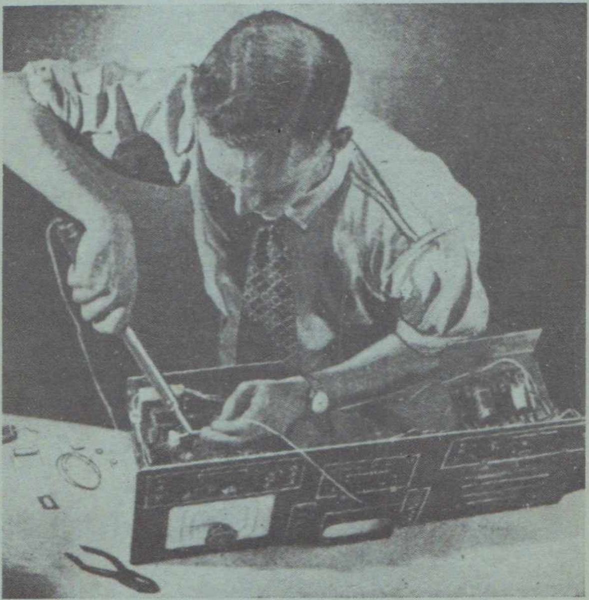
AUSTRALIAN RADIO & TELEVISION COLLEGE PTY. LTD.

PRACTICAL RADIO COURSE



of

HOME PRACTICAL INSTRUCTION

Lesson No. 7

CONSTRUCTING A THREE-VALVE RECEIVER AND TEST INSTRUMENTS.

This lesson will show you how to:—

RESISTOR COLOUR CODE.

Body Colour or First Coloured Ring	First Digit	End Colour or Second Coloured Ring	2nd Digit	Dot Colour or Third Coloured Ring	Remaining Digits
Black	0	Black	0	Black	—
Brown	1	Brown	1	Brown	0
Red	2	Red	2	Red	00
Orange	3	Orange	3	Orange	000
Yellow	4	Yellow	4	Yellow	0,000
Green	5	Green	5	Green	00,000
Blue	6	Blue	6	Blue	000,000
Violet	7	Violet	7	Violet	0,000,000
Grey	8	Grey	8	Grey	00,000,000
White	9	White	9	White	000,000,000

EXAMPLE.

A resistor of 250,000 ohms would have a red body or first coloured ring indicating that the first figure was 2, a green end or second ring indicating that the second figure was 5, and a yellow dot or third ring indicating that there are four noughts. Similarly a 25,000 ohm resistor would have a red body or ring and green end or ring and an orange dot or ring. In this case the dot would indicate that there are only three noughts after the first two digits.

HOME PRACTICAL INSTRUCTION
LESSON No. 7

The large assortment of parts contained in Practical Kit No. 7 will enable you to conduct a great many interesting and varied experiments in improving the performance of your receiver and also in constructing a number of testing instruments. To begin with, we will effect various improvements in the receiver's construction which will enable it to perform more successfully. Then we will conclude the experiments with a number of test instruments which you can employ for testing some of the parts supplied to you or for testing a radio receiver, if you have one.

The principal improvements to the receiver you constructed with Practical Kit No. 6 will be to add an extra valve, firstly as an audio frequency amplifier and then as a radio frequency amplifier. You will also be able to conduct a number of experiments with tone control systems.

Due to manufacturers producing resistors in certain "preferred" values only, it is not always possible to supply resistors marked exactly in accordance with the values shown on the diagrams in this book. Where diagrams show resistors whose first two numbers are 50, it is sometimes necessary to substitute resistors whose first two numbers are 47. This will make no difference to your experiments.

The following materials are contained in Kit No. 7 and I suggest that you check the list through carefully to see that everything is present:

1 Metal Chassis.
1 Length of resistor panel.
1 1T4 Valve.
1 Bantam 7 pin valve socket.
2 ⅜" x 8BA bolts and nuts.
1 5 or 4.7 megohm resistor.
1 1 megohm resistor.
1 .1 megohm resistor.
1 50,000 or 47,000 ohm resistor.
1 15,000 ohm resistor.
1 10,000 ohm resistor.
1 5.000 or 4,700 ohm resistor.
1 500 or 470 ohm resistor.
1 1 megohm potentiometer.
1 .1 megohm potentiometer.
1 .1 mfd. tubular condenser.
1 .02 mfd. tubular condenser.
1 .01 mfd. tubular condenser.
1 .001 mfd. mica condenser.
1 .0001 mfd. mica condenser.
2 Adjustable trimmer condensers.
1 Length of 1½" dia. coil former.
1 Coil mounting bracket.

6" 20 s.w.g. resistance wire.
1 Pointer knob.
6" Varnished insulating type.

Immediately upon unpacking the parts, examine the 1T4 valve supplied to see that the glass is not broken and also test the filament by applying the test leads from your ohmmeter to Pins 1 and 7. With the leads plugged into the socket marked "Low Ohms", the meter should indicate a resistance of approximately 25 ohms. The valve has been carefully tested before being despatched to you, so it should arrive in perfect condition.

EXPERIMENT 1.

A.F. AMPLIFIER.

The 1T4 valve supplied is a pentode voltage amplifier which can be employed for the amplification of either audio frequency or radio frequency signals.

The first application for this valve will be to use it as an audio frequency amplifier to amplify the signals coming from the 1S5 detector stage and strengthen these signals before they are finally applied to the grid of the 3S4 power output valve.

rent for the other valves and the amplified signals emerging from the 1T4's plate circuit are passed through a .02 mfd. condenser to the grid of the 3S4.

In order that the 1T4 valve may give its greatest degree of amplification, it is necessary that it have just the right amount of screen grid voltage supplied. Instead of feeding the screen grid through a fixed resistor, which would give just one value of screen grid voltage, which might or might not be correct, we will make use of the 1 megohm potentiometer supplied in this kit to furnish

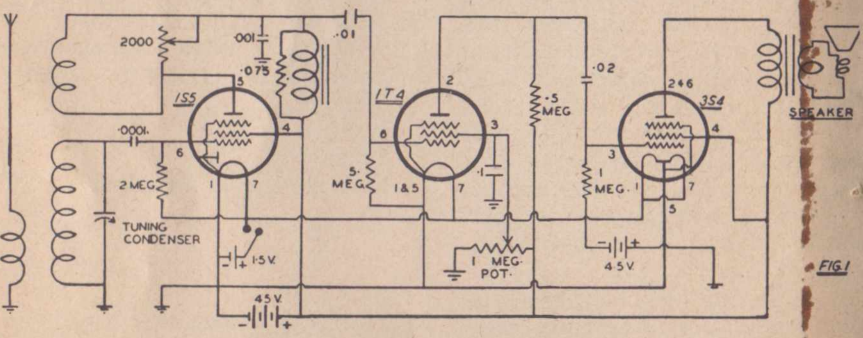


FIG. 1

The circuit arrangement showing the manner in which the 1T4 valve is wired between the 1S5 and 3S4 is shown in Figure 1. On examining this diagram, you will find that the signals emerging from the plate circuit of the 1S5 through the .01 mfd. condenser are now applied to the control grid of the 1T4 valve instead of the 3S4. The filament of the 1T4 valve is heated from the same 1.5 volt battery which furnishes cur-

a variable amount of screen grid voltage, so that the performance of the valve can be studied as the screen grid voltage is changed from zero, when the sliding arm on the potentiometer is moved to the left hand end, as shown in Figure 1, or as the voltage is gradually increased when the potentiometer is rotated and its arm moved towards the right hand end. With the potentiometer turned fully in a clockwise direction, the screen grid will receive the full 45 volts from the battery, so that its voltage will be higher than that applied to the plate of the tube. You will find, under these conditions, that the valve does not give very much amplification. In practice, the screen grid voltage of a voltage amplifying tube should always be lower in value than the plate voltage and consequently you will find, as you adjust the 1 meg. potentiometer, that at some point, about half way through its rotation, the amplification of the 1T4 valve is greatest and the signals loudest.

ASSEMBLY.

Before attempting to make any alterations to the receiver, you should disconnect both A and B batteries in case the soldering iron, a bead of solder or stray piece of wire should cause a short circuit whilst working on the set and damage the batteries. The valves should also be removed.

The valve socket for the 1T4 valve should be mounted in the hole almost directly behind the tuning condenser gang on the chassis supplied with kit 5. Socket contacts 1 and 7 (the two widely spaces ones) should point towards the aerial and earth terminals on the rear of the chassis.

The 1 megohm potentiometer can be mounted in the vacant hole in the centre of the front flange of the chassis.

WIRING.

The connections to the 1T4 valve socket can be fairly readily followed from the circuit diagram of Figure 1, the photograph of Figure 2 and the wiring diagram shown in Figure 3.

The first step is to connect Pin 5 on the valve socket to the tinned copper earth wire running around the chassis and also extend a connection from Pin 5 to the metal sleeve in the centre of the valve socket, so that this, too, will be connected to the earth wire. If you have not already earthed the metal sleeve in the centre of the other two valve sockets, you should do so at this stage by connecting the sleeve to Pin No. 1 on the 1S5 valve socket and to Pin No. 5 on the valve socket for the 3S4. Filament voltage is applied to the 1T4 by connecting Pin 7 on its socket to Pin 1 on the 3S4 valve socket.

Socket contact 3 connects to the screen grid of the valve, so a wire should be run from this lug to the centre lug on the 1 megohm potentiometer. The left hand lug on the potentiometer in Figs 2 and 3, is connected to the right hand end of the iron cored transformer, so that B plus voltage is applied to it, and the right hand lug on the potentiometer is connected to the 18 gauge earth wire.

After fitting these wires in place you may proceed to install the various small resistors and condensers. The .01 mfd. condenser, which previously

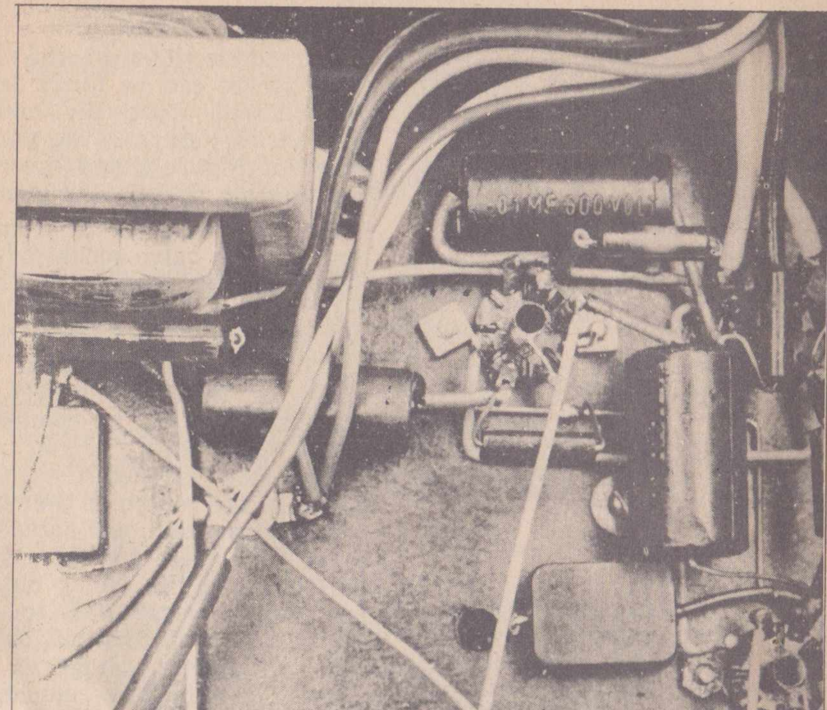


Fig. 2.

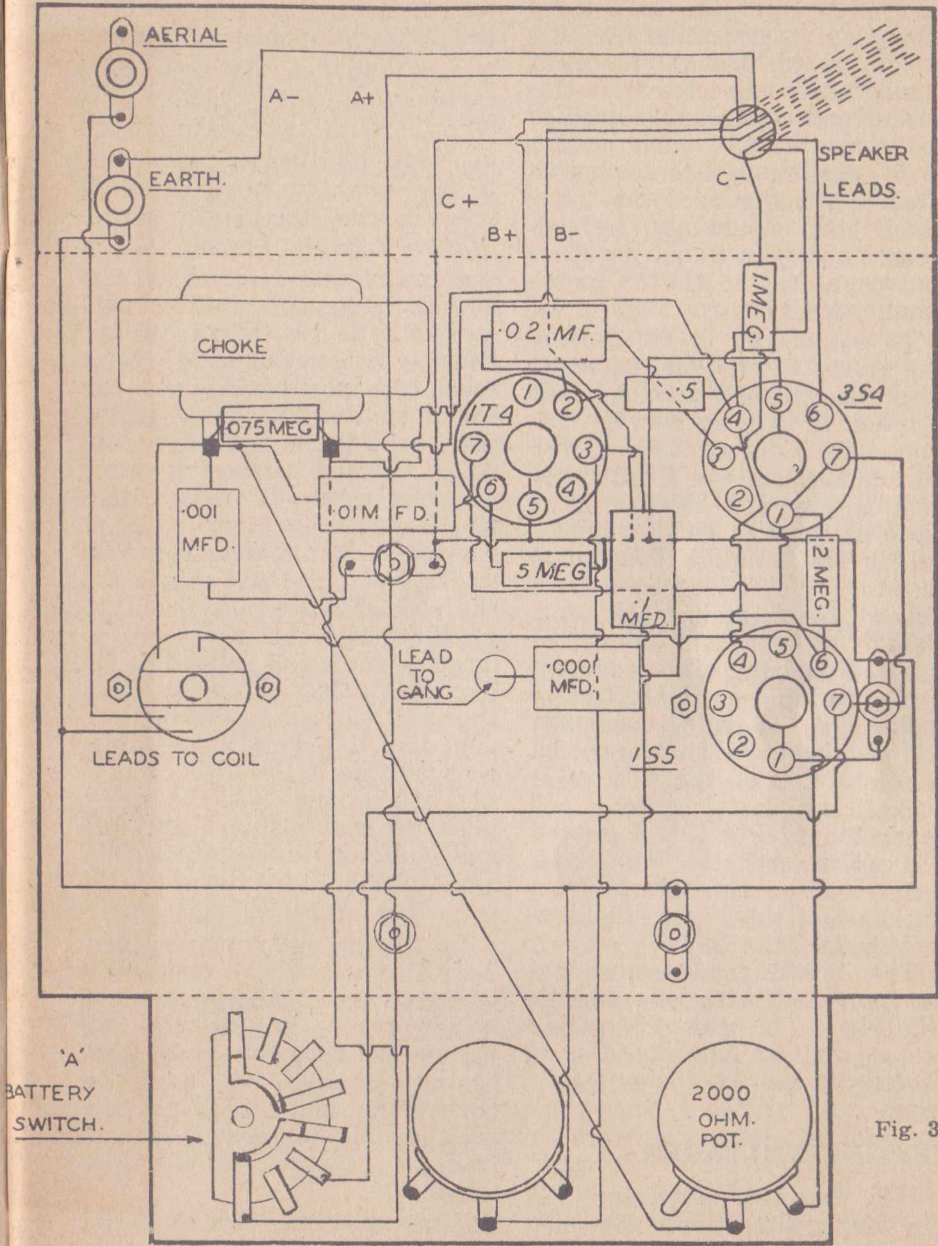

AERIAL
EARTH.
A−
A+
C+
B+
B−
C−
SPEAKER LEADS.
CHOKE
·02 MF.
·075 MEG
·001 MFD.
·01 MFD.
1T4
3S4
1 MEG.
·5
5 MEG
·1 MFD.
2 MEG.
LEAD TO GANG
·0001 MFD.
LEADS TO COIL
1S5
'A' BATTERY SWITCH.
2000 OHM. POT.

Fig. 3.

connected from the iron cored choke or transformer to Pin No. 3 on the 3S4 valve socket, should be disconnected from this socket and connected instead to No. 6 on the 1T4 valve socket. A 5 megohm resistor, coloured green with the exception of a black end, should also be connected onto Pin 6 and its other end connected to the 18 gauge earth wire.

To assist you in recognising the values of the various resistors you will find a colour code printed in A.R.C. Service Engineering Course, Lesson No. 10 and also on the front cover of this practical lesson. The plate of the 1T4 valve connects to Pin No. 2 and a .5 megohm resistor, coloured green with a yellow band and black end, should have one end connected to Pin 2 and the other end connected to Pin 4 on the 3S4 valve socket. A .02 mfd. condenser will also have one end connected to Pin No. 2 of the 1T4 valve socket and its other end connected to Pin No. 3 on the 3S4 valve socket. This condenser carries the signals from the plate of the 1T4 to the control grid of the 3S4.

The .1 mfd. condenser should be connected with one end to Pin No. 3 on the 1T4 valve socket and its other end connected to the 18 gauge earth wire.

TESTING VOLTAGES.

Now that you have completed the wiring alterations, you may reconnect the batteries, but, before inserting the valve, check the voltages applied to the 1T4 socket, and see that you have carried out your wiring correctly. With the negative lead of your multimeter connected to the earth terminal or earth wire on the chassis, touch the positive lead to Pin No. 2. If the instrument is used on the 50 volt range, the needle should move a little less than 1/10th of the way across the scale. Next touch the positive lead to Pin No. 3 on the 1T4 valve socket and you will find here a reading which changes between zero and 45 volts as the 1 meg. potentiometer on the front panel is rotated. Next touch the lead to Pin No. 7 and you should see the pointer move only about 1½ graduations across the scale indicating the small voltage of 1.5 from the A battery. Next touch the positive lead to Pin 6. Here you should obtain no reading, because this is the grid connection of the valve. If the meter indicates that voltages are normal, you may safely proceed to plug in the 1T4 valve and observe the set's performance.

On trying out the receiver, you will find that the sensitivity of the set is far superior to what it was when you had only two valves operating. Signals from nearby stations will come in quite loudly and clearly and you will be able to receive signals from more distant stations than previously.

When you first try out the set, you may find that, as you turn on the 2,000 ohm potentiometer to increase the amount of regeneration, there is a tendency for the receiver to produce a pulsing or "motorboating" sound. If you do experience this trouble, then you will be able to rectify it by connecting either the 75,000 resistor supplied to you in Kit No. 4 or the 50,000 ohm resistor supplied in this kit across the two outside terminals of the iron cored transformer. Try holding the 75,000 ohm resistor across these terminals firstly and, if this rectifies the trouble, solder it in place. If the 75,000 ohm resistor does not cure the trouble, then solder the 50,000 ohm resistor into position.

On bringing your hand near the 1S5 valve, you may experience some trouble with the receiver producing a very loud humming or roaring sound. If this is so, you can overcome the trouble by procuring a piece of tin or any other thin metal about 2" x 1½" and rolling it to form a cylinder or sleeve which will fit around the 1S5 valve. If you place this sleeve over the 1S5 valve and allow the metal to rest on the chassis or on the metal flange of the valve socket, you will find that this "electrostatic" pickup of stray voltages from your body is eliminated.*

When your receiver is working nicely, you should notice particularly the effect of the 1 megohm potentiometer on the sensitivity of the set. You will note, that, if you start with the potentiometer turned in an anti-clockwise direction, the receiver is silent, because the 1T4 valve cannot amplify without any positive voltage applied to its screen. As you gradually rotate the potentiometer, the loudness of signals will increase steadily to a maximum when the control is turned about halfway around. If you continue turning the control, you will find that the signals, although they do not cease, become softer again, because the screen voltage becomes higher than the plate voltage. This will show you how important it is to have the right screen voltage applied always to pentode valves.

* See A.R.C. Service Engineering Course Lessons No. 21 and 37.

THE 1T4 AS A TRIODE.

Triode valves in general will not provide as much amplification as pentodes and consequently you can compare the relative efficiency of a triode and pentode by making the IT4 operate as a triode. This is easily done by disconnecting the .1 mfd. condenser from the screen of the valve and disconnecting the long wire running to the centre lug of the potentiometer from the potentiometer and connecting it instead to Pin No. 2, which is the plate pin. By joining the screen grid and plate together, the valve operates as a triode, because we then have effective only the filament, control grid and plate. The screen grid and plate act together as a plate. (See Fig. 4.)

If you have the receiver tuned to a station before making the change and then switch off and rapidly make the change and switch on again, you will find that the signals are noticeably weaker when the valve is acting as a triode, because of its lower amplification. When acting as a pentode with a .5 megohm resistor connected to its plate, the 1T4 will provide an amplification

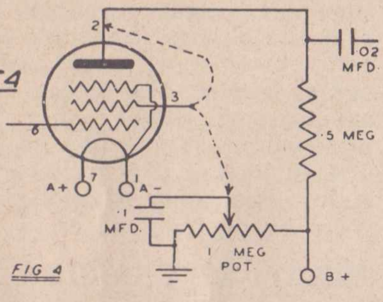


FIG 4

of approximately 30 times, but, when connected as triode, its amplification factor is 10 times, but the actual stage gain provided by the tube working in conjunction with the .5 megohm plate load resistor will only be about 8 times.

EXPERIMENT 2.

TONE CONTROLS.

Engineers in a broadcasting station go to a great deal of trouble to preserve a correct and natural balance between treble notes, middle pitched notes and bass notes when music is being transmitted. Theoretically, if a receiver is designed on the same basis, it should not be desirable to alter, at the receiver, the balance between the treble and bass notes. However, most commercial receivers are fitted with a "tone control" to enable the listener to alter the balance between bass and treble notes to his own liking. There is a tendency on the part of pentode power output valves, when operated in conjunction with loud speakers, to over emphasise the treble notes, and consequently most tone controls fitted to receivers are of a type which allows the treble notes to be weakened to avoid this over emphasis or even weakened still further to make them lower in strength than the bass frequencies. This tends to make the bass frequencies stand out at a greater level than middle and treble notes, and gives the effect of the bass frequencies being accentuated.

Another purpose for a tone control is that, by weakening the reproduction of treble notes, it also minimises the reproduction of static and hissing sounds which usually accompany a programme. Most of these annoying static and hissing sounds represent rather shrill audio frequencies and, by using a tone control to weaken the higher frequencies, these signals are weakened more than middle pitched and bass pitched musical notes.

There are a number of ways of applying tone control systems in radio receivers and three different methods are explained, with which you can conduct experiments on your receiver.

(A) The circuit arrangement of the first tone control is shown in Figure 5. The alterations to the set are emphasised by heavy lines on the diagram. It will be necessary to remove the 1 megohm fixed resistor from the control grid circuit of the 3S4 valve and to wire this C Battery. Between the centre lug of the potentiometer and the outside lug which connects to the C battery, you should connect first a .001 mfd. condenser.

With the potentiometer turned in an anti-clockwise direction, so that the sliding arm is at the end marked 1 in Figure 5, the .001 mfd. condenser

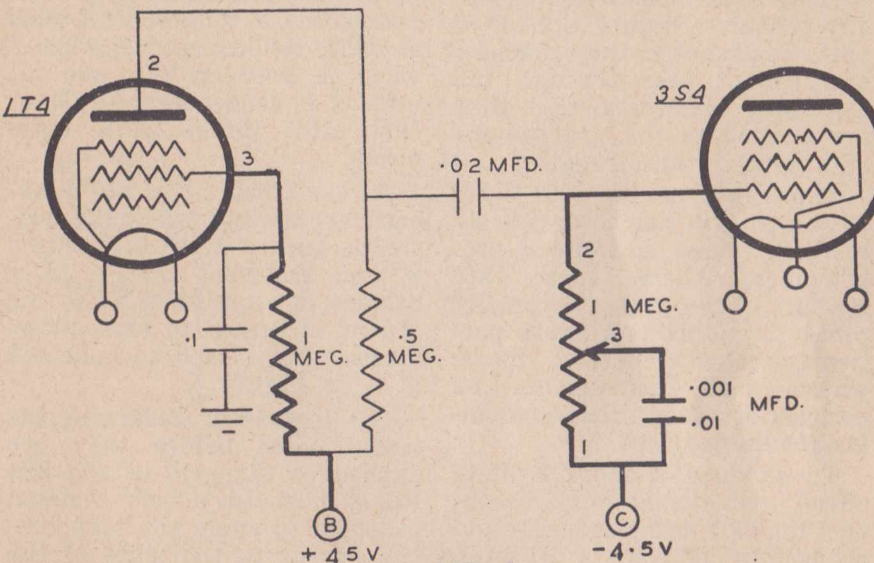


FIG. 5

in the screen grid circuit of the 1T4. The 1 megohm potentiometer can then be connected in the control grid circuit of the 3S4. Be certain to disconnect one end of the 1 megohm potentiometer from the earth wire running around the chassis, because this end must instead be connected to a long lead which joins, at its other end, to the negative terminal on the 4½ volt will have no effect and the full range of audio frequencies will be reproduced without the treble notes being weakened. By moving the potentiometer shaft to the other extreme position corresponding to Position 2 in Figure 5, the .001 mfd. condenser is connected directly between the grid of the 3S4 and C battery, so that the treble notes in a musical programme will find an easy path through the .001 mfd. condenser and C battery to chassis.

As you quite well know, high frequencies produce a much lower reactance in a condenser than do low frequencies. Therefore, the high frequencies can pass through the condenser fairly readily.

On the other hand, middle pitched notes and bass frequencies produce a higher number of ohms reactance in the condenser and cannot pass through the condenser readily, so that they are applied to the grid of the 3S4 at their full strength.*

The effect of the .001 mfd. condenser will not be extremely marked, except on musical programmes where there are strong treble notes normally present. This will apply particularly to orchestral music where such instruments as piccolos or other shrill wind instruments are used.

To produce a more definite effect, you should next disconnect the .001 mfd. condenser and connect in its place a .01 mfd. condenser. You will find that as you now rotate the shaft of the 1 meg. potentiometer, a much greater effect is noticeable, and when the shaft is turned to Position 2 on Figure 5, the treble notes will be severely weakened. In fact, the reactance of the .01 mfd. condenser will be so low that, not only the treble notes, but most of the middle pitched notes will be weakened also, leaving only the deep bass notes to be reproduced at their original loudness. Because both treble and middle pitched frequencies are weakened, there will be a general decrease of volume, but, if you listen carefully, you will notice that the bass notes are not affected.

Probably an ideal sized condenser for a tone control such as this would be one with a value in between .001 and .01 mfd. A condenser of .004 or .005 mfd. would work quite nicely.

As the treble notes are weakened excessively when the control is turned fully to Position 2, you will find that a nicer balance is established when the control is turned to some intermediate point such as indicated at 3 on Figure 5.

(B) Instead of weakening the treble notes before they are applied to the grid of the 3S4 valve, it is also a very common principle to apply the tone control circuit to the plate of the 3S4 and weaken the treble notes before they are applied to the loud speaker.

Figure 6 shows how to rewire the circuit so that the tone control operates in the plate circuit of the 3S4. The alterations you will need to make will be to remove the 1 meg. fixed resistor from the screen circuit of the 1T4 and connect it back as the grid leak for the 3S4. The 1 megohm potentio-

*** See A.R.C. Service Engineering Course Lessons 14 and 46.**

meter should be re-wired to the screen grid of the 1T4, as previously. The .02 mfd. condenser connecting the plate of the 1T4 to the grid of the 3S4 should be removed and replaced by the .01 mfd. condenser.

The tone control potentiometer itself in this experiment is the .1 megohm potentiometer supplied with the kit. As there is not a spare hole available in the front flange of the chassis, it will be necessary to connect

The .02 mfd. condenser is a little on the small side to have a very marked effect, but you will notice that the treble notes are weakened as the potentiometer shaft is rotated and the arm moves from Position 1 to Position 2 on Figure 6.

To produce a more pronounced effect, you can now disconnect the .02 mfd. condenser and replace it with the .1 mfd. condenser. The .1 mfd. condenser will, of course, have to be re-

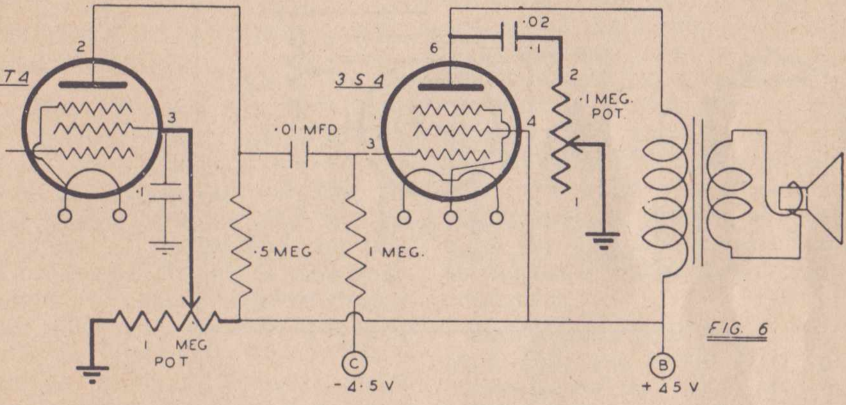


FIG. 6

this potentiometer to the receiver by two fairly long leads, so that the potentiometer lies on the bench or table beside the set. These leads should be long enough to enable the potentiometer to be well clear of the metal chassis.

With this type of tone control, I suggest that you firstly connect the .02 mfd. condenser to the potentiometer and observe the effect of the potentiometer on the treble notes of a musical programme.

moved from the screen grid circuit of the 1T4 valve and replaced by the .02 mfd. condenser.

When the .1 mfd. condenser is connected to the tone control, you will find it has a greater effect than previously, but the size of this condenser is really a little large, so that, not only the treble notes, but the middle pitched notes, will be weakened also.

Probably the best size of condenser for this type of circuit would be one with a value of .05 mfd.*

(C) Figure 7 shows still another tone control circuit, which is being applied in quite a large number of modern receivers. The principle of operation of this circuit is a little different from that of the previous circuits. In this case, instead of the treble frequency simply being by-passed to chassis by the tone control condenser, some of the treble signals are applied through the .001 mfd. condenser shown in Figure 7 to the control grid of the 3S4. In some radio receivers the signals are returned to the plate of the 1T4 instead.

When the arm on the .1 megohm potentiometer is turned to Position 1, there are no signals present, and so no signal energy passes through the .001 mfd. condenser and it has no effect. On rotating the .1 megohm potentiometer so that the arm is moved to Position 2, the treble voltages appearing at this point are applied back through the .001 mfd. condenser to the grid of the 3S4 and arrive at the grid of the tube in such a manner that they tend to cancel, or weaken, the signals reaching the grid from the 1T4. In this way the treble frequencies only are weakened, and so the treble notes emerging from the loud speaker are also weakened.

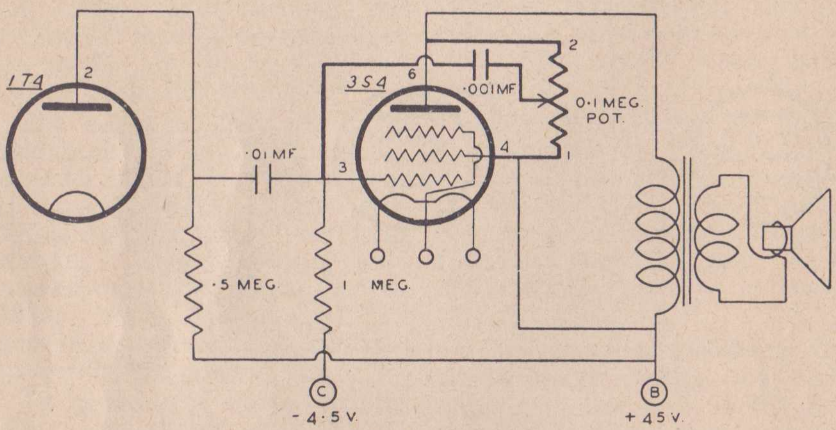


FIG. 7

Bass frequencies and middle pitched frequencies cannot readily pass back through a condenser with a capacity as small as .001 mfd. and consequently these signals are not affected.

When signals are sent from the plate circuit of a valve back to its own grid circuit or to another point in a receiver in such a manner that they weaken the signals normally there, the sys-

* See A.R.C. Service Engineering Course Lesson No. 28.

tem is known as inverse feedback, or negative feedback.

Inverse feedback systems are applied in quite a lot of modern receivers.*

Before proceeding with the following experiments, disconnect the tone control to avoid any chance of the potentiometer or wires causing a short circuit by touching the chassis or other parts.

EXPERIMENT 3.

PRE-SELECTOR WITH MUTUAL INDUCTIVE COUPLING.

The receiver we have constructed so far has employed only one tuned circuit to enable the selection of the required programme and the rejection of unwanted signals. One tuned circuit is not sufficient to enable a good degree of selectivity and consequently you have possibly found that it is very difficult to tune in, clearly, signals from weak stations without interference from signals from nearby powerful stations. Of course, the inclusion of regeneration improves the selectivity of the set considerably, but we can make it even more selective, and thus better able to reject unwanted signals, by making use of two tuned circuits between the aerial and the detector valve. The additional tuned circuit or "selector" is generally known as a "pre-selector", because it precedes the normal tuned circuit.

* See A.R.C. Service Engineering Course Lessons 46 and 28.

The circuit arrangement of the first pre-selector circuit we will use is shown in Figure 8.

The action of the pre-selector is as follows:—Alternating signal currents flowing in the primary winding of the coil produce magnetic lines of force around the primary of this first coil, and these, in spreading out and collapsing back, pass through the turns of the 89 turn coil, which is tuned by means of one section of the tuning condenser. The current flowing in this tuned circuit must oscillate between the upper tuning condenser plate, the 89 turn coil, the lower end of this coil, the 5 turn coil wound on the second coil former, to chassis, and then back through the metal chassis to the rotor plates of the tuning condenser.

In passing through the 5 turn coil, the radio frequency current produces lines of force around this coil and this coil acts as a primary for the 90 turn secondary. The voltage induced into this secondary produces current which oscillates between this coil and the second section of the tuning condenser, and so generates a signal voltage for the grid of the 1S5 valve.

Provided each tuned circuit possesses the same amount of inductance and capacity, the tuning condenser will tune each circuit to resonance at the same frequency, so that wanted signals will pass readily through both tuned circuits. However, unwanted frequencies will be weakened in passing through the first tuned circuit and further weakened by the second tuned circuit, and so the set will be better able to reject unwanted signals.

Although it is necessary that the inductance of both tuned circuits be identical, this does not necessarily mean that both

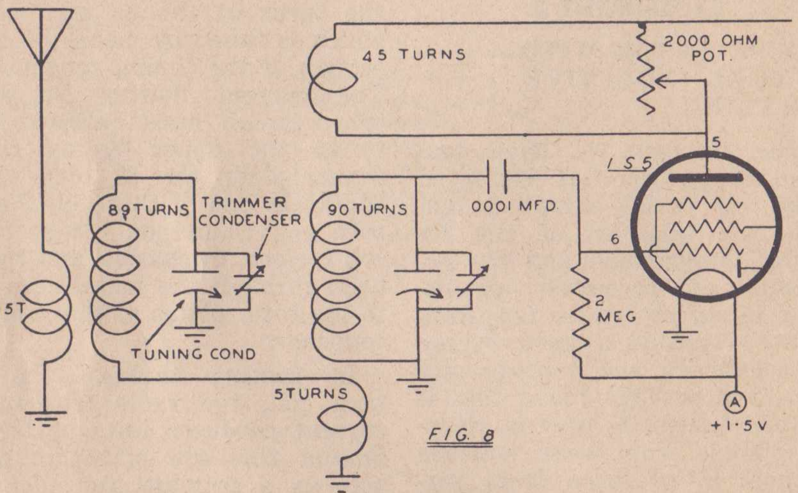


FIG. 8

large coils must have exactly the same number of turns. You will notice that the first tuned circuit embraces, not only the 89 turn coil, but also the extra 5 turns wound on the second former. This really makes a total of 94 turns included in the first tuned circuit, but, because the 5 turns are wound on a separate former from the 89 turn coil, they have very little effect in adding to the inductance of this coil and the effect of this extra 5 turns is only really equivalent to about 1 extra turn wound on the original former, so that the combination of the 89 turn coil and 5 extra turns produces about the same value of inductance as the 90 turns wound on the second coil.

To assure that the capacity of each tuning circuit is identical, small adjustable "trimmer" condensers are connected to each section of the main tuning condenser gang. These may then be adjusted, so that each section will have the same amount of capacity to assure that each tuned circuit will tune to the same frequency as the other.

The trimmer condensers are mounted directly on top of the main tuning condenser gang.

In soldering the trimmer condensers into position, it is important that you connect the right lug of the trimmer to the metal frame of the tuning condenser. If you examine the trimmer condensers carefully, you will find that looking on top, you see the head of a screw, immediately underneath which is a metal washer. Underneath the metal washer again is a disc of metal with a piece extending to one side and passing down through a slot in the moulding.

Underneath this piece of metal is a disc of mica, which is transparent like thin glass, and consequently you may not notice this unless you look carefully. Underneath the mica again is another disc of metal with a piece extending to one side and passing down through the moulding, forming the second connection lug. This lower piece of metal must be connected to the stator plates of the condenser gang or, actually, to the long solder lug, which extends up from the centre of each section of the condenser. The upper disc of metal connects to the metal frame of the tuning condenser. It is very difficult to solder directly to a heavy piece of metal such as the end plates of the condenser, and the easiest way of connecting the trimmer to the frame is to bolt a solder lug onto the front and rear plates of the tuning condenser gang by means of a ⅜″ x ⅛″ whitworth screw, which will pass through the hole in the solder lug and thread into the threaded hole provided near the centre at the top of both the front and back plates of the condenser gang. These lugs can be bent over the top edge of the front and rear plates, and the trimmer condenser soldered directly to them.

The second connecting lug on the trimmer condenser can be soldered directly to the long solder lugs protruding up from the centre of each section of the condenser gang.

WINDING THE PRE-SELECTOR COIL.

Included with this kit of parts is a length of tubing on which you may wind the preselector coil. Commencing at the end of the former near the two large holes for the mounting bracket, you should wind 15 turns of the thinnest gauge of wire supplied to you. Leave fairly long ends on this winding, as it will be necessary to extend these leads across the chassis and around the end near the iron cored transformer to reach the aerial and earth terminal mounted on the rear.

After leaving ⅛″ space, you may commence to wind the secondary coil which consists of 89 turns of 28 gauge wire. The ends of this coil should be left about 4″ long.

This new coil is mounted in position on the receiver chassis in the place where the old coil was mounted, and the old coil is removed, and, after alteration, is mounted on the side of the chassis opposite to the 1S5 valve, as shown in Figure No. 9.

When the new coil is mounted in position, the upper end of the 89 turn winding can be threaded through a piece of insulating tubing, passed through the opening in the rear condenser mounting bracket and soldered to the long lug projecting downwards from the of doing this is to unthread the lower end of the 90 turn coil and unwind two turns. You should then place about a ½″ length of a small wood match stick or similar piece of wood about ⅛″ square on the coil former and wind the first turn back over the top of this match

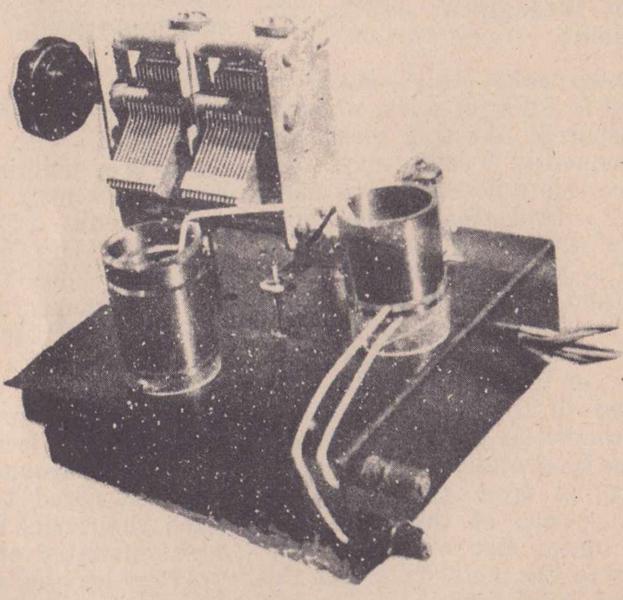


Fig. 9

rear section of the tuning condenser.

Before bolting the original coil in its new position, it is necessary to make two alterations to it. The first is to provide a tapping two turns up from the lower end of the 90 turn winding. The best way stick to hold it in place and the second turn back underneath it. The end of the wire may then be threaded through the holes again to secure it.

Where the upper of the two turns passes across the top of the stick of wood, you should carefully scrape the enamel covered insulation off the wire until the bare copper is exposed. You may then similarly remove the enamel from another length of 28 gauge coil wire and carefully solder the new length of wire to the bared portion on the second bottom turn.

This tapping will not be needed in this experiment, but will be required in the next experiment, so leave the length of wire connected to the second turn about 3" long, but see that the end of it does not touch the metal chassis or condenser frame.

The second alteration to the coil is to unwind the 15 turn coil, which previously connected to aerial and earth and wind a coil consisting of 5 turns of 28 gauge wire in its place. The lower end of this 5 turn coil is passed through the hole in the chassis and, after the coil is bolted into position, soldered to the 18 gauge earth wire. The upper end of the 5 turn coil is bared of enamel and soldered to the lower end of the 89 turn coil, as suggested by Figure 8.

The lower end of the 90 turn coil will also be connected to the earth wire. The upper end of the 90 turn coil will be connected to the centre lug protruding downward from the front section of the condenser gang and the ends of the reaction winding will connect to the same places as previously.

On completing the alteration, reconnect the batteries, test the voltages at the pins of the 1S5 valve socket to see that they are the same as described in Lesson 6 and then insert the valves in their sockets. Tune in a broadcasting station as near as possible to the high frequency end of the tuning range, that is, with the tuning condenser plates as nearly as possible out of mesh. You should then adjust the trimmer condensers on top of the tuning condenser gang until the signals from the station are heard as loudly as possible. The best position is with the adjusting screw of both trimmers unscrewed about half a turn from the full in position.

After completing this adjustment of the trimmer condensers and rotating the tuning dial slightly, you will find that the signals from any particular broadcasting station will not spread as far over the tuning condenser rotation as previously. In other words, a small movement of the tuning dial will be more effective in rejecting signals from a station and bringing in those from some other station than previously.

EXPERIMENT 4.

PRE-SELECTOR WITH DIRECT INDUCTIVE COUPLING.

An alternative pre-selector circuit which will give slightly louder signals than the last one is shown in Figure No. 10. This requires very little alteration from the last experiment. In this case, the 5 turn coil wound on the bottom of the 90 turn coil is completely disregarded, but, after disconnecting both ends, be sure that they do not touch the metal chassis or any other metal part.

The lower end of the 89 turn coil is, in this case, connected to the wire you soldered on to the tapping you made two turns up from the lower end of the 90 turn winding.

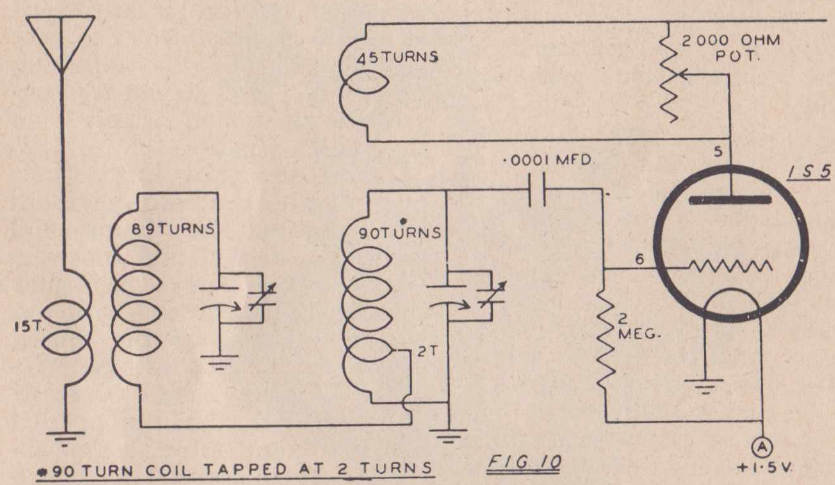


FIG. 10

In this circuit arrangement, current oscillating in the first tuned circuit passes from the upper tuning condenser plate through the 89 turn coil and then through the two lowest turns on the 90 turn winding to chassis, and from chassis back to the tuning condenser gang frame. In flowing through the two lower turns on the 90 turn coil, the signals will produce magnetic lines of force, which will induce a larger voltage in the remaining turns on this coil and cause signal current to flow to and fro in this second tuned circuit.

As the signal current from the first tuned circuit is connected directly into the second tuned circuit, the signals will be a little louder than in the last experiment where current, passing through the 5 turn coil, had to produce lines of force which passed through space before inducing signals in the 90 turn coil.

On operating the receiver, you should find the degree of selectivity is about the same as that obtained with Experiment 3, but that the signals are a little louder.

After making the alterations to the receiver, you will probably find it necessary to make some slight readjustment in the setting of the trimmer condensers, when the set is tuned to a station at the high frequency end of the dial, before the best results are obtained.

EXPERIMENT 5.

R.F. AMPLIFIER.

Instead of using the third tube in our receiver as an audio frequency voltage amplifier, we could quite well have used it as a radio frequency amplifier to strengthen the signals received from the aerial and earth system, before they are applied to the detector valve. It will be interesting now to alter the receiver so that the 1T4 valve becomes a radio frequency amplifier instead of an A.F. amplifier, so that we may compare the results of both systems.

Figure 11 shows the circuit diagram of the receiver with the R.F. stage. You will notice that the two tuning circuits are again employed, so that the degree of selectivity will be approximately the same as that obtained with the pre-selector circuits described previously.

Several alterations are necessary in the construction of the receiver to enable the R.F. stage to function properly. In order to provide the greatest possible separation between tuning coils and important wires, to prevent the R.F. amplifier from oscillating, it is necessary to move both coils and to move the 1T4 valve over to the side of the chassis near the switch. Firstly remove all valves and disconnect all batteries.

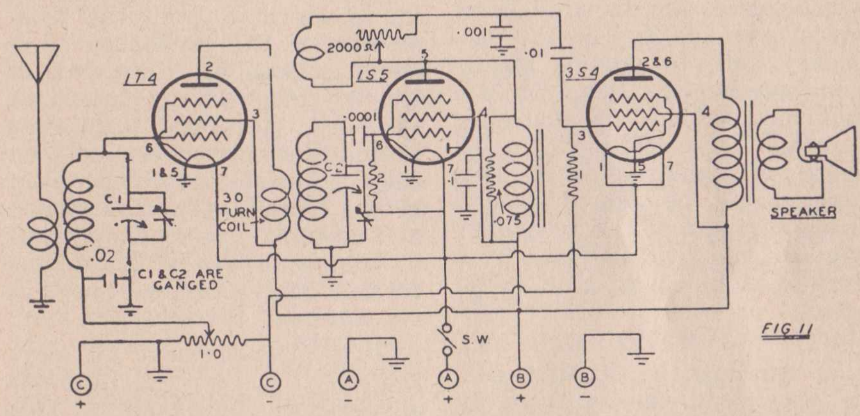


FIG. 11

To enable the socket for the 1T4 to be mounted on this side of the chassis, it is necessary to remove the tuning coil which was previously bolted over the valve socket hole. The socket may then be bolted into position in the hole where the coil was placed.

Before remounting the coil on the chassis, it is necessary to wind a new primary winding suitable for matching the plate circuit of the 1T4 valve.* At the present time this coil has a winding of 5 turns on the lower part of the former, below the secondary winding. This is an insufficient number of turns to provide an effective "plate load" for the 1T4.

The new primary winding will need to consist of 30 turns of the fine 34 gauge wire. As there is not sufficient room to wind 30 turns on the former below the secondary winding, it will be necessary to wind these turns over the top of the secondary, but, to provide insulation between the two, you will find included in the materials supplied with this kit a 6″ length of insulating tape. This tape should be wound around the lower part of the secondary winding and held in place by a drop of molten wax, glue, liquid cement or other adhesive substance.

In winding the 30 turn coil, its lower end can be fixed by threading the wire through the pair of holes second from the bottom of the coil former. After winding the 30 turns, the upper ends of the wire will have to be held in place again with a drop of molten wax or a small dab of glue or liquid cement.

After winding the coil it may be bolted into position by means of a single screw passed through one of the outside holes in the bracket and passed down through the hole which exists in the chassis a little further forward than the hole for the 1T4 valve socket. In mounting the coil, it will be necessary to rotate it to a position such that it just clears the tuning condenser gang plates as they open. In mounting the coil, arrange it so that the wire from the upper end of the secondary winding faces towards the front section of the tuning condenser, so that this wire, which connects to the centre lug protruding downwards from the front section of the condenser is as short as possible. The ends of the 30 turn winding should be threaded through insulating tubing and carried around over the cut out section on the front of the chassis, near the switch and brought around underneath to connect to the plate and screen grid pins on the 1T4 valve socket.

It is also desirable to move the aerial coil in the interests of greater efficiency. This should be unbolted from its existing position on the chassis and moved centrally over the hole which was previously occupied by the 1T4 valve socket. In this way, the coil is shielded from the R.F. coil by means of the metal end plate of the tuning condenser, and this helps considerably in preventing oscillation which results in whistles when the receiver is being tuned.

The ends of the aerial coil primary winding, which pre-

* See A.R.C. Service Engineering Course Lesson No. 19.

viously were extended around the end of the chassis to the aerial and earth terminals, may now be passed down through the valve socket hole and will be long enough to again reach the aerial and earth terminals. No actual wiring diagram is shown of the R.F. stage, because by this time you should have had sufficient experience and practice in conducting the previous experiments to be able to wire the socket of the 1T4 directly from the circuit diagram shown in Figure 11.

A lead from the switch on the front of the panel carries current from the A battery via the switch contact to Pin No. 7 on the socket. Pin No. 6 is connected by a wire which passes across the chassis and up through the hole under the rear section of the tuning condenser to the long lug protruding down from the centre of the back section of the tuning condenser. Here, of course, it is joined onto the wire from the upper end of the secondary of the aerial coil.

Lug No. 5 on the valve socket is joined to the centre shield and also to the 18 gauge earth wire running around the chassis. Lugs 1 and 4 are not used. Lug No. 2 is the plate connection to the valve and joins onto the fine wire emerging from the upper end of the 30 turn primary winding on the R.F. coil. Lug No. 3 is the screen grid connection and joins onto the bottom end of the 30 turn primary and also to the lead which connects it to the B plus end of the iron cored transformer, so that it receives the full B plus 45 volts from the B battery.

To avoid annoying whistles when tuning the receiver, it is important that the grid circuit of the 1S5 valve be kept as far away as possible from the grid wire of the 1T4. Consequently, it is necessary to move the .0001 mfd. condenser connecting to the grid of the 1S5 over towards the 2,000 ohm potentiometer, so as to keep it as far as possible from the long wire joining Pin 6 on the 1T4 to the condenser.

The lead from the .0001 mfd. condenser can be passed up through a hole in the chassis a little in front of the socket of the 1S5 and taken across to the centre lug protruding down from the front section of the tuning condenser gang.

VOLUME CONTROL.

If we permit the 1T4 valve to give its full amplification all of the time, then we would find that, on tuning in to powerful signals from a nearby station, the 1T4 would amplify these signals so strongly that they would be too strong for the 1S4 valve, overloading it and producing unpleasant sounds from the loud speaker. To avoid this, it is necessary to reduce the amplification of the 1T4 valve when strong signals are received, so that it amplifies them only by a small amount, but, on the other hand, it is necessary to increase the amplification of the 1T4 when weak signals are received, so that it may strengthen them by the greatest possible amount.

The most convenient way of varying the amplification of the 1T4 and consequently the volume of sound from the loud speaker is by altering the negative grid bias voltage applied to the control grid of the valve. In Figure 11, if you follow back from the control grid circuit, you will find that it connects firstly to the secondary winding of the aerial coil and that the lower end of this coil is connected to the .02 mfd. condenser and also to the centre arm of the 1 megohm potentiometer which is fitted to the front flange of the chassis. One lug of the potentiometer is still connected to the 18 gauge copper earth wire, but, in this case, it should not be the left hand lug which was earthed previously, but should be the right hand lug. The left hand one is disconnected from the chassis and instead is connected to the negative terminal of the 4.5 volt C battery. The positive terminal of this battery is also joined by a flexible lead to the chassis.

If the volume control is turned until the slider is moved to the outside lug which is connected to the chassis, there will be no negative bias applied through the coil to the control grid of the 1T4 valve, and the valve will give its utmost amplification. This will also cause the loudest sounds to be heard from the loudspeaker. On the other hand, if the potentiometer is rotated until the sliding arm is moved towards the lug connecting to the 4½ volt negative terminal on the C battery, the negative bias, reaching the grid of tne valve through the coil, will reduce the plate current and also the valve's amplification.

The regeneration control will, of course, also provide some variation in loudness and again the correct setting for this control is at a point just before squeals are heard. In tuning for a station, one should turn on the regeneration control and the volume control and rotate the tuning dial until a whistle is heard. The reaction control should then be turned back until the whistle just ceases, and if the signals are unpleasantly loud, the volume control may then be turned down until the volume is at a satisfactory degree of loudness.

TESTING.

Before inserting the 1T4 valve or reconnecting the batteries, you should very carefully check over the connections you have made to the 1T4 socket and see that they conform with Figure No. 11. If you feel sure that you have carried out the wiring of the socket correctly, then connect on the A and B batteries, but again, before inserting the 1T4 valve, test the voltages with your voltmeter.

With the meter set on the 50 volts range, you should obtain a reading of approximately 45 volts when you touch the positive test lead to Pins 2 and 3 on the valve socket, provided, of course, that the negative test lead is clipped onto the metal earth wire. On touching the positive test lead to Pin No. 7, the needle should move only about 1½ graduations across the face, indicating the 1.5 volt A battery voltage, and, on touching the positive lead to Pin No. 6, the needle should move backwards slightly or remain at zero, depending upon the position of the 1 meg volume control. If the needle moves up the scale in this position, it shows that you have made a mistake in the wiring and that a positive voltage is reaching the control grid of the valve. If this is so, you must carefully determine the cause of this before proceeding.

If you now reverse the test leads connecting the positive one to the chassis and the negative one to Pin No. 6 on the valve socket, you will find that, as you rotate the volume control, the needle will change gradually from a reading of zero when the control is full on to a reading of 4.5 volts when the control is fully off. You may use the 10 volt range on your meter for this check.

If the test described above proves to be satisfactory, then you may safely plug in the 1T4 valve and proceed to try out the receiver.

EXPERIMENT 6.

DIODE DETECTOR.

Although the receivers with which we have been experimenting up to the present time have employed the 1S5 valve as a grid leak detector, this type of detector arrangement is not commonly used in modern receivers.

The advantage of the grid leak type of detector is that it gives more sensitivity, that is, greater amplification, than does a diode detector, and it also permits the use of regeneration, which we have been employing to boost up the amplification of the receiver.

The principal disadvantage of grid leak detectors is that they produce a certain amount of distortion of the audio frequency signal so that the speech or music is not as pleasant to the ear, when reproduced from the speaker, as in the case where a diode detector is used. For this reason the majority of modern sets employ diode rather than grid leak detectors.

As you already know, the 1S5 valve is really two separate valves in the one glass envelope. It consists of a small diode plate, connected to Pin No. 3 in the base, so that the filament and the diode plate form the two necessary parts of a diode valve, which is simply a two-element rectifying valve. The action of a diode detector is identical with that of a crystal detector in general principle.*

* See A.R.C. Service Engineering Course Lessons 3, 30 and 32.

Only when the upper end of the tuned circuit, in Figure 12, is positive can pulses of current pass between the filament and diode plate and pass on through the 2 megohm resistor, producing audio frequency voltages. The audio frequency voltages are passed through the .5 meg. resistor to the .0001 mfd. condenser, where the radio frequency impulses are filtered out any external connection to this grid. The pentode section is employed as a conventional audio frequency amplifier and the signals reaching the control grid produce changes in plate current which, passing through the iron cored transformer, produce audio frequency signal voltages, which are, in turn, fed on to the grid of the 3S4 valve.

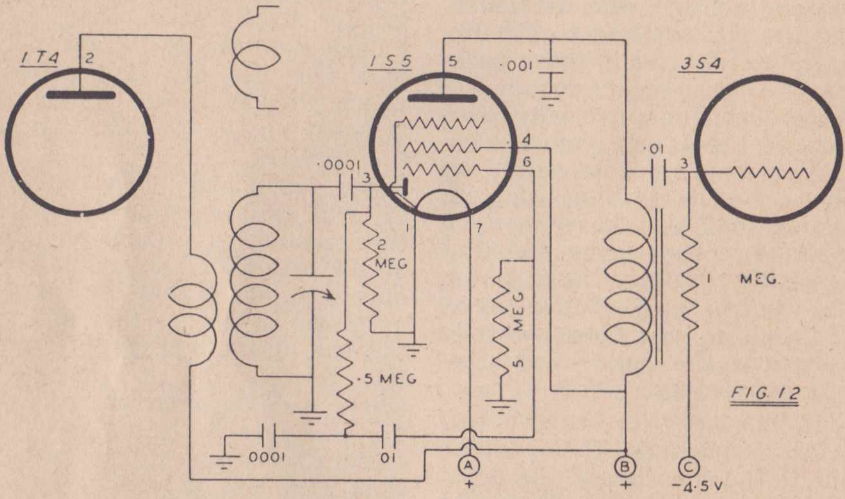


FIG 12

and the smooth audio frequency voltages continue through the .01 mfd. condenser to the grid of the 1S5 pentode section at Pin No. 6.

Apart from the diode section of the valve, the envelope also contains the remaining part of the filament, a control grid, screen grid, suppressor grid and plate. These are clearly shown in the symbol in Figure 12, the suppressor grid being internally connected to the filament, so that you do not have to make

Due to the fact that the .5 meg. resistor and .0001 mfd. condenser filter out the radio frequency pulsations, there will not be any appreciable amount of radio frequency current in the plate circuit of the 1S5 valve, and consequently regeneration cannot be used. Therefore, you should disconnect the regeneration coil and 2,000 ohm potentiometer entirely from the plate circuit of the 1S5. This coil will not be used, but need not be unwound from the coil former. Simply disconnect the plate wire from the 2,000 ohm potentiometer and join it directly to the end of the iron cored transformer to which the .001 mfd. condenser also connects. As regeneration is not employed, the 75,000 ohm resistor may be disconnected from the two ends of the iron cored choke.

As is always the case, it is essential that you remove the tubes and disconnect the wires from the A and B batteries before making any alterations to the receiver, and, after carrying out the alterations in accordance with Figure 12, you should check the voltages at the 1S5 valve socket before reinserting the valves. With the batteries connected once more and the negative test lead from your voltmeter connected to the chassis, using the positive test lead in the 50 volt socket, you should obtain the following approximate voltages: At Pins 4 and 5 a reading of approximately 45 volts. At Pin 7 a movement of about 1½ graduations on the scale and at Pin 3 no reading. There should also be no reading at Pin 6. After satisfying yourself that the voltages are correct, you may plug the 1S5 and other valves in their sockets once more and test the receiver.

On switching on, you will find that the sensitivity of the receiver is not as great as it was previously. The decrease in sensitivity is due principally to the fact that the receiver does not now employ regeneration to boost up the strength of signals. There is not very much difference between the degree of amplification provided by a diode detector followed by a pentode audio frequency amplifier, and that obtained from the grid leak detector we were using previously. If the only change we had made in the receiver was to change from the grid leak to the diode and pentode audio amplifying stage, there would not have been a very noticeable difference in the performance of the receiver. However, as it is necessary to dispense with regeneration on using the diode detector, this factor reduces the ability of the receiver to pick up weak signals quite considerably.

From these tests you will be able to judge for yourself the relative merits of using regeneration in simple sets in which the sensitivity is not very great, due to the small number of valves used.

EXPERIMENT 7.

AUTOMATIC VOLUME CONTROL.

If you have been able to receive signals from broadcasting stations more than about 40 miles distant, you will have noticed that, instead of the signals remaining at constant loudness all the time, there is a certain amount of increasing and decreasing of volume, due to what is called "fading". This fading is brought about by the fact that when radio signals travel over a distance of more than about 40 miles, they do not travel in a straight path, but some of them shoot up into the air from the transmitting aerial, and are reflected back to the earth's surface by a layer of gas present in the upper atmosphere. Due to turbulence in this layer of gas and other effects, the signals arriving back at the receiving point are not constant in strength, but vary from minute to minute, so that at one instant the signals may be loud and clear and the next instant may fade away to a much lower volume. If the amplification provided by the valves in the receiver could be automatically regulated to increase when the signals are weak and to decrease when the signals become stronger, the volume from the loud speaker would remain much the same and an efficient system of "automatic volume control" will very nearly compensate for the effects of fading and keep the signals at an approximately equal loudness all the time.

You will also have noticed that, in tuning into signals from the nearby stations, the volume control can be turned down, reducing the amplification of the valves and that, when tuning into weaker stations, it is necessary to turn up the volume control. This manipulation of the volume control could be avoided if, again, the amplification of the valves could be automatically regulated to give maximum amplification when weak signals are received and little amplification for strong signals. A system of automatic volume control again will tend to hold the signals from both strong and weak stations at a constant loudness from the loud speaker.

The system of a.v.c. causes a negative voltage to be developed at the detector valve, or at a separate diode valve used especially for the purpose, and this negative voltage will automatically increase and decrease with the strength of signals. If some or all of this negative voltage is applied back to the control grid of the r.f. amplifier or any other valves preceding the detector, it will tend to automatically decrease their amplification as the signals become stronger.*

If you examine Figure 13, you will see the way in which this negative voltage, developed at the diode plate of the detector, is sent back through the 5 megohm resistor to the lower end of the aerial coil secondary and then is applied through this coil to the control grid of the 1T4 valve. This portion of the circuit is drawn in heavy lines. Whereas previously the control grid of the 1T4 received whatever negative grid bias was applied to it by means of the 1 megohm volume control, it now

* See A.R.C. Service Engineering Course Lessons 43 and 48.

receives, through the tuning coil, whatever negative voltage reaches it from the diode detector circuit.

Due to the rectifying action of the diode detector plate, the voltages present at socket contact No. 3 on the 1S5 socket consist of pulsating negative voltages which vary in average strength to represent the audio frequency signals. In Figure 13, the audio frequency signals are fed from socket contact 3 through the .01 mfd. condenser to the 1 megohm volume control and from the moving arm on this control, that is, the centre lug, to the control grid of the pentode section at socket contact No. 6.

The automatic volume control system endeavours to maintain signals at a constant strength at the diode detector circuit, and if the control grid of the 1S5 were connected permanently to the diode plate, either directly or through a .5 meg. resistor as in Figure 12, the signals from the loud speaker would be loud all the time. There would be no volume control knob with which one could reduce the loudness to a desired level. For this reason, the 1 megohm potentiometer is now wired to supply only a desired portion of the signal voltages available at the diode plate, to the grid of the valve. By moving the volume control knob so that the sliding arm is moved to the left in Figure 13, a larger amount of the signal voltage will be applied to the grid and the signals from the loud speaker will become louder. If the arm is moved to the right by rotating the knob in the opposite direction, no signals will be available as the grid will be directly connected to the

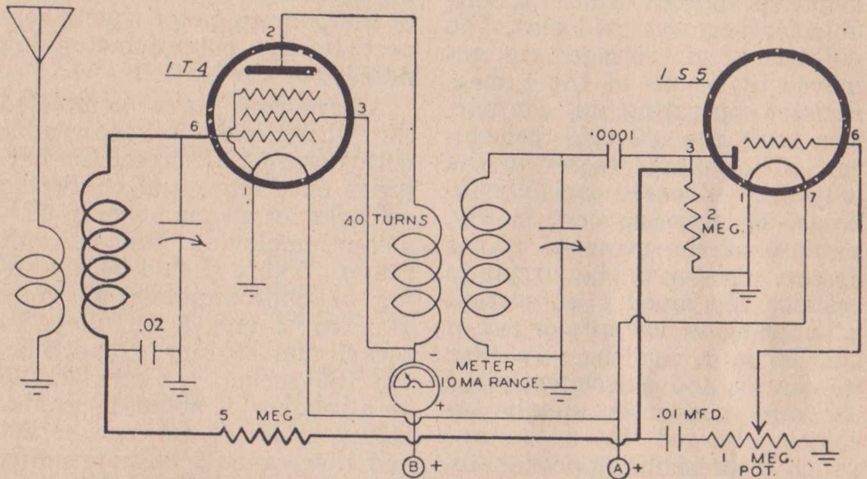


FIG. 13

chassis and the loud speaker will be silent.

Due to the fact that the voltages at the diode plate are pulsating negative impulses of voltage, and not a smooth steady direct voltage, they cannot be directly connected to the control grid of the 1T4 valve. It is firstly necessary to get rid of the pulsations of voltage and smooth these out to a steady negative voltage, which is suitable for negative grid bias. The pulsations of voltage are removed by means of the 5 meg. resistor operating in conjunction with the .02 mfd. condenser. The voltage stored in the .02 mfd. condenser can only increase or decrease very slowly, because of the presence of the 5 meg. resistor in the circuit to restrict the amount of current attempting to flow into or out of the .02 mfd. condenser to alter its charge, and consequently the .02 mfd. condenser simply becomes charged to a voltage which represents approximately the average value of the audio frequency variations in the voltage at the diode plate. Because the voltage at the left hand plate of the .02 mfd. condenser is now a smooth direct voltage, which changes only slowly, in accordance with changes of signal strength fed into the receiver, it is suitable for applying through the tuning coil to the control grid of the 1T4.

Once again, before making the alterations to your receiver as shown by Figure 13, you should disconnect the batteries and remove the valves.

In connecting the 1 megohm potentiometer to the grid circuit of the 1S5, the grid lead from socket contact No. 6 connects to the centre lug and it is the left hand lug, that is the one near the 2,000 ohm potentiometer, which should be connected to the bare earth wire. The .01 mfd. condenser carrying signals from the diode plate to the potentiometer should connect to the potentiometer lug nearest to the switch.

After you have completed the alterations in accordance with Figure 13, connect the batteries once more and check the voltages by means of your voltmeter employing the 50 volt range. There should be a reading of approximately 45 volts at Pins 2 and 3 on the 1T4 socket and at Pins 4 and 5 on the 1S5 socket. There should be a reading of about 1½ graduations at Pin 7 on each socket and there should be no reading at Pin 6 on the 1T4 socket or at Pins 3 or 6 on the 1S5 socket.

If the voltages seem to be in order you can insert the valves in their sockets and test the receiver. If there are several broadcasting stations, some near to your district and others a considerable distance away, you will be able to notice the fact that the signals are much the same in loudness as you tune from one to the other and also, if you were previously troubled by fading, you will find that this effect has been reduced considerably, even if it has not been completely eliminated. An a.v.c. system cannot be extremely effective in reducing fading unless it operates on more than one valve, and in large receivers employing four or more valves, it is possible to devise quite an effective a.v.c. system. In your simple receiver the a.v.c. voltage can be applied to one valve only and consequently it will not be completely effective in eliminating fading.

If you have not been experiencing fading previously, then you will probably not notice very much difference in the performance of the receiver when the a.v.c. system is included. To tell whether it is functioning or not, you should disconnect the wire carrying B plus voltage from one end of the iron cored transformer to socket contact No. 3 for the 1T4 valve. The wire should be disconnected where it joins onto the lug of the valve socket. You should then use the milliamp range of your multimeter by plugging one test lead into the negative terminal and the other into the terminal marked "+ 10 m.a." to observe the variations in plate and screen grid current caused by the a.v.c. system. The position at which the meter is included in the circuit is indicated by the circle in Figure 13 marked "meter".

If you switch on the receiver, but have the tuning dial tuned away from the position of any station, you should obtain a reading of a little over 2 milliamps. If you now tune the receiver into some strong signal, the a.v.c. action will develop a negative voltage at the diode detector, which will be applied through the 5 meg. resistor and coil to the control grid of the 1T4 valve as negative bias. This negative voltage will reduce the plate and screen current of the 1T4 and you will observe that the meter will show a reduction in current. This reduction is due to the action of the a.v.c. system.

If you can tune into a number of different stations, you will find that the stronger the signals, the greater the reduction in plate current caused by the a.v.c. action in reducing the valve's amplification. With weak signals there will not be any noticeable reduction in plate current, as the valve will need its full amplification for handling these weak signals.

TEST INSTRUMENTS.

For a person to be successful as a radio engineer, it is important that he be not only capable of constructing equipment, but also of making the necessary tests and measurements to assure himself that the equipment is working successfully, and also to enable him to diagnose faults when equipment is not functioning properly.

You have already constructed an efficient multimeter, and shortly you will be constructing an oscillator and signal tracer. However, there are a number of other service instruments which are somewhat less frequently used in radio work and with which you should be familiar. The amount of material contained in these kits is not sufficient for you to construct elaborate and complete instruments in commercial form, with the exception of the three instruments already mentioned, but it is desirable that you should at least be familiar with the operating principle of such instruments as valve testers, vacuum tube voltmeters, megohm meters, capacity meters, audio frequency oscillators, etc. Consequently, we will now leave our experiments with the receiver and employ some of the materials to construct basic models of the instruments listed above. These will enable us to at least understand the principle of operation of the instruments and to appreciate their features and usefulness. The following experiments in this lesson will, therefore, consist of a description of the method of constructing and using some of these instruments. We will carry on with our experiments with the radio receiver when you receive the next kit of parts.

VALVE TESTERS.

In the case of a person engaged fully upon the servicing of radio receivers, it is desirable, although perhaps not absolutely essential, to have a valve tester with which one may quickly and reliably test the condition of valves in a receiver to determine whether they need replacement or not. An alternative method of overcoming this problem is to maintain on hand an extensive stock of valves, so that if, in servicing a receiver, one doubts the efficiency of a valve, one may try a new one and notice whether the performance of the receiver is improved or not. However, there are now so many different types of valves in use in receivers that it is rather impracticable to carry a stock of every type, and consequently a valve tester enables any doubtful valve to be tested and its condition determined.

Modern valve testers capable of testing the hundreds of different types of valves which have been used in receivers in recent years are most complex and costly affairs. However, the majority of them operate on either one of two principles. One is to test the emission of which the valve's cathode is capable. The majority of valves cease to function satisfactorily in a receiver, not because they are actually broken or burnt out, but simply because the cathode loses its ability to emit electrons. Consequently, if a tester is available which can rapidly and efficiently test the ability of the cathode to emit electrons, one can obtain a very good idea of the efficiency of the valve.

Occasionally other faults develop in valves which do not affect the emission but still render the valve unsuitable for use in a receiver. To determine these other more obscure faults, a more elaborate type of valve testing equipment is required, and it is preferable that the type used should determine the mutual conductance of the valve. We will examine the principle of operation of both the emission and mutual conductance type of valve testers.

EXPERIMENT 8.

EMISSION TESTER.

In order that valve testers throughout the world may all give somewhat similar performances when testing a tube with a certain fault, the Radio Manufacturers Association of America have recommended certain standards which should be adopted in constructing emission type valve testers. The general principle of an emission type valve tester is shown in Figure 14. Here it will be seen that the filament of the valve is heated from a source of filament current, and that all the other elements are joined together and connected to a B battery or other source of voltage through a meter and resistor marked "R". The test voltage makes the various elements of the valve all act together as an anode and a positive voltage applied to the anode attracts electrons from the cathode. The number of electrons emitted from the cathode is registered by the reading of the meter, and consequently gives an indication of the cathode's ability to emit electrons. As the cathode surface deteriorates through prolonged use, it will be able to emit only fewer electrons, and the reading of the meter will gradually decrease if the valve is tested a number of times throughout its life. Ultimately, when the reading is very low, the valve must be rejected and replaced by a new one.

The complexity of modern valve testers is brought about by the fact that the large number of valves at present in use

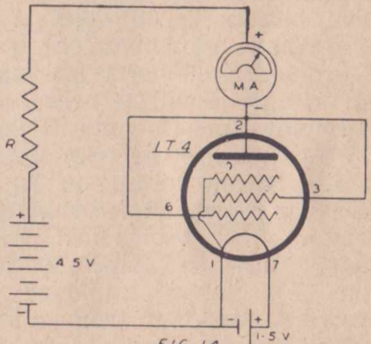


FIG 14

have no standard method for allocating pins in the base to the filament connections. This means that testers must be capable of applying a filament or heater voltage between almost any pair of pins in the base of a valve and complex switching systems are necessary, or, alternatively, a large number of valve sockets are necessary to cope with the variations in filament connections. The matter is still further complicated by the variety of elements available in present day valves, and the cost and complex construction of modern valve testers is mainly brought about by providing sufficient switching or other means to accommodate these variations in socket connections.

We cannot hope to duplicate the complex switching systems of a modern valve tester, but we can connect our valves, one by one, in the manner suggested by Figure 14, to test the emission of each.

The value of test voltage recommended for adoption in valve testers is 30 volts A.C. As we have no convenient way of providing 30 volts alternating voltage, it will be necessary to employ our 45 volts B battery for making the test. When an alternating voltage of 30 is used it is recommended that the resistor "R" mentioned previously have a value of 200 ohms for valves employed in receivers working from alternating current power mains and for battery operated power output valves and rectifiers. The resistor should have a value of 1,000 ohms for battery valves, such as the 1T4 and 1S5 and the resistance should have a value of 5,000 ohms when testing diode plates such as that included in the 1S5.

In our case we will be employing a higher voltage than the recommended value, that is, 45 volts instead of 30, and consequently it is necessary to increase these values of resistance to protect the valve from excessive current drain. In our case, we will employ 500 ohms in place of 200 ohms for testing the 3S4 valve, 2,000 ohms instead of 1,000 ohms for testing the 1S5 and 1T4, and 10,000 ohms instead of 5,000 ohms for testing the diode section of the 1S5.

The most convenient way of mounting these resistors is to connect the 10,000 and 500 ohm resistors between pairs of lugs on the length of resistor panel supplied and to bolt this into position on the chassis supplied with this outfit, as suggested by Figure 15. You should place one or two nuts on the bolts, between the panel and chassis to prevent the eyelets on the rear of the panel from touching the chassis. One of your valve sockets can also be mounted on one of the holes in the chassis. As you have no ordinary resistor with a value of 2,000 ohms, it will be necessary to employ the 2,000 ohm potentiometer out of your receiver to act as a 2,000 ohm resistor. This can be mounted in one of the holes in the front flange of the chassis and connections made to the two outside lugs only. The centre lug should be entirely disregarded.

To commence with we shall test the 1T4 valve by connecting up the valve socket as shown in Figures 14 and 15. 1.5 volts from the A battery should be applied between Pins 1 and 7 and Pins 2, 3 and 6 should all be connected to one-another. Plug the test leads of your multimeter into the minus and the + 50 m.a. socket, connect the positive lead to the end of the 2,000 ohm potentiometer which does not connect to the battery and connect the negative lead to Pin 2, 3 or 6 on the valve socket. When the A battery is connected and a valve plugged in, you should obtain a reading somewhere between 14 and 20 milliamps. Make a careful note of the reading you obtain on a piece of paper or in a notebook, so that, at any later time, if you wish to test the efficiency of the valve to determine whether it is still good or not, you may compare the figure you obtain with this reading and you will be able to tell whether the valve has decreased in emission.

To test the pentode section of the 1S5 valve, the A battery is left connected to Pins 1 and 7, but, instead of Pins 2, 3 and 6 being joined together, Pins 4, 5 and 6 must be joined. The positive lead of the milliamp meter is still connected to the 2,000 ohm resistor, and the negative end is connected either to Pins 4, 5 or 6. When the 1S5 valve is in the socket, you should obtain a reading somewhere between 11 and 16 milliamps.

To test the diode plate of the 1S5, connect the positive lead of the meter to the end of the 10,000 ohm resistor, which does not connect to the battery. The positive lead should be inserted

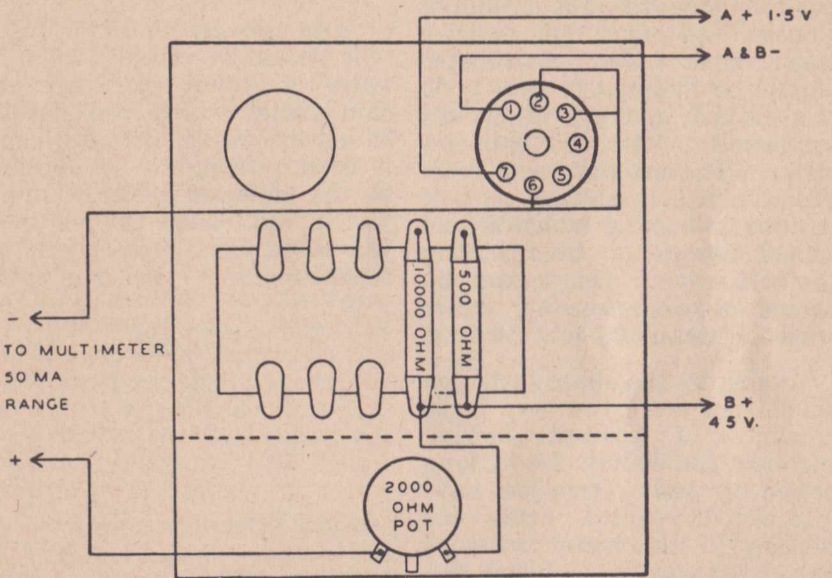


FIG 15

in the multimeter socket marked "+ 10 m.a." instead of the "+ 50 m.a." socket. The negative test lead of the multimeter can now be connected to Pin No. 3 on the valve socket, and you should obtain a reading of between 2 and 4 milliamps. Finally, to test the 3S4 valve, the negative side of the 1.5 volt A battery connects to Pin 5, the positive side to Pins 1 and 7 joined together, the positive lead from the multimeter should be inserted in the + 50 m.a. socket and the other end connected to the 500 ohm resistor. The negative lead from the multimeter should connect to Pins 3, 4 and 6 which are all joined together. On inserting the 3S4 valve in the socket you should obtain a reading somewhere between 35 and 50 m.a.

In making the above tests you should not leave the very large amounts of current flowing through the valves for a long period of time. Once you have inserted the valve, make the reading of the meter scale as quickly as you can and then disconnect the B battery or remove the valve from its socket. The values of current you have forced to flow through the valve during this test greatly exceed the amount flowing through the valve under normal operating conditions, and they should not be permitted to flow for a long period of time, or the valve's emission may be decreased.

As mentioned earlier, you should make a careful note of the result, so that at any time in the future you may check the efficiency of your valve by setting the equipment up once again as shown in Figures 14 and 15 and repeating the tests.

EXPERIMENT 9.

MUTUAL CONDUCTANCE TESTER.

Although an emission tester will usually reveal when a valve is faulty, there are certain faults which can develop in a valve which will still cause a good reading to be obtained in the emission tester, but yet which will cause the valve to fail to function properly in an actual receiver. In some cases,

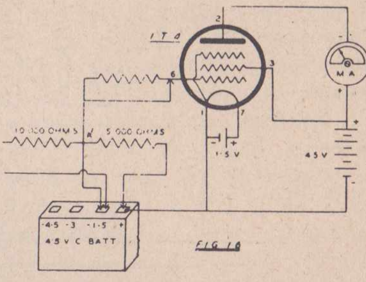


FIG 16

more reliable results are obtained by setting up a valve under conditions more closely corresponding to those in an actual receiver. You will see in Figure 16 that the valve is set up in a fashion such that positive voltage is applied to the plate and screen grid, the filament is heated in the normal way and negative grid bias is applied to the control grid. A milliamp meter is connected in the plate circuit to register the plate current and provision is made for altering the negative grid bias to represent a signal impulse. The cnange in plate current resulting from the change in negative grid bias is revealed by an increased reading on the meter and this gives an indication of the valve's mutual conductance.*

The most practical way of building up this tester is to employ the socket mounted on the chassis supplied with this kit, and to fit the 1 megohm, 10,000 ohms and 5,000 ohms resistors onto the resistor panel which can be bolted on top of the chassis. During the process of testing it will be necessary to short circuit two of the resistors, and consequently it will be much more convenient to do this if the resistor panel is bolted on top of the chassis, so that it is not necessary to turn the chassis upside down each time a valve is to be tested.

The socket numbers marked on Figure 16 apply to the 1T4 valve which we will test first.

The line terminating in an arrowhead, which is drawn near the 1 megohm resistor in Figure 16, represents a length of wire which normally short circuits this resistor so that it has no effect on the valve. Similarly, you will notice a line drawn from the junction of the 10,000 and 5,000 ohm resistors to the minus 1.5 volt tapping on the battery. This wire short circuits the 10,000 ohm resistor, so that it has no effect when the wire is touched to the battery terminal. Thus, the voltage from the 1.5 volt tapping on the battery is applied directly through this wire and past the 1 megohm resistor to the grid of the valve. When the valve is operating with the 45 volt battery applied to the plate and screen grid and 1.5 volt negative bias, you will find that the milliamp meter connected in the plate circuit provides a reading somewhere between .5 and 1 milliamp. The positive test lead of your milliamp meter should be plugged into the + 10 m.a. socket on the milliamp meter, even though the current is below 1 milliamp to start with and causes a reading down near the left hand end of the scale.

Make a note of the reading of the milliamp meter and then disconnect the lead which runs from the junction of the 10,000 and 5,000 ohm resistors to the 1.5 volt tapping on the battery. Leave the end free, but see that it does not touch the metal chassis or any other part. As soon as this wire is disconnected you will observe that the reading on the milliamp meter increases by approximately .5 milliamp. This increase is due to the fact that, with the lead removed from the battery, the negative voltage applied to the control grid is reduced from 1½ volts to ½ volt. This corres-

* See A.R.C. Service Engineering Course Lesson No. 23.

ponds to a positive impulse of 1 volt applied to the grid, and it is this rise of 1 volt in grid voltage which produces the increase in plate current.

With the lead disconnected from the 1½ volt tapping on the C battery, the 10,000 and 5,000 ohm resistors together form a voltage divider and, due to the fact that the resistance between point "A" and the positive terminal in the battery, being 5,000 ohms, is only one-third of the total resistance connected across the battery, which is 15,000 ohms, the voltage at point "A" will be one-third of that available from the battery, or, in other words, ½ volt. When the wire from point "A" is touched back to the minus 1.5 volt tapping on the battery, it short circuits the 10,000 ohm resistor so the full voltage from the 1.5 volt tapping is once more applied to the grid, dropping the voltage by 1 volt and causing the current to return to its original value.

If you subtract the normal value of plate current from the increased value of plate current, the difference will probably be approximately .5 milliamp. Expressing this in microamperes, the value will be approximately 500, because there are 1,000 micramperes in 1 milliamp, and consequently .5 milliamp would correspond to 500 microamperes. This means that the plate current has been increased by approximately 500 microamperes, due to a change of 1 volt in grid bias; in other words, the mutual conductance is 500 microamperes per volt, or this may also be expressed as 500 micromhos.*

The number of micromhos is known as the mutual conductance of the valve under the conditions applying when it was tested.

GAS TEST.

One fault which is not normally revealed by an emission type valve tester but which can be determined in this type of tester is the presence of any slight traces of air or gas in the envelope of the valve. If any gas is present and a resistance is included in the grid circuit of the valve, there will be a resulting change in plate current. Up to the present time the 1 megohm resistor connected in the grid circuit of the valve in Figure 16 has been shirt circuited by the wire shown across it. If you now disconnect one end of this wire, there should be no change in the reading of the milliamp meter. If the reading of the milliamp meter alters when the wire is disconnected from the 1 megohm resistor, it shows the presence of some gas in the tube and, depending upon the amount of change, whether the gas is likely to upset its performance or not. With most valves there should not be any noticeable movement of the meter pointer

* See A.R.C. Service Engineering Course Lesson No. 23.

when the wire is removed from the resistor and consequently, as the valves supplied to you are carefully tested before they are despatched, it is improbable that there will be any gas in them and that you will notice any change of the plate current meter.

Having tested the 1T4, you may now proceed to test the pentode section of the 1S5. This is done in a similar fashion to the testing of the 1T4, with the exception that socket Pin No. 4 is connected to the positive terminal of the battery instead of Pin 3. Also, the negative terminal of the milliamp meter is connected to Pin No. 5 instead of 2. The 1 megohm resistor is still connected to Pin No. 6, which corresponds to the control grid. There should not be any connection made to Pin No. 3, which is the diode plate. It is not possible to apply a mutual conductance test to a diode valve, as this type of valve can only be tested for emission, as explained earlier.

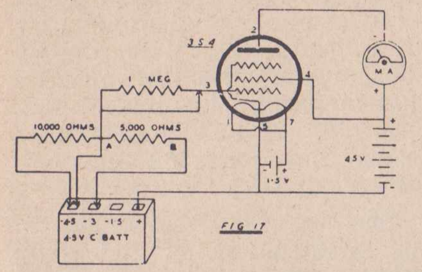
After having altered the connections to the valve socket, you may plug in the 1S5 valve and should obtain a reading of approximately .2 milliamp. In order to read this small value of current you may safely plug the positive lead of your multimeter into the socket marked "+ 1 m.a.".

On removing the wire from Point A to the minus 1.5 volt tapping on the C battery, the plate current will increase to approximately .5 milliamp. Subtracting the first reading from the second reading given is an increase of approximately .3 milliamp, which is roughly 300 microamperes and indicates that the valve has a mutual conductance of 300 micromhos under the condition applying during our test.

Due to slight variations in the construction of individual valves, the increase in plate current you obtain may not be exactly 300 microamperes, but will be somewhere near this figure. The real value of this type of test is that it reveals exactly the way in which the plate current changes when a small voltage change, representing a signal, is applied to the grid.

Next you should remove the wire which is normally short circuiting the 1 megohm resistor and test the 1S5 valve to see if gas is present in it. If there is no change in the reading of the milliamp meter, you may safely assume that the valve is satisfactory in this respect.

Finally, you may test the 3S4 valve in a similar manner. In this case it is necessary to alter the connections to the filament battery, as the positive side of the 1.5 volt battery should connect to Pins 1 and 7 joined together, and the negative side to Pin 5 on the valve socket. The milliamp meter should be connected to Pin No. 2, which is the plate, and the screen grid, connected to Pin 4, should be joined directly to the positive side of the B battery.



One end of the 1 megohm resistor should connect to the control grid of the valve at Pin No. 3 on the socket. It is also necessary to move the two leads shown connecting to the minus 1.5 volt tapping on the C battery in Figure 16 to the minus 4.5 volt tapping and the lead marked "B" from the 5,000 ohm resistor should be moved from the positive tapping on the battery to the minus 3 volt tapping. The lead from the negative terminal of the 1.5 volt battery and also from the negative terminal of the 45 volt battery should still continue to connect to the positive terminal of the C battery. Because the lead from "A" now connects to the minus 4.5 volt tapping on the C battery, the valve will have 4½ volts bias applied to it to start with, as this is the correct bias for the 3S4 type valve. Figure 17 shows the connections for testing the 3S4. Before inserting the valve in the socket, the positive lead of your multimeter should be plugged into the "+ 10 m.a." socket and you will find that, when the valve is inserted, the normal plate current is somewhere about 3 milliamps.

On removing the wire from "A" to the minus 4.5 volt tapping on the battery, the plate current will increase by a little more than 1 milliamp. This will correspond to an increase of a little more than 1,000 microamps and so the valve has a mutual conductance of a little more than 1,000 micromhos.

On restoring the lead to the minus 4.5 volt tapping of the C battery and removing the short circuiting wire from the 1 meg. resistor, you will be able to determine whether there is any gas present in the 3S4 or not.

As with the last set of experiments for testing the valves, you should keep a careful record of all the readings you have obtained with these valves set out in a table like that shown below, so that at any time in the future you can always retest your valves and compare them with their condition at the present time.

Valve	Normal Plate Current.	Inc'd. Plate Current.	Mills Change	Mutual Conductance Micromhos.	Mills with 1 meg. in grid wire.
1T4 ..	.72	1.2	.48	480	.72
1S5 ..	.2	.52	.32	320	.2
3S4 ..	3	4.2	1.2	1200	3

Of course, the figures included in the table above apply to only one particular set of tubes. The figures you obtain will doubtless differ slightly from these, but should be approximately the same.

EXPERIMENT 10.

THERMO-ELECTRIC E.M.F.

A fundamental principle of electricity which finds many applications in the measurement of temperature, the measurement of radio frequency current and which influences the behaviour of electrons in radio valves and other circuits is illustrated by Experiment No. 10.

It is a fundamental fact that, if two different conducting materials are joined together at one point and the temperature of this junction is increased by the application of heat, a small voltage will be developed between the two dissimilar substances. The strength of the voltage will never be very great; in fact, it will only be a few thousandths of a volt, but it will increase as the temperature of the junction of the metal is raised. For any particular pair of substances, there is a definite relationship between the voltages produced and the temperature, and consequently, if we take two dissimilar wires and connect them to a sensitive voltmeter, we have the ability to measure the temperature of the point at which the wires meet by the indication obtained on the meter scale.

Included in this kit of parts is a short length of fairly thick, 20 gauge, resistance wire, which consists of an alloy of copper and nickel. This resistance wire may be either bare, so that it looks very much like the 18 gauge tinned copper wire supplied with Kit No. 1, or it may be covered with brown enamel. If the wire supplied to you is covered with enamel, it will be necessary for you to scrape or sandpaper the enamel off for a distance of about an inch at each end.

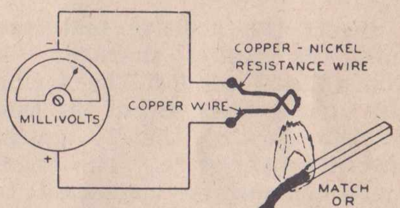


FIG 18

Cut a similar length of 18 gauge tinned copper wire from the coil supplied with Kit No. 1 and twist these two wires together at one end as shown by Figure No. 18. You should then apply a little soldering flux to the twisted ends of the wires and solder the ends together. The parts of the wires twisted together and the area covered by solder should be about ¼″ long. There should be sufficient twists to hold the wires securely together even before the solder is applied.

When using your multimeter on the 1 milliamp scale, it has an internal resistance of 100 ohms, and consequently, although it is normally used for measuring milliamps in this fashion, it is also capable of measuring very small voltages up to 100 millivolts or one-tenth of a volt. The needle will reach the right hand end of the scale with 100 millivolts applied, will move half way across the scale with 50 millivolts applied and will move to other positions in proportion. Each individual graduation mark on the scale will thus correspond to 2 millivolts.

Insert the positive test lead into the socket marked "+ 1 m.a." and connect the spring clip at the other end of the lead to the end of the 18 gauge tinned copper wire. The negameter should be connected to tive test lead from the multithe length of resistance wire. If the soldered joint, where the copper and resistance wire meet, has cooled, there will be no movement of the meter pointer when the connections are made, because of the fact that the temperature of the wire junction is the same as the temperature at the point where these wires connect to the meter test leads.

If you now heat the junction of the wires by means of a match, candle or any other flame, you will find that, as the wires become hotter at the end where they join one another, the meter needle will move across the scale. The greater the temperature of the wires, the further the needle will move. In fact, from the table set out below, you will be able to determine the approximate temperature of the "hot junction" of the wires from the meter indication. The temperature indicated by the table is not the actual temperature of the hot junction, but the number of degrees by which the hot junction exceeds the temperature of the point at which the thermocouple wires connect to the meter lead. Thus, if the meter pointer moves one-fifth of the way across the scale, to the first major graduation against which numbers are marked, this will correspond to 20 millivolts, and from the table you will see that the temperature to produce this deflection is 694 degrees fahrenheit or 386 degrees centigrade. If the temperature of the room is which the experiments are being conducted is 70°F. or approximately 20°C., then these numbers would have to be added onto the figures from the table to determine the actual temperature of the junction.

By inserting the soldered junction of the wires into an oven or any other hot area, you can measure the temperature of the area quite accurately by means of the meter indication and the following table:—

Millivolts	Temperature Difference °F.	Temperature Difference °C.
2	88	49
4	168	93
6	244	136
8	316	176
10	384	213
12	450	250
14	514	286
16	576	320
18	636	353
20	694	386
22	754	418
24	810	449
26	864	479
28	917	509
30	968	538
32	1020	567
34	1073	595
36	1123	623
38	1170	650
40	1218	677

"Pyrometers", used in industry for the measurement of furnace temperatures and other temperature measuring application, in many cases consist of nothing more than the pair of dissimilar wires and a meter. However, where a thermo-couple is to be permanently installed in a furnace or oven for temperature measurement, it is customary to use wires other than copper and copper nickel resistance wire. The copper wire will corrode rather quickly at high temperatures and would melt at extremely high temperatures. Consequently, actual thermo-couples usually consist of special metal alloys welded together at the end. For very high temperatures, corresponding to a white heat, platinum and an alloy of platinum and rhodium are used.

It is very difficult to devise an ordinary instrument for measuring radio frequency current, because the inductance or capacity effect of ordinary meters or copper oxide rectifiers, such as described in Lesson 4, would cause extreme inaccuracy at high frequencies. To overcome this effect, radio frequency currents are generally tested by means of a "thermocouple" made up as shown in Figure 19. The thermo-couple consists of a short length of

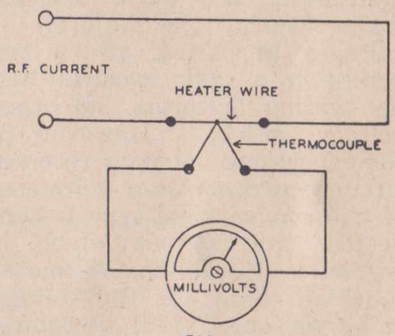


FIG 19

very thin resistance wire through which the current to be measured is passed. The current, in flowing through this wire, heats it and consequently heats the junction of a thermocouple attached to the heater wire near its centre. The thermo-couple may be welded to the heater wire or joined to it by a tiny glass bead. The heat from the heater wire heats the thermo-couple and this, in turn, causes an indication on a moving coil instrument somewhat similar to the one supplied to you.

It is not practicable for you to conduct an experiment along these lines, because the equipment supplied to you is not capable of generating sufficient radio frequency current to heat the thick resistance wire supplied. The principle, however, is just one logical step further than the thermo-couple you have just experimented with.

VACUUM TUBE VOLTMETERS.

The voltmeter ranges of your multimeter are quite suitable for measuring the majority of voltages appearing at various points in a radio receiver and for testing batteries and other voltage sources. However, in some portions of radio receiver circuits, as soon as a voltmeter of the conventional type is connected, the current which is needed to operate the voltmeter causes a change in the voltage being measured and, therefore, the voltmeter does not give a true indication of the voltage, but reads a lower figure. One way of reading the accurate value of the voltage being measured is to make the measurement with a type of voltmeter which consumes little or no current from the circuit under test. In this way the voltage will not be disturbed when the voltmeter is applied and the meter will be able to register the true voltage of the circuit.

One way of achieving a high input impedance is to apply the voltage to be measured to the grid of a radio valve and to connect an ordinary milliamp meter in the plate circuit. The voltage applied to the grid causes a change in plate current, and this change in plate current will move the indicator of the meter in accordance with the strength of voltage. The stronger the voltage, the greater the change in plate current and the greater the meter reading. An instrument of this type can fairly readily be calibrated so that, by the aid of a table or graph, a reading on the milliamp meter can easily be converted to indicate the voltage applied to the grid, and this voltage determined. There are several ways of combining a valve and meter to represent a "vacuum tube voltmeter", which is generally abbreviated to V.T.V.M. These instruments are also sometimes called "electronic voltmeters".

EXPERIMENT 11.

D.C. VACUUM TUBE VOLTMETER.

One type of vacuum tube voltmeter suitable for measuring direct voltages without drawing any current from the circuit being tested is shown in Figure 20. On the right hand side of this diagram you will see that the IT4 valve has its filament heated by a 1.5 volt battery, and that the multimeter on the 1 milliamp range is connected in the plate circuit.

The screen grid and plate are both joined together to act as the plate.

You can conveniently build up this piece of equipment by mounting a socket for the 1T4 valve and the two potentiometers on the chassis supplied with this kit.

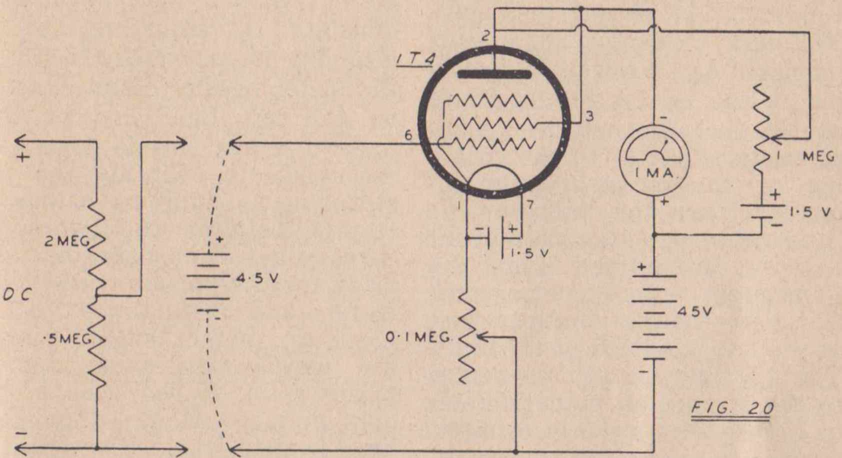


FIG. 20

The .1 megohm potentiometer is connected in the line between the negative filament terminal of the valve and the negative terminal of the battery to provide a certain amount of negative grid bias for the grid of the valve. The plate current of the 1T4, in flowing through this resistor, produces a voltage drop across it which makes the voltage at the moving arm, indicated by the arrowhead in Figure 20, negative, compared with that at the outside lug, which is connected to Pin No. 1 on the valve socket. In wiring up the potentiometer, if you look at the rear of it with the connecting lugs pointing up in the air, you should make a connection to the centre lug and to the outside lug on the left hand side of the centre. The value to which this potentiometer is adjusted will not only determine the amount of negative bias provided for the grid of the valve but also the number of volts which must be applied to the grid to send the meter pointer right across to the right hand end of the scale.

As you will be using your test leads for connecting the multimeter to the positive terminal of the B battery and to Pin 2 on the valve socket, you will not be able to use these long test leads for connecting to the grid of the valve and the minus terminal of the B battery to act as test leads for the vacuum tube voltmeter. Instead, you should cut two rather long lengths of wire from your supply of hook-up wire and use these as test leads. One will connect to Pin No. 6 on the valve socket and the other can be joined either to the negative terminal of the B battery or to the centre lug on the .1 megohm potentiometer.

When you have wired up the equipment as shown in Figure 20, touch these two long leads indicated by arrowheads pointing to the left in Figure 20 to one another, so that the grid is connected directly to the centre lug of the .1 meg. potentiometer. Turn the knob on the .1 megohm potentiometer about half way around and adjust the 1 megohm potentiometer until the meter needle points to zero at the left hand end of the scale. The 1.5 volt battery connected to the 1 megohm potentiometer in Figure 20 is used to counteract the normal plate current of the valve which would still be passing through the meter and causing the needle to point upscale by several graduations. This is due to the fact that the bias voltage produced by the .1 megohm potentiometer will not be great enough to reduce the 1T4 valve's plate current to zero, but will leave some plate current flowing and, unless we compensate for this by the "bucking" voltage of the 1.5 volt cell, our meter needle would not start from zero on the scale. The needle can be made to commence from zero on the scale by sending some current "backwards" through the meter by means of the 1.5 volt cell and 1 megohm potentiometer. This 1.5 volt cell will have to be borrowed from the ohmmeter for the time being. Disconnect the cell completely from the ohmmeter circuit of your multimeter and use it for providing bucking current as shown in Figure 20. You will not have any difficulty in adjusting the 1 megohm potentiometer to cause the meter needle to rest exactly on the left hand end of the scale. When this is done you are ready to calibrate the instrument by applying a known voltage between the two long wires you will be using as test leads for the vacuum tube voltmeter and adjusting the .1 megohm potentiometer until the needle reaches an appropriate point on the scale. The only known voltage which you have is that provided by the 4.5 volt C battery. Before you actually undertake the job of calibration, it is not wise to assume that the 4.5 volt C battery has a voltage of exactly 4.5, but to measure it first with your voltmeter. Plug the positive lead from your multimeter for a moment into the Plus 10 volt socket and measure the voltage of the 4½ volt battery. Make a note on a piece of paper of the reading. If you have used the battery extensively for other experiments, you may find that its voltage is now somewhat lower than 4.5 and will probably be somewhere near 4 volts.

After having determined the

voltage of the battery, plug the positive lead of the meter back into the Plus 1 m.a. socket and reconnect it to the plate circuit of the 1T4 valve and the positive side of the B battery.

Now that you have a battery of known voltage, you may connect the test leads of your vacuum tube voltmeter to it, as shown by dotted lines in Figure 20. The wire connecting to Pin 6 on the valve socket will connect to the positive end of the battery, and the one from the centre lug on the potentiometer to the negative end of the battery. When you connect the wires to the battery, the meter needle will move across the scale, but probably will not fall on the graduation corresponding exactly with the battery's voltage. If, for example, your battery has a voltage of 4, you should adjust the knob on the .1 megohm potentiometer until the meter registers 4 on the 10 volt range. That will be a little less than half way across.

After making the needle register the voltage of the battery, disconnect the 4.5 volt battery, touch the leads together and check to see whether the needle still registers zero at the left hand end of the scale. It will probably not do so, because of the fact that you have altered the .1 megohm potentiometer. Readjust the 1 megohm potentiometer until the meter needle again rests at zero at the left hand end and then apply the test leads to the 4.5 volt battery once more. In this case you will probably find it necessary to slightly alter the .1 megohm potentiometer, to again make the meter register the same voltage as that possessed by the battery. You may need to alter the settings of the two potentiometers three or four times before you find that, with the test leads touched together, the needle rests at zero and, with the test leads applied to the battery, the meter indicates the battery voltage. Once you have juggled the settings of the two potentiometers in this way, you have "calibrated" the instrument and you may then apply the test leads to any other source of direct voltage. You can use the instrument for checking the voltage of other batteries, provided the full voltage does not exceed 10. You may also use the instrument for measuring the value of grid bias voltage or automatic volume control voltage in any radio receiver you possess. In measuring the value of grid bias or A.V.C. voltage, you can depend on the fact that the meter will indicate fairly accurately, voltages present in the circuit and in the case of bias and A.V.C. voltages, this would not be the case if an ordinary voltmeter were used.

You will find that the vacuum tube voltmeter will indicate voltages up to about 10 volts before the needle reaches the right hand end of the scale. In many cases it will be desirable to measure still higher voltages, and you can increase the range, either by increasing the setting of the .1 meg. resistor or by connecting a "voltage divider" at the input of the voltmeter, as shown at the left hand side of Figure 20.

The disadvantage of increasing the setting of the .1 megohm potentiometer to increase the range is that you will need to recalibrate the instrument on the higher range by applying a higher value of known voltage. With this method, the range could only be increased up to a value of about 25 volts or, in other words, up to a little more than half of the B battery voltage. As you have no known voltage of about 25 volts, it is impracticable to produce an increase in range in this fashion.

The most practical way of increasing the range of the instrument is by means of a voltage divider consisting of two resistors connected in series. If you examine the left hand half of Figure 20, you will see that a 2 megohm and .5 megohm resistor are connected together and that an unknown voltage can be applied across the two resistors. The lower end of the .5 megohm resistor is connected to the centre lug on the .1 megohm potentiometer and the test lead from Pin 6 on the valve socket connects to the junction of the two resistors. Due to the fact that the .5 megohm resistor is exactly one-fifth part of the total resistance of 2.5 megohms, any voltage applied across the two resistors will be reduced to exactly one-fifth of its value at the junction point. Consequently, if we have previously calibrated our instrument alone to register up to 10 volts; when the lead from the grid of the valve is connected to the junction of the two resistors we may apply any value of voltage up to 50 to the two resistors. When 50 volts is applied, 10 volts will be available at the junction of the two and this 10 volts will just be enough to send the meter needle across to the right hand end of the scale. Consequently, we may measure the voltage by observing the position of the needle on the set of figures terminating at 50 at the right hand end. An unknown voltage applied at the extreme left of Figure 20 and causing the meter needle to move half way across the scale would be a voltage of 25, because the 25 volts applied at the input would be reduced by the voltage divider to one-fifth or 5 volts, and this would be enough to send the needle only half way across the scale.

The range of the instrument could be increased still further by altering the ratio of the two resistors forming the voltage divider. If you place the 5 meg. resistor in place of the 2 meg. resistor, then the lower resistance in the voltage divider will be one-eleventh of the total resistance, and it would take 110 volts applied across the two resistors to send the needle across to the right hand end of the scale. This is not a very convenient range because there are no numbers on the meter base terminating in 110 at the right hand end, and consequently this range would be somewhat difficult to use. However, in practice, other values of resistors may be chosen, such that the ratio will increase the range of the instrument by 25, 50, 100 or any other convenient number of times.

To check the effectiveness of the voltage divider consisting of the 2 meg. and .5 meg. resistor, you may touch the lead connecting to the upper end of the 2 meg. resistor to the positive terminal of your 45 volt battery. This will cause the meter needle to move about four-fifths of the way across the scale, indicating a voltage of about 40 or 45 volts on the 50 volt range of the meter. The voltage indicated will be the approximate voltage of your battery. If you have used your battery extensively prior to making these tests, this voltage will probably be much lower than 45, but the meter will give you an indication of its value.

A vacuum tube voltmeter such as this is not as accurate or as reliable as a multimeter which does not employ a vacuum tube, because of the fact that radio valves do not have a direct and constant relationship between the voltage applied to the grid and the current flowing in the plate circuit. If there is any disagreement between the value indicated by the vacuum tube voltmeter and that of your multimeter when testing the voltage of a battery, the multimeter will be the more accurate. However, in testing voltages in the grid or automatic volume control circuits of receivers, the vacuum tube voltmeter will probably give the more accurate result.

The circuit arrangement shown in Figure 20 is most suitable for testing voltages in receivers which are positive compared with the chassis. In this case the lower test lead, connecting to the centre lug of the .1 megohm potentiometer, may be connected to the chassis of the radio receiver and the other test lead, connecting to the grid pin on the valve socket or to the upper end of the 2 meg. resistor when the voltage divider is used, may be touched to other points in the radio receiver to measure values of positive voltage. If the test lead is connected to points of negative voltage the needle will tend to move below zero or to the left of zero on the scale.

To measure negative voltages it is possible to connect the test lead joining to the grid pin in the valve socket to the receiver chassis and to touch the lower test lead in Figure 20 to the point of negative voltage in a radio receiver. However, if the readings are to be accurate, the batteries and chassis of the vacuum tube voltmeter must not in any other way be connected to the receiver being tested.

When measuring negative voltages the presence of any wires carrying alternating power mains voltage near the chassis or batteries of the voltmeter, or even the effect of placing one's hand on the chassis or near the batteries, may cause the meter needle to move across the scale and give a reading when no actual voltage is applied. In commercially made vacuum tube voltmeters a different circuit arrangement is sometimes employed to overcome this effect and to enable either positive or negative voltages to be measured rapidly without the necessity for changing over the test leads.

EXPERIMENT 12.

CENTRE ZERO V.T.V.M.

If you alter the circuit arrangement of your vacuum tube voltmeter to that shown in Figure 21, you will be able to adjust the two potentiometers so that the meter needle commences half way across the scale and so that a positive input voltage applied to the lead connecting to the grid of the valve causes the needle to move further to the right, whereas a negative voltage is revealed by making the meter needle move towards the left.

As we require .5 milliamp of current to pass through the meter to commence with, a "bucking voltage and resistor", as shown at the right of Figure 20, are not needed.

After wiring up the valve socket, as shown in Figure 21,

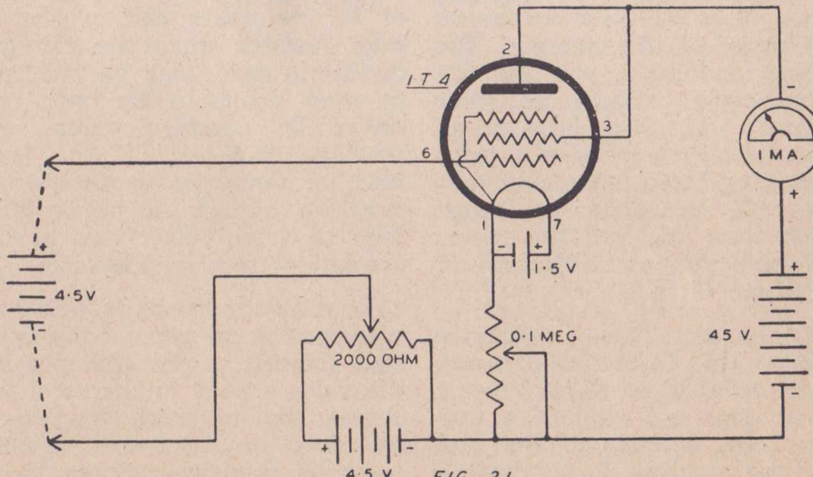


FIG 21

insert the valve and adjust the value of the 2,000 ohm potentiometer until the moving arm is nearly at the end connecting to the negative terminal of the 4.5 volt battery and the B battery. Touch the test leads, indicated by the arrowheads pointing to the left in Figure 21, together and adjust the .1 megohm potentiometer until the needle registers exactly half way across the meter scale. Next separate the test leads and of this battery. We are endeavouring to make this instrument register up to 5 volts in either direction, and consequently the scale values would correspond with those indicated in Figure 22.

Because zero now corresponds to the position of the pointer half way across the scale whenever the needle is in this position it corresponds to no voltage applied, and you will see in Figure 22 on the lower set of

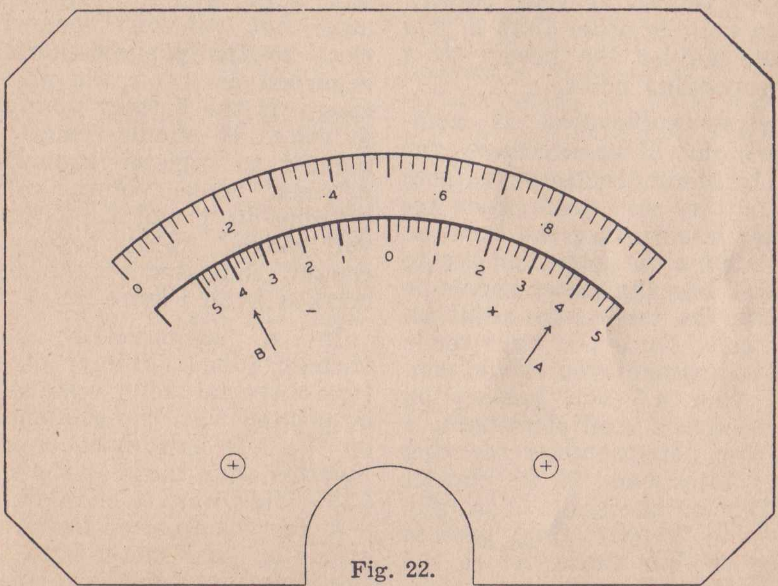


Fig. 22.

connect the upper one to the positive terminal of your 4.5 volt battery and the lower one to the negative terminal, as shown by the dotted line in Figure 21. You will now have to readjust the .1 megohm potentiometer until the meter registers on the scale the value numbers, zero marked at this point. The application of 5 positive volts to the grid of the valve will, when we have completed our calibration, cause the needle to reach the right-hand end of the scale and so in Figure 22 you will see the number 5 placed at this point. Four corresponds to the number 9 on the original meter scale and 3 volts corresponds to the original point marked 8. If your battery now has a value of 4 volts, then you should adjust the .1 megohm potentiometer until the needle takes up a position corresponding to 4 volts on the lower scale in Figure 22. This would correspond to the point normally regarded as 9 volts on the original scale. This point is shown by an arrow in Figure 22. Of course, if your battery has a voltage other than 4, you should adjust the needle to a corresponding point.

Before calibration is completed, it will be necessary for you to disconnect the wires from the battery and touch them together, readjusting the knob on the 2,000 ohm potentiometer to again cause the meter needle to register at the centre point on the scale. Once you have made this adjustment you should connect your 4.5 volt battery on again and readjust the .1 megohm potentiometer to bring the pointer back to its correct position on the scale. You may have to repeat this process three or four times before the calibration is complete. Once you have completed the calibration you can apply any other unknown positive voltage up to a value of 5 volts to the upper test lead and estimate its value by reference to Figure 22.

If you wish to measure voltages higher than 5, you may use the 2 meg. and .5 meg. resistor, as shown at the left hand side of Figure 20. This will extend the range up to 25 volts.

If you connect the 4.5 volts battery with a negative terminal joined to the upper test lead and the positive terminal to the lead from the 2,000 ohm potentiometer, you will find that the needle moves to the left of the centre point. Due to the fact that the valve has a bend in its characteristic curve, minus 5 will not correspond with the left hand end of the meter scale, but will come somewhere close to the position normally regarded as 1 on the 10 volt range. If the battery voltage is 4 volts, it should cause the pointer to register somewhere between scale points corresponding to 1 and 2 on the 10 volt range. This position is roughly indicated by the arrow marked B on Figure 22.

In a commercially made vacuum tube voltmeter of this type a special meter scale would be printed with the graduations on the left half more crowded together than those on the right half. However, it is impracticable for you to alter the graduations on your meter scale, but the important point is to realise the principle of a vacuum tube voltmeter of this type, and you will be able to do this in conjunction with Figure 22.

These two diagrams by no means complete the range of vacuum tube voltmeters for the measurement of direct voltages. In commercial instruments several other circuits are used, which vary slightly from these, but most are based on the arrangement shown in Figure 20 or the one shown in Figure 21, and consist only of elaborations on these principles. Consequently, if you understand the principles involved in these two diagrams it will help you at any time in the future when constructing or using a more elaborate vacuum tube voltmeter based on these principles.

EXPERIMENT 13.

ELECTRONIC MEGOHM METER.

In constructing your multimeter you have already equipped it with two ranges for the measurement of resistance. The "low ohms" range covers the measurements of resistance up to 1,000 ohms, and the "high ohms" range covers the measurements of resistance up to 100,000 ohms. It is not practicable to make your instrument measure values of resistance higher than 100,000 ohms without the use of a voltage greater than that of the 1.5 volt cell. To increase the range of the instrument to enable it to measure up to 1 megohm would need the use of a 15 volt battery, and to enable it to measure up to 10 megohms would require a source of 150 volts. These high voltages are necessary to drive measureable amounts of current through the high values of resistance to be measured. The voltage must be great enough to force through these high resistances enough current to give a substantial indication on the meter face.

As an alternative to using the higher voltages, we may use a more sensitive indicator, which will respond to the very small

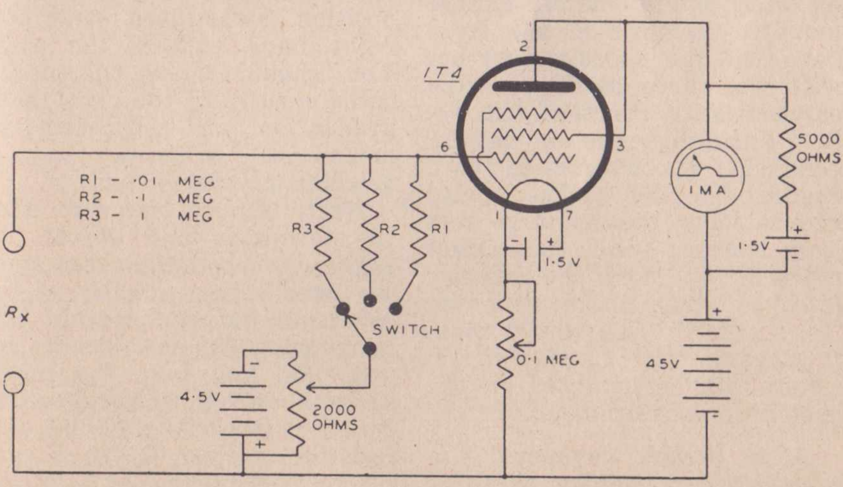


FIG 23

values of current which flow through high resistances, even with the application of a small voltage.

The principle of the sensitive vacuum tube voltmeter may be applied for resistance measurement. For example, Figure 23 shows a circuit diagram of an instrument which is capable of checking the approximate values of resistances up to 25 megohms, although a test voltage of only 4.5 is applied. This instrument is fundamentally a vacuum tube voltmeter, measuring the proportions in which the voltage from the 4.5 volt battery divides between the standard resistors, shown as R1, R2 and R3 in the diagram, and the unknown resistance connected across the terminals, marked RX.

In constructing this instrument, the 2,000 ohm and .1 megohm potentiometers can be mounted in holes in the front flange of the chassis, together with the three position switch supplied with Practical Kit No. 5. Carefully wire up the instrument in accordance with Figure No. 23. The meter should have the negative test lead inserted into the socket marked "—" and the positive lead in the socket marked "+ 1 m.a." The 10,000 ohm, .1 megohm and 1 megohm resistors can be mounted on the length of resistor panel.

After having completed the wiring and carefully checking it for accuracy, you may connect on the batteries. The 1.5 volt battery applying bucking current to the meter should be connected first. When this is connected you will find that the meter needle moves backward to the left of zero until it comes against the stop. This is quite in order and does not indicate that the battery is reversed.

The 4.5 volt battery should be connected to the 2,000 ohm potentiometer next, then the 1.5 volt battery to the filament of the tube and finally the 45 volt battery.

ADJUSTMENT.

To prepare the megohm meter for use, connect the two terminals marked "Rx" in Figure 23 together by means of a short length of bare 18 gauge copper wire. When the two terminals are linked together, the meter needle should take up its position somewhere near the right hand end of the scale. You should make the needle point exactly to the right hand graduation on the scale by means of adjusting the .1 megohm potentiometer.

Next, remove the wire from the terminals and adjust the 2,000 ohm potentiometer until the needle rests exactly at the left hand end of the scale. The instrument is now ready for use. If you turn the three-position switch to the position which connects the 10,000 ohm resistor, marked R1 in Figure 23, to the moving arm of the 2,000 ohm potentiometer, the instrument will be capable of testing resistances up to approximately 250,000 ohms.

Unfortunately, the resistance indications will not agree with the markings on the ohms scale of your meter face.

Due to the fact that a valve has a bend in its characteristic curve, as indicated in Figure 16 of Practical Lesson No. 4, there will be no definite relationship between the measurements of resistance with this electronic megohm meter and the indication of resistance on the ohms scale. However, Figure 24 of this lesson gives an indication of the relationship between the various values of resistance and the resulting reading on the 1 milliamp range of your meter face.

You will be able to confirm that your instrument agrees approximately with Figure 24 by connecting various resistors in turn to the terminal marked "Rx". You will be able to try the 500 ohm resistor, the 15,000 ohm, 50,000 ohm and 75,000 ohm resistors in turn, and observe that the reading on the meter agrees roughly with that marked opposite to these resistance values in Figure 24.

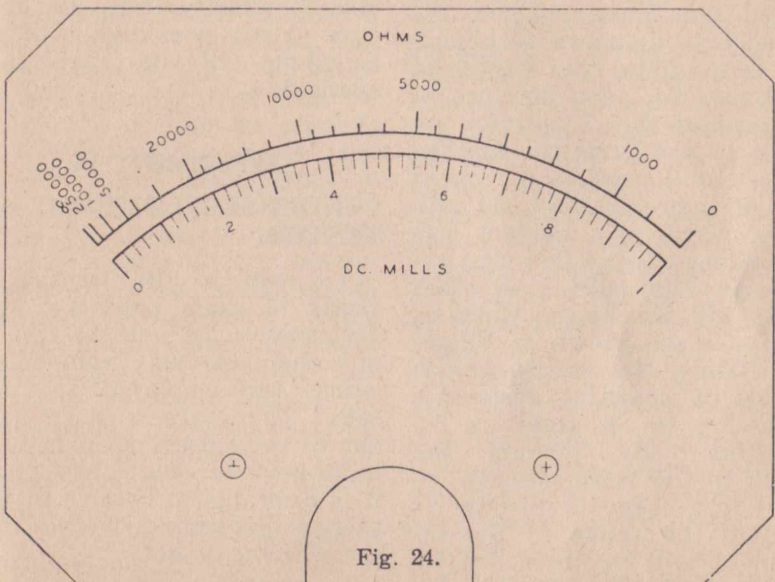


Fig. 24.

The instrument you construct may not agree exactly with the scale shown in Figure 24, because of variations in individual valves. A slight change in the characteristics of the valve will cause the readings to disagree with those in Figure 24, particularly with high values of resistance connected. However, your instrument should agree fairly closely with Figure 24 and will be accurate enough to give you some idea of the value of any other unknown resistance you may connect to the terminals "Rx".

By turning the three-position switch to the middle position so that the .1 megohm resistor is connected in place of the 10,000 ohm resistor, the range of the ohmmeter will be extended ten times, so that the value of an unknown resistance will be ten times that suggested by Figure 24. For instance, if you connect the .5 megohm resistor to the terminal marked "Rx" it will produce a current flow of approximately .06 milliamp, which is a current corresponding to a 50,000 ohm resistor in Figure 24. All other values will also be ten times as high as those shown in Figure 24. Thus, the instrument is capable of detecting resistance values up to as great as 2.5 megohms. By turning the switch to the third position, so that the 1 megohm resistor is selected, the range of the instrument will be increased by one hundred times. On connecting the .5 megohm resistor to the terminals, you will again find the instrument giving an indication of approximately .06 milliamp, which is marked against 50,000 ohms in Figure 24. However, this value of 50,000 ohms should be multiplied by 100 when the 1 megohm resistor is selected by the switch, and this applies also to all other values of resistance. Because it is necessary to multiply the value indicated in Figure 24 by 100, you will observe that the instrument can detect resistance values up to 25 megohms when the current passing through the instrument is .01 milliamp. The highest resistance supplied with this kit of parts is 5 megohms, but if you have any other unknown resistances, you will soon be able to classify them and measure values even higher than 5 megohms, if you have them available.

EXPERIMENT 14.

CONDENSER LEAKAGE TESTER.

To help in the location of faults in radio receivers, it is desirable to be able to test all of the various components which are employed in radio sets. There are a large number of condensers used in most radio receivers and consequently it is desirable to be able to test these to determine whether they are efficient or not.

In testing condensers there are two characteristics which should be checked. One is to see that the condenser has the correct capacity, in accordance with the value marked on the label, and the other characteristic is to see that the insulation material in it is not defective, allowing direct current to leak through it.

We will deal with equipment for determining the capacity of condensers later on in this lesson.

As you are well aware, a condenser consists of two conducting materials separated by insulation, called the dielectric.*

Although theoretically a good quality insulation material has an infinitely high resistance, in practice the mica or waxed paper used as the dielectric in condensers has a definite value of resistance which allows a small amount of direct current to leak through it. It is, of course, desirable that this resistance be as high as possible and it usually exceeds 100 megohms per microfarad in good quality condensers and should, in all cases, be higher than 10 megohms per microfarad, with the exception of electrolytic condensers, which have a much lower resistance than this. Of course, the value of resistance should become greater in condensers of smaller capacity because of the smaller quantity of insulation material used. Thus, if a condenser of 1 microfarad has a resistance of 100 megohms, a condenser of .1 microfarad should have a resistance of 1,000 megohms, and so on in proportion.

It is very difficult to measure these very high values of resistance without specialised equipment. Even the electronic megohm meters described in our last experiment will only allow us to measure conveniently up to about 25 megohms. However, by increasing the value of resistance connected to the grid of the tube and increasing the test voltage to 45 volts, we may determine the values of leakage resistance in a condenser up to about 1,000 megohms.

A circuit which shows how you may construct a high range megohm meter especially suitable for testing the leakage resistance of condensers but also equally suitable for measuring any other high value of resistance, such as leakage between windings of a transformer or between one winding and a metal case of a transformer or between the element and frame of electric appliances or electric motors, is shown in Figure 25. You will see that this arrangement differs only slightly from that in Figure 23.

After wiring up the circuit arrangement as shown in Figure 25 and checking your wiring very carefully to detect any possible errors, you should connect on the batteries in the same sequence as previously, that is, the 1.5 volt battery for supplying bucking current to the meter should be connected first. As before, this will cause the meter needle to move backwards a few degrees before the 1T4 valve commences drawing its plate current.

Next you should connect the

* See A.R.C. Service Engineering Course Lessons 6 and 34.

4.5 volt battery to the 2,000 ohm potentiometer, then the 1.5 volt battery to the filament circuit of the tube and finally the 45 volt battery to the plate circuit of the tube. Voltage from this same 45 volt battery is applied to one of the test leads to be applied to the condenser or other device to be tested for resistance.

ADJUSTMENT.

When the equipment is first switched on, and without having anything connected to the terminals shown at the top of the diagram, the meter needle should fall somewhere near the left hand end of the scale. You can use the 2,000 ohm potentiometer to adjust the meter needle to the zero position at the left hand end of the scale. This corresponds to an infinitely high resistance. If, by any chance, you cannot make the meter needle register at the left hand end of the scale, but find that, no matter how you turn the 2,000 ohm potentiometer, the needle stays a few graduations up the scale, then it may be necessary to change the 10,000 ohm resistor connected to the 1.5 volts bucking battery and replace it with the 5,000 ohm resistor. Normally, however, the 10,000 ohm resistor will prove satisfactory in this position.

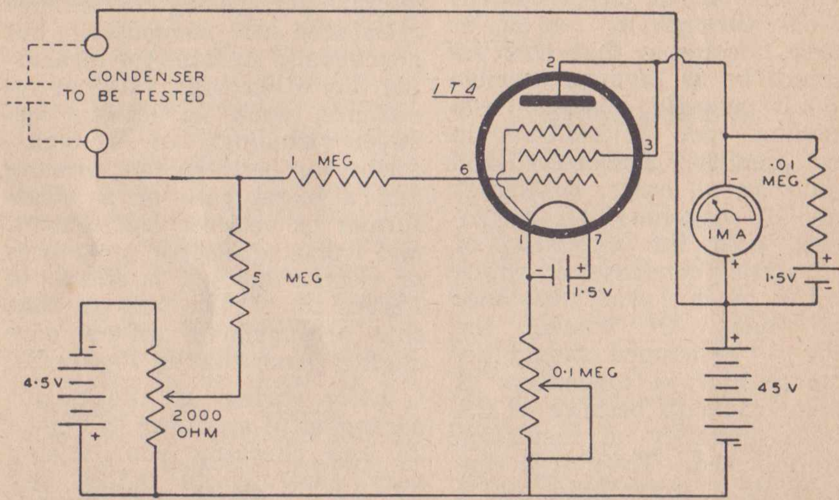


FIG 25

After having adjusted the needle to zero at the left hand end of the scale, connect a piece of wire across the terminals shown at the upper left hand side of Figure 25, or touch the test leads connecting to these points to one another and adjust the .1 megohm potentiometer until the needle rests at the right hand end of the scale. After having done this, you will probably find it necessary to readjust the 2,000 ohm potentiometer to again make the needle rest at the left hand end of the scale with nothing connected to the terminals, and you may have to make slight readjustments to these two potentiometers in turn until the needle reaches each end of the scale, depending upon whether the terminals are connected together or left disconnected.

After adjusting these two potentiometers you may apply the test leads connected to the terminals to a condenser to be tested. I suggest that you try each of the condensers supplied to you.

In some cases you will doubtless find that the needle gives a reading part of the way up the scale, indicating the presence of a finite value of resistance in the condenser. You will find that the number of megohms indicated by the meter is roughly the number indicated by the pointer on the ohms range at the top of the instrument face. That is, if the needle comes to rest at a point corresponding to 100 on the instrument's face, this would correspond to 100 megohms and you will be able to obtain an approximate indication ot the value of any high resistance connected to the instrument by regarding the numbers on the ohms scales as being megohms. The accuracy of the instrument is not extremely precise when the meter pointer is registering near the right hand end of the scale, but nevertheless gives an approximate indication. You will see that the ohms scale on your meter face is numbered up to a value of 1,000 near the left hand end and consequently you may detect resistance values up to approximately 1,000 megohms with this instrument. Electrolytic condensers will always have a much lower resistance than paper and mica types but their resistance generally will exceed .1 megohm. If you apply the test leads from this instrument to various household appliances you may have, you will probably be surprised at the low value of insulation resistance present. In devices such as household irons, toasters, electric soldering irons and electric stoves, one frequently finds that the resistance between the elements and the frame is only a few megohms, but for safety's sake, as long as the resistance exceeds 1 megohm, there is little chance of a person receiving an electric shock and the equipment may be considered as satisfactory. In testing electric motors the resistance present between the windings and the metal frame should normally exceed 10 megohms, although in conditions of extremely high humidity, the resistance may fall below this value.

If you attempt to test electric motors, household electrical appliances or other such devices, it is most important that you always disconnect the units completely from the power mains before connecting them to the instrument. If, at any time, you connect the instrument to the power mains wiring, the high voltage from the power mains applied to the instrument will be certain to damage it.

EXPERIMENT 15.

V.T.V. METERS FOR ALTERNATING VOLTAGE.

The vacuum tube voltmeters you constructed in Experiments 11 and 12 were really only suitable for the measurement of direct voltages. It frequently arises in practice that it is desirable to measure alternating voltages and a radio tube may be used in conjunction with a direct current meter for this purpose. This point has already been explained in some detail in Practical Lesson No. 4 in which Figures 19 and 20 show the valve used as a rectifier to enable the instrument to measure alternating voltages.

There are several ways, however, in which a valve may be used for this purpose. In some ways the tube is merely a rectifier which does not provide the advantage of an extremely high input impedance and consequently, when attempting to measure alternating voltages in circuits containing high resistance values, the meter will not give a true reading. On the other hand, it is also possible to construct vacuum tube voltmeters for alternating voltages which do have an extremely high input resistance, thus permitting the accurate measurement of alternating voltages in high resistance circuits. We will examine five different methods of measuring alternating voltages with the aid of a radio tube, in the following experiments.

If we are to study the behaviour of valves in measuring alternating voltages, we must obviously have some alternating voltages available for testing purposes. The majority of you will not have alternating voltage power mains available in your dwelling and consequently it is necessary to construct an audio frequency oscillator to produce an alternating voltage. Figure 26 shows a circuit arrangement of an audio frequency oscillator, which is almost identical with that shown in Figure 1 of Practical Lesson 5. In this case, however, the loud speaker is not used, but the loud speaker transformer is employed to step up the low voltage supplied by the voice coil winding on the oscillator transformer to a useable value. The principle of operation of this type of oscillator is explained in the early part of Practical Lesson No. 5 and you should read this over again to refresh your memory. The pulsations of current flowing through the primary winding of the iron cored transformer will produce magnetic lines of force in the core and these, in turn, will generate an alternating voltage in the secondary winding. Due to the fact that the secondary winding has only a very few turns of wire wound on it, the voltage available from the secondary winding will only be about 1 volt. This voltage is too low to be of very much use to us in the following experiments and consequently we can employ the and two wires. The bolts and nuts can easily be removed and the wires carefully unsoldered from the small eyelets to which they are connected. In some of the loud speakers the transformers are rivetted in position and consequently it will not be possible for you to remove the loud speaker transformer if it is rivetted in position. However, by examining the transformer, you will observe that,

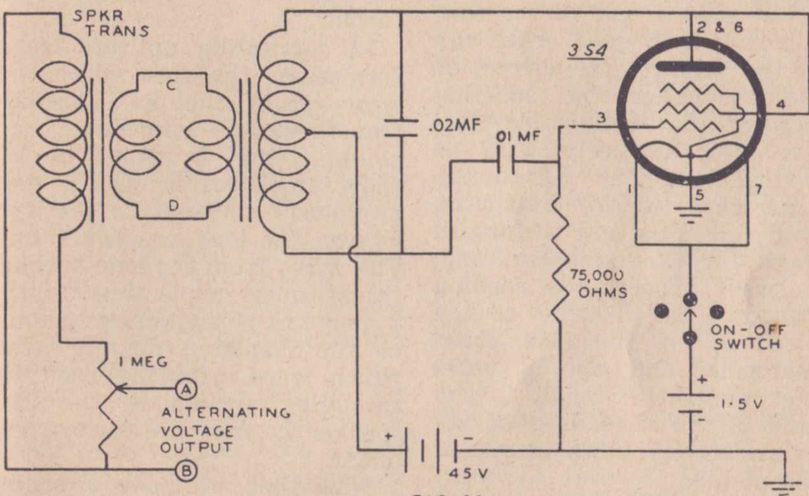


FIG 26

transformer supplied with your loud speaker to step up this low voltage to a higher value of somewhere about 20 or 30 volts.

It is not absolutely essential for you to remove the output transformer from the loud speaker, but you may do so if you wish to. In most of the loud speakers supplied with Practical Kit No. 5 the transformer is only attached to the speaker by means of two bolts apart from the long flexible wires connected to the primary, there are also two short wires emerging from the transformer and connecting to the eyelets referred to previously, attached to the loud speaker frame. It is desirable for you to disconnect these two wires and to solder to them long pieces of flexible hook-up wire.

If you do remove the transformer from the speaker, you can bolt it onto the chassis on which the audio oscillator is constructed. This chassis will be the one you were using previously for your radio receiver experiments. The 1 megohm potentiometer, which can be used to vary the strength of signals supplied by the oscillator, can be mounted on the front flange of the chassis.

After having wired up the oscillator, as shown in Figure 26, you should test to see that the wiring is in good order and that the voltages are correct as explained under the heading "Testing" and "Connecting Batteries" in the early part of Practical Lesson 5. Of course, in this case we are employing the 45 volt B battery to furnish voltage for the oscillator, and, instead of expecting a reading of about 5 or 6 volts at the centre tap of the iron cored transformer and also at valve socket contacts 2 and 4, you should obtain a reading of approximately 45 volts at all of these points.

If the testing indicates that conditions are correct, you may plug in the 3S4 valve. To make sure that the oscillator is functioning and producing an audio frequency voltage, you should connect two short lengths of wire to the points marked C and D in Figure 26, and touch these onto the two eyelets on the loud speaker frame, from which you disconnected the secondary of the loud speaker transformer. The voltage from points C and D on Figure 26, when applied to these eyelets, will reach the voice coil of the speaker and will produce a loud howling sound from the speaker if the oscillator is functioning. Do not leave the loud speaker permanently connected, as the howl will become annoying and the power absorbed by the loud speaker will reduce the voltage available for testing purposes from the high impedance winding of the loud speaker transformer.

In connecting up this transformer in the first place, the wires from the loud speaker transformer connecting to points C and D should be the short thick wires which were previously soldered to the eyelets on the loud speaker frame. The wires from the loud speaker transformer connecting to the 1 megohm potentiometer should be the insulated flexible wires which were originally used for supplying signals to the loud speaker in your previous experiment.

Now that we have a source of alternating voltage available we may proceed to construct various rectifier circuits to enable our meter to register the value of the alternating voltage.

EXPERIMENT 16.

DIODE RECTIFIER.

Figure 27 shows the 1T4 valve connected as a diode, that is, with the control grid, screen grid and plate all joined together to act as the plate of the valve. In this application, the 1T4 acts as a diode in exactly the same fashion as the 3S4 acted as a diode in Figures 19 and 20 in Practical Lesson No. 4. The principle of operation is also the same as for the 3S4 and, if you are not familiar with

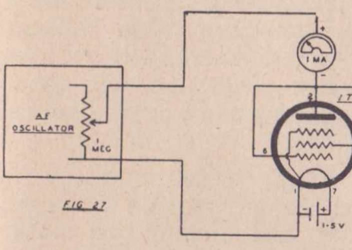


FIG. 27

this, you should read the text of Lesson 4 relating to Figures 19 and 20.

The socket for the 1T4 can be mounted on the chassis supplied with this kit of parts, and the meter should be used on the 1 milliamp range.

With only the meter and valve in the circuit, and with no extra resistance, the meter will reach the right hand end of the scale when a voltage of approximately 7.5 is applied. Actually, your oscillator is capable of furnishing between 20 and 30 volts, so you should commence with the 1 megohm potentiometer turned fully off, that is, in a counterclockwise direction and gradually turn it on until the meter reaches the right hand end of the scale. Progressively smaller voltages, produced by turning the potentiometer in an anticlockwise direction, will produce corresponding reductions in meter needle deflection.

Even with no voltage applied, that is, with the potentiometer turned fully off, there will still be some reading on the meter face. The needle will move about two graduations across the scale, due to "contact potential" in the valve.*

In many parts of a radio receiver, in which we may wish to measure alternating voltages, there are also direct voltages present. If the positive lead from the meter is touched to the plate circuit of one of the valves or some similar point, the meter would be deflected hard across to the end of the scale, because the positive voltage at this point would be able to send direct current through the meter and on through the valve, thus causing a substantial reading apart from the presence of the alternating voltages. On the other hand, if the test leads were reversed so that the test lead connected to the negative side of the 1.5 volt battery was touched to the plate circuit of a valve, then the meter would not read a direct voltage, or the alternating component, because the filament of the valve would then be positive compared with its anode.

To avoid this irregularity in performance depending upon whether or not direct voltage is present, we may include a condenser in the circuit as shown in Figure No. 28.

* See A.R.C. Service Engineering Course Lesson No. 32.

EXPERIMENT 17.

PEAK READING DIODE VOLTMETER.

The presence of the .1 mfd. condenser in Figure 28 will prevent any direct voltage forcing a flow of direct current through the circuit and consequently direct voltages applied to the test leads will not cause any deflection of the instrument. The

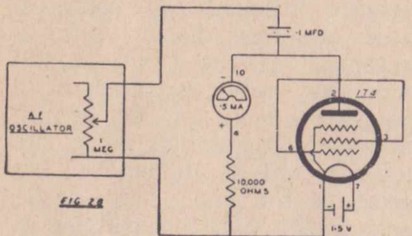


FIG 28

meter will only give a reading when alternating voltages are applied.

In setting up the equipment, instead of plugging tne test leads into the Minus and Plus 1 milliamp sockets on the front panel of your multimeter, connect two long lengths of hookup wire to Contact No. 4 and 10 on the selector switch of your multimeter. You will be able to determine these contacts quite easily by reference to Figures 4 and 5 of Lesson No. 4. With the selector switch set to the position marked "A.F." your meter will have a sensitivity of .5 milliamp, which is more suitable for this class of measurement than if the sensitivity of 1 milliamp were employed. When the switch is turned to the position marked "A.F." the multiple shunt is disconnected from the meter, and consequently the meter's own sensitivity of .5 milliamp alone determines its range.

When the equipment is first set up, as shown in Figure 28, and with the 1 megohm potentiometer turned fully off, there will be no alternating voltage applied, but there will still be a steady deflection of about three graduations on the meter face.

As the potentiometer is turned up to provide a signal for the instrument the meter needle will move across the scale, indicating the peak value of the voltage applied on the lower scale of the instrument face. The lowest range on your instrument is calibrated from zero at tne left hand side to 10 volts at the right hand side and the indications on this scale will indicate reasonably accurately the peak value of the voltage applied to the instrument. Thus, it will take an alternating voltage which rises from zero to a peak value of 10 volts and then falls to zero again on each half cycle to send the instrument's pointer across to the right hand end of this lowest set of calibration. As a result, the lower scale on the instrument can be used for measuring with a reasonable degree of accuracy the peak value of any alternating voltages, apart from those from the oscillator, which might be applied to the two test leads.

The peak value of an alternating voltage is not the same value which is normally indicate by most types of voltmeters. It is obvious that an alternating voltage, which starts from zero and rises to a peak value of 10 volts and then falls to zero again, will not be doing an amount of work proportionate to 10 volts the whole of the time. It only reaches a value of 10 volts for a brief instant during each half cycle, and consequently the effective amount of work done by an alternating voltage of this nature will be something less than 10. Actually, an alternating voltage which rises to a peak value of 10 volts will only do as much useful work as will a direct voltage of 7.07 volts, and most alternating voltages are measured in terms of their effective or "R.M.S." value. Most alternating voltmeters are designed to measure the effective or R.M.S. value of an alternating voltage, and would read a voltage which rises from zero to a peak of 10 and then falls to zero again as having an effective value of 7.07 volts.

The inclusion of the condenser in the voltmeter arrangement of Figure 28 makes it respond, not to the effective value of the alternating voltage, but to the highest peak reached during each positive half cycle and consequently this type of meter is often called a "peak reading diode voltmeter".

In measuring the maximum strength of signal which can be safely applied to the grid of a valve in amplifiers it is often more important to know the peak value than the effective value.

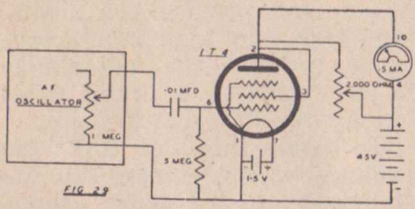
EXPERIMENT 18.

PEAK READING GRID LEAK VOLTMETER.

The circuit arrangements shown in Figures 27 and 28 permit the measurement of alternating voltages with our meter, but do not provide the advantage of a very high input resistance, so that the meter may be connected to a circuit without appreciably disturbing it.

To obtain this high input impedance which enables the instrument to measure signal voltages in the various stages of a receiver without producing any appreciable disturbance, you may use the grid leak arrangement shown in Figure No. 29. This arrangement is similar to that of a grid leak detector employed for the receiver shown in Figure 1 of Practical Lesson 6. In addition to offering a high input impedance to the circuit being tested, this arrangement also has tne advantage that it is impossible to damage the meter by passing too much current through it, due to an excessively strong signal. In most types of voltmeters, including those described in Figures 27 and 28, the stronger the signal applied, the further the meter pointer moves across the scale, and there is always the possibility that an excessively strong signal will overload the meter to such a degree that it will damage it.

In the circuit arrangement of Figure No. 29, the stronger the input signal applied to the valve, the less the current passes through the meter and the further the needle moves back towards the left hand side of the scale. Thus, it is impossible to overload the meter and damage it. Of course, it is possible to apply too strong a signal to the grid of the valve. The valve will safely handle signals up to about 50 or 100 volts, but the circuit arrangement should not be used to attempt to measure the power mains voltage or any other very high value of alternating voltage.



In constructing the instrument, you should wire up the valve socket in accordance with Figure 29. In this case, again, you may use the two long lengths of hook-up wire extending from switch terminals 10 and 4 on your multimeter, so that the meter has a sensitivity of .5 milliamp.

In soldering to the 2,000 ohm potentiometer, the lead from the positive side of the 45 volt battery should connect to the centre of the three lugs, and the lead from the plate pin on the valve socket, that is, Pin No. 2, should connect to the left hand lug if the potentiometer is viewed from the back with the lugs pointing upwards. Before connecting the batteries rotate the shaft of the 2,000 ohm potentiometer until it is turned fully in an anti-clockwise direction.

After checking carefully the wiring of your circuit connect up the batteries and plug in the tube. Have the 1 meg. potentiometer turned fully off so that no input voltage is applied. When you plug in the tube you will find that the meter needle may move slightly across the scale. Rotate the shaft of the 2,000 ohm potentiometer until the meter takes up a position at the right hand end of the scale. In this case you will use the upper scale, normally used for the measurement of direct voltage and current.

If you now rotate the shaft of the 1 megohm potentiometer, to apply an input voltage to the instrument, you will find that as the voltage is increased the meter needle moves to the left giving a progressively lower and lower indication. The stronger the input voltage the further the meter needle will move down to the left until it has travelled about two-thirds of the way across the scale. When it is giving a reading about one-third of the way up from the left hand end it will not decrease any further.

Although you have no means for calibrating the instrument you will find that no input signal produces a flow of current through the meter which moves the needle to the right hand end of the scale and which we may call one milliamp. The application of a one volt signal will reduce the current to .6 milliamp and so on in accordance with the table set out below:—

TABLE 1.

Alternating Voltage (Effective Value)		Meter Reading
0	—	1 ma.
1	—	.6
2	—	.48
3	—	.42
4	—	.39
5	—	.36
6	—	.34
7	—	.32

You will notice from the table that as the voltages increase the current decreases at first rather rapidly and then by quite small amounts until by the time the input voltages reach the strength of 7 volts there is no further substantial alteration in plate current. A signal of 8 or 9 volts supplied will still produce a reading of approximately .32 on the meter scale.

This principal of vacuum tube voltmeter, in a more elaborate form, is sometimes used in commercial instruments where there is a risk of excessively strong signals being applied to the input terminals as it is quite impossible to overload the meter and cause it any damage.

EXPERIMENT 19.

ANODE BEND VOLTMETER.

An extremely high input impedance can be obtained by operating the valve as a biased detector or "Anode Bend Rectifier" as shown in Figure No. 30. In this instrument, the meter needle will normally rest at the left hand end of the scale with no voltage applied and will move across the scale in a conventional fashion as the signal becomes progressively stronger. The principal of operation is identical with that of an anode bend detector used in some radio receivers.*

The principle of operation is that the negative bias supplied by the C battery to the grid of the valve, through the circuit being tested, reduces the plate current of the valve almost to zero in the absence of a signal. A small amount of plate current does continue to flow through the valve but this can easily be cancelled out by sending an equal amount of current backwards through the meter by means of the 1.5 volt bucking battery and 10,000 and 5,000 ohm resistors connected across the meter terminals. Thus, the meter needle will normally rest at the left hand end of the scale when no signal is applied.

The negative grid bias applied by the battery to the valve's grid is far more than is normally used when the valve is em-

* See A.R.C. Service Engineering Course Lesson No. 31.

ployed as an amplifier and consequently, when a signal is applied to the grid circuit of the valve, instead of the valve merely amplifying it and producing equal increases and decreases in plate current the excessive bias causes the positive half cycles of the signal to produce substantial increases in plate current, whereas the negative half cycles can produce practically no reduction in plate current because it is almost zero to commence with. Thus, the positive half cycles applied to the grid of the valve, with their resulting increases in plate current, cause a rise in meter indication. The meter pointer will move across towards the right hand end of the scale in accordance with the strength of signal applied to the grid.

To construct the equipment, wire up the valve socket to the potentiometers and the batteries as indicated in Figure 30. The meter will be connected by means of the lengths of hook-up wire soldered to contacts 10 and 4 on the multimeter switch so the meter itself will have a range of .5 milliamp. The wires soldered to pins 1 and 7 on the valve socket should be long enough to reach to the 1.5 volt battery which is furnishing filament power for the 3S4 oscillator valve and of course the one 45 volt battery is also used to supply plate current to both the oscillator tube and the vacuum tube voltmeter valve. The 1.5 volt battery furnishing bucking current to the meter will be the 1.5 volt battery you removed from the ohmmeter circuit of your multimeter.

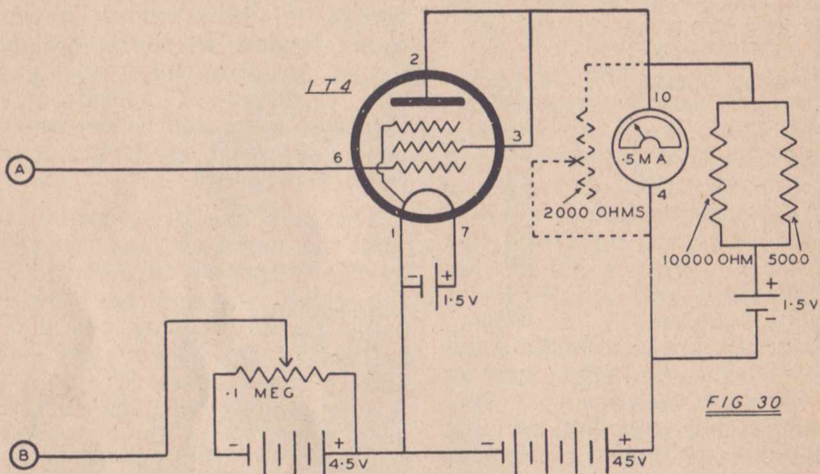


FIG 30

After having wired up the equipment in accordance with Figure 30, check over your wiring very carefully and then insert the valve. Have the 1 meg. potentiometer on the oscillator chassis turned off, so that no signal voltage is applied to the valve. When first switched on, the meter needle may move up the scale or to the left below zero. Regardless of which way it moves, you will be able to adjust it to the zero position by means of the .1 megohm potentiometer connected to the 4.5 volt battery. At one particular setting of this potentiometer you will apply the right amount of negative voltage to the grid of the valve to regulate its plate current to just exactly counteract the bucking current furnished by the 1.5 volt bucking battery and resistors. Thus, with no signal applied, you can make the needle register at the left hand end of the scale.

If the 2,000 ohm potentiometer, shown connected to the plate circuit of the valve in Figure 30 by dotted lines, is not included, you would find that turning on the 1 megohm potentiometer and applying a signal to the grid circuit of the valve would cause the meter needle to reach the right hand end of the scale with only a very weak signal strength applied. It would actually need only about 2 volts applied to the valve's grid to produce full scale deflection.

If you have any other type of rectifier A.C. voltmeter available, you may connect it across the input terminals of this instrument at the points marked A and B of Figure 30 and adjust the 1 megohm potentiometer to produce a voltage of 2.5 volts on the scale of this other instrument. You would then know that an alternating voltage of 2.5 volts was applied and you could adjust the 2,000 ohm potentiometer, so that the meter pointer reached the right hand end of the scale. Thus, it would take 2.5 volts to produce full scale deflection. If the sensitivity of the instrument is calibrated in this way, you can use your vacuum tube voltmeter for measuring any other unknown values of alternating voltage up to 2.5 volts by means of the table set out below:—

TABLE 2.

Alternating Voltage (Effective Value)		Meter Reading
2.5	—	1 ma.
2	—	.76
1.5	—	.53
1	—	.32
.5	—	.15
0	—	0

Of course, if you have no other voltmeter available, it will not be possible for you to accurately calibrate the instrument, and you will not be sure of just what voltage is necessary to produce full scale deflection. Therefore, the values in Table 2 will not apply and it is not necessary for you to connect the 2,000 ohm potentiometer. Without being able to calibrate this instrument you will, however, notice that as the 1 megohm potentiometer on the oscillator is turned up to increase the signal, the meter needle advances uniformly across the scale.

There is another method of calibrating the voltmeter without the use of a separate, rectifier type voltmeter, but this method does not produce very accurate results. However, in the absence of another meter, it is perhaps the best method of calibrating the instrument if you wish to use it for any measurement purposes.

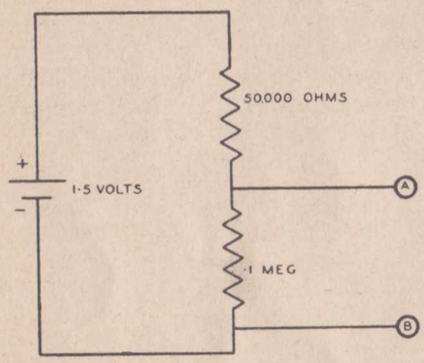


FIG. 31

It makes use of part of the direct voltage from a 1.5 volt cell. There are not sufficient of these cells supplied with your kits to enable you to use one of those furnished, but if you have a spare 1.5 volt cell from a torch or flashlight, you can employ this to calibrate the instrument. The cell, of course, should be in good condition and should preferably be new, so that its voltage is the full 1.5.

Connect the cell, a 50,000 ohm resistor and .1 megohm resistor together, as shown in Figure 31. The full voltage of 1.5 from the cell is applied across the two resistors, but, because the .1 megohm resistance has a value equal to two-thirds of the total resistance, the voltage at Point A will be two-thirds of that of the cell, and will thus be 1 volt.

When the points marked A and B in Figure 31 are connected to the points marked A and B in Figure 30, the D.C. voltage from the battery is applied to the grid of the valve and will cause an increase in plate current. You should adjust the 2,000 ohm potentiometer until the meter provides a reading of .77 m.a. with this 1 volt D.C. signal applied to the grid. If you now disconnect the equipment shown in Figure 31, you may use the voltmeter shown in Figure 30 to make measurements according to the Table 2, or a graph you may prepare from it.

This instrument is quite suitable for the measurement of alternating voltages at a frequency of 50 cycles per second, at audio frequencies, or even at radio frequencies up to many megacycles per second. In the form shown in Figure 30 it is only capable of measuring voltages which have a strength less than about 2 or 2.5 volts. It can be used for the measurement of higher values of voltage by making up a resistance voltage divider out of two resistors as shown at the left hand side of Figure 20. By using the 2 meg. and .5 meg. resistors, as shown in Figure 20, the range would be increased to five times the original value, or, by using other values of resistance, the range could be increased to any desired degree.

From Table 2 above, you may construct, if you wish to do so, a graph somewhat similar to that shown in Fig. 13 of Practical Lesson 4. In this case you would mark the values of alternating voltage along the bottom allowing .5 volt for each inch on the graph paper. After plotting the five points from Table 2, join them up by a line curving at its lower end. By means of this graph, you will be able to determine the value of any applied alternating voltage which produces a certain current. The graph would be used by observing the value of current indicated on the meter face, finding this value on the scale at the left of the graph, projecting across to the curve and then projecting down to the scale of voltage.

EXPERIMENT 20.

REFLEX V.T.V.M.

The accuracy of a vacuum tube voltmeter constructed along the lines of Figure 30 is dependent to some degree on the voltages of the batteries used with the instrument and also on the constancy of the valve's characteristics. The battery voltages, of course, change with the age of the batteries and the valve constants vary somewhat through its life. These effects can be minimised to quite a considerable degree by including a resistor in the cathode circuit of the valve. This provides a form of "nega-

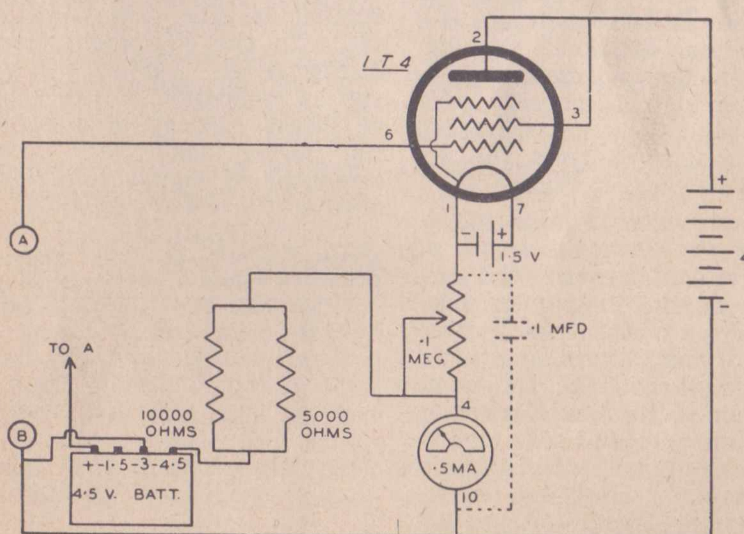


Fig. 32

tive feed back" and it is through this that the instrument is known as a "reflex" circuit.*

The principal difference between the circuit of Figure 32 and that of Figure No. 30 is that the negative bias for tthe grid circuit of the valve in Figure 32 is derived by means of the resistance in the cathode circuit of the valve, this resistance taking the form of the .1 megohm potentiometer. The voltage drop across this resistor is such that the lower end connected to the meter and then from the meter through the input terminals to the grid of the valve is negative, compared with the upper end of the potentiometer which is connected to the valve's filament. This means that a negative voltage is applied to the grid of the valve, but is derived by the voltage drop across the .1 megohm potentiometer and meter resistance due to plate current flowing through these parts, instead of being derived from the 4.5 volt battery as in Figure 30.

The presence of the resistance in the cathode circuit of the valve will decrease the sensitivity of the instrument considerably, so that it will need about 10 volts signal applied to the grid to produce full scale deflection of the needle, whereas with Figure 30, full scale deflection was obtained with about 2 or 2½ volts. However, where fairly strong signal voltages are to be measured, the arrangement of Figure 32 is to be preferred.

* See A.R.C. Service Engineering Course Lesson No. 28.

In first connecting up the equipment, omit the .1 mfd. condenser connected by dotted lines in the diagram.

After wiring up the instrument, checking your wiring carefully, and connecting the batteries, plug in the valve and have the 1 megohm potentiometer on the oscillator turned off, so that no signal is applied. Adjust the .1 megohm potentiometer until the meter needle rests at the left hand end of the scale. If you now turn up the 1 megohm volume control, you will find that the application of a signal will cause the needle to move across the scale towards the right hand end, but that you will have to turn up the potentiometer considerably further in this case than you did with the equipment shown in Figure 30. Table 3 will give you an indication of the values of direct current produced on the meter scale by various strengths of signal voltage applied to the valve's grid.

TABLE 3.

Alternating Voltage (Effective Value)		Meter Reading
10	—	1 ma.
9	—	.9
8	—	.79
7	—	.66
6	—	.53
5	—	.42
4	—	.3
3	—	.2
2	—	.1
1	—	.05
0	—	0

If you have a rectifier type voltmeter available you may check the accuracy of the vacuum tube voltmeter by connecting the rectifier voltmeter across the output terminals of the oscillator and adjusting the 1 megohm potentiometer until an output of 10 volts is applied. If the meter connected to the vacuum tube voltmeter does not read at the right hand end of the scale, you can make it do so by varying the .1 megohm potentiometer slightly. Once you have done this, you may find that, on removing the signal, the needle no longer rests at the left hand end of the scale. If this is so, then you may experiment with various combinations of the 15,000 ohm, 10,000 ohm and 5,000 ohm resistors you have available. The 10,000 and 5,000 ohm resistors together will probably be the best combination, but the needle may come nearer to the left hand end of the scale with the 15,000 and 5,000 ohm resistors alone, or with all three resistors connected in parallel with one another.

If you have no rectifier type voltmeter available for accurately calibrating, then again you may resort to the use of direct voltage as explained in connection with Figure 31. In this case you will not need to use any resistors, but merely apply 3 volts from your 4½ volt battery between terminals A and B. The positive terminal of the battery should be connected to Point A. The Minus 3 Volt terminal is already connected to point B as the section of the battery between the —3 and —4.5 volt terminals furnishes bucking current. When this 3 volts D.C. is applied, the meter should give an indication of .8 m.a. If it does not do so, then you may use the .1 megohm potentiometer to make it read .8 m.a.

After calibrating, either by means of the rectifier voltmeter or with D.C. voltage, the instrument can be then used to measure alternating voltages up to 10 at any frequency up to several megacycles per second. Higher values, up to 50 volts, may be measured by employing the 2 meg. and .5 meg. resistors connected as shown at the left of Figure 20.

If the .1 mfd. condenser shown drawn by dotted lines in Figure 32 is connected, you will find that the sensitivity of the instrument is increased somewhat. For a certain signal voltage applied to the grid of the valve, the meter needle will move further up the scale when the condenser is present and you will find that it needs only about an 8 volt signal to send the needle fully across to the right hand end of the scale. In some A.C. voltmeters a condenser of this type is used, whereas in others it is omitted.

EXPERIMENT 21.

CAPACITY TESTER.

In Experiment No. 14, we constructed equipment for determining the resistance of a condenser. This tester, of course, did not enable any idea to be obtained of the condenser's actual capacity. We will now construct a piece of equipment which enables the measurement of a condenser's capacity to be obtained. Thus, a condenser which is not clearly marked may be tested and its capacity found.

The circuit arrangement of the capacity meter is shown in Figure 33. You will see that, fundamentally, it is a vacuum tube voltmeter, almost identical with that of Figure No. 30. The best combination of resistors in the "bucking" circuit is the 10,000 and 5,000 ohm resistors connected in parallel. The meter will still have its range of .5 milliamp provided by making a connection to switch contacts 4 and 10 on the multimeter switch.

The filament of the valve can be operated from the same 1.5 volt cell, which also heats the filament of the oscillator valve.

When you first wire up the equipment, connect the .1 mfd. condenser to the grid of the valve. Another alteration you will have to make is to remove the 1 megohm potentiometer from the output circuit of the oscillator and substitute the 2,000 ohm potentiometer.

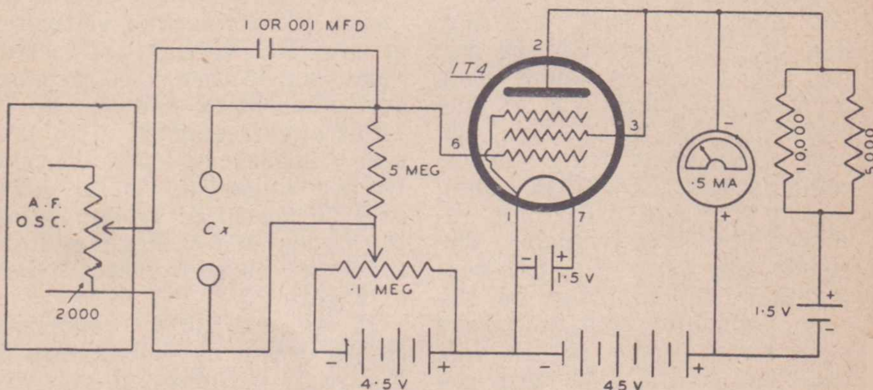


FIG 33

After completing your wiring, carefully check it, connect up the batteries and insert the valve. Have the 2,000 ohm potentiometer turned fully off and adjust the .1 megohm potentiometer until the meter needle rests at the left hand end of the scale.

Now turn on the 2,000 ohm potentiometer until the meter needle reaches the right hand end of the scale and leave the

2,000 ohm potentiometer set at this position. If you now connect a variety of condensers to the terminals marked "Cx" in Figure 33, you will find that the needle takes up a position across the scale varying with the capacity of the condenser you have applied. A large condenser with a capacity of .5 mfd. will cause the needle to remain near the left hand end of the scale, whereas a small condenser with a capacity of .002 mfd. will cause the needle to reach almost full scale deflection. The various positions on the scale corresponding to condensers of different capacity is revealed in Figure No. 34. Consequently, if you connect some unknown condenser and for example it produces a reading of .47 m.a., then you would know its capacity to be .05 microfarad.

With a .1 mfd. condenser installed in the instrument you can see that the range covers the measurement of condensers down to .002 mfd. For the measurement of still smaller values of capacity is it possible to substitute the .001 mfd. condenser you have, for the .1 mfd. condenser. When this condenser is wired in place of the .1 mfd. it may be necessary to slightly readjust the 2,000 ohm potentiometer to cause the needle to come to the right hand end of the scale with no other condenser connected to the terminals marked "Cx". Once you have made this initial adjustment, however, you can connect condensers to the ter-

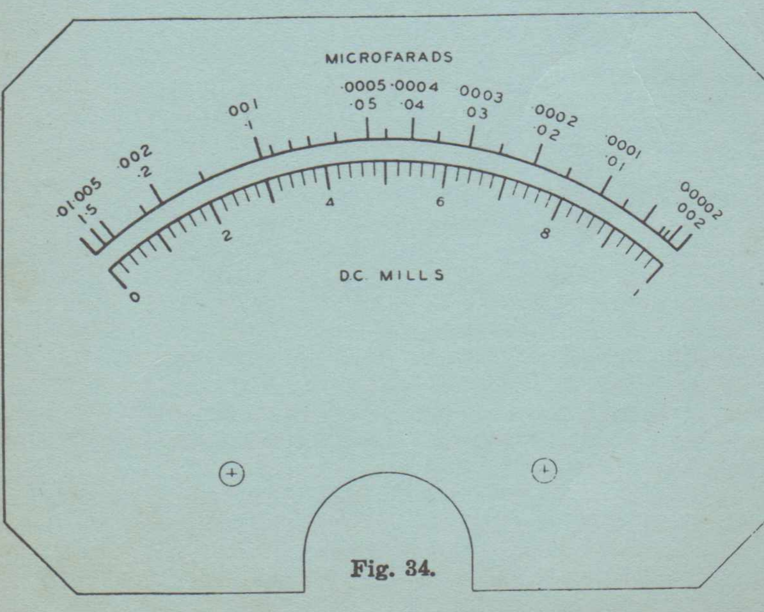


Fig. 34.

minals "Cx" and their value will be that indicated by Figure 34 divided by 100. For example, if the needle points to a current value corresponding to .47 m.a., this is equivalent on the scale of Figure 34 to .05 mfd. but because we have changed the value of the standard condenser we must divide the value of capacity revealed by Figure 34 by 100 and this gives a reading of .0005 mfd. This value, of course. is also equivalent to 500 micromicrofarads.

The alternative values of capacity are marked on Figure 34 and all you have to do is to remember to read the values ranging from .002 to .5 mfd. when using the .1 mfd. condenser and the values reading from .00002 mfd. to .01 mfd. when using the .001 mfd. condenser in the instrument.

You will find this instrument capable of a fairly high degree of accuracy and the accuracy will, of course, depend upon how true are the values marked on the .1 and .001 mfd. condensers you wire into the instrument. These condensers are virtually used as standards and all other unknown condensers are compared in value with these. However, those supplied with the kit are fairly accurate and will provide a sufficiently high degree of reliability to be quite useful when built into the condenser tester described in Figure 33.

Although you have not yet been supplied with a great variety of condensers you may test those you have in your possession and compare your results with the scale set out in Figure 34.

The experiments you have conducted with this lesson should have not only improved your knowledge of receiver principles but should have enabled you to obtain a very sound knowledge of principles of measurement and particularly of vacuum tube voltmeters. In the next lesson we will take up a study of amplifiers and oscillators in particular.