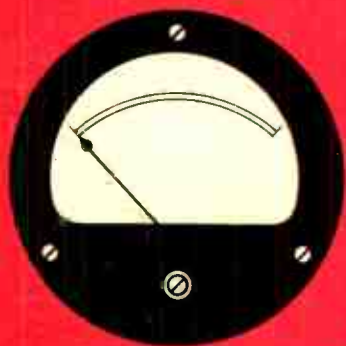# Electronic Test Equipment Construction

F.G. RAYER, T.Eng. (CEI), Assoc. IERE

ELECTRONIC
TEST EQUIPMENT
CONSTRUCTION

by
F. G. RAYER, T.Eng. (CEI), Assoc. IERE

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CONTENTS

Measure Volts, Amps, Ohms with your mA Meter

A multi-range test meter can be made from a milliammeter or microammeter, to which are added resistors and other items. This can be an excellent introduction to Ohm's Law for a newcomer expecting to become a licensed transmitting amateur in due course.

The basic milliammeter has a pivoted moving coil with attached pointer. The coil can turn in a magnetic gap, and hairsprings hold it in such a position that the pointer rests at zero on a scale. When current passes through the coil, it is displaced, moving the pointer to a new position on the scale. The instrument can be of any reasonable size, and can have a degree of sensitivity chosen for the purpose in view.

A 50 mA instrument would need 50 milliamperes direct current to move the pointer to its full-scale reading. Similarly, 10 mA and 1 mA meters would require 10 mA or 1 mA to do this. Microammeters are more sensitive. A 500 μA (or 0.5 mA) meter would need 500 microamperes (0.5 mA) for a full-scale reading, and a 100 μA instrument 100 microamperes.

Use as Voltmeter

In Figure 1 at A a 1 mA instrument is to be used to measure up to 2 volts. So 1 mA needs to flow when 2V are applied. From Ohm's Law, *Resistance in Ohms* equals *Voltage* divided by *Current in Amperes.* 2/0.001 = 2000 ohms. The total resistance thus needs to be 2,000 ohms. As the meter itself is of 100 ohms resistance here, this is taken from the overall value, to obtain the value of R1 = 2000 less 100 = 1900 ohms, or 1.9k.

So with R1 added, the 1 mA meter now reads from 0 to 2V. Several points may be noted. Resistors such as R1 are 1 percent tolerance, for accurate readings. For high voltage ranges, the meter resistance itself becomes so small a portion of the whole it is ignored. Accuracy in testing circuit points where there is much resistance increases when little current is drawn

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FIG. 1.
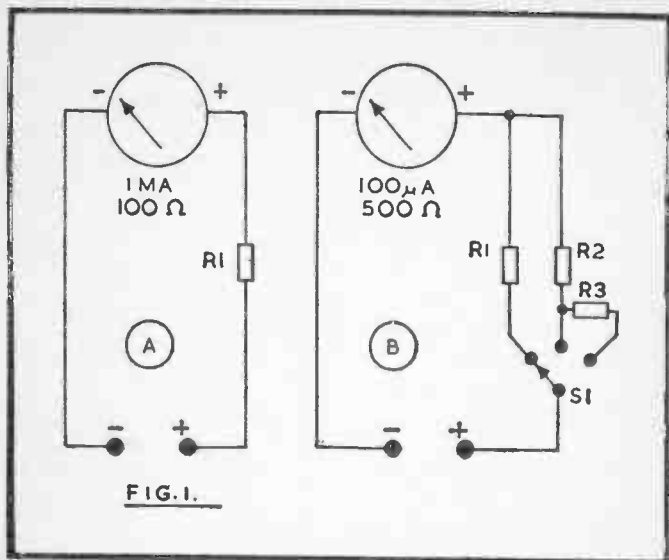
from the circuit tested, so the instrument may have greater sensitivity than 1 mA. Calculation can be directly in milli-amperes *and* k-ohms, and other ranges can be provided at will by further resistors.

B shows a 3-range voltmeter, this time using a 100 μA (0.1 mA) meter. R1 is 100k, for 10V, and R2 is 1 megohm, for 100V ranges. R3 is so connected that R2 and R3 are in series for 250V, to avoid a high voltage across a single resistor. So R3 is 1.5 megohm, the 250V range being secured with 2.5 megohm in all.

Voltmeter A has a resistance of 1000 ohms for each 1V of its scale, or is 1k/V, while voltmeter B is 10k/V. Unless completely new scales are to be drawn, the ranges should be chosen to allow easy reading on the meter scale already fitted.

Properly insulated leads, sockets and prods must be used for other than low voltages.

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For any range, with any meter, R1 (A) will be:

Resistance (Ohms) = Full-scale Voltage/Current (Amperes)

As a further example, assume the meter at A is to read 0-10V 10/0.001 = 10,000 ohms, less 100 ohms for the meter, so R1 is 9,900 ohms.

If necessary, unusual values can be made up from two or more resistors, either in series, or in parallel. The overall value of resistors in series will be found by adding their individual values. Thus 9,000 ohm (9k) and 900 ohm in series would provide 9,900 ohm.

The overall value R of resistors in parallel can be found from:

$$R = (R1 \times R2)/(R1 + R2)$$

The overall value will be less than that of the lower value individual resistor.

Assume 10 ohm and 15 ohm resistors are in parallel. 10 x 15/10 + 15 = 150/25 = 6 ohm. Some such combinations of resistors in parallel may be conveninet for shunts used to increase current ranges.

Further Current Ranges

Used alone, the 1 mA meter will indicate currents in the 0—1 mA range. Greater currents can be measured by allowing part of the current to flow through the meter, and part through a parallel resistor or shunt, S, A, Figure 2.

The value of the shunt resistor can be found as follows:

$$Shunt = Rm/(N-1)$$

Rm is the meter resistance, and N the number of times the meter scale is to be multiplied. Assume up to 10 mA will be read with the 1 mA meter whose coil resistance is 100 ohm.
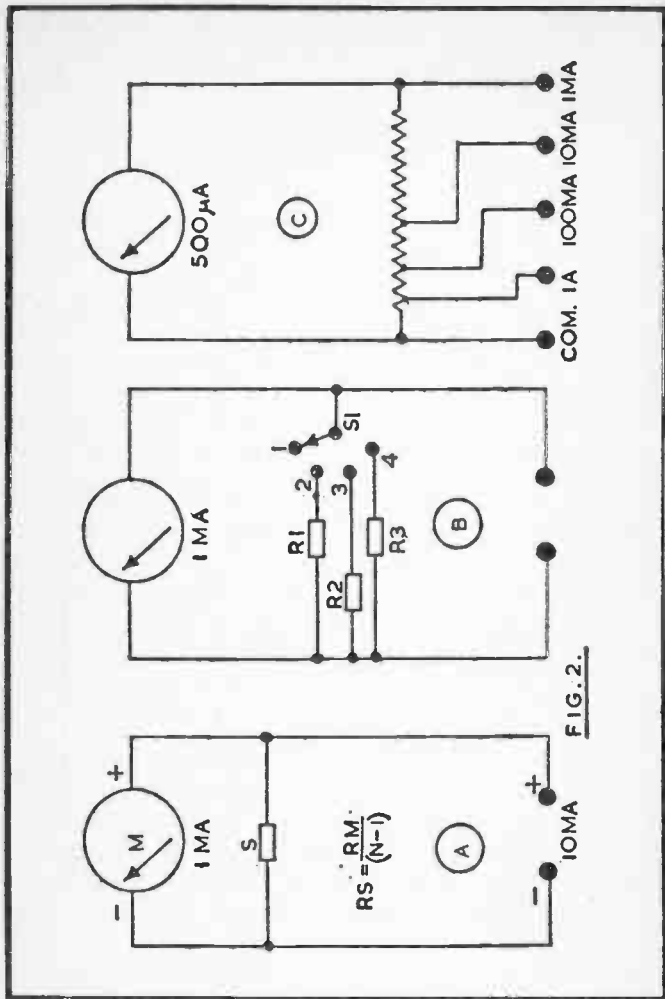
3

FIG. 2.

N—1 = 9. 100/9 = 11.11 ohm. So with this resistor across the meter, it now reads up to 10 mA.

At B, a 4-way switch allows use of the unshunted meter, or the introduction of shunts R1, R2 or R3, for ranges of 1 mA,

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10 mA, 100 mA and 1 ampere.

Because of the values necessary, it will generally be necessary to use two or more resistors in parallel for each shunt; or to wind these from resistance wire of suitable current rating.

If a calibrated multi-range meter can be used, the shunts can be found by trial. Connect both instruments in series, with a low voltage battery, and adjustable series resistor. Take care always to have sufficient resistance in circuit to prevent damage to either meter. R1 can then be made by finding the length of resistance wire necessary to give the wanted range, as shown by the calibrated meter. Disconnect the battery each time before disconnecting the wire to modify its length. The wire is then wound on a strip of insulated material, to form R1, and the same method used for R2, and R3.

C shows an alternative method of making shunts. Its disadvantage lies in the fact that the full meter sensitivity is not available on any range. The main advantage arises from the ease with which taps can be slid along a portion of the shunt, to find the tapping points for the various ranges.

Ohms Range

Figure 3 shows the basic circuit for resistance measurements. With the 1 mA meter, and a 4.5V (3-cell) dry battery, the total series resistance needs to be 4500 ohms, for the meter to read full-scale, or zero ohms. This is made up from R1 to safeguard the meter, and VR1 for "zero adjustment". Short the test terminals X—X, and set VR1 for zero ohms.

It is apparent that, from Ohm's Law, when test leads connected to X—X are taken to a resistor, current will be reduced by an extent which depends on the value of this resistor. As example, if it were 4500 ohms, the total resistance present is now 9000 ohms, so the meter will show half scale, or 0.5 mA. In this way, an ohms range can be prepared, and transferred to the meter. The one shown (Figure 3B) is marked from 500 ohms to 100.

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FIG. 3.

FIG. 3B.

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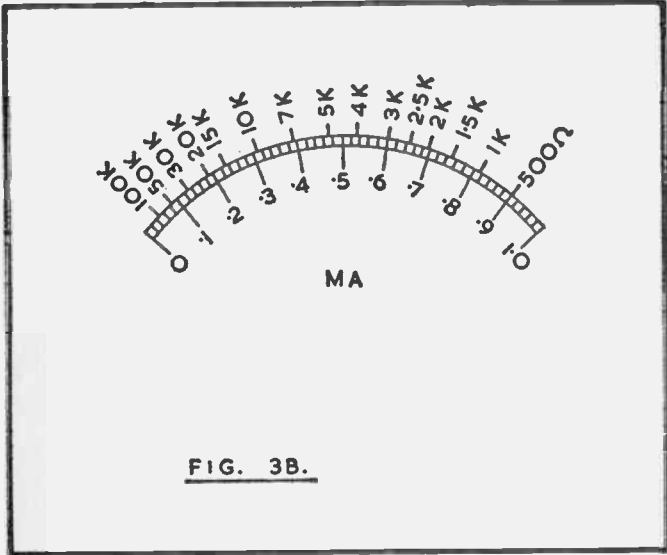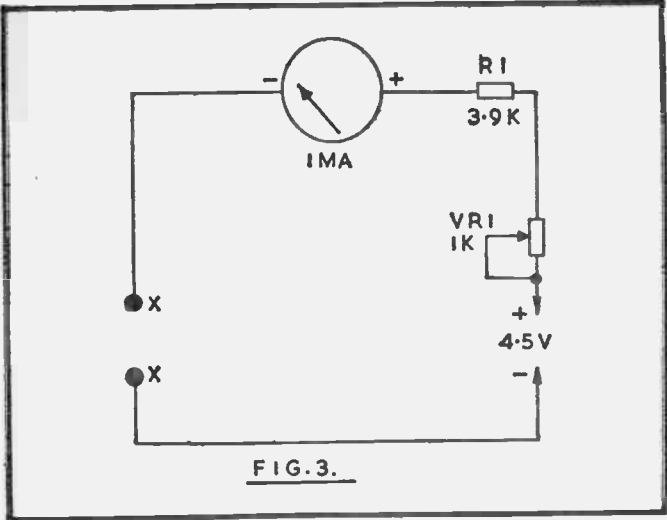
By combining these circuits, an instrument having DC voltage
and current ranges, and for continuity and resistance measure-
ments can be made. Selection of ranges can be by panel
sockets, or switching.

Figure 4 shows the circuit for an 8-range testmeter. With the
switch as shown, the 1 mA instrument alone is in circuit. The
next position places shunt S1 in parallel, for 10 mA, and
subsequent positions introduce S2 and S3 for 100 mA and 1
ampere ranges. The following position places R1 in series with
the meter, for a 10V range, and this is followed by 100V and
250V ranges. R1 will be 10k, R2 100k, and R3 150k, 1
per-cent.

Shunts, and particularly when associated with high current
ranges, should be made as described, and checked actually in
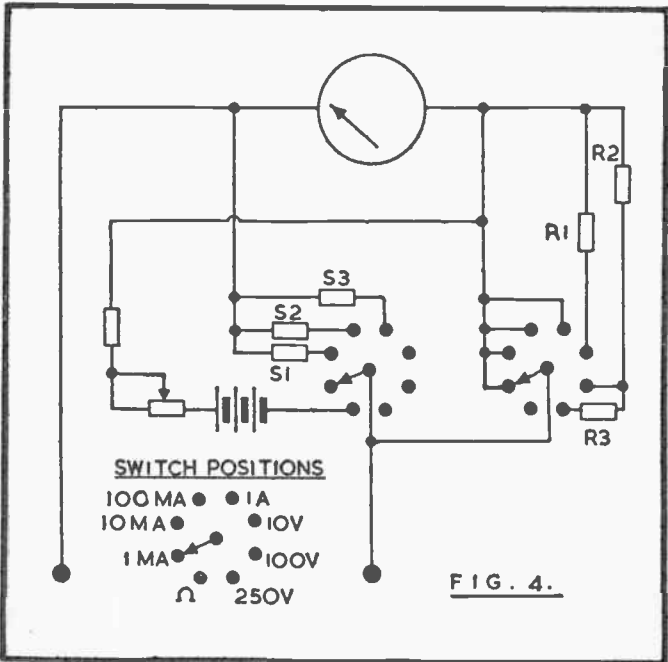
FIG. 4.

their circuit position, to avoid unnecessary error. S3 will be of so low resistance, that circuit and switch resistance can be material in making up the total.

The final switch position provides a useful resistance or continuity range, with 4.5V (3-cell) dry battery, 1,000 ohm Zero Set potentiometer, and 3,900 ohm series resistor.

Similar circuits are readily prepared to suit any particular meter to be used, or for wanted ranges or particular purposes. The usual type of non-miniature rotary switch is generally satisfactory for ranges up to 1 ampere.

AC Ranges

One method of obtaining AC voltage ranges is shown in Figure 5. Here, R1 is placed in series with the meter to bring the

FIG. 5.

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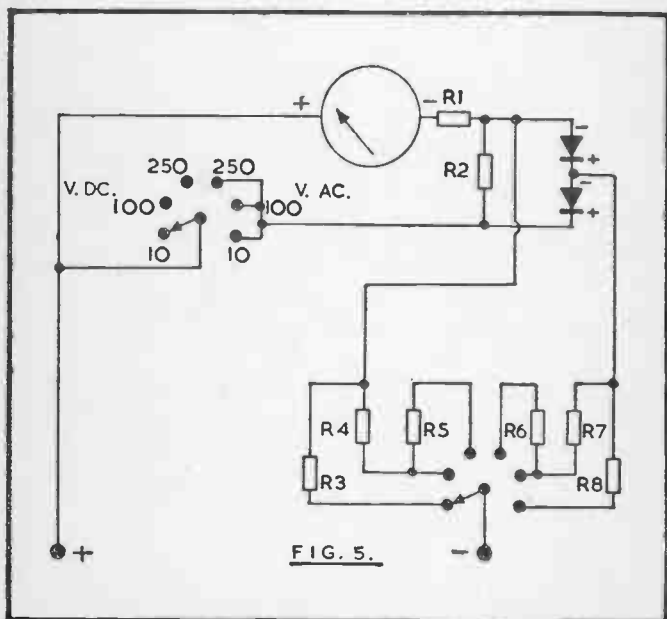
combination up to a specified resistance value, or to "swamp" variations in the coil resistance. Resistors R3, R4 and R5 are in series with this, for DC ranges.

With the remaining three switch positions, R6, R7 and R8 provide the required ranges, and the rectifiers are introduced across the meter, with R2. It is quite usual for such a meter to have a higher Ohms/Volt rating on DC, than on AC. Actual figures might be 10k/V DC and 1k/V AC.

If the instrument uses a 100 μA movement, made up to a total series resistance of 1k by means of R1, then R3 will be 99k for 10V, R4 1 megohm for 100V, and R5 1.5 megohm for 250V. The AC ranges can use 9k for R8, 99k for R7, and 150k for R6. R2 is approximately 270 ohm, and may be trimmed for correction of the AC ranges. Such an instrument (in common with commercially made meters of this type) is expected to show the RMS or Root Mean Square voltage.

Higher Resistances

For high values of resistance, movement of the meter pointer will be very small. This can be overcome, so that higher values may be read, by using an increased battery voltage, or an instrument of greater sensitivity, such as 100 μA. In each case the series resistor value (total of R1 and VR1) must be modified to suit.

Lower Resistances

It may be wished to read very low resistor values, and for this purpose the meter may be shunted to 10 mA full-scale (or even higher current) and R1 and VR1 again modified suitably to secure full-scale or 10 mA with test leads shorted. The range will then cover low values.

Low resistance values are occasionally obtained by switching the meter circuit to that in Figure 6. Circuits, components or resistors connected to the prods then act as shunts across the

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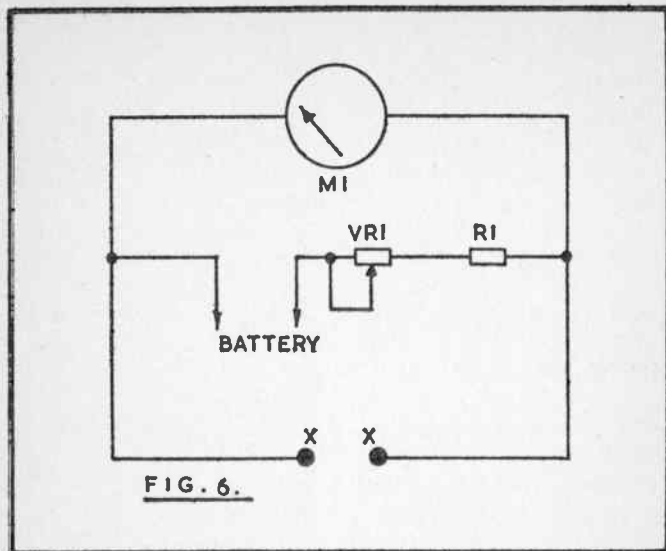
FIG. 6.

meter, so that its reading falls as resistance is reduced. (The range will be reversed with values increasing towards the right, if compared with those of earlier circuits).

In a comprehensive multi-range meter, there may be two or more batteries, with individual zero setting controls VR1, for various ranges. Or two or more ranges may be obtained with a single internal battery.

High Voltage Probe

For measuring potentials in a transmitter, linear amplifier, scope, or other item with high voltages, a high voltage probe like that in Figure 7 may be used, and will extend the range of a voltmeter.

The total series resistance necessary can be calculated as already described. (Resistance = Voltage/Current). As example, per 100V, with 0.1 mA or 100 μA meter = 1 megohm. Thus, five 1 megohm resistors in series will make a 500V probe

PROD   CASE

INSULATED LEAD

FIG. 7.
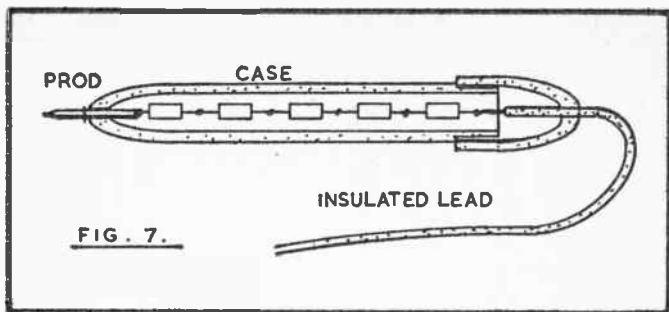
for a 100 μA instrument.

Such probes are more likely to be needed for 1 kV and higher voltages. The voltmeter is best set to its highest voltage range. As example, if the range is 0–500V, adding a 500V probe will increase this to 1 kV, and markings on the meter scale will be doubled. With small ½-watt resistors, one resistor each 100V is adequate; or 250V each for 1W resistors.

For anything over 500V the lead and all other items must be very adequately insulated, and EHT type cable should be used for 1kV and over.

With some multi-range meters, an individual socket is provided for 1kV, 2kV, or other EHT range, and the resistors can then be inside the meter casing.

It must always be noted and remembered that anything other than low voltage can be dangerous, and full precautions must be observed always.

Zero Current Voltage Measurement

The moving-coil voltmeter draws current when operating. This current can be small, but nevertheless it causes a drop in voltage in a circuit where resistance is present. The error arising from this cause falls as the voltmeter sensitivity is increased, but can only be zero if the meter draws no current. Figure 8 permits this.

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FIG. 8.
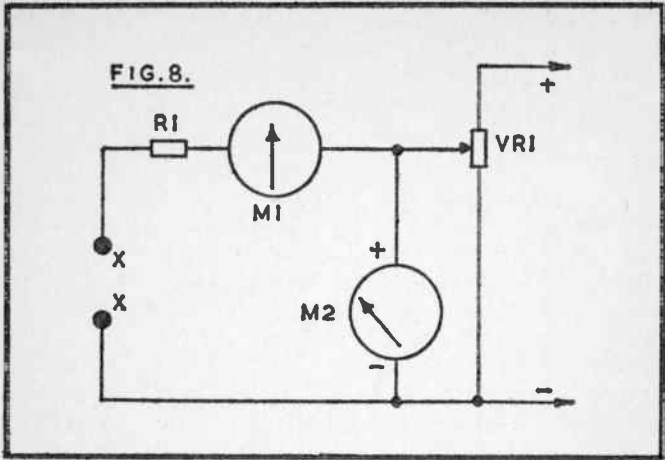
Meter M1 is a centre-zero microammeter, and M2 the voltmeter of suitable range. A DC supply is provided for VR1, so that any necessary potential can be taken at the wiper. When the voltage at the test prods X—X is the same as that shown by M2, no current passes through M1 and no current is taken from the external circuit by the prods. In use, VR1 is rotated to return M1 to zero, and the voltage is then read on M2.

R1 is to limit current in the case of a considerable difference in voltage. It has no effect on readings on M2, but makes M1 sluggish if too high in value. Assuming an approximate check of voltage will be made first with a high resistance meter, and VR1 set accordingly before connecting the prods, R1 may be as low as 10k, with a 100 μA centre zero meter. In practice, such a circuit can be hooked up in a few moments with two multi-range or other meters, if one included at M1 has some back movement of its pointer, which can be observed. Protection can then be obtained by initially setting M1 at some adequate range, such as 100V, reducing this to 10V, then 1 mA, then 100 μA, as VR1 is adjusted correctly.

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FET Amplified Voltmeter

By using a field effect transistor amplifier, a voltmeter with an input resistance of approximately 10 megohms, and with ranges of 0.5V, 5V and 50V can be constructed, using the circuit in Figure 9.

Resistors R1, R2 and R3 form a voltage divider network, so that the 3-way switch allows selection of any of the three ranges. R4 is largely to safeguard TR1. Changes to the gate voltage of TR1 cause changes in source current, and consequently modify the emitter current of TR2, drawn through R5. The indicating meter M1 occupies a bridge, R5 and R8 being the lower arms, and TR2 and VR2 with R7 the upper or opposite arms. When VR2 is set for balance, current through M1 is zero. This balance is upset by changes to TR1 gate voltage, as described.

VR1 allows calibration, or adjustment to the sensitivity of M1, R6 being included to help protect M1 against severe

FIG. 9.

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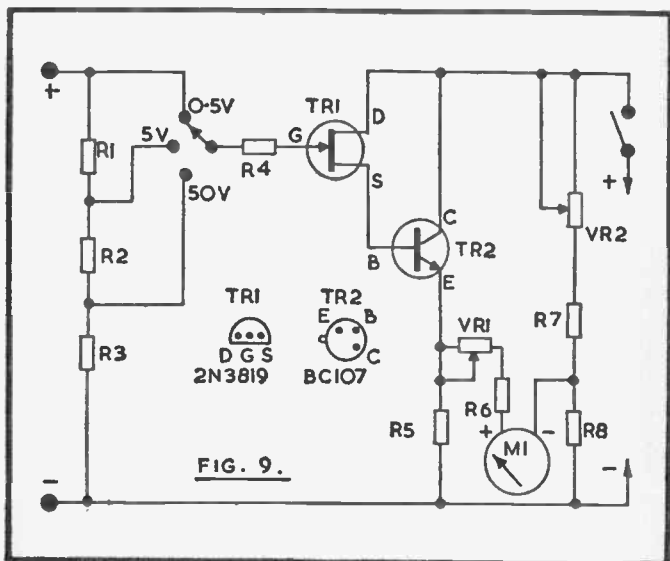
mis-adjustment of VR1.

In use, initially set VR2 for zero reading on M1 with no voltage input at the FET voltmeter terminals. Then adjust VR1, with a known DC voltage applied. This may conveniently be on the 5v range, with input from an adjustable source, and measured with a conventional meter, using a figure around that at which checks are to be made. It will be found that the 0—50 scale of M1 can agree reasonably with 0.5, 5, and 50v ranges, for easy reading. VR1 allows fairly large compensation for the actual gain of Tr1 and Tr2. Modifications to resistor values, transistors, and battery voltage can be adopted to modify agreement between input voltages and M1, or to allow a different meter to be used if to hand.

An adjustable voltage input to both the FET voltmeter and parallel voltmeter connected to allow calibration can be from a potentiometer, connected to a battery or other DC supply. Take outer tags to battery, and wiper and one outer to the voltmeters.

Because of its very high input resistance — approximately 10 megohms — the FET voltmeter draws only an extremely low current from circuits tested, and thus has little influence on the actual voltage present, even when circuits tested themselves have appreciable resistance.

Components: FET Amplified Voltmeter (Figure 9)

R1	9 megohm 1%
R2	900k 1%
R3	100k 1%
R4	1 megohm 5%
R5	10k 5%
R6	5.6k 5%
R7	1k 5%
R8	2.2k 5%
VR1	2.2k linear potentiometer
Tr1	2N3819
Tr2	BC107, 2N2925

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3-way rotary switch
M1   50 μA meter
On-Off switch
6v battery, clips, panel sockets, etc.

Restistance Bridge

A resistance bridge will allow the measurement of resistors,
including those of very high and very low value, if wished.
Its method of operation will become clear from Figure 10.

Direct current is applied to the bridge from a battery or other
source. If the voltage drop in R1 equals the voltage drop in
R2, and the voltage drop in R3 equals that in R4, points
X and Y will be at the same potential. So the centre-zero
meter will give no reading, and the bridge is balanced. Should
the value of any resistor result in the bridge not being balanced
a voltage arises between X and Y, and the meter does not
indicate zero.

In practice, unknown resistors may be included in one arm —
as example, in the position of R4. If R1 and R2 are of the same
value, balance is obtained when R3 equals R4. So a calibrated

FIG. 10.

$$RX = RC \frac{R2}{R1}$$

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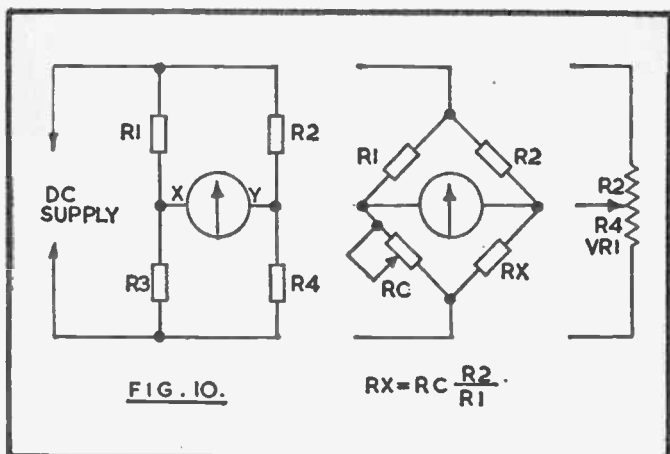
variable resistor RC, or decade box adjustable in 1 ohm, 10 ohm, 100 ohm and other steps, could be fitted for R3. With balance restored, the value of R4 could then be ascertained by referring to the resistance present at RC.

A popular alternative is to replace R2 and R4 by a single potentiometer, VR1. As the wiper is moved downwards, the part of the element representing R2 increases in value, while that replacing R4 falls in value; It is also possible to have a switch to select two or more fixed 1 per-cent resistors, for a position such as R1. By this means, the range of the bridge can be greatly extended.

With a little modification, the bridge can also allow capacitor values to be read.

4-Range Bridge

Figure 11 shows the circuit of a 4-range bridge, and the push switch S1 is pressed to take a reading. Current is limited by R1 when measuring low value resistors. The rotary switch S2 selects R3, R4, R5 or R6, for each range. These cover 0.5 ohm to 200 ohms, 50 ohms to 20k, 5k to 2 megohm, and 50k to 20 megohm.

The diodes D1 and D2, with R2, prevent excess voltage across the meter M1 for all ranges and settings of VR1. The accuracy of readings will depend on R3, R4, R5 and R6, and 1 per-cent components should be fitted; and upon the calibration accuracy of VR1. The battery voltage does not affect accuracy.

The simplest and clearest method of marking the scale is to calibrate S2 for the mid-scale values, which are of course those of the resistors R3, R4, R5 and R6, then to use a 'multiplier' as in Figure 12. In use, VR1 is set so that the meter indicates balance or no current, and the S2 range is then taken in conjunction with the multiplier.

As example, R3 is 10 ohm. If balance is at 1 on the scale, Rx is also 10 ohm. With balance at 1.5 on the scale, the multiplier

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F I G. 11.
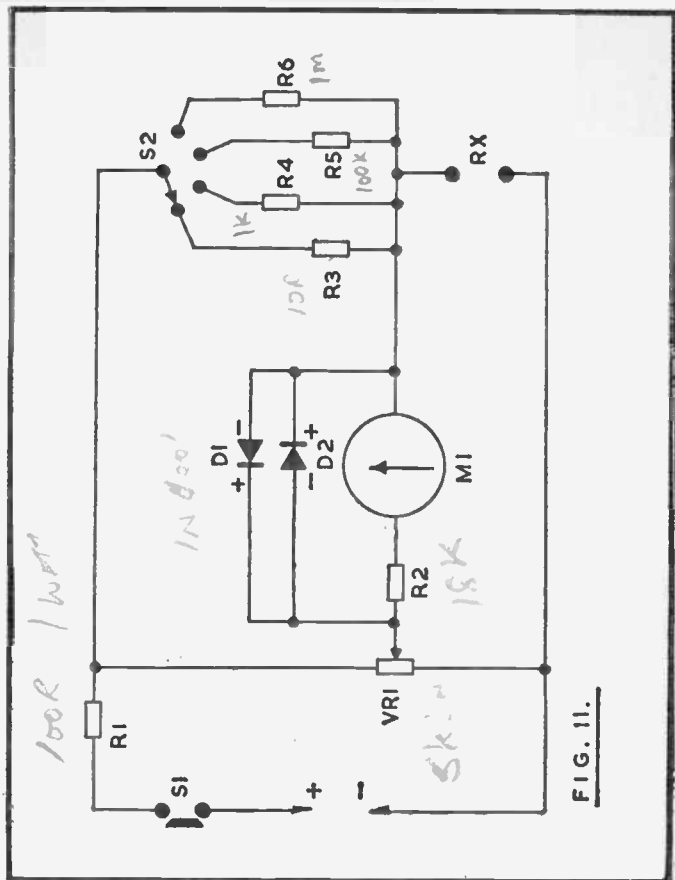
is 1.5, so Rx is 15 ohm. Similarly, 2 on the scale will be 20 ohm, while 0.3 would be 3 ohm, and so on. With the next range, R4 is 1k, so 2 on the scale indicates 2k, 0.5 indicates 500 ohm, and so on. Ranges overlap so that the extreme ends of the scale are usually not required.

MULTIPLIER.

FIG.12.
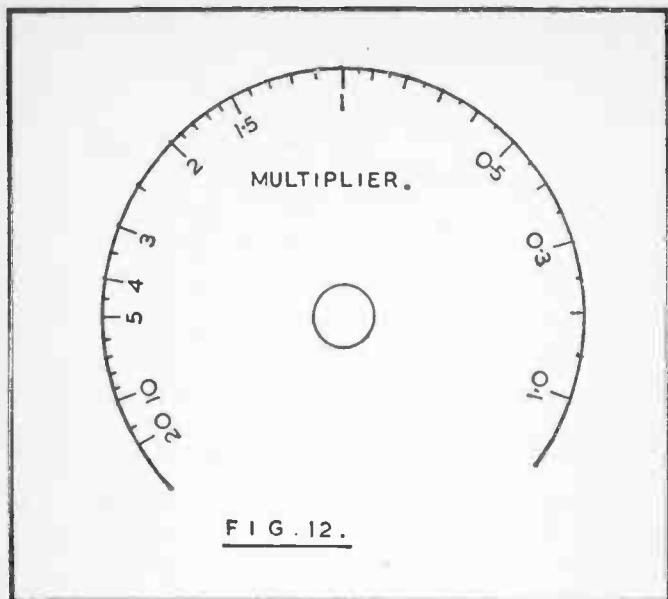
Construction

Figure 13 shows the layout in a box about 6 x 4 x 4 in.
(150 x 102 x 102mm.) This can be wood, metal or plastic.
The two terminals for the unknown resistor Rx must of course
be insulated from the panel if necessary.

Unwanted tags on the range switch can be ignored. Battery
polarity is not important, except that it is convenient to have
the meter pointer movement follow the direction of rotation
of VR1. A 4.5V to 9V battery is convenient.

The meter fitted in a 50—0—50 μA centre zero instrument,
2in. (51mm.) in diameter. The meter only has to show balance,
so it need not be calibrated, and this allows varous surplus
instruments, and 'level' meters to be employed. A sensitive
instrument gives a better indication for setting VR1, with very
high and very low resistance values at Rx, than a less sensitive
meter.

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FIG. 13.
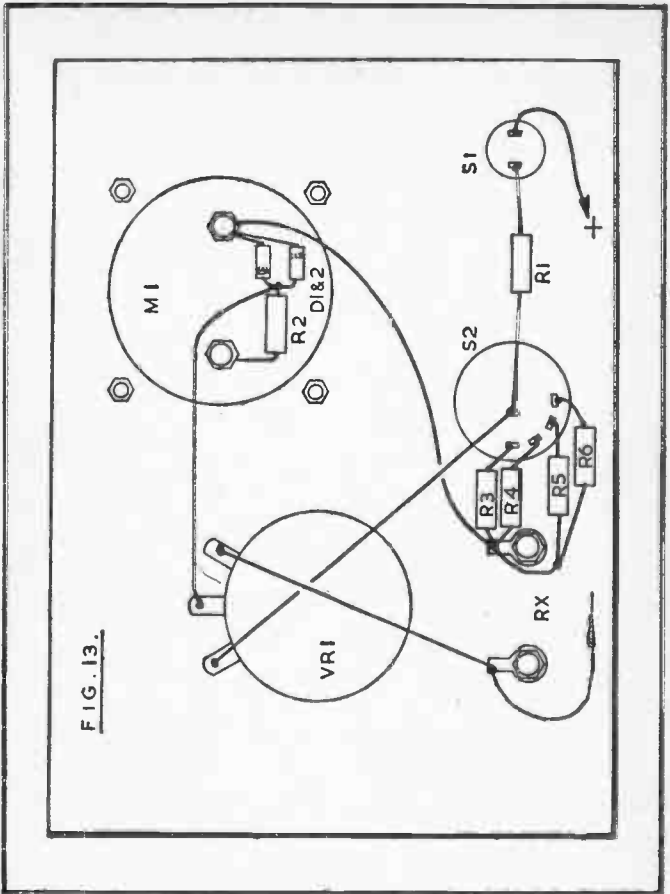
In some cases an ordinary meter can be utilised. Carefully open the meter and rotate the back and front hairspring adjustment tags to bring the pointer to the middle of its scale with no current flowing. Do not bend the pointer to do this. When the instrument is of lower sensitivity than about 50 μA, it is feasible to reduce the value of R2. This will help maintain sensitivity, while not allowing the meter pointer to be driven beyond its full-scale position, for any setting of VR1.

To use the instrument, connect the unknown resistor to the terminals and rotate VR1 for zero current on the meter. If necessary, rotate S2 to a different range, to secure this. For external tests, two leads with clips can run from the terminals to circuits or components.

Components: 4-Range Bridge (Figure 11)

R1	100 ohm 1W 5%
R2	18k ¼W 5%
R3	10 ohm ¼W 1%
R4	1k ¼W 1%
R5	100k ¼W 1%
R6	1 megohm ¼W 1%
VR1	5k linear potentiometer
D1	1N4001
D2	1N4001
S1	Push for 'on' switch
S2	4-way rotary switch
M1	50—0—50 μA meter, or similar

Knobs, insulater terminals, box, etc.

Capacitance Bridge

A bridge with which to check capacitor values is extremely useful. It operates in a similar manner, but requires an audio tone input. This may be obtained from a simple multivibrator, of the type shown later, and employing two transistors.

Figure 14 shows the bridge part of the circuit. Switch S1 allows selection of C1, C2 or C3, for three ranges, while VR1 is adjusted for the 'null' or quiet or silent point. In these circumstances, the unknown capacitor, connected at X, will be compared with one of the capacitors C1, C2 or C3.

Its value can then be read from a scale fitted to VR1. The audio tone should be reasonably strong and not of low frequency, but other oscillators, transistors or component values may be used. A high impedance (2k) headset will be

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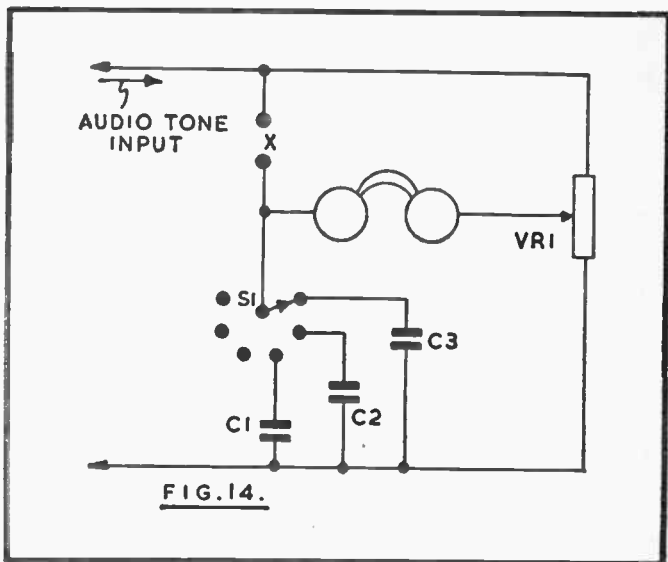
FIG.14.

most satisfactory for detection. VR1 should be a high grade
linear component. C1 can be 0.01 μF, C2 0.1 μF and C3 1 μF.

The capacitor scale Figure 15 for VR1 shows multiples of the
value introduced by the switch. Thus, where 1 μF is in use,
values are shown directly from 0.05 μF to 25 μF. For other
ranges, the central position '1' shows balance between capacitor
X and that switched into circuit, and multipliers to the left will
give lower values, and those to the right higher values. The
internal capacitors should be 1 per-cent types, but need not be
of the values given, provided the manner of reading the scale
for VR1 is remembered.

Further contacts on the multi-way switch can provide more
ranges, down to about 100 pF, or may be used for resistor
ranges. If the latter are incorporated, it will be necessary to
have a second scale for VR1, with multipliers appearing in the
opposite direction. The actual method of operation will become
clear after a few moments use, with one or two components of
known value clipped to terminals X.

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MULTIPLIER

F I G . 15.
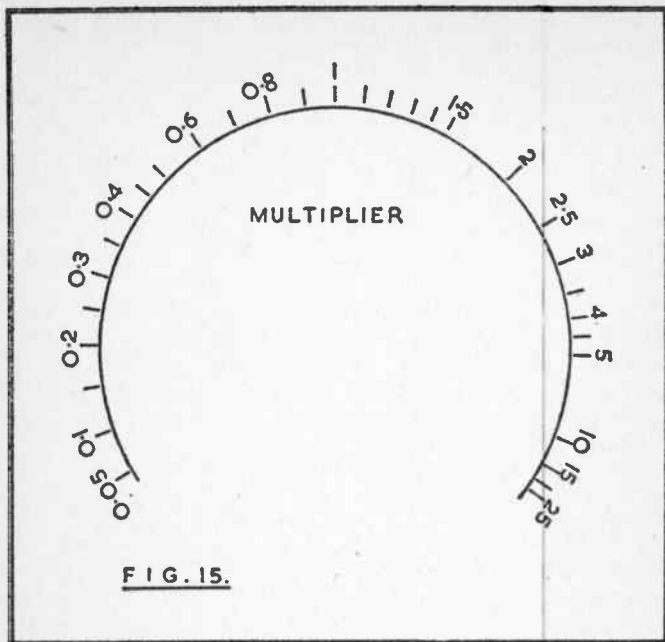
Individual calibration of the scales can prove to be quite easy, and will allow greater accuracy, and compensate for stray capacitance with the smaller values. A number of 1 per-cent capacitors will be required, and these are connected to the test terminals, and VR1 rotated for balance. The value can then be marked on the scale provided for VR1; or a multiplier may be incorporated instead, as shown. If ranges bear a 10x relationship to each other, a calibration point obtained on one range will provide 10 nF and 0.1 μF settings for the following ranges, and so on.

To avoid the need for a large number of capacitors, two (or more) may be used in series or parallel, to obtain lower or higher overall values, in the usual manner.

Individual calibration in this way is also readily carried out with resistance ranges, using a number of 1 per-cent tolerance

resistors. These may also be employed in various series and parallel combinations, to secure further calibration points.

Wattmeters

Information on the wattage or power dissipated or available may be required in (a) Direct Current circuits, (b) Audio (or AC) Circuits and (c) Radio Frequency Circuits.

The need for (a) will generally arise in power supply and voltage dropping circuits, and for similar purposes in transmitting or general equipment. Measurements (b) are required from time to time with audio amplifier or modulator equipment, while (c) will generally be used to determine the RF power output of a transmitter or RF power amplifier, and thus its efficiency.

For many purposes it is convenient to arrive at the power indication indirectly, as this reduces the need for special instruments. In a circuit where two of the factors Voltage, Current or Resistance are known, power in Watts may be found as follows:-

Watts equal Voltage x Current ($W = V \times I$, or $W = E \times I$)
Watts equal Voltage squared divided by resistance ($W = V^2/R$)
Watts equal Current squared x Resistance ($W = I^2 \times R$)
The units employed are Volts, Amperes and Ohms.

Figure 16 shows how to determine power by measuring the voltage across a known resistance. Assume R1 is 100 ohm, and the meter shown indicates 12V. $W = 12 \times 12$ divided by $100 = 1.44W$. So if this were a power dropping resistor, a 1½W component would be the minimum size to fit.

Multi-range meters of good manufacture are suitable for audio frequencies, and their literature will generally indicate the frequency range over which they may be used. M1 in Figure 16 is such a meter, set to read AC (or audio) voltage across R2 and R3. It is assumed that an amplifier requiring a 16 ohm load and rated to deliver 20 watts, sine wave, is tested, and so R2 and R3 will be 8 ohm 10W each. Input is increased until

FIG. 16.
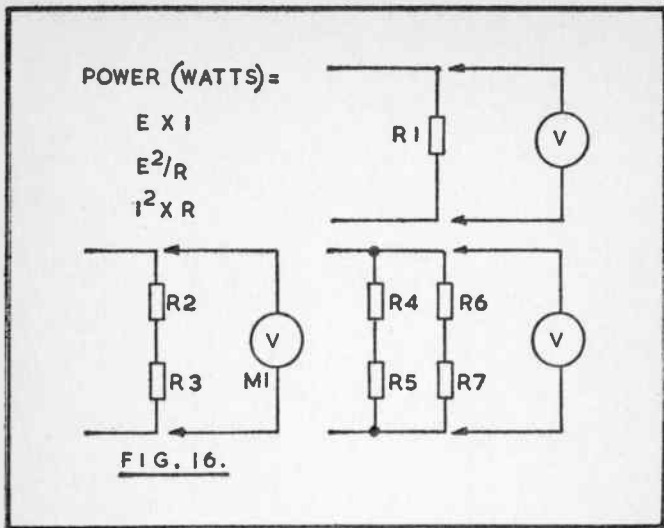
the output, as observed with a scope, just fails to flat-top.
Suppose M1 then reads nearly 20V. Power = 400/16, or nearly
25W, so it is evident that the amplifier is able to meet its
specification.

(Information on the use of a scope will be found in book
number BP57, How to Build Your Own Solid State
Oscilloscope — Bernard Babani (publishing) Ltd.)

For large amplifiers or modulators, it will often be necessary
to prepare a load from a number of resistors, such as R4, R5,
R6 and R7, unless suitable components of very large wattage
are to hand. For the time required for a test — say 15 to 30
seconds — the wattage rating of a resistor in free air may be
doubled.

At Radio Frequency

As mentioned, power may be determined from $I^2 \times R$. That is,
Current x Current x Resistance (with figures in Amperes or

fractions of an Ampere and Ohms). In Figure 17 assume that
R1 is 100 ohm and meter M1 indicates 100 mA or 0.1A
Power = 0.1 x 0.1 x 100 = W. Note that a rise in current to
200 mA increases power by 4, as follows: 0.2 x 0.2 x 100 = 4W.

F I G. 17.
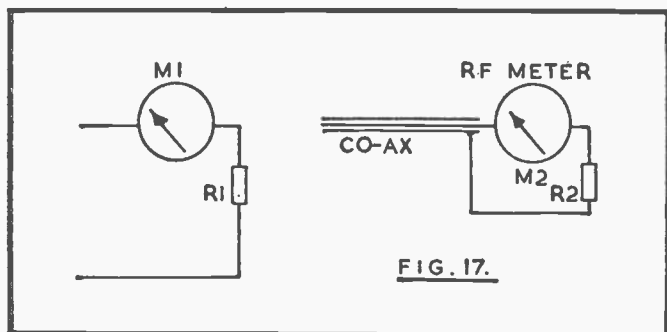
Current at radio frequency can be indicated by a thermo-
couple instrument, and the load resistor may be chosen to be
of similar value to the usual aerial feeder. Where dipoles are
used, and these are general on many amateur bands, the
resistor R2 in Figure 17 can be 70 ohm or 75 ohm. M2 is a
thermo-couple meter chosen to suit the power expected, and
will usually be 350 mA, 1A or 2A full-scale. A list may be
prepared, giving actual power, in terms of the reading
obtained on M2.

Resistors especially suitable for dummy loads of this type can
be obtained, and a co-axial lead taken to the transmitter
output. Transmitter power amplifier input is V x I, as shown
by DC meters. Output would normally be expected to be
6- per-cent or better of the DC input.

A thermo-couple meter is not suitable for VHF use, and its
readings can also be expected to fall off on high frequency
bands. Despite this, such instruments are very useful for RF
power output tests.

Audio Tester

Quick trouble-shooting through amplifiers and the audio sections of receivers can be accomplished with the aid of an audio tester which allows an audio tone to be injected at various circuit points. Figure 18 is a typical multivibrator for this purpose. It is in order to use other transistors and component values, provided a suitable tone is produced. If necessary, resistor or capacitor values may be modified to achieve this. Increasing the capacitor values from base to collector will lower the frequency; reducing the values raises frequency. Both capacitors need not be the same. Figure 18 has NPN transistors, so the ground line is negative. Two PNP transistors, if to hand, can be used, with positive ground line. (See 'Two Transistor Electronic Projects', Book No. 30 Babani Press). The circuit can be arranged to operate from 1.5V to 9V, and can be assembled on perforated board, to occupy a small insulated case. A flying lead with clip for earthing should be provided, and an insulated lead with a prod.

Only low voltages will be encountered in small transistor equipment, but for higher power items and valve equipment C3 should be of at least 500V rating, and care must be taken not to touch any high voltage circuits where a shock hazard is present.

AC/DC type amplifiers or equipment, in which high tension power is derived directly from the mains, can present a particular shock hazard, and it is essential that the chassis be taken to mains neutral, and that the usual full precautions against shock should be taken. With such equipment, mains voltages may arise on the chassis or any metal parts or circuits connected to it. *Amateur servicing is not recommended.*

R4 may be replaced by a potentiometer, with C3 taken to its wiper. This allows the strength of output to be adjusted, to avoid over-loading an amplifier when applying the signal to early stages. The method employed to locate the site of a fault causing loss of audio is to work *backwards* step by step from the output stage. Clip the negative line to the equipment chassis of battery operated equipment, or items drawing

FIG. 18.
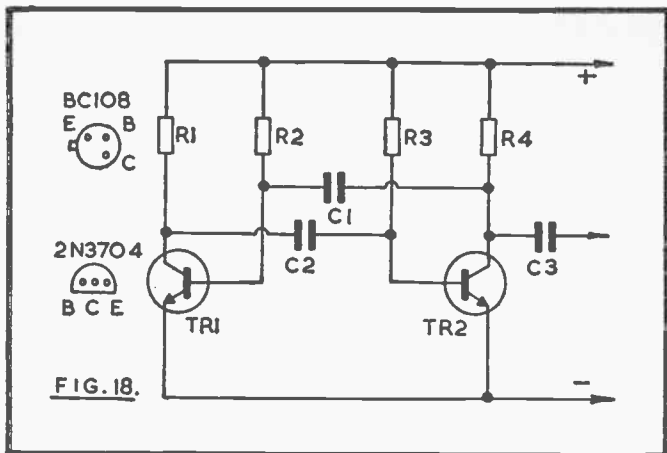
power from a mains transformer and having an earthed
chassis. Put the output prod on points in the audio circuit,
one by one, working systematically, so as to take in only one
item, connection, foil, or stage at a time. As example, should
the audio tone be heard in the equipment speaker with the
prod taken to an audio-driver stage anode, but not when the
prod is removed to its control grid, then this stage is not
operating. The valve would then be checked or examined and
electrode voltages checked.

In a similar way, loss of audio signals can be localised to a fault
such as a broken conductor or board foil, or defective coupling
capacitor, or failure at switches, volume or other audio controls.
or input jacks or sockets, etc. As extra stages of amplification
come into circuit, VR1 will need adjusting, to reduce volume.
When audio ceases to be heard, the fault is between this point,
and the one to which the prod was applied earlier, when audio
was reproduced.

Output from the tester may be sufficient to allow direct
checking of the speaker, depending on the impedance or
sensitivity of this item. If no audio signal is obtained with the
audio tone applied to the output stage, then clearly this is not
operating. An initial check here would include a meter test

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for supply voltage, whether from battery or transformer and rectifier.

This audio generator is used to feed the capacitor bridge by taking C3 to the audio input point of the bridge circuit.

Components: Audio Tester (Figure 18)

R1	5.6k (Resistors 5% ¼W)
R2	100k
R3	100k
R4	5.6k
C1	22 nF
C2	22 nF
C3	22 nF
Tr1	2N3704 etc.
Tr2	2N3704 etc.

6 to 12V supply.

Sine Wave Generator

The multivibrator and similar oscillators produce tones rich in harmonics, and not having the correct waveform for sine wave tests. A sine wave can be used to help find the maximum power handling capability of an amplifier, and for similar purposes, and also to help determine the presence of harmonic distortion.

When a sine wave is viewed with an oscilloscope, it will have equal excursions above and below the centre or zero line, as at A in Figure 19. The amplitude or height of the wave will depend on the peak-to-peak voltage of the sine wave, assuming the scope gain is not changed. A comparison of the input and output signals of a stage will thus give an indication of the stage gain.

Where harmonic distortion arises, the sine wave will be distorted. B and C show distorted traces from 3rd harmonic distortion, the actual waveform depending on the phase

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FIG.19.
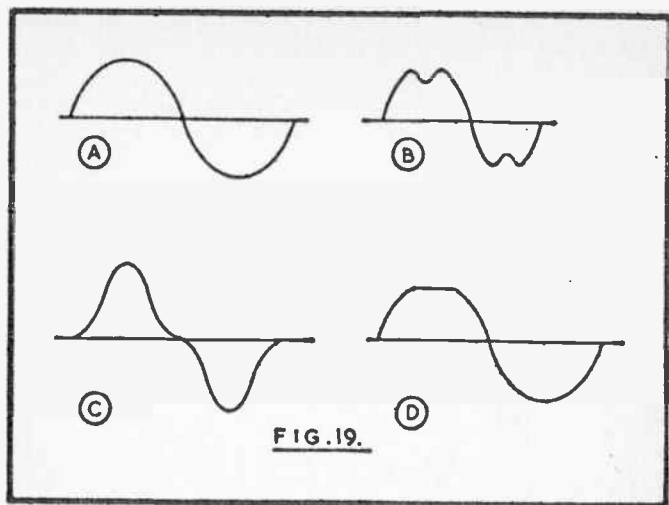
relationship between the original and spurious harmonic frequencies.

At D, the amplifier is not able to handle the positive peak, so a flat top has developed. This could be present on the negative peak instead, or on both, and arises from incorrect Class-A or push-pull operation, or overloading and other causes.

Returning to the trace A in Figure 19 if the scope timebase speed is left unchanged, the number of waves will depend on the frequency at which the sine wave is generated. It is useful to be able to modify the frequency, as amplifier performance can be expected to fall off at low and high frequencies.

Figure 20 is the circuit of a stabilised and adjustable sine wave generator, covering from approximately 12 Hertz to 22 kHz. The feedback frequency depends largely on the component values in the Wien network. Here, pairs of capacitors are selected by switching, and fine control is by a ganged linear potentiometer. The amplitude of oscillation is governed by the thermistor R4 (RS 151–114, BR16, or STC R53). With this in use, amplitude is within a few per-cent over the whole

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range. Results are much less satisfactory with a fixed resistor here, as the value needs to be changed with changes in frequency, though a fixed value is possible for a small frequency range, provided the output level is checked with a scope or similar means if necessary. With thermistor control,
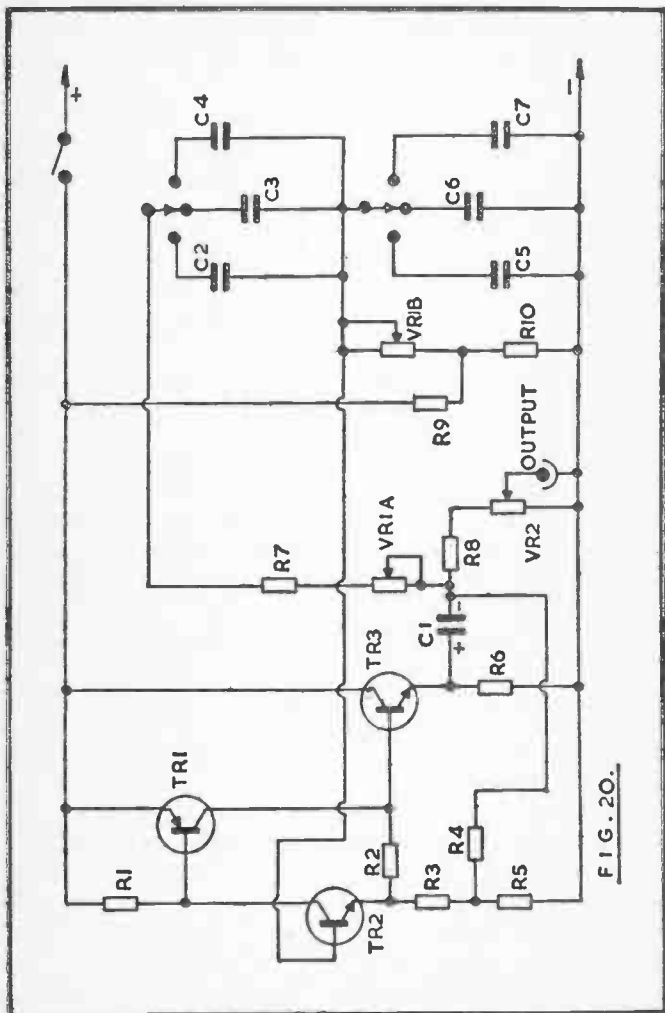
FIG. 20.

output is 1 volt R.M.S. The minimum load should be 1k.
Running is from a 9V supply.

All components for this oscillator, including the ganged
potentiometer and range switch, can be assembled on a
perforated board about 4 x 5 in. or 100 x 125mm. A 3.5mm.
jack socket will be convenient for audio output, as a plug with
screened lead can be inserted here, to obtain ground and
input connections to amplifier input points.

Ideally, an amplifier output should maintain the sine waveform,
as displayed by the scope, throughout its frequency range, and
up to its rated sine-wave power handling capacity. Audio
output may be diverted into a suitable load, of correct
impedance, as described (Wattmeters). It should be noted that
if the power handling maximum of an amplifier is given as
speech or music handling capacity, or in some such term, the
amplifier may not be able to deal with a sine wave of equal
power rating, except for a very brief interval, without overheating
or possible damage. An amplifier should not be driven
beyond its rating, or without its correct load.

Somewhat similar considerations apply to transmitting equip-
ment. Excess audio power will cause overmodulation, breaking
of the carrier with splatter, or other faults. These are
additional to possible overloading of the audio section of the
equipment itself.

Components: Sine Wave Generator (Figure 20)

R1	1.5k (Resistors 5% ¼W except R4)
R2	6.8k
R3	1.2k
R4	STC thermistor R53
R5	100 ohm
R6	470 ohm
R7	820 ohm
R8	100 ohm
R9	3.5k
R10	820 ohm

VR1A/VR1B 2-gang 10k each section, linear potentiometer.
VR2   1k linear potentiometer with switch
C1   1000 μF 10V
C2   10 nF
C3   0.1 μF
C4   1 μF
C5   10 nF
C6   0.1 μF
C7   .1 μF
Tr1   2N3702
Tr2   BC147A
Tr3   2N3704
2-pole 3-way switch.

Indicating Wavemeter

A wavemeter which operates by absorbing some radio frequency energy from tuned circuits being investigated is virtually an essential item of equipment for setting up home built transmitting apparatus. For all but low frequencies, the transmitter frequency control oscillator will operate at a lower frequency than that at which the signal is radiated. Generally, the oscillator will be followed by one or more multipliers. These will double, triple, or provide 4x or some other wanted multiplication, to enable the eventual transmission frequency required to be reached.

The harmonic relationship of the Amateur bands facilitates this. As example, if a transmitter variable frequency control oscillator or VFO is designed to tune from 1.75 MHz to 2.0 MHz, the 1.8 MHz to 2.0 MHz portion of this range would be used for '160 metres' or the 1.8–2.0 MHz band, while the 1.75 MHz to 1.9 MHz portion of the VFO range would be doubled, and provide coverage of '80 metres' or the 3.5–3.8 MHz band. In a similar manner, a VFO operating around 7 MHz could be used for 7 MHz, 14 MHz, 21 MHz and 28 MHz bands. The 14 MHz output would be obtained by doubling 7 MHz, and the 21 MHz output by tripling 7 MHz. For 28 MHz, a single multiplier giving 4x could be used, or a

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multiplier doubling to 14 MHz, followed by a further multiplier again doubling from 14 MHz to 28 MHz.

A wavemeter allows a check to be made that the correct multiple is being tuned in the multiplier output stage. Chances of errors of this type are small with a doubler, but become increasingly likely with larger multiplication factors, especially with home-constructed equipment put into use for the first time.

With VHF equipment, checks of this kind become very necessary. As example, for 2 metres or 144 MHz, channel control with 6 MHz (24x), 8 MHz (18x) and 12 MHz (12x) crystals is popular. If 8 MHz crystals are in use, it would be popular to employ x3 to obtain 24 MHz, followed by x3 again, for 72 MHz, and then 2x to secure 144 MHz, to drive the final power amplifier. By checking each stage in turn with the wavemeter, it can be assured that correct operation is obtained, and not some wrong adjustment such as 2x, 4x, 2x, giving 128 MHz output, which might fall within the range of the coils.

The indicating wavemeter will also allow each stage to be tuned for maximum efficiency, corresponding to maximum indication of the wavemeter microammeter.

Wavemeter Circuit

This is shown in Figure 21A. L1 is generally a plug-in coil, so then any of a number of coils may be fitted. For the ranges covering the 1.8 MHz to 28 MHz bands, VC1 may be 150 pF. A small reduction drive can be fitted; or a scale which can be calibrated directly, or a dial marked 0−100 or 0−180, to be calibrated with a graph. D1 may be any point contact detector type diode. C1 may be 1 nF. The meter M1 is conveniently 100 μA, but can be 50 μA to 250 μA or so, if to hand.

Construction can best place L1 externally at the end of a small case containing VC1, D1, C1 and the meter, so that L1
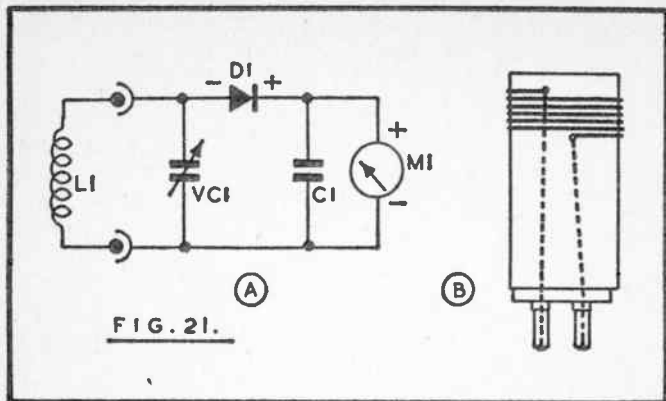
F I G. 21.

can be brought near other inductors where RF is present.

The coils can be wound on plain formers, which should
in any case not have cores. Various home-made plug-in
coils can be devised from paxolin tube and obsolete valve
bases, or plugs and sockets.

Using formers 1in. in diameter, turns may be as follows:-

1 to 3 MHz	110 turns
1.8 to 6 MHz	47 turns
5 to 15 MHz	13 turns
12 to 36 MHz	5 turns.

In all cases the wire is 32 swg enamelled, and the turns are
closely wound side by side. A typical coil is shown in Figure
21B. Lightly cement the windings in place before calibration.

Calibration

A wavemeter is used to distinguish the order of multiples, not
to check closely related frequencies in the same Amateur band.
It is used, as example, to distinguish between 21 MHz and
28 MHz harmonics from 7 MHz, or to locate the 144—146 MHz
band, not to provide calibration or checks at 21.1 MHz,

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21.2 MHz, and other close frequencies. (For the latter, use crystal reference and other means described).

So each range only needs quite broad calibration. Frequencies can be obtained from oscillator, multiplier and output stages of a transmitter already adjusted. If a few points are obtained for each range, the scale can be filled in by interpolation, or by using a graph.

At VHF, similar means can be used, or a simple tunable oscillator and lecher line can be easily prepared and will give calibration up to about 300 MHz.

A grid dip oscillator (or solid-state equivalent) can be used to calibrate the wavemeter. So can many signal generators, taking the output to a coupling loop near the wavemeter coil.

Indicating Method

To use the wavemeter, hold or place it so that L1 is coupled to the inductor where RF energy is present, and tune VC1 for maximum indication on M1. If there is appreciable RF energy present, L1 should be some inches away, or at right angles to the multiplier or other inductor, to avoid possible damage to M1. For low-level circuits, L1 needs to be near the inductor, and probably in line with it.

When an approximate indication has been obtained, move the wavemeter as required so that M1 gives only a very small reading, with VC1 correctly tuned, as minimum coupling in this way results in less pulling of frequency. The frequency is then shown by VC1 scale.

With some compact equipment, it may be easier to use a link to couple the wavemeter. This is a twisted pair of insulated wires, with a turn or two each end. Place one loop near the equipment coil, and the other near L1, initially adjusting coupling as described. Elsewhere, as with screened coils, it may be convenient to place L1 adjacent to a connecting lead feeding the 'live' end of the coil.

Unwanted output harmonics may be checked by tuning the wavemeter to multiples of the transmitter output frequency. This will show how bad is the occasional practice of doubling in the power amplifier.

Indicating Wavemeter for VHF

For VHF, it is better to reduce the value of VC1, for easier and more accurate tuning, and to use smaller diameter coils. VC1 can be a 50 pF air-spaced short-wave type variable capacitor. Plug-in formers 3/8 in. (10mm.) in diameter which fit the B9A type of holder are obtainable (Denco, Clacton, Ltd.) and may be used for the coils, as follows:-

```
  6 MHz to  14 MHz  54½ turns, 30 swg.
 13 MHz to  30 MHz  22½ turns, 28 swg.
 30 MHz to  70 MHz   6½ turns, 28 swg.
 65 MHz to 150 MHz   1¾ turns, 28 swg.
110 MHz to 300 MHz  14mm. x 7mm. loop, 20 swg.
```

Turns are side by side. Only the lowest frequency coil has a core as supplied for these formers. The loop plugs directly into the holder, with no base.

Use of the VHF Wavemeter is as already described.

Lecher Line for VHF Calibration

Figure 22 shows the line, which is best supported by a plank. It consists of two stout bare wires, separated by about 1 in. to 1½ in. (25 to 40mm.), and strained taut between insulators clear of the board. The overall length should be greater than a wavelength at the lowest frequency needed. The coupling loop is self-supporting, insulated wire.

If the loop is coupled to an oscillator or other circuit where RF is present, resonance can be found by moving a straight-edge along at right angles to the line, and in contact with the wires. One resonant point might be found at A, and a second

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FIG. 22.
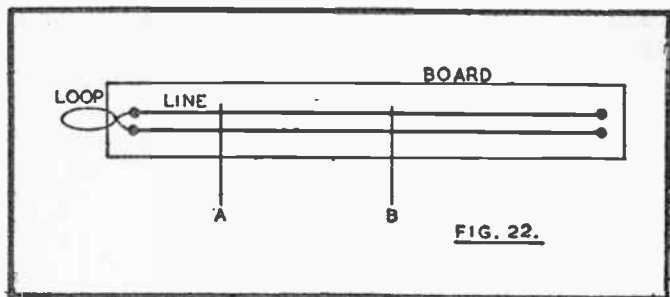
with the straight-edge at B. Measure from A to B with a metric rule. The frequency in MHz is: 150/Distance A to B in metres.

Ignore the section from the loop to A. Resonance will be shown by a small change in current drawn by the stage energising the tuned circuit coupled to the loop. For best accuracy, use the loosest possible coupling, after finding approximate resonance.

An alternative means of showing resonance is to place L1 of the wavemeter in line with the loop. Tune the wavemeter for an indication as described, use the line to determine the frequency (which will cause a dip on M1) and calibrate the wavemeter accordingly.

Such a line is easily practical for VHF work (say 8–10ft. or 2m. or so long) and allows determination of frequency without the need for calibrated instruments.

It is feasible to construct a VHF oscillator, to provide RF for the line and wavemeter, to calibrate the latter. Figure 23 shows a transistor circuit. For approximately 75 MHz to 150 MHz L1 can be 4¾ turns of 20 swg wire, 3/8 in. (10mm.) outside diameter, and with turns spaced to occupy 7/8 in. (23mm). Higher frequencies can be covered by reducing the capacitance of VC1 and number of turns on L1, though an upper frequency limit of oscillation will be reached. RF output is small, so careful coupling to L1 is necessary.
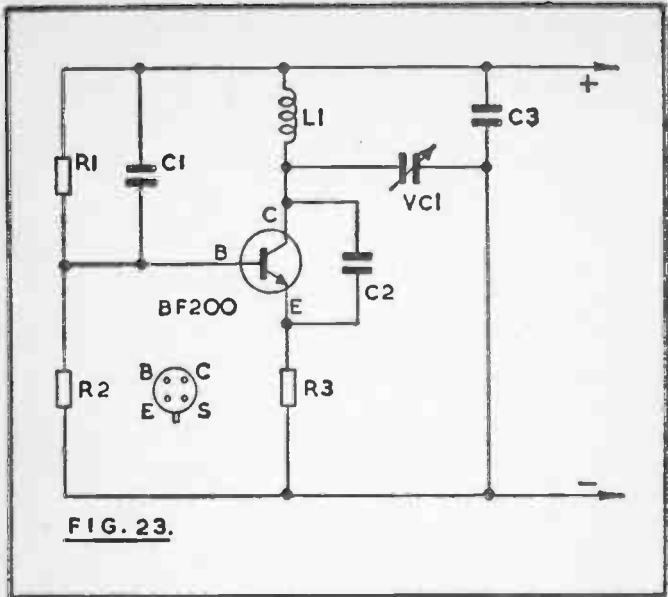
37

FIG. 23.
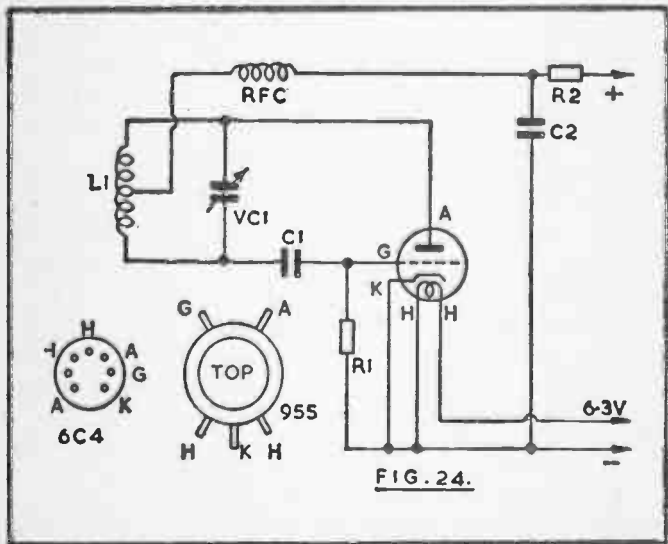
FIG. 24.

A valve circuit using a VHF power triode or 955 VHF acorn is shown in Figure 24. This provides a considerably greater RF output. R2 can be chosen to limit voltage and current to 7 mA at 180V maximum for the 955 or 300V at 25 mA for the 6C4. L1 is centre-tapped, and resembles L1 in Figure 23.

With either oscillator, find suitable frequencies such as 100 MHz, 125 MHz, 150 MHz or as required, by adjusting VC1 and checking with the line. Then tune the wavemeter to resonance, and calibrate it.

If wished, similar means can be used to calibrate a wavemeter in the 1.8 MHz to 30 MHz range, a valve or transistor oscillator being constructed, and its frequency determined by means of the station receiver.

Both circuits, Figures 23 and 24, operate in the same way, in that they provide a source of RF energy whose frequency can be adjusted and found my means of the lecher line, and used to calibrate a VHF absorption wavemeter and other equipment. As mentioned, the RF output of Figure 23 is small, and a sensitive meter will be needed to obtain a reasonable indication of resonance. Resonance can also be found by noting the slight change in battery current which arises when power is drawn from L1 by resonance in the lecher line or wavemeter. Here, again, a sensitive meter is required. Layout should allow minimum lead lengths and stray capacitances, if the highest possible frequency is to be reached.

With Figure 24, power input is considerably larger, and RF output thus much greater than with the transistor circuit. For maximum frequencies, layout must be appropriate, with very short, direct leads, and low circuit capacitances. It is possible to solder the 955 directly into circuit, but soldering should be to the extreme ends of the pins only, and must be carried out with care, the iron being removed instantly, or the glass seal may be cracked and the valve rendered useless.

Components: Transistor Calibration Oscillator (Figure 23)

R1	10k (Resistors 5% ¼W).
R2	10k
R3	1k
C1	1 nF disc ceramic
C2	4.7 pF
C3	10 nF disc ceramic
VC1	10 pF or 25 pF miniature air spaced variable

BF200 and other VHF oscillators

Components: Valve Calibration Oscillator (Figure 24)

R1	15k 1W
R2	see text
C1	47 pF mica
C2	10 nF
VC1	10 pF or 25 pF miniature air spaced variable
RFC	Radio frequency choke for VHF

6C4 and B7G ceramic holder or low-loss holder,

or

955 acorn, with holder optional.

Field Strength Indicator for 2M Man

A meter to show radiated field strength is very useful when adjusting a final amplifier, its tuning or coupling to the feeder, or matching to the aerial itself. As such a device shows the relative field strength at a distance from the aerial, adjustments to equipment are directed towards securing the maximum reading on the field strength meter, which will correspond to maximum transmitted power.

Readings may also be checked on later occasions, to see that the transmitter is providing its accustomed output.

The instrument, Figure 25 picks up RF energy by means of a short telescopic or plug-in aerial, and rectifies this to give readings on a sensitive DC meter. L1 may be tuned to resonance

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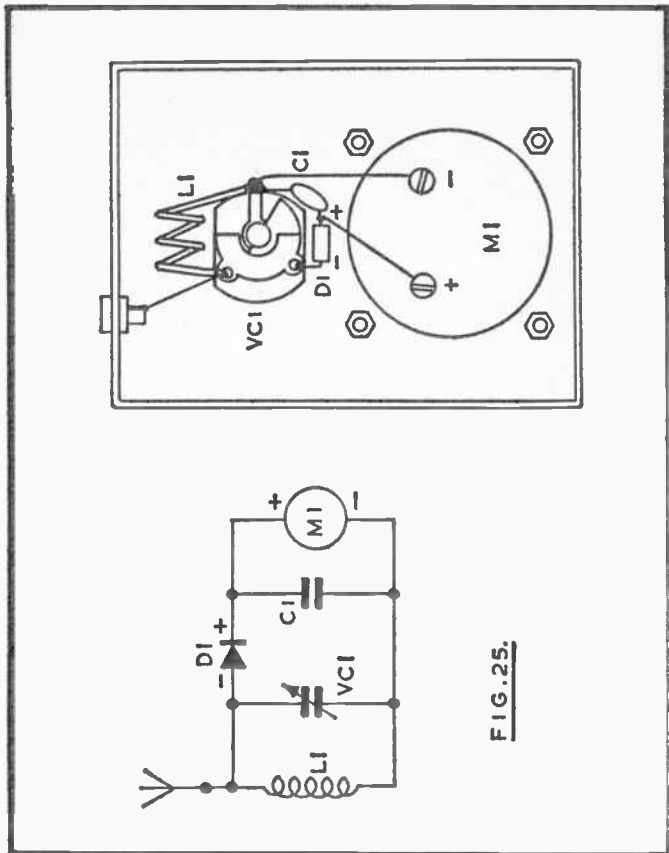
FIG. 25.

by the small parallel capacitor VC1, of 15 pF to 50 pF. Or L1 may be a VHF choke, no parallel capacitor being fitted. The former method results in larger meter readings, with a given power. A suitable choke can be made by winding about 70 turns of 36 swg or 38 swg enamelled or silk-covered wire side by side on an insulated rod or tube about 4in. (6mm.) in diameter. Do not varnish or wax the turns. For a tuned inductor, 20 swg or other stout wire can be used, employing about three turns ¼in. in diameter and ½in. long (6 x 14mm.) Resonance depends on VC1, the stray capacity of wiring etc.,

and the aerial used for pick-up, but the coil can easily be modified if necessary. The diode may if wished be tapped down L1 to reduce loading. If VC1 is 15 pF, resonance will be at almost minimum capacitance setting.

A large meter is most suitable, so that it can be seen at a little distance. All items can be fitted in a metal case about 4 x 4in. (100 x 100mm.) or so in size, with the pick-up aerial projecting vertically, for vertically polarised signals.

Initially tune the field strength indicator to resonance, as shown by maximum reading. It is then placed a little distance from the vehicle, or aerial site, and is left untouched, while all necessary adjustments are made at the transmitter, feeder and transmitter aerial. It may be preferable to place the indicator on a box or use some other means of raising it. Exact readings will depend on adjacent objects, and even the positions of individuals near-by, so these factors should remain unchanged while making any adjustments.

Changes to the indicator aerial will make necessary re-tuning by VC1. If all equipment is in the clear, and some distance can separate transmitter aerial and field strength indicator, the readings obtained will be most reliable.

RF Probe

A radio frequency probe suitable for use up to frequencies of about 100 MHz can be made using the circuit in Figure 26. If only for high frequencies, the coupling capacitor C1 can be 22 pF. With many circuits power supply voltages will also be present, so this capacitor can well be mica, of 500V rating. Diodes such as the 1N34A or OA90 can be used (point contact types).

Rectified current is via the series resistor R1 to an external indicating device — conveniently a scope or valve voltmeter or solid-state voltmeter imposing negligible load. R1 is then 4.7 megohm. For some tuning-up purposes or comparative tests, a high resistance moving coil instrument (10k/V or higher

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FIG.26.
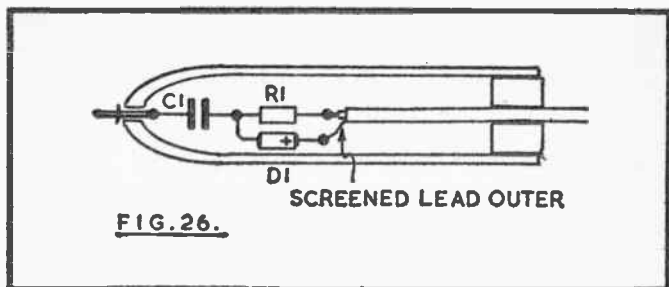
resistance) may be used. R1 may then be reduced to 1
megohm. A meter which draws significant current to obtain
its reading cannot be used, because of the high value series
resistor present in the probe.

The three components can be assembled in a small pen case,
with the screened lead issuing at the top, and prod projecting
from the bottom. The latter can then be placed into contact
with the various RF circuit points to be tested. Introduction
of some load on tuned circuits by the prod cannot be avoided,
but the extent to which this matter will depend on the
frequency and type of circuit investigated. Circuits ahead of
those to which the prod is applied can be adjusted for maxi-
mum RF indication, but the circuit feeding the prod can be
expected to need some re-adjustment when the prod is
removed. It is intended for RF potentials up to about 20V.

Signal Tracer for RF and AF Circuits

A rapid method of locating the faulty section of a receiver,
audio amplifier or modulator is to trace the presence of the
signal, beginning as near as possible to the input source — this
would be the microphone, with voice equipment. It is
possible to take in items such as jacks and switches, coupling
capacitors, and individual conductors, typically beginning at
the microphone (or other source of audio signal, as example).
The first audio stage can then be included, with its individual
gain or tone control circuits, or other items in the signal path,
this being continued until the signal is no longer heard. The

fault will then lie in the section or component last introduced, and can be localised by testing individual circuits or components in the small section of the equipment thereby shown to be defective.

The procedure is the opposite of that employed when using a signal injector, as the presence of the wanted signal is being traced from the earliest point at which it can be found.

The tracer consists of an audio amplifier of adequate gain for raising the level of audio signals to be traced, and a plug-in RF prod, for the detection of amplitude modulated RF signals, such as arise in earlier stages of a receiver. There is considerable latitude in the audio amplifier, provided its sensitivity is sufficient for weak inputs, and that an input gain control is fitted so that it is not overloaded when the audio prod is taken to circuits where a strong audio signal is present.

The audio prod contains an isolating capacitor Figure 27, to avoid shorting supply or other voltages to stages tested. This item is rated at 500V, which will be adequate for average valve equipment, and transistor amplifiers. The prod can be made from a ball-pen case or anything similar, a short, stout projection being arranged from the capacitor. The screened lead is necessary to avoid pick-up of hum, or instability. A suitable jack-plug allows this to be connected to the amplifier used for signal tracing.

An earthing lead between equipment is most often necessary, and a flexible connection with clip is provided for this. The tracer input level control VR1 is adjusted for a suitable volume level when the prod is touched on the audio circuit being investigated.

The RF prod has a similar lead and plug, so that it can replace the AF prod. See Figure 26. Here, the isolating capacitor is about 220 pF, mica or other high voltage. It is not essential to include the diode and resistor within screening, and this will allow the prod to be made along similar lines to that employed for the AF prod.

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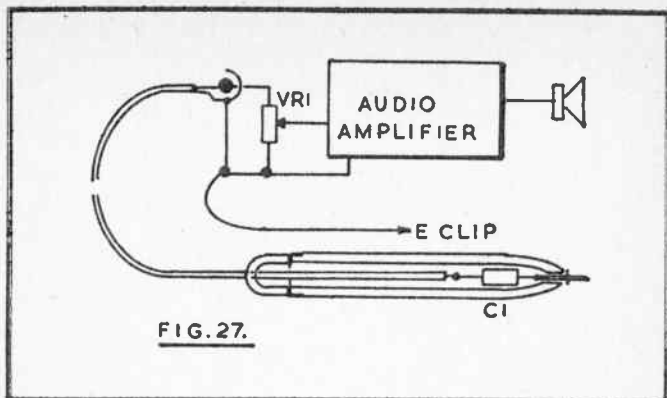
FIG.27.

With the RF prod, the presence of amplitude modulated signals can be detected in any RF or IF circuit where they are of a sufficiently high level. Signals may be found by tuning the receiver, or may be obtained from a signal generator.

Tests can be at mixer grid and anode, or equivalent points with semi-conductors, and at intermediate frequency transformer primary and secondary circuits, gain being reduced with VR1 as needed.

RF Multi-Band Signal Generator

A signal generator able to cover the usual amateur, broadcast and communication frequencies from about 150 kHz to 30 MHz will prove to be of great use in trimming, aligning or adjusting ready-made or home constructed receivers. The circuit in Figure 28 employs two transistors, one as RF oscillator, and the second as modulator.

Tr1 is the RF oscillator, and section S1A of the 5-way switch selects the tuned windings L1, while section S1B brings in the feed-back winding for the appropriate coil, L2. Five coils are fitted, and the ranges are approximately as follows:-

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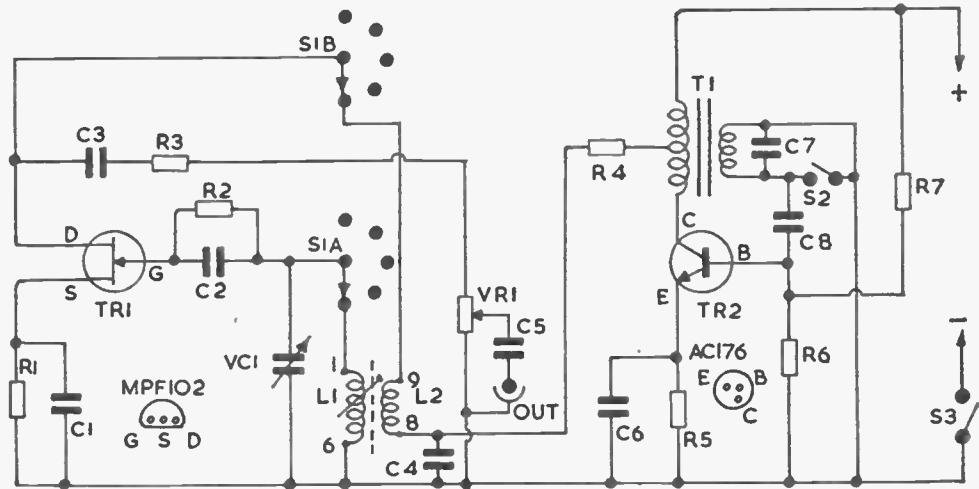
FIG. 28.

150 — 550 kHz
550 — 1800 kHz
1.8 — 4.2 MHz
4.2 — 11.5 MHz
11.0 — 32 MHz

Each range is covered with the capacitor VC1. A third pole of this switch, S1C, is connected to short out L1 of the coil next lower in frequency to that in use. E.g., the 150 — 550 kHz coil is shorted on the 550 — 1800 kHz range, and so on. This is to avoid unwanted absorption effects from resonances in the larger coils in the series.

Output is taken via the attenuator VR1. A simple potentiometer cannot control RF output fully, especially at high frequency, but nevertheless this control does allow signal level to be kept down, when required.

Pin numbers are for the 'Denco' BLUE *Valve Type* miniature plug-in coils. The Range numbers and approximate inductance of these are as follows: 1 — 2350 μH; 2 — 271 μH; 3 — 27.2 μH; 4 — 2.9 μH; and 5 — 0.65 μH. Coverage on each range can be modified somewhat by adjusting the core position, and the cores should be locked with 6ba nuts, before calibration of the tuning scales. Should no RF oscillation be obtained on any range, try reversing connections to L2 (this particularly applies if alternative inductors are fitted). It can also be worth while modifying the value of the resistor feeding the drain circuit of this stage, R4, to suit individual coils or transistors.

Tr2 is the modulator section. T1 is a driver transformer, as used between driver and push-pull output stages of small transistor receivers and amplifiers. If no audio tone is produced, connections to one winding may need to be reversed, to obtain correct feedback. Component values — and particularly that of the capacitor C7 in parallel with the transformer winding — may be modified to obtain a suitable tone, if necessary, as this depends to some extent on the transformer. S2 allows the audio tone to be switched off, for those purposes needing only a CW signal.

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Rigid assembly in a metal case is preferable, and this will provide complete screening. Layout should allow short leads from VC1 to S1A and L1, and from Tr1 to S1A, S1B and L2, for the highest frequency ranges. No RF output will be obtained on any range where Tr1 is not oscillating. If necessary, a check for oscillation can be made by placing a meter in series with R4, and shorting L1. A small change in drain current to Tr1 should be observed. Oscillation is influenced to some extent by the core position, as this can modify coupling between L1 and L2.

With S2 open and Tr2 operating, the audio tone produced here should accompany the RF signal, when tuned in on a receiver. A co-axial lead can be prepared to suit the output socket, and can be equipped with a prod and earthing clip. Small diameter audio type screened lead is not recommended.

First check with a general coverage communication or similar all-wave receiver, and adjust the coil cores so that the ranges overlap. The extreme settings of VC1 are not required for this. If wished, and particularly with other coils, the ranges can be trimmed by fitting pre-sets of about 50 pF across L1, for each range.

VC1 should have a ball or other reduction drive, or integral drive, and scales. Various dials for home calibration can be obtained.

Very accurate calibration is possible if a receiver is used in conjunction with one of the harmonic crystal markers described, as the receiver is then only used to compare marker harmonic and generator signals, so that generator calibration accuracy does not depend on the receiver.

Should a communications receiver of sufficient accuracy be available, loosely couple the generator output to the receiver aerial socket — this can be done with a small capacitor, or by means of two insulated wires twisted together for an inch or so. Tune the receiver to a convenient frequency, adjust the signal generator so that its signal is at the same frequency, then mark the frequency on the appropriate scale. This is repeated

for as many points as wanted.

Harmonics of the signal generator frequency will be heard in
the usual way. These harmonics are multiples. As example, if
the generator is tuned to 300 kHz, its fundamental will be
tuned in at 300 kHz. The 2nd harmonic will be heard at
600 kHz, the 3rd harmonic at 900 kHz, and so on. The
harmonics grow progressively weaker. These harmonics may
be used for receiver calibration over frequencies higher than
30 MHz. In some cases they also allow additional low frequency
calibration points to be found for the generator. Thus the latter
could be calibrated at 150 kHz by tuning it so that its 4th
harmonic is heard at 600 kHz on the 500 − 1500 kHz band of
a receiver. But to avoid errors, the order of harmonic must
be checked, and the harmonics are best employed systematically.

It is useful to have calibration over frequencies around 1.6 MHz
and 465 kHz, so that signals may be injected into the IF
stages of receivers employing these frequencies in the
intermediate frequency amplifier. This will assist in trouble
tracing, and the alignment of IF transformers.

The steady signal from the generator, attenuated by VR1 as
required, may be used for RF, mixer, and other circuit align-
ment. The receiver output may be into an audio meter,
operated by the tone (see details given earlier) or a high
resistance meter may be clipped from AVC line to chassis.
Alignment is directed towards securing the best AVC voltage,
but signal level should be kept down by means of VR1.

Components: RF Multi-Band Signal Generator (Figure 28)

R1	2.7k (Resistors 5% ¼W)
R2	1 megohm
R3	820 ohm
R4	5.6k
R5	1k
R6	4.7k
R7	27k
VR1	20k linear pot with switch S3
C1	10 nF

C2	27 pF
C3	15 pF
C4	10 nF
C5	10 nF
C6	47 nF
C7	47 nF
C8	47 nF
VC1	365 pF single gang air spaced
S1A/S1B	5-way 3-pole rotary switch
Tr1	MPF102, etc.
Tr2	AC176
L1/L2	see text
T1	LF transformer, see text
S2	On-off switch

Output socket, knobs and dial, etc.

Transistor Testers

Eventually the need to test transistors will arise, either as a check that such a device in a piece of equipment is operating, or to establish that its performance is at least equal to that expected. A transistor tester may be an extremely simple device indeed, hooked up temporarily to a multi-range test-meter. Or it can be a comprehensive piece of equipment, able to test both PNP and NPN devices over a large range of base and collector currents.

Figure 29 shows a basic circuit which allows silicon NPN transistors to be tested. Switch S1 selects any one of the base resistors R1, R2 or R3. M1 shows the collector current of the transistor under test. Switch S2 is to interrupt the battery circuit, and may in some cases be spring loaded, so that contact is only made when it is held down.

It is convenient to arrange some ready means of connecting Base, Emitter and Collector leads or tags of the transistor, for any configuration. This can be arranged by means of thin, colour coded flexible leads, with miniature croc clips. Mark which must be used for each circuit, so that no error will be made here.

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FIG . 29.
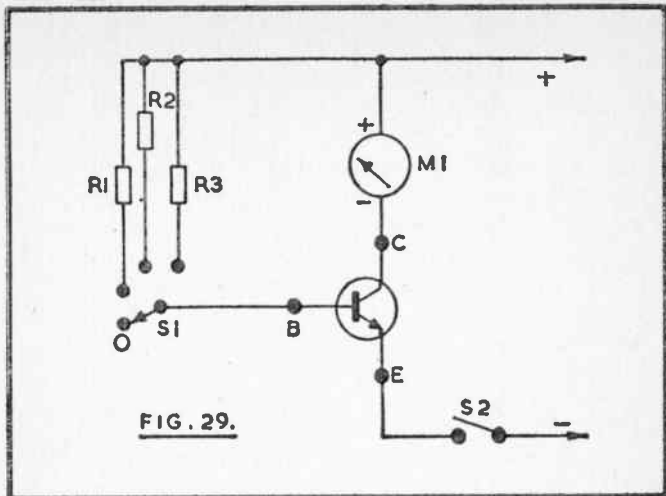
If a 4.5V (3-cell) battery is used, and allowing for the emitter-base potential of the transistor, then R1 may be 330k, R2 33k and R3 3.3k, for base currents of approximately 10 μA, 100 μA and 1 mA. The lowest resistor value, corresponding to highest base current, will be for power type transistors.

When S1 is at 0, the base is open-circuited. In all cases set M1 to a sufficiently high range to protect it. As example, assume that the transistor should have a current gain of about 150, in the common emitter circuit. With S1 at the 2nd position, and R1 in use, base current is about 10 μA, so M1 should indicate roughly 10 μA x 150 = 1.5 mA. Collector current, with S1 at 0, should be virtually zero. If these figures are shown, it can be assumed that the transistor is in order.

For other than low power transistors, S1 could be turned to bring in R2, where M1 should indicate approximately 15 mA (for 150 current gain). Larger power transistors may have R3 switched in, with a corresponding increase in base (and collector) currents.

The current gain of random specimens of the same type of

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transistor will vary widely. As example, a quite typical audio preamplifier transistor may have a gain of between about 100 and 500. (Where closer gain figures are essential, certain types are available which are sorted into a, b and c gain-groupings).

Should M1 indicate an unusual current even with S1 at 0, and this current remain the same for any position of S1, then the transistor is faulty (probably with emitter-collector short). If no current is shown by M1 with S1 in positions providing base current, the transistor is also defective (open circuit).

Figure 30 is a development of this circuit, in which the meter M1 indicates base current, which can be adjusted by means of the potentiometer VR1. M2 indicates collector current. The current gain which the transistor is providing in the circuit can then be plotted or noted, by adjusting VR1 for various readings on M1, and at the same time noting the collector current shown by M2. For small, low-signal transistors, M1 can be 100 μA full-scale, and M2 10 mA. For larger transistors, it is convenient to have shunts, so that M1 can have ranges of 0–1 mA and 0–10 mA, and M2 can cover 0–100 mA and 0–1 A. This will allow audio power and similar transistors to be tested.
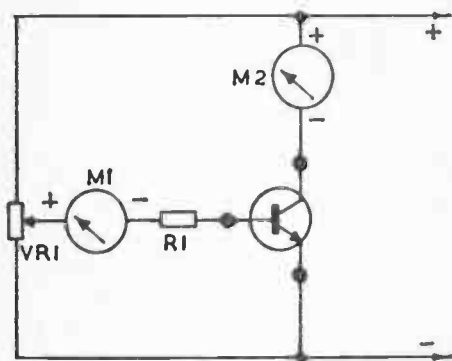

FIG. 30.

The circuits shown are for NPN transistors, with emitter at negative. PNP transistors require positive at the emitter circuit. Should it be necessary to deal with PNP transistors, then the battery and meter polarity must be reversed. The need for reversing the meter polarity can be avoided by using surplus or other centre-zero instruments. An alternative is to provide a switch, giving change-over from NPN to PNP, with poles to reverse battery and other connections. Either arrangement makes for better operational convenience.

To safeguard the collector current meter against a possible emitter-collector short, a resistor may be included in series with it, to limit current. This may be 470 ohms, for a 10 mA instrument and 4.5V supply. A switch in parallel with the resistor may be closed when the reading has made it clear no danger exists.

In most circuits, the gain characteristic which will be of importance will be the hfe, or current amplification factor, with the transistor used with a common or grounded emitter. This is shown, though under static conditions, by the circuits described. The expected current gain will be found listed for individual transistor types. Surplus or sub-standard transistors of low gain can be used in some circuits, but will in general not be expected to give a full performance.

As mentioned, silicon transistors will normally have negligible leakage current. Germanium transistors are expected to give some reading, however, and the gain calculation can then be corrected to take this into account. Note collector current on M1 with S1 at 0, corresponding to zero base current. Then measure collector current, by means of M1, for some convenient base current, selected by S1. Take the zero base current figure obtained on M1 Figure 29 from this reading, and divide the result by base current, to obtain the gain.

Thus, for negligible leakage, hfe may be taken as:-

Collector Current/Base Current.

But if leakage is significant and it is wished to take it into account

hfe = (Collector Current − Leakage Current)/Base Current.

The 'leakage current' is, of course, the figure obtained with S1 at 0, as described.

FET Dipper

A single FET provides good results in a solid-state development of the grid dip oscillator, or GDO. A GDO or FET dipper enables the resonant frequency of a tuned circuit to be found, without the need for RF energy being developed in the latter. It is thus popular to set transmitter circuits to approximate frequency, before applying power, and is also used to find resonant frequencies of tuned circuits generally, as well as that of items such as loading coils or aerials. The FET dipper has the advantage of portability, as it operates from a small 9V internal battery.

Figure 31 is the circuit. For wide range, plug-in coils L1 are used, and are tuned by VC1A/B, a 2-gang capacitor with similar sections. Feedback, to produce oscillation, is from the FET drain D by means of C1, and from C2 to the gate G. Rectification of the oscillation voltage produces current through R1, which is indicated by the meter M1. This provides a reading of about half-scale on M1 (the actual reading is not very important). When L1 is near a resonant circuit tuned to the same frequency, some RF energy is drawn. The strength of oscillations falls, causing the indication given by M1 to fall back. This dip or drop in current on M1 shows that the dipper and unknown circuit coupled to L1 are tuned to the same frequency, which is then read from the dipper scale.

Both MPF102 and 2N3819 FETs were found to allow operation over the range 5.5 MHz to 220 MHz, using five plug-in inductors, and no doubt other HF and VHF type FETs could be used. The upper frequency limit is likely to be determined by the smallest inductance which can be used at L1,

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FIG. 31.
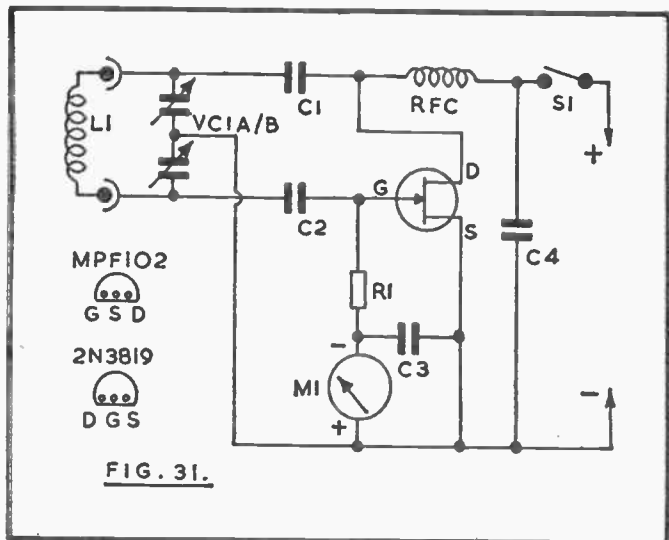
oscillation being maintained, together with the lowest mini-
mum capacitance for VC1A/B.

With these transistors and the values given, indications on M1
were found to lie between about 70 μA and 40 μA, so M1 can
be a 100 μA meter, directly connected as shown. If a more
sensitive instrument is to hand, it can be used by connecting
a 10k linear potentiometer in parallel with C3 (that is, from
R1 to negative line) and taking meter negative to the wiper of
this control. Sensitivity can then be adjusted with the
potentiometer, to avoid having M1 off-scale.

Inductors

These can be wound on 3/8 in. or 9.5mm. miniature plug-in
formers, which are obtainable for such purposes. Figure 32
shows details, and it will be noted that the windings are kept
at the free or top ends of the formers. Pins 1 and 6 are used
for all coils. Very small holes are drilled so that the wires may
pass down inside the formers, and emerge near the pins, to

FIG. 32.
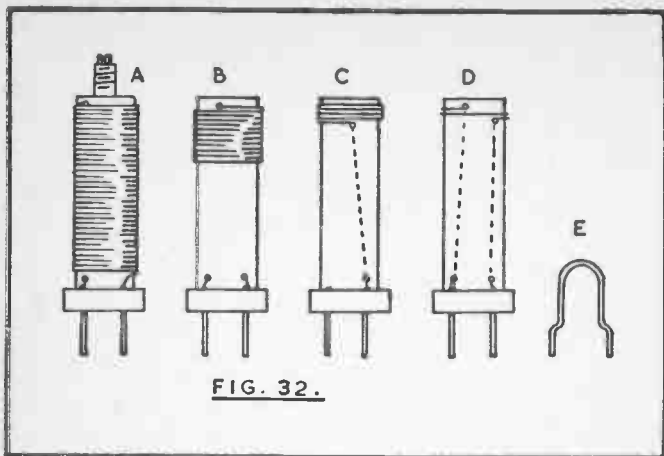
which they are soldered. Undue or lengthy heating of the pins must be avoided, and it is wise to fit the former into its holder before soldering, and leave it there until cool, to avoid displacing the pins.

Coil A is for 5.5 to 13 MHz, and has 56 turns of 30 swg enamelled wire. This coil has its original core replaced. The other coils have no cores, and the threaded portion can be sawn off to allow easier manipulation of the coils inside equipment

Coil B is for 13–32 MHz and has 20½ turns of 26 swg enamelled wire. Coil C, for 28–70 MHz, has six and three-quarter turns of 26 swg enamelled wire, while coil D has one and three-quarter turns and is for 55–160 MHz. The loop E is for the highest range, 160–220 MHz, and is of wire the same diameter as the coil pins. That is, 20 swg or 0.036 in. The loop portion is 8mm. centre-to-centre, and 12mm. long, followed by 2mm. portions turned outwards, and 5mm. portions to plug directly into the holder.

Figure 33 shows a simple form of construction. The chassis or case consists of a 'universal chassis' flanged member long enough to form top and both ends. Cut 90-degree sections
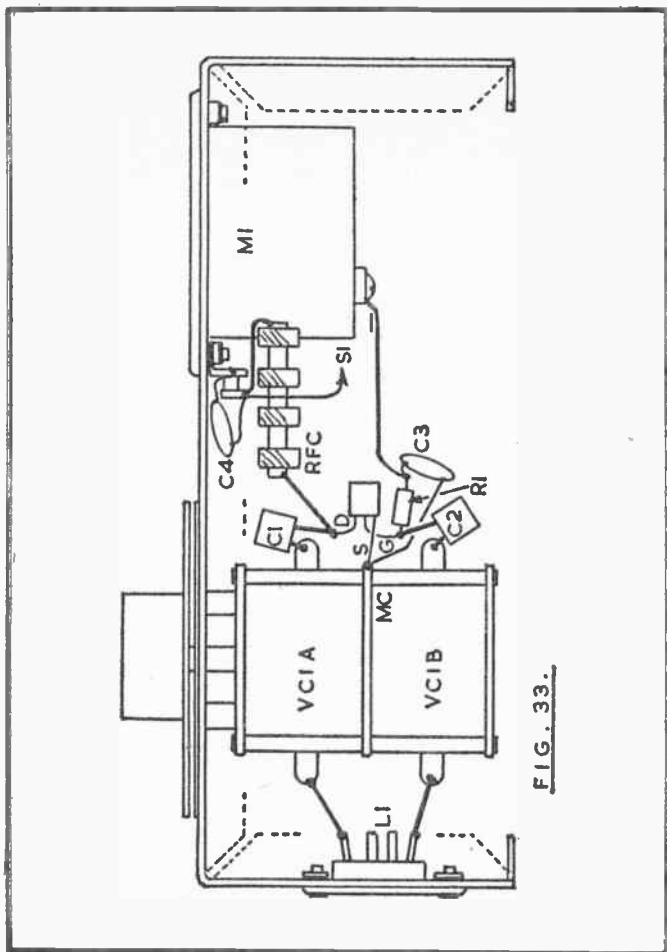
F I G. 33.

from each side flange at the bending points, and bend at right angles over a block of wood, to obtain the open box shown. The holder for L1 is fitted at one end, and VC1A/B and the meter (and S1 or potentiometer with on-off switch) on the top.

Note that the layout allows short, direct connections in the important parts of the circuit — L1 to VC1A/B, VC1A/B to

C1 and C2, and for source, gate and drain of the FET. C1, C2, R1, C3 and the FET are all supported by their leads, which are reasonably short. An insulated tag strip helps support the RFC and C4. M1 positive and battery negative return to the metal chassis, as in the circuit.

When wiring is finished and the dipper has been tested, make a U-shaped cover from aluminium sheet, bent to fit. This can then be attached with self-tapping screws passing into the flanges, shown in broken lines for clarity.

M1 should indicate current, with each inductor in place. If not, oscillation is not being obtained. The full capacitor swing is not used with inductance E, but only approximately one-half to minimum.

Calibration of ranges from 5.5 MHz to 30 MHz can be with the aid of a general coverage communications type receiver. The dipper will produce a steady carrier, which may be observed with the receiver tuning meter, or made audible with the receiver beat frequency oscillator switched on. The receiver can then be set to various convenient frequencies, the dipper tuned to place its signal on the same frequency, and the scale marked.

For the VHF ranges, it may be most convenient to set up a lecher line, as described, and couple this to L1. Resonance between line and dipper will then produce a dip on M1, so that the scales can be calibrated. For frequencies above 30 MHz, it may also be possible to make use of harmonics, as explained elsewhere, in conjunction with a VHF receiver or converter.

To use the dipper, place it so that L1 is near and in line with the inductance where resonance is to be found. VC1A/B is then rotated until a dip is seen on M1, and the frequency is read from the dial. Subsequently loosen coupling, by moving L1 away, so that the dip is small, as this gives more accurate readings.

Where transmitter circuits are tuned without power being present, the dipper can be set to the wanted frequency. The

transmitter tuning is then adjusted until a dip is observed on M1. A wavemeter is readily calibrated from the dipper, by similar means. It can also be used to adjust aerial tuners, or for other purposes where resonance has to be found.

Components: FET Dipper (Figure 31)

C1	47 pF silver mica
C2	47 pF silver mica
C3	4.7 nF disc ceramic
C4	47 nF disc ceramic
VC1A/B	2-gang, 100 pF each section, miniature short-wave variable capacitor
R1	100k ¼W
FET	MPF102, 2N3819, etc.
M1	100 µA (or more sensitive instrument if wished)
L1	Denco (Clacton) Plug-in formers. Holder for same
RFC	Radio frequency choke, sectional 2.5 mH

On-Off switch, battery clips, materials for case, etc.

Crystal Frequency Standards

For the exact determination of frequency within an amateur or other band, spot frequencies are usually obtained from a crystal standard. The crystal will have a very much higher degree of stability than a conventional tuned circuit, and will provide calibration points of very high accuracy. For maximum possible accuracy, the crystal oscillator usually has some means of adjusting frequency over narrow limits, by 'pulling' the crystal. The crystal can then be set by reference to some highly accurate and readily available source, such as BBC long wave transmissions on 200 kHz, or the standard frequency transmissions which can be heard on 2.5 MHz, 5 MHz, and other frequencies.

The simplest type of crystal frequency standard to make consists usually of a 100 kHz oscillator whose harmonics or multiples will be available up to 30 MHz or higher frequencies. A harmonic is a multiple of the basic oscillator frequency. Thus

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if the oscillator is operating at 100 kHz, its harmonics will be heard at 200, 300, 400, 500 kHz, and other multiples. The harmonics grow progressively weaker, but are normally detected without difficulty up to 30 MHz with a communications type receiver, so may be used for all the amateur bands — 160, 80, 40, 20, 15 and 10 metres.

Figure 34 will help show how the harmonics help provide exact calibration points in some of the amateur bands. On Top Band or 160, they will be available at 1.8 MHz, 1.9 MHz, and 2.0 MHz, and those at 1.8 MHz and 2.0 MHz also set the band limits.

For the 80-metre band, harmonics will be heard at 3.5, 3.6, 3.7 and 3.8 MHz, while harmonics to assist in locating or calibrating the 40 and 20-metre bands are also shown.

Harmonics are not of course confined to the amateur bands, but exist through the whole spectrum, so can be used to locate short wave broadcast bands or other frequencies.

Where the receiver calibration is already reasonably correct, the 100 kHz harmonics can be identified with reasonable ease. This is particularly so at the lower frequencies. At higher frequencies, or where calibration is initially poor, or when calibrating home-built equipment, harmonics can be identified either by listening for band activity, or by counting off from some known frequency. As an example of the former method, since 80m amateur activity is confined to 3.5 to 3.8 MHz, it will be found to lie within those harmonic marker points giving these frequencies. Counting off from a known frequency can, as example, be from 2.5 MHz, as the harmonic for this frequency will fall on the standard frequency trans-mission. So if the receiver is carefully tuned in, as example, a high frequency direction, subsequent harmonic points can be marked 2.6, 2.7, 2.8 MHz, and so on, to complete the receiver band.

An alternative method is to have a second crystal frequency. This could be at 1.75 MHz, so that its harmonics identify the low frequency band ends of the amateur bands, at 3.5, 7, 14,
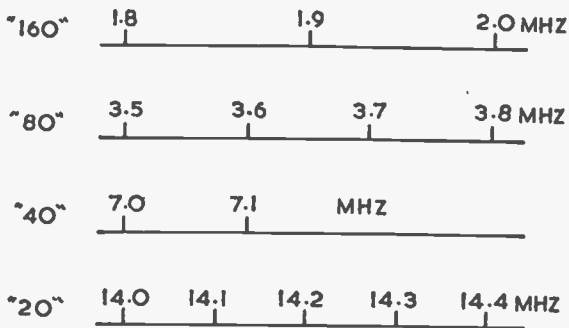
FIG. 34.

21 and 28 MHz. S somewhat similar method is to employ a
1 MHz oscillator, which will give harmonics at 1 MHz intervals,
for initial identification.

Closer calibration of the receiver scales can be obtained by
using one or more frequency dividers, a second oscillator with
a lower frequency crystal, or by interpolation on a scale.

100 kHz Oscillator

A single 100 kHz oscillator will meet many amateur needs, and
Figure 35 is a typical circuit. It is essential to use a 100 kHz
crystal intended for transistor circuits (some older types, made
for valve oscillators, are unsatisfactory) and this will typically
be for a circuit capacitance of about 30 pF. Trimmer or pre-
set T1 allows small adjustments to the crystal frequency. T1
may be replaced by fixed and pre-set components in parallel;
as example, 22 pF fixed with 50 pF parallel trimmer. Very
many transistors will operate in this circuit, using about 4.5V
to 9V. Oscillation can be tested for by noting if battery
current changes slightly when the crystal is shorted (e.g.,
between oscillating and non-oscillating conditions), or by

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FIG. 35.
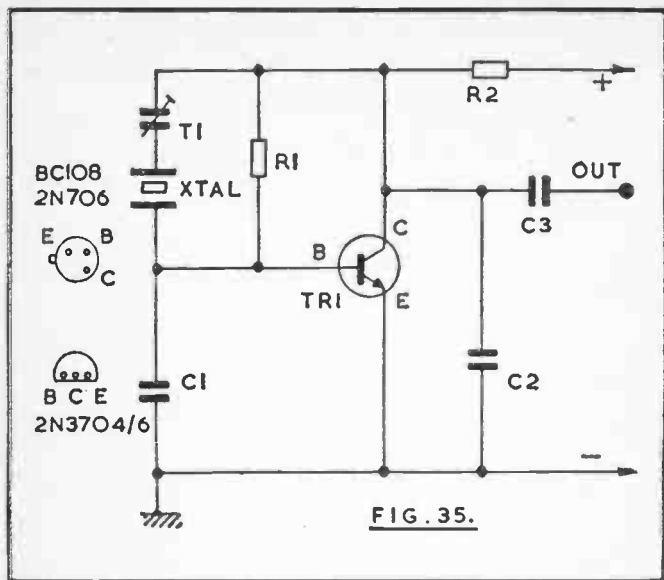
listening with a receiver at harmonic points as described later.

Components: 100 kHz Oscillator (Figure 35)

R1	1.5 megohm (Resistors 5% ¼W).
R2	2.2k
C1	330 pF silver mica preferred
C2	800 pF silver mica preferred
C3	22 pF
XTAL	100 kHz standard
Tr1	BC108, 2N3704, etc.

Construction may be on insulated board or a tag-strip, and the oscillator can be fitted in a metal or insulated box, with battery and on-off switch. An output socket can be provided, or an insulated flexible lead run from C3.

The oscillator may be trimmed to frequency by reference to the BBC transmission on 200 kHz. with any receiver having a

long wave band. Tune in this transmission, and place the oscillator, or its output lead, near the receiver, to obtain suitable coupling so that a beat note is obtained. This may be very low in frequency, and is the difference between the oscillator 2nd harmonic, and 200 kHz. (Receiver tuning has no effect on accuracy). Adjust T1 so that the beat falls to a flutter, or slow rise and fall in noise. This is most easily done during speech or silent intervals of the programme.

To set by a standard frequency transmission, such as that on 2.5 MHz, tune this in with a short wave receiver, and couple the oscillator output to the receiver aerial lead. It is best if the two signals are of somewhat similar strength. Do not swamp the standard frequency signal by close coupling of the oscillator; or if necessary only use a short temporary aerial for reception if the standard transmission is very strong. The beat note will be heard as a tone, or as a flutter, or rise and fall in noise, as adjustment corrects the crystal oscillator frequency. At low frequency differences, the receiver meter will also rise and fall. An accuracy of a few cycles per second will be much greater than required.

To calibrate a receiver, couple the oscillator to the aerial input socket. The harmonics will be audible when the receiver beat frequency oscillator is on, and can also be seen with the receiver tuning meter, when strong enough to operate this item. With the high order harmonics, it will be necessary to remove the receiver aerial so that other signals do not swamp the harmonics.

To calibrate an oscillator, such as that used to control the frequency of a transmitter, couple both crystal and tuneable oscillators into the receiver aerial input. If necessary, arrange individual coupling so that both inputs are of somewhat similar strength, or at least so that one does not completely swamp the other. Tune the receiver to a known harmonic of the crystal oscillator, and tune the variable frequency oscillator to zero beat with this, and mark its dial. Repeat for a suitable number of points for each VFO band. Receiver tuning accuracy does not influence calibration accuracy. The receiver BFO is not in use, when beating VFO and crystal oscillator signals in

FIG. 36.
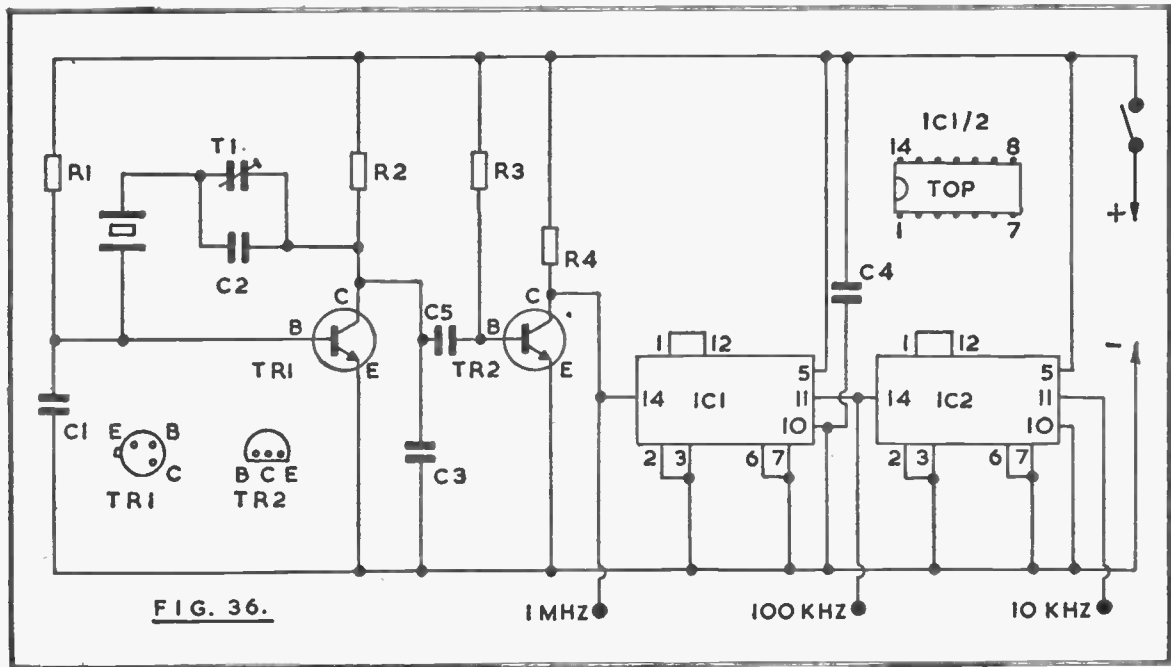
this way.

Standard with Dividers

Figure 36 is the circuit of a more comprehensive crystal harmonic calibration oscillator. This uses a 1 MHz crystal, and Tr1 is the oscillator stage. Frequency is adjusted by means of the small trimmer T1, in the way previously explained, in conjunction with a receiver. C1, C2 and C3 also influence the exact frequency here, but no difficulty is usual provided the crystal is of correct type.

Tr2 is an amplifier, and provides sufficient output to drive the first integrated circuit, IC1. A 1 MHz signal, and harmonics at 1 MHz intervals, may be taken from the 1 MHz socket indicated.

IC1 is connected so that division is by a factor of 10, and its output is thus at 100 kHz, and is available at the 100 kHz socket. This frequency passes to the second similar divider, so that further division provides a 100 kHz output. The lower frequency outputs will be used to fill in between the 1 MHz marks, or for more exact calibration within narrow bands.

IC1 and IC2 are designed for an operating voltage of about 4.75V to 5.25V, and will normally be run from a 5V regulated power supply unit. However, it will be found that satisfactory operation is possible from 4.5V, so a 3-cell supply can be used. Should a 6V or other supply of more than 5V be chosen, then a dropping resistor or other means must be used to reduce this, for the ICs.

If wished, harmonic output can be boosted by adding a further transistor amplifier, similar to Tr2, but receiving input from 1 MHz, 100 kHz or 10 kHz points, as required.

Components: Standard with Dividers (Figure 36)

R1   470k (Resistors 5% ¼W).

R2	3.3k
R3	220k
R4	2.2k
C1	147 pF silver mica preferred
C2	47 pF silver mica preferred
C3	470 pF silver mica preferred
C4	0.47 μF
C5	47 pF
Tr1	2N706
Tr2	2N3704
IC1	7490
IC2	7490
2 off 14 pin DIL holders	
T1	50 pF trimmer
On-off switch, insulated board, case, etc.	

Standing Wave Indicator

When a transmitting aerial presents the correct impedance
load to the feeder supplying it, there is a smooth flow of
radio frequency energy along the feeder into the aerial. No
RF energy is reflected back along the feeder. Operational
conditions at the transmitter end of the feeder resemble those
which would be present if the aerial were disconnected and
replaced by a non-inductive resistor offering the same load.
It is said that the system is matched, or that a standing wave
radio of 1:1 exists, and RF energy flows with minimum loss to
the aerial to be radiated.

A half-wave dipole, cut at its centre and fed with 75 ohm
co-axial cable, will be an approximately matched system, and
can be operated directly from a transmitter whose output may
be adjusted to loads of around 75 ohm. Similarly, a Marconi,
ground-plane or other aerial system with a feed impedance of
about 50 ohms, and fed with 50 ohm cable, will be approxi-
mately matched, and the SWR on the cable will be low.

Various other aerial arrangements will present impedances far
removed from these figures, and are generally employed with
some form of tuning or matching unit. This unit, placed

between aerial and transmitter, allows the aerial impedance feed point to be changed to present a suitable load for the transmitter. Without such a unit, or with any incorrect impedance match between feeder and aerial, some power will be reflected from the aerial back along the feeder. It is usually considered desirable to operate with a feeder SWR of not greater than 1.5:1, though the importance of losses, or such difficulties as radiation from the feeder, or inability to load the transmitter suitably, will depend on frequency and other factor.

If a standing wave ratio indicator is accurately calibrated to read forward and reflected voltages, Vf and Vr, then the SWR can be found as follows:-

$$SWR = (Vf + Vr)/(Vf - Vr)$$

Home constructed instruments can give satisfactory indications, especially as aerial matching adjustments will be directed towards securing a 1:1 ratio.

Figure 37 shows the general arrangement of one of the easiest SWR indicators to construct. It employs a piece of 50 ohm or 75 ohm co-axial cable, to match use of the indicator in 50 ohm or 75 ohm feeders. A pick-up wire is threaded inside the outer conductor, and RF is rectified by D1, and indicated by the meter M. C1 is a RF by-pass capacitor (typically 1 nF). VR1 allows adjustment of meter sensitivity, and will usually be some 25k or so. Sensitivity to low power depends on the line length and meter M, as well as on frequency, so M can be a 100 μA instrument. Some 12 in. or 300mm. of line will be suitable for 1.8 MHz to 30 MHz, except for very low power. A longer line will increase output from D1 to M. However, more than about twice this length is not recommended for frequencies as high as 30 MHz. For VHF use, the line needs to be up to about 4 in. or 100mm. long.

R1 should be arranged so that if power is fed into the correct impedance dummy load, M reads full-scale for forward power (with VR1 suitably adjusted) but zero when input and output connections are reversed.

FIG. 37.
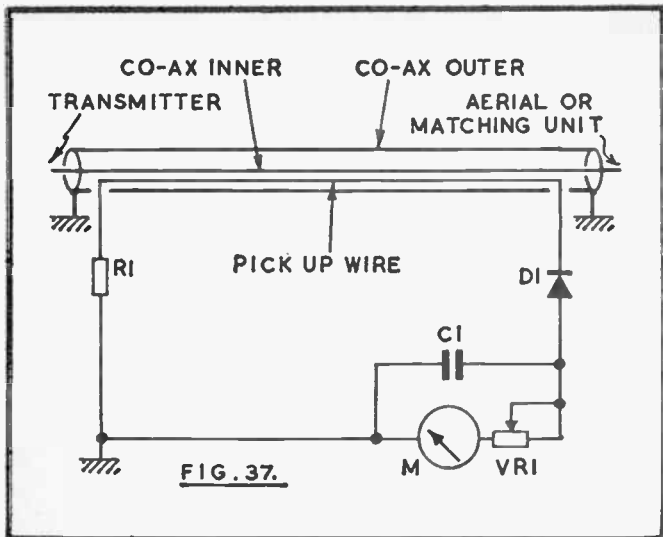
To allow simultaneous indication of forward and reflected
power, a second pick-up wire may be used, with its own diode
and meter, the placement of items being reversed (R1 at right,
D1 at left). Both meters may then be observed while
adjusting aerial matching, to secure minimum reflected power,
with maximum forward power. Some SWR indicators instead
use a single meter, with 2-way switch, so that the meter can be
switched to forward or reflected diode circuits as wished.

Figure 38 shows the inside layout of an indicator to show
forward and reflected power. Take a 14 in. (350mm.) length
of 75 ohm co-axial cable, and unwrap the outer braid ½ in.
(13mm.) each end. Cut back insulation ¼ in. (6mm.) each end.
Cut away the outer insulation and separate the braid at the
middle of the cable, if of the type allowing a 28 swg enamelled
wire to be threaded inside the braiding. If braiding and
insulation do not allow this, squeeze the brading towards the
middle to gain clearance, and thread in this wire, which
emerges through the outer brading so that R1 may be soldered
on as shown. The cable is formed into a loop, to save space,
and soldered to sockets S1 and S2, for transmitter and aerial

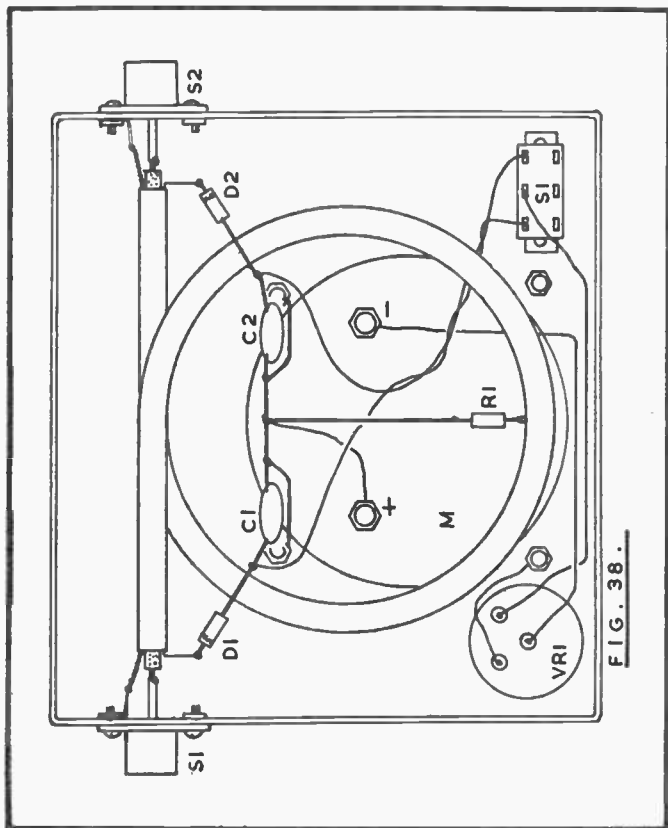F I G . 3 8 .

(or matching unit).

D1 and D2 are 0A95 or similar diodes, and C1 and C2 can be 10 nF, disc ceramic. R1 is 68 ohm, but may be modified slightly as described later if necessary. The potentiometer is 20k and meter M 100 μA.

Situate the sockets and co-axial loop towards the back of the case. So far as practical, wiring to the diodes, capacitors and R1 should be symmetrical.

To test the SWR indicator, connect the transmitter to S1 with a suitable co-axial lead, and use a second lead from S2 to connect a dummy aerial load, which can be made up as described earlier. With switch S1 set to read forward power, adjust VR1 for full-scale reading on the meter, when the transmitter is correctly tuned for maximum meter indication. When S1 is placed in the other position, the meter reading should be near zero. With the transmitter connected to S2, and load at S1, similar results should be obtained, but with the opposite position for switch S1. Exactly similar readings on this test cannot be expected, and are not really required. Resistor R1 can be adjusted by substitution, to secure the best minimum, when the indicator is operating into the correct load.

In use, S1 may be set for power indication, and transmitter adjustments are then directed towards securing the greatest meter reading. Also switch to reflected power, and adjust any tuner or matching device for minimum meter indication.

Figure 39 shows the order of connecting items — the SWR indicator is placed between the transmitter and impedance matching device (Z match) or tuner, employing co-axial leads.

Figure 39 also shows a typical tuner for an end-fed aerial which is a half wave, or multiple of half waves in length. Thus about 136 feet may be used on all bands, 80 to 10 metres. For 80m, VC1 can be a non-miniature type broadcast receiver 2 x 500 pF gang or similar capacitor, with 4 turns for L1. For higher frequencies, a smaller capacitor will be adequate. VC2/3 can be 2 x 250 pF, wide spaced for other than low power. L2 can be 26 turns of 18 swg bare wire, 2¼ in. or 60mm. in diameter, with turns spaced to occupy about 2¼ in. L1 is insulated wire, wound on top of the middle of L2. Other values and windings may be used. VC2/3 and the aerial can be tapped equally inwards for 40m and higher frequencies.

In use, adjust VC2/3, and VC1, for minimum reflected power. This can be zero, in most cases. For alternative or awkward aerial lengths, the aerial may be tapped in on L2 towards the centre of the coil, as found necessary. Zepp or doublet

FIG. 39.
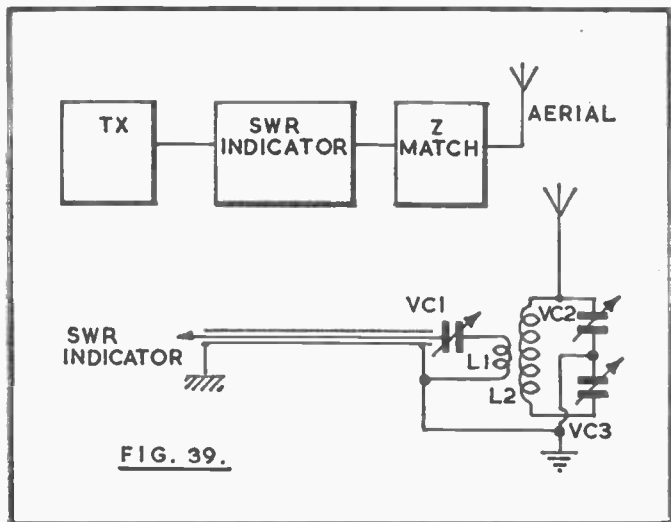
feeders may be connected to each end of L2, where the feed point here is high impedance.

Capacitance Meter

This instrument has three ranges, extending from approximately 25 pF to 50 nF. It is by no means difficult to extend these ranges, but individual calibration will then be almost essential for values under 25 pF, to allow for stray circuit capacitance, and other effects which will detract from accuracy.

Readings are presented on a 50 μA meter, and the three scales are intended to have values of 500 pF, 0.005 μF or 5 nF, and 0.05 μF or 50 nF for full deflection of the meter. This means that values can be read with reasonable accuracy directly from the meter scale. On the lowest value range 10 μA shows 100 pF, 15 μA 1500 pF, and so on, while the remaining range readings would be 10 μA for 10 nF, 25 μA for 25 nF, and so on. It is not feasible to take extremely low readings on the meter, but the need for this is avoided in most cases by having the ranges overlap.

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The circuit, Figure 40 consists essential of two sections — the unijunction transistor oscillator, and indicating meter M with rectifier D1. The range switch S1 selects capacitor C1 with pre-set potentiometer VR1; or C2 with VR2, or C3 with VR3. C1 charges through VR1 until a particular emitter voltage is reached, and the UJT then conducts, discharging C1, and producing a pulse at base 1. C1 then charges again, and this is repeated.
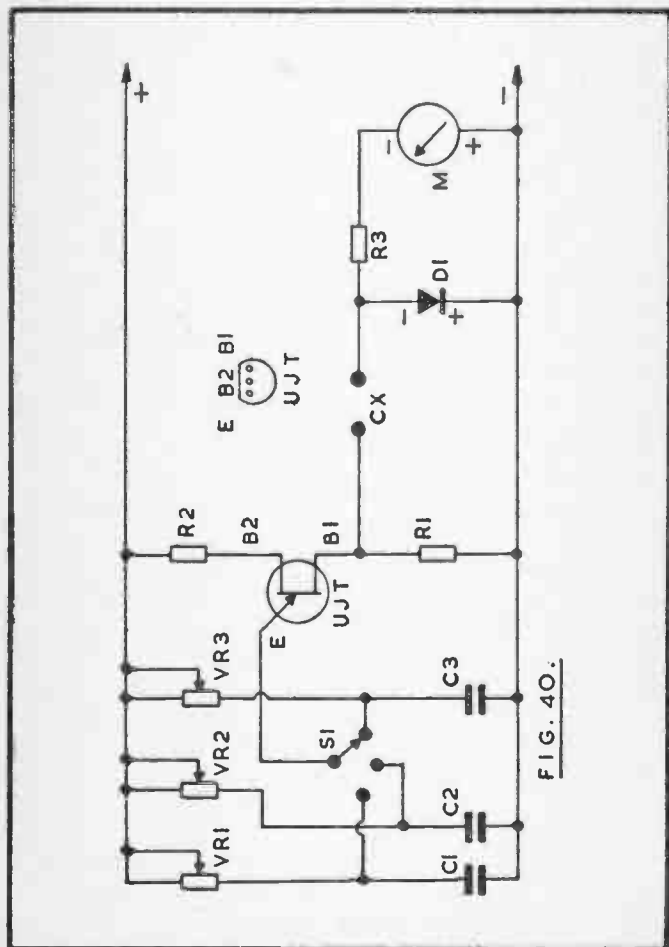

FIG. 40.

The frequency depends on the capacitor value, and setting of VR1.

Three frequencies are provided, depending on the position of the switch S1.

The unknown capacitor is placed in circuit at Cx. Its capacitor reactance is $1/2 \pi fC$, where π may be 3.14, f is frequency in Hertz, and C capacitance in Farads. This means, that for a given frequency, obtained from base 1 of the UJT, the reactance in Ohms rises as capacitance decreases, so that a lower reading is obtained on meter M.

Diode D1 provides rectification, to obtain direct current for the meter, and resistor R3 helps to obtain a more linear scale. Precision components are not necessary, because the pre-set potentiometers allow adjustment of frequency, and thus modification of the readings obtained on M. It is convenient to set these at about half scale. To do this, switch S1 to VR1/C1, and place a 250 pF or 300 pF (or other convenient value) capacitor at Cx. Adjust VR1 until M reads correctly. That is 25 μA, 30 μA, or as required. Reasonable agreement should then be found over the whole range. Repeat for the second range, with a capacitor of 2500 pF, or other accurate component available, and finally set VR3, for the largest value range, with a 25 nF or other suitable calibration capacitor at Cx.

It is possible to make fine adjustments of linearity by altering R3, or substituting a pre-set here, or by slightly modifying the supply voltage, or by fitting a pre-set resistor in the supply lead. It should not, however, be found that this is necessary. Thus it is only required to connect the unknown capacitor at Cx, switch to a suitable range, and read the value from meter M. An on-off switch is placed in one battery lead, though current drain is small.

If wished, a fixed resistor of about 27k can be placed in series with each pre-set potentiometer, to limit minimum circuit resistance. For further ranges, it is necessary to fit other capacitors and pre-set potentiometers (VR4/C4, etc.) but

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operation becomes less satisfactory with very large and very small values, and individual calibration of the ranges can become necessary.

Components: Capacitance Meter (Figure 40)

C1	1000 pF
C2	10 nF
C3	0.1 μF
VR1	150k pre-set
VR2	150k pre-set
VR3	150k pre-set
R1	1.5k (Resistors 5% ¼W)
R2	560 ohm
R3	10k
UJT	TIS43
D1	0A95
S1	3-way rotary switch
M	50 μA moving coil meter

On-off switch, 22½V battery or PSU, case, terminals, etc.

Digital Counter Uses

Very much 2m band amateur activity, fixed and mobile, consists of FM working on pre-set crystal controlled channels. Commercial equipment with provision for many channels will synthesize these, but portable hand-held and home-built equipment will generally use one crystal for each channel. It may be wished to use Simplex or S channels, in which operation is directly between the two or more stations concerned. Or Repeater (R) channels are now useful in most parts of the country. These allow relatively weak signals to actuate and energise a favourably placed repeater station, which re-transmits the signals. In this way, communication can be obtained with a reliability, and over distances, impossible with Simplex.

The table below lists popular Simplex channels for FM work, and also for Repeaters.

Channel	Frequency
S13	145.325
S14	145.350
S15	145.375
S16	145.400
S17	145.425
S18	145.450
S19	145.475
S20	145.500
S21	145.525
S22	145.550
S23	145.575
S24	145.600
R0	145.000
R1	145.025
R2	145.050
R3	145.075
R4	145.100
R5	145.125
R6	145.150
R7	145.175
R8	145.200
R9	145.225

The crystal oscillator will be operating on a lower frequency, and will be followed by multipliers. A quite typical method is to multiply 8 MHz crystals into the 144 MHz band. The crystal required may be purchased by channel number, or by frequency. The frequency is found by dividing the channel frequency by the multiplication factor to be used. The crystals are accurately made, but normally the oscillator circuit in which they are used can be trimmed, to move the frequency very slightly in either direction.

As example, a crystal for Channel 21, 145.525 MHz, would probably be approximately 8.0847 MHz. With the oscillator followed by a stage giving 3x multiplication, 24.2541 MHz is then obtained, and a further 3x multiplied produces 72.7623 MHz. Doubling this in a further stage gives a final or output frequency of 145.5246 MHz, and trimming would allow

adjustment of this to 145.525 MHz.

Commercially made transceivers, which are set up correctly for reception on switched channels, give a degraded performance when contact is made with home-built or wrongly adjusted equipment where there is some error in frequency. It is thus necessary to set the home-constructed transmitter oscillator to the correct frequency. If a frequency counter which operates up to over 145 MHz is available, this can be done by monitoring the output frequency with it, and adjusting crystal trimming until the transmitter output is correct.

Many less expensive and popular counters will not extend to these frequencies. Some, as example, operate up to 30 MHz. Such a counter may be utilised either by connecting a 10x scaler between the transmitter and the frequency counter input, or by using the counter to check frequency at an earlier stage in the transmitter, where the frequencies are within its range.

The scaler is a pre-divider with circuits able to operate at the required high frequency. As example, if this unit itself divides by 10, then a signal of 145 MHz will be presented to the digital frequency meter as 14.5 MHz, and all readings shown by the latter will need to be multiplied by 10 to find the actual frequency.

Figure 41 shows points at which a transmitter with stages as discussed could be checked. Assuming that operation is to be on S21 or 145.525 MHz. Frequencies (backwards from the power amplifier or PA) will be 145.525, 72.7623, 24.2541 and 8.0847 for the oscillator. So with the counter with 30 MHz upper frequency limit, it could be coupled at 1, and trimming adjusted for 8.0847 or 8.0848. Alternatively, couple at point 2 and adjust the trimmer for 24.2541 or 24.2542. Similarly, for S20, frequencies would be 145.5, 72.75, 24.25 and 8.0833.

Similar considerations apply where the oscillator operates with 6 MHz or 12 MHz crystals, with the following stage providing 4x or 2x to obtain 24 MHz.

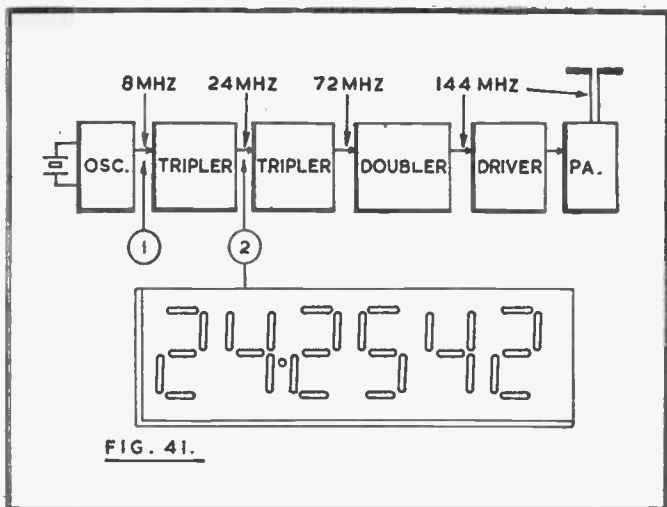Exact setting is not necessary, though if the frequencies are

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FIG. 41.

substantially in error speech quality will be very poor, as the transmitted signal will not fall correctly in the pass-band of the listener's fixed-tuned receiver.

The method of coupling should be such, as not to upset the transmitter frequency, while providing complete DC isolation, and very loose coupling will be sufficient with a counter of good sensitivity. Clip the counter input lead ground to the transmitter chassis or ground circuit. Coupling to a point such as 1 can then be tried by a single half-turn or 'hook' of well insulated wire, placed round the coil connection or lead at the live end of the coil. At point 2, where the RF level is higher, it may be adequate to hold an insulated lead near, or touching at right angles, to the RF circuit concerned, even with attenuation selected at the counter. Loading circuits at points such as 2 will not normally cause any change in frequency (though RF drive to later stages may be slightly reduced). With coupling at 1, loading must be as light as possible to avoid undue changes in frequency.

By this means a single channel, or the number provided by a multi-way switch, may all be checked and set to allow

immediate working. This method can also be used to calibrate a variable frequency oscillator, such as may be used for the AM sector, or other purposes.

Repeater Access

Activation of a repeater on its channel is typically by means of an audio tone, followed by speech, and may be at 1750 Hertz, plus or minus 50 Hertz (some specify closer tolerances). The counter operating on a low frequency range will thus allow setting an adjustable oscillator to frequency.

An oscillator adjustable over a fairly narrow range around that required is shown in Figure 42. With R4 being 220 ohm, it may be run from a 12V to 15V supply. Operation from a 9V battery is possible by omitting R4 and the Zener diode.

Output is coupled by C2 into the audio amplifier of the modulator. One method is to take this through a high value series resistor (470k or larger) to an early stage, so that this connection can remain permanently made without affecting speech. An alternative is to have this circuit completed by the second pole of a 2-pole push switch, the other pole of which closes the circuit to R4, to bring the oscillator into action.

If R1 is relatively large, compared with VR1, adjustment of the latter is less critical, though a narrower range of frequencies can be covered. Frequencies obtainable can be modified by changing R1 (or VR1) or C1.

Checking of tone access naturally requires that a receiver, or converter and receiver, will be available for off-set reception of the repeater, and listening will show that the signal is within range and the repeater is operating. When other signals have dropped out, briefly operate the tone button, and follow at once with the station call (some repeaters require a minimum of five seconds' speech).

The actuation of repeaters towards the limit of range will depend on propagation conditions, so may be possible some

FIG. 42.
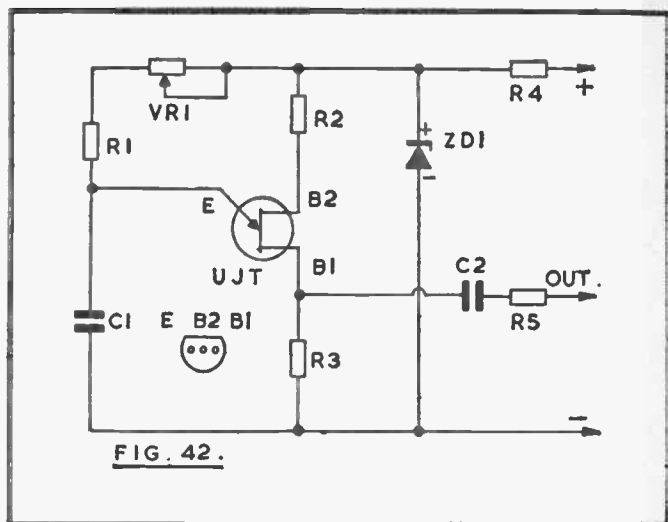
days, but not others, and in cases of doubt, a quick test of equipment can usually be made on a more local repeater.

Components: Oscillator Figure (42)

R1	68k (Resistors 5% ¼W)
R2	560 ohm
R3	820 ohm
R4	220 ohm
R5	22k
VR1	25k linear potentiometer
C1	10 nF
C2	10 nF
UJT	UT46 unijunction transistor
ZD1	9V Zener diode, 400 mW

Heterodyne Frequency Meter

This frequency meter or frequency standard allows critical determination of frequencies in the 3.5, 7, 14, 21 and 28 metre

FIG. 43.
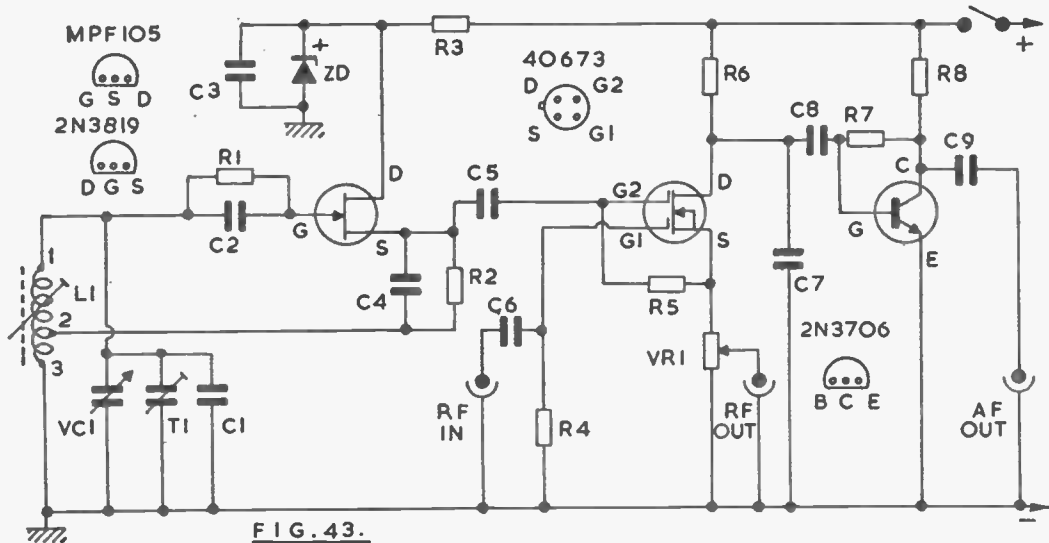
amateur bands. Where the heterodyne method is used, the unknown frequency is found by beating it with a signal of known frequency. When there is a small difference between these two frequencies, this is heard as an audio tone. Thus, beating together signals at 3,500 kHz and 3,501 kHz, would result in an audio tone of 1 kHz, or 1000 Hz. As the signals come more nearly to the same frequency, the difference grows smaller, so the tone heard falls in pitch. Eventually, when both signals are at the same frequency, there is no difference, no heterodyne is produced, and no tone is heard. This is called 'zero beat'. By tuning to zero beat in this way, using a stable calibrated oscillator and its harmonics, critical determination of frequency is possible.

The frequency meter, Figure 43 uses three transistors. The MPF105, 2N3819 or similar type acts as oscillator, the dual-gate 40673 as mixer, and the 2N3706 as audio amplifier. There are two output sockets, and one input socket. RF input may be taken for calibration of the frequency meter from a crystal harmonic marker, or from a source of RF whose frequency is to be determined. RF output can be taken to external equipment where calibration is from the frequency meter. The AF output is to take headphones, when the frequency meter variable frequency oscillator or VFO is to be compared with RF input, and the result of mixing in the dual-gate FET is to be heard, to find zero beat.

Inductor L1

This is wound on a 3/8 in. or 9.5mm. diameter former, Figure 44. Lead 3 is as near the pin end of the former as possible, and eight turns are wound to loop 2. From here, a further 25 turns in the same direction allow the winding to finish at 1. Apply a little clear adhesive to secure the turns.

When construction is complete, adjustment of L1 in conjunction with trimmer T1, allows some modification of band coverage. With T1 near minimum capacitance, and L1 core fairly well in, band coverage is greatest. This is reduced by closing T1, and unscrewing L1 core, until coverage is from
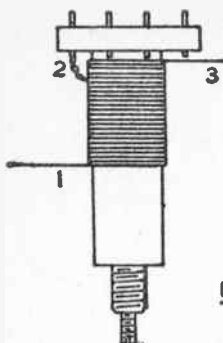
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FIG. 44.

3.5 MHz to 3.8 MHz, without the extreme maximum and minimum settings of VR1 being used.

To secure exact calibration of these and the 3.6 and 3.7 MHz points, take the output of a 100 kHz crystal harmonic marker, such as described earlier, to the RF IN socket. Plug 2,000 ohm or similar high impedance headphones into the AF OUT socket. The 3.5, 3.6, 3.7 and 3.8 MHz tuning points for VR1 will then be heard as the zero beat settings for the crystal marker harmonics. Enter these readings as accurately as possible on a graph giving dial readings against frequency. Tuning for all intermediate frequencies can then be taken from the graph. It is also possible to use a 1 MHz marker with decade divider; or a marker with dividers which provides 10 kHz harmonics, to fill in between the 100 kHz points.

When harmonics are in use, these will be the appropriate multiple of the dial reading. That is, 3.5 MHz will become 7 MHz, 14 MHz, 21 MHz and 28 MHz, for the 40, 20, 15 and 10 metre bands. The other required frequencies are arrived at in the same way. Thus 5.55 MHz will be 7.1 MHz, 14.2 MHz, 21.3 MHz and 28.4 MHz. Similarly, 3.6 MHz will be 14.4 MHz, or 3.7 MHz will be 29.6 MHz, and so on.

RF input may be from a transmitter variable frequency oscillator, or in some cases as pick up from the transmitter without direct coupling, and frequency can then be found from the calibrated scale of VC1.

RF output can be into a receiver, either by coupling through a small capacitor, or by placing a lead from the RF OUT socket near the receiver aerial socket or aerial lead. The frequencies covered by VC1, and the harmonics as described, will then be heard up to 30 MHz and higher, with the receiver beat frequency oscillator in use. A receiver may also be employed to find zero beat between frequencies obtained by adjustment of VC1, and those from other equipment, and in these circumstances the receiver BFO is not brought into use. Accuracy will depend on the critical adjustment of the two sources of oscillation, not upon the tuning of the receiver, which is only a means of finding zero beat.

Construction should place the heterodyne frequency meter in a rigid, screened box, and strong mechanical construction is recommended so that calibration is accurately maintained. VC1 should have a good quality reduction drive. The accuracy of calibration can be checked at any time by applying the 100 kHz crystal standard to the RF IN socket, and tuning for zero beats, with phones plugged into the AF OUT socket. Operation is from a 9V battery.

Components: Heterodyne Frequency Meter (Figure 43)

C1	150 pF silver mica
C2	100 pF silver mica
C3	10 nF
C4	1 nF
C5	27 pF
C6	27 pF
C7	2.2 nF
C8	0.1 μF
C9	0.1 μF
T1	25 pF air-spaced trimmer
VC1	50 pF variable capacitor

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R1	1.2 megohm (Resistors 5% ¼ watt)
R2	1.5k
R3	220 ohm
R4	820k
R5	100k
R6	2.2k
R7	·270k
R8	2.7k
VR1	1k linear potentiometer with switch
Tr1	MPF105, 2N3819
Tr2	40673
Tr3	2N3706
L1	1 1/8 x 3/8 in. (9.5mm.) dia. cored former (Denco, Clacton-on-Sea) 33 turns 24 swg enamelled wire
ZD	6V 400 mW zener diode
	Case, reduction drive with scale, knob, sockets, etc.

Transmitter Monitoring

Various aspects of transmitter operation can be observed with an oscilloscope. Where the upper frequency of operation of the scope is too low, radio frequencies can be applied directly to the plates to cause vertical deflection. Typically, a voltage swing of some 100V to 300V or so will be needed here. This is generally available from a parallel resonant tuned circuit, link coupled to the transmitter output, A, Figure 47. Very high voltages can be made available in this way, so coupling by the link loop should be reduced, or the resonant circuit supplying the plates should be de-tuned, where the trace is too long.

Deflection of the trace in the horizontal direction is obtained from the audio modulator, for testing amplitude modulation. With equipment using valve modulators, sufficient sweep may be obtained directly from the modulation transformer, by coupling this through an isolating capacitor to a potential divider feeding the horizontal plates. A variable potentiometer will allow the voltage swing at the plates to be adjusted.
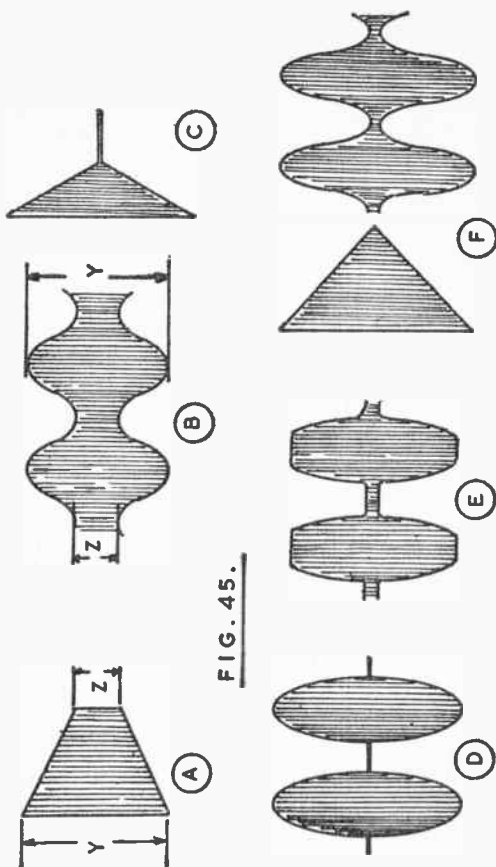
FIG. 45.

With modulation, a display resembling that at A in Figure 45 will be obtained. The modulation percentage is as follows:

$(Y - Z)/(Y + Z) \times 100$

As example, if Y is 3 cm and Z is 1 cm, then $(3 - 1)/(3 + 1)$

= 2/4 and 2/4 x 100 = 50%

Where horizontal sweep is applied to the tube, no audio coupling is required. The display then resembles B, Figure 45. Similar methods of determining modulation apply.

As modulation is increased, depth Y increases, and is twice the height of the unmodulated carrier at 100 per-cent. Audio drive beyond this point results in over-modulation or interruption of the carrier, causing interference, and is shown by patterns like C (line beyond trapezoid) and D (line between envelope outlines).

Critical examination of displays will be much easier if input to the transmitter is from an audio oscillator. Speech should just fail to produce the carrier breaks described, seen as bright, straight flashes. Overloading of the modulator produces flattening before full modulation is reached, E. Displays F are for about 100 per-cent modulation.

With a scope with amplifier, enough RF for patterns of type B can be picked up by a small capacitance from the transmitter dummy load, or even by means of a short insulated lead near the latter, or near an unscreened aerial or tuner lead carrying RF.

Transistor transmitters operating on low voltage will produce equal RF voltages across a parallel tuned circuit for driving the CRT plates directly, for equal power. However, high modulator voltages will not usually be available, so amplification on this aixs will be required for displays of type A, or the use of a step-up transformer.

CRT Display Unit

Some transmitter operating conditions can be displayed directly on a cathode ray tube without the need for a time-base, or X or Y amplifiers. A display unit of this type is a relatively simple piece of equipment to build, using a small CRT which will operate from an easily obtained HT supply,

very high voltage being unnecessary. The displays obtainable are limited as there is no timebase, but by driving the deflection plates directly a very high upper frequency limit is obtainable, and a conventional scope may sometimes be used in this way, to secure this advantage.

The circuit shown in Figure 46 is divided into two sections — the power supply unit, and cathode ray tube controls and associated components. The PSU uses a standard 250–0–250V 60 mA or similar transformer. Two silicon rectifiers supply the positive line reservoir capacitor C1. With a 250V secondary, peak voltage will be approximately 1.4 times this, or about 350V, so C1 (and the other capacitors here) is best of 375V or 400V working. The peak inverse voltage across the recitfiers will be twice this, or around 700V. It is convenient to use 1N4007 or similar 1A 1 kV rectifier diodes. Resistor R1, with C2 offers some smoothing, so that about 350V relative to chassis will be obtained across C2.

The other two silicon rectifiers, with C3, R2 and C4, produce a similar supply of about 350V peak, but negative with respect to the chassis. It is thus possible to take approximately 700V from the points shown, for the tube circuit.

The CRT pin numbers are for the 3BP1, which is 3 in. (76mm.) and green, medium persistence. Other similar tubes may be used. The 3PB1 is here operating with about one-half its full voltage, but was found to provide reasonable brilliance. To increase voltage, it would be necessary to use a 350–0–350V or higher voltage transformer, or a voltage-multiplying rectifier circuit, and to increase the capacitor and rectifier ratings as necessary, or employ these in pairs with voltage equalising resistors across them.

This CRT requires a 6.3V heater supply, and the winding on the transformer normally present for use with a valve type rectifier is employed. This winding is at high voltage negative.

There is considerable latitude in the type of power supply circuit used, and in capacitor values and other items. Note that if the PSU is tested alone, the capacitors may retain a

FIG. 46.
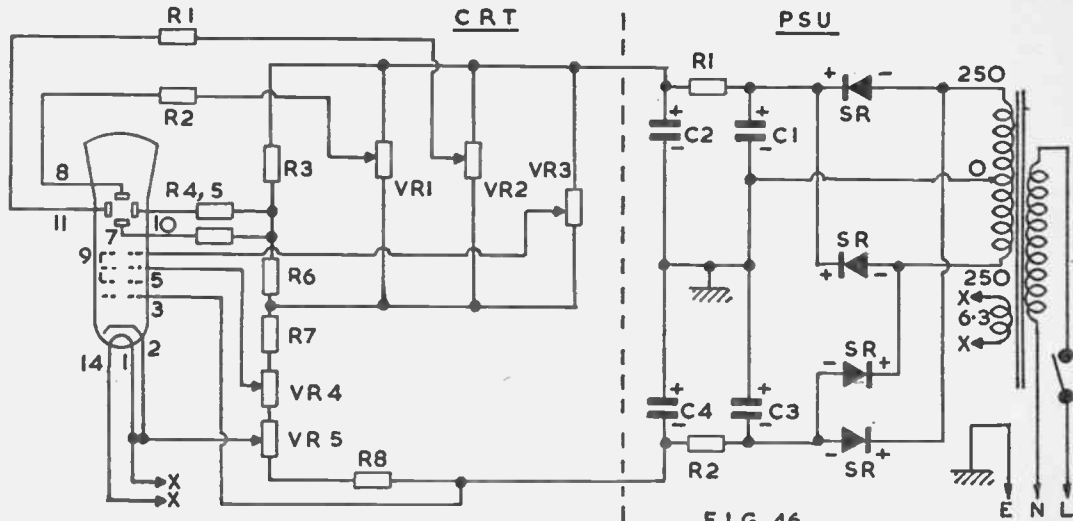
charge for a considerable time. If wished, bleeders of about 100k can be connected across C1 and C3.

R1 and R4 are in series with the horizontal deflection plates (10 and 11) and R2 and R5 in series with the vertical plates (7 and 8). Trace deflecting voltages can thus be taken directly to the plates. One vertical and one horizontal plate potential is obtained from the divider formed by the two equal resistors R3 and R6. The opposite plates receive the voltages available from VR1 and VR2, which perform as vertical and horizontal shift controls to move the trace on the CRT screen.

VR3 is for astigmatism, and VR4 (slider to 5) for focus. These adjust the spot shape and size.

VR5 (and also the value of R8) controls the voltage between cathode (2) and grid (3) and thus the brilliance. When the grid is excessively negative relative to cathode (all of VR5 in circuit from cathode to R8) bias cuts off the emission.

A bright spot should not be allowed to remain on one point of the CRT screen, in the absence of any input to vertical or horizontal plates to deflect it, or a burn may permanently mark the screen.

When first testing this circuit, VR1 should move the spot up and down, and VR2 from side to side, while VR5 adjusts brightness. Results obtained depend to some extent on limitations of the PSU. With full voltage, sensitivity is 0.2mm./v on the Y axis, and 0.15mm/v on the X axis. That is, 5V will move the trace 1mm. on the Y axis, or 50V will move it 10mm., and so on. With operation at reduced voltage, sensitivity is raised.

This sensitivity is fairly typical of small instrument tubes. Alternatives may have different pin numbers, and a different heater voltage. The heater must receive its correct voltage.

If three resistors, of 2.2 megohm, 2.2 megohm, and 1.5 megohm, are connected in series, from 10 of the CRT to one 250V secondary tag of the transformer, this would be expected

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to give a scan of about 30mm. on the screen. Rotate the tube to bring this horizontal.

Construction should place the transformer well clear of the tube, or magnetic effects may blur the trace. Surplus tubes are occasionally provided with a mumetal screen, and this should be retained. Where no screen is present, metal for this will be costly.

The CRT can be fitted to a wooden or metal mount shaped to fit, with clearance to take some soft rubber or similar packing, and a metal clamp over it, also with soft packing.

The fixed resistors may be soldered directly to the CRT holder tags, and associated potentiometers. It will be necessary to obtain connections to vertical and horizontal plates tags, to obtain a display.

In the PSU section, rectifiers and capacitors are best mounted on tag strips. Take care with C3 and C4, as insulated types are best here, since the cans of metal types will be at high voltage negative. Remember that high voltage is present, but with suitable construction and shielding of mains and HT points, no particular danger should exist. Power is drawn from a 3-pin plug which also provides earthing of the chassis. Fit a 2A or 3A fuse.

Components: CRT Display Unit (Figure 46)

R1, R2, R4, R5   560k (Resistors ½W 5%)
R3, R6   330k
R7   470k
R8   8.2k
VR1, VR2, VR3, VR4   500k (470k suitable) linear
VR5   25k linear
3BP1   B14A holder

PSU

C1, C2, C3, C4   1′µF, 375V minimum
SR   4 x 1k piv

250--0--250V   6.3V 1A transformer
Chassis, case, panel and knobs, etc.

Voltage Doubler

With some tubes and operating conditions it may be felt
worthwhile to brighten the trace. This is most readily
achieved with the circuit in Figure 46 by altering the negative
supply into a voltage doubler. The circuit for this is shown in
Figure 47B. Approximately 1,000V will then be obtained for
the CRT. The potentiometer and other values remain as in
Figure 46. As a potential of some 700V or more will now be
present on the negative line, with respect to the chassis,
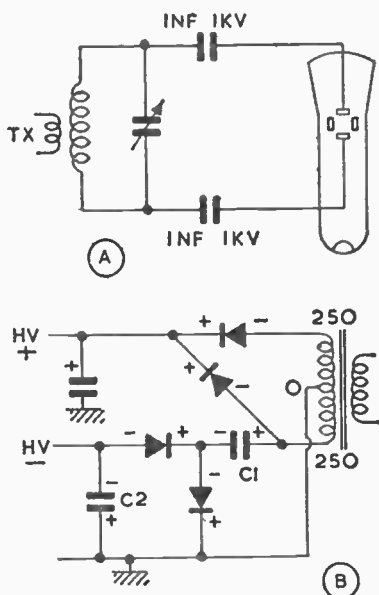construction, insulation and layout must be safe for this.

FIG. 47.

Single Sideband

With some carrier inserted, a display similar to A in Figure 48 should be obtained, with the scope set up as for B in Figure 45. A stable sine wave will provide the most readily examined display, but is not essential.

With carrier reduced, the height of the display should fall. With balanced carrier conditions and no modulation, only the horizontal trace should be obtained, and carrier balance can be adjusted for this. During tune-up and loading, adjustments can be directed towards obtaining maximum RF output, or vertical amplitude of the trace.

With a 2-tone input, a display resembling that at B should be obtained. Tones may be 600 Hz and 1 kHz. There are straight cross-overs, and no distortion to the envelope.

Distortion will be shown when operating conditions are not correctly adjusted. C has flattened peaks from excess drive, and D incorrect power amplifier bias.

FIG. 48.
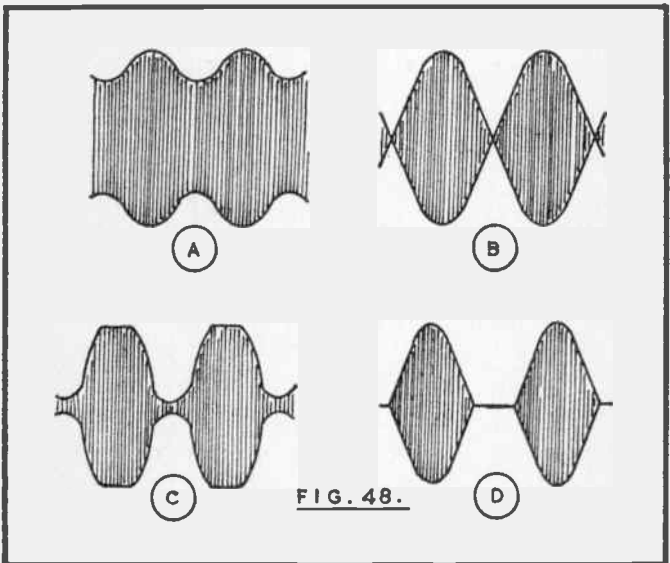
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