RADIO SERVICING INSTRUMENTS

E. N. BRADLEY

The construction, calibration and use of instruments in this class.

Included are various types of direct reading meter and multi-meter, valve voltmeter, signal generator, oscilloscope, wobbulator, electronic beam switch, a.c. bridge and signal tracer.

Practical instructions arranged in sequence are given for the use of the instruments in tracing faults, aligning receivers, etc.

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MEASURING INSTRUMENTS

FOREMOST among radio servicing instruments are those for the measurement of current and voltage. Two types of measuring instrument are common: (1) The direct measuring instrument in which a moving coil meter is connected directly into the circuit under test (generally *via* resistors or a device such as a thermo-couple); and (2) The indirect measuring instrument where the moving coil is isolated from the circuit under test by electronic devices, as in the valve voltmeter. The direct instrument has the advantages of relative cheapness, great stability when properly used and maintained, and considerable accuracy and flexibility. The valve voltmeter (the usual type of indirect instrument) although flexible is considerably less stable unless carefully designed; but it has the outstanding advantage of having an extremely high input impedance, and so has practically no disturbing effect on the circuit under test.

A moving coil meter (more properly termed a moving coil instrument, and referred to as a d'Arsonval instrument in American publications) consists of a small coil of light wire free to rotate on pivots in a powerful magnetic field. The pointer of the instrument is mounted on the coil. Current is fed *via* two springs which also control the movement of the coil to a degree. When current passes through the coil a magnetic field is set up around the coil that interacts with the existing field to produce a force on the coil. Since the coil is free to move, it rotates until the force of the springs balances the force due to the current, the pointer moving over an arc and indicating by the degree of movement the strength of the current flowing in the coil.

In all direct measuring instruments, with one exception, the indication is primarily due to current flowing. The exception is the electrostatic voltmeter which has no coils at all. The moving member is a vane moving between two fixed vanes; or it may consist of sets of vanes moving and fixed, interleaved. The potential to be measured is applied across the vanes or sets of vanes, so that the rotor is electrostatically attracted by the stators, thus moving the indicating pointer. No current is consumed in this instrument apart from a very small leakage current.

The moving coil instrument is adjusted in manufacture to have some particular sensitivity, the most common instrument having a range of from 0 to 1 mA d.c. Moving coil meters by themselves can respond only to direct current because alternating current supplied to the coil would make its field alternate and so trying to swing the coil first one way and then the other, finally producing nothing more than a tremble. To measure a.c. by the moving coil instrument it is necessary first to rectify the alternating current; full wave rectification is desirable and bridge rectification is commonly used.

The coil has resistance which produces a potential drop across the instrument when a current is passed through it. In some cases the resistance of a " swamp " or internal coil of copper wire is included for better temperature variation compensation to build up the complete internal resistance of the instrument.

To measure currents greater than those for which the instrument is designed it is necessary to use a " shunt " (Fig. 1 (a)). Only a proportion of the current is measured, the surplus being passed through the shunt. Since the relationship between the shunt and meter resistances is fixed, the

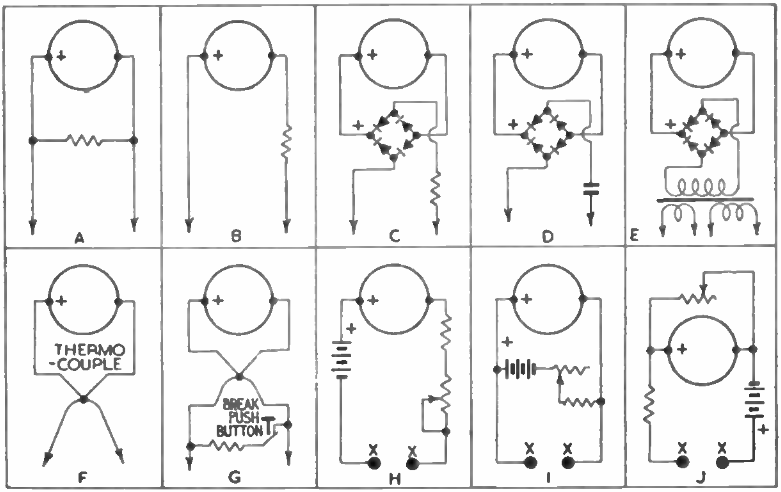


FIG. 1. VARIOUS CIRCUITS EMPLOYING MOVING COIL INSTRUMENTS

accuracy of the measurement is not affected, and the instrument scale can be calibrated in terms of the full current if desired. The resistance of any shunt may be determined from the formula

$$Rs = \frac{r}{n - 1}$$

where Rs is the resistance of the shunt in ohms, r is the internal resistance of the instrument, and n is the factor of multiplication. Thus, if it is required to measure up to 100 mA with a 1 mA instrument, n is then 100 and the term n — 1 is 99, the formula becoming

$$Rs = \frac{r}{99}$$

Assuming the meter resistance to be 100 ohms (a common value) the shunt resistance would then be 1·01 ohms.

Shunts should be made of a suitable resistance wire which will carry the required current without causing undue heating, and its associated variation of resistance value. Manganin is a very satisfactory material.

Direct current or voltage is measured by a moving coil instrument by permitting the potential to set up through the meter a current flow, the value of which is determined by the total resistance of the meter. The internal resistance of the moving coil instrument must, therefore, be increased for all except very low voltages, the added resistance being known as a " multiplier " (Fig. 1 (b)). The resistance of the required multiplier may be found from the formula

$$Rm = \frac{V}{I}$$

where Rm is the multiplier resistance in ohms, V is the required voltage to be measured and I is the full scale current of the instrument in amperes. For low voltage ranges the formula must be adapted to

$$Rm = \frac{V}{I} - r$$

where r is the internal resistance of the moving coil instrument. This resistance is printed on the scale of a good instrument. In the case of milliameters the formula in either case may be adapted to save the trouble of converting the full scale current into amperes, and becomes

$$Rm = \frac{1{,}000V}{i} \qquad \text{or, for low voltages:}$$

$$Rm = \frac{1{,}000V}{i} - r$$

where i is the full scale current of the instrument in mA. Thus, to measure a voltage of 10 volts using a 0–5 mA instrument whose internal resistance is 20 ohms

$$Rm = \frac{1{,}000 \times 10}{5} - 20$$

$$\textit{or} \quad Rm = 1{,}980 \text{ ohms.}$$

The multiplier must be capable of carrying the full scale current of the instrument—usually no arduous task—and of sustaining the required voltage drop across its body. When high voltages are to be measured it is usual to split up the multiplier into a number of separate resistors to avoid flash-overs and break-downs. The ordinary "radio" type of resistor is rated to take no more than 1,000 volts across its leads.

The values of both shunts and multipliers should be as accurate as the instrument calibration to maintain meter accuracy. A normal accuracy for a moving coil instrument is 2 per cent. of full scale value, and for multipliers (which are obtainable commercially as high stability resistors) 1 or 2 per cent. Shunts are not readily obtainable commercially, but they can be made by the constructor as detailed later.

For measuring alternating voltage the moving coil instrument is used in combination with a rectifier and multiplier as shown in Fig. 1 (c). The meter rectifier should be obtained to suit the instrument, a 0—1 mA meter being fitted with a 1 mA meter rectifier. Westinghouse meter rectifiers are readily available. They should be used with care; the long flexible leads should not be shortened when connected in circuit, nor soldered back on to their lugs should they get broken, as heat has a bad effect on the rectifier elements. Broken leads should be replaced by multi-strand flexible wire securely tied on to the lugs.

The multiplier formula already given is not applicable to alternating voltmeters, for the current through the multiplier is the input current to the rectifier rather than the meter current; for sinusoidal a.c. input the current is 1·11 mA rather than 1 mA for 0—1 mA meters. In some circumstances it is also necessary to make a further allowance for the rectifier resistance, whilst the linear scale of the moving coil instrument does not hold good for low alternating voltage measurements. In a multi-purpose instrument, therefore, all direct current and voltage readings, together with the higher alternating voltage readings, use a linear scale, while a specially calibrated arc serves for alternating voltages below about 10 volts.

An alternative type of multiplier for alternating voltmeters is shown in Fig. 1 (d), where a capacitor is employed in place of a resistance, the reactance of the capacitance being made the appropriate value. The scheme has little to recommend it, for it is generally simpler to obtain or make up the odd resistance value required for the multiplier than to make up an odd capacitance, and the resistor should be as stable as the capacitor and less likely to break down. Also the capacitor only gives correct reading at the frequency for which it is calibrated.

The instrument rectifier, as already shown, can handle currents no greater than the full scale current of the moving coil instrument with which the rectifier is to be used. When it is required to measure greater alternating currents, moreover, the rectifier cannot be shunted with any accuracy or safety; a current transformer is employed, as at Fig. 1 (e), to give up to 1·11 mAs. output for a chosen input. Different primaries permit the measurement of various alternating currents, common values in multi-purpose meters being 0·5, 2·5 and 5 amperes.

The constructor who wishes to make a multi-purpose measuring instrument may build such a current transformer using standard laminations and published details; but the work is tedious and the component can prove to be expensive. Also, the circuit is easily overloaded and the transformer and rectifier damaged.

A more convenient method of measuring some forms of alternating current is to employ a separate thermo-ammeter. This consists of a moving coil instrument across whose terminals, and contained within the meter case, is a thermo-couple, a junction of two dissimilar metals which when heated sets up a small current flow through the meter. Terminals on the rear of the case provide connection to the heater wire in contact with the thermo-couple. This instrument has two disadvantages; it is non-linear, the scale closing up considerably near the zero end; and the heater is fairly readily overloaded (which can, however, be easily guarded against). The circuit of the thermo-ammeter is shown at Fig. 1 (f).

Thermo-ammeters are readily obtainable on the surplus market at the present time, the most useful sensitivities being 0—0·5 amps. and 0—2·5 amps. The scales of many of these instruments are marked " For radio frequencies only "; but this may be disregarded and the calibration considered as correct both on alternating and direct currents. (It will be remembered that the heating effect, and thus the deflection of the thermo-ammeter, is equal for direct and r.m.s. values of alternating currents).

Thermo-ammeters may be protected as at Fig. 1 (g). The resistance of the heater wire is shown on the scale of all good thermo-ammeters (it is generally less than one ohm) and a suitable shunt may be connected by means of a push-button contact across the heater to approximately double or treble the meter range. A rough reading of the current flowing can then be taken before depressing the button, so bringing the thermo-ammeter up to full sensitivity. The shunt resistance should not be too low (*i.e.* the meter range should not be multiplied by too high a factor) because the push-button contacts will introduce some resistance on their own account. A well-sprung contact, of the self-cleaning type, should be used.

Resistances of all values can be measured by the direct use of a moving coil instrument connected in the circuit of Fig. 1 (h) for high and medium resistances, and Fig. 1 (i) for low resistances. To use the circuit at (h) the two terminals X, X, are short-circuited and the instrument brought to a full scale deflection by the variable resistance. The terminals are then separated and the unknown resistance connected between them. Current again flows and the instrument indicates a lower reading; a comparison of the new current with the full scale current gives the resistance value. The meter may be calibrated directly in terms of ohms, or the resistance value calculated from the formula

$$Rx = \frac{(Ro \times i)}{I} - Ro$$

where Rx is the unknown resistance in ohms, Ro is the total resistance of the ohmmeter itself (including the instrument, the battery, the fixed and the variable resistors), i is the full scale current and I is the new current reading when the unknown resistance is connected in circuit. Ro is, of course, given by the battery potential and the full scale current; for a 0—1 mA meter and a 9 volts battery, Ro obviously would be 9,000 ohms.

The circuit at (h) is known as a series-connected ohmmeter, and that at (i) as a shunt connected ohmmeter. In the latter circuit the variable resistor is first adjusted to bring the instrument to the full scale reading (in this case the X, X, terminals are, of course, left disconnected during this process) and the unknown resistor is then connected between the X, X, terminals where it acts as a meter shunt, so causing a fall in the indicated current reading. The value of the unknown resistance may be calculated from the formula

$$Rx = \frac{(Rm \times I)}{(i - I)}$$

where Rx is the unknown resistance, Rm is the meter resistance (NOT the resistance of the total ohmmeter circuit, but simply the resistance of the moving coil instrument alone), i is the full-scale current and I is the new current reading when the unknown resistance is connected into circuit.

In both circuits the basic accuracy of the ohmmeter is influenced by the stability of the supply circuit, *i.e.* on the regulation of the battery potential under varying conditions of load and the fall of battery potential with age. For this reason the series resistor controlling the current flow from the battery through the meter is divided into fixed and variable portions. The variable section of this resistance is made fairly low in value so that, as the battery ages and the potential falls, it becomes impossible to bring the moving coil instrument to the full scale reading. This indicates that a new battery is required. This variation of accuracy is much greater in the series type ohmmeter.

A third ohmmeter circuit is shown in Fig. 1 (j) suitable for general purpose and medium range resistance measurements with the advantage that it practically overcomes the source of inaccuracy mentioned in the previous paragraph. As in the simple series ohmmeter the instrument is first zeroed by short-circuiting the X terminals and adjusting the variable control, in this case a shunt across the meter, to give a full scale reading. The short-circuit is then removed and the unknown resistance connected across the X terminals. The instrument scale can be calibrated in ohms directly, or a conversion chart can be employed.

The series resistance R is made equal to the required mid-scale resistance reading, when the full scale current of the ohmmeter is very nearly

$$I_1 = \frac{E}{R}$$

where E is the battery potential.

When an unknown resistance, X, is connected across the terminals the new current reading is given by

$$I_2 = \frac{E}{R + X}$$

Eliminating E gives the equation

$$X = R\left(\frac{I_1}{I_2} - 1\right)$$

the reading thus depending on the fixed value of R and the ratio of the currents. The actual currents flowing are therefore not of importance so long as their ratios are known, and so the shunt across the moving coil instrument can be used to bring the pointer to full deflection no matter what the battery voltage may be. In practice the battery voltage is not allowed to fall too far with age—in the multimeter in which this type of circuit is employed the battery will fail to give a full scale reading when its voltage is reduced to approximately

1·2 volts on the low ohms range, and 11 volts approximately on the high ohms range.

Meter Resistance—It will have been noted that for many applications it is desirable to know the internal resistance of the moving coil instrument. In many cases this will be marked on the instrument scale, but unmarked instruments are sometimes encountered. The shunt connected ohmmeter circuit can obviously be employed to discover the meter resistance if a resistance of accurately known value is connected across the X terminals and the formula worked back to calculate the value of Rm. The circuit at Fig. 1 (i) should be employed with high values of series resistance and a correspondingly high battery E.M.F. for accuracy. Suitable values are a 120 volts h.t. battery, a 100,000 ohms series resistor (fixed) with a 50,000 ohms variable adjusting resistor. These values are for a 0—1 mA meter; instruments of different sensitivities require a higher or lower series resistance. Adjust the circuit so that the instrument reads exactly full scale, then shunt across it at the X, X, terminals, a known resistance of the best possible accuracy, using resistors of one to five per cent. tolerance. If possible, choose a resistance that gives a new current reading of a round figure such as 0·5 mA to avoid difficulty in reading off the exact current from the scale. Do not use too small or too large a resistance; use one that will give a new current reading round about middle scale. The internal resistance of the instrument may then be calculated from the formula

$$\mathrm{Rm} = \frac{X\,(i - I)}{I}$$

where Rm is the required meter resistance, X is the standard known resistance connected across the X, X, terminals, i is the full scale current of the instrument and I the new current indicated. As an example, assume that connecting a 50 ohms resistance across a 0—1 mA meter, set up as described, brought the current reading from 1 mA to 0·4 mA. Then

$$\mathrm{Rm} = \frac{50\ (1 - 0{\cdot}4)}{0{\cdot}4}$$

$$= 75\ \text{ohms.}$$

Moving coil instruments with internal resistances lower than a required value may have their resistances increased without affecting the meter sensitivity. For example, the 0—1 mA meter as above, with an internal resistance found to be 75 ohms, could be included in a circuit designed for a 100 ohms meter of the same sensitivity by placing 25 ohms in series with the movement. This increase in the overall resistance of the meter has no effect on the current sensitivity which remains at 1 mA for full scale deflection: what is changed is the potential drop across the meter which, in this case would rise from 75 to 100 millivolts.

MULTI-PURPOSE MEASURING INSTRUMENTS

For the servicing engineer the most useful type of measuring instrument s probably the multi-purpose meter, generally known as a Multimeter and also as a Circuit Analyser. A multimeter should as a general rule provide for the measurement of various ranges of Direct Current, Direct Voltage, Alternating Voltage and Resistance. Commercial models also provide for the measurement of Alternating Current; but as already mentioned the constructor is well advised to employ a separate thermo-couple ammeter for this purpose.

For normal use the sensitivity of a multimeter should not be lower than 1,000 ohms per volt—by which is meant that the moving coil instrument in the multimeter should have a full scale current of not more than 1 mA. In this case it will be necessary to provide a multiplier resistance of 1,000 ohms for every volt to be indicated at full scale reading (on d.c.) hence the quotation of sensitivity as 1,000 ohms/volt. It is easily possible to increase sensitivity to 20,000 ohms/volt by employing a 0—50 micro-amperes moving coil instrument in the meter; but this increases expense very considerably and makes the meter a good deal less robust, points which outweigh the greater sensitivity in many cases.

The circuit of a multimeter suitable for general radio service work is shown in Fig. 2, providing an instrument which may be built up into any suitable box or carrying case. Note that moving coil instruments should not be mounted on iron or steel panels, which will cause a permanent error in the reading. If a good instrument is obtained with multipliers of the specified accuracy the multimeter can read to within one or two per cent. on the direct voltage and current ranges, with an accuracy of about three or four per cent. on the alternating voltage ranges. Accuracy of the a.c. ranges is usually less than that of the d.c. ranges, but is still adequate. The ohmmeter has an accuracy well within five per cent. and is quite satisfactory for the measurement of 10 and 20 per cent. tolerance resistors.

The components list which follows is based on the use of a 0—1 mA meter with an internal resistance of 100 ohms. If the meter in use has a different internal resistance this will have an effect on the multiplier for the 10 volts d.c. range, which should be checked by the multiplier formula previously given. The shunt resistances will also vary, of course, but since these will probably be made by the trial and error method to be described, it is of importance only in ensuring that the correct lengths of resistance wire are obtained.

COMPONENTS LIST FOR THE MULTIMETER (Fig. 2)

R1	10 mAs shunt 11·1 ohms	Specially constructed: see text.
R2	100 mAs shunt 1·01 ohms	
R3	1,000 mAs shunt 0·1 ohm	
R4	900 ohms, 1 watt, 1%	
R5	9·9 K, 1 watt, 1%	
R6	100 K, 1 watt, 1%	
R7	1 Meg., 1 watt, 1%	
R8	8·25 K, 1 watt, 1%	
R9	90 K, 1 watt, 1%	
R10	900 K, 1 watt, 1%	
R11	1 K, variable, wirewound, Zero set.	
R12	1 K, 1 watt, 1%	
R13	10 K, 1 watt, 1%	
B1	1·5 volts.	
B2	3 volts.	
B3, B4	4·5 volts.	
S1a, b	D.P. 12-way rotary selector switch.	
S2a, b	D.P. 4-way rotary selector switch.	

2 Terminals; 2 Control knobs; Test prods; Wire; Sleeving, etc.; Battery clamps (cut from scrap sheet metal); Case.

Constructing the Shunts—The shunts may be made of Eureka or Nickel-Chrome resistance wire. The lengths for the specified instrument are: R1 (10 mAs shunt), nearly two yards of 30 s.w.g. Eureka or 26 s.w.g. Nickel-Chrome; R2 (100 mAs shunt), just over 6 ins. of 30 s.w.g. Eureka or 26 s.w.g. Nickel-Chrome; R3 (1,000 mAs, 1 amp. shunt), about 2 ins. of 24 s.w.g. Eureka or 20 s.w.g. Nickel-Chrome.

A paxolin former or board as shown in Fig. 3 is used, R1 and R2 being made by winding the wire round the board with the ends soldered to tags. The two lengths of wire should be cut at their centres, cleaned and then twisted together again. (Resistance wires require careful cleaning if they are to solder well.) The third shunt, R3, is made by supporting the length of stouter resistance wire in an arc between two substantial tags.

The shunts must be adjusted when the multimeter is completely wired up owing to the fact that the selector switch contacts enter the shunt circuits. For this reason stout switches should be used in the multimeter.

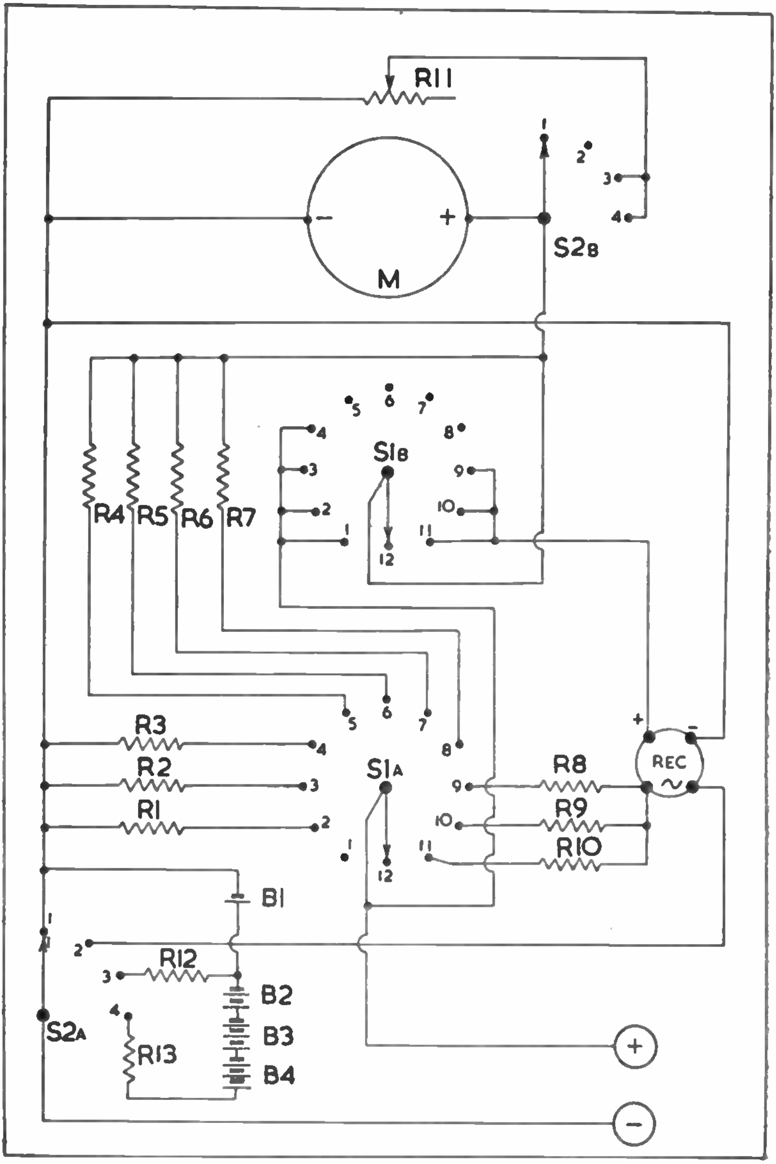


FIG. 2. A USEFUL MULTIMETER CIRCUIT

An external source is required for the setting of the shunts, and this consists ideally of an accumulator battery and a variable resistance, the voltage being between 2 volts (when only a single cell is available) up to 12 volts when a car battery is available. The variable resistor should be wirewound, with a

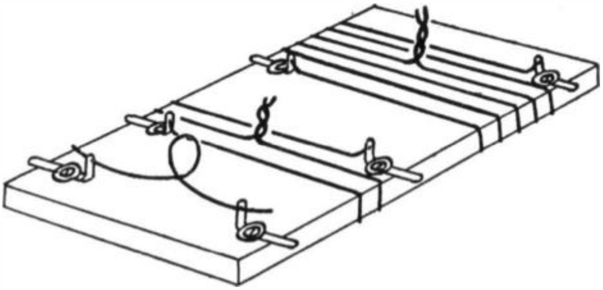


FIG. 3. CONSTRUCTION OF THE MULTIMETER SHUNT FOR D.C. RANGES

maximum resistance of 2,000 or 3,000 ohms for a 2 volts cell; 10,000 ohms for a 6 volt battery; and 20,000 ohms for a 12 volt battery. The battery, resistor and multimeter are connected in series with the meter switched to point 1 on S1 to measure 1 mA full scale and the variable resistor is adjusted to give exactly the full scale reading. (Before switching on remember to check the instrument for zero setting.)

With exactly 1 mA flowing through the shunt adjustment circuit (Fig. 4), switch the multimeter to position 2 on S1 to bring in the 10 mA range. The meter reading will drop and the shunt R1 must be adjusted so that the reading becomes exactly one-tenth of full scale, *i.e.* to the 0·1 mA point on the instrument scale. If the meter reading is too high the shunt resistance must be reduced by twisting together more of the wire at the centre of the shunt; the stated lengths will probably need a fairly large reduction. If the meter reading is too low the shunt resistance must be increased by untwisting some of the join, by stretching the wire slightly or, in the case of heavy shunts, by scraping or filing the wire. Continue to adjust the shunt at its central joint until the meter reading becomes exactly one-tenth of the full scale reading,

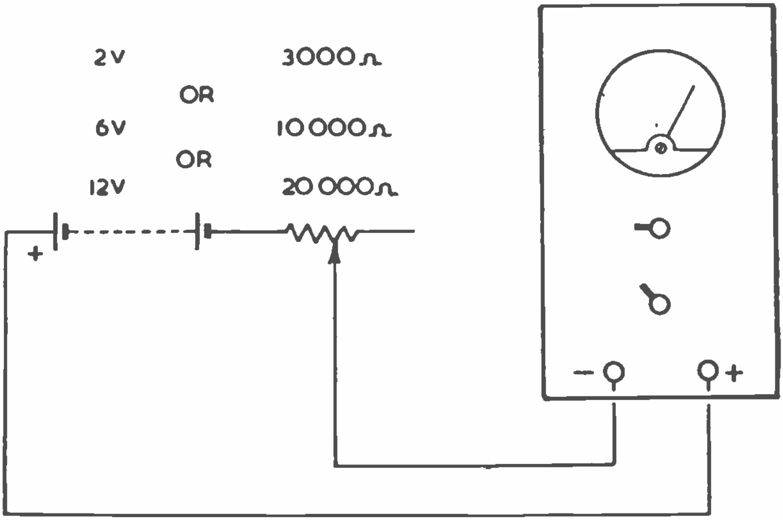


FIG. 4. CIRCUIT FOR ADJUSTING SHUNT VALUES

frequently checking back on the setting of the variable resistance by switching back to the 1 mA position of S1 in the multimeter. Then lightly solder the joint, ensuring that the solder does not run past the twisted portion of the shunt wires, and allow the joint to become absolutely cool before rechecking. If necessary a slight decrease of resistance can be made by tinning a short distance at a time along the wires from the joint; a slight increase of resistance can be made by slightly untwisting the first turn of the joint.

The first shunt is now adjusted to give a full scale instrument reading of 10 mA and the variable resistance should be reset to pass this current through the multimeter with S1 at position 2, the 10 mA position. Switch the multimeter S1 to position 3, the 100 mA range. The meter reading will fall, and the shunt R2 must now be adjusted, in the manner just described, again to give exactly one-tenth of the full scale reading. Check back frequently on the 10 mAs range to ensure that the current through the circuit is held constant at 10 mAs. With R2 adjusted, it remains only to set the resistance of R3. Set the meter to read full scale on the 100 mAs range, then switch to the 1,000 mAs range, and adjust R3 to give a one-tenth of full scale reading.

If possible check the shunted current ranges against a meter of known accuracy, connecting both meters in series in the circuit of Fig. 4. The described method of adjusting the shunts is perfectly satisfactory so long as the work is carried out patiently and with care. An error introduced at one stage will be continued into the following stages; painstaking work is therefore worth while.

With the shunts adjusted and set check the lowest alternating volts range, as the linearity of the instrument scale is lost in this application of the meter. The only satisfactory method is to wire the meter in parallel with an accurate alternating voltmeter in the circuit of Fig. 5, using a mains transformer to supply 12 volts a.c. with which the 10 volts range can be calibrated. First check the full scale reading of the multimeter which should be accurate; if the pointer is off the full scale mark this indicates that the multiplier, R8, requires adjustment. If the reading is high, R8 can be filed away slightly at one spot, to increase the resistance to the correct value. (File a slot into the body of the resistor, frequently checking the meter reading.) If the reading is a little low the value of R8 must be reduced, which can be done by shunting R8 experimentally with a fairly high value resistor. For example, shunting R8 with 220,000 ohms will reduce the multiplier resistance by approximately 300 ohms. Precision resistors need not be used for this since the value required is found by trial.

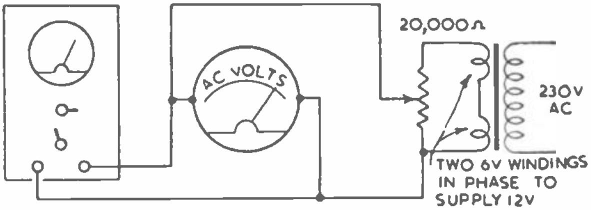
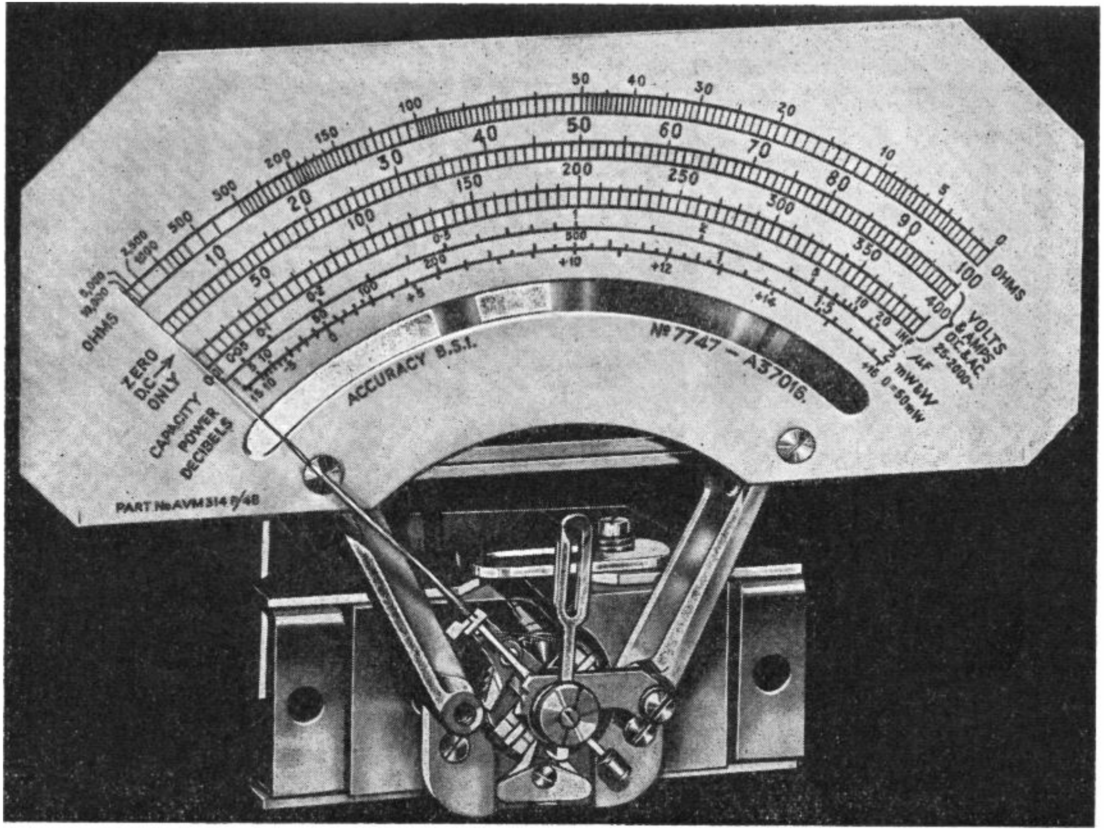


FIG. 5. CIRCUIT FOR CHECKING AND CALIBRATING THE 10 V. A.C. RANGE

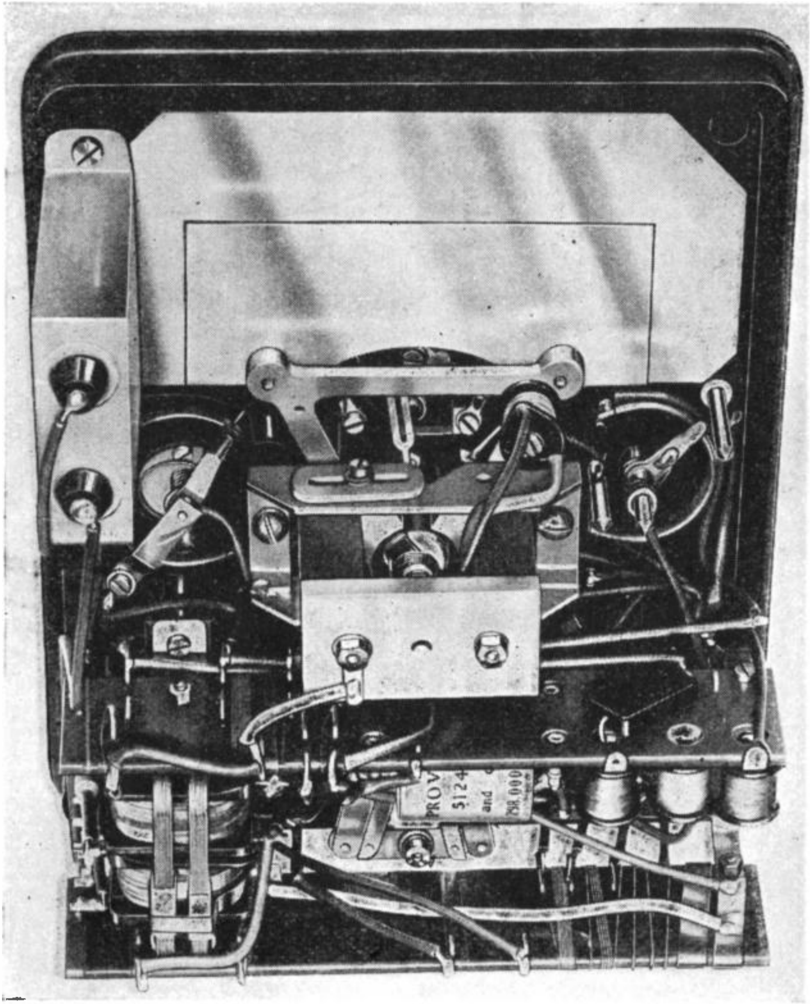
Alternatively, R8 may be made a 10,000 ohms wirewound potentiometer set to the correct value for a full scale reading of 10 volts by observation against the comparison voltmeter, and then locked in position. Suitable spindle locks can often be obtained from odd items of ex-service gear. Wirewound resistors should not be used as a.c. multipliers where the range is not to be set by inspection, as their self-inductance may increase the final impedance of the multiplier.

With the alternating volts 10 volts range set for a correct full scale reading, the scale should now be calibrated down at the 9, 8, 7, etc. cardinal points. If desired, a new arc may be drawn on the instrument scale, and these points



(Courtesy of Automatic Coil Winder & Electrical Equipment Co., Ltd.)

PLATE 1. MOVING COIL INSTRUMENT AND SCALE, WITH SUPPORT CUT AWAY TO SHOW MOVEMENT



(Courtesy of Automatic Coil Winder & Electrical Equipment Co., Ltd.)

PLATE 2. REAR VIEW OF HIGH CLASS COMMERCIAL MULTI-RANGE INSTRUMENT WITH COVER REMOVED

calibrated and drawn in; or a correction chart may be made up to convert the d.c. readings to a.c., this chart being pasted in the meter case. When a new arc is drawn and calibrated on the meter scale, the scale must be removed and very carefully replaced, keeping the meter movement covered as much as possible to prevent dust and (particularly) metal filings entering the gap. Remember to adjust the pointer stops when replacing the scale, and pay attention to the zero pip when replacing the instrument cover: the pip is easily broken.

The 100 and 1,000 volts ranges may be considered accurate for linearity of reading down the meter scale on alternating volts. A non-linear scale is required on the 10 volts a.c. range only.

The ohmmeter sections of the multimeter are capable of measuring resistances between about 100 ohms and 0·1 megohm with fair accuracy, giving reasonable indication of value beyond this range. It is also useful as a continuity tester. Again, it is necessary to calibrate the instrument in some way to avoid having to use the formula for series type ohmmeters at every reading. If an instrument with a large and clear scale is employed it might be possible to draw on it yet a further arc for resistance calibrations (making three arcs in all for: d.c., low alternating volts, and ohms); but if only a small instrument is employed it is recommended that a conversion chart be used. This is quite convenient in use, bearing in mind that in practically all radio applications the ohmmeter is called upon to supply a good indication rather than an accurate valuation.

An accurately drawn conversion scale for the ohmmeter section is shown in Fig. 6. This may be carefully copied to serve as the conversion chart for the multimeter. It may be as well to say that the diagram will only serve for the circuit as it stands: different values for the resistors R12 and R13 will require a different chart since these will change the range of the ohmmeter.

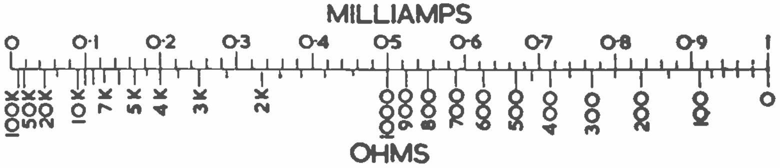


FIG. 6. CONVERSION SCALE FOR OHMS RANGE, USING 1 MILLIAMP MOVEMENT

The multimeter switches should be coded as follows:

S1a, b. MAIN RANGE SWITCH

Position 1	1 mA d.c. and ohms.
„ 2	10 mAs d.c.
„ 3	100 mAs d.c.
„ 4	1,000 mAs d.c.
„ 5	1 volt d.c.
„ 6	10 volts d.c.
„ 7	100 volts d.c.
„ 8	1,000 volts d.c.
„ 9	10 volts a.c.
„ 10	100 volts a.c.
„ 11	1,000 volts a.c.
„ 12	OFF

S2a, b. SELECTOR SWITCH

Position 1	d.c.
„ 2	a.c.
„ 3	Ohms.
„ 4	Ohms × 10.

Using the Multimeter—Normal and obvious precautions must be taken when using the multimeter. The selector and range switches should always be carefully checked for correct settings before connecting the test prods to the external circuit, and especial care must be taken to ensure that the meter is not overloaded. This is particularly important when the a.c. ranges are in use, the rectifier being unable to withstand appreciable overloads.

To use the ohmmeter section of the meter, first short-circuit the test prods and adjust R11 to give a full-scale reading. Then connect the prods across the unknown resistance and read off the value from the scale or chart.

When the ohmmeter can no longer be brought to full scale deflection the batteries must be renewed—B1 only, if only the lower ohms range is affected, and B1, B2, B3 and B4 if both ohms ranges are affected.

A very good indication of the condition of radio, amplifier and general electronic circuits can be obtained by current and voltage checks, particularly when circuit data is available. Even without data the readings obtained can be compared with the valve type employed and the circuit constants in use, when experience will show whether the readings appear normal and satisfactory or not. Generally it is most convenient to take voltage readings across resistances (to take current checks means breaking the circuit at some point or another, usually an inconvenient procedure). The effect of connecting the meter across a resistive circuit must always be borne in mind, and allowance made for the meter current. In Fig. 7 the meter is shown connected into a typical amplifier stage for the measurement of the anode voltage. The meter current will be drawn through the anode load resistor in addition to the anode current of the valve. The voltage drop across the anode resistor accordingly rises, giving a meter reading lower than the true anode voltage; in a circuit with a high value resistance the apparent fall of anode voltage is so great as to make the meter reading useless, except perhaps for comparison purposes. It is for this reason that a meter with a high sensitivity (*i.e.* a high ohms-per-volt value) is desirable; at the same time the meter should be switched to the highest voltage range which will give a readable indication on the scale.

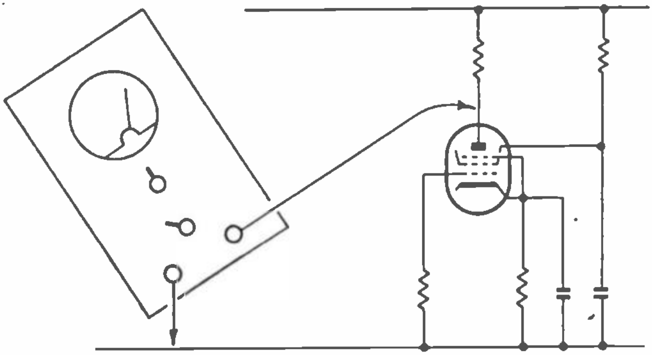


FIG. 7. TYPICAL USE OF MULTIMETER TO MEASURE ANODE VOLTAGE ON VALVE

Wide Range Ohmmeters—The ohmmeter section of the multimeter will serve for general rough checks and continuity tests, but it can be extended either as a separate instrument or as a section of the multimeter to give a wider range of measurements. The circuit of a wide range ohmmeter is shown in Fig. 8, where it can be seen that the instrument is a combination of both series and shunt circuits. The highest accurate resistance measurement possible with this circuit is still 0·1 megohm, but a number of lower ranges are provided extending down to 0·1 ohm. Great accuracy at such low readings is not claimed, but a very good indication is obtained.

Range multiplication is achieved by shunting the basic instrument, an 0—1 mA meter whose internal resistance should be 100 ohms or thereabouts.

The shunts can be made up as already described, dividing the 1 mA range by 10 for the 10 mAs shunt, and the 10 mAs range by 10 for the 100 mAs shunt.

The addition of shunts to the ohmmeter circuit obviously necessitates variations to the multipliers. The proportion of variable to fixed resistance in the series meter-setting circuit must be maintained roughly in the same ratio for each range to keep up the meter accuracy, and to indicate when the battery voltage is falling so that the batteries can be renewed. Accordingly a ganged three-pole switch is used to change both shunt and multiplier, and to shunt the variable resistor, R2 (Fig. 8) so that it will serve over all the ranges.

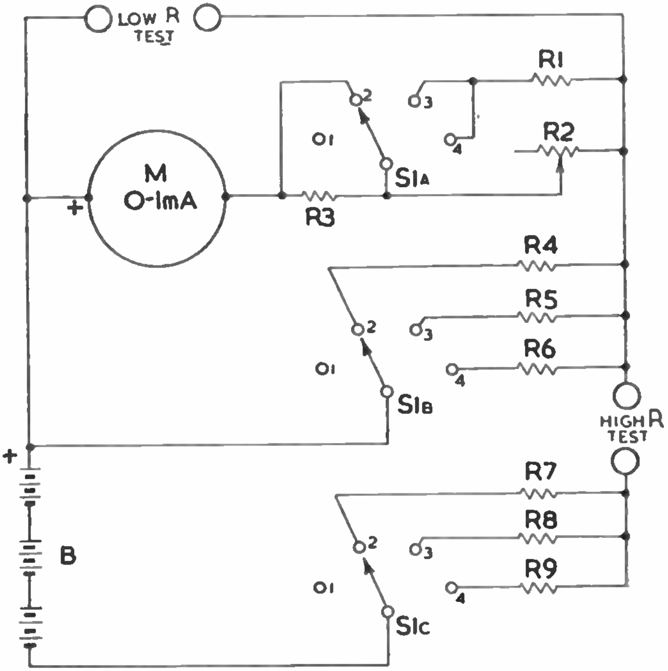


FIG. 8. A MULTI-RANGE OHMMETER CIRCUIT

COMPONENTS LIST FOR THE OHMMETER (Fig. 8)

R1	47, ¼ watt, 20%	
R2	100, W.W. Zero set.	
R3	22, ¼ watt, 20%	
R4	470, ¼ watt, 20%	
R5	10·8, 10 mA shunt.	Resistors may be carbon or wirewound.
R6	1, 100 mA shunt.	
R7	10 K, 1%	
R8	1 K, 1%	
R9	100, 1%	
M	0—1 mA moving coil instrument, 100 ohms internal resistance.	
S1a, b, c	3-pole, 4-way rotary switch.	
B	13·5 volts battery (three flat batteries in series).	

4 Terminals, heavy duty type; 1 Control knob; Battery clamps (cut from scrap sheet metal) Wire; Sleeving, etc.; Case.

The ohmmeter may be built up in any convenient box with a non-magnetic panel. The terminals must, of course, be insulated from a metal panel. The moving coil instrument should be in the horizontal plane; layout is unimportant.

To use the ohmmeter for measuring high resistances, first short-circuit the " High R Test " terminals, and set the meter to a full scale reading by adjusting R2. Then separate the terminals and connect the resistance between them. If the range is not suitable switch to another range, *resetting the full scale reading before further measurement.*

To measure low resistances it is first necessary to short-circuit the " High R Test " terminals, preferably with a metal strap. The instrument is then set to full scale reading and the unknown resistance afterwards connected across the " Low R Test " terminals. After switching to another range, should this prove necessary, reset for full scale deflection before further measurement.

The instrument scale may be removed and calibrated with a basic ohms range, or a conversion scale may be prepared and used with the original current calibrations of the instrument. In Table 1 the necessary figures are given for the preparation of a quite comprehensive conversion scale of this kind for the basic ohms range, the values being multiplied appropriately for the R × 10 and R × 100 ranges.

TABLE 1

FIGURES FOR CONVERSION SCALES FOR THE OHMMETER

(Fig. 8)

Correct to nearest decimal.

Basic Range " R " (100 mA).

High R Test		Low R Test	
Ohms	Scale Reading mA	Ohms	Scale Reading mA
0	100	∞	100
10	90·9	10	90·9
15	87	9	90
20	83·3	8	88·9
25	80	7	87·5
30	76·9	6	85·7
35	74·1	5	83·3
40	71·4	4	80
50	66·7	3·5	77·8
60	62·5	3	75
70	58·8	2·5	71·4
80	55·6	2	66·7
90	52·6	1·5	60
100	50	1	50
150	40	0·9	47·4
200	33·3	0·8	44·4
250	28·6	0·7	41·2
300	25	0·6	37·5
350	22·2	0·5	33·3
400	20	0·4	28·6
500	16·7	0·35	25·9
600	14·3	0·3	23·1
700	12·5	0·25	20
800	11·1	0·2	16·7
900	10	0·15	13
1,000	9·1	0·1	9·1
∞	0	0	0

These figures will also serve for the conversion chart for the single ohms range of the multimeter. Note that the range of the instrument movement is 0—1 mA, so the current reading listed should be considered as applying to a scale of 100 arbitrary divisions; for the multimeter, the resistance value given must be multiplied by 100 to give the 10,000 ohm centre scale range values. The " High R Test " figures only are used; the " Low R Test " figures have no connection with the multimeter ohms range.

Code the ohmmeter switch:

		CENTRE SCALE READINGS	
		High R Test	Low R Test
Position No. 1	OFF		
„ „ 2	R × 100	10,000 ohms	Do not use this scale.
„ „ 3	R × 10	1,000 ohms	10 ohms
„ „ 4	R	100 ohms	1 ohm.

Output Meters—Output meters could often be used for receiver alignment because they give definite comparative readings of volume which are preferable to the more usual aural observations. By careful testing it is possible to obtain an approximate selectivity curve of a receiver with an output meter in the absence of a wobbulator and oscilloscope. An added advantage is that an output meter temporarily replaces the loudspeaker and the monotonous note of the signal generator modulation.

The multimeter can be used as a comparative output meter by connecting it in the circuit of Fig. 9. The loudspeaker is disconnected from the secondary of the output transformer and replaced by an equivalent resistance (3 ohms 5 watts in the majority of cases), where the full benefit of the meter is to be obtained by muting the speaker; or the speaker can be left connected normally. The power output of the stage can be calculated from the formula

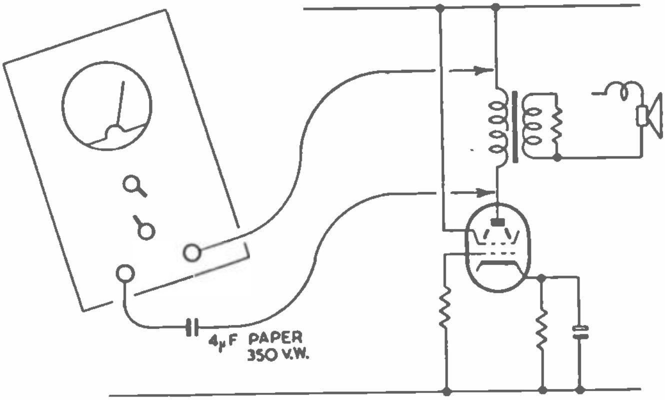


FIG. 9. USING THE MULTIMETER AS AN OUTPUT METER

$$P = \frac{V^2}{R}$$

where P is the power in watts, V is the alternating voltage set up across the primary of the output transformer, and R is the optimum load of the valve employed. It is presumed that the transformer and speaker voice coil are correctly matched into the valve. A 4 mfds capacitor isolates d.c. from the meter, which is switched for A.C. operation.

The volts range must be chosen before the multimeter is connected into circuit, commencing with the 1,000 volts range when in doubt. Assume, for example, that a valve with an optimum load of 10,000 ohms is supplying an output of 2 watts; so the maximum voltage to be expected is approximately 140 volts. The chief use of the circuit will be as a comparative meter, so it will probably be used well below this. Tuning the receiver through the test signal and observing the rise and fall of the meter pointer gives an indication of the response curve of the set; the meter pointer should rise and fall steadily and at equal rates. A swift rise followed by a steady reading followed by a further rise indicates a hump to one side of the response curve.

If a comprehensive output meter is required the unit may be based on the skeleton circuit shown in Fig. 10. Here an output transformer of fixed ratio has its secondary connected *via* a switch to various resistances to provide a device capable of serving as a multi-value output load, the primary of this transformer being connected into the output stage under test in place of the existing transformer and speaker. A further ganged section of the switch throws in the correct multiplier (*via* a blocking capacitor) to make the moving coil instrument—rectifier circuit into an alternating voltmeter of range representing fixed power readings; the range being chosen to measure, say, up to 10 watts for each chosen value of output load. The calculations needed now follow.

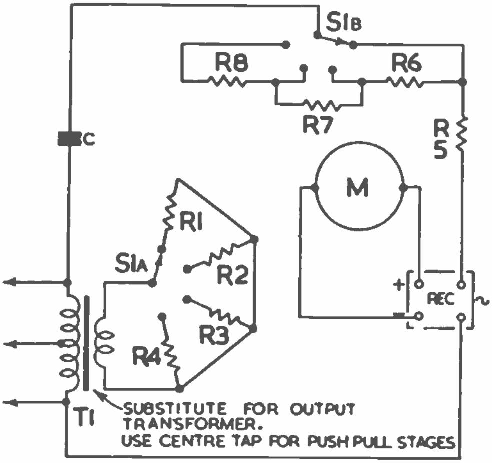


FIG. 10. A SIMPLE OUTPUT METER CIRCUIT

To choose the resistance switched into the secondary use the formula

$$R = \frac{\text{Load Impedance}}{\text{Ratio}^2}$$

where R is the required resistance (R1—R4, Fig. 10), the Load Impedance is the optimum load required by the valve under test, and Ratio is the ratio of the transformer.

To choose the multiplier resistance (R5—R8, Fig. 10), first determine the maximum power to be measured: a suitable figure is 10 watts. Calculate the voltage which will be developed across the Load Impedance by this power by the formula, quoted earlier, transposed to the form

$$V^2 = P \times R \quad \textit{or} \quad V = \sqrt{P \times R}$$

and then calculate the multiplier resistance required (for 1 mA rectifiers of the

Westinghouse type and 0—1 mA instruments) from

$$\mathrm{Rm} = \frac{1{,}000\mathrm{V}}{1{\cdot}11}$$

where Rm is the multiplier resistance, V is the voltage and where 1·11 mA can be taken as the current input to the rectifier.

For example, consider that the circuit of Fig. 10 is to indicate 0—10 watts for the loads of 5,000, 6,000, 8,000 and 10,000 ohms, covering a representative group of output valves. The component list then becomes as follows, using a 50 : 1 output transformer:

R1, 2 ohms, 10 watts; R2, 2·4 ohms, 10 watts; R3, 3·2 ohms, 10 watts; R4, 4 ohms, 10 watts.

Values for the instrument multipliers are given by the nearest preferred values, with the accurate value required in brackets. This may be selected from a batch of stock resistors with the aid of one of the a.c. bridges described in Chapter 4, or, if access to a batch is not available, the correct value may be built up by connecting other resistor(s) in series or parallel with one initially near the correct value.

R5	220K	(201K)
R6	22K	(20K)
R7	33K	(33K)
R8	33K	(30K)

M .	Moving coil instrument, 0—1 mA. Internal resistance not important, 50—150 ohms.
Rec.	Westinghouse 1 mA instrument rectifier.
C. .	8 mfds paper, 500 v.w.
T1 .	10 watts output transformer, 50 : 1.
S1a, b	2-pole 4-way rotary switch.

It can be seen from the components list that the multipliers are made up from standard value resistors with little departure from the actual values required—the variation in resistance would not be sufficient to give a noticeable change in reading. T1 could with advantage be a 1 : 1 transformer; a modulation transformer would be ideal. R1, R2, R3 and R4 could then be made equal to the required output loads whilst the multiplier resistances (with no changes in values) could be connected to the transformer secondary.

To calibrate the output meter it may either be compared with a commercial model or employed with a conversion chart compiled from the following:

Power, watts	mA Scale Reading (To nearest decimal)
10	1·00
9	0·95
8	0·90
7	0·84
6	0·77
5	0·71
4	0·63
3	0·55
2	0·45
1	0·32
0·5	0·22
0·25	0·16

The output meter cannot be of great accuracy, particularly at the lower readings where the curvature of the scale shape due to the rectifier is introduced; but the meter can be useful as a comparator over the range of outputs from a single receiver or amplifier, or over a number of amplifiers, etc.

THE VALVE VOLTMETER

A well constructed valve voltmeter can be very useful in radio servicing as it is capable of giving practically exact voltage readings over high resistance circuits (unlike the moving coil instrument whose current demands cause error). It can also be employed over a very wide range of frequencies as well as for d.c. measurements. The meter rectifier used in the multimeter and the output meter will serve over the lower audio ranges, holding its accuracy reasonably well; but with a rise in frequency the rectifier losses increase considerably until at radio frequencies the rectifier is useless. A valve voltmeter, whilst still requiring a rectifier, can employ a valve or germanium rectifier, so retaining high frequency efficiency.

Broadly speaking, the valve or valves in a valve voltmeter may be regarded as an impedance transformer. They control the current through a moving coil instrument through the agency of a grid potential, sometimes also providing an amplification effect. Degeneration, or negative feedback, is often employed to make the electronic circuits as linear as possible in operation between the potential to be measured and the measuring instrument; working the valve or valves on a curved characteristic would obviously mean that the final meter response would be non-linear. The circuit should be so designed that reversing the polarity of the input potential, and the polarity of the moving coil instrument itself, makes no variation in the reading. Many valve voltmeter circuits fail in this respect, the meter reading for a positive input being very different from that obtained for an equal negative input. This is known as turnover effect. In some cases it can be tolerated with no bad results, *e.g.* in a built-in valve voltmeter in equipment such as audio oscillators, which never requires reversing; but, in general, the multi-range valve voltmeter should be reversible in input polarity.

The rectifier for a.c. measurements is generally incorporated in a probe, so that the unit is both shielded and, for high frequency measurements, has a very short source-rectifier lead, with correspondingly low losses. The rectifier is connected to the external circuit *via* a capacitance, and it is very desirable that at least two capacitance values should be available; a small one for the high frequencies and a larger for power and audio frequencies.

For the preparation of this book every common valve voltmeter circuit was tested, but none was found to have the sensitivity, stability and over-all excellence of the push-pull type shown in Fig. 11, which owes several points in its design to the American McMurdo " Vomax " instrument—probably the outstanding commercial valve voltmeter. The potential to be measured is applied across a dividing network or " stick " which has a total resistance of 50 megohms—a really high input resistance which gives negligible loading when connected into an external circuit. When the instrument is employed on the a.c. ranges the input impedance is not so high, due to the rectifier effect and the probe capacitances, but may still be reckoned as high as 6 megohms or more, shunted by approximately 10 pF. This means that the probe may be connected across a tuned circuit with very little effect; a slight retuning of the circuit to compensate for the added capacitance will enable the voltage to be measured under normal working conditions to all intents and purposes. (It is important that the circuit be retuned where necessary when connecting the probe into tuned circuits.)

The meter, switched to measure d.c., can also affect the external circuit in cases where r.f. is also present, by reason of the meter capacitance. A typical example is the measurement of AVC voltages directly at the grid of r.f. or i.f. valves; a further example is the checking of oscillator grid voltages. In either case, connecting the meter directly across the circuit would change the r.f. working conditions so much, despite the 50 megohms input resistance, that the final reading would be meaningless. The effect can easily be prevented, however, by incorporating a 1 megohm resistor within the test prod used for d.c. connection (R1 of Fig. 11). The meter is set up and calibrated with this resistance in circuit so that its effect is accounted for; the d.c. prod can then be connected into any circuit with the knowledge that the shunt capacitance of the valve voltmeter is isolated from the external circuit by 1 megohm. (By

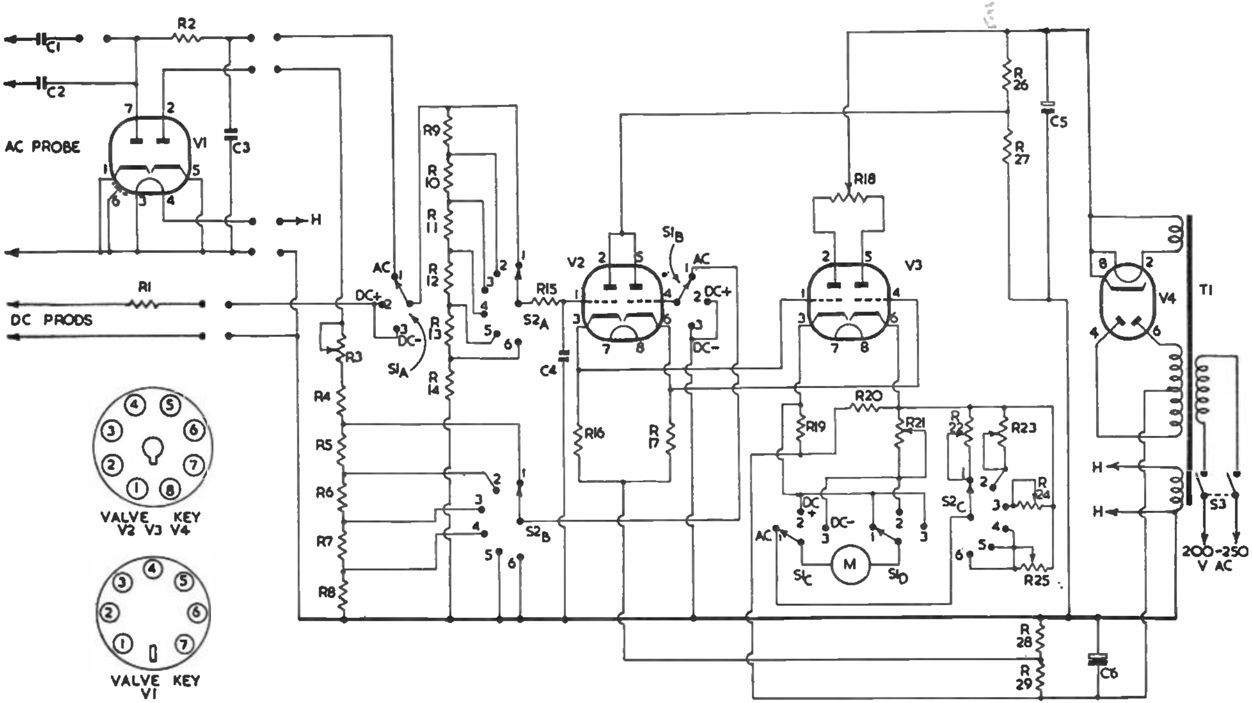


FIG. 11. A USEFUL VALVE VOLTMETER CIRCUIT

keeping the hand well up, the prod hand-capacitance effects are similarly nullified.)

In a good valve voltmeter both gas current and grid current effects must be avoided. To prevent grid current the grid must always be substantially negative with respect to the cathode of the valve. Gas current does not often make an appearance in valves used in more normal circuits. It becomes apparent only with high grid resistances and its effect is to vary the zero setting of the indicating instrument as the range selector is moved up the resistance stick. For example, in the present instrument the first grid is switched into a 100,000 ohms resistance for 1,000 volts measurements, the resistance rising to 50 megohms for 2 volts measurements. If gas current is permitted, the zero setting, adjusted at the 1,000 volts range, will vary very considerably as the selector is run up the stick until the instrument is reading appreciably off zero on the 2 volts range. In some valve voltmeters the effect is ignored, the prods being shorted together for the zero setting to be effected, then separated for a reading to be made with no regard for any gas current which may be present. This is poor practice, and the voltmeter should be so designed that gas current cannot have any serious effect. In the present voltmeter the gas current is overcome by running the first valve at a very low anode potential. Variation of the grid resistance is reduced very considerably by the inclusion of R15 in the grid circuit. This resistance is added to whatever resistance is tapped from the stick between the grid and earth so that the grid resistance as a whole never falls below a little more than 10 megohms. In this way the effect of gas current is levelled off from range to range.

Grid current is prevented by keeping the grid sufficiently negative so that the highest permitted input voltage cannot drive it positive.

Gas current in the second valve is unimportant, since in this stage the input grid resistance (the cathode resistance of the preceding stage) does not change. The second valve is simply a meter amplifier; the first valve could be employed to drive the moving coil instrument but, owing to the low voltages employed and the heavy negative feedback applied, the instrument would have to be both very sensitive and delicate. By using an amplifying stage a 0—1 mA instrument can be used.

A further trouble often encountered in valve voltmeters is contact potential in the diode employed on the a.c. ranges. This contact potential, in the present voltmeter, can set up as much as 1 volt d.c. across the stick with no input applied to the probe, so giving a half-scale reading. Obviously this reading will drop as the range selector is turned down through the higher voltage ranges until on the 200 and 1,000 volts ranges a zero error of 1 volt is quite negligible.

A device known as a self-bucking probe was tested with the circuit (using a double diode, the contact potential of the second diode being fed back in opposition to the first diode to balance out the spurious potentials); but the correcting circuit as shown is the only really satisfactory remedy. A double diode is still employed in the probe, but the contact potential from the second or " reference " diode is applied through a simple dividing stick to the grid of the second section of the first double triode. When the voltmeter is first set up the value of R3 is adjusted to balance out the zero error in the probe circuit, then left adjusted until the diode is renewed, when it must be readjusted. It would really be most convenient to employ a single 10 megohms variable resistance in place of R3 and R4 in series, but such a component is not easily obtained and it may be difficult to procure a 5 megohms variable resistor. Some experiment is, therefore, recommended so far as R3 and R4 are concerned in order that the total resistance in this position may match the characteristics of the actual diode employed. In some cases it might be possible to use a single 2 megohms or 5 megohms control; in others a 5 megohms control may need 1, 2, 3 or 5 megohms in series with it. The diode itself will dictate the resistance needed.

The diode specified for use in the probe is rated to withstand a peak inverse voltage of 420 volts, but tests indicate that the valve will permit voltage measurements of up to 1,000 volts without undue stress, provided that only momentary contact between the probe and source is made. The life of the diode is lengthened, however, if high voltage measurements on a.c. are kept to a minimum.

So far the points discussed have shown how gas and grid currents, and contact potentials, may be made to have no effect on the final valve voltmeter. Mention has not yet been made of the effect on the circuit of variations in h.t. and heater supplies. Such variations can be serious, and in many valve voltmeters neon stabilisation of the anode supplies is provided. In the present circuit a simpler course is followed by balancing the two essential triodes with further triodes, variations of anode and heater supplies then being balanced out by what is analogous to " push-pull " action. In addition it is apparent that the second section of the first double triode serves to introduce the balancing contact potential from the probe.

COMPONENTS LIST FOR THE VALVE VOLTMETER (Fig. 11)

C1	0·05 μF 3,000 v.w. tubular.	
C2	500 pF 1,000 v.w. mica.	
C3	0·002 μF 1,000 v.w. mica.	
C4	0·01 μF 350 v.w. mica.	
C5, C6	8 μF 450 v.w. electrolytic.	
R1	1 Meg, 1 watt, 5%	
R2	20 Meg, 1 watt, 5%	(2 of 10 Meg in series).
R3	5 Meg, variable	See text.
R4	4·7 Meg, 1 watt, 10%	
R5	5 Meg, 1 watt, 1%	
R6	1 Meg, 1 watt, 1%	These values, which must be exact for correct readings, may be built up using a number of resistors in series, either bridged for exact values or obtained as 1% accurate types.
R7	500 K, 1 watt, 1%	
R8	100 K, 1 watt, 1%	
R9	40 Meg, 1 watt, 1%	
R10	5 Meg, 1 watt, 1%	
R11	4 Meg, 1 watt, 1%	
R12	500 K, 1 watt, 1%	
R13	400 K, 1 watt, 1%	
R14	100 K, 1 watt, 1%	
R15	10 Meg, 1 watt, 5%	
R16, R17	3·3 Meg, 1 watt, 5%	
R18	5 K, variable, wirewound, Zero Set control.	
R19, R20	33 K, 1 watt, 5%	
R21, R22, R23 R24, R25	5 K, variable, wirewound, range adjusters, pre-set.	
R26, R29	47 K, 1 watt, 10%	
R27, R28	4 K, 1 watt, 10%	
V1	EB91 Mullard.	
V2, V3	6SN7 GT.	
V4	GZ32 Mullard.	
1 B7G ceramic valveholder.		
3 Int. octal valveholders.		
S1a, b, c, d	4-pole, 3-way rotary switch. Main function switch.	
S2a, b, c	3-pole, 6-way rotary switch. Range switch. Both switches, ceramic type.	
T1	200–250 volts primary. 250–0–250 v. 60 mAs. 6 v. 3 a. 5 v. 2 a.	
S3	D.P. Q.M.B. mains switch.	
M	0—1 mA moving coil instrument.	
3 control knobs.		
1 chassis, 9½″ × 4½″ × 3″.		
1 case to take chassis. Metal for probe, etc.		
Flex, wire, solder, tags, nuts, bolts, etc., etc.		
Terminals or sockets.		
Test prods.		

CONSTRUCTION AND ADJUSTMENT

A suggested chassis layout with drilling dimensions is shown in Fig. 12, with probe details in Fig. 13. Construction is simple and follows normal practice, the chief requirement being the avoidance of any hum pick-up in the high resistance grid and cathode circuits. For this reason all grid leads should be of screened flex, the screen being earthed at each end to the nearest earthed soldering tag. The single heater lead (chassis return being employed) should be kept up tight against the chassis and taken by direct routes.

The probe cord should be anchored to a tagboard beneath the chassis. A normal three-core screened lead may be used for this cord (the screen

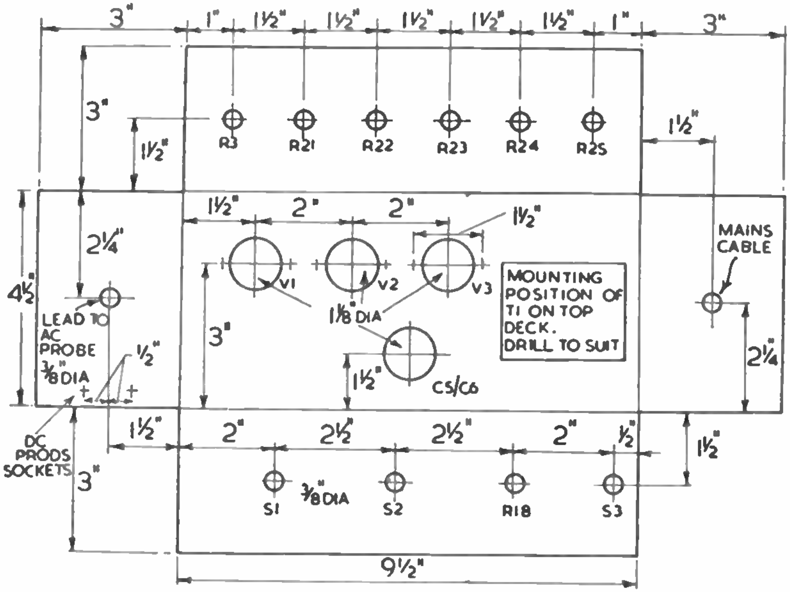


FIG. 12. CHASSIS LAYOUT OF THE VALVE VOLTMETER (TOP VIEW)

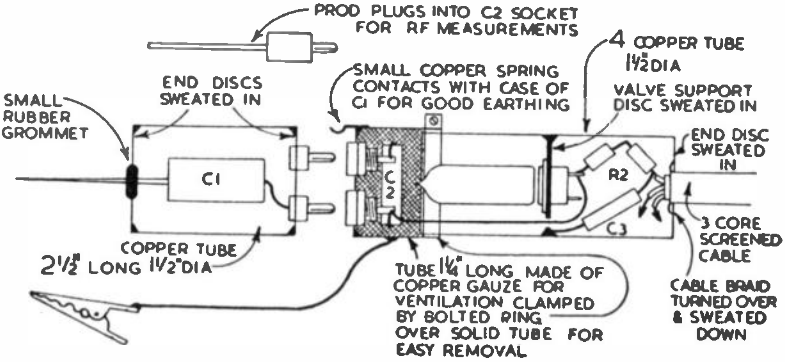


FIG. 13. THE VALVE VOLTMETER A.C. PROBE

serving as a common return); however it would, perhaps, be worth while to use a separately screened heater lead, or separately screened leads from the diode anodes. The extra complication should be avoided unless there is hum pick-up on the diode leads, which would lead to variations in the zero set as the probe is moved about, and normally should not be encountered.

Two probe capacitors are required as already described, and it is desirable that the large capacitance should be disconnected from the probe circuit altogether when the unit is in use on high frequencies. It is recommended, therefore, that the high capacitance is plugged into circuit for low frequency measurements and contained within its own screening can as shown in Fig. 13. A metal-cased capacitor, with its case earthed, is not recommended for this purpose as some models have a high capacitance between the case and internal parts which would provide a shunt path for signals.

For convenience the probe may be clipped into a sprung clamp fitted to the voltmeter case or, as in the Vomax instrument, made to slide into a probe housing within the voltmeter body.

The moving coil instrument should be mounted on a front panel fitted to the front edge of the chassis. The dial should be as large as possible for clarity and ease of reading.

Ceramic switches are specified for the function (S1) and range switches, to reduce the possibility of leakage resistances being set up across the switchgear, in view of the high input resistance. To obtain the full benefit of this type of switch the range resistors forming the sticks (R4–R8 and R9–R14) should be mounted directly on the switch contacts.

The switches should be coded:

S1a, b, c, d—

Position 1 . . .	a.c.
„ 2 . . .	d.c. positive.
„ 3 . . .	d.c. negative.

S2a, b, c—

Position 1 . . .	2 volts.
„ 2 . . .	10 volts.
„ 3 . . .	20 volts.
„ 4 . . .	100 volts.
„ 5 . . .	200 volts.
„ 6 . . .	1,000 volts.

To adjust the valve voltmeter first check the wiring thoroughly, then insert the valves and switch on, setting the function switch to d.c. –. The instrument pointer will swing from side to side as the valves warm up, finally taking up some position either above or below the zero point. By adjusting R18 it should be possible to zero the instrument with the moving arm of the potentiometer at roughly its central position. If the potentiometer has to be far off centre to set the instrument to zero, first suspect V3 and check the effect of a different valve.

It is now necessary to connect the d.c. test prods to a source of exactly 2 volts in order that the d.c. ranges may be set up. An accumulator cell which has had some use after being charged could be employed, loaded with a resistance of approximately 10 ohms to draw a steady current; but it is obviously better to set up an exact potential, using a circuit similar to that of Fig. 5, but employing a d.c. source and a d.c. comparison voltmeter.

Before connecting the prods across the source, switch the range switch to the 2 volts point and touch the prods together. The meter reading should not vary from the zero point: should it vary considerably try the effect of changing V2.

Connect the prods across the 2 volts supply, taking the "live" prod to the negative side of the circuit. The meter will indicate a reading depending on the setting of R21, which should be adjusted to bring the instrument pointer to the full scale mark. Disconnect the prods from the supply; the instrument will no longer return to zero but to some other reading. Correct this by means of the zero adjuster, R18, bringing the meter reading to zero, and again connect the prods to the 2 volts supply. The instrument will now fail to indicate full scale deflection and must again be brought to the full scale mark by means of R21. Continue to adjust R21 and R18 in turn until, with the prods disconnected, the meter reading is exactly zero, and, with 2 volts applied, the reading is exactly full scale.

The meter is now set for all the d.c. ranges, and the spindle of R21 should not be touched again. Check down the scale for linearity against the standard voltmeter, then switch the function switch to d.c.+ to ensure that the 2 volts setting holds good for reversed input to the voltmeter. Should linearity fail, or should the setting of R21 not hold good for the reversed input, first suspect V2 and try the effect of using another valve.

Although a single control sets up all the d.c. ranges, the three lower a.c. ranges have individual controls, with the three higher ranges sharing a single setting control. Further, it will be found that the lowest a.c. range is non-linear, and must either be separately calibrated or provided with a conversion chart. The circuit of Fig. 5 must be employed for the a.c. range setting, and a transformer and potentiometer used, capable of supplying 2, 10, 20 and 100 volts, also the standard voltmeter must be capable of reading these ranges accurately. Should such a voltmeter not be available, and should it be necessary to improvise methods of calibration, a mains transformer may be employed as a source, and loaded normally to give approximately correct output voltages. The centre tap of a 4 volts heater winding will supply 2 volts a.c.; two 4 volts and the half of a further 4 volts windings will supply 10 volts when connected in phase, and 20 volts may be drawn from three 6 volts heater windings connected in series and only lightly loaded. A 100 volts supply may be drawn from the taps on the primaries of some mains transformers. ROUGH AND READY SUPPLIES SHOULD NEVER BE USED WHEN MORE ACCURATELY MEASURED VOLTAGES CAN BE OBTAINED.

With the range switch set to the 2 volts range turn the function switch to a.c. The meter reading will probably rise above the zero point, and must be returned to zero by adjusting R3 to balance out the diode contact potential. The values of R3 and R4 may require some variation as already mentioned.

Set up the 2 volts a.c. range as already described, adjusting first R22 (the range setting control) then the zero control, with a 2 volts a.c. input. To make the probe suitable for power frequencies the 0·05 μF probe capacitor must, of course, be plugged in. After setting up the range disconnect the probe from the supply circuit and switch the function switch to d.c.+. The zero setting should still hold good; should it vary correct it on the d.c. setting of the function switch. Then return to the a.c. position, again correcting for contact potential by adjusting R3, following by a correction of the range setting on 2 volts a.c.

To calibrate the low a.c. volts scale, or to prepare a conversion scale, a reference voltmeter is essential. The process is carried out as for the a.c. range of the multimeter.

The remainder of the a.c. ranges are set up at zero and full scale marks by the method already used, R23 being the full scale adjuster for the 10 volts range, R24 the adjuster for the 20 volts range, and R25 the adjuster for the remaining three ranges which can be set up on 100 volts. With these ranges set up and checked (they should be substantially linear with accuracies of the order of 5 per cent. of the full scale reading) the valve voltmeter is ready for use, and capable of reading direct and alternating voltages in all types of circuit with the minimum of circuit disturbance.

2

THE SIGNAL GENERATOR

COMMERCIAL generators of many patterns and capabilities are available; but the constructor wishing to build his own generator is advised to keep to a fairly simple circuit. Commercial models cost from £7 10*s*., so the home-built generator must cost less than this, unless it is constructed for a particular task, if the proposition is to be an economical one.

The circuit of a simple generator is shown in Fig. 14, where a double triode is utilised as an r.f. oscillator in the first section, and an audio oscillator in the second section. Modulated and unmodulated r.f. and audio outputs are available from a very simple low impedance attenuator. Five tuning ranges in the original instrument can be reduced to three ranges if desired by using a Wearite PHF3 coil for short wave coverage from 16 to 47 metres; a Wearite PHF7 for medium and i.f. range coverage from 250 to 750 metres (1,200 to 400 kc/s); and Wearite PHF1 long wave coil. An intervalve transformer is used in the audio oscillator which can be tuned to the accepted frequency of 400 c.p.s. by parallel capacitance, in the majority of cases.

The generator must be built in a metal case giving complete shielding. The artificial aerial should be constructed within this case, whilst the mains lead has capacitors by-passed to the case to prevent leakage of r.f. along the cable. A full vision and completely calibrated tuning scale is a considerable advantage, but a good slow-motion drive (such as the Muirhead) in conjunction with calibration charts, can almost be as convenient and is much more simply arranged. A full wave power supply is fitted to isolate the generator from the mains, so that it may be used safely with any type of receiver.

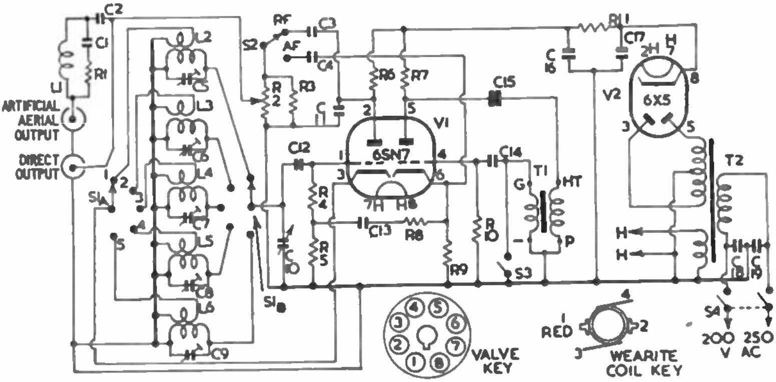


FIG. 14. A SIMPLE BUT EFFECTIVE SIGNAL GENERATOR

COMPONENTS LIST FOR THE SIGNAL GENERATOR (Fig. 14)

C1	400 pF, 350 v.w. mica.
C2, C11	200 pF, 350 v.w. mica.
C3, C13, C14	0·001 μF, 350 v.w. paper or mica.
C4, C15	0·01 μF, 350 v.w. paper.
C5, C6, C7, C8, C9	4–50 pF trimmers. (Or *see text.*)
C10	500 pF variable tuner.
C12	50 pF, 350 v.w. mica.
C16, C17	8+8 μF, 450 v.w. electrolytic.
C18, C19	0·001 μF, 500 v.w. mica.
R1	390, ¼ watt.
R2	2 K, variable, Output Control.
R3	220, ¼ watt.
R4	47 K, ¼ watt.
R5	10 K, ½ watt.
R6, R10	100 K, ½ watt.
R7, R8	220 K, ½ watt.
R9	4·7 K, ½ watt.
R11	4·7 K, 2 watts.
L1	60 turns 28 s.w.g. enam. on ¼" diameter former (paxolin tube) closewound to 1" long.
L2	Wearite PHF3. 16–47 metres.
L3	Wearite PHF5. 34–100 metres.
L4	Wearite PHF6. 90–260 metres.
L5	Wearite PHF7. 250–750 metres.
L6	Wearite PHF1. 700–2,000 metres.

NOTE: The tuning coils are connected with tag No. 1 taken to the grid *via* S1a and C12; tag No. 3 taken to the cathode *via* S1b, and tags Nos. 2 and 4 earthed to the chassis.

S1a, b	2-pole 5-way tuning range rotary switch.
S2	S.P.D.T. R.F.–Audio switch. Toggle or rotary.
S3	S.P.S.T. Audio on–off switch. Toggle.
S4	D.P.D.T. Mains on–off switch. Toggle.
T1	3 : 1 or 5 : 1 intervalve transformer.
T2	200–250 volts primary. 250–0–250 v. 60 mAs. 6·3 v. 1·5 a.
V1	6SN7 GT.
V2	6X5 GT.

2 Int. octal valveholders.

Chassis; screening case; and panel. *See text.*

Slow motion drive and dial. For full calibration of tuning scale, use Jackson Bros. "Caliband," or Eddystone, or Q Max. blank dials.

For use with calibration charts use Muirhead drive with numbered edge dial.

3 or 4 knobs; 2 output sockets, with plugs; Belling-Lee coaxial.

Coaxial lead (for output leads); Crocodile clips; Sleeving; wire; nuts; bolts; etc.

CONSTRUCTION

In earlier signal generator designs the author has generally given chassis dimensions with layouts; but judging from correspondence received and from specimen models shown by constructors, it would appear that the signal generator in particular is built up in any metal box which happens to be handy, the original layout seldom being followed carefully. For this reason no layout is given for the present instrument. The original was constructed on a 10" × 8" × 2½" chassis, but this was considerably larger than necessary.

In Fig. 14 each tuned circuit is shown as having its own trimmer by means of which the coil may be adjusted to a maximum or starting frequency with the main tuner, C10, completely unmeshed. There is sufficient overlap between the various tuning ranges if the trimmers are omitted, however, and it may be preferred to omit C5–C9 inclusive, replacing these individual trimmers by a single trimmer across C10, brought out as a panel control (a 15 or 25 pF midget tuner would serve admirably). The signal generator could then be zeroed on the long wave Light Programme at 200 kc/s (beating the generator output against the Light Programme carrier in a broadcast receiver) whenever a check was required.

Code the generator switches as follows:

S1—

Position 1	Short 1.
„ 2	Short 2.
„ 3	Short 3—Medium.
„ 4	Medium—i.f.
„ 5	Long.

S2—

Position 1	R.F. Mod. and Unmod.
„ 2	Audio.

S3—

Audio On–Off.

The audio output from the audio oscillator can be tuned to a required frequency within limits determined by the intervalve transformer used as T1, a capacitance across the grid winding (the secondary of the transformer) usually serving to bring down the frequency to the normal 400 c.p.s. note. If the transformer note is low suspect blocking action, and try the effect of reducing C15 or C14, or both. The values of R4 and R5 suited the various transformers tested in the T1 position of the original trial model generator, and should give a carrier modulated to a depth of roughly 30 per cent. The output of the generator can be inspected on an oscilloscope (the one to be described or any other), the generator being switched to the lowest frequency range, any adjustments needed in the depth of modulation can be made by varying the proportional values of R4 and R5. The output from the audio oscillator should also be checked for shape, and the audio section of the unit adjusted for as good a sine wave output as possible. Too vigorous oscillation will almost always be the cause of harmonic and other distortion; again the remedy is the reduction of C14 or C15 and possibly an increase in R7.

Should the chosen transformer be a poor oscillator it may be necessary to reduce R8 to give satisfactory modulation of the carrier.

The signal generator should also be checked over its complete range against a suitable receiver, with both modulated and unmodulated outputs, checks for weak or dead spots, and for squegging, being made without audio modulation. Squegging (a rough hissing carrier extending over a band of frequencies instead of being sharply tunable) is best cured by reducing the value of C12. Should weak or dead spots occur, then conversely C12 should be increased in value, or R6 might be reduced to increase the effective anode voltage.

A generally weak output from the generator can be overcome by removing R3, leaving R2 alone as the output control; but it should be noted that not too great an output was intended when the generator was designed. Medium output, with the oscillator held well back, gives better stability and a cleaner signal than a circuit operating at high output.

Calibration—When the generator has had its first tests as described, the next step is to calibrate the instrument over its various ranges, either directly on a hand-drawn scale or by graphs or charts. The calibration may be carried out against a standard signal generator, or against broadcast signals of known frequency. As an indicator a wide range receiver is employed.

Before commencing calibration the signal generator should be switched on for a warm-up period and allowed to reach its operating temperature. At this point the temperature should be checked and, if considered necessary, the ventilation of the generator should be improved to keep the temperature down. This will not only improve the operating stability of the signal generator, but will give less arduous working conditions to the components. If extra ventilation seems necessary this may be provided by drilling holes in the metal case, the holes being screened by a covering of copper gauze, or similar material.

If a standard signal generator is used both the generators must be coupled loosely into the receiver. It is generally sufficient to run a short length of wire from the receiver's aerial terminal together with short lengths of wire from the generators' artificial aerial outlets, the three wires being run fairly close together for a foot or so, and properly insulated from each other. This is sufficient to give clearly audible signal pick-up without over coupling between the generators, which could result in frequency pulling.

Commencing with the low frequencies, tune the standard generator to exactly 150 kc/s (2,000 metres) and tune in this signal on the receiver. Now tune the generator under test until its carrier is heard to beat with that of the standard. Both generators should be supplying unmodulated signals. Tune the test instrument until the frequency of the beat note is inaudible, when the generators are exactly in tune. The dial of the test generator or the tuning chart can be marked with the 150 kc/s tuning point.

(If a single trimmer across C10 is being used as a zeroing control it should be set to half capacitance before calibration is commenced, and locked in a position which must not be touched until the whole calibration is completed.)

With the 150 kc/s point calibrated, tune the standard generator to the next chosen point; on the low frequency range this might well be 10 kc/s away, at 160 kc/s. Retune the receiver to the carrier and then tune the test generator to give a beat note. Again, by careful tuning, find the zero beat. Calibrate this tuning point as 160 kc/s. Continue in this way at 10 kc/s intervals over the whole frequency range of the generator.

Over the medium and i.f. tuning range given by the PHF7 coil the calibration is complicated to some degree by the fact that the receiver will not tune directly over part of the range—say, from 550 to 750 metres (545 to 428 kc/s approximately). In this case the receiver should be tuned to the second harmonic of the standard generator after it has been run off the tuning scale on fundamentals—for example the 500 kc/s signal from the standard generator should be tuned in at 1,000 kc/s (*i.e.* 1 Mc). The 470 kc/s signal should be tuned in at 940 kc/s, and so on. If the standard and test generators are run together up to the change-over frequency there can be little or no chance of mistuning the test generator to an incorrect harmonic.

Over the medium wave range the calibration points may be separated by 20 or 25 kc/s—commencing at the 250 metres, 1,200 kc/s end of the band, and tuning the standard generator, receiver, then test generator as before, calibrate the test instrument down to the change-over point at about 550 kc/s, depending on the receiver. Then set the standard generator to 525 kc/s, tune the receiver to bring in the second harmonic at 1,050 kc/s, and tune the test generator to give the required beat note. With some receivers it may help to switch on the modulation of the standard generator until the second harmonic is correctly identified.

Over the i.f. range the calibrations may with advantage be made closer together—at 10 kc/s intervals if the standard generator will permit of this separation. Calibrate down to 430 or 420 kc/s.

The short wave ranges, assuming that the receiver being used as an indicator has a wide tuning range, are calibrated directly without the use of harmonics. If the receiver is poor on second channel rejection extra care should be taken at the highest frequencies to ensure that the two generators are tuned correctly. Over the 90–260 metres band (3·3 to 1·15 Mc approximately), the calibration points may be separated by 25 kc/s or 50 kc/s, points on the two highest bands being made 50 or 100 kc/s apart.

Where broadcasting stations are to be the frequency standards it will prove practically impossible to calibrate direct reading tuning dials, and it will be sufficient to draw up tuning graphs or charts, one for each range of the generator. The instrument should be coupled into the indicating receiver by running a lead from the artificial aerial socket beside the aerial lead-in for a foot or so, the length of lead being made sufficient to give satisfactory pick-up of the generator signal.

On each tuning range of the generator a number of broadcast signals should be chosen from a station list to give a set of tuning points spaced out at approximately equal intervals. The first of such a series of signals should be tuned in on the receiver (it may be necessary to wait for good reception conditions) and the generator then tuned to beat its unmodulated carrier against the broadcast signal, obtaining a zero beat as nearly as possible. The reading of the generator dial should be plotted on a chart against the station frequency. The receiver should then be tuned to the next chosen signal, the generator heterodyned against the signal and the next point plotted on the chart, and so on. It is, of course, essential to identify the received signal as being actually the required station on the correct chosen frequency, but with a reasonably good receiver this is not a difficult matter.

The i.f. range must again be covered by harmonics, stations being chosen with frequencies, divided by two, give suitable check points over the i.f. range. As the generator is run up towards the change-over point of about 550 kc/s the receiver, therefore, must be tuned back to chosen stations over about the 1 Mc to 850 kc/s range whilst the generator is tuned on to the 500 kc/s to 425 kc/s range, the second harmonic of the generator signal actually being heterodyned against the broadcast signals.

Over the high frequency ranges care must be exercised in the choice of station and its identification, as well as in the tuning of the generator, to avoid second channel effects.

RECEIVER ALIGNMENT

Although the signal generator has many uses it is chiefly employed in the realignment of broadcast receivers—the superhet. definitely requires alignment with the aid of a signal generator. The author's correspondence shows there is still a considerable demand for an outline of the correct procedure, so the following, based on the typical superhet. circuit of Fig. 15, should satisfy this requirement.

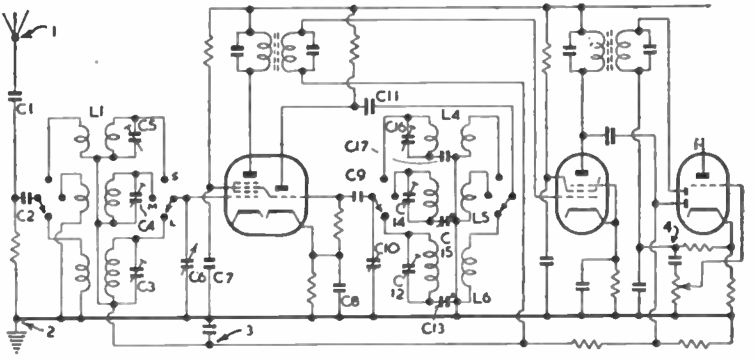


FIG. 15. A TYPICAL SUPERHET. CIRCUIT (R.F., I.F. & DET. STAGES) USED THROUGHOUT THE TEXT TO ILLUSTRATE USE OF INSTRUMENTS

1. Switch on the receiver and the generator and allow a generous warm-up period.
2. Connect the generator earth line to the receiver earth terminal or to the receiver chassis. (Be particularly careful with Universal mains receivers, using the earth terminal only in these circuits. This should be isolated from the receiver chassis by a capacitor.) Connect the artificial aerial output lead from the generator to the control grid of the frequency changer, leaving the grid cap in place in the case of top-grid valves.
3. Tune the receiver roughly to the low frequency end of the medium wave band. Tune the signal generator to the receiver's correct i.f. Unless the

set is far off tune the generator signal should be heard when the modulation is switched on.

4. Turn up the receiver volume control and turn down the signal generator output control, until the signal is only just clearly audible. Preferably use an output meter for indications of output.
5. Trim the i.f. transformers for maximum volume, commencing with the secondary of the last transformer (the detector circuit) and working forward to the primary of the first transformer. As the circuits are brought into tune and the volume rises, turn down the generator output.

   If the i.f. transformers are seriously off-tune it is possible that the generator signal will not be heard even with the output control fully advanced. In this case first tune the generator round about the correct intermediate frequency to ascertain whether the signal can be heard at a different setting; then, if the signal is still inaudible, reset the i.f. transformers by bringing their trimmers or cores to mid-point settings. By tuning the generator round about the correct frequency, it should then be possible to bring in a signal; from this starting point it will be a simple matter to bring the transformers into tune at the required frequency.
6. Throughout the alignment the signal generator output must be kept low to avoid operating the receiver's AVC line as well as to make variations in the receiver's output volume more readily audible. If an output meter is used the receiver's volume control may be advanced and the generator output increased; the receiver AVC line should be short-circuited (between points 2 and 3 in Fig. 15). If the receiver AVC line comes into action at all, the receiver tuning will be effectively broadened, and resonant points will be poorly defined.
7. When the receiver's i.f. circuits have been brought into tune they should be left at that setting and not touched again. Watch for instability during i.f. alignment, and cure any evidence of feedback before proceeding further with the work. In some locations a slight alteration in the receiver i.f. may prove desirable. In a coastal area near to a ship/shore transmitting station, C.W. break-through directly into the i.f. stages of receivers may be experienced. The best i.f. in such a case may be found by trial. Generally, an increase in frequency to about 473 kc/s, from the normal 465 kc/s, gives best results.
8. Remove the generator output lead from the frequency changer grid and connect it into the receiver's aerial terminal. Switch the receiver to the long wave band. Tune the generator to 300 kc/s (1,000 metres) and tune the receiver to this setting on the tuning dial. Adjust the long wave oscillator trimmer, C12, until the generator signal is tuned in.
9. Adjust the aerial circuit trimmer, C3, for any possible increase in volume.
10. Tune the generator to 171·4 kc/s (1,750 metres) and tune the receiver to this setting on the dial. Tune the oscillator until the signal is brought in by varying the padder, C13. In a receiver with iron cored coils the padder capacitors will probably be fixed. In this case vary the core of the long wave oscillator coil, L6, screwing the core in or out of the coil until the signal is heard. Do not use metal screwdrivers for adjusting iron-dust cores, as these cores crumble rather easily. A suitable trimming blade can be filed on to the end of a plastic knitting needle, if a set of trimming tools is not available.
11. Retune both the generator and receiver to the 300 kc/s setting and adjust C12 until the signal is again tuned in at the correct point on the dial.
12. Retune both the generator and receiver to 171·4 kc/s. Now the padding adjustment will require further correction. Adjust C13 (or the appropriate iron-dust core) until the signal is again tuned in at the correct point on the dial.
13. Repeat steps 11 and 12 consecutively until the trimming and padding operations fail to affect one another, and the set tunes correctly to the test signals at both test frequencies.

   Note that on each adjustment made at the low frequency end of the scale (the padding adjustment) the tuning control of the receiver should be "rocked" as the padder capacitor or coil core is adjusted. This rocking consists of turning the tuning control a few degrees forward, then a few degrees back, so that the tuning capacitor is turned slightly high and slightly low of the correct point during the adjustment. This will be found of assistance in determining the correct setting of the padding control.

14. Tune the generator and the receiver to 300 kc/s and adjust C3 for best volume. For air cored coils the long wave alignment is complete.
15. If iron cored coils are employed tune the generator and receiver to 171·4 kc/s and adjust the core of the long wave aerial coil, L3, for best volume.
16. (For iron cored coils only.) Repeat steps 14 and 15 consecutively until it is impossible to improve volume at either frequency. The long wave alignment is then complete.
    Rocking need not be carried out for steps 14 and 15.
17. Switch the receiver to the medium wave band and the generator to the appropriate tuning range.
18. Tune the generator to 1,200 kc/s (250 metres) and tune the receiver to this setting on the tuning dial. Adjust the medium wave oscillator trimmer, C14, until the signal is tuned in.
19. Adjust the aerial trimmer C4 for any possible increase in volume.
20. Tune the generator to 600 kc/s (500 metres) and tune the receiver to this setting on the dial. Adjust the padder C15 (or the appropriate coil core) while slightly rocking the main tuner until the signal is correctly tuned.
21. Retune the generator and receiver to 1,200 kc/s and readjust C14 until the signal is again tuned in at the correct point on the dial.
22. Retune both the generator and receiver to 600 kc/s and readjust C15 or the appropriate coil core, rocking the main tuner, until the signal is again tuned in at the correct point on the dial.
23. Repeat steps 21 and 22 one after the other until the trimming and padding operations fail to affect one another, and the set tunes correctly to the test signals at both test frequencies.
24. Tune the generator and receiver to 1,200 kc/s and adjust C4 for best volume. For air cored coils the medium wave alignment is complete.
25. If iron cored coils are employed tune the generator and receiver to 600 kc/s and adjust the core of the medium wave aerial coil, L2, for best volume.
26. (For iron cored coils only.) Repeat steps 25 and 26 consecutively until it is impossible to improve volume at either frequency. The medium wave alignment is then complete.
27. On the long and medium wave ranges it is generally possible to bring the trimmers and padders into tune without any difficulty, no matter at what setting the trimmers and padders are placed at the commencement of the operation. When a new receiver is undergoing its first alignment it is usually sufficient to set trimmers and padders at approximately half full capacitance. In the case of coil cores, these may be placed at about their mid positions.

    On the short wave range or ranges it is preferable to commence with the oscillator trimmers in the minimum capacitance setting, to obviate second channel effects. For example, to bring in a 15 Mc/s signal in a normal receiver with a 465 kc/s i.f. the oscillator should be set to 15·465 Mc/s and the aerial circuit to 15 Mc/s. If the oscillator trimmer was screwed down hard at the commencement of operations, however, the oscillator frequency might well pass through 14·535 Mc/s as the trimmer was unscrewed, giving a response from the loudspeaker which in an unselective receiver would seem to indicate correct tuning of the oscillator.
28. Switch the receiver to the short wave band and the generator to the appropriate tuning range.
29. Open the oscillator trimmer, C16, to minimum capacitance.
30. On the normal short wave band (15 to 50 metres) tune the generator to 15 Mc/s (20 metres) and tune the receiver to this setting on the tuning dial. Increase the capacitance of C16 until the signal is tuned in.

31. In receivers with air cored coils it remains only to adjust C5 for maximum volume, as the majority of such receivers have fixed short wave padder capacitors.
32. In receivers with iron cored coils, tune the generator to 7·5 Mc/s (40 metres) and tune the receiver to this setting on the dial. Rock the main tuner slightly and adjust the core of the short wave oscillator coil until the signal is tuned correctly.
33. Retune the generator and receiver to 15 Mc/s. The trimming adjustment will require further correction. If the core of the coil was moved an appreciable amount, open the trimmer C16 and run it into its correct setting again as in step 30. If the core of L4 was not moved by any great amount, simply correct the setting of C16 in the normal way.
34. Retune both generator and receiver to 7·5 Mc/s and readjust the coil core, rocking the main tuner until the signal is correctly tuned.
35. Repeat steps 33 and 34 one after the other until the trimming and padding operations fail to affect one another and the set tunes correctly to the test signals at both test frequencies.
36. Tune the generator and receiver to 15 Mc/s and tune C5 for best volume.
37. Tune the generator and receiver to 7·5 Mc/s and adjust the core of the short wave aerial coil, L1, for best volume.
38. Repeat steps 36 and 37 one after the other until it is impossible to improve volume at either frequency. The short wave alignment is then complete.
39. Remove the signal generator connections and test the receiver on its normal aerial. Correct the setting of the aerial trimmer capacitors by tuning to a weak station at the high frequency end of each tuning range, readjusting the aerial trimmers slightly for any possible improvement in volume.

    If the AVC line was short-circuited during alignment, the short-circuit must be removed before carrying out this final test.

3

THE OSCILLOSCOPE AND AUXILIARY GEAR

The oscilloscope, once considered a luxury, is now almost a necessity in a well-equipped servicing shop, and a circuit suitable for the constructor is shown in Fig. 16. This illustrates quite a comprehensive 3-in. oscilloscope, the design being similar to that in the author's *The Oscilloscope Book*, in which there are full descriptions of various circuits and their uses.

In the oscilloscope a normal full wave power pack provides a 300–350 volts h.t. line for the timebase, sync. stage and amplifier. A voltage doubling circuit is taken from one side of the transformer to supply about 600 volts negative, *via* selenium rectifiers, for the cathode ray tube. The final anode and deflector system of the CRT can be earthed to prevent spurious traces, and to simplify connection to external circuits. A power take-off socket can be fitted to provide for auxiliary apparatus, such as a wobbulator. A VCR139A surplus tube was used in the original oscilloscope, but an ECR35 (VCR138) can be connected into circuit with no change of components (in some cases it may be found advantageous to make a slight variation in the shift and focus network). The larger tube really requires a greater e.h.t., however, if full advantage is to be taken of its capabilities, although a 350–0–350 volts transformer gives an ample output from the voltage doubler. A dropper will then be needed in the h.t. supply line to the timebase, etc., if these valves are not

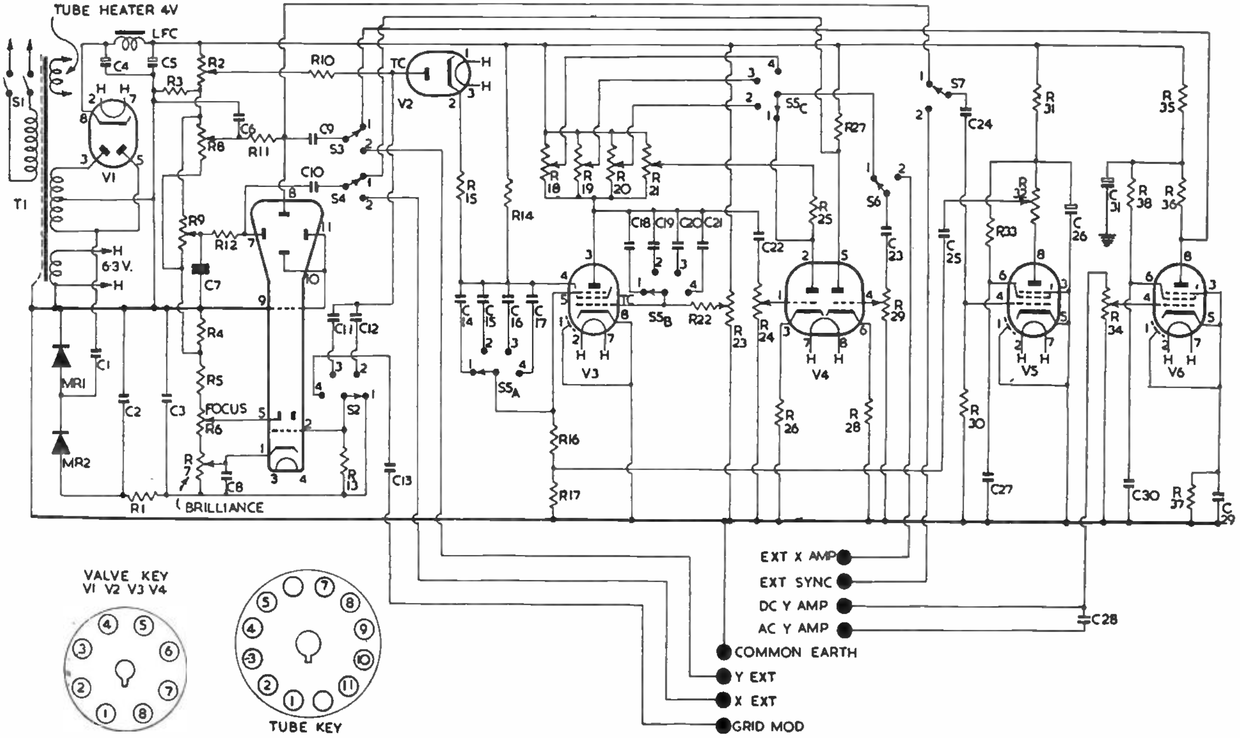


FIG. 16. A USEFUL OSCILLOSCOPE CIRCUIT

to be overrun. The effect of omitting the reservoir capacitance and giving extra smoothing might be tried as an alternative to a dropping resistor.

If a 350–0–350 volts transformer is used the present 250 volt rectifiers in the MR1 and MR2 positions must be replaced by 350 volts components. Some may find a simpler solution is to use 1,000 volts rectifiers of the K3/40 type, which may be obtainable on the surplus market, should 350 volts components not be readily obtainable.

A Miller timebase is employed, switched over four ranges to give a very satisfactory variation in sweep speeds from about 5 to 120,000 sweeps per second. The Miller timebase has two slight defects as commonly used: its output varies from range to range; and its normally excellent linearity fails at the lowest frequency. These defects are corrected in the present circuit by switching in separate output potentiometers, one for each speed range, whilst a lineariser is added to the lowest range (the first section of the double triode V4). A substantially equal output is then obtained from the timebase irrespective of the range employed. This output is fed to the timebase amplifier, the second section of V4. The timebase could readily be made to give a satisfactory output without an amplifier, but the isolation of the timebase from the tube (and from external apparatus sometimes employed, such as a wobbulator), and the excellent control of amplitude obtained are found to be so beneficial in practice that the amplifier is well worth fitting.

Also worth while is a separate synchronising valve. The signal to which locking of the timebase is required is fed to this valve from either the Y deflector plate of the tube or an external point. The valve is arranged so that grid current charges a grid capacitor, biassing it back to cut-off except on positive signal peaks, which set up negative-going output pulses at the anode. These pulses are fed to the suppressor of the Miller timebase valve and effectively synchronise the timebase to the signal under inspection. In the original oscilloscope a fixed sync. stage was fitted, but it has been found desirable to permit of some adjustment in the circuit, and the present sync. stage has accordingly been made controllable by means of the potentiometer R32.

Many different types of signal amplifiers may be designed for oscilloscopes depending on the purpose for which the unit is required. For general service work it is probable that a single valve amplifier is quite satisfactory, especially in view of the fact that extremes of frequency have not to be inspected (this, of course, refers to ordinary radio servicing and not TV service work). Such an amplifier is included in the circuit. Those requiring greater gains in the amplifier system, or wider frequency ranges, are referred to *The Oscilloscope Book*.

Two input terminals to the amplifier are provided: one, marked A.C. being isolated by capacitance from the control potentiometer; and the other, marked D.C. being directly coupled. The coding " D.C." is not intended to convey that there is a d.c. path between the input terminal and the deflector plate (in the video amplifier sense); but shows that the input is suitable for circuits requiring a d.c. path across them, or for low voltage circuits where there is no potential to be blocked off from the amplifier grid circuit.

COMPONENTS LIST FOR THE OSCILLOSCOPE (Fig. 16)

C1	0·1 μF 600 v.w. paper.
C2	1 μF 1,000 v.w. paper.
C3	0·1 μF 1,000 v.w. paper.
C4, C5	8 + 16 μF 450 v.w. electrolytic.
C6, C7, C14, C25	0·01 μF 350 v.w. paper.
C8, C11, C13, C27, C30	0·1 μF 350 v.w. paper.
C9, C10, C22, C23, C28	0·5 μF 350 v.w. paper.
C12, C16	500 pF 350 v.w. mica.
C15, C19	0·001 μF 350 v.w. paper.
C17, C24	250 pF 350 v.w. mica.
C18	0·015 μF 350 v.w. paper.
C20	150 pF 350 v.w. mica.
C21	75 pF 350 v.w. mica.

C26, C31	8 μF 350 v.w. electrolytic.
C29	0·005 μF 350 v.w. mica.
R1	100 K, ½ watt.
R2	1 Meg. variable. Beam Blanking set.
R3	1 Meg. ½ watt.
R4, R5, R10, R22	470 K, ½ watt.
R6	1 Meg. variable. Focus control.
R7	100 K, variable. Brilliance control.
R8, R9	2 Meg. variable. Shift controls.
R11, R12, R30	2·2 Meg. ½ watt.
R13, R27	47 K, ½ watt.
R14	22 K, ½ watt.
R15	330 K, ½ watt.
R16, R17, R36	68 K, ½ watt.
R18, R19, R20, R21	250 K, variable. Timebase output controls. (Preset.)
R23	1 Meg. variable. Fine speed control.
R24	0·5 Meg. variable. Low Frequency Lineariser.
R25, R38	150 K, ½ watt.
R26	220 K, ½ watt.
R28, R37	3·3 K, ½ watt.
R29	100 K, variable. X Amplitude control.
R31, R35	33 K, ½ watt.
R32	100 K, variable. Sync. control.
R33	120 K, ½ watt.
R34	1 Meg. variable. Y Amplitude control.
V1	6X5GT.
V2	Mullard EA50.
V3	Mullard EF37.
V4	6SN7GT.
V5, V6	6AC7.

5 Int. octal valveholders.

1 Diode cradle holder.

1 CRT with holder, VCR 139A or E4412/B/9 (G.E.C.) or similar.

T1	Transformer, 200–250 v. 250–0–250, 60 mAs. 6v. 3a. 4v. 1a.
Rec. 1, 2	SenTerCel rectifiers, 250 v. 30 mAs.
S1	DP on–off mains switch, ganged with R7.
S2	SP 4-way rotary, Beam Blanking/External Grid Mod.
S3, S4	SP 2-way rotary or toggle. Internal/External deflection.
S5a, b, c	3 P 4-way rotary. Coarse Speed control.
S6	SPDT rotary or toggle switch. Internal/External X Amplifier.
S7	SPDT rotary or toggle switch. Internal/External Sync.

Chassis, aluminium, 16″ × 7″ × 3″. Panel, Millboard, 8½″ × 9″. (See Figs 15 and 16.)

Knobs to suit potentiometers and switches (rotary), 14 if all rotary switches are used.

Nuts; bolts; sleeving; wire, etc. 1 Octal grid clip. 1 Diode anode clip. 8 insulated terminals or sockets with plugs.

CONSTRUCTION AND ADJUSTMENT

The chassis and panel layout are shown in Figs. 17 and 18 from which it will be noted that a rather long chassis was employed for the original oscilloscope. This allows the tube to be placed well before the mains transformer so that there was no possibility of mains hum fields interfering with the trace (a tube with a Mumetal screen was employed) whilst spare chassis space was

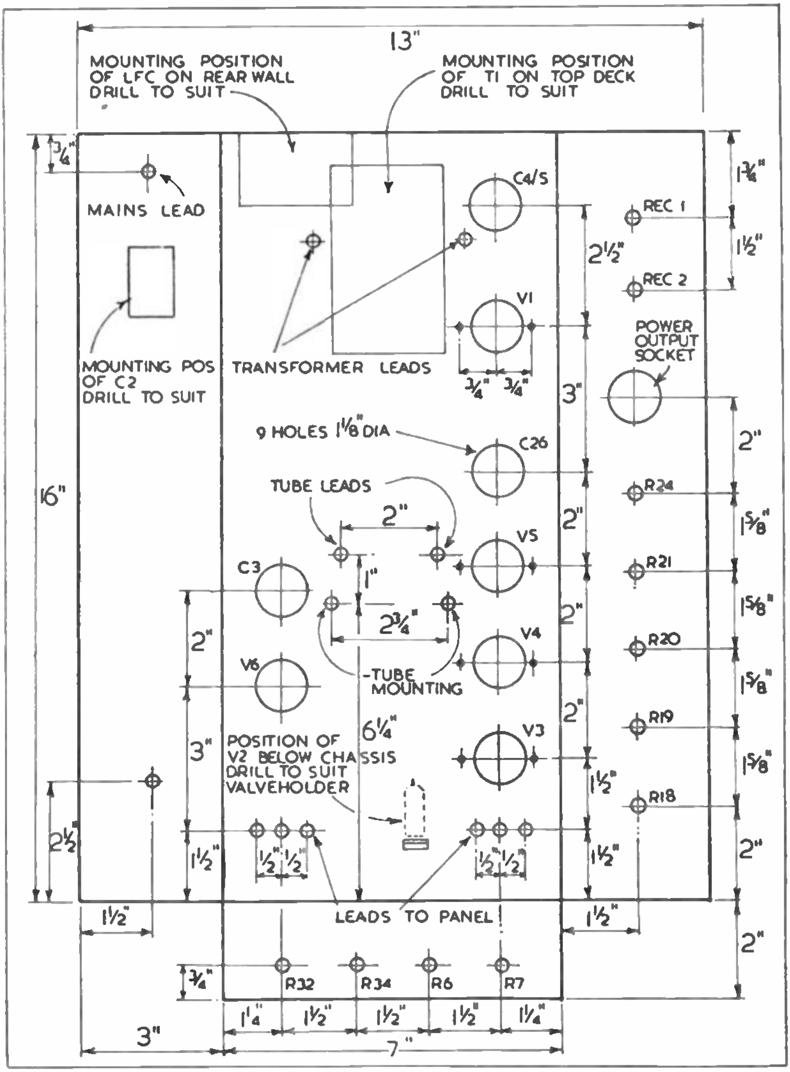


FIG. 17. CHASSIS LAYOUT OF THE OSCILLOSCOPE (TOP VIEW)

left for the addition of later gear such as a wobbulator, square wave generator, etc. The lightly loaded power pack of the oscilloscope can easily supply sufficient power for the operation of simple additional units.

A shorter chassis may be used to reduce the overall length of the oscilloscope, but the mains transformer should then be well screened.

The mounting holes shown in the diagram, marked with their respective component numbers, serve as a guide to the layout of the oscilloscope parts. The only circuit in any sense critical is the Miller timebase. The two groups

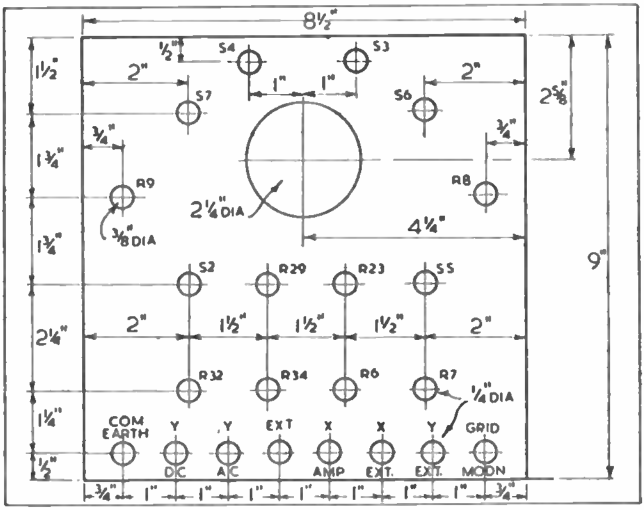


FIG. 18. FRONT PANEL LAYOUT OF THE OSCILLOSCOPE

of capacitors are mounted directly on their switch contacts, the anode-grid capacitors on the leaf nearest the front panel with the components standing upright and touching the rear of the panel. The screen-suppressor capacitors are mounted on the second leaf whilst the third leaf controls the preset gain switching. The leaves of the timebase switch should be separated by no more than ⅜ in. and if greater separation is found in the procured switch unit the leaf spacers may be removed and either cut down or replaced and the switch rebuilt.

Resistors and other small components below the chassis may be mounted either directly in the wiring or on tagboards. If tagboards are used they should be small units, each holding the resistors and capacitors for an individual stage and mounted beside the appropriate valveholder. The large coupling capacitors (the values are chosen to give good response to the lower frequencies) may be clamped to the underside of the chassis; if they are of the metal-cased variety it is better to insulate them from the chassis to avoid high frequency losses.

The X and Y plate wiring should be kept separate to prevent coupling between the leads. The leads from the Y amplifier and X amplifier to the S3 and S4 switches should be screened, using low loss cable—coaxial cable is ideal for this purpose. Screening is not essential for some purposes, but at high (radio) frequencies it assists in preventing pattern distortion and gives cleaner synchronisation.

V2, the beam blanking diode, is mounted below the chassis parallel with the underside surface. This valve has its working conditions set so that whilst it is cut off during the timebase sweep, during the flyback the cathode is driven negative to the anode by a negative-going pulse on the timebase valve screen. The diode conducts, causing a voltage drop across R10 and consequently a negative-going pulse at the tube grid (with S2 in position 2 or 3) so blanking out the tube trace during the flyback time. This offsets the disadvantage of the rather slow flyback of the Miller timebase at the high frequencies. The two capacitors between S2 and the blanking diode permit different " depths " of blanking to be applied.

The oscilloscope controls and switches should be coded:

R6	Focus.		
R7	Brilliance and On–Off.		
R8	Y Shift.		
R9	X Shift.		
R23	Fine Frequency.		
R29	X Amplitude.		
R32	Sync. Control.		
R34	Y Amplitude.		
S2	BEAM BLANKING:		
		Position 1	Blanking Off.
		,, 2	Blanking Soft.
		,, 3	Blanking Hard.
		,, 4	External Grid Modulation.
S3		,, 1	Y Internal Amplifier.
		,, 2	Y External Direct.
S4		,, 1	X Internal Amplifier.
		,, 2	X External Direct.
S5	TIMEBASE COARSE FREQUENCY:		
	Frequency ranges 1, 2, 3, 4.		
S6	X AXIS AMPLIFIER:		
		Position 1	Amplify Timebase.
		,, 2	Amplify External.
S7	SYNCHRONISATION CONTROL:		
		Position 1	Internal Sync.
		,, 2	External Sync.

Code terminals as shown in Fig. 16.

When the oscilloscope is completed and the wiring carefully checked, it should be set up and tested, the work being carried out in the following steps:

1. Switch on and leave the Brilliance control at a low setting.
2. Set S2 to position 1, Blanking Off.
3. Set S3 and S4 to position 1 for internal deflection.
4. Set S5 to position 1 for the slowest speed timebase.
5. Set S6 and S7 to position 1 for internal X amplification and internal synchronisation.
6. Turn up the brilliance until a spot or line can be seen, then adjust the Focus control to bring the trace into sharp focus. Centre the trace if necessary by means of R8 and R9. Never use greater brilliance than will give clear visibility, and if only a spot is shown on the screen keep the brilliance right down.
7. Turn the linearising control, R24, until the moving arm is earthed—*i.e.* until the control is off.
8. Set R29 to about the midway point and adjust the preset control R21 to give a timebase trace from one side of the screen to the other.
9. Connect the Y Amp. a.c. terminal to the oscilloscope's 6 volts heater line and adjust R34 to give a suitable size of trace without distortion.
10. It will be noted that as R23 is turned to show about three or four full cycles on the screen, non-linearity will be shown by a slight opening of the pattern at the left-hand side. Adjust the sync. control, R32, as necessary for a steady trace.
11. Turn the preset linearity control, R24. At some point the trace will commence to shrink, the open waveform on the left closing up to give a more linear appearance.

12. Correct for shrinking by turning up R21.
13. Again correct for linearity until the end of the trace tends to curve in on itself. This indicates the limit of useful control.
14. Disconnect the Y Amp a.c. terminal from the heater line, thus displaying a straight trace. With a Chinagraph pencil, strips of adhesive paper, etc., mark the ends of the trace. Leave R29 set at its present position and turn S5 to position 2, bringing in the next timebase speed range. The trace will either shrink or lengthen. Bring it to the same length as already marked on the screen by turning R20. Repeat at positions 3 and 4 of S5, correcting the trace length by turning R19 and R18 respectively.
15. During all these tests the direction of the spot movement should be from left to right across the screen—this can be checked with the timebase set at its slowest speed. If the movement is in the reverse direction the connections to the X plates of the CRT should be changed over.
16. Set the Y amplifier to give full gain and temporarily connect a dry battery or other source of potential across the Common Earth and Y Amp. a.c. terminals, making the Y Amp. terminal positive. The trace should flick upwards—if it flicks downwards reverse the connections to the Y plates of the CRT. This makes the amplifier show a conventionally correct trace, the spot moving up the screen for the application of a positive potential to the amplifier input circuit.
17. Again connect the Y Amp. a.c. terminal to the 6 volts heater line and turn S5 to position 1. Set up a trace of three or four sine waves, locking the trace steady with R32. Turn up the brilliance—the flyback line will be seen.
18. Turn S2 to position 3. The trace may momentarily brighten. Now turn R2, the preset control, so that the flyback line is just blacked out. Turn S2 to position 2—the flyback line will partially return. Use position 3 of S2 for slow speeds and position 2 for high speeds.
19. Test the oscilloscope for high frequency work by disconnecting the Y Amp. terminal from the heater line and connecting, between this terminal and the Common Earth, a signal generator set to give a 100 kc/s unmodulated output. Turn S2 to position 1, S5 to position 4, turn up the Y amplifier gain and endeavour to resolve a clear trace by R23. There will be some blurring due to flyback effects.
20. Switch S2 to position 2 and correct for best sync. by R32.
21. Switch on the generator modulation. The trace will blur. Switch S5 to position 1 and adjust R23—a modulated r.f. envelope will be displayed.

THE WOBBULATOR

A particularly useful piece of auxiliary gear for use with the oscilloscope is the wobbulator, by means of which the response curve of straight or superhet. receivers can be displayed and adjustments made. Basically the wobbulator consists of an oscillator tunable over a chosen range of frequencies, and also frequency modulated—*i.e.* the oscillator can be tuned to a set frequency and then swept over a band of frequencies centred on this frequency. If the wobbulator is tuned to the resonant frequency of a tuned circuit and then frequency modulated, the tuned circuit is " swept " by a signal. If the output from the tuned circuit is inspected on the oscilloscope, the frequency modulation of the wobbulator being in step with the timebase, a curve will be drawn which will exactly resemble the response of the tuned circuit to the frequency band being swept by the wobbulator. The same technique can be applied to the whole of a receiver, when the trace on the oscilloscope screen will show the overall response of the set under test.

The circuit of a simple wobbulator suitable for use with the present oscilloscope or with a commercial instrument is shown in Fig. 19. This unit is designed to operate from the power output socket of the oscilloscope, and is frequency modulated by the timebase sweep of the 'scope, the sweep circuit being supplied directly from the X plate of the oscilloscope. The second section of the 6SL7 acts as a medium wave oscillator tuned by C6, the oscillator being frequency modulated by a reactance stage formed by the

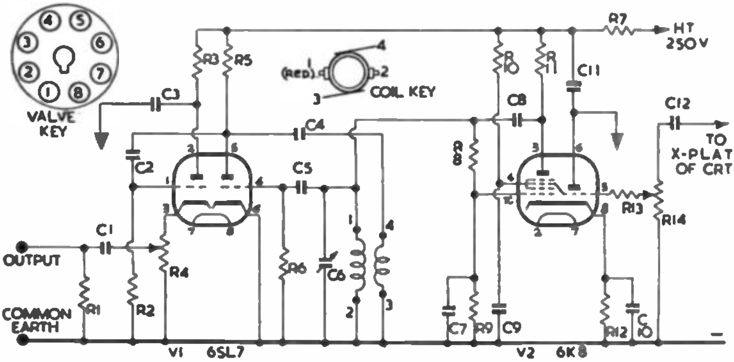


FIG. 19. A SIMPLE WOBBULATOR CIRCUIT

hexode section of the 6K8. R8 and C7 are connected across the grid circuit of the oscillator; since the value of R8 is large compared with the reactance of C7 the r.f. current through the network can be considered as being practically in phase with the voltage across the tuned circuit. The r.f. voltage across C7, however, lags the current by nearly 90 degrees. The lagging voltage across the capacitor is applied to the control grid of the hexode whose r.f. anode current, being in phase with the grid voltage, also lags 90 degrees behind the tuned circuit r.f. voltage. This lagging r.f. current is shunted across the tuned circuit and so gives the same effect as an extra inductance connected across the tuned circuit. The magnitude of the lagging current is controlled by the d.c. voltage applied to the grid of the triode section of the triode-hexode, hence the final frequency of the tuned circuit is also controlled by the triode grid voltage. Application of a saw-tooth voltage to the triode grid causes the oscillator to sweep over a band of frequencies in a linear manner, returning on the flyback to the commencing frequency. Synchronisation is unnecessary, and the final trace on the oscilloscope screen is always steady and central.

Output from a low impedance source is provided by the first section of the double triode which is capacitively coupled to the oscillator and acts as a cathode follower. Careful screening of the wobbulator is unnecessary although the coil should be below the chassis and the oscillator valve should be covered with a screening can.

The use of a medium wave oscillator coil makes the wobbulator suitable for use with any normal receiver, the unit being tuned into the receiver's aerial circuit. Some engineers prefer to use wobbulators tuned to the receiver's i.f., injecting the signal into the frequency changer grid of the set under test, but there seems little point in adjusting the i.f. response of a receiver without consideration of the response of the remaining (r.f.) tuned circuits. The present wobbulator shows the response of the receiver as a whole; if i.f. response only is required the tuning coil must be changed for a component covering the required frequencies.

A simple power pack may be built into the wobbulator if desired, employing a small mains transformer to give isolation from the supply.

COMPONENTS LIST FOR THE WOBBULATOR (Fig. 19)

C1, C4, C5 . .	100 pF 350 v.w. mica.
C2	20 pF 350 v.w. mica.
C3, C9, C10, C12 .	0·1 μF 350 v.w. paper.
C6	500 pF variable tuner, midget, solid dielectric.
C7	10 pF 350 v.w. mica.
C8	250 pF 350 v.w. mica.
C11 . . .	8 μF 450 v.w. electrolytic.

R1	100, ½ watt.
R2, R9	470 K, ½ watt.
R3, R5	220 K, ½ watt.
R4	50 K, variable. Output control.
R6, R7, R8, R13	47 K, ½ watt.
R10	33 K, ½ watt.
R11	68 K, ½ watt.
R12	330, ½ watt.
R14	0·5 Meg. variable. Sweep control.

1 6SL7GT.
1 6K8 G.
2 Int. Octal valveholders.
1 coil, Wearite PHF2, 1,500–550 kc/s.
4 Control Knobs.
1 small chassis, 8" × 4" × 3" as Fig. 20.
3 Sockets with plugs; 1 octal grid clip; Wire; Sleeving; Nuts, bolts, etc. Power plug to fit oscilloscope socket.

Construction of the unit is perfectly straightforward and requires no special remarks; layout and the mounting of components is seen from the chassis diagram, Fig. 20.

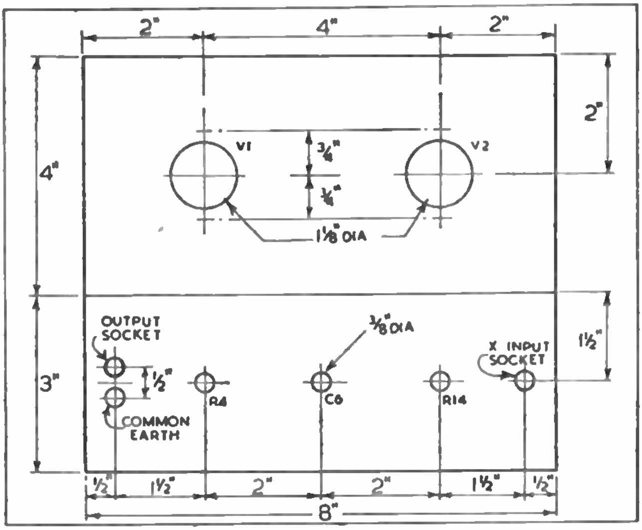


FIG. 20. CHASSIS LAYOUT OF THE WOBBULATOR

THE INSPECTION OF RESPONSE CURVES BY WOBBULATOR

To draw out the response curve of a complete superhet. receiver using the wobbulator, proceed as follows:

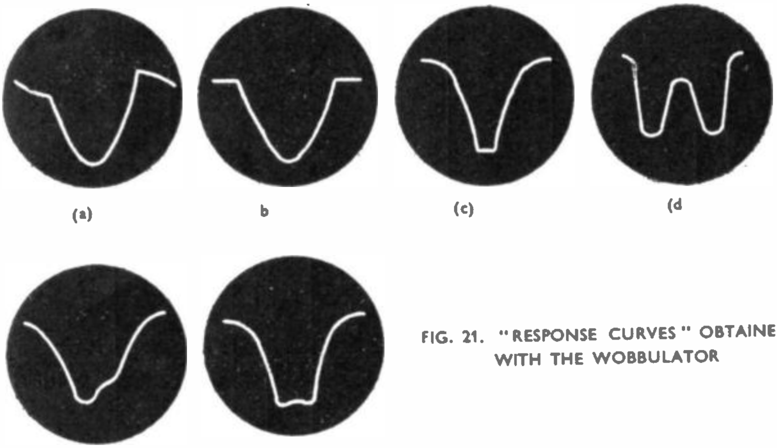
1. First check the alignment of the superhet., using the signal generator, in the manner described in Chapter 2.
2. Disconnect the signal generator. In its place, to points 1 and 2 of Fig. 15, connect the wobbulator output sockets. Connect the oscilloscope Common Earth terminal to the receiver chassis at point 2 and take the a.c. Y Amplifier terminal to point 4 of Fig. 15. Short-circuit the AVC line if this has not already been done.

3. Connect the X input lead of the wobbulator direct to the X plate (timebase input) of the CRT in the 'scope. Connect the wobbulator to the 'scope power output socket or switch it on if it has its own power supply.
4. Set the oscilloscope—S2 to Blanking Hard, S3 and S4, Internal, S5, Slow speed range, S6 to timebase and S7 to External sync. since synchronisation is automatic and no input to the sync. valve is needed. The amplifier gain control must be set by inspection to give a suitable trace.
5. Set the wobbulator controls R4 and R14 to the off position.
6. Tune the receiver over the medium waveband to a clear position where there will be no interference from strong local signals. Turn the receiver volume control right off and check the trace on the screen—it should be only a timebase line showing no hum, signals, etc.
7. Turn up the wobbulator output control, R4, and tune C6 until a signal is indicated on the oscilloscope screen. The trace should thicken to an r.f. envelope although the thickening should be of only small degree. In well filtered receivers the trace will show very little thickening indeed and the only indication of correct tuning will be seen as a momentary upward or downward movement of the whole trace. Obtain the best possible accuracy of tuning, *i.e.* maximum momentary deflection.
8 Keeping the setting of R4 as low as will give a satisfactory input to the receiver, advance R14. The trace will deflect in a downward curve and as the X input control is further advanced to give a greater frequency sweep, the curve will steepen until a complete response curve is drawn.
9. The remaining portions of the straight timebase may tilt as in Fig. 21(a). This indicates too slow a sweep speed with consequent phase distortion. Increase the sweep speed if necessary until the remaining parts of the timebase trace are flat as in Fig. 21(b). A sweep frequency of about 50 per second should prove satisfactory, high speeds being avoided as they result in an inaccurate response curve. The i.f. transformer adjustments can now be altered experimentally to observe the effects of the trace and to correct the tuning if necessary—remember that it is the response of the whole receiver which is being displayed.
10. The curve of Fig. 21(b) indicates the correct form of response for which to aim. Fig. 21(c), a flat-topped curve, indicates overloading at some stage, and the output from the wobbulator should be reduced to give a rounding-off. The curve of Fig. 21(d) may also indicate overloading, but is usually caused by off-tuning effects; before correcting the i.f. transformers try the effect of retuning the receiver by the main tuning control. The curve of Fig. 21(e) indicates a poorly aligned i.f. transformer and the side hump should be tuned out by realigning the i.f. stages. The double-humped curve of Fig. 21(f) is given by some types of i.f. transformer and also by staggering the i.f. tuning for broad response. This curve is also the type of response to expect from high fidelity t.r.f. receivers.
11. The short-circuit across the AVC line may be removed for overloading tests. The response curve will decrease in size as the AVC comes into play, and the wobbulator output may then be increased to test the efficiency of the automatic control.

ELECTRONIC BEAM SWITCHING

Double beam oscilloscopes, built round the Cossor double beam tube can be of considerable use and advantage in the laboratory, but they are by no means essential for normal receiver testing and servicing. However, there are occasions when a double beam oscilloscope, capable of presenting two different traces simultaneously, can be extremely useful. Obvious examples are tests on phase splitters, push-pull stages, and current and voltage checks.

An ordinary oscilloscope can be made to present a pair of separately controllable traces (in the Y direction) by means of an electronic switch. Such a switch consists of two amplifiers which are alternately keyed on and off by a square wave generator and keying or " gating " stage. The two inputs are applied to these amplifiers, and their gated outputs are combined. Each input



(a) b (c) (d

(e) (f

FIG. 21. "RESPONSE CURVES" OBTAINED WITH THE WOBBULATOR

is, therefore, sampled at regular intervals, and a sequence of samples—rather than a complete waveform—is displayed on the screen. At the same time it is arranged for one set of samples to be lifted above the other on the screen, the two traces thus being separated and made visible as separate waveforms. If the gating frequency is reasonably high the traces appear as continuous, and the connecting vertical excursions of the spot cannot be seen. This is made clear in Fig. 22.

FIG. 22. SHOWING THE DEVELOPMENT OF TWO TRACES WITH THE USE OF AN ELECTRONIC SWITCH

In the electronic switch circuit shown in Fig. 23 the square wave is derived from a multivibrator circuit built round a double triode, V1. (There are more modern circuits for producing a square wave which have advantages such as closer control of operating frequency; but the multivibrator generator is best suited for the electronic switch because it produces a push-pull output, which is essential.) The square wave output is fed to the grids of a further double triode, V2, whose cathode loads are common with the two signal amplifying stages. Square wave potentials are developed across the cathode resistors of an amplitude sufficient to key the amplifying valves on and off.

In the present circuit triode signal amplifiers are employed because, although they give a smaller gain per stage than pentodes, they operate very cleanly. The combined signal from the electronic switch cannot be passed through a further amplifier, *e.g.* the internal oscilloscope Y amplifier, so all amplification should be provided before the gating stage.

To try the effect of pentodes in the electronic switch, valves such as the 6SJ7 may be used. The two cathode resistors R9 and R10 must be increased

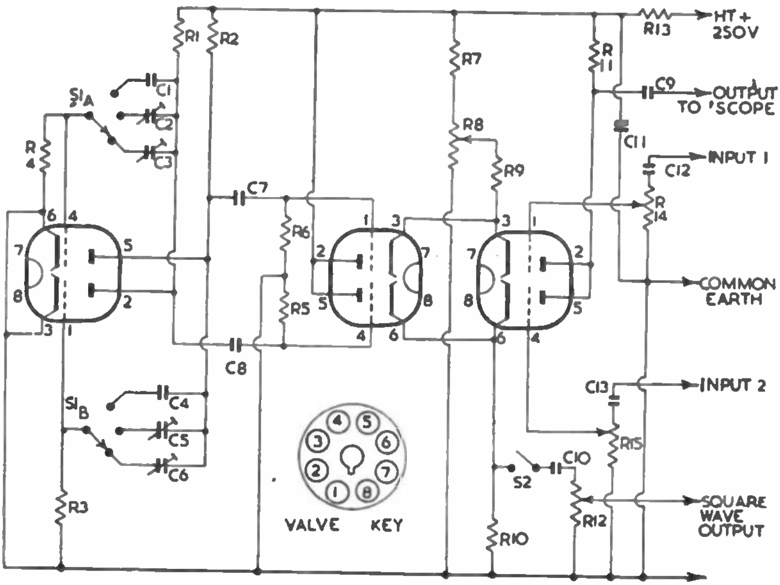


FIG. 23. CIRCUIT FOR AN ELECTRONIC SWITCH

to 1,000 ohms or thereabouts. Alternative suppressor grid connections should be tried: earthed directly to the chassis or connected to the pentode cathodes, choosing the connection giving the best results. The present anode load, R11, may be retained, or the effect of increasing it to 47,000 ohms may be tried. The screen grids should be tied together and taken directly to the h.t. line.

Separation of the traces is achieved by applying bias to one of the amplifier stages, the common cathode resistor R9 being run up and down the potentiometer, R8, across which is set up a positive potential. Too wide a separation should not be sought, as this may result in too much bias being applied to the amplifier with consequent distortion.

Three square wave frequencies may be chosen by means of S1, which switches in three pairs of capacitance values into the multivibrator. If a two gang potentiometer is available, with a pair of 1 or 2 megohms sections, this may be used in place of R1 and R2 to give a widely variable square wave frequency. Limiting resistors should be placed in the leads from grids of V1 to the moving arms of such a potentiometer to prevent the grid-earth resistance falling to too low a value, which causes rounding off of the square wave.

The electronic switch can also be used as a simple square wave generator for amplifier tests, etc., by a switched output circuit consisting of S2, C10 and R12. This makes a variable amplitude square wave available from a low impedance source on the three operating frequencies of the electronic switch. S2 must always be left open when the unit is to be used as an electronic switch.

COMPONENTS LIST FOR THE ELECTRONIC SWITCH

(Fig. 23)

C1, C4 . . .	0·001 μF 350 v.w. mica.
C2, C5 . . .	70 pF trimmers.
C3, C6 . . .	30 pF trimmers.
C7, C8, C9, C10 .	0·1 pF 350 v.w. paper.
C11 . . .	8 μF 350 v.w. electrolytic.
C12, C13 . .	0·01 μF 350 v.w. paper.

R1, R2	150 K, ½ watt.
R3, R4	2 Meg. ½ watt.
R5, R6	470 K, ½ watt.
R7	47 K, ½ watt.
R8	1 K, midget variable. Trace Separation control.
R9, R10	510, ½ watt.
R11, R13	22 K, ½ watt.
R12	1 K, midget variable. Square Wave Output control.
R14, R15	250 K, midget variable. Input 1 and Input 2 controls.

V1, V2, V3	6SN7GT.

3 Int. octal valveholders.

S1a, b	2-pole, 3-way rotary switch. Frequency Selector.
S2	S.P. On–Off toggle switch. Square Wave Output switch.

4 control knobs; Chassis, 9½″ × 4½″ × 2½″ as Fig. 24.
5 Sockets with plugs; Wire; Sleeving; Nuts; Bolts; etc.

Construction of the unit is perfectly straightforward, calling for no special remarks. The chassis drilling diagram in Fig. 24 shows the layout adopted for the original unit. Power supplies were taken from the oscilloscope power output socket, though the electronic switch may alternatively be provided with its own small power pack.

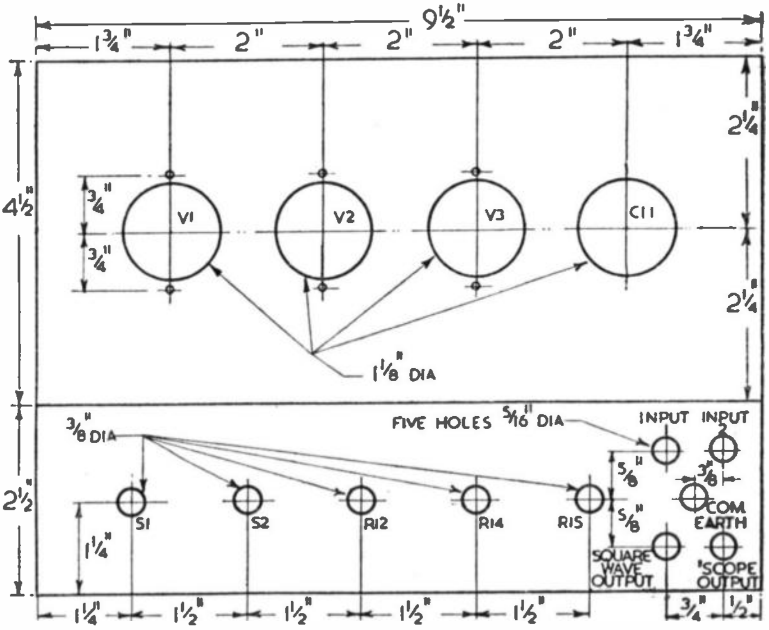


FIG. 24. CHASSIS LAYOUT OF THE ELECTRONIC SWITCH (TOP VIEW)

USING THE ELECTRONIC SWITCH

To use the electronic switch proceed as follows:

1. Connect the switch to the oscilloscope power socket.
2. Set the oscilloscope—S2, Blanking Hard; S3, External Y deflection; S4, Internal; S5, choose speed by inspection of trace; S6, Internal; S7, Internal Sync.
3. Connect the oscilloscope Common Earth terminal to the electronic switch Common Earth socket, and the Y Ext. terminal to the Square Wave output socket.
4. Switch on the oscilloscope. Close S2 and turn up R12 on the electronic switch. Adjust the oscilloscope controls to draw out a square wave with S1 of the electronic switch in the No. 1 (low frequency) position. If necessary employ the oscilloscope amplifier to obtain sufficient amplitude.
6. Check the shape of the square wave on the three frequencies provided by S1 in the electronic switch, ascertaining that the negative and positive sections of the square wave are substantially equal. Inequalities which will probably be found on the Nos. 2 and 3 positions of S1 can be balanced out by trial and error by adjusting the trimmer capacitances used (keep these near to full capacitance). First, however, check the square wave on the low frequencies. Serious inequalities between the positive and negative sections will probably be due to unbalance between the valve sections, when another valve should be tested in the V1 position. Small inequalities, however, are due to component tolerances, and may be balanced out, should this seem desirable, by adding a small amount of capacitance across either C1 or C4, determined by trial.
7. With satisfactory square wave operation obtained, connect the Y External terminal of the oscilloscope to the electronic switch Output socket, opening S2. Turn the Trace Separation control, R8—two separate and distinct traces should appear on the screen, with variable spacing between them as the control is turned. Check at all three positions of S1.
8 Feed in two different inputs to the amplifier input sockets and the Common Earth socket—6 volts a.c. and a broadcast programme signal, for example. By observation select the best square wave frequency and obtain two clear traces, setting the amplitude to suitable levels by means of R12 and R13. Obtain satisfactory separation of the traces, and ensure that the amplifiers are neither overloaded with too great an input, nor introducing distortion through too great a separation bias.

SQUARE WAVE TESTING

A square wave, like any other periodic waveform, may be analysed into a series of harmonically related sine waves, the relative amplitudes and phase of the component harmonics determining the final waveshape. If a square wave is passed through a circuit which modifies this relationship the waveshape becomes distorted, and the nature of the distortion shows where relative discrimination is taking place, at the high or low frequencies. Very searching and definite tests on circuit performance can be made by square wave application.

In Fig. 25 are shown a number of typical traces obtained from specimen circuits, demonstrating the circuit effect on a square wave. Before actually employing square waves for amplifier testing it is worth while to pass the output from the square wave generator through typical circuits of the types shown in Fig. 25 in order that the effects may be seen on the screen. Several widely differing component values should be tried in each circuit to give different time-constants. It is clear that the overall effect of different couplings, tone control and similar circuits in amplifiers can immediately be seen on square wave tests, which on an amplifier are conducted as follows:

1. Set the oscilloscope—S2, Blanking Hard; S3, S4, Internal; S5 set to suit the square wave frequency; S6, Timebase; S7, Internal Sync. Connect the oscilloscope to the secondary, or voice coil, terminals of the amplifier output circuit, replacing the speaker voice coil by an equivalent resistance. Use the Common Earth and d.c. Y amplifier terminals for these connections.

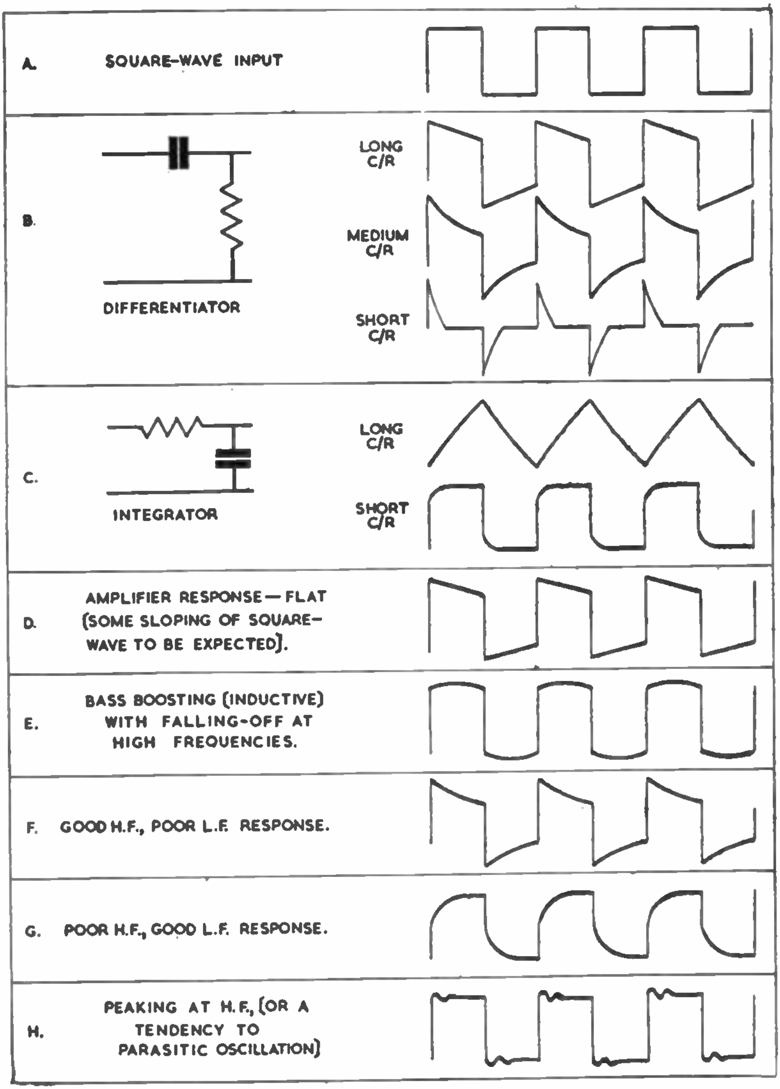


FIG. 25. SQUARE WAVE RESPONSES

2. Connect the square wave output socket of the electronic switch to the amplifier input socket, with the amplifier chassis connected to earth socket of the switch unit.
3. Plug the electronic switch into the oscilloscope power output socket and switch on the oscilloscope and amplifier.
4. Switch the electronic switch unit to supply a low frequency square wave. Adjust the input into the amplifier under test, and the output to the oscilloscope, as necessary, and set the timebase to give three or four full cycles on the screen. Note the waveshape obtained from the amplifier.

Some sloping of the flat top of the wave is practically certain to occur, whilst differentiation curvature may be seen (as at b in Fig. 25) if the amplifier has a poor l.f. response.

5. If necessary, transfer the oscilloscope input lead temporarily to the electronic switch unit square wave output socket, so that the amplifier input and output waveforms may be compared.
6. Repeat the test at the medium and high frequency switch positions of the electronic switch unit.
7. The behaviour of the amplifier can be deduced from the examples of waveshape distortion shown in Fig. 25.
8. Repeat the test with the loudspeaker voice coil reconnected across the output transformer secondary. Should this introduce new distortions —spikes or sharply defined peaks, etc.—in the waveshape, the matching of the speaker to the amplifier probably requires some attention.

4

THE A.C. BRIDGE

One of the most common checks required in the radio workshop is a quick measurement of capacitance, together with a test for insulation and, in the case of large capacitors, power factor. A simple bridge of widely used design capable of giving both resistance and capacitance checks is shown in Fig. 26.

The component to be measured is connected into circuit as one arm of a bridge, the companion arm consisting of a standard resistance or capacitance (depending on whether the part under test is a resistor or capacitor). The ratio

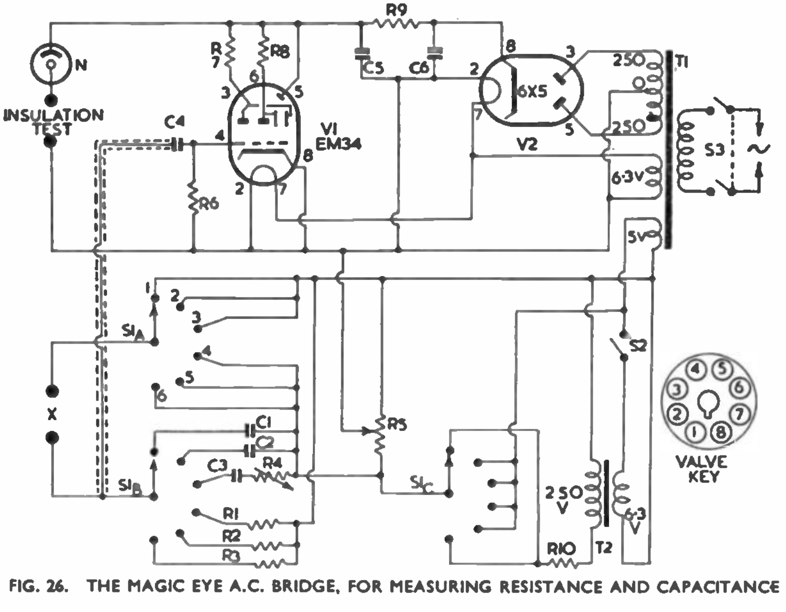


FIG. 26. THE MAGIC EYE A.C. BRIDGE, FOR MEASURING RESISTANCE AND CAPACITANCE

arms of the bridge (the two sides of R5 either side of the slider) are adjusted to bring the bridge into balance. The bridge is energised from an a.c. source, the source potential being high for low values of capacitance and high values of resistance. For low values of resistance and high values of capacitance a low energising potential is employed.

The bridge indicator is a Magic Eye valve so connected that balance of the bridge is shown by maximum opening of the Eye, with the shadow at its broadest. With a suitable input voltage to the bridge the edges of the shadow are sharply defined at the null point, blurring slightly immediately the balance is upset, so that very sharp indications are possible. The Magic Eye specified has two shadows, one more sensitive than the other, so that one serves as a broad and the other as a narrow indicator.

The bridge has six ranges, three of resistance and three of capacitance, the limits of each range being set by the standard resistor or capacitor switched into circuit. The ratio arms—*i.e.* R5—starting from a central position equivalent to 1 : 1 can be varied to give indications of 100 : 1 at either end of the potentiometer, so that with a standard resistance of 10,000 ohms, for example, a range of from 100 ohms to 1 megohm can be covered. Great accuracy is not possible without very elaborate calibration, but very good indications are obtained with the calibration to be described.

With standards of 100, 10,000 and 1,000,000 ohms and 100 pF, 0·01 and 1 μF the complete range of the bridge is 1 ohm to 100 megohms, and 1 pF to 100 μF in theory. In practice a good indication is obtained down to 10 pF, and the extremes of each range fall off in accuracy because the null indication is not so sharp. However, accuracy is still perfectly adequate for service work.

The bridge may be used for electrolytic capacitor measurements, and power factor is calibrated on R4 so that the " goodness " of capacitors of value from approximately 0·1 μF upwards may be assessed. The h.t. line is brought out to a test point *via* a neon lamp so that insulation, too, may be inspected on all types of capacitor capable of standing a test voltage of 200 volts. Good capacitors cause the neon lamp to flash at long intervals after the first charging flash, whilst a component with poor insulation will cause rapid flashing or light the neon lamp steadily, this latter condition indicating a complete short-circuit within the capacitor. Small value capacitors will not draw sufficient charging current for high resistance leakage tests, although they may still be checked for total short-circuits and low resistance leaks.

The switching of the bridge is so arranged that the calibration points can serve for both resistance and capacitance. If the double switching of the standards provided by S1a and b is omitted the calibrations for resistance and capacitance run in opposite directions, calling for double calibration of the bridge.

Two energising voltages are provided by employing 5 volts direct from the rectifier heater winding on the small mains transformer (a 6X5 rectifier being used with the heater fed from the 6·3 volts heater line) with a stepped up voltage from a back-connected heater transformer for the high voltage requirements. A press button control must be depressed to bring the back-coupled transformer into circuit. This prevents overheating of the bridge components, should the switch be left on one of the ranges using high voltage.

COMPONENTS LIST FOR THE A.C. BRIDGE (Fig. 26)

C1 . .	100 pF 350 v.w. mica.
C2 . .	0·01 μF 350 v.w. mica or paper.
C3 . .	1 μF 350 v.w. mansbridge paper.

The above are standards and should be as accurate as possible in value: 1 per cent. or 2 per cent. components are desirable.

C4 . .	0·01 μF 350 v.w. paper.
C5, C6 .	8 − 8 μF 450 v.w. electrolytic.

R1 . .	100, 1 watt	These are standards and should be as accurate as possible in value: 1 per cent. or 2 per cent. components are desirable
R2 . .	10 K, 1 watt	
R3 . .	1 Meg. 1 watt	

R4	3 K, variable. Power Factor balance.
R5	10 K, variable. Main Calibrated control.

Both the above are panel controls and should be wirewound and of fairly high wattage rating for stability and long life. (Rating of 2 to 5 watts.)

R6	4·7 Meg. ½ watt.
R7, R8	1 Meg. ½ watt.
R9	10 K, 1 watt.
R10	47 K, 1 watt.
V1	EM34 Mullard.
V2	6X5GT.
N	Small half-watt neon lamp, with holder.
T1	200–250 volts primary. 250–0–250 volts 60 mA. 6·3 v. 3 a. 5 v. 2 a.
T2	Small heater transformer, 250 v.—6·3 v.
S1a, b, c	3-pole 6-way rotary switch, ceramic (preferred) or paxolin. Main Range Selector.
S2	Press-button heavy duty on–off switch.
S3	D.P. Mains on–off switch.

2 Int. octal valveholders; 3 Control knobs, pointer type; 4 Insulated terminals; Chassis and screening case, see text following; Screened sleeving; Wire; Sleeving; Nuts and Bolts, etc.

CONSTRUCTION

The bridge circuit is in no way critical and may be built up in any convenient form on any suitable chassis. The circuit does require screening against stray hum fields, however, and so is best constructed in a metal case; for this reason no chassis and panel layout is shown since the constructor will probably have a suitable case that can be used. Careful internal screening is by no means essential, and the only screened lead is that from C4 to S1b. C4 itself should be close to the valveholder, making the lead between the grid pin and the capacitor very short.

The main calibrated control, R5, should be central on the panel of the bridge, and a large pointer knob should be employed; alternatively an ordinary round control knob may have a perspex pointer with a central engraved indicating line bolted to it. The calibrated arc over which the pointer moves may be drawn on millboard mounted on the panel and secured by the potentiometer nut. This material takes India ink satisfactorily and the final calibrated scale can be varnished to make a neat and durable job.

The range switch should be coded:

Position 1	100 pF.
„ 2	0·01 μF.
„ 3	1 μF.
„ 4	100 ohms.
„ 5	10,000 ohms.
„ 6	1 megohm.

These are the values of the standards, and also of the unknown components which, connected into the X terminals, bring the bridge to balance with R5 at its central point.

The main control should be calibrated with the bridge switched to range 5, centred about 10,000 ohms, this range extending from 100 ohms to 1 megohm. The type of calibration required is shown in Fig. 27, where the ratios marked round the scale arc can clearly be seen. To take a reading from the scale it is necessary only to multiply the standard switched in on the range switch by the ratio indicated on the scale when the bridge is brought to balance. For example, the main range switch is at position 6, and with an unknown

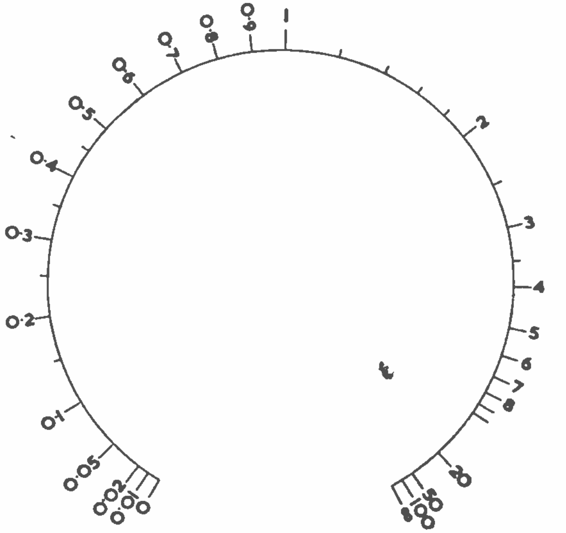


FIG. 27. CALIBRATION FOR THE A.C. BRIDGE
(CALCULATED, BASED ON PERFECTLY LINEAR POTENTIOMETER)

resistance across the X terminals the bridge is balanced, as shown by the Magic Eye being fully open, with the pointer of R5 on the 0·5 calibration point; the value of the unknown resistance is 1 megohm × 0·5, *i.e.* 500,000 ohms.

The bridge is calibrated by connecting in various standard resistance values across the X terminals, balancing the bridge, then marking the position of the indicating arm of R5 as a calibrated point. For example, with the range switch in position 5 and a standard 10,000 ohms across the X terminals the indicating arm will require to be in the central position, indicating a ratio of 1 (*i.e.* 1 : 1).

If a suitable selection is to hand the bridge can be calibrated by connecting in ordinary 1 per cent., 2 per cent. or, for very rough calibration, 5 per cent. resistors. Alternatively a potentiometer or rheostat, carefully set to the required values on a good ohmmeter or a commercial bridge, can be employed.

The easiest method of calibrating the bridge is with a decade resistance box. The required resistances can be set up, one after the other, with absolute accuracy and the work takes the minimum of time.

The following table gives the required X resistance together with the calibration points, for the usual number of calibrations. If further subdivision of the scale is required the extra points and resistances can immediately be deduced.

RANGE SWITCH AT POSITION 5

Resistance Value at X Terminals (in ohms)	Fraction of R5 from one end	Ratio to be Marked
100	0·0099	0·01
200	0·0196	0·02
500	0·0476	0·05
1,000	0·0909	0·1
1,500	0·1305	0·15
2,000	0·1667	0·2
2,500	0·2	0·25
3,000	0·231	0·3
3,500	0·259	0·35
4,000	0·286	0·4

RANGE SWITCH AT POSITION 5—(cont.)

Resistance Value at X Terminals (in ohms)	Fraction of R5 from one end	Radio to be Marked
4,500	0·31	0·45
5,000	0·333	0·5
6,000	0·375	0·6
7,000	0·412	0·7
8,000	0·444	0·8
9,000	0·474	0·9
10,000	0·5	1 (Centre Scale)
12,000	0·545	1·2
14,000	0·583	1·4
16,000	0·615	1·6
18,000	0·643	1·8
20,000	0·667	2
25,000	0·714	2·5
30,000	0·75	3
35,000	0·778	3·5
40,000	0·8	4
50,000	0·8333	5
60,000	0·8572	6
70,000	0·875	7
80,000	0·8889	8
90,000	0·9	9
100,000	0·9091	10
200,000	0·9524	20
500,000	0·9804	50
1,000,000	0·9901	100

To calibrate the Power Factor control, R4, a decade box is also very desirable, otherwise a fairly wide range of standard value resistors will be needed, the units of which must be connected in series and parallel to obtain the odd values required. To calibrate this control switch the main range switch to position 3, for 1 μF and short out the standard 1 μF capacitance within the bridge with a direct link across its terminals. Connect the following stated resistances into the X terminals, set the main ratio control, R5, to the 1 (mid-scale) position, and balance the bridge by rotating R4 to give the correct null setting of the Magic Eye.

Resistance Value at X Terminals (in ohms)	Calibration of the Power Factor Control
160	5 per cent.
320	10 ,,
485	15 ,,
650	20 ,,
823	25 ,,
1,004	30 ,,
1,190	35 ,,
1,390	40 ,,
1,600	45 ,,
1,840	50 ,,
2,100	55 ,,
2,380	60 ,,

Remember to remove the short-circuit from the 1 μF capacitor when the calibration is complete.

To use the power factor control, first balance the bridge in the usual way with the main range switch in the No. 3 position. In all probability it will be found that the null indication on the Magic Eye is less sharp than on the other ranges. Obtain the best possible balance, then rotate the Power Factor control which should be left at the zero setting when not in use. By varying both controls together it will be found possible to make the indication on the Magic Eye more sharply defined, and the Power Factor control is correctly set when the sharpest possible indication is obtained. Both the power factor of the unknown capacitor, and its value, may then be read off.

A SIMPLE BRIDGE

Some constructors may prefer the simple indicator shown in Fig. 28. This unit has the same basic ranges and calibration as the Magic Eye bridge, but it dispenses with the power factor measurement control, employs a pair of headphones as a null indicator, and is energised from a buzzer. The unknown component is connected across the X terminals, the correct range switched in by trial, and the ratio control, R4, varied until the note in the 'phones is balanced out as nearly as possible. An important requirement in such an instrument is to eliminate direct buzzer noise, and for this reason the bridge should be built up into a metal or wooden box. An enclosed buzzer should be employed (suitable components are obtainable commercially), and once the contacts are set satisfactorily, the complete buzzer may be set in a block of sponge rubber for improved sound isolation. For accurate measurements it should be possible to hear the buzzer note only through the 'phones.

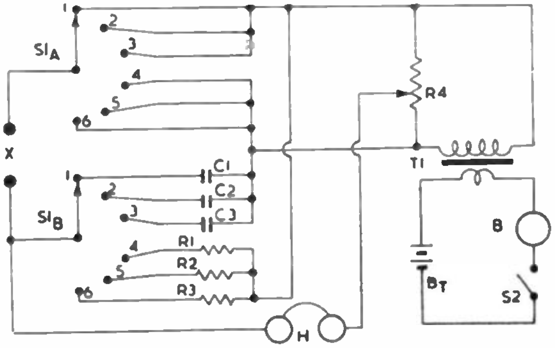


FIG. 28. A SIMPLE A.C. BRIDGE, USING HEADPHONES AND A BUZZER

The range switch, S1, and the main calibrated control, R4 (Fig. 28) are coded and calibrated in the same manner as the equivalent controls in the Magic Eye bridge, whilst the same calibration data holds good. The null point indication on the 'phones will be found to be rather less sharp, but good indications can still be obtained, with almost complete silence in the 'phones at the null point.

Some experiment with T1 is worth while to obtain the bridge energisation which suit the 'phones in use. An output transformer may be used in this position, the thick wire secondary being in series with the buzzer and the primary supplying the bridge energisation.

High resistance 'phones must be used with the bridge (or low resistance 'phones with another matching transformer).

COMPONENTS LIST FOR THE SIMPLE BRIDGE (Fig. 28)

C1	100 pF 350 v.w. mica.
C2	0·01 μF 350 v.w. mica or paper.
C3	1 μF 350 v.w. mansbridge paper.

Above capacitors are standards and should be as accurate in value as possible: 1 per cent. to 5 per cent. components.

R1 . . .	100, 1 watt.
R2 . . .	10 K, 1 watt.
R3 . . .	1 Meg. 1 watt.

Above resistors are standards and should be as accurate in value as possible: 1 per cent. to 5 per cent. components.

R4 . . .	10 K, wirewound variable, 1 or 2 watts.
T1 . . .	Output transformer, or to suit, by trial.
B . . .	Buzzer.
Bt . . .	Battery, voltage to suit buzzer.
S1a, b . .	2 P, 6-way rotary. Main Range switch.
S2 . . .	S.P. On–Off toggle switch.
H . . .	High resistance headphones.

4 Insulated terminals (2 for X and 2 for 'phones); 2 Control knobs; Wire; Sleeving; Case; Damping rubber; etc.

It may be mentioned that in place of the buzzer it is possible to employ a neon "oscillator" as a source of bridge energisation potential at audio frequencies, when T1 may be an intervalve transformer of 3 : 1 or 5 : 1 ratio. The neon oscillator is driven from a 180 to 200 volts source, and consists of a resistance-capacitance circuit as in Fig. 29. A lower voltage could be employed if a different neon lamp were used; but, since the circuit can be switched, as shown, to provide a short-circuit and leak capacitor test the provision of a fairly high voltage is worth while.

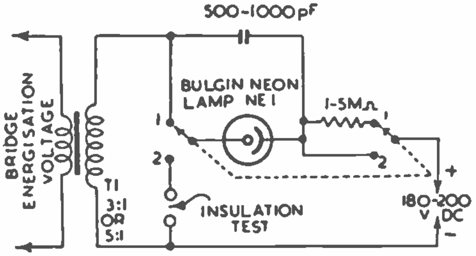


FIG. 29. A NEON OSCILLATOR BRIDGE SUPPLY AND LEAKAGE TESTER

5

THE SIGNAL TRACER

When servicing faulty receivers many engineers nowadays make a first diagnosis with a signal tracer. The same name is sometimes rather loosely applied to a device which should more correctly be termed a " signal injector." The true signal tracer, with detector type input stage, high gain amplifier, and loudspeaker, complete with an internal power pack, is designed to connect in to any stage of a receiver to investigate the signal at that point, to find whether the correct signal reaches it, or whether it is dead or introducing distortion, etc. Receiver checking with the signal tracer commences at the aerial or input end of the receiver and works through to the loudspeaker.

The signal injector, on the other hand, consists of a self-contained multivibrator working on a fundamental frequency within the audio band. The high harmonic content of the multivibrator output waveform makes the signal detectable by radio circuits, so that the output from such a multivibrator may be coupled directly into either an audio, r.f. or i.f. stage without any changes in the multivibrator circuit. With this unit receiver checking starts with the loudspeaker and works back to the aerial socket of the receiver.

The circuit of a true signal tracer is shown in Fig. 30. In this tracer a germanium crystal probe connects the amplifier to the receiver stage under test, the probe rectifying (*i.e.* demodulating) r.f. and i.f. signals and passing them on as audio signals. The probe may thus be presented to any type of stage to enable the signal at that point to be passed on as an audio signal to the amplifier of the tracer. The amplifier, a pair of triodes in cascade, gives quite high gain without trouble from instability or hum, and feeds into a conventional output stage using a 6V6. More elaborate tracers can be built

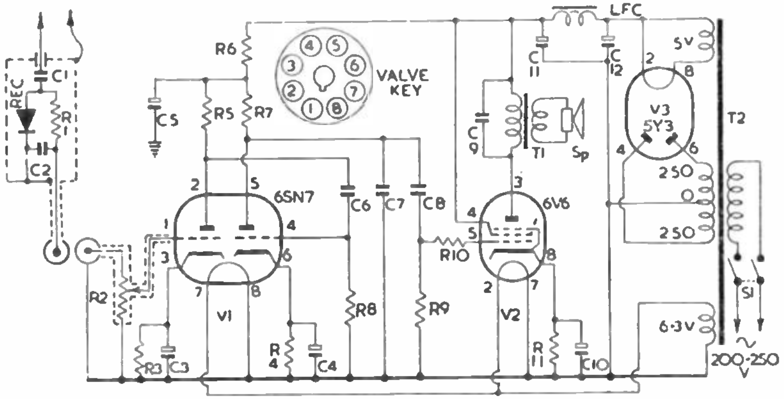


FIG. 30. THE CIRCUIT OF A SIMPLE SIGNAL TRACER

using Magic Eye indication, but experience with different types of tracer suggests that a straightforward audio output from a loudspeaker is quite adequate. The only signal not detected by this means is an unmodulated carrier. Superhet. oscillators are the only places in a normal receiver where unmodulated carriers are encountered and they can very readily be checked by inserting a microammeter or milliammeter in series with the earthy end of the grid leak. If the oscillator is working correctly the instrument will register a current.

The layout of the original signal tracer is shown in Fig. 31, and it is recommended that a similar arrangement be used to avoid hum pick-up. The probe plugs into a Belling-Lee coaxial input socket which in turn connects by as direct a route as possible to the gain control, and so to the first triode grid. Coaxial cable must be used from the probe to the plug, and screened cable from the socket to the control and valveholder.

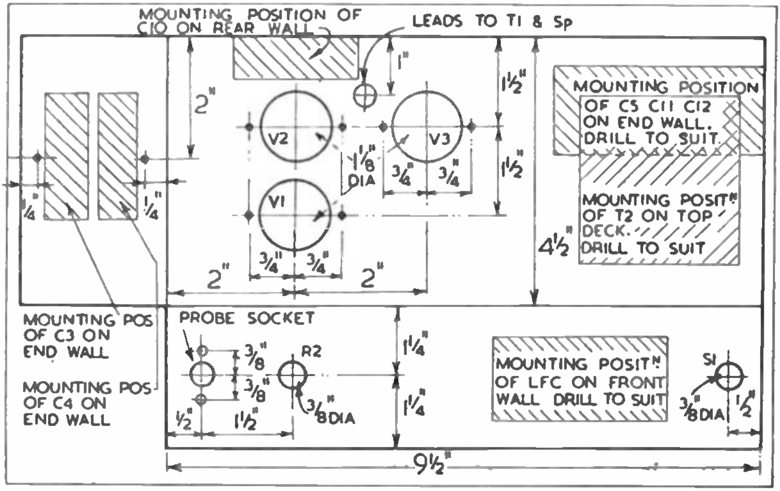


FIG. 31. CHASSIS LAYOUT OF THE SIGNAL TRACER (TOP VIEW)

COMPONENTS LIST FOR THE SIGNAL TRACER (Fig. 30)

C1	0·005 μF 500 v.w. mica.
C2, C7 . . .	200 pF 350 v.w. mica.
C3, C4, C10 . .	25 μF 25 v.w. electrolytic.
C5, C11, C12 . .	8—8—8 μF 450 v.w. electrolytic.
C6, C8 . . .	0·01 μF 350 v.w. paper.
C9	0·002 to 0·01 μF 350 v.w. paper, chosen by trial.
R1	47 K, ½ watt.
R2	1 Meg. variable. Gain control.
R3, R4 . . .	1 K, ½ watt.
R5, R7 . . .	100 K, ½ watt.
R6	33 K, ½ watt.
R8, R9 . . .	330 K, ½ watt.
R10 . . .	10 K, ½ watt.
R11 . . .	270, 1 watt.

V1	6SN7GT.
V2	6V6 metal or GT.
V3	5Y3.
T1 with Sp.	5" P.M. speaker with output transformer to match into anode load of 5,000 ohms.
T2	200–250 volts primary. 250–0–250 volts 60 mA. 6 v. 2 a. 5 v. 2 a.
S1	D.P. On–Off toggle switch.
Rec.	Germanium diode, any type.
L.F.C.	10 or 20 henrys choke.

3 Int. Octal Valveholders.

Chassis: 9½" × 4½" × 2½" with aluminium front panel to carry speaker and output transformer; Metal for probe head; 1 Coaxial plug and socket Belling-Lee; 1 Control knob; Coaxial cable; Wire; Sleeving; 1 Crocodile clip, probe earthing clip; Nuts and Bolts, etc.

When installing the germanium diode in the probe (Fig. 32) see that the side corresponding to cathode is connected to earth.

When the tracer is first built and tested V1 may be chosen by trial if a number of valves are available, as in odd cases a valve may be found with a rather high hum level. Without the probe plugged in turn up R2 to check for hum; the level should be low. Plug in the probe; should the hum level rise by more than a slight degree check the probe cable and head for faulty screening.

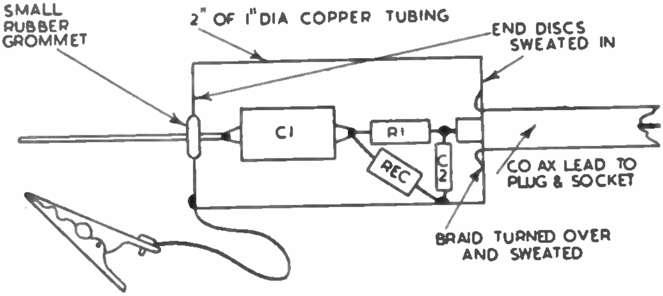


FIG. 32. THE SIGNAL TRACER PROBE

USING THE SIGNAL TRACER

Before using the signal tracer for fault finding on a broken-down receiver ensure that the receiver power pack is in order and that it may be switched on with safety. Connect in to the receiver either a good aerial and earth if strong local signals are receivable, or, in a poor reception area, a modulated signal generator. Then, as nearly as possible, tune the receiver to the local station or to the generator. (It is presumed that the set is " dead " and that there is no sound from the loudspeaker.)

Connect the probe earthing clip to a suitable earthing point on the receiver chassis. Turn up R2 on the tracer and apply the probe to the receiver aerial socket. If the local station gives a reasonable signal this should be heard, mixed with fainter signals; if the generator input is employed this, of course, should be heard from the tracer loudspeaker. Transfer the probe to the grid of the receiver frequency changer and adjust the main tuner of the receiver slightly if necessary. The local signal, or generator signal, should be tuned in on the tracer at reasonable strength. If the signal is not heard, examine the receiver aerial input circuits and switching. Check for open circuit coils, etc. Tuning adjustment is necessary because adding the probe capacitance to a tuned circuit causes some mis-tuning.

Transfer the probe to the anode connection of the frequency changer, readjusting the main tuner by trial. The signal should be heard at increased volume, as an i.f. signal. If no signal can be heard check the oscillator circuit (low valve emission may have stopped the oscillator working), and the h.t. supply circuit, including the primary of the i.f. transformer.

If the signal is heard, transfer the probe to the grid of the i.f. amplifier, then to the anode of the valve. The i.f. signal from the anode of the i.f. stage should be quite strong and if the receiver is satisfactory up to this point, the tracer gain control will need turning down.

Transfer the probe to the slider of the gain control in the receiver, turning it up to the full position. This tests both the secondary of the final i.f. transformer, and the diode detector. If no signal can be heard at this point first check over the transformer winding for continuity or short-circuited turns, then test the detector diode—probably one section of a double-diode triode.

If the signal is heard at the slider of the receiver's volume control check that it is being fed to the grid of the triode audio amplifier (no signal here will indicate a faulty coupling capacitor; a short-circuit, etc.). Then transfer the tracer probe to the anode of the amplifier, where the strength of the signal should be such that simply bringing the probe near the anode is sufficient to pick up the signal. Ensure that the signal is being passed to the grid of the output valve, then check at the anode of this valve—the probe will only need to be held near the anode pin if the valve is operating. If the signal is not heard at this point it probably indicates a faulty valve. If the signal is heard here but the receiver's loudspeaker is dead, the fault must lie in the speaker or output transformer.

Once the faulty stage has been located it is usually a simple matter to discover the cause by the usual test procedure. Valves can be checked in a commercial tester, and voltage and current readings taken. Intermittent faults can also be found by means of the tracer, though this generally takes rather more time; eventually the stage producing the intermittent will be located by having both the tracer and receiver loudspeakers on, with the tracer connected into each receiver stage in turn. The tests should continue through the stages where the tracer is not affected by the intermittent until a stage is found where the tracer and receiver loudspeakers show the intermittent fault together. The fault will lie either in that stage or between it and the last good stage.

Microphones with their transformers and gramophone pick-ups can be tested on the signal tracer by plugging them in in place of the probe unit. Pick-ups will be tested on records and microphones by direct speech. The amplifier has sufficient gain to give clear audibility from any normal type of microphone.

For receiver fault finding by signal injection the square wave section of the electronic switch may be used, the unit being switched to its highest frequency. The audio sections of the receiver may be tested on one of the lower frequencies.

To use the square wave generator as a signal injector connect the common earth terminal of the electronic switch to the earth or chassis socket of the receiver under test, and take a lead from the square wave output socket to the various test points throughout the receiver. First ascertain that the receiver may be switched on without damage to the power pack; the square wave generator may be powered from a separate pack or it might be connected to the power pack of the receiver under test. The greater power demand is made by the heater line of the electronic switch and a separate power pack should be employed wherever possible.

With the square wave generator and the faulty receiver switched on, commence by connecting the square wave output lead *via* an 0·1 μF 500 v.w. paper capacitor to the anode of the receiver output valve. The harsh note due to the generator should be heard in the loudspeaker of the receiver; if it cannot be heard this indicates a fault in the output transformer or speaker. All being well, transfer the lead to the grid of the output stage, next to the anode of the audio amplifier and then to the grid of the audio amplifier. As each stage is included in the operative chain the volume of the note from the speaker should rise. Take the output lead to the top of the receiver volume control and operate the knob; the note should be heard and the volume should be controllable. Proceed by taking the output lead to the anode of the i.f. amplifier valve—this tests the second i.f. transformer, and the detector up to the point of the preceding test, and any failure in the note from the speaker indicates that the fault must be in this section of the receiver. The square wave generator is now being employed on a high harmonic modulated by the fundamental frequency.

Presuming all to be in order take the output lead to the grid of the i.f. amplifier to test the valve, then to the anode of the frequency changer to test the first i.f. transformer. If the signal is still heard transfer the output lead to the grid of the frequency changer, checking the valve and oscillator circuits, and also the main tuned circuits, if the note is not heard. Finally test the complete aerial tuning section of the receiver by connecting the square wave output lead into the aerial socket.

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