.m.s. full-scale deflection is

$$R = \frac{V - 0.9}{0.001} \times \frac{1}{1.11} = \frac{1{,}000\ V - 900 \text{ ohms}}{1.11}.$$

Therefore, R for 10 volts full-scale deflection = 90,000 ohms.

R for 500 volts full-scale deflection = 450,000 ohms.

R for 1,000 volts full-scale deflection = 900,000 ohms.

The 0-10 volt range should be calibrated against an accurate meter, as the scale is non-linear due to the measured voltage being comparable with 0.9 volt, the potential drop across the rectifier. From the maker's data, the output of the rectifier is uniform for frequencies up to 10 kc.

A current transformer is used in conjunction with the meter rectifier. See Fig. 3-e. The ranges covered are 0-10 ma, 0-100 ma and 0-1 amp.

As a current of 1.11 ma is required from the secondary to give full-scale deflection on the meter, the turns ratios, not allowing for losses, are as follows:

1-amp range, ratio = 1,000/1.11 : 1 = 900 : 1,
100-ma range, ratio = 100/1.11 : 1 = 90 : 1,
10-ma range, ratio = 10/1.11 : 1 = 9 : 1.

For linear scale-shape, the voltage drop in the secondary winding should not be more than 0.1 volt. Hence the maximum permissible resistance of the secondary is $0.1/1.11 \times 10^{-3} = 90$ ohms. To keep the secondary turns as low as possible a single-turn primary winding is used on the 1-amp range; thus the secondary turns are 900. To keep losses low the stampings must be made of a high-permeability material. A set of stampings was available with the following dimensions.

Core, ¾ in. square, *Over-all size of stamping,* 1⅞ in. × 2¼ in.
Winding area, 1 in. long by 0.3 in. deep.
Weight of set of stampings, ¾ lb.

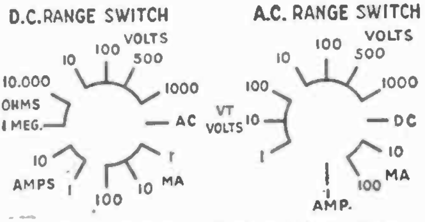


Fig. 1—Settings of 12-position range switches.

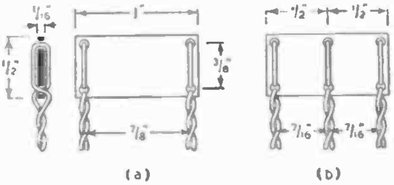


Fig. 2—Mounting forms for shunt resistors. (Fig. 3 on page 9).

It was found that, to allow for iron loss, the secondary turns should be reduced to 880; 34 AWG e.s.s. (enamelied and single silk) copper is used for the secondary, giving a resistance of 70 ohms. The primary windings are:

10-ma range, 100 turns 34 AWG enamel or e.s.s.
100-ma range, 10 turns 26 AWG enamel or e.s.s.
1-amp range, 1 turn 19 AWG enamel.

The secondary is wound on first and the other windings in the order shown above. There are two layers of empire cloth between the secondary and the primaries and one layer between each primary. The stampings are interleaved.

There are two ranges, covering resistance values from 10 ohms to 1 megohm. The fundamental circuit is shown in Fig. 3-f.

If the meter, of which the resistance and full-scale deflection are r ohms and i ma respectively, is connected in series with a resistance of value R ohms across a voltage V, then, for full-scale deflection (with "Test" terminals shorted):

$$R + r = \frac{1{,}000\,V}{i}. \qquad (1)$$

If now a resistance R′ ohms is connected across "Test," then its value for half-scale deflection of the meter is given by:

$$R' + R + r = \frac{1{,}000\ V}{0.5\ i}. \qquad (2)$$

From equations (1) and (2):

$$R = R' - r$$

$$\text{and } V = iR' \times 10^{-3}.$$

In this instrument, $r = 118$ ohms, $i = 1$ ma and the mid-scale readings are 500 ohms and 50,000 ohms; hence the values of R are 382 and 49,900 ohms respectively; the corresponding values of V are 10.5 and 50 volts. These voltages are supplied from a line-operated power pack by means of a voltage divider network, the tappings being variable over a small range to provide zero-ohms adjustment. The internal resistance of the supply should be small compared with $(R + r)$. In this case, the internal resistances are 15 and 700 ohms respectively.

High-frequency diode rectifier

A small high-frequency diode (such as a 6AL5) is housed with its associated smoothing components in a cylindrical container; this is connected to the main instrument through about a yard of 3-conductor cable. A 6H6 would be quite suitable for all but the highest radio frequencies. A 5-pin plug and socket are used for the connection on the front panel. For the very highs one of the germanium crystals such as the 1N34 would make an interesting and probably an excellent rectifier for the probe, and would simplify cable design at all frequencies. However, the 1N34 had not been released at the time this instrument was made.

The rectified voltage from the diode head is applied to a meter control tube, the supply voltages for which are taken from the power pack. A potential-divider circuit across the B supply voltage is used to "back off" the meter. Fig. 3-g. The range is changed by tapping down the diode load resistance. The standing current through the diode produces a small voltage across this resistance; this voltage applies a negative bias to the grid of the control tube, the value of which depends on the setting of the range switch. This would necessitate resetting the zero when the range is changed. Automatic compensation for this is provided by shunting the lower end of the power pack voltage-divider by R3 on the 10-volt a.c. and 50-volt d.c. ranges, and R4 on the 1-volt a.c. and 5-volt d.c. ranges.

The d.c. ranges were originally the same as the a.c. (0-1, 0-10, 0-100 volts) but trouble was experienced when the tube voltmeter was connected across a low-resistance circuit, as this reduced the standing bias due to the diode, thus altering the zero setting. The simplest method of eliminating this effect is to use a large resistance (R2) in series with the input; this forms a potential divider with the diode load and therefore reduces sensitivity. R2 is chosen to give ranges to fit in with the calibrated scale: 0-5, 0-50, 0-500 volts.

As the input resistance on the d.c. ranges is high, approximately 13 megohms, the shunting effect on a high-resistance source of voltage is small.

In high-resistance circuits it is advisable to measure only voltages

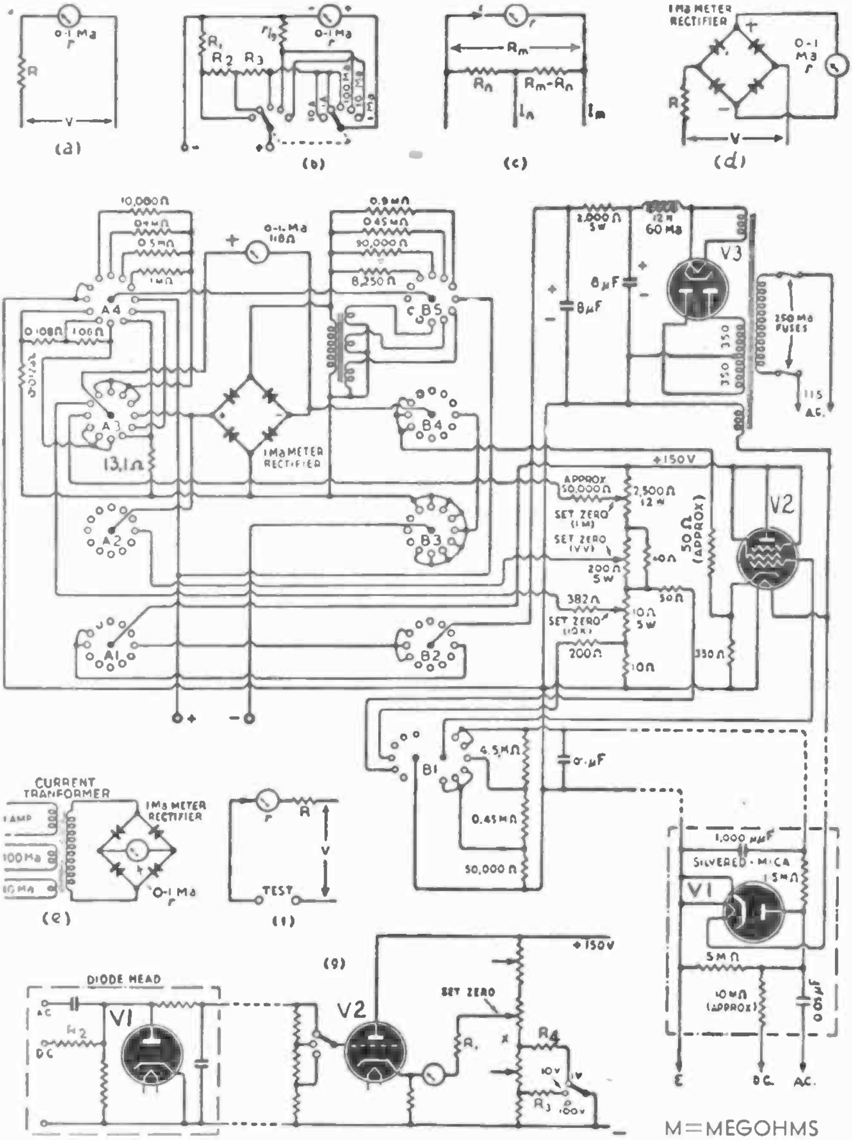


Fig. 3—Circuit of the multitester—basic circuits across top; complete diagram in center; bottom—complete details of v.t.v.m. and a.c. milliammeter.

of which the positive side is grounded; if the negative side of the source is grounded, the leakage resistance and capacitance of the high-voltage line to the chassis are shunted across the source, as the negative side must be connected to the "live" lead of the tube voltmeter.

The 10- and 100-volt a.c. and 50- and 500-volt d.c. ranges are substantially linear, and no further calibration is required. For greatest accuracy on the 1-volt a.c. and the 5-volt d.c. ranges separate calibrations should be made; this is due to the non-linear characteristic of the diode.

The frequency characteristic is flat between 50 cycles and 50 mc. It was not measured above 50 mc, but the error is probably small up to at least 100 mc with the high-frequency diode used.

The meter control tube is a high-mu r.f. pentode, similar in characteristics to the 6J7, connected as a triode.

If a voltage much larger than full scale is applied to the input, the current through the 1-ma meter does not exceed about 2 milliamperes; most meters can withstand this overload momentarily without harm.

Adjustment of resistor for 7.5-volt a.c. range

Adjustment of resistors is carried out as follows:

(1) Meter series resistance R1 to give 1-volt full-scale deflection on most sensitive a.c. range.

(2) Input resistance R2 to give 5-volts full-scale deflection on most sensitive d.c. range.

(3) Compensating resistances R3 and R4 adjusted so that the zero-setting does not change on the 10-volt and 1-volt a.c. ranges respectively when switching from the 100-volt range.

The complete circuit is shown in Fig. 3. It will be seen that there are two switch-wafer banks A and B. A consists of four single-pole 12-way units and B of one two-pole 6-way and four single-pole 12-way units. A is the d.c. range selector and B the a.c. A1 and B1 are mounted nearest the front panel. A3, A4, B4, B5 switch the various ranges, A1, A2, B2, B3 ensure that the h.t. supply voltage to the tube voltmeter and ohmmeter is switched on only in certain positions, and B1 selects the tube voltmeter ranges and switches the tube voltmeter zero-set compensating circuit.

The chassis is fixed to a vertical frame-mounted front panel. The front panel is 9 in. by 12 in. and the chassis 8 in. by 10 in. A detachable cover is held by two screws on the vertical frame members.

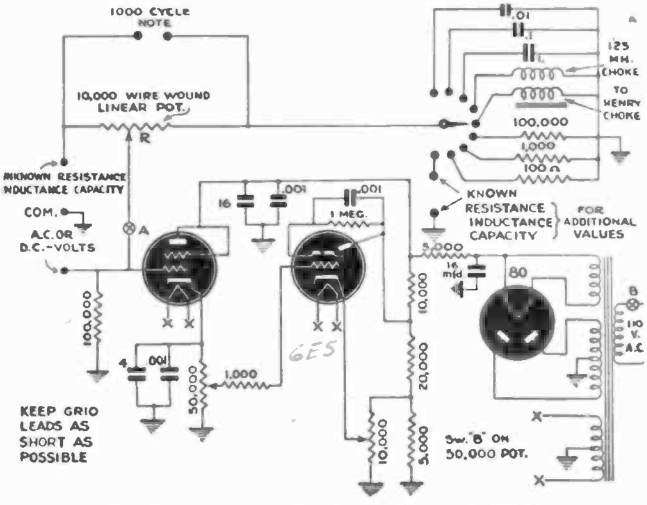
The diode head consists of two discs of insulating material of diameter 1⅝ in. held together by two 3/16 in. brass pillars, 3 in. long. A length of plastic tube slides over this assembly, and is fixed by screws into the insulating discs. One of the discs has two tip-jacks, one for a.c., the other for d.c.; either a flexible lead or a rigid prod can be plugged into these jacks, according to the type of work in hand. The ground connection is a permanent short flexible lead terminating in a crocodile clip, which can conveniently be attached to the nearest part of the chassis.

The 0.05-μf diode input coupling condenser should have a high resistance and a low inductance; the tubular type with wire ends fits best into the small space available. It should be remembered that the working voltage of the condenser must be high enough to withstand the d.c. component when measuring an r.f. voltage at the plate of a tube. The condenser leads are as short as possible, and thus it is connected directly between the a.c. input socket and the diode plate circuit.—*Wireless World, London*

ELECTRONIC MULTICHECKER

THIS MULTICHECKER can be used for a large number of tests and measurements on resistors, capacitors, and inductors. In addition, it is an a.c. or d.c. voltmeter.

All bridge measurements are made with the potentiometer R, which must have a calibrated dial. Voltage measurements are made with the 50,000-ohm resistor in the cathode circuit of the meter tube, which may be a 6K6 or similiar output pentode, tetrode, or even triode. This control must also have a graduated dial, calibrated with known voltages. Separate calibration for a.c. and d.c. scales is necessary.



Circuit diagram of the electronic multichecker.

To calibrate, set the 50,000-ohm potentiometer to just close the "eye" of the 6E5 tube with the Volts and Common terminals shorted, and mark this point zero. Then apply known voltages, turn the potentiometer to where the eye again just closes, and mark the voltage. To measure unknown voltages, simply repeat the process and read the voltage from the calibrated dial. A 1,000-cycle note may be provided by a vacuum-tube oscillator, as described under "Capacity Bridges" on page 35.

A COMPACT MULTITESTER

THIS TESTER is a genuine junk-box job, built from what parts were available, and for that reason may be unconventional in spots.

It measures voltages from 5 to 500 in ranges of 5, 10, 50, 100 and 500 d.c., and from 7.5 to 750 in ranges of 7.5, 15, 75, 150 and 750 volts, a.c. Current ranges of 1, 10, 50, 100 and 200 milliamperes are provided, and there are three ohmmeter ranges, permitting measurement of resistors from 1 to 300,000 ohms. With the help of a 0.5-μf condenser, it acts as an output meter and can be used as such in aligning receivers.

The multitester was built around a Ferranti 1-ma meter, a d.p.d.t. toggle switch, a cheap copper-oxide rectifier, and a two-gang, 12-point switch.

Although there is a tendency toward lower and still lower-reading meters, there have been no difficulties in the use of this instrument. Most readings that cannot be made with it require a vacuum-tube voltmeter. The important thing is to know what you are measuring and *to consider the possible effect of the meter on the measurement.* Then you cannot be misled by the readings.

Steps in construction

Mount the meter first, then the pin jacks, the variable resistor for ohmmeter, the zero adjustment, the toggle and gang switch, and the rectifier. The meter is then connected to the center arms of the d.p.d.t. switch, and the incoming a.c. and d.c. leads are connected to the arms of the gang switch.

This hookup makes it possible to get both a.c. and d.c. readings with a two-gang switch, and is one of the reasons why we can get 18 ranges with 11 switch positions.

It was necessary to provide three sets of pin jacks in order to cover all the ranges. Those on the left are a.c. voltages. The pair on the right cover d.c. voltage and current, and two ohmmeter ranges; while the two at the top of the meter are used for measuring low-ohms and for the 1-ma scale.

A connection from the a.c. switch arm to the d.c. negative jack makes it possible to use the switch for milliammeter and ohmmeter readings.

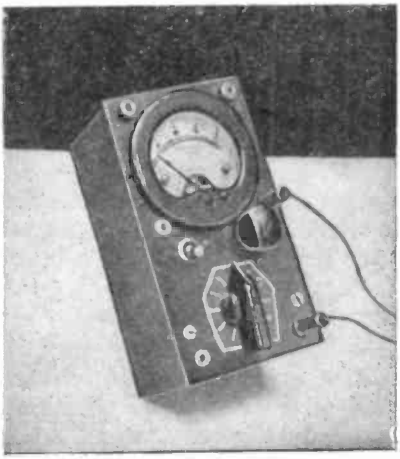
With the exception of the five a.c. voltage ranges, all readings are d.c. The change from one to the other is made by the toggle switch, the "up" position covering a.c. voltages, and the "down" being used for all other tests.

The next step in the construction of the meter was wiring up the voltage ranges. The voltmeter resistors are calculated, according to Ohm's law, at 1,000 ohms per volt. The 500-volt range uses a 500,000-ohm resistor, the 100-volt range a 100,000-ohm resistor, etc.

Analysis of current flow is as follows: With the positive d.c. test lead on the positive terminal of the voltage source and the negative d.c. lead on the other side, the current course is: to the d.c. switch arm, through the resistor selected by it, and down the common positive lead through the d.p.d.t. switch to the meter, and directly to the negative terminal. (Note well that this is the old-fashioned current that moves from positive to negative, not the new radioman's electronic stream, which always goes in the opposite direction!)

The arrangement on the a.c. side is a little different. The resistors are only 90 percent of the value calculated by Ohm's law. This is because a d.c. meter reads only 90 percent of the *effective* value of rectified alternating current. By cutting down on the resistors, we compensate for this, and the meter reads the same on a.c. as on d.c.

Before a.c. readings can be taken, the meter has to be switched across the rectifier, REC., using the d.p.d.t. switch. Analysis of current is as follows: With the switch in the a.c. position ("up"), alternating current enters through one of the a.c. pin jacks to the a.c. switch arm, through the selected resistor, to the rectifier and out the other a.c. pin jack terminal. The *rectified component* of this current then goes through the meter and completes its circuit back to the rectifier.



This multitester has a wide range.

The set was calibrated over the various scales by comparing with a standard for one of the ranges—then making the other ranges agree with it. The value chosen for the a.c. ranges was 120 volts. This point can be found readily, either from the local electrician, a laboratory, or a trip to the nearest power station. Setting this at 0.8 on the meter (150-volt scale—all readings multiplied by 150) we have a zero to 150-volt scale. It is then possible to adjust the 75-volt scale. A voltage that reads full scale on it will read 0.5 on the 150-volt scale. One hundred and fifty volts reads full scale on the range where we have the 120-volt point, and 0.2 on the 750-volt scale.

It is usually easy to get a standard for the d.c. scales, but if no accurate voltmeters are available a rough calibration may be made with two good B-batteries—assuming the voltage to be 90.

The actual adjustments were made chiefly with a file. It was necessary to save as much space as possible, so resistors of odd values could not be made up of two or three units. If it was necessary to have a 45,000-ohm resistor, a 40,000-ohm carbon resistor was chosen and filed down till the meter calibrated properly. A few wire-wound Davohms which were left from some ancient resistance-coupled amplifier were used to good advantage, all the low-range resistors being wound from them. It was possible to wind them to the exact resistance without trouble, and they were very compact.

The 7.5-volt resistor on the a.c. side cannot be wound according to calculations, at least not with the rectifier used in this set. The rectifier itself has so much resistance that it is necessary to wind the external resistor experimentally, increasing the resistance from zero till the meter calibrates correctly.

A certain lack of linearity was evident on this range, so the resistor was adjusted to give readings as near correct as possible at 6.3 and 2.5 volts, the other points being let fall where they would. This was the only scale where non-linearity of the a.c. readings gave any trouble. The reason was, no doubt, that most of the resistance in this scale was in the meter rectifier, so that small changes of rectifier resistance caused large percentage differences in the circuit. On the higher ranges practically all the resistance in the circuit is in the external resistor, and errors introduced by the rectifier are negligible.

The ohmmeter circuit

The high-ohm range reads to about 200,000 ohms. Voltage is supplied by three large flashlight cells, which have lasted more than three years.

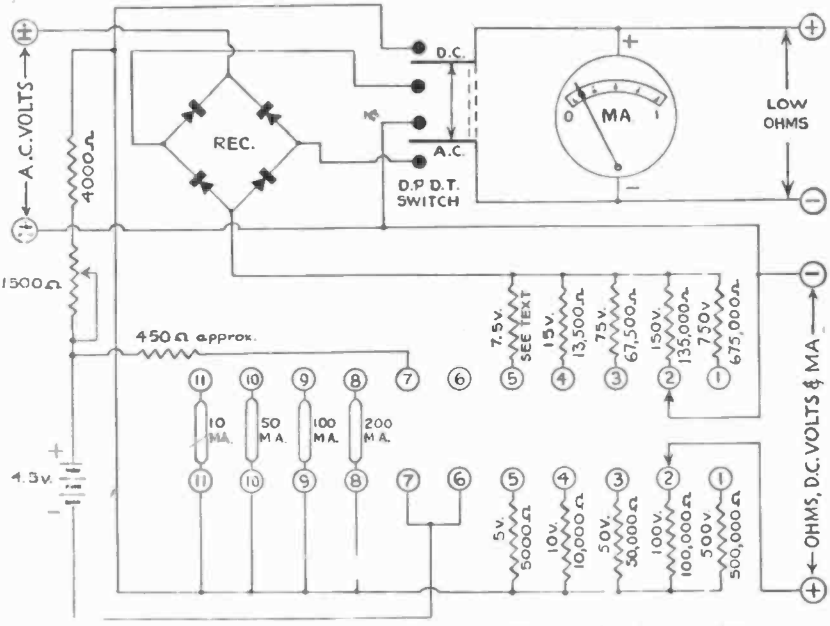
The current flow in the ohmmeter circuit is as follows: From the positive terminal of the battery through the 1,500-ohm variable resistor, through the fixed 4,000-ohm resistor, through the meter, and out the negative terminal to and through the resistor to be measured. Then back to the positive d.c. pin jack and through point 6 on the gang switch, to the negative end of the battery.

The medium range was made by shunting a resistor of slightly more than 450 ohms (made from the old Davohm) across the variable and fixed resistors and the meter. Now the current has two paths, the same one as before, and a new one—through the shunt, through the resistor under test, and back to the battery. By carefully removing turns of resistance wire from the shunt till it reaches the right value, the medium-ohms scale can be made to fall right on top of the high-ohms scale; 1,000 ohms on the medium being the equivalent of 10,000 on the high. Nine-tenths of the current from the battery goes through the shunt and the unknown resistor, and only one-tenth goes through the circuit with the meter in it.

Low-ohm resistors are measured across the pin jacks at the top of the instrument. These are connected directly to the positive and negative terminals of the meter. The d.c. positive and negative pin-jacks are short-circuited and the zero adjustment made with the 1,500-ohm variable resistor. Then the unknown low-ohm resistor is connected to its jacks.

The meter is a shunt-type instrument when used on this range, and the readings are in the opposite direction from those of the high-ohm and medium-ohm ranges. The low-ohm range was calibrated in a few minutes with the help of a decade box with resistors from 1 to 1,100 ohms, in 1-ohm steps.

These two terminals are also used for the 1-ma scale. To avoid possible accident, the switch may be turned to one of the high-voltage scales during measurements on this range.



Simple circuit of the versatile multitester, built around a 1 ma meter.

Points 8 to 11 on the gang switch are milliampere ranges. The internal resistance of this meter is 60 ohms. This was discovered by setting the meter to full scale with the help of a variable resistor and a dry cell, then shunting various resistances (from the decade box) across the meter terminals till it dropped to half scale. Since half the current is flowing in each circuit, the external resistor must be equal to the resistance of the meter, and the external resistance reading was 60 ohms.

To get a reading of 10 milliamperes we need 10 current paths, each one with the same resistance as the meter. Then one-tenth of the current, or 1 ma will flow through the meter and the other nine-tenths will flow through the external shunt. In other words, to get a 10-ma reading (or to multiply the meter range 10 times), we have to have a shunt 1/9th the resistance of the meter. To multiply the meter range 100 times, the shunt would have to be 1/99th of the meter resistance, etc.

Our 10-milliampere shunt, by this calculation, had to have a resistance of 6.67 ohms. The 50-milliampere shunt (1/49th the resistance of the meter) was roughly 1.2 ohms. These were cut to the approximate size from a spool of fine nichrome, and adjusted till they were right. Nichrome wire was used for all the shunts, several of the fine wires being twisted into a cable for the higher ranges.

Copper wire could have been used, but it changes resistance with changing temperature, and the nichrome made shorter and smaller shunts possible. It is hard to solder, so the connections were made by twisting the nichrome wire around the lugs of the switch firmly to make a good electrical connection, then flowing in solder and rechecking to see that the conductivity of the shunt had not been changed by the soldering. The connection between the solder and the nichrome is purely mechanical, so the contact lugs must be well cleaned and thoroughly soldered.

One of the pin jacks at the top was originally connected to the top a.c. terminal through a condenser and used for output measurements. The output meter was abandoned in favor of the low-ohm range. When it is necessary to measure output, the meter is connected up to the output circuit under test through a 0.5-μf condenser, and the switch set for the a.c. range which gives the best results.

It will be noted that no marks were made on the scale of the meter. It is marked with only one range—0 to 1 milliampere, calibrated at 0.1, 0.2, etc., ma. For the 10- and 100-volt or milliampere scales, the reading is direct. Readings are multiplied mentally for the other scales required.

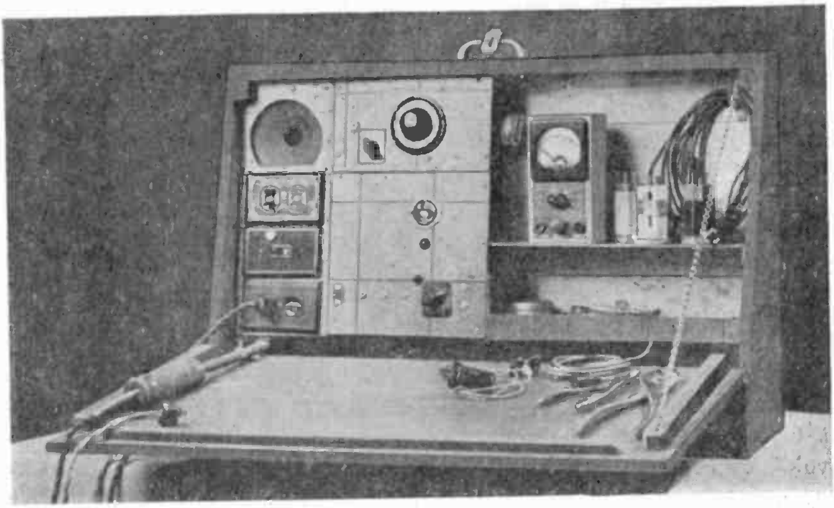
The same is true of ohms. A chart giving the ohms for each milliampere reading on the scale is attached to the bottom of the meter. This is good for the high- and medium-ohms scale. The low-ohms scale, not so often used, is kept on a piece of paper in a drawer. A typewritten chart was found more convenient than a graph. Attached to the bottom of the meter is a sheet showing the range for each setting of the switch. One ma is read directly from the low-ohm tip-jacks.

D.C. "DOWN"	Switch Position		A.C. "UP"
1	500 volts	750	1
2	100 volts	150	2
3	50 volts	75	3
4	10 volts	15	4
5	5 volts	7.5	5
6	High Ohms		–
7	Medium Ohms		–
8	200 ma		–
9	100 ma		–
10	50 ma		–
11	10 ma		–

PORTABLE SHOP

THIS SIMPLE carrying case contains a complete service laboratory comprising a signal tracer, audio amplifier, vacuum-tube voltmeter and condenser tester. Ample space for storage of tools and parts is provided, outlets for plugging in radios or other equipment are available, and the open lid of the case itself can be used as a bench.

The audio channel (Fig. 2) consists of a 6SQ7 and a 6V6. By throwing a switch, the output stage is cut out and a 6E5 electron-ray tube connected in its place. The 6E5 is especially useful in making voltage tests and balancing phase-inverter circuits. Voltages may be checked by noting how far the eye closes with a given input. When the 6E5 is switched in, the diode rectifier of the 6SQ7 is placed across the grid circuit. This does not affect measurements of audio voltages, and makes it possible to check strong i.f. signals.



Portable test cabinet with tool compartment.

The combined r.f.-i.f. signal tracer and signal generator is shown in Fig. 3. It is a simple Hartley circuit with a variable regeneration control. Used below the point of oscillation, it is a useful signal tracer.

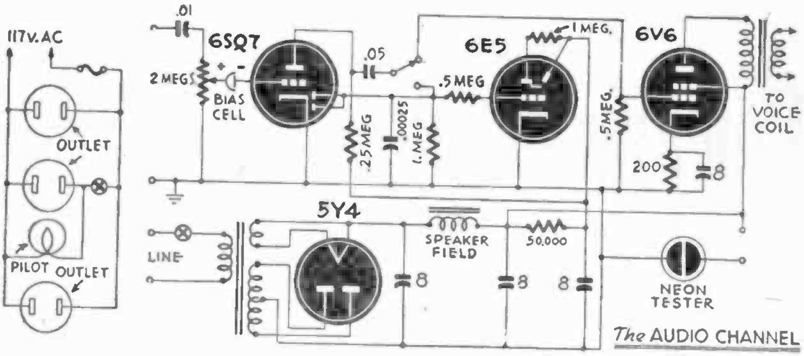


Fig. 1—left—Outlet receptacle hookup. Fig. 2—right—The audio channel.

Above this point, it becomes an r.f. signal generator, and by turning the regeneration control "full on" it acts as a squegging oscillator, producing a modulated r.f. signal. Its output (as signal tracer) may be plugged into the audio channel for greater sensitivity and output. Standard 4-prong coils and a broadcast (365 $\mu\mu$f) variable condenser are used.

Careful shielding and wiring are required if the section is to work smoothly as an oscillator and with a minimum of hum as a signal tracer.

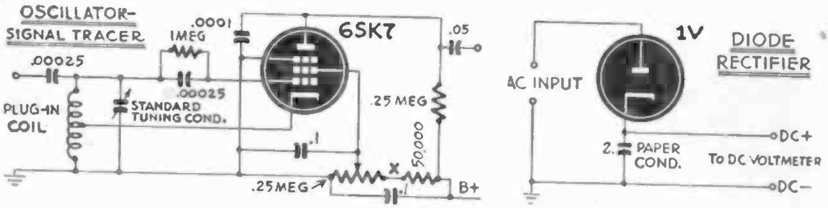


Fig. 3—left—Combined r.f. and i.f. signal tracer and signal generator. Fig. 4—right—Vacuum tube voltmeter.

The vacuum-tube voltmeter (Fig. 4) is a simple 1-v rectifier (though a 6H6 or other rectifier can of course be used). Readings are in peak volts, which may be reduced (approximately) to ordinary r.m.s. values by multiplying the readings by 0.7. The 2-μf condenser shown must be a *high-quality* paper type.

A neon tube is connected between high voltage and an output jack.

Coil table

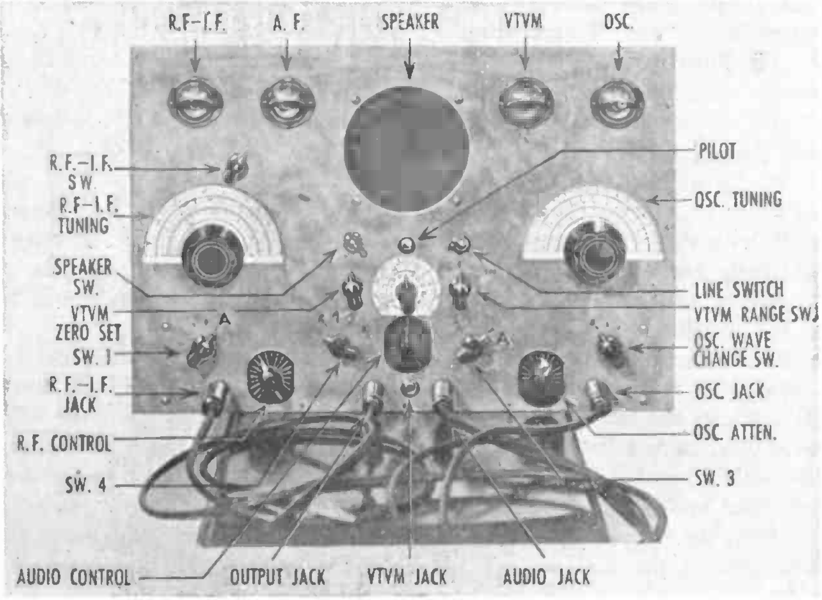
(All coils are wound on 1½-inch forms)

I.f. (456 kc)—No. 26 enamel wire. 170 turns close wound; cathode tap 50 turns from ground.
Broadcast—No. 22 d.c.c. 100 turns close wound; cathode tap 13 turns from ground.
80 Meter—No. 22 d.c.c. 29 turns close wound; tap 2 turns from ground.
40 Meter—No. 22 d.c.c. 16 turns spaced 1¾-inch; tap 1½ turns from ground.
20 Meter—No. 22 d.c.c. 7 turns spaced 1¼-inch; tap 1½ turns from ground.

A SENSITIVE TRACER

BECAUSE OF the distance from powerful broadcast stations, many signal tracers are not sensitive enough to give a positive indication when applied to the antenna or first stage of a radio receiver. This tracer was built with the idea of getting a stronger signal and has given satisfactory service over a long period of time.

Standard practice has been largely followed. Switch 1 at the input tunes that stage roughly to i.f. or r.f. It also has a position for antenna, providing a source of modulated signal where needed.

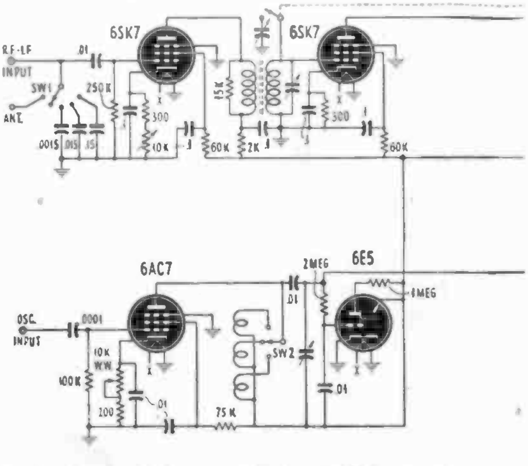


Front view of the instrument, with principal parts labelled.

Practically all radios have intermediate frequencies falling between

440 and 480 kc. The i.f. range was set for these frequencies, no provision being made for the few receivers which use 175 kc. Adjustable Meissner iron-core r.f. coils and 365-$\mu\mu$f tuning condensers were used for the r.f. circuits, and by shunting these with small padders it was possible to tune across the selected intermediate-frequency band very nicely. A push-pull wave-change switch out of an old Victor radio was used for this purpose.

If old-style 500-$\mu\mu$f tuning condensers could be obtained, it is possible that the padders could be dispensed with, although there has been absolutely no trouble with the present arrangement.



Read this circuit in connection with balance of diagram on facing page.

To get the required sensitivity, three tuned stages were needed. Shielding was also necessary to prevent oscillation, as were the 15,000-ohm resistors across the first two primaries. If two tuned stages are used, there is no tendency to oscillate and there will be enough gain for most applications.

The oscillator section is simple and of standard design. The coils, switch and tuning condenser for it were salvaged from an old Philco radio. The primaries were removed from the coils. This section is the least-used part of the instrument, but proves its worth in locating intermittent troubles.

Probes for the r.f. and oscillator sections are made from microphone cable with tiny capacitors near the point of the prod. These capacitors are made from two small strips of copper overlapping each other a quarter of an inch and dressed down to go into the probe. About 30 inches is fine for cable length.

The vacuum-tube voltmeter needs no explanation. The cable for this part of the instrument has a 1-megohm resistor near the prod point. SW6 selects the voltage range. The 1,000-ohm control used for the volts scale must have a linear taper. Its pointer is the center one on the panel. The scale was made from Bristol board and calibrated by using a power pack and voltmeter. Zero is in the center. The zero setting is made by the 100-ohm wire-wound variable resistor in series between ground and center-tap of the high-voltage winding (the most negative point in the power circuit).

Dial scales for the r.f.-i.f. and oscillator condensers were also made of white Bristol board. They were calibrated with the help of a signal generator and broadcast stations. The left-hand dial, which controls the r.f.-i.f. gang, has the padder switch mounted above and slightly to the right. When it is in the OUT position, the instrument tunes over the broadcast band. In the IN position, it tunes intermediate frequencies. The padders can be seen mounted above the gang, in the rear-view photograph. The dials are of the large 2-1/16-inch type with celluloid pointers. These look very well, and the hair-line makes accurate readings easy.

The front panel was made from ⅛-inch sheet aluminum, 12 inches high by 18 wide, with the 5-inch speaker mounted as shown in the photos. The chassis is 10 x 17 x 3 inches, which is about the right size to mount the parts. Standard phone jacks and plugs were used on the ends of test cables.

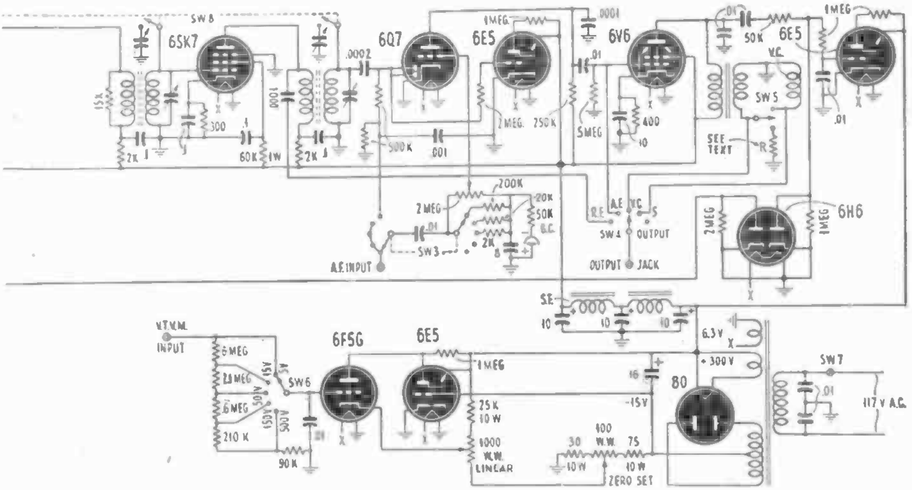


Diagram of sensitive tracer. It covers many different tests. Resistor at one position of SW5 has value equal to speaker's voice coil impedance.

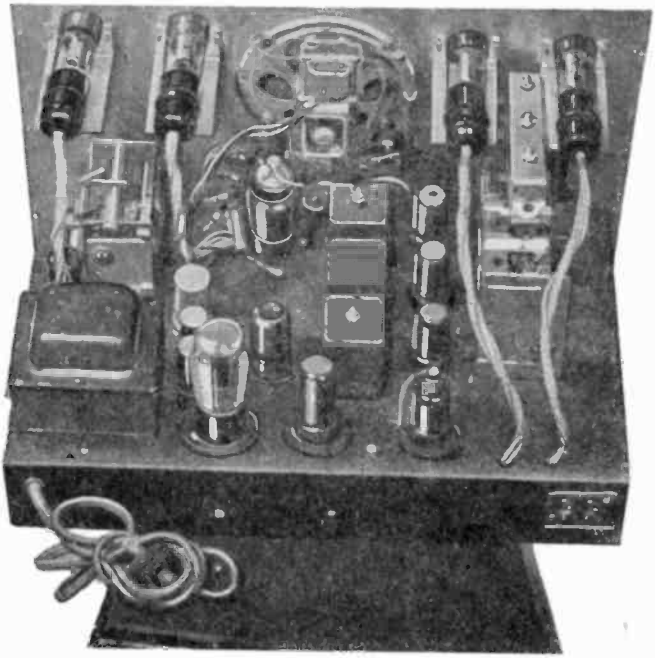
The various controls may be seen from the photo. The four electron-ray tubes are lined up along the top, the indicators reading from left to right: r.f.-i.f.; a.f.; v.t.v.m.; and oscillator. The speaker is in the center. The pilot light is directly below with the line switch and speaker switch on either side of it. Farther down is the pointer and scale for the v.t.v.m., with its zero-set adjustment on one side and its range switch on the other side of it. The two pointers and scales at either side of the panel are the r.f.-i.f. tuning, and the oscillator tuning scales. At the bottom of the panel, reading from left to right (in a staggered line) are the antenna switch (SW1), the r.f. level control, the output switch (SW4), the audio volume control, the audio input switch (SW3), the oscillator attenuator, and the oscillator wave-change switch (SW2). The jacks used with some of these switches are placed as close to them as possible, to avoid long leads.

Functions of all switches, ray-tubes, dials, and input and output jacks are given in the combination photo-sketch. The more important points may be marked directly on the panel face, as was done in the case of this instrument. For example, all the ranges of the v.t.v.m. were printed on the panel. The antenna position of SW1 is marked with a large A.

The same A (this time for Audio Input) appears on SW3. It indicates the full-volume position of the switch, when the volume control has no signal-reducing shunt resistors in parallel with it.

Possibly the constructor should print the names of every one of the various controls, jacks and indicators on his panel. The designer of an instrument feels so familiar with it—even before it is built—that he seldom feels the need for most of these indications, but a person constructing it from the diagram would doubtless save time if he could distinguish between all controls and switch positions at a glance.

A study of the schematic will show how the tracer may be used for different purposes. A full explanation of the manner of employing it would take a lot of space and is unnecessary. There is no difference in the operation of this and any comparable tracer, and a standard work on signal tracing equipment and methods will cover all points that might be raised in connection with this piece of apparatus. The instrument is adapted to use as a multi-channel signal tracer. Clips may be attached to the cables and connected to several parts of a set at the same time. (Note that though the diagram shows standard post-and-ground symbols, these are jacks in the actual instrument, and the ground is made to the shield of the probe cables.) The radio may be left to play till it stops by itself. The eye which opens locates the defect.



Rear view of signal tracer. Note trimmer condensers on top of variable condenser gang.

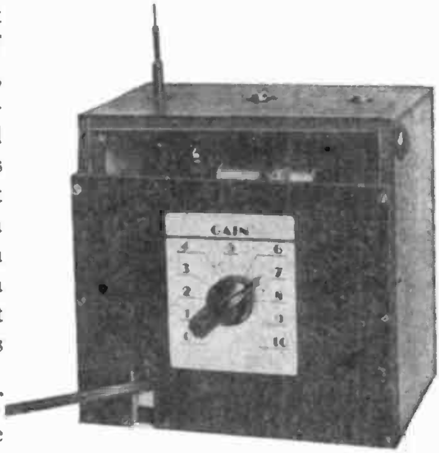
For tracing intermittents a broadcast signal should be used.

MIDGET SIGNAL TRACER

THIS TRACER will do away with power transformers, external test probes, specially constructed test prods, coils, tuning condensers, tap switches, external amplifiers, high cost of construction, and save valuable space on the service bench.

The tracer was assembled on an a.c.-d.c. midget radio chassis which was cut in half, leaving the four tube sockets and speaker already mounted, and the wiring of the output tube and rectifier intact (because it is usually standard on all midget receivers). This saved quite a bit of work of cutting tube socket holes, speaker cut out and of doing considerable wiring. There are several well-known makes of midget radios from which the chassis can be cut to leave four tube sockets and a speaker cut-out remaining. If a small set cannot be obtained, a chassis layout is illustrated so that the serviceman can cut the chassis himself.

The builder has his choice of tubes to be used in the tracer. The author used a 12Q7, a 12SQ7, a 50L6, and a 35Z5 tube. These were the tubes on hand at the time of construction. However, a 12F5, a 12SF5, a 50L6, and a 35Z5, or a 45Z5 can be used; or if those tubes are not available, substitute a 6Q7 or a 6F5, a 6SQ7 or a 6SF5, a 25L6, and a 25Z6, in which case use a line-cord resistor to drop the voltage for the tube filaments.



This signal tracer is a mere handful.

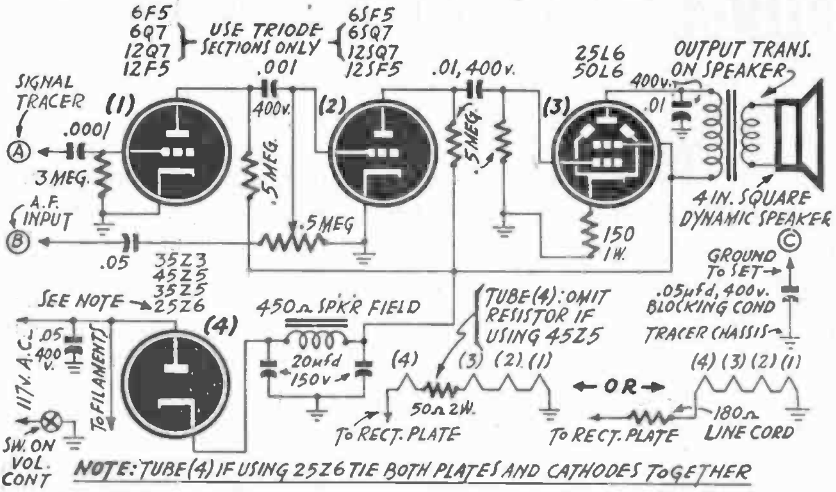
The filaments should be wired as shown with tube No. 1 filament connecting to ground to prevent hum.

The tubes are used in this order:

1—untuned detector; 2—1st audio; 3—output; 4—rectifier.

Various circuits were tried such as using 12A7 as an untuned r.f. stage into a 12SQ7 diode plate as a diode detector, into the triode section of the 12SQ7 as first audio, but the results were not as good as the circuit shown.

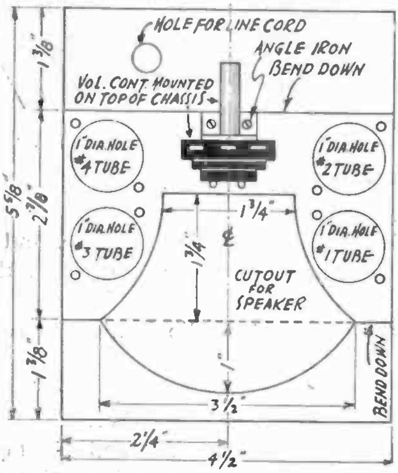
The tracer is so sensitive that it is not even necessary to touch an i.f. or audio grid or plate—just place the prod near the grid or plate and you can pick up a signal, the volume depending on which stage you are testing. In service work this tracer is capable of picking up a signal over 3 feet away from a dead set which has an open voice coil in the speaker.



Only four tubes and a small speaker are used in this instrument.

Stage gain can be checked by touching the grid and then the plate of every stage working toward the speaker.

An isolation transformer is unnecessary because of the blocking condenser in the circuit. The volume control controls the volume of both the r.f. and a.f. sections of the signal tracer.



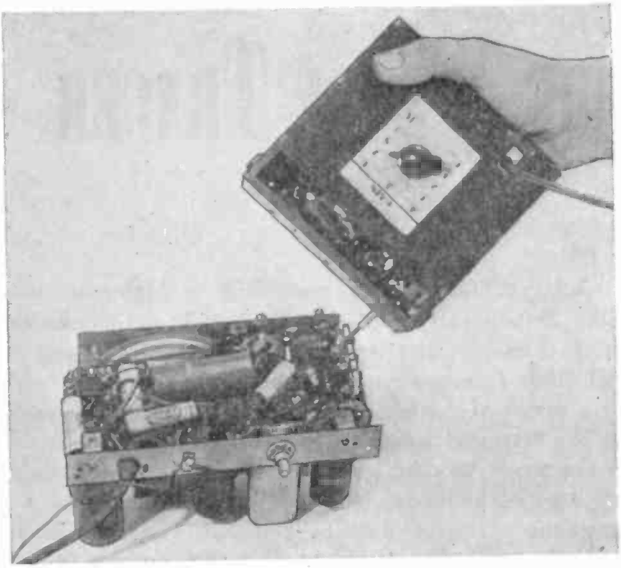
Chassis layout of compact signal tracer.

To operate the tracer, plug into electric outlet, touch an antenna to prod A on top of tracer; several stations should come in at once. If a loud hum is noticed, reverse plug in outlet.

Testing procedure will depend on whether a set is inoperative, noisy or fading. If set is inoperative, the short prod is used. It consists of nothing more than a phone tip with a nail soldered to it. The tracer is held in the hand because it only takes a few seconds to touch a grid or plate terminal of a socket to determine if that stage is working properly.

If set is noisy or fades, the tracer can be left on the bench and ordinary test leads applied to it to test the various stages of the defective set.

There will be a slight detuning due to the long leads when this is done, but this does not interfere with the test that you are making. It may be necessary for you to retune the set a trifle.



Front and bottom views of midget tracer.

When testing an a.c.-d.c. set, make certain that the plug is inserted so that the chassis is connected to the grounded side of the line.

When testing a.c.-d.c. sets, only prod A should be used because both the set and the tracer have a common ground.

When testing an a.c.-d.c. set that uses a common positive on the filter block, connect prod C first to one negative of the condenser, using only the one that gives the least amount of hum.

When testing the first r.f. or detector stage of a loop-operated set, an external antenna will be required on the set.

There is no danger of a short circuit because of the blocking condenser. There is no danger of an electric shock because of the wooden cabinet insulating the chassis. The short test prod is covered with a piece of spaghetti, except at the very tip, to prevent accidental shorts.

The cabinet was constructed from thin walnut panelwood, but if the serviceman should desire he can build the cabinet out of plywood.

Connections to phone jacks A, B, C, are made after the tracer is mounted into the cabinet. The grid leads on the first tube should be made as short as possible to prevent hum.

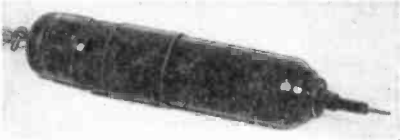
When testing audio circuits, the short prod is removed and a shielded wire with two phone tips at one end and a pair of alligator clips at the other end is used. The shielded wire should be plugged in at B and the shield at C.

TRIODE - PROBE TRACER

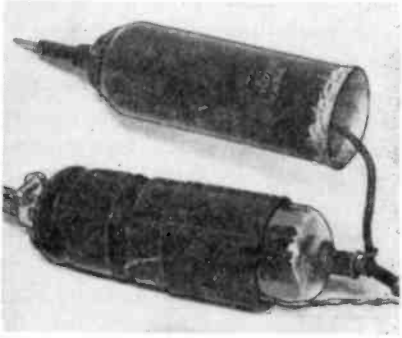
THIS INSTRUMENT is essentially a high-gain amplifier for signal tracing both aurally and visually, and is designed along conventional lines. It differs in that it uses a triode probe in place of the more conventional diode type ordinarily in use.

By using a series of these amplifiers and omitting the output stage in all but one, the instrument may be used for multiple-channel signal tracing. The probe grids may be connected into the path of the signal and, by injecting a constant modulated signal and adjusting the volume controls, intermittent operation may be detected. The volume controls are adjusted until the eye is barely closed. If a component part breaks down, it will be indicated by the eye.

A feature of this unit is that although the amplifiers may be built on the same chassis and use a common power supply, there is very little interaction. If four or five units are used from the same power supply, a heavy-duty power transformer sufficient to handle the load should be used. A switching arrangement could be employed to cut out the channels not in use.



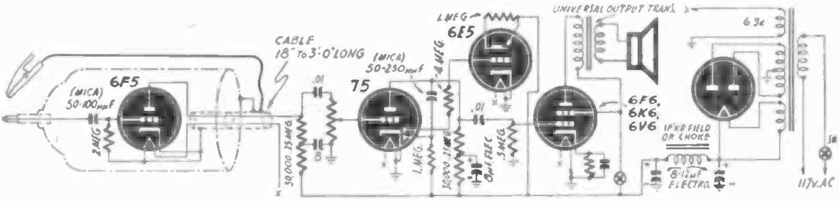
Above—Case of probe is made from old metal tubes.



Right—Triode probe open — attached to grid-cap is a 2-meg resistor. Condenser is near the tip.

When checking signal quality, tune in a good local station, close the switch which connects the output stage and speaker into the circuit, and connect the shield of the probe to ground or chassis. The tip of the probe is then applied to the grid of the first r.f. tube. A signal should be heard. Then proceed from there to the plate and so on down the line through the set until the trouble is located. Reduce the gain control on the tracer as you proceed toward the speaker. By injecting a modulated signal at a constant level, a fair idea of the stage gain can be obtained by observing the 6E5 tube and proceeding as already outlined above.

This tracer can also be used as an output indicator by simply placing the test probe near the output tube of the set being aligned and observing the 6E5, retarding the volume control as the set comes into alignment.



Schematic of signal tracer. A switch permits use of either 6E5 tube or speaker.

A very small signal from a signal generator will give a good indication. Phonograph crystal pickups can be checked with the tracer by connecting the ground lead to the ground lead of the crystal, and touching the probe lead to the other crystal connection. The crystal will oscillate and this will be indicated by the closing of the eye. If the speaker is thrown into the circuit during this test, a loud squeal will be heard. This test must be conducted with the crystal on the work bench or other insulating material, but not held in your hands, as it will not work that way.

The probe can be constructed from anything from bicycle grease guns to pieces of tin cut from ordinary tin cans. The one shown in the photo was made from a metal tube. One way to make it, is to cut a piece of tin long enough to accommodate the condenser, grid resistor and the 6F5 tube, and wide enough to overlap itself slightly when bent snugly around the tube base. After taping securely, the shield is soldered together and another small piece of tin is soldered to the end to form a cap. This end is used for the probe tip. When alligator leads are used in place of the probe tips, the wire should be not more than 3 or 4 inches long. The grid resistor can be any value from .5 to 2 megohms. If the metal shielding for the probe cable is not available, a single shielded wire can be used for the plate lead and the shield grounded. This would leave one wire outside the shield, but it could be taped to the shield at short intervals. The probe cable can be from 18 to 36 inches long.

The front panel may be made from masonite, bakelite, or other similar material. The subpanel can be of either metal or bakelite. The size of the panel and subpanel will have to be determined by the constructor, depending on the number of channels he decides to build.

Channels 1, 2, 3, and 4 would consist of a 6F5, 6E5, and a 75. Channel No. 5 consists of the entire schematic.

The tuning eye mounting assemblies can be purchased or, the constructor may fashion brackets and mount them to suit his taste.

THE CAPACITESTER

THE CONDENSER quality tester described here is the result of considerable experiment and design and has the following advantages: (1) Checks the quality of the condenser while connected to the circuit. (2) Positive indication with no charts or figuring. (3) Ease of operation using ordinary test prods, no shielded wires or awkward terminal connections. (4) Provision to test resistance or voltage across the condenser, simultaneously with the quality test. (5) *A locking circuit* which can be used in cases where the tester has to remain across a suspected condenser for a period of time and which gives a positive indication without the necessity of the operator constantly watching the indicator.

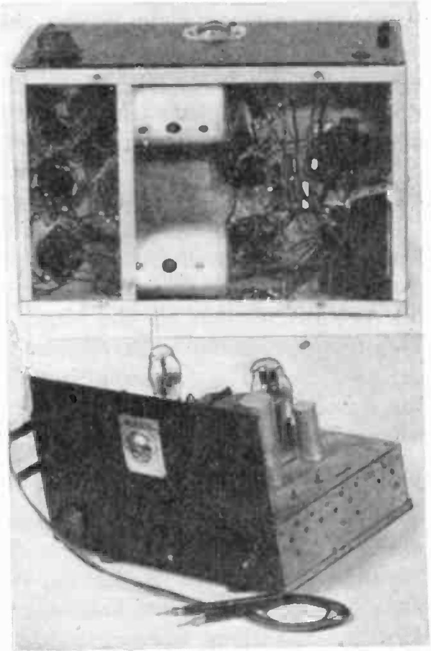
The circuit consists of a 76 oscillator, link-coupled to a tuned circuit, both operating at 1,800 kilocycles. The link circuit is broken on one side and brought out to pin tip jacks. The tuned circuit is connected to a 6B7 pentode section. The output of the pentode section is rectified in the diode section and the negative potential developed is applied to the grid of a 6E5 tuning indicator tube.

Link circuit is point of test

Since the link circuit is carrying radio frequency at low potential, any resistance or reactance in series with it will lower the energy transfer from the oscillator to the tuned circuit. The frequency chosen, 1,800 kilocycles, will encounter a reactance of approximately 10 ohms when applied in series with a .01-μf condenser. Most condensers used in radios and associated circuits have capacities greater than this. It follows that their reactance will be less. Since the values of resistances used in radios are generally 200 ohms or greater, if a .01-μf condenser is placed across a 200-ohm resistor and this combination tested by this instrument, taking the energy transfer to represent 100 percent, it will be found that 95 percent passes through the condenser, and only five percent through the resistor. Therefore if the condenser should open there will be a loss of 95 percent of the energy transfer in the link circuit.

In a case where the resistance is developed internally in the condenser (contact resistance as it is generally called) the energy transference loss will be governed by the voltage drop across this resistance. It readily can be seen that the resistance or reactance connected across the condenser is so much higher than the reactance of the condenser itself, that for all practical purposes it may be disregarded. Any internal resistance or contact resistance in the condenser itself will reduce the energy transfer in direct proportion to the amount of resistance developed.

The locking part of the circuit is as follows: The negative bias used to close the 6E5 tube's shadow is also applied to the grid of a 6F5 used as the locking tube. Its plate is connected through a toggle switch to one side of the secondary of a three-to-one-ratio audio transformer. The primary of the transformer is connected to the a.c. line connections across the regular power transformer. The ground return of the secondary goes through a 500,000-ohm resistor.



Photos show two views of instrument.

It takes approximately eight volts negative bias to completely close the shadow on the 6E5 magic eye tube; this same voltage is applied to the grid of the 6F5. Due to the tube's high mutual conductance it is biased to plate current cut-off. However, if there is any failure of the energy transfer link circuit caused by the condenser under test opening or the circuit being opened in any way, there is no longer any radio frequency flowing through the circuit. The result is with no radio frequency to amplify and rectify in the tuned circuit, the grid bias falls to zero potential on both the indicator and locking tube grids, the indicator tube's shadow opens wide and the locking tube passes plate current, the negative component of which is applied to the grid of the 6B7 pentode section, stopping it from amplifying any further even if the energy transfer link circuit should be closed again. Therefore the indicator tube's shadow remains locked open until the switch in the plate circuit of the 6F5 tube is opened, allowing the other circuits to operate normally again.

A chassis nine by twelve inches was used. A panel twelve by eight inches is mounted on one side with the indicator tube located in the upper center, the gain control and a.c. switch on the lower left, and the locking switch on the lower right. The tip jacks are mounted one pair on each side. The oscillator and radio-frequency amplifier coils are ordinary solenoid broadcast coils with the primary windings removed. The oscillator coil is tapped two-thirds of the way down from the grid end for the cathode connection. Two holes were drilled in each coil form, an eighth of an inch apart and a quarter inch below the bottom of the winding. A single turn of hookup wire was wound here and cemented in place, with the ends threaded through the holes and leading out the bottom of the coil form and shield can in which each coil is mounted. A 15-$\mu\mu$f mica trimmer condenser is connected across each of the larger windings and a hole drilled in each shield can opposite the trimmer screw to permit the coils being tuned to the same frequency. A screwdriver is used for the tuning.

The frequency used does not have to be exactly 1,800 kilocycles. Any frequency near this will be satisfactory, preferably the highest one to which both coils will tune accurately. The two shield cans containing the coils are mounted under the chassis three inches apart and the link coupling turn leads are fastened in place by means of tie points. The constructor can place the rest of the parts to suit himself, providing the oscillator and the tuned circuit are so arranged there will be no interaction with the link coupling circuit open.

On the opposite side of the link circuit connected to the pin jacks, the circuit is again broken and a .1-μf condenser inserted. This enables continuity or voltage tests across the condenser being tested, simultaneously with the quality test. A small condenser is connected from one side of the pin jack circuit to ground. This prevents any radio frequency pickup due to capacity between the larger winding and the link coupling turn. This tip jack should be marked and used as the ground potential side of the test leads. The link coupling circuit is isolated from ground except for this small condenser, so voltage or continuity checks can be made across the condenser under test or from either side of it to ground.

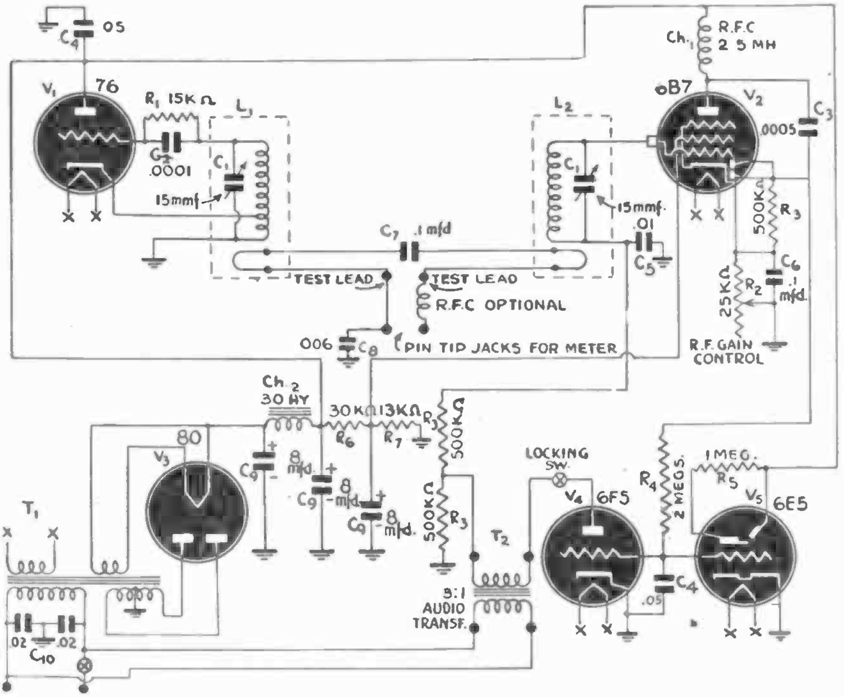
Putting unit into operation

To place the unit in operation, allow the tubes to heat for about 15 minutes. Connect a jumper across the pin tip jacks or clip the test leads together, making sure the locking switch is in the OFF position. Advance the gain control until the indicator tube shadow starts closing. By means of the screwdriver trimmer condensers, tune the oscillator and radio-frequency amplifier circuits accurately to the highest frequency to which both will respond. This peak will be indicated by the degree of closing of the indicator tube shadow. The process will have to be repeated several times, reducing the gain control each time the indicator tube shadow closes completely until the point of sharpest tuning is obtained.

When this is reached the testing portion of the instrument is complete. Now adjust the locking circuit as follows: With the link coupling circuit still closed, advance the gain control until the indicator tube shadow just comes together. Close the locking switch. If the indicator tube shadow opens it indicates too much plate voltage on the 6F5 tube. This will have to be reduced until closing the switch has no effect on the indicator tube.

This can be done by placing a small load on the secondary of the audio transformer by means of resistors placed across it or by a potentiometer across the a.c. line with the primary of the audio transformer connected to one side of the a.c. line and the center tap of the potentiometer. Whichever method is used, adjust the voltage until the locking switch no longer affects the indicator tube. When this point is reached, open the link coupling circuit momentarily and then close it again. If the unit is wired correctly the indicator tube shadow will open and remain so indefinitely until the locking switch is turned off.

There are only two controls, the r.f. amplifier gain control and the locking switch. Heat the tubes to operating temperature, hold the test prods together and adjust the gain control until the indicator tube's shadow just closes. Plug an ohmmeter or voltmeter, depending on whichever method you prefer, into the two extra pin tip jacks provided for this purpose and proceed to check the condensers in their circuit, remembering to use the grounded prod on the ground potential end of the circuit. An open condenser will be indicated by the indicator tube's shadow refusing to close completely and, in most cases, refusing to move at all. The operator of this unit can familiarize himself with its operation by making tests of combinations of various-sized resistors and condensers in parallel, noticing the shadow positions with the condenser in and out of the circuit.



Schematic diagram for the Capacitester.

If a condenser is suspected to be intermittent, the test leads should be clipped across it and the condenser squeezed with the fingers or tapped with a rubber tube tapper or similar instrument. If the condenser makes and breaks contact due to this treatment, it will be shown by the indicator tube's shadow blinking or opening. To test a condenser over a period of time, the leads are clipped across it and the locking switch closed. If the condenser open circuits at any time, the locking tube will keep the indicator tube's shadow open, showing the condenser to be intermittent. A shorted or partially shorted condenser will be shown by the discrepancy of the ohmmeter or voltmeter reading in comparison with the circuit diagram or voltage chart. This makes a very handy combination; both a condenser quality check and a point-to-point resistance or voltage reading simultaneously, using the ohmmeter or voltmeter already in the shop.

In some instances it may be necessary to insert a low-resistance radio-frequency choke in series with the pin tip jacks used for the meter connection, but in most cases it will be found the meter movement has enough reactance in itself so that it will not move the tuning indicator shadow when connected to this instrument.

The tester does not indicate the capacity of electrolytic condensers. The capacity of paper and mica condensers is either marked on them or the circuit diagram, and does not vary with age or use as with the electrolytic ones. This instrument *will* check electrolytics for radio-frequency reactance and will pick out a defective one that may be causing radio or audio feedback due to common coupling in the filter circuit. In most cases where the electrolytic condenser checks O.K. for capacity and is still operative in its filtering action a mica or paper condenser placed in parallel with it will cure it temporarily until a new one can be obtained.

In checking plate-to-grid coupling condensers, after making the quality test it is always a good plan to test the condenser for leakage by means of a vacuum-tube or high-resistance voltmeter placed across the grid leak of the amplifying tube while the test is in operation and no signal tuned in. If any voltage is present it indicates either a leaky coupling condenser or a gassy tube.

This brief outline, plus a few minutes' use of this instrument, will prove its ease of operation and value in speedy servicing.

List of Parts

RESISTORS
R1—15,000 ohms, ½ watt
R2—25,000-ohm pot. with a.c. switch
R3—500,000 ohm, 1 watt
R4—2 meg, 1 watt
R5—1 meg, 1 watt
R6—30,000 ohms, 5 watt w.w.
R7—13,000 ohms, 5 watt w.w.
CONDENSERS
C1—15 μμf mica trimmer, screwdriver type
C2—.0001 μf mica
C3—.0005 μf mica
C4—.05 μf, 600 v tubular
C5—.01 μf, 400 v tubular
C6—.1 μf, 400 v tubular
C7—.1 μf, 600 v tubular
C8—.006 μf, 600 v tubular
C9—8 μf, 450 v electrolytic
C10—0.02 μf, 600 v tubular
MISCELLANEOUS
CH1—2.5-millihenry r.f. choke
CH2—30-henry filter choke
L1/L2—Solenoid bc coils, per text
V1—76
V2—6B7
V3—80
V4—6F5
V5—6E5
T1—5-tube bc power transformer
T2—3:1 audio transformer
4 pin tip jacks, tube sockets, msc. hardware, hookup wire, solder, etc.

A CAPACITANCE METER

HERE IS a capacity tester that will measure accurately the capacity of an unknown condenser, and if the standards used are of the value as shown in Fig. 1, two scales or markings may be calibrated on one dial. One scale (Scale "A" in Fig. 2) measures from .0001 to .1 microfarad. Using the same calibration marks on the lower scale, which we shall call Scale "B", measurements from .1 μf (100,000 $\mu\mu$f) to 40 μf may be made.

The serviceman often wishes to measure the capacity of a condenser which is suspected to have changed in value and which may upset the whole circuit system or frequency spectrum. Such condensers can become leaky from being exposed to dampness, as in auto radios or portables exposed to rain.

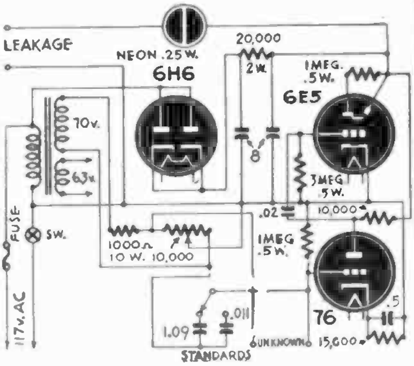


Fig. 1—above—Diagram of 3-tube capacity bridge.

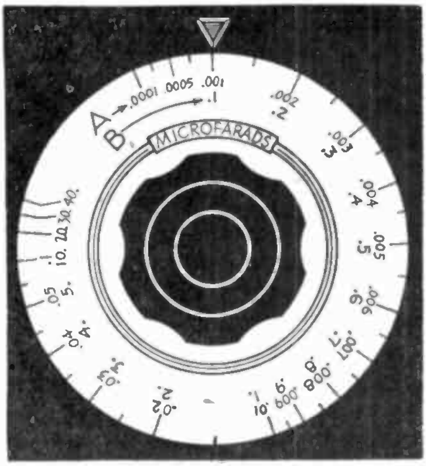


Fig. 2—right—Direct-reading dial.

Leaky, open or shorted condensers can be checked instantly with this simple tester. Leaky coupling condensers will cause a positive potential to be impressed on the grid of the following stage, upsetting the bias on the grid and seriously distorting the signal sent to following stages.

The capacity tester shown is of the Wheatstone bridge type and uses a null indicator such as the 6E5 or 6U5 electron-ray tube, designed to indicate visually on a fluorescent target the effects of a change in the controlling voltage. The tube is used as a convenient means of indicating the accurate tuning of a radio receiver to a desired station.

The transformer with the 70-volt secondary was wound on a small power transformer from which all windings but the primary had been stripped. A tube tester transformer will, however, have a 70-volt winding which can be used. The voltage of this winding is not critical and may vary at least 10 percent up, or 20 percent down, without affecting operation of the instrument.

The leakage test incorporates a neon lamp and leaks in condensers can be determined by how the lamp glows. If the condenser is good, a short time elapses between the time the lamp glows and goes out until the next flash; the exact period for a given size condenser may be determined by periodic tests. A leaky condenser flashes much more often while one that is really bad will show a continuous glow. This does not hold true for the larger electrolytic capacitors. There is a certain amount of leakage in this type of condenser and it takes a little time to charge up and for the neon glow to cease. Care must be taken while testing electrolytics to observe polarity on the leakage test, although it makes no difference on the capacity test. Due to the resistors in circuit, electrolytics can be measured safely on the a.c.

The bridge provides for no power factor measurement, as the author maintains that if a condenser being checked for capacity does not open the eye of the tube it undoubtedly has a large loss and the power factor is altogether too low for efficient operation.

The instrument is operated on a.c. and is easily calibrated against capacitors of known value. If possible, a condenser decade box should be used, or one may check different values of condensers on a master bridge to obtain a greater degree of accuracy. If the calibration of this instrument is kept within close tolerances it should prove to be a most useful and reliable piece of equipment and can be constructed for portable use or behind a test panel for radio servicing.

The rectifier circuit is novel in design as it utilizes no transformer and is connected directly to the line. The 6H6 supplies all the current drawn by the 6E5 and 76 tube. With plates and cathodes tied together, the rectifier, which has a normal rating of four milliamperes per plate, will not overload.

The 1,000-ohm, 10-watt resistor reduces current to the 10,000-ohm potentiometer (linear taper), therefore the instrument can be left on for several hours at a time without overloading the transformer or potentiometer in series with it. The current can be determined by Ohm's law: 70/11,000 = .00636 amp or a little over 6.3 milliamperes, depending on voltage variations in the line.

A double-pole single-throw switch is used in the instrument for switching from "A" to "B" scale, thus giving a range from .0001 to 40 μf. One final point should be remembered in the calibration of the instrument—the accuracy of the bridge depends entirely on the accuracy of the standards or condenser decade box employed.

CAPACITY BRIDGES

Bridge circuits are widely used for capacitor measurements. The fundamental Wheatstone bridge is shown in Fig. 1. If all four resistors are equal, voltage drops across each will be the same, and points A and C will be at the same voltage. Thus no current can flow through galvanometer G. If R4, the unknown, is larger or smaller than R3, A and C will not be at the same voltage, and current will be registered by G.

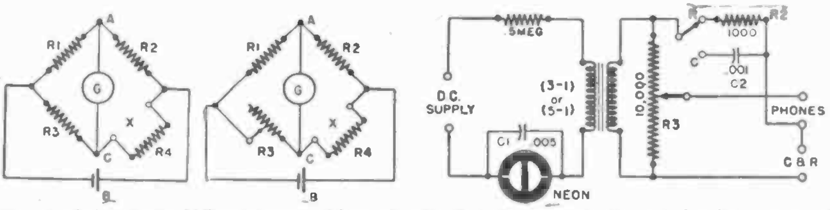


Fig. 1—left—Basic Wheatstone bridge circuit. Fig. 2—center—Practical adaption, with one variable arm. Fig. 3—right—D.c.-operated capacity checker.

By making R3 variable, as in Fig. 2, R4 may also vary. As long as R3 and R4 are equal, points A and C are at the same voltage, and G registers zero. The range of the bridge may be increased by varying the

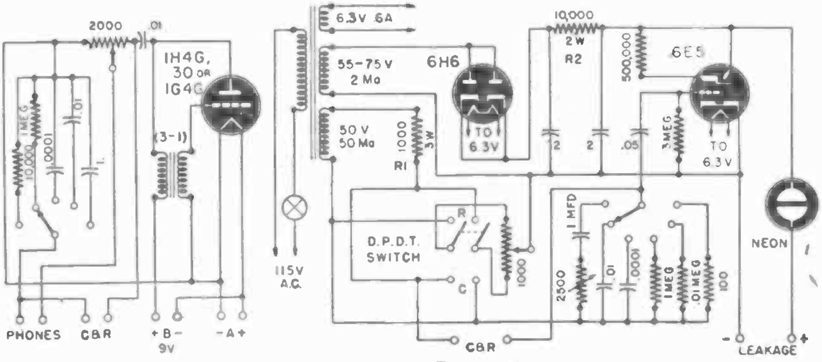


Fig. 4—left—Simple tube oscillator circuit. Fig. 5—right—Ray tube resistance-capacity meter.

ratio of the arms. Thus if R2 is twice as great as R1, G will register zero current when R4 is twice as great as R3.

A simple practical circuit, which can be operated from a 90-volt B-battery or a low-voltage power supply, is shown in Fig. 3. A neon lamp is used as a relaxation oscillator. Its output is applied to the bridge through an audio transformer. A switch permits the bridge to be used for measuring either resistors or capacitors. Another form of bridge using an audio transformer is shown in Fig. 4. A small battery-type tube is the oscillator. Two resistance and three capacity ranges are shown, but others could be added if desired.

Details of construction

A more elaborate capacitor-checker is shown in Fig. 5. Besides measuring capacity and resistance, it provides means for leakage tests and for measurement of power factor. An electron-ray indicator tube is used to mark the null point instead of the less sensitive headphones. A special transformer supplies 55 to 75 volts at 60 cycles to the bridge. (In most cases, this transformer will have to be wound for the job, though a tube-tester transformer can be used.)

The bridge shown in Fig. 5 utilizes the 6E5 magic eye tube as the balance indicator, so doing away with headphones and enabling greater accuracy to be obtained, as well as a greater range of measurement. This bridge will measure resistances from 10 ohms to 10 megohms and capacities from 10 $\mu\mu$f to 10 μf. It incorporates a leakage test using a neon lamp and also has provision for measurement of power factor. When constructed with close tolerances it is a most versatile instrument, and should help fill the need of servicemen for a reliable and portable instrument.

The instrument is a.c.-operated and completely self-contained. There is nothing difficult in its construction and it is quite easily calibrated against known values. If possible a resistance box should be used for the calibration. This will ensure a greater degree of accuracy. When an unknown resistance or capacity is connected across the C and R terminals and the range set to the appropriate position, the potentiometer is turned until maximum shadow is indicated on the 6E5. The value of the unknown element is then read on the calibration scale. When testing condensers, if balance is difficult to obtain, probably the condenser has a large loss.

All the above checkers may be calibrated by checking capacitors or resistors of known values.

THE TRANSIGENERATOR

NEXT TO a good multimeter, the signal generator is probably the electronic technician's most useful piece of test equipment. It is possible for even the careful beginner to construct an efficient signal generator of the utmost simplicity. It is only necessary to make use of an oscillator circuit which has been repeatedly neglected by the practical man since its inception. That oscillator is the *transitron.*

The basic circuit is shown in Fig. 4. Operation depends upon the fact that any slight change in screen voltage is transmitted in like polarity to the suppressor grid. An increase in suppressor voltage *reduces* the screen current and vice versa. Thus a negative resistance effect is observed at terminals x-y. A resonant impedance—such as an L-C tank circuit—connected between x-y will cause the circuit to oscillate at the natural resonant frequency of L and C.

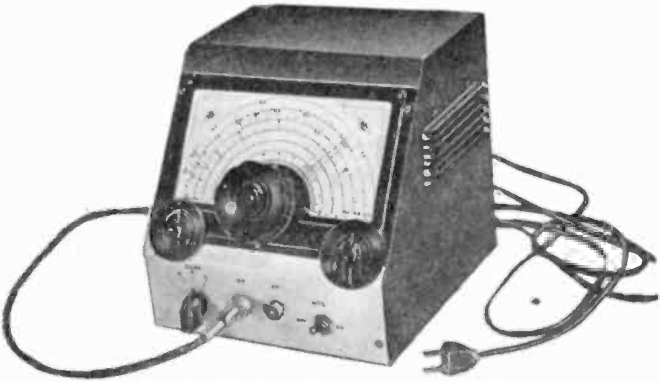


Fig. 1—The Transigenerator—front view.

The advantages of the transitron are:

1—Extreme simplicity.

2—Unusual stability easily obtained.

3—Good wave form the rule rather than the exception.

4—Two-terminal coil usable (i.e., no critical coil tapping).

These advantages have been combined in the instrument whose circuit is shown in Fig. 6. Two tubes (plus rectifier) are employed—the r.f. and the a.f. oscillators. For modulated r.f. output, the a.f. oscillator grid-modulates the r.f. circuit which then also functions as a mixer. Circuit voltages and electrode currents are given in Fig. 6. Pictorial views are shown in the photos.

The r.f. unit employs the type 6SK7 remote cut-off pentode. The tuned circuit is placed in the suppressor rather than the screen circuit to permit grounding of the tuning condenser rotor (it could have been placed in the plate or cathode circuit with no change in operation). Note that this stage operates with a plate potential of only 9 volts, while the screen potential is +50 volts to ground. Considerable deviation is allowable, but it is suggested that the constructor use the voltages shown. The r.f. output attenuator consists simply of a variable suppressor-bias resistance R1 in the cathode circuit. The 400-ohm fixed cathode resistor sets the operating point and precludes waveform distortion.

The tuning condenser C is of the dual-gang variety; the capacity of each section ranges from 30-350 $\mu\mu$f. Switch SW1 chooses tuning inductance L1, L2 or L2 plus L3 and hence selects the frequency range. The ranges are approximately: Band A—160 to 660 kc; Band B—550 to 2,000 kc; Band C—2 to 8 mc. Additional ranges may be added.

To obtain the ranges given, a one-millihenry r.f. choke is used for L1. L2 and L3 are wound on the same ⅝-inch coil form to save space. L2 has an inductance of 25 μh and consists of 17 turns of No. 30 enamel wire. Winding length is 3/16 inch. Inductance L3 is 120 μh and is wound with 120 turns of No. 30 enamel wire. The winding length is 1-5/16 inches. A permeability-tuned manufactured coil could be substituted for L2-L3 and then adjusted to give the range desired. It was considered more expedient to wind coil L2-L3, this being a simple matter.

The 8-mc upper-frequency limit was considered adequate for most purposes; and the second harmonics of band C have been used to extend the range to 16 mc. Use of the third and higher harmonics is not feasible because of the Transigenerator's relative purity of wave form.

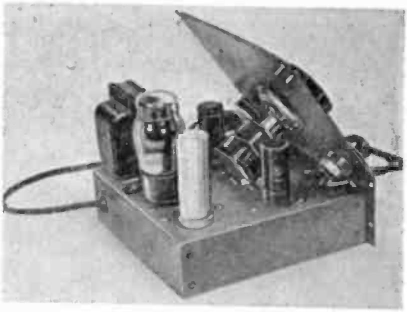


Fig. 2—Rear view of transitron signal generator.

The r.f. output is taken directly from the suppressor grid through the 25-$\mu\mu$f isolating condenser. This condenser not only blocks d.c. but also prevents detuning of the oscillator by the circuit to which the r.f. lead is connected. It is connected directly to a male chassis-mounted microphone connector, J1. A single shielded cable, terminated in a female microphone connector, feeds either the r.f. or a.f. to the external circuit. This is clearly shown in Fig. 1. This figure also shows the general arrangement. SW1 is shown in the lower left-hand corner with the r.f. jack immediately to its right. The r.f. attenuator can be seen above and slightly to the left of SW1. The National ACN dial adds finish to the Transigenerator's appearance, suggesting a professional model.

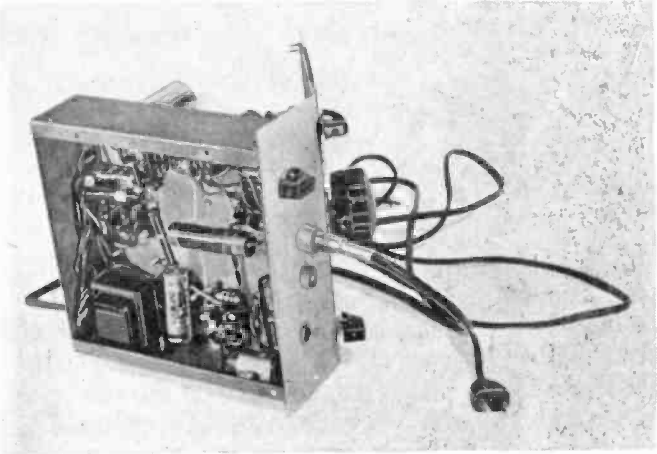


Fig. 3—Both audio and radio-frequency coils are mounted under the chassis.

The a.f. oscillator follows the same design principles used in the r.f. unit. The coil and condenser L4 and C1 determine the frequency of operation, which in this case is 400 cycles. A separate a.f. attenuator is employed. It is connected directly across the tank. The a.f. output is taken from the potentiometer and feeds the microphone male jack J2 through a blocking capacitor. A cathode resistor biases both the control and suppressor grids, and, with the correct plate and screen potentials given in Fig. 6, places the operating point at the center of the linear portion of the tube's operating curve. The result is an essentially pure 400-cycle note (measured distortion 3 percent), a result not too often encountered in commercial signal generators. For proper operation of the a.f. oscillator the modulation switch SW2, should be in the "off" position.

A maximum audio frequency voltage of approximately 4 volts r.m.s. may be expected at the a.f. output jack. This is ample for most purposes.

A few words regarding the L4-C1 frequency-determining network is in order. Trouble may be experienced in obtaining a suitable inductance. The value of C1 is given as .1 μf. Actually, *the condenser used measured* .125 μf. Other .1 μf condensers checked were also found to have an average capacity of .125 μf. This means that an inductance of 1.27 henries is necessary to tune to 400 cycles. Calculations show that an inductance of 1.25 henries will resonate at a frequency of 403 cycles with a capacity of .125 μf. This is close enough to 400 cycles.

An inductance of 1.25 henries may not be available. The one used in the Transigenerator was obtained by placing stacked sheets of transformer laminations inside a multilayer air core coil, whose previous inductance was approximately 350 millihenries. The laminations were taken from a discarded transformer and cut to fit. L4 may be seen in the lower right-hand corner of chassis in Fig. 3.

Suggested combinations of L and C to tune to 400 cycles or thereabouts are tabulated below and may serve as guide to the prospective constructor:

L (H)	C (μf)	Remarks
.5	.316	Voltage
1.0	.159	output
1.25	.125	decreases
2.0	.08	Distortion of wave
4.0	.04	increases

If it is impossible to obtain a suitable L4-C1 combination, an R-C-tuned version of the transitron may be employed. The circuit is shown in Fig. 5. This circuit is simpler and requires no inductance. It was not used in the Transigenerator only because it was considered more expedient to operate both plates (r.f. and a.f.) at the same potential of 9 volts (as per Fig. 6), with one common bypass condenser. Moreover, a suitable inductor for L4 was easily obtained.

If the values in Fig. 5 are followed closely, the output waveform will also approximate a sine wave much more closely than average signal generators.

To obtain unmodulated r.f. output at jack J1, the modulation switch SW2 is placed in the "off" position. For a.f. modulation at 400 cycles, SW2 must be placed in the "on" position. Grid modulation of the r.f. oscillator then takes place at the audio rate of 400 cycles per second. Percentage of modulation is controllable. Two volts (r.m.s.) is necessary to modulate the r.f. oscillator 100 percent. From this, it can be seen that only a small voltage is required to produce the 30-percent modulation required by the I.R.E. Standards Committee. A high percentage of modulation in a signal generator is often useful when checking a receiver which is so badly out of alignment that high output is necessary to force the signal through.

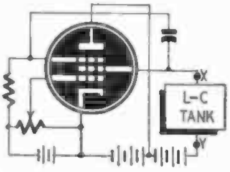


Fig. 4—Basic transitron circuit.

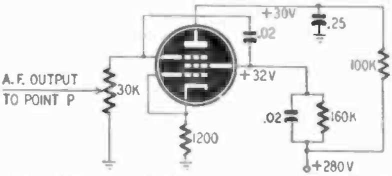


Fig. 5—Alternate R-C audio circuit ("Point P" refers to Fig. 6).

The capacitor which connects the SW2 "on" contact to ground keeps r.f. energy out of the a.f. circuit; it has negligible effect upon output.

The r.f. oscillator may be externally modulated if desired. Thus an a.f. source, such as a variable-frequency audio oscillator, phonograph pickup or microphone, may be superimposed upon the r.f. test signal, through the external modulation jack.

Fig. 6 includes this in dotted line form, since it is still in the "plan" stage. Clearly, switch SW2 must be changed to the single-pole three-position type. The jack will be mounted on the panel near SW2. Another condenser goes from the jack to the chassis as shown.

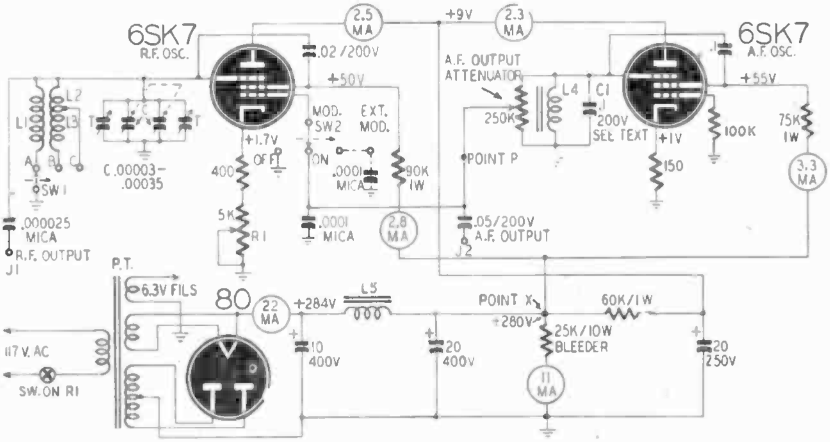


Fig. 6—Schematic diagram of Transigenerator (Alternate a.f. circuit is shown in Fig. 5).

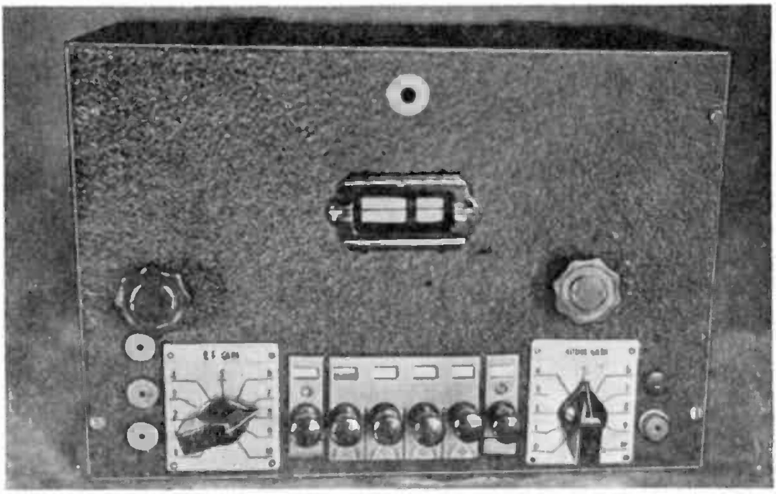
Any small power transformer may be used. If the voltage at point "X" exceeds 280 volts, a 10-watt resistor may be used in place of choke L5. The value must be found by trial, and this can be simplified by employing a resistor with an adjustable slider. If the voltage at point "X" does not exceed 280 by more than 15 or 20 volts, it will be simpler to reduce or remove the input filter condenser.

Much has been written about calibrating signal generators, so little need be said here. The entire broadcast band can readily be calibrated with the help of a broadcast receiver, by zero-beating the generator against known stations. Short-wave bands can be spotted in the same way.

The i.f. band is not so easily calibrated, due to the pure wave of the Transigenerator, with its consequent lack of harmonics. The best method is to set the generator at 600 kc, then tune the receiver used to help calibration to 1,200 kc. The generator's second harmonic will be heard. Now back off generator and receiver, taking care not to lose the harmonic, and calibrate at every known station. For instance, when the second harmonic zero-beats with a station on 1,000 kc, the generator is tuned exactly to 500 kc. This method will carry calibration down below 300 kc, but will not work for 175 kc. If a good signal generator can not be borrowed to use as a standard, a rough method of setting 175 kc is to tune for maximum output through a well-aligned 175-kc superheterodyne.

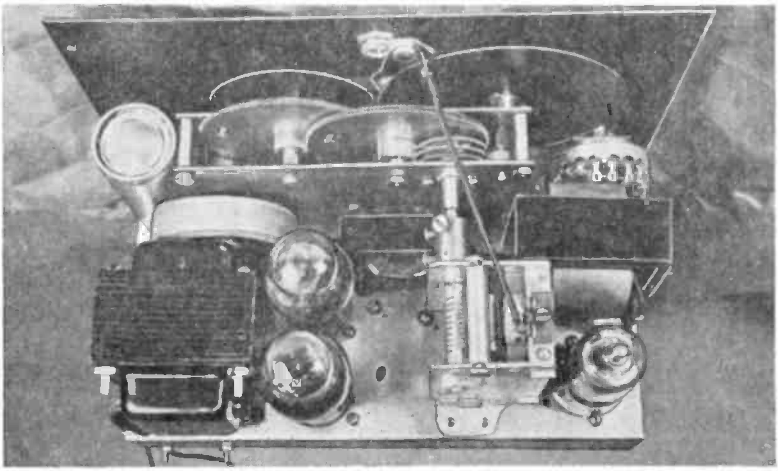
A Wide-Range Generator

USING QUITE a simple but highly efficient circuit, this signal generator has several operating conveniences. Consisting of a 6K8-GT tube used as an r.f. oscillator, a 6L5-G audio oscillator to modulate the r.f. signal and a 6ZY5-G rectifier, the entire unit is mounted behind a 7 by 10-inch panel, in a 6-inch deep cabinet. The 6K8-GT triode section acts as the r.f. oscillator; the pentode section serves not only as a mixer for the audio oscillator, but effectively prevents any reaction from the output load on the r.f. oscillator. Varying the output control can have absolutely no effect on the oscillator frequency. For ease in switching from one band to another, a push-button switch having six buttons, each controlling a d.p.d.t. switch, was used. The six coils should be mounted close to the switch in order to keep all leads to a minimum length. Use heavy bus bar in wiring the entire r.f. circuit, since floppy leads will affect the stability of calibration.



Front view of all-wave signal generator.

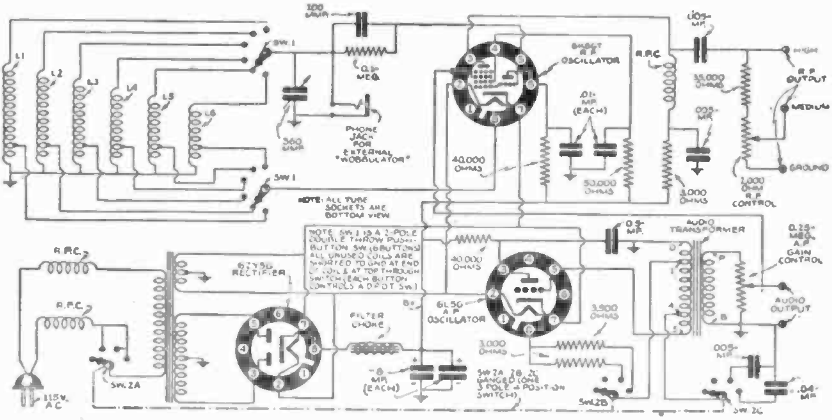
The audio oscillator is quite unusual in that two frequencies, 400 and 1,000 cycles, are provided for modulating the r.f. oscillator. Special care was taken to have the audio output level at the same amplitude at both frequencies, thereby necessitating the use of a separate cathode resistor for each audio frequency. If additional audio frequencies are desired, another condenser can be added for each additional frequency.



Top view of signal generator.

The r.f. oscillator can also be externally modulated by a phonograph pickup or other method, by connecting the external modulator to the audio output jacks and turning the control switch (SW2) to the position opening the 6L5-G cathode, thereby silencing the built-in audio oscillator.

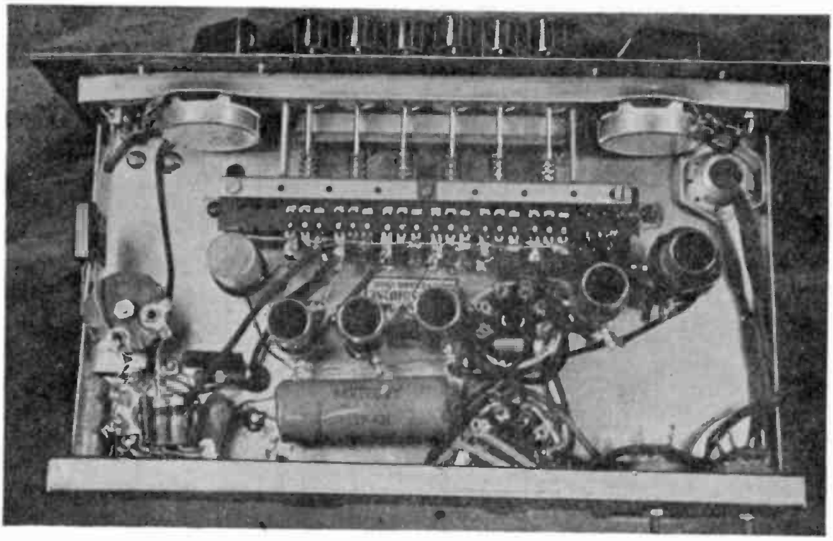
A single switch controls the application of line voltage to the entire unit, as well as turning on the audio oscillator and changing the audio frequency. This is accomplished by the 3-pole, 6-position rotary switch



Schematic diagram of all-wave test instrument.

SW2, of which only 4 positions are used at present; the other 2 being available for the use of additional audio frequencies as described above.

Before making use of the *signal generator*, it should be calibrated as accurately as possible. The best way would be to calibrate it against the harmonics of a 100-kc oscillator checked against the standard frequency transmissions of WWV. Alternatively, the signal generator can be checked against a calibrated oscillator.



Bottom view, showing coils and push-button switches.

COIL SPECIFICATIONS

	Range	*Turns*	*Wire Size*	*Winding*	*Tap from Gnd. End*	*Coil Diameter*
L1	110-360 kc	300 turns	#36 s.s.e.	Universal	75th	9/16"
L2	300-900 kc	150	#36 s.s.e.	Universal	50th	9/16"
L3	800-2700 kc	100	#32 enam.	Close wound	30th	9/16"
L4	2.5-8.5 mc	32	#26 enam.	Close wound	8th	9/16"
L5	7-26 mc	8½	#24 enam.	Space wound 5/16" long	3½	9/16"
L6 (Home-made)	24-75 mc	3¼	#18 enam.	Space wound ½" long	1½	⅝"
R.F. CHOKES (3)		300	#32 d.s.c.	Universal		⅜"

List of Parts

3—.005-μf mica condensers
1—.0002-μf mica condenser
1—.04-μf paper condenser 400 v
1—.5-μf paper condenser 400 v
2—.01-μf paper condensers 400 v
1—8 x 8-μf condenser 450-volt
1—365-μμf tuning condenser

RESISTORS

2—40,000 ohms ½ watt
2—3,000 ohms ½ watt
1—35,000 ohms ½ watt
1—3,500 ohms ½ watt
1—50,000 ohms ½ watt
1—100,000 ohms ½ watt
1—2,000-ohm potentiometer
1—.25-meg potentiometer

MISCELLANEOUS

1—Octal steatite socket
2—Bakelite octal sockets
1—580-volt c.t. power transformer
1—Output transformer
1—10-henry filter choke
1—Tuning dial
2—Dial plates
1—"R.F. GAIN" name plate
1—"AUDIO GAIN" name plate
1—6K8-GT tube
1—6L5-G
1—6ZY5-G
1—6-button push-button switch
1—3-pole, 6-point rotary switch
1—Phone jack
5—Phone tip jacks
1—7 x 10 x 6" cabinet
1—Chassis
1—Condenser coupling
1—Set of signal generator coils (including chokes)

Simple Audio Generator

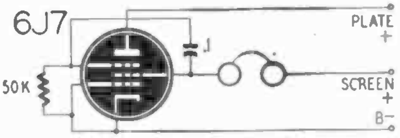
HERE IS one of the simplest and most stable types of oscillators which can be constructed. Besides power supply, only five components are required: pentode tube, socket, resistor, condenser and pair of phones. The power input is very small and the output is a pure sine wave, containing no trace of distortion as observed on an oscilloscope.

The circuit is a transitron. Experiments were carried on with a type 6J7 as a typical pentode, but any other type, preferably the miniature styles, can be used. The condenser and resistor used may be of low rating and small size since the voltages used are low.

Following are combinations of voltage inputs used and the output voltage measured across a pair of phones:

Plate	Screen	Output
3 v	4.5 v	0.1 v
3	6.0	0.4
3	7.5	0.6
7.5	7.5	1.4
1.5	25.0	8.0

At the lower values listed the cathode current is approximately 200 microamperes. The pure sine wave is obtained when using the first three listed conditions. The higher the voltages the greater the distortion.



Low-voltage transitron audio oscillator; it produces a pure sine-wave output at 800 cycles.

In general the transitron requires a higher voltage on the screen than the plate, but note that oscillations were obtained with 7.5 volts on each.

The note obtained depends upon the impedance of the phones and the voltages applied. It may also be changed to some extent by shunting the phones with a condenser, but it was found that at very low voltages, the tube went out of oscillation when a large capacitance was connected. A frequency of 800 cycles was obtained.

This source of low-power, audio-frequency oscillation should be excellent for bridges, testing and code oscillator work. If more power is needed, the output of this oscillator can be amplified to any desired level.

Tube Testers

DYNAMIC TUBE CHECKER

WITH FEW exceptions, all the tube testers on the market today are the total emission type. All elements but the cathode are tied together and the emission of the cathode is measured by a d.c. milliammeter. Such testers require few parts and are useful for short and emission tests of rectifiers and output tubes, where the emitting ability of the cathode is one of the major factors. In other types of tubes they have severe limitations, for they give no indication of the tubes' transconductance, abbreviated Sm. (Mutual conductance, abbreviated Gm, means the same.)

Transconductance by formula is:

$$\mathrm{Sm} = \frac{dI_p}{dE_g} = \frac{\text{change in plate current}}{\text{for given change in grid voltage}}.$$

Thus, if an a.c. signal of 1 volt is impressed between grid and cathode of a tube with normal plate and bias voltages and its a.c. plate component measured in microamperes, the result is a direct reading in micromhos (μmhos). If the a.c. output is 1 ma:

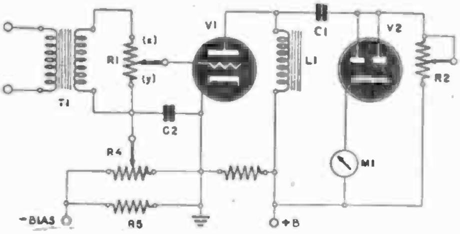


Fig. 1—left—Basic circuit of transconductance tube tester.

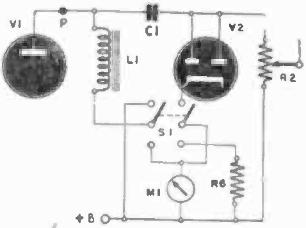


Fig. 2—right—Modified circuit for emission tests.

$$\mathrm{Sm} = \frac{dI_p}{dE_g} = \frac{.001}{1} = 1{,}000\ \mu\text{mhos.}$$

Since the tube's Sm is directly affected by emission, plate resistance, positioning of elements, etc., and the test is made under conditions closely approximating actual working conditions, this type of test is greatly superior to straight emission tests. It has even been found in life tests on a number of tetrodes that while emission fell off with some tubes to a point where they might have been rejected by an emission tester, their Sm had actually increased and they were more efficient amplifiers than when first tested.

Fig. 1 shows the basic circuit for such a tester. Theoretically the output measuring device should be an a.c. milliammeter of the dynamometer type which responds only to a.c. However, since such instruments are costly, it has been replaced with a choke L1 to apply the plate voltage, an isolating capacitor C1, a diode rectifier and d.c. milliammeter M1. It will be noted that the output impedance of the circuit comprised of L1, C1, V2, M1 and R2 is quite low. Here the Sm test differs from actual operating conditions, for the purpose is to measure the a.c. output into a load small compared to the tube's plate resistance.

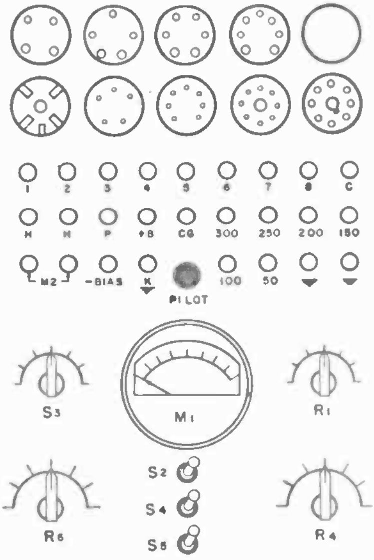


Fig. 3—Panel layout of transconductance meter.

T1 supplies the 60-cycle a.c. signal for the control grid and can be any step-down transformer, a winding on the power transformer, filament, bell-ringing or even an output transformer, since no current is drawn from it. R1 is to adjust the voltage applied to the grid and can be any value of volume control. It can be set at one volt, or if the meter hasn't sufficient flexibility, it can be put on the panel and set for various conductance scales. This would also be a simpler procedure than switching shunts across the meter for lower range meters. L1 can be a filter choke, audio choke or the primary of an output transformer. It should have low resistance so that too great a d.c. drop will not be created across it when testing power tubes. It should have fairly high impedance at 60 cycles—say at least 30 henries. C1 and C2 should be paper capacitors offering low impedance at 60 cycles—2 μf, preferably larger.

The meter can be any d.c. milliammeter with a fundamental range of from 1 to 6 ma, though a higher range could be used if the fixed grid input voltage of one volt was increased. Lower range meters can have their scales extended with suitable shunts. Since tubes vary in Sm from a few hundred to about 6,000 micromhos, the scale or scales will have to be readable from approximately 0.2 to 6 ma. V2 can be a diode such as

6H6 or 84. Any tube with good cathode emission can have its grids and plate tied together to operate as a diode, and will work here. R2 can be any potentiometer that will carry the meter current. It forms the diode load and is adjusted for maximum meter reading with a given input signal. Once adjusted it can be left set or replaced with a fixed resistor. R4 is the potentiometer (any volume control) for giving the tube its required bias. It must be much larger in value than R5—which may conveniently have a value of 1,000 ohms—so that it will not pass too much current due to the drop across R5. It will be a front panel control and will be calibrated; its setting determined by meter measurement, and listed for each tube.

The rest of the instrument requires: 1—A tapped filament transformer T2, to supply all tube requirements between 1.1 and 117 v; 2—A source of B supply of about 350 v with good regulation and bleeder tapped about every 50 v to supply various plate and screen potentials and bias; 3—An array of sockets to accommodate all types of receiver tubes in use, wired together according to standard pin numbering, with each of the nine possible contacts brought out to pin jacks or terminals.

Switching done by pin-jacks and plugs

This is essentially a technician's instrument and switching arrangements would be complicated and costly. Therefore, with the exception of the filament, no switching arrangement was considered. Instead pin jacks and pin tip leads are used to make the various connections externally. This gives the instrument complete flexibility and freedom from obsolescence unless new type sockets are brought out, at which time they could easily be added.

Referring to Fig. 4, it will be seen that the instrument must be used with a tube manual for the application of proper voltages to the correct pins and to find the Sm to be expected under these conditions—unless the builder prefers to make a complete list of pin numbers, voltages, and Sm to be expected. We found it simpler to enter the bias setting and Sm in the tube manual.

Calibration of new scales for the Sm meter is carried out with known good tubes. The procedure will vary with the type of d.c. milliammeter used. Let us assume that it is a 0·6 ma. This should give us a range up to 6,000 μmhos. First we must set R1 to apply one volt peak between cathode and grid. This should be measured with a v.t. voltmeter if resistance of R1 is high. If one is not available calculate it from the output of T1 and the resistance ratio of R1:

$$Eg = \frac{x + y}{Et}$$

when Eg is signal output, Et is transformer output and equals 1.414 times voltage measured on ordinary meter; x and y are values in ohms either side of tap.

Insert a known good tube, say a 6C5, and apply voltages for an Sm of 2,000 μmhos. If the output circuit were completely efficient a reading of about 2 ma should be obtained. In any case, mark the scale for 2,000 μmhos. Similarly, repeat with, say, a 6J5 for 3,000 μmhos, a 27 for 1,000, a 6V6 for 4,000, and so on. By consulting the tube manual, tubes with other values can be chosen and different tubes with the same Sm used for a double check of the calibration, which should be fairly linear.

Some constructors may prefer to put R1 on the front panel and log an arbitrary value for each tube which will give it the correct Sm reading to correspond to the manual data for given conditions. It should also be mentioned that the bias control R4 can be used to vary the output reading.

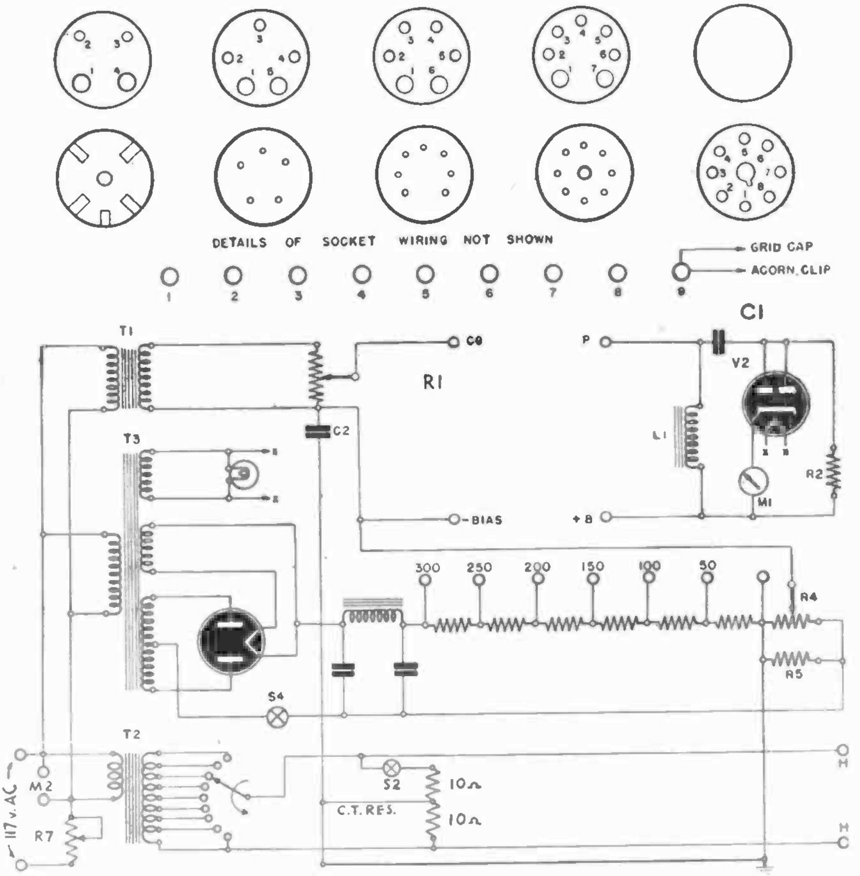


Fig. 4—Complete diagram of the checker. Tube socket terminals are wired in parallel and to the numbered posts just below. Connections to voltage posts are made with aid of tube manual.

If a 1- or 2-ma meter is used, it would be best to have two or even three scales, increasing the meter's range with a switch and shunts. In the case of a heavy current meter of 10 ma or more it would be advisable to increase the input signal voltage to give full-scale deflection for a 6,000 μmho reading. An Sm scale of 0-3,000 will handle the great majority of tubes; in fact all but about twenty. A 0-6,000-μmho scale will take care of all but nine, such as the 25L6 and 6Y6. The 6AG7 is highest with an Sm of 11,000. The builder can decide whether or not it is justifiable to extend the ranges in order to measure these tubes at their full rated value.

It is of course essential to hold all voltages constant. Hence, rheostat R7, capable of dissipating 30 to 40 watts. If an a.c. voltmeter is not available to incorporate in the instrument, pin jacks can be provided to use an external one.

Also note that it is necessary to use a center-tapped resistor when checking filament-type tubes, or a 60-cycle voltage will be impressed on the grid (independent of T1), due to unbalance in the filament circuit. If the center-tapped resistor is low in value it will have to be opened by switch SW2 for high-filament-voltage tubes, or it will burn out. If a high value is chosen to avoid this it will bias the tube.

Emission test circuit optional

No provision was made for emission or short tests since it would further complicate the circuit. However, the output circuit could be modified as shown in Fig. 2 to provide emission tests by throwing S1. The switch is double-pole double-throw type. When used for emission tests the meter shunt R6 is connected across the meter to give it a suitable range and the meter is inserted in series with the plate supply. Emission readings should correspond with manual data for given voltages. The meter should cover from a few ma to at least 60, and it may be desired to add another shunt and switch to give more easily read ranges.

Since the operator may come in contact with 350 volts, it is advisable to break the plate supply with a switch, S4, while setting up for a test. Also, of course, care must be taken in making correct connections, or the tube might be damaged. Dual-purpose tubes will require two or more separate tests.

If a tapped filament transformer is not available, it can be wound on any power transformer with a good 117-v primary. (When removing the old windings observe the number of turns per volt. If a 5-v winding has 30 turns the transformer has 6 turns per volt. This can be used to compute where to tap off leads. In this case the 1.4-v tap will be at 6 x 1.4 = 8.4 turns and 6.3 v at 6 x 6.3 = 37.8 turns approximately.)

The dynamic tester is a most useful instrument and will well repay the builder in time saved, particularly when a replacement tube is not readily available for a substitution check, or a receiver for a check under operating conditions. At the same time it will save the rejection of low emission but otherwise good tubes.

Modernizing Old Testers

Almost any checker can be modernized by first determining the basic test circuit, then designing adequate switching and filament supply circuits to supplement the obsolete ones. To illustrate, modernization of a Triplett Model 1503 is described. New tubes are connected through a control panel to the original test circuit; quality tests are made with the tester controls and meter; and the old circuits need not be changed. The advantages of this method are:

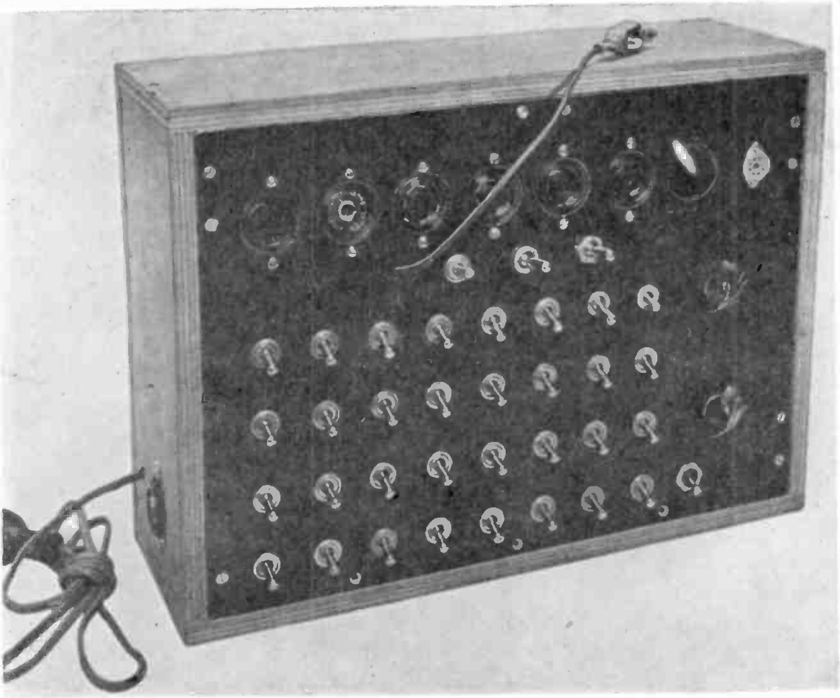


Fig. 1—Front panel of conversion unit. One socket hole is blank for future use.

1—Full use of the obsolete checker; cost is kept to a minimum.
2—Calibration is required for new tube types only.
3—The volt-ohm-milliammeter circuits of a combination tester are in

no way disturbed. (This is important to those who wish to retain the volt-ohm-milliammeter circuits, but would like to modernize the tube-testing section.)

Tube checkers can be divided into groups according to the tube characteristic tested to indicate quality. Emission, transconductance (mutual conductance), and amplification (or power output) tests are popular. Fundamental schematic diagrams are shown in Fig. 3.

Emission testers (Fig. 3-a) measure total tube current (emission) under specified test conditions. The filament is operated at rated voltage. The cathode is connected to B—, all other elements are tied to the plate, a low positive voltage is applied, and emission is read on the meter. The test is essentially for "end of life"; it is not always an accurate indication of tube quality—a *defect* may cause normal emission.

A good transconductance tester provides a better test for quality. The transconductance test circuit shown in Fig. 3-b forms the basis for many.

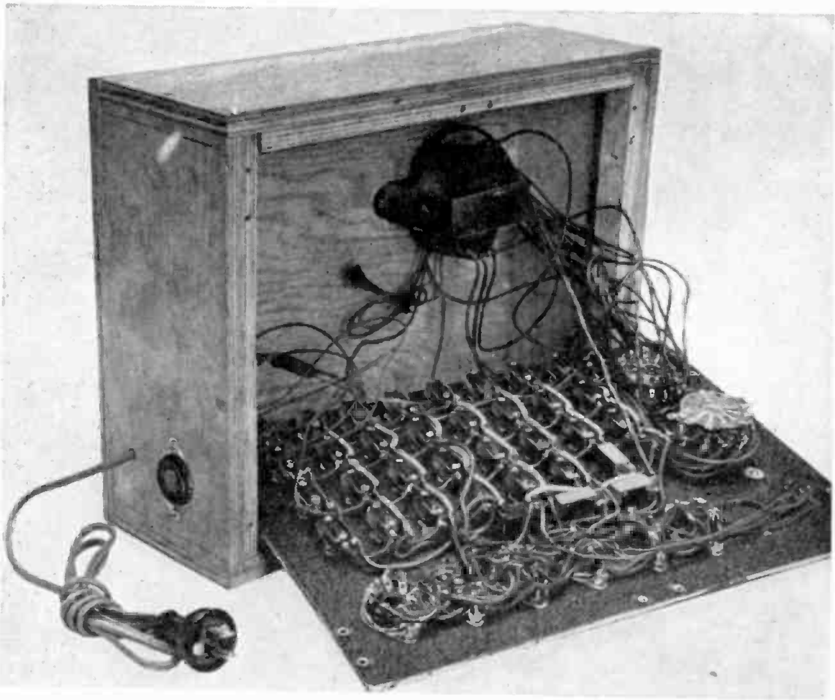


Fig. 2—Rear view of adapter, disclosing internal construction and wiring.

The power output test (Fig. 3-c) is not as popular as the transconductance test. For power output tubes the test is a close check on quality; for voltage amplifiers, power output is an indication of the amplification that can be expected.

The transconductance of Class-B amplifiers, such as the 6N7, is difficult to check with ordinary circuits; therefore a special power output test (Fig. 3-d) is sometimes employed.

To determine the basic circuit in an obsolete tester, isolate the circuit on the schematic. A simplified diagram of the Triplett test circuit for

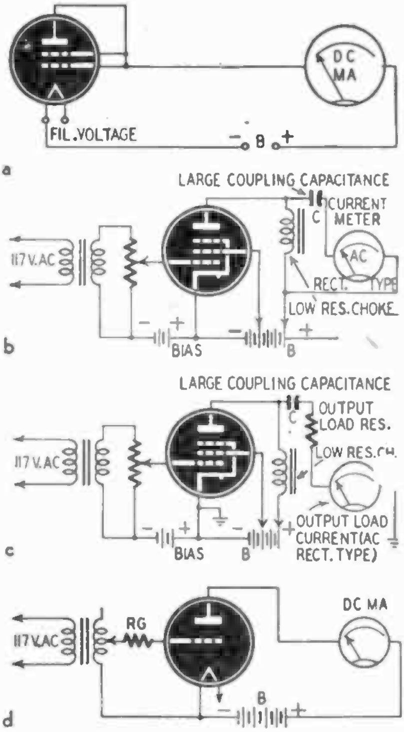


Fig. 3—Four fundamental tube test circuits.

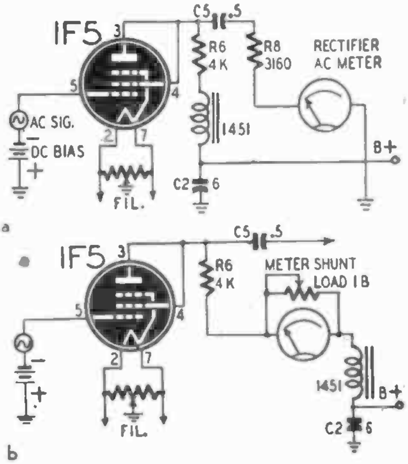


Fig. 4—Two test circuits used in Triplett 1503.

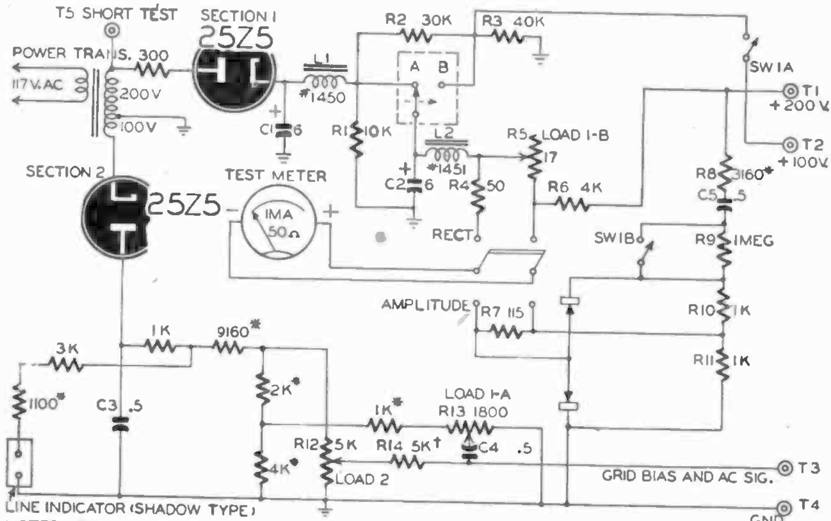
amplifier tubes is shown in Fig. 4-a. (For simplicity, symbols represent the a.c. meter, d.c. bias and a.c. signal circuits.) The 1F5 tube in Fig. 4-a is tested as a triode in a modified power output test circuit (Fig. 3-c). For many tubes, the Triplett tester uses the emission circuit of Fig. 3-a. For certain tubes the circuit of Fig. 4-a is used, but the meter is placed in series with the plate load to indicate plate current (Fig. 4-b).

To determine supplementary circuit connections and the need for changes in the original tester, make a schematic which shows all the components that must be in operation when a tube is tested (Fig. 5). For example: The single-pole double-throw switch (within dotted lines) was added to the Triplett, so that miniature tubes could be tested. With this switch at A, the original circuit is unchanged; at B a suitably low voltage is available.

Fig. 5 shows that plate voltage is applied through choke No. 1451 and resistor R6; therefore a lead was run to T1, one of the base pins on a six-pin tube base used to connect the tester to the control panel. Similarly, screen voltage is taken from switch SW1A to a second tube-base pin T2; the combined bias and a.c. signal voltages are taken from the poorly-filtered rectifier circuit (25Z5, section 2) through a third tube-base pin

T3. (The voltage across the resistance network is unidirectional and pulsating; the d.c. component provides bias, the pulses provide signal.)

Switches SW1A and SW1B are controlled by the checker VALUE pushbutton. These switches are normally open; SW1A to prevent the application of screen voltage before plate voltage, SW1B to prevent burning out the meter while the calibration controls (LOAD 1 and LOAD 2) are adjusted. *Always make certain that such protective circuits are not left inoperative when supplementary circuits are wired into the tester.*



NOTES: VOLTAGES ARE GIVEN WITOUT LOAD; *CALIBRATOR; †NOT USED IN MODEL 1502

Fig. 5—Simplified diagram—basic testing circuits of Triplett models 1502 and 1503.

Three s.p.d.t. toggle switches, mounted immediately below the test sockets, connect tube pins 1, 2, or 7 through the filament voltage selector switch SF2 to the fil. line, or to the main bank of switches. These pins were chosen because they enabled application of filament voltage to all tubes then listed in the RCA receiving tube manual. For "full-floating" filament connections, connect a similar switch to each pin (Fig. 7).

The main bank of switches contains 32 single-pole toggle switches, arranged in four horizontal rows. From left to right, switches S1 through 8 are connected to the test socket contacts. Closing any switch in the plate line will connect the corresponding socket contact to the tube tester plate load (T1 in Fig. 5). Similarly, the screen line connects socket contacts to T2; the bias and a.c. signal line to T3; and the GND line provides a common ground connection T4. The ninth switch in the plate row is normally closed across a 250,000-ohm resistor. For testing diodes this switch is opened, so that the proper diode load is obtained (Fig. 6).

If the obsolete tester is an emission tester, only the plate and ground rows of switches will be needed. Similarly, if all tubes are to be tested as triodes, the screen line can be omitted.

The upper rotary switch in the photo is a filament pin selector switch (SF1 in Figs. 6 and 7); the lower rotary switch (SF2) is the filament voltage selector, for filament voltages from 1.1 to 110.

The short-test circuit (Figs. 6 and 8) is incorporated in a different panel. A.c. voltage from the tube tester power transformer (T5 in Fig. 5) is brought into the control panel and through capacitor C (Fig. 8) to the movable contact of the upper switch section. The movable contact of the lower section is wired to an 80,000-ohm resistor and neon bulb. With switches S1 through S8 in the positions shown, all tube pins are connected to the upper switch section, and the upper contacts are wired to the lower section.

With the switch in position 4, as shown in Fig. 8, tube pins 1 through 4 are connected together by the shorting bar, and through capacitor C to the power transformer. Pin 5 is connected through a jumper to the lower switch and to the 80,000-ohm resistor and neon bulb. If there is a short between pin 5 and the other 4 pins, the neon lamp will glow.

The short test will indicate filament continuity. For example, if a tube filament were between pin 5 and pin 1 in Fig. 8, the neon bulb would glow.

The capacitance of C must be low enough to provide a *high* reactance, so that the current will be limited to a safe value for all tube filaments. The capacitance C in Fig. 8 will limit the current to 50 milliamperes, when the transformer voltage is less than 250.

The circuit also enables short tests with the tube filament heated. Set the control panel switches to apply filament voltage (Fig. 7) and repeat the short test. Filaments that can be connected either in series or in parallel must be connected in parallel, so that the *lower* filament voltage may be applied.

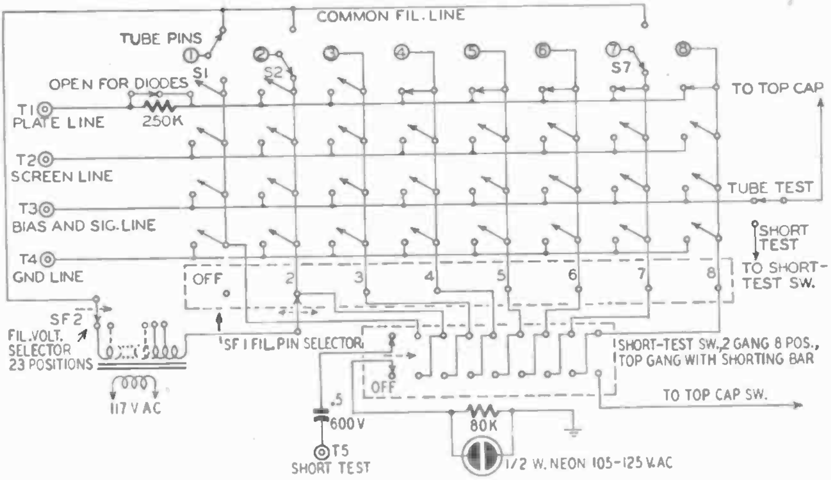


Fig. 6—Schematic of the adapter unit; short-test circuit is shown in Fig. 8.

All line switches must be in their OFF positions while short tests are made. Conversely, the short test switch must be at OFF when a tube is checked for quality.

Operation of the control panel is simple, for it is seldom necessary to use more than five switches to check quality. A few precautions must be observed. The filament selector switches should be adjusted first. This will prevent the application of plate voltage across the filament. Be sure to close the *right* switches; otherwise, you will make short circuits. *Know your circuits.*

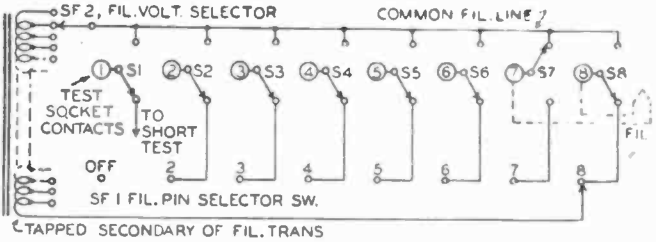


Fig. 7—Circuit for applying filament voltage to pins 7 and 8.

Calibration is required only for tubes that cannot be checked in the original checker. The tube checker chart can be used for any tube that is the equivalent, except for socket connections, of one that can be tested in the old tester. It is not advisable to attempt a too precise calibration. To calibrate:

1—Place a known good tube in the control panel. Refer to the receiving tube manual for correct socket connections, and set the control panel and tester switches.

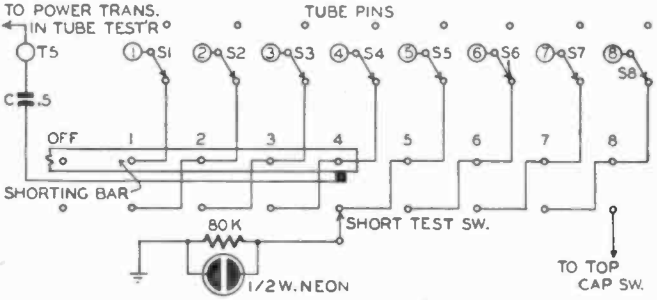


Fig. 8—Short-test circuit. Input (from power transformer in tester) is shown at left.

2—Carefully adjust the checker calibration controls to obtain a meter reading at the proper point in the GOOD area of the scale.

3—Record the adjustments for future reference.

Electronic Voltmeters

V.T.V.M. ADAPTER

TO GAIN the full advantage of a d.c.-reading vacuum-tube voltmeter a circuit must have the following features:

1—High impedance input on all ranges.

2—Isolating resistor in the probe to allow measurements to be made without disturbing signal-carrying circuits.

3—Polarity reversing switch to make it possible to read plus or minus voltages without reversing the leads.

4—Capable of reading high and low voltages.

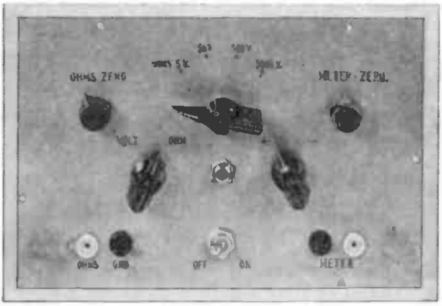
5—Complete meter protection on all ranges.

6—Use readily available parts, especially the meter.

7—Read 100 megohms or more on a high-ohms scale for measuring leakage resistances.

Note: Since the average meter will read resistance values up to ten megohms it was not deemed necessary to include these ranges on the adapter.

8—Have a zero at the left end of the scale instead of center so entire meter scale is utilized.



The simple v.t.v.m. adapter.

A scheme was worked out to use meters which are available in the average shop. This was to be done with an adapter so that the normal use of the meter would not be affected.

On the assumption that 20,000-ohms-per-volt meters are in fairly common use it was decided to build the adapter around the 2.5-volt (or lowest) scale of one of these meters. The vacuum-tube voltmeter was built with pin jacks to connect to the meter. When the vacuum-tube meter is not in use the 20,000-ohms-per-volt meter can be disconnected and used normally. Thus it is not tied up. Fig. 1 shows the basic circuit, an old and well-known one.

With no voltage applied to the grid of V1 both tubes conduct and a bias is developed due to current flow through R8 and R9. If both tubes were identical the voltage drop in each cathode circuit would be equal and there would be no voltage difference from cathode to cathode. Since V1 and V2 are never quite identical, R8 is made adjustable to bring the reading to zero.

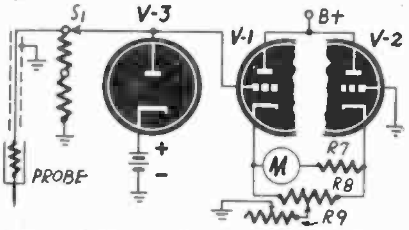


Fig. 1—V.t.v.m. adapter basic circuit.

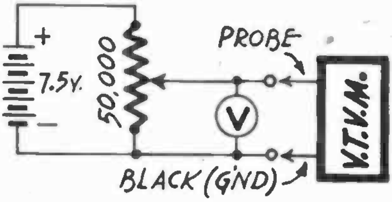


Fig. 2—Equipment for calibrating meter.

When a voltage to be measured is applied to the grid of V1 the action is as follows: Assuming the voltage to be positive, the plate current of V1 will increase. This increase of current through the cathode resistances will cause the cathode voltage to increase with respect to ground. Since R9 is common to both tubes this increase of plate current through V1 will increase the bias on V2 and its plate current will decrease. Thus the cathode of V1 becomes more positive while the cathode of V2 becomes less positive and a voltmeter connected between them will indicate.

How much the cathode voltages vary depends on the gain of the tubes. This can be adjusted by R9. R9 therefore becomes a calibration adjustment which determines the amount of input voltage necessary to give full-scale indication.

If the 2.5-volt scale of a meter is used, the lowest scale on the vacuum-tube voltmeter must be 4 or 5 volts.

When a negative voltage is applied to V1, its current will decrease and the current through V2 will increase. The meter would read backward in this case so it is necessary to use a d.p.d.t. switch to reverse the external meter connections.

The purpose of V3 in Fig. 1 is to protect the meter against accidental overloads. Without this tube the plate current of V1 would be very high in the event a high positive voltage were applied with the meter on a low range. When the voltage at V1 exceeds 7.5, V3 will conduct and the voltage drop through the 1-megohm isolating resistor in the probe will prevent the voltage at V1 from reaching a dangerous value.

The first important thing in the design of any ohmmeter is to have the ohmmeter range be a multiple of the existing meter scale. In the Hickok 133-B (the meter used in the author's model) the Hi-ohms scale was 10 megohms. It was decided to make the v.t.v.m. read 0-100 megohms, since this would multiply the existing scale by 10.

The rules followed in designing the range may be followed for any meter to be used. First, determine the amount of resistance to give half-scale reading on the ohmmeter scale. (In this meter the center of a 100-megohm scale would be 15 megohms.) Second, subtract the input resistance of the vacuum-tube voltmeter from this figure. Example, 15 − 11 equals 4 megohms. This value (4 meg) is the value that must be used for R6 in the schematic. It should be a close-tolerance resistor if the ohmmeter is to be accurate.

For ohmmeters with different scales the same procedure should be followed to determine the value of R6.

Fig. 3 is the complete schematic of the voltmeter. The resistors R1 to R4 should be as near the indicated values as possible. If semi-precision resistors are not available, ordinary resistors may be connected in series to obtain the correct values. These resistors should be measured on a Wheatstone bridge to get the proper values, or measured with a good ohmmeter.

The triode is a single 6SN7, but may just as well be two 6C5 or 6J5 tubes. The diode is a 6H6. The .01-μf condenser should be the best quality available and have zero leakage if possible.

The photo shows the physical construction of the unit. It is fitted into a 9 x 6 x 5-inch crackle-finish box. The front panel is made of aluminum and the letters inked on. After the ink is dry it is a good idea to paint over the lettering with clear lacquer or nail polish to protect it.

After the unit is finished, connect the voltmeter to be used to the output jacks J4 and J5. Set the voltmeter to a high range to protect it in case there is a wiring error. Turn the voltmeter on and allow it to warm up. Keep turning the meter zero knob to keep the meter at zero.

After the unit has reached operating temperature set the 20,000-ohms-per-volt meter to its lowest scale (2.5 v). Reset the vacuum-tube voltmeter zero adjustment if necessary and turn it to its lowest range (5 v). Connect a 7.5-volt battery and potentiometer as shown in Fig. 2. Connect a good 1,000-ohms-per-volt meter or better as shown. Adjust the potentiometer until this meter reads exactly 5 volts. Connect the v.t.v.m. to the potentiometer as shown in Fig. 3. Adjust the calibrating potentiometer

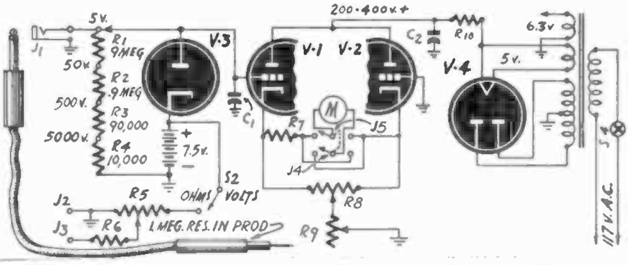


Fig. 3—Schematic. Feature is the overload tube V3, which prevents the application of potentials above plus 7.5 volts.

in the vacuum-tube voltmeter until the v.t.v.m. reads full scale. Disconnect the v.t.v.m. and adjust its zero adjustment to get the meter to return to zero. Again reconnect the v.t.v.m. and adjust the calibration potentiometer for full-scale reading. Go over these two adjustments as many times as necessary until the meter will read zero with no voltage applied and full scale when connected to the voltage source.

The calibration will now be complete for all ranges and R9 should require no further adjustment unless a tube is replaced.

To use the v.t.v.m. connect the ground lead to the chassis of the radio set under test (B-minus on a.c.-d.c. sets) and the probe to the voltage being measured. If the meter reads backward reverse the meter switch.

To read high resistance throw the Ohm-Volt switch and the meter-range switch to Ohms. Connect the lead from the Ohms jack to the voltmeter probe. Adjust the Ohms Zero adjustment for full-scale reading (zero ohms). Connect the resistance to be measured between these two leads. *Caution*: Never leave the Ohm-Volt switch on Ohms when not using the ohmmeter or the battery will discharge.

The great advantage of a v.t.v.m. is that one can connect the probe to the grid of a tube without materially affecting its operation. To prove this tune in a station on a radio and connect the meter probe to one of the i.f. amplifier grids. Read the a.v.c. voltage and try tuning the radio through the station to see how this voltage varies. Connect the probe to the oscillator grid and read the voltage there. This will slightly detune the radio. How much detuning takes place can be determined by noticing how much the dial must be moved to bring the station in clearly again.

Using a voltmeter of this type for a short while will convince anyone that: "Where voltages are to be measured in a radio receiver a vacuum-tube voltmeter will do it better."

List of Parts

R1—9 meg
R2—900,000 ohms
R3—90,000 ohms
R4—10,000 ohms
R5—10,000 ohm pot
R6—See text
(22,000 ohms on Hickok 133-B)
R7—30,000 ohms for Weston 772
R8—10 000 ohms meter zero
R9—10,000 ohms calibration
R10—5,000 ohms 10 w.
V1, V2—6SN7
V3—6H6 or 6H6-G
V4—80 or 5Y3.
S1—Range switch 4 point
S2—S.p.s.t. Ohm-Volt switch
S2—S.p.s.t. Ohm-Volt switch
S4—S.p.s.t. off-on switch
C1—.01 μf, 600 v
C2—4 or 8 μf, 450 v
J1—Vacuum-tube voltmeter jack
J2, J3—Ohmmeter jack
J4, J5—Jack for meter

METERLESS VOLTMETER

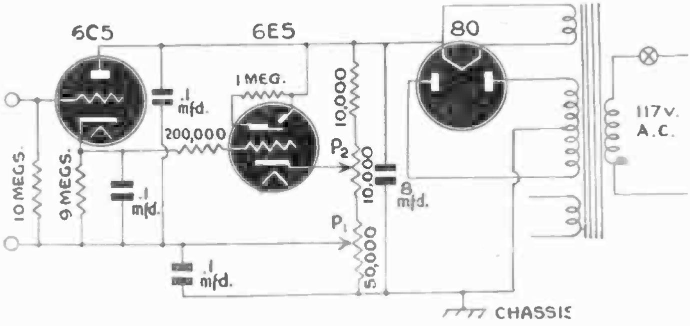
THIS METERLESS vacuum-tube voltmeter is not only an a.c. and d.c. instrument, but also an output and a.v.c. indicator.

This meter is of simple design, using a "magic-eye" tube, so any great amount of advice on construction would be out of place. The reader already understands that high-grade components, which will not change their resistance or capacity under load, are necessary in any type of meter.

The power pack may supply any voltage from about 200 to 250. Little filtering is necessary on account of the small current drawn, so the 8-μf condenser across the resistor bank will be plenty. The 50,000-ohm volume control should be a heavy-duty type, as it has about one-half watt of power to dissipate.

Excellent insulation is required, especially around the posts to which the prods are connected. If the resistance here should fall as low as 200 megohms, this would mean an error of 5 percent in readings. This is true of all v.t. voltmeters, because of their high ohms-per-volt ratio.

A word as to the theory may help the constructor. The relative potential of the grid and cathode of the 6E5 control the opening and closing of the eye. This relative voltage can be controlled by making the cathode more positive or negative with the potentiometer P2. A closed eye indicates that the grid is negative enough (cathode positive enough) to stop



Schematic. Electron-ray tube replaces meter frequently employed in such instruments. If proper care is exercised in its calibration and use, it should be accurate enough for all radio service applications.

current flow. In practice the bias is adjusted so that the eye is just closed.

The grid of the 6E5 is attached to the cathode of the 6C5 through a 200,000-ohm resistor. (Any low-mu tube may be used here in place of the 6C5 shown). The cathode resistor is large enough so that no current flows. Now if a voltage—either a.c. or d.c.—is applied between the two input points, the grid will become more positive and current will flow. This will cause a voltage drop across the cathode resistor, and raise the voltage of the 6E5 grid, opening the eye.

Note that the bias can be varied by adjusting either P1 or P2. If the arm of P1 is at the top (in the diagram) and the arm of P2 at the bottom, the two are at the same potential. We can change the bias by moving either one. Having already set the voltmeter to the no-shadow point with P2, we now compensate for the voltage being measured by moving the arm of P1 until the eye just closes again.

This measuring—or calibration—may be done with the aid of a source of several known voltages (say a battery, potentiometer and a good voltmeter), various voltages being applied and the position of P1 noted. It is an excellent idea to put a long pointer on P1 and cement a white card to the panel for marking the scales. After the meter is calibrated, the card may be covered with a sheet of celluloid or other transparent plastic.

Note that this will measure d.c. or *peak* a.c. voltages. To measure a.c. conveniently it is best to have a scale marked out in the standard r.m.s. voltages. This scale may be calculated by multiplying the d.c. or peak voltages by .707. A better method is to calibrate the a.c. scale directly with known a.c. voltages.

Meter range is flexible

The range of the meter is limited to the amount of drop across P1. This should be over 100 volts on the average power supply. For greater range, the usual resistor network may be used at the input. With such a network a certain definite fraction of the voltage to be measured can be applied to the input posts and the voltage measured can be multiplied accordingly. For example, the voltage to be measured may be applied to a 20-megohm resistor consisting of two 10-meg resistors connected in series. If only one of these resistors is connected across the input posts, only half the voltage to be measured is applied to the meter, and its range is consequently doubled.

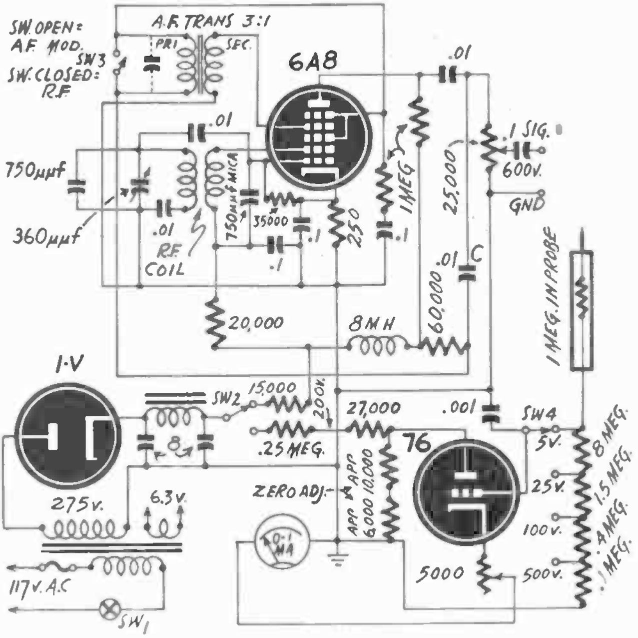
The process of measuring a voltage with this meter sounds rather complicated, but actually takes less time than it does to describe it. First, simply short the input terminals (with P1 in "top" position) for zero adjustment of the eye. Then adjust P2 until the eye is *just closed*. The meter is now ready for use. Apply the voltage to be measured. This will cause the eye to open again. Adjust P1 till the eye *just closes,* and read the voltage on the calibrated scale under the pointer of P1.

The accuracy of your readings depends a great deal upon the care with which the adjustment of P2 and P1 are made, as they must be brought to the point of exact closing, and no further.

V.T.V.M. & OSCILLATOR

A SIGNAL generator is one of the most useful pieces of test equipment. This signal generator will fulfill most of the requirements of average service work. Signals can be traced in the r.f., i.f. and audio frequency stages with very little trouble, working from grid to plate of each succeeding stage.

A 1,000-ohm potentiometer was first used to control the output which is a 440-cycle note, but was found to cut the gain to two-thirds of what the generator was capable of putting out. The 1,000-ohm potentiometer was replaced with one of 25,000 ohms and the output voltage raised from .3 to 1 volt.



This duplex test instrument utilizes but three tubes. It permits tracing signals in the r.f., i.f., and audio-frequency stages, working from grid to plate of each succeeding stage.

Care must be taken while building this generator to keep certain components well away from parts most likely to affect the tuning coil and 440-cycle audio-frequency note. Place the 6A8 tube and r.f. coil well away from the power supply. The r.f. coil should be well shielded and the audio-frequency transformer kept away from the tuning stage. If possible, place the audio-frequency transformer under the chassis to isolate it from these components.

A single-pole, single-throw toggle switch is used across the primary of the audio-frequency transformer. When the switch is open a modulated 440-cycle audio-frequency note results and the capacity of the toggle switch alone acts as a condenser. If any other type of switch is used, any condenser up to .01-μf may have to be shunted across the primary, depending on the tone desired. For r.f., simply close the switch.

The r.f. coil may be any conventional one with a tuning condenser to match so long as it tunes to the standard broadcast band. The range, with the harmonics, extends above and below the standard broadcast band of 500 to 1,650 kilocycles. To calibrate the instrument, we used a Ferris Noise Meter. However, any radio can be used.

Care must be taken, if one desires to calibrate the generator accurately, to distinguish the true signal from a harmonic. The true signal will be the loudest and clearest. To calibrate, connect the generator output to the radio antenna, and ground to chassis. Be sure the radio is in good working order and aligned properly.

To supply the direct current, any rectifier tube can be used as long as the filament transformer is not overrated. A 15-henry 20-ma choke is all that is required to keep hum down to a minimum. The power transformer should supply around 275 volts in order to attain high gain.

Electronic voltmeter details

An electronic d.c. voltmeter can be added if desired, and is very useful in checking voltages at grid and plate terminals without seriously upsetting any radio's operation.

If you do not have such an instrument, one can be included by using a double-pole, single-throw toggle switch to cut out the B supply to the generator. A 0-1 milliammeter is used and its rating varies from 2,200,000 ohms per volt on the 5-volt scale to 22,000 ohms on the 500-volt scale.

Current through the 76 tube is adjusted to fall within the range of the 0-1 milliampere meter by means of the two resistors which shunt the tube. A 10,000-ohm resistor was first inserted and sufficient resistance added till a zero setting (half-scale reading) was obtained with the 5,000-ohm cathode resistor at half scale. In the case of the meter shown, an additional 6,000 ohms was required, but this will vary in different instruments. The cathode adjustment control is first adjusted until the meter reads half scale; this calibrates the meter. When 5 volts d.c. is applied, the meter should read full scale if the test prod is connected to plus 5 volts, and zero if connected to minus 5 volts.

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