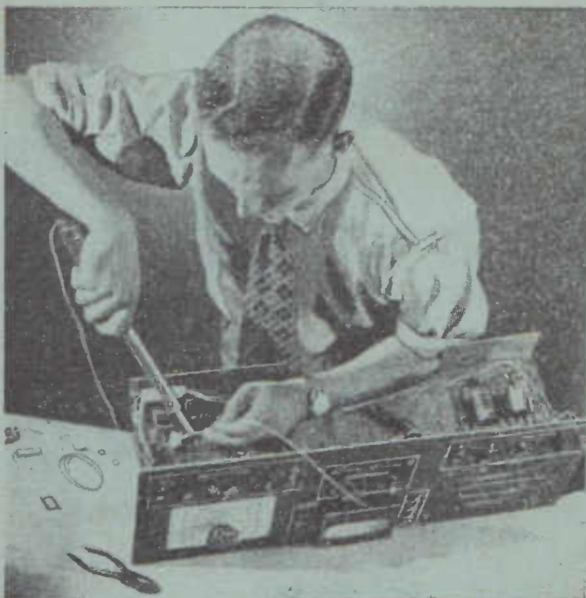
AUSTRALIAN RADIO & TELEVISION COLLEGE PTY. LTD.

PRACTICAL RADIO COURSE



of

HOME PRACTICAL INSTRUCTION

Lesson No. 1

THIS Radio Course of practical home instruction is the result of many years' experience, and months of final experimental work by some of Australia's most competent Radio engineers. It is designed so that you acquire a thorough and most comprehensive practical Radio training by building up the kits which are supplied with these lessons. When the course is finished, and all the kits have been built up into the final unit, you will possess a complete professional outfit of Radio testing apparatus, which in itself is not only worth far more than the money you pay for it, but which will also enable you to earn many times its actual value from the Radio work you can perform with it.

This lesson will show you how to:—

HOME PRACTICAL INSTRUCTION

LESSON No. 1.

Radio is indeed a most fascinating and interesting subject to study. Whether it be studied with the object of obtaining a lucrative career in the radio industry, for the betterment of one's position, or merely to provide an entertaining hobby, it has an appeal to thousands. Perhaps this is due to the glamour associated with any thriving, young industry, developing at a rate faster than any other industry. Perhaps it is due to some of the achievements of radio in the past or the unlimited potentialities of radio in the future, but whatever the cause, it is hard to conceive any more fascinating or interesting subject to study.

Some students have the ability of absorbing knowledge readily from textbooks or printed lesson papers. Their minds are able to clearly grasp the subject they are studying from the printed text and illustrations, and many become just as proficient ultimately as others who are more favourably placed in obtaining extensive practical experience. There are some, however, who find it much easier to visualise the intricate actions which occur in radio apparatus and are able to more readily understand a written description of a particular radio component or circuit if they are able to handle actual radio parts, assemble them into practical working circuits and make the necessary tests and experiments to bear out in practice what is set down in a text.

Many people,. especially those in remote locations, are handicapped in not having ready access to radio parts and test instruments with which to experiment. It is with the needs of these enthusiasts in mind that a practical instruction kit has been evolved especially to cater for them, to provide a means for carrying out hundreds of interesting experiments and which will ultimately make possible the construction of an extremely efficient and useful set of radio servicing apparatus.

The kit of equipment described is fundamentally intended to be used in conjunction with the Australian Radio College course of Radio Service Engineering. This course deals thoroughly with the principles of radio and electricity, performance of the various stages in radio receivers and efficient systematic service technique. For this reason, some reference is contained in these practical instruction papers, which accompany the kits of parts, to the lesson papers contained in the Radio Service Engineering Course. These references are intended only to amplify the descriptions contained in the practical instruction papers accompanying the practical material kit. These instruction booklets are clearly set out, explained in simple language and profusely illustrated to enable the student to carry out a large number of experiments with every kit he receives. This course may therefore be considered to be complete in itself, the cross-references to the lessons of the A.R.C. course merely serving to provide additional and amplified descriptions of the actions being explained.

As a particular instruction kit will be of particular interest to those in outlying areas where electric power supplies are rarely available, it has been decided to base it principally upon battery operated equipment; and the necessary batteries for operating amplifiers, receivers, test instruments and so on, constructed throughout the course of training are included with the kit. This makes the course completely universal so that it can be used with equal efficiency in any area regardless of whether or not electric power is available.

Every student taking up a course of radio training desires ultimately to become proficient in adjusting new receivers and locating faults in defective receivers and for this class of work needs some testing instruments. The most essential testing instruments are a multimeter for checking voltages, currects and resistances in radio apparatus: a test oscillator for providing radio frequency signals for testing receivers and a signal tracer for rapidly and efficiently locating defects in faulty receivers. This practical course of training has been very carefully planned to provide a variety of radio parts which may be assembled in many combinations to provide instructive practical training throughout the course and yet, towards the completion of the course of training, the parts can be grouped in such a fashion that they form an efficient multimeter, a modulated radio frequency test oscillator and a 3-valve signal tracer. Thus, the student on the completion of his course becomes the proud possessor of one of the most modern test outfits possible; which will enable him to make practical use of the knowledge he has gained throughout his training period.

You will receive nine big parcels of radio parts at regular intervals throughout the course of training. Each of these parcels enables a large number of individual experiments to be carried out. Each parcel is accompanied by a carefully prepared instruction booklet which explains in full detail the experiments to be conducted with the kit supplied, tests to be made and examples of the principles examined in actual radio apparatus. Each component part supplied in the parcel is clearly labelled so that no difficulty will be experienced in recognising it or applying it in the correct manner.

Parcels themselves do not all contain goods of equal monetary value. This is necessary because some of the parcels, to make them complete and versatile, contain quite a lot of expensive components. To enable the student to build up credit for these expensive parcels the preceding one may not contain goods of quite as much value. For example, the first parcel contains a soldering outfit, a quantity of wire, solder, resistance panel, insulation tape, and a soldering iron to enable the student to become proficient at soldering. The monetary value of this first parcel is somewhat below the average value and this enables the second parcel to contain some more costly items such as a high quality permanent magnet moving coil meter, fitted in an attractive plastic case and provided with a universal scale. This will eventually become a complete multimeter.

As most people have a few simple tools available no tools have been included in the kits with the exception of a small soldering iron which can be heated over a fire or stove of any kind. The other necessary tools are something with which to cut wire, e.g., an old pair of scissors or a knife, a pair of pliers, a file or sheet of emery cloth for keeping the soldering iron clean and a small and large screwdriver. The metal chasis frames provided for the assembly of experimental units are furnished complete with all necessary mounting holes already cut in so that other tools are not essential although they may prove handy if available.

LISTS OF KITS CONSTRUCTED.

To give some indication of the flexibility and wide variety of experiments which may be carried out the following list, of units constructed during the course of training, is provided. This list merely indicates some of the work and a few of the units which are constructed and it should be borne in mind that on each of these units there are many experiments which may be conducted so that the extent of practical training is very great.

Soldering instruction.
Wire splices and joining.
Insulation.
Aerial construction.
Fault location with voltmeter.
Continuity tester, - for testing radio and electrical parts and circuits.
Coil winding.
Ohmmeter.
Multimeter.
Output meter.
Valve testing.
Valve Curves.
Valve amplifiers.
1 valve receiver.
2 valve receiver.
Radio frequency oscillator.
Audio frequency oscillator.
Morse code practice oscillator.
Modulated radio frequency oscillator.

3 Valve T.R.F. receiver.
Vacuum tube voltmeters, for D.C.
Vacuum tube voltmeters, for A.C.
Class A,B and C amplifiers.
Inverse feedback.
Push-pull amplifier.
Condenser tester.
Superheterodyne receiver.
Signal tracer.

The experience gained from the construction of units such as those listed above will not only promote a clearer understanding in the student's mind of the basic principles and theory of operation of the equipment but it will also breed a feeling of confidence so that on completing the course the student will not only be the possessor of a sound technical training, but will also be thoroughly equipped and confident to carry out radio receiver construction or repairing work.

KIT 1. SOLDERING OUTFIT.

A radio receiver constructed without the use of soldered connections would be entirely impracticable. Even though it may perhaps be coaxed into working at first, before very long crackles and noises would interfere with reception and the receiver would soon become inoperative. It is essential for all the connections in a radio receiver to be soldered and consequently one of the first essentials is for you to learn the art of soldering efficiently and quickly.

The reason for the widespread use of solder in radio receiver construction is the fact that the amount of electricity which will flow in any circuit is dependent upon the resistance of the paths through which it has to flow. Most metals have a fairly low resistance and if their surfaces are perfectly clean merely clamping them together will initially cause a low resistance path so that normal values of current can pass through the connection. However, all metals in contact with the air, will eventually have a film of oxide formed on their surface. This oxide, in the case of iron, is called rust. Other metals also have a film which is not always as apparent as in the case of rust, on iron, but nevertheless exists to some degree. The oxide films on metals are normally fairly good insulators of electricity and consequently would increase considerably the resistance to the path of electricity and reduce the current to a lower than the correct value. Eventually, the thickness of the oxide film may become so great, as the result of moisture in the atmosphere that in a radio circuit it may completely prevent current from flowing. This may happen even though the oxide film may only be a fraction of a thousandth of an inch in thickness and hardly noticeable to the eye.

The use of soldered connections is not so important in high voltage circuits such as those used used for electric power and lighting because the high voltages used are strong enough to cause any oxide film to break through and for the current then to be able to flow directly from one metal surface to the other. With receivers, however, some of the signal voltages are only a few thoudandths or even millionths of a volt in strength and these low voltages are not enough to drive electric current through an oxide film of any appreciable thickness. The film will form even on pieces of metal which are fairly tightly clamped together due to air getting in between the surfaces and corroding them. One certain way of assuring a permanent connection of low resistance between two pieces of metal is to exclude any possibility of air reaching the surfaces across which the current has to flow and at the same time bridging the gap between the two pieces of metal, with a third metal, solder, which is itself a good electrical conductor.

Solder is not a very strong metal and consequently should not be relied upon where a great deal of mechanical strength is required. It is always preferable to make a strong mechanical joint before the solder is applied. This can often be achieved by carefully twisting together two wires to be joined or, where a wire is to be connected to a solder lug the wire can sometimes be passed through a hole in the solder lug as shown in Figure 2.

If no hole is prvoided in the solder lug, it may be possible to wind the wire once or twice around the solder lug before

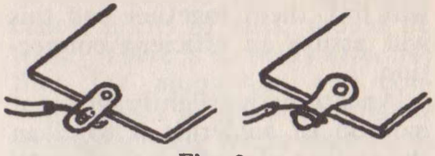


Fig. 2.

solder is applied. After this has been carried out, the application of solder will fill any spaces between the two wires or the wire and lug and will assure a permanent and lasting connection of low resistance between them.

Solder will only "wet" a surface of metal which is perfectly clean and free from any oxide coating. Therefore, the first principle of soldering is that both surfaces to be joined must be thoroughly clean, any oxide film being removed from them.

It is not sufficient only to remove any oxide coating from metal surfaces to be soldered together. It is essential that a substance called "flux" should be applied to the metal surfaces to that when heat is applied the flux will melt and flow over the hot surfaces to prevent air from coming in contact with them and forming a new oxide film. Preferably the flux is applied simultaneously with the solder. The particular type of solder supplied with this kit enables this to be done quite easily because the flux is actually contained within the solder as a central core. When the two surfaces to be joined have reached a temperature higher that the melting temperature of solder, the solder will flow onto them and coat them both. A film of solder will link them together and this will assure an efficient connection.

An alternative slightly different method of soldering is to clean the surface of each piece of metal separately and then apply solder, flux and heat to each. As each heats solder will eventually flow over them and form a coating of solder. This is known as "tinning" a surface. The two pieces to be joined are then brought together and heat again applied until the two lots of solder melt and merge into one. On removal of the heat the solder will solidify and hold the two surfaces together.

SOLDER

Solder is a metal consisting of a mixture of tin and lead. The most suitable type of solder for radio work is composed of 50% tin and 50% lead. This solder, when heated, starts to become soft at a temperature of 358 degrees F. and becomes really fluid at 415 degrees F. At any temperatures higher than this, it flows quite readily. Due to the high cost and shortage of tin there is a tendency nowadays to use solder composed of 40% tin and 60% lead. This solder also becomes soft at a temperature of 358 degrees F. but does not really melt and become fluid until it is heated to 460 degrees. On cooling, it remains quite liquid until its temperature drops to 460 degrees and it then becomes plastic or soft until it cools to 358 degrees and then it finally sets hard at temperatures below this. Although not quite as good as 50–50 solder it is nevertheless quite satisfactory for radio work.

FLUX

Previously it was mentioned that it is essential for both materials to be joined to be thoroughly cleaned before any attempt is made to solder them. This is necessary to remove any oxide film. After the surfaces have been cleaned, the application of heat from a soldering iron would immediately tend to form a new oxide film before the surfaces became hot enough for solder to flow on them. To prevent this new oxide film from forming, a flux is employed. There are a number of different fluxes which may be used in soldering although for radio purposes resin is desirable. The purpose of a flux is to melt as soon as heat is applied, and form a film over the surface of the metal. Thus air is excluded and an oxide film cannot reform. As the temperature of the surfaces increases, the flux boils and commences to evaporate. When solder is applied it penetrates through the film of flux and flows over the surface of the metal. Meanwhile the continued application of heat evaporates most of the flux so that by the time the process of soldering is complete there should be little, if any, flux remaining.

Resin, while being fairly effective in preventing the formation of an oxide film during the soldering process, is not very active in removing any corrosion or film which has not been thoroughly removed by prior scraping, filing or cleaning of the metal. For this reason, resin is only suitable as a flux on work that has been previously cleaned efficiently. Some of the soldering pastes available are more effective in their cleaning action than resin and have the property of removing to some degree small amounts of corrosion or film on surfaces so that is many instances, especially in the case of tinned copper wire, no previous scraping or cleaning is necessary unless the wire is badly corroded. However, most of these patent fluxes are slightly corrosive and therefore should not be used in radio or electronic equipment of any kind. Although these patent soldering fluxes when used very carefully by thoroughly experienced technicians are reasonably safe, the risk of using too great a quantity is very real so far as the beginner is concerned and so he should avoid them completely.

For soldering large sheets of metal it is sometimes preferable to use a liquid known as "zinc chloride". This is manufactured by dissolving the metal zinc in hydrochloric acid until no more zinc will dissolve. The remaining fluid is then suitable as a soldering flux for use on most metals with the exception of aluminium, zinc and galvanised iron. For galvanised iron or zinc a dilute solution of hydrochloric acid, sometimes called spirits of salts, should be used. There is no really effective flux for aluminium and consequently it is almost impossible to satisfactorily solder aluminium. Zinc chloride and hydrochloric acid are of course corrosive, and should never be used in the wiring of a radio receiver. They are only suitable for joining together large sheets of material. If they are used in the construction of a radio set, after a period of time the thin wires will be corroded completely through.

Because of the suitability of resin as a flux for radio work, most solder used for radio is supplied in the form of a thick wire or rather, a tube with a centre core of resin. Where two clean bright surfaces are to be joined, some of this solder can be applied either by transferring a drop with the iron to the surfaces to be soldered or by applying the end of the wire solder to the joint and melting some of the solder and resin contained in it onto the material with the hot iron. In this case, the resin and solder will flow together over the surface of the metal.

SOLDERING IRON

The name soldering iron is not really a correct one for in practice the end of the soldering tool is always made of copper. For this reason a more correct name is "soldering bit". However, most people refer to the tool as a soldering iron.

A simple soldering iron, such as the one supplied with the kit of parts, may be heated by placing the copper portion over any flame. It is preferable to use a blue coloured flame such as that from a gas stove, blow lamp, or correctly adjusted kerosine burner rather than the yellow flame similar to that produced by an ordinary fire. A yellow flame will deposit a film of soot on the iron and this makes soldering difficult. Where electric power mains are available a far more convenient form of soldering iron is an electric one which will operate from the power. These are extremely handy and remain hot while ever the power is switched on.

In the case of an ordinary soldering iron, care should be exercised not to heat it excessively. If it is made red hot the surface will become badly oxidised and it will be difficult to solder with. Before any soldering iron is used it must first be "tinned". This consists of heating the iron to a fairly high temperature, filing the pointed surface of it until it is thoroughly clean and then applying solder so that the solder spreads readily over the end of the iron leaving a silvery coating.

INSTRUCTIONS FOR SOLDERING PRACTICE.

Having read the foregoing basic principles of soldering you are now in a position to carry out some experiments yourself by soldering various forms of wires together and onto solder lugs.

Supplied in the first kit of equipment you should find the following goods:

1 Soldering iron.
1 Coil of resin cored solder.
1 Coil of aérial wire.
1 Coil of insulated hook-up wire.
1 Coil of bare tinned copper wire.
1 Coil of heavily insulated lead-in wire.
1 Piece of sandpaper.
1 Length of resistor panel.
1 Reel of insulation tape.
2 Plastic insulators.

As mentioned previously, the first step is to heat the soldering iron. This is done by heating it in a flame until it is hot enough for solder to run freely when applied to it. You will notice, however, that the solder instead of spreading smoothly over its surface merely drips off. This is because of the oxide film which is present. You then quickly take a file, and file the pointed surface of the copper until it is quite shiny and then, before it has cooled, immediately apply some resin cored solder to the pointed end. Instead of the solder dripping off it will now spread in a film over the surface you have cleaned.

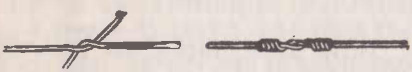
If you experience difficulty in getting a smooth film or surface on the pointed end of the copper the first time you try, then repeat the process again.

If you do not possess a file you will be able to clean the end of the iron by polishing it thoroughly first with sandpaper, before it is heated. You should then heat it in a flame and quickly polish it again with sandpaper before applying the flux and solder.

If you should ever overheat the iron, by making it red hot, you will burn off the film of solder and it will be necessary to repeat this process of tinning.

EXERCISE 1
BARE TINNED COPPER WIRE

Take two short pieces of the bare tinned copper wire and join them together mechanically by forming a splice as illustrated in Figures 3a and b. The splice is made by crossing the ends of the wires so that about an inch of each is protruding as shown in Figure 3a. The end of one is then twisted several times around the second and then the end of the second is twisted several times around the first as illustrated in Figure 3b. Pulling the two wires will simply lock the joint tightly and it will be found quite strong mechanically. Before crossing and twisting the wires, the ends of each should be cleaned with the sandpaper for about two inches so that the wires are perfectly clean and shining.



a. b.

Fig. 3.

The best method of applying heat to a joint of this nature is to hold the hot soldering iron underneath the twisted portion of the wires and at the same time hold a length of resin core solder in contact with the joint until the solder and flux melts and flows freely down through the wire. The flux will sizzle and smoke and, after a few moments, the wires will become so hot that the solder resting on them will become molten and run down through all the crevices of the twisted wires, filling them with solder.

After the solder has flowed down through the wire the soldering iron may be removed. It is not necessary to continue pasting a lot of solder on top of the wire so that all of the turns are completely hidden under a thick pasting of solder. The joint will be quite secure so long as the crevices are each filled with solder.

It will probably be necessary to start at one end of the twisted section of the wire and then, after the solder has run through this portion, to move the iron along a little further towards the other end, at the same time moving the solder along so that it spreads and eventually covers the whole length of the joint.

Repeat this exercise over several times until you feel quite confident that you can make a successful soldered connection.

EXERCISE 2
JOINING INSULATED STRANDED WIRE

Cut two short lengths of the insulated hook-up wire supplied. Before soldering, it is of course necessary to remove the insulation from the portions of the wire to be joined. One method of removing the insulation is to cut lightly around the outside of the wire with a razor blade or knife. Care must be exercised not to press so heavily as to cut the thin strands of wire inside. After making a circular cut right around the insulation the section to be removed may be pulled off with one's fingers. This method is not to be recommended because of the liklihood of cutting through the insulation and cutting off some of the strands of wire inside.

A far more effective method which can be used in the event of a pair of pliers with wire cutting jaws being available, or alternatively in the case of a pair of scissors being used is to grip the scissors, place the wire between the jaws and then squeeze just tightly enough to make an indentation in each side of the insulation with the jaws. Do not squeeze too hard or you will cut the insulation and wire right through. After making the indentation you should pull the scissors along the wire firmly and you will find that they strip off the insulation between the point where they are touching the wire and the end.

In the case of a pair of pliers fitted with wire cutting jaws, they should be held as illustrated in Figure 4.

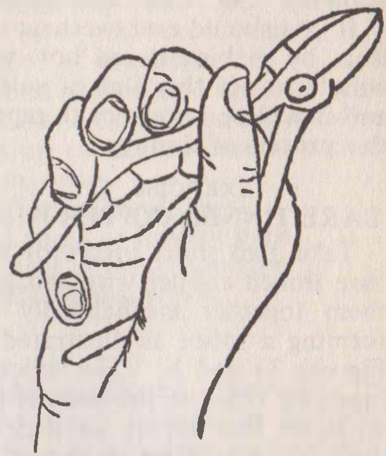


Fig. 4.

It is most important to keep the little finger on the inside of one of the handles and not to place all of the fingers around the handle in the natural manner. By keeping the little finger inside the handle it is possible to hold the jaws slightly apart and prevent them cutting right through the wire when they are squeezed gently onto the insulation. When the pliers have been closed sufficiently for each jaw to bite gently into the insulation the pliers may be pulled firmly along the wire and they will strip off the insulation.

The natural tendency at first, is to close the pliers too firmly so that the jaws bite not only through the insulation but through the wires too and cut several or all of the strands. Several attempts may be necessary before you are successful in stripping off the insulation without damaging the wire but it is most important to practise this art so that you can strip wire cleanly and quickly.

Having bared about two inches of each of the wires to be joined, you will probably find the strands of wire inside are perfectly clean and bright because the surrounding insulation minimised the tendency to oxidise. In this case you can probably twist them without any further cleaning and proceed to carry out the soldering operation. The wire should be crossed and twisted as illustrated in Figures 3a and b. and then the soldering carried out as explained in the foregoing exercise. One point about which we must be particularly careful is not to apply the hot soldering iron for too long a period. The iron must be used cautiously so that it is applied long enough to allow the solder to run down through the wires but yet not long enough to melt off the insulation for a considerable distance back from the joint. The type of insulation used on hook-up wire will generally melt or soften under the influence of the heat of the soldering iron and will tend to peel back from the joint. If you are not fairly quick in carrying out the soldering operation you will find the insulation damaged for an inch or so back from the joint.

If you have used the right amount of soldering flux in the first place, no surplus will remain, but if you have used an excessive amount quite a lot will remain and this will have to be removed by means of a cloth dampened with methylated spirits or alcohol before any insulation is placed over the joint.

After joining insulated wire it is generally necessary to replace some form of insulation to prevent a short circuit where the wire has been bared for purposes of making the joint. Enclosed with your kit you will find a reel of insulation tape which you should use to wind carefully around the joint to restore the insulating quality of the wire.

When using insulation tape it should not be peeled back off the reel until you are ready to use it. You then peel it off the reel and commence winding a length of it around and around the wire starting about half or three-quarters of an inch along the insulated part of the wire and working towards the joint, across the joint and for about another three-quarters of an inch on the other side. Each time you wind the tape around the wire you should move the tape along a distance about equal to half of the width of the tape so that the insulated joint is covered everywhere with at least two thicknesses of insulation tape. The final joint will appear somewhat as illustrated in Figure 5.

Fig. 5.

Practise stripping the insulation off the wire until you can do this without damaging the wire and practise soldering the spliced joint till you can carry out the soldering without damaging the insulation on each side of the joint.

EXERCISE 3.
ATTACHING LEAD-IN TO AERIAL WIRE *

The aerial and lead-in wires are provided so that later on you may erect an efficient aerial and earth system for use in conjunction with some of the receivers you will be building. It is not advisable for you to complete the erection of the aerial and earth system in this case unless you have some receiver with which you can use it, but you can practise the correct method of attaching a lead-in wire to an aerial so that you will be proficient when the time comes to erect your aerial and earth system.

The wire normally used for an outdoor aerial consists of three strands of fairly thick gauge copper wire. This wire is normally bare but the lead-in wire has to be insulated. Consequently, because of the necessity for using two different types of wire a soldered connection is necessary where they join.

One method of attaching a lead-in wire to the aerial wire is to carefully scrape the aerial wire so that it is quite clean for a length of about two inches at a point a distance of about 6 inches or so in from one end. You should then remove the outside braiding and rubber insulation from the thick lead-in wire provided. It will be found difficult to remove two or three inches of this insulation in one attempt so it is generally necessary to remove about an inch of insulation at a time and make two or three attempts to bare the necessary length of lead-in wire. Even after this process it will probably be found that particles of the rubber insulation are adhering to wire and these must be very thoroughly removed by scraping the wire with a knife or alternatively, cleaning it properly with the sandpaper provided. When the wire is perfectly clean it may be wrapped around the aerial wire itself as shown in Figure 6a and b. After it has been twisted around the aerial wire five or more times you may apply flux to the joint

* See A.R.C. Service Engineering Course. Lesson 4.

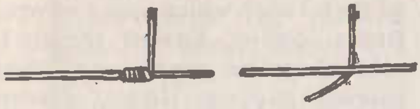


Fig. 6.

and carry out the soldering operation as explained in Exercise 1.

Because of the difficulty of procuring 3/.036 bare copper wire which is the type normally used for outdoor aerials, a special single copper wire covered with special insulation to withstand outdoor climatic conditions has been supplied in the kit. The wire should not be mixed with the ordinary hook-up wire because it is especially suitable for aerial construction, and you will need it for this purpose later on. However, you may practise with a few short lengths cut from one end of it at this stage, to become proficient in making a joint.

Because the thin strand of copper wire used in this form of aerial wire is not very strong it is not advisable to remove the insulation at a point somewhere along the length of the aerial and attach the lead-in. With this type of wire, it is desirable to thread the aerial wire through or around the insulator and then to knot the end of the aerial wire around the aerial itself as shown in Figure 7. The end of the knot may then be bared of insulation, a length of lead-in wire formed into a right angle to lie parallel with the aerial wire and the end. The aerial wire is then wound around the bared end of the lead-in wire and solder applied. After the soldering is completed a heavy binding of insulation tape should be used to bind the lead-in wire, aerial itself and the end of the aerial wire, all into one solid mass. The tape should be extended over the soldered joint so as to minimise corrosion at the point where the insulation is removed from the thin aerial wire. This is illustrated in Figure 7.

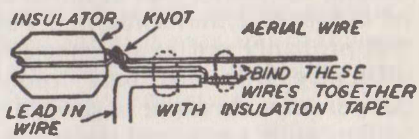


Fig. 7.

EXERCISE 4

RESISTOR PANEL WIRING

Before attempting to solder any wires to solder lugs attached to a length of resistor panel, it is desirable to tin the solder lugs. This is accomplished by applying a very small dab of flux to each lug and then picking up a drop of solder on the end of the soldering iron and carrying it across to deposit it upon the lug. The iron of course should be left in contact with the solder lug long enough for the lug to be heated and for the solder to flow freely from the hot iron and spread over the lug. It any difficulty is experienced in making the solder flow over the lug it will be necessary to sandpaper the surface of the solder lugs until they are perfectly clean and bright. However, in the case of new resistor panels the lugs are usually clean enough to enable the soldering operation to be carried out without any necessity for cleaning the lugs with sandpaper.

After you have tinned the solder lugs, cut several short lengths of bare tinned copper wire and several short lengths of insulated hook-up wire. You can then practise twisting these around the solder lugs as illustrated in Figure 2, and soldering. You will probably not experience any difficulty with the bare tinned copper wire, because it generally solders quite easily and there is no insulation on it to be damaged by leaving the iron in contact with the work for too long a period.

In the case of the insulated hook-up wire, however, after baring the wire and twisting the end around the lug you should carry out the soldering operation fairly quickly so that the heat of the iron does not damage the remaining insulation on the wires. At the same time, the iron must be left in contact with the work long enough to heat both the wire and the solder lug up to such a temperature that the solder will run freely onto both.

After carrying out the exercises described you should be fairly proficient in soldering lengths of wire. It is still desirable, however, for you to obtain additional practice by soldering small pieces of metal to one another. You will doubtless be able to find several small pieces of metal with which you can practice soldering. Easiest metals to solder together are pieces of clean shining tin plate. Do not attempt to solder very large pieces of metal with the small soldering iron supplied with this kit. Cut the pieces of metal up into strips about half an inch wide and practise on these. If you can obtain any brass, copper and other metals, practise with these also because unless you are very thorough in cleaning these metals, you will find them difficult to manage and consequently some practise is desirable. As mentioned earlier, it is not an easy task to solder aluminium and consequently it is unlikely that you will meet with any success should you try.

The resin core solder provided will be sufficiently effective on all metals excepting aluminium so that it will not be necessary for you to worry about trying any other special form of soldering flux.

SOLDERING

In conclusion, I will again list briefly the important points which must be observed before you can solder successfully.

(1) The iron must be clean and well tinned.

(2) The two surfaces to be joined must be thoroughly cleaned of all forms of oxide film so that both surfaces of metal are bright and shining.

(3) The soldering iron must be left in contact with the work long enough to enable both surfaces to be joined, to be

heated to a temperature higher than the melting point of solder, about 450 or 460 degrees F., so that the solder flows readily from the iron and spreads evenly over both surfaces. If the iron is not left in contact with the work long enough to heat each surface sufficiently, the solder may be pasted onto the work but it will be found later that the solder will peel off easily when given a slight pull. This is known as a "dry joint".

(4) When the solder has run freely onto the work and the soldering iron is removed, care should be taken not to shake or disturb the work or the solder until it has had time to cool and solidfy. If the work is shaken when the solder is in the plastic state, before it finally sets hard, a bad connection will often result as the solder will not effectively grip the wire it surrounds.

Good soldering is quite an art and is only learnt through a considerable amount of practice. Therefore, repeat the various exercises outlined over and over again until you feel quite confident and efficient at soldering.

* *

Lesson No. 1

Australian Radio & Television College Pty. Ltd.
206 Broadway, N.S.W.
AUSTRALIA

AUSTRALIAN RADIO & TELEVISION COLLEGE PTY. LTD.

PRACTICAL RADIO COURSE

of

HOME PRACTICAL INSTRUCTION

Lesson No. 2

THIS Radio Course of practical home instruction is the result of many years experience, and months of final experimental work by some of Australia's most competent Radio engineers. It is designed so that you acquire a thorough and most comprehensive practical Radio training by building up the kits which are supplied with these lessons. When the course is finished, and all the kits have been built up into the final unit, you will possess a complete professional outfit of Radio testing apparatus, which in itself is not only worth far more than the money you pay for it, but which will also enable value from the Radio work you can perform with it.

•

CAUTION

THE TWO SLOTTED SCREW HEADS ON THE BACK OF THE METER CASE ARE NOT TERMINALS. THEY MUST NOT BE UNSCREWED.

•

This Lesson will show you how to:—

HOME PRACTICAL INSTRUCTION

LESSON No. 2.

The principal feature of the second practical instruction kit is that you receive in it your permanent magnet moving coil meter which you will eventually combine with other parts to form a high quality multimeter. However, even before you completely construct the multimeter, you will be able to obtain quite a lot of useful experience with the parts contained in this kit, so that you will become familiar with the principles of electrical measurement and you will become practised at using your meter and reading the indications on its scale in carrying out the tests and experiments listed below.

LIST OF PARTS.

The parts contained in your second practical instruction kit are as follows:

1 0-500 microamp moving coil meter.
1 4½ volt battery.
1 2.5 volt flashlight lamp.
1 miniature lamp holder.
1 14.8 ohm resistor.
1 10,000 ohm resistor accurate within plus or minus 1%.

As most of the experiments to be conducted with this kit are based upon the use of the meter, a brief description will first be given of its construction and method of operation so that you will be able to use it more intelligently in making your tests.

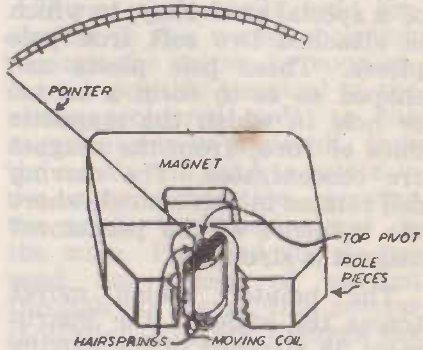


Fig. 1.

METER CONSTRUCTION.

There will probably be a strong temptation, on the part of many, to unscrew the cover of the meter case so as to examine the construction of the meter and to compare the construction with the following description. It would, however, be most unwise for you to attempt to unscrew the case of the meter so as to examine it, because of the fact that it is carefully sealed, before leaving the factory, to prevent the ingress of any moisture or dust which would impair the efficiency of operation. Furthermore, some of the parts in the instrument are just as delicate as those in a watch or clock and the slightest bump or damage to any of the internal parts could quite easily upset the accuracy of the instrument. Therefore, on no account should you open the case and attempt to examine or adjust the meter's mechanism.

The principle of operation is that inside the case there is a large permanent magnet, made of a special steel alloy, to which is attached two soft iron pole pieces. These pole pieces are shaped so as to form a tunnel or hole in which the magnetic lines of force from the magnet are concentrated. The moving coil rotates in this tunnel, where the influence of the permanent magnet is strongest.

The pointer, which moves across the scale of the instrument, is attached to the moving coil. The moving coil itself is a small rectangular winding of copper wire on an aluminium former. The coil has to be small enough so as to rotate in the tunnel formed in the magnet, without touching the sides. The coil is wound with extremely thin copper wire, only about 2/1000 of an inch in diameter and your meter coil comprises about 500 turns of this wire.

So that the coil may swing freely, and carry with it the pointer, it is pivoted by means of hardened steel pivots sharpened to a needle-like point. The points of these steel pivots fit into conical recesses in sapphire jewels because there is very little friction between a polished steel surface and a sapphire jewel. The jewels are mounted in the ends of fine screws which in turn are assembled into the main frame of the instrument. By the observation of a high degree of precision in the manufacture of these pivots and jewels and in their positioning and assembly in the construction of the meter, friction is kept to a neglibly small amount and the coil is quite free to swing to a position determined by the passage of current through it.

To hold the needle normally at zero and to provide an opposition against the tuning force of the electrical current to be measured, two hair springs are attached. These hair springs are thin spirals, very similar to those used in watches. One is attached to the top of the coil and the other to the bottom of the coil and both assist one another in normally holding the needle at zero on the meter scale. These hair springs have a second purpose also, they serve to provide a means for carrying the current to be measured to and away from the moving coil. In other words, the current to be indicated by the instrument passes from one of the terminals to the outside end of one of the hair springs, around through the turns of the hair spring to its inside, there it is soldered onto one end of the moving coil so that the current then passes around through the turns of the moving coil to its other end. This other end of the moving coil is attached to the inner end of the second hair spring so that the current then passes out through the second hair spring and away to the rest of the circuit through the other meter terminal. As a current passes through the turns of the moving coil it sets up a magnetic force around the coil and this force inter-acts with that produced by the permanent magnet to produce a turning effect. This effect causes the coil to rotate, carrying the needle with it, so that the needle registers the strength of the current by moving a certain number of divisions across the scale.

When current causes the coil to rotate, it has to deform both of the hair springs as these are endeavouring to hold the meter pointer at zero on the scale. The sensitivity of your meter is such that the needle will move right across to the extreme right hand end of the scale with 500 microamperes of current passing through it. If a smaller value of current is passed through the coil then the turning force produced by this smaller current is not enough to fully deform the hair springs and consequently the meter may only move a smaller distance across the scale. For example, 250 microamperes would produce half the turning force and this would only be sufficient to move the needle halfway across the scale. Similarly, other values of current will move the needle by a proportionate amount.

Naturally, if a current stronger than 500 microamperes is forced to flow through your meter, it will tend to turn the needle too far and this may result in damage to the meter, so always exercise the greatest caution to see that too much current is not passed through your meter, by carelessness, or an accidental connection.

If you accidentally send the current in the wrong direction through the meter, by connecting the positive terminal of the meter (coloured red) to the negative side of a circuit, then the needle will tend to rotate in the opposite direction, carrying the needle back below zero on the scale. Provided you do not send an excess of current through the meter, this reverse indication will not damage the meter in any way.

An instrument of this type will only measure direct current and should never be connected to a source of alternating current, such as the alternating current power mains, unless it is used in conjunction with a rectifier such as will be described in one of the later instruction papers.

Your meter is a precision instrument and it cannot be too strongly stressed that it is necessary to handle it with care so that it will retain its accuracy for a long period of time. You should always handle the meter carefully as any undue bumping or vibration may damage the polished surface of the pivots and jewels, you should always think carefully before connecting it to a circuit, so as to avoid electrical overload which would perhaps bend the pointer or if extremely severe, burn out the thin wire of the coil. No meter is foolproof, and if you carelessly apply an excess of voltage or current to it you will be certain to damage it, so always check your connections very carefully before applying current and ask yourself whether there is any chance of damaging the meter by the possibility of too much voltage or current being present.

METER SCALE

Your meter, as it is originally supplied to you, is quite unsuitable for measuring voltages and is in fact simply an ammeter, or more correctly, a microammeter, with a full scale value of 500 microamperes. This means that 500 microamperes of current must be passed through the coil to make it turn sufficiently to carry the needle right across to the end of the scale. If the meter were to be used only as an 0/500 microammeter it would only be necessary to mark the scale with one set of numbers terminating in 500 at the right hand end and with other progressively smaller numbers down to zero at the left hand end. However, a little later on, you will be converting this instrument into a multimeter with a wide variety of voltage, current and resistance scales and consequently the meter is supplied to you with the somewhat complex scale needed on a multimeter of this type, instead of a single scale range of 0/500 microamps. For the purpose of the experiments you will be conducting with this kit of parts you can entirely disregard all but one scale on the meter face. The set of graduations you will use will be the second row of graduations from the top. These are the ones marked "Volts, Mills D.C." If you examine this set of graduations you will find that there are 50 of them and that each fifth one is made a little longer than the others so that it may easily be distinguished. Later, when we convert our instrument into a multimeter, this set of graduations may be used for making measurements on one of several ranges. We may use these graduations for measurements up to 10 volts or milliamps, 50 volts or milliamps, 250 volts or milliamps, or 1,000 volts or microamps. Consequently, these various numbers are marked under the set of graduations at the right hand end. The proportionately smaller values of voltage or current, are marked in their respective positions across the face of the meter and their meanings will be quite clear from an examination. As mentioned earlier, you should at this stage completely disregard the upper graduations labelled "Ohms" and the lower sets of graduations marked "A. C. volts".

EXPERIMENT 1.

D.C. MICROAMPS.

A microammeter must only be used for measuring the value of current flowing in a circuit and must never be used, without the use of other additional parts, for measuring voltages. That is, it must never be directly connected to the terminals of a battery or any other source of voltage. However, if a battery is connected to a circuit containing sufficient resistance to restrict the value of current flowing to a few microamps, we may use our meter for measuring the intensity of this current flow.

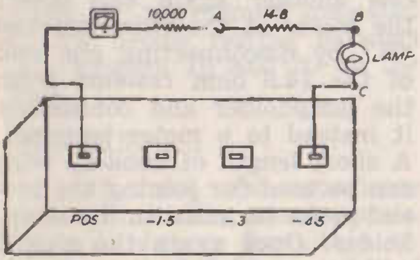


Fig. 2.

To provide some exercise in using our meter for the measurement of current intensity, let us connect the battery supplied, the 10,000 ohm resistor, the 14.8 ohm resistor, and the lamp altogether in a circuit as shown in Figure 2. It is best to solder the ends of the connecting wires of the resistors to one another and to solder one wire of the 14.8 ohm resistor onto the lampholder. The two wires connecting the meter to the battery and the meter to the 10,000 ohm resistor can be short lengths of hook-up wire. One length of hook-up wire can be soldered to the 10,000 ohm resistor. Its other end is bared for a distance of about 1" and is soldered to the right hand lug on the back of the meter. The other length of wire can be soldered to the second meter terminal and its other end attached to the clip on the battery by pressing downward on the clip, then passing the wire under the notched piece of brass showing. On releasing pressure on the clip it will spring up and grip the wire securely. Another short length of hook-up wire can be used for connecting the lamp to the other terminal of the battery.

To protect the meter against damage, the meter, resistors and lamp should all be connected to one another first and the battery connected on last of all. You will find, when the battery connections are made that the needle will move up the scale and will register the strength of current flowing in the circuit. You will probably find that the needle reaches about 9/10th of the way across the scale.

If the needle were to reach the extreme right hand end of the scale this would correspond to a current flow of 500 microamps but actually there is no number "500" at the right hand end of the scale. However, the number 50 appears in the second row of figures at the right hand end and it is quite easy to imagine this as 500, whilst the 40 should be regarded as 400, the 30, 300, and so on. Thus it will be seen that the needle comes to rest at a position between 400 and 500 microamps. There are ten small divisions between 400 and 500 on the scale so each of these will represent 10 microamps. Thus, if the needle rests on the first division above the 400 point this will be 410, whilst the second division would be 420 and so on. You will easily be able to measure the exact value of current flowing. With this small amount of current flowing, the lamp will not light, so do not worry over the fact that it does not glow.

To prove that the same amount of current flows in all parts of a series circuit, I now want you to insert the meter at various other points in the circuit to observe that the current has the same strength at all positions. To do this, disconnect the meter entirely from the circuit and then connect the left hand end of the 10,000 ohm resistor directly to the positive battery terminal. Next, separate the junction of the 10,000 ohm resistor and 14.8 ohm resistor at the point marked "A" on the diagram. You then connect one end of the 10,000 ohm resistor to one of the meter terminals whilst the other meter terminal is connected to one end of the 14.8 ohm resistor. You will now find that the needle again gives a registration of current and if you observe carefully you will see that the current has exactly the same strength at this point as it did at the first point in the circuit. If, during any of these experiments the meter needle tends to move to the left instead of up the scale, it simply means that you have reversed the connections to the battery or meter and you can make the needle move in the right direction by either exchanging the two battery connections or exchanging the two meter connections.

Next, remove the meter from the point marked "A" in the circuit, join the two resistors to one another again and insert the meter at the point marked "B" by disconnecting one end of the 14.8 ohm resistor from the lampholder and connecting it instead to a meter terminal. A short length of hook-up wire can be used for joining the second meter terminal to the lampholder. Once again the circuit will be completed, current will flow, and the same strength of current will be registered.

Now repeat this operation, by inserting the meter at the point marked C instead of that marked B and again observe that the current has the same strength.

When using the two outside terminals of the battery, as shown in Figure 2, you are employing the battery's full voltage of 4½ volts to drive current around the circuit. You should now repeat the experiments outlined above by using only 3 volts from the battery. This is done by moving the wire from the battery terminal marked "-4.5" to the next terminal, marked "-3". With only 3 volts in use, the current will not be as great and the needle will move only about two-thirds of the way across the scale to a point near where the figure "30" is marked. Of course, this corresponds to 300 microamps.

The next step is to repeat the experiments after having moved the lead from the -3 terminal of the battery to the one marked "-1.5". You will find that the current has become still weaker and now has a strength of about 150 microamps, indicated by the needle resting between the numbers 10 and 20 on the scale.

CONCLUSION.

Apart from the experience gained in reading a meter scale, you will observe from this experiment that the same value of current exactly flows at all points in a series circuit such as the one illustrated in Figure 2. Further, if there is a break at any point in a circuit such as this, the current will be prevented from flowing at any point in the circuit. The strength of current flowing in a circuit is dependent upon the strength of voltage forcing the current to flow. The stronger the voltage, the greater the intensity of current which will flow. The weaker the voltage, the less the current which will flow.

EXPERIMENT 2.

VOLTAGE MEASUREMENT.

Although the meter supplied to you is basically a microammeter, it can be converted into a voltmeter and employed for measuring voltages merely by connecting a resistor to it. To make your meter into a voltmeter capable of measuring direct voltages up to a strength of 5, connect one end of the 10,000 ohm resistor to one of the meter terminals and connect two lengths of flexible hook-up wire, each about two feet long, one to the other meter terminal and the other length to the unused end of the 10,000 ohm resistor. These connections are shown in Figure 3.

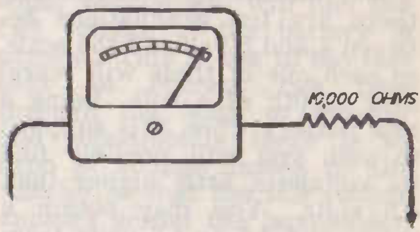


Fig. 3.

Your meter is now capable of measuring voltages and a value of 5 volts applied to it would send the needle across to the right hand end of the scale. Actually, there is no number "5" appearing at the right hand end of the scale but again, we will use the second row of numbers which actually terminates in 50 and we will disregard the nought so that the 50 we will imagine as being 5. Similarly, the 40 will become 4 and the 30 will be regarded as 3 and so on.

To measure the voltage of your battery, connect the two lengths of hook - up wire, marked with arrow heads in Figure 3, to the two outside terminals of the battery. If the battery is in good condition, it should have a voltage of approximately 4.5 volts and this will cause the needle to move nearly to the right hand end of the meter scale. The needle will come to rest about halfway between the numbers 40 and 50 on the scale. As I have already explained, these numbers really correspond to 4 and 5 volts so that if the needle is halfway between, this would indicate 4½ volts. Actually there are ten graduations between 4 and 5 volts on the scale, so each one of these will represent 1/10th of a volt. Being a new battery when it is supplied to you, you will possibly find its voltage a little higher than 4.5 volts. You may obtain a reading of 4.6 or 4.7 volts from it.

You should now measure the voltage of the other sections of the battery by connecting the ends of the hook-up wire between the various pairs of terminals. In some cases you will obtain a reading of 3 volts and in other cases a reading of approximately 1½ volts.

Your meter will now prove to be an accurate instrument for checking any other low voltage batteries you may have, such as flashlight batteries. Each cell of a flashlight battery should give an indication of about 1½ volts when in good condition, and you will find that the cells are not much use once their voltage drops below 1 volt.

On no account should you attempt to use your meter and resistor for measuring values of voltage higher than 5 volts. Never connect the meter and resistor to a radio B battery or any other battery which has a voltage greater than 5. Never attempt to measure voltage unless your meter itself is used in conjunction with a high value of resistance as shown in Figure 3.

EXPERIMENT 3.

FAULT-FINDING WITH A VOLTMETER.

A voltmeter is a very useful instrument for tracing faults in electrical circuits because frequently a fault causes the voltages in the circuit to be different to those normally existing. If you know what voltages should normally exist in a circuit when it is in good condition, then you will quickly be able to determine the faults by measuring with the meter to find out which voltages have changed and are no longer normal.

To provide a circuit on which to practise, connect together the battery, 14.8 ohm resistor and lampholder as shown in Figure 4. On screwing the lamp into the holder you will find that it glows dimly if all your connections are in good order.

The lamp used in this manner may represent the filament circuit of a radio valve.

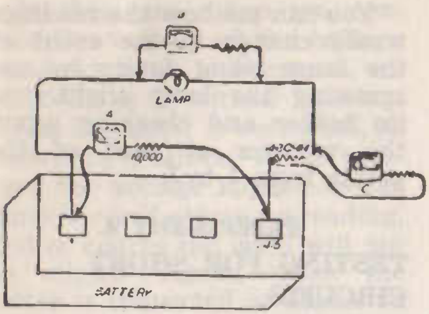


Fig. 4.

Now with your meter connected to the 10,000 ohm resistor as shown in Figure 3, so that it is a voltmeter, connect the two ends of the flexible wires, which should be 2 or 3 feet long, firstly to the two terminals of the battery as shown at A in Figure 4. If the meter shows full battery voltage of approximately 4½, you will know that the battery itself is in good condition.

Now move the voltmeter to B and touch the two sides of the lampholder. The meter in this case should register a voltage of approximately 1 volt. Make a careful note of the exact reading of the meter at this point.

Next move the voltmeter to C and measure the voltage drop across the 14.8 ohm resistor. If you add the voltage measured at this point to the voltage measured at position B you will find that the two added together exactly equal the voltage of the battery as measured at position A. Thus, you can see that the voltage of the battery divides between the various parts making up a series circuit like that of Figure 4.*

Now let us purposely introduce a simple fault into this circuit and you will see how the voltage indications change from the correct ones. Let us prevent the lamp from lighting by unscrewing it slightly in its socket. This will have the same effect as if a faulty lamp is used.

If you now make your measurements, you will find at position A that the voltage of the battery is still correct. At position B, instead of finding a small voltage you will find the full voltage of the battery is present. This is due to the fact that no current can pass through the lamp or resistor and consequently there is no drop in voltage caused by the resistor so that the full voltage appears across the lampholder, even though this voltage is unable to drive any current through the lamp itself.

When you connect the meter to position C you will find that no reading is obtained because of the fact that no current is passing through the 14.8 ohm resistor and therefore will not produce any drop in voltage across it.

Unfortunately, you cannot very well make the 14.8 ohm resistor defective to test and see what happens when this condition arises without actually damaging it. However, if this resistor were to be broken, you

* See A.R.C. Service Engineering Course Lesson 7.

would find on making your measurements that you would obtain full battery voltage at A, no voltage at B, because no current would be passing through the lamp, and you would obtain full battery voltage across the two ends of the resistor with the meter at position C.

Another slightly different method of using a voltmeter for locating a break in a circuit is illustrated in Figure 5. In this case, one of the flexible leads from the meter should be permanently connected to the positive terminal of the battery and the other flexible lead moved around the circuit from one

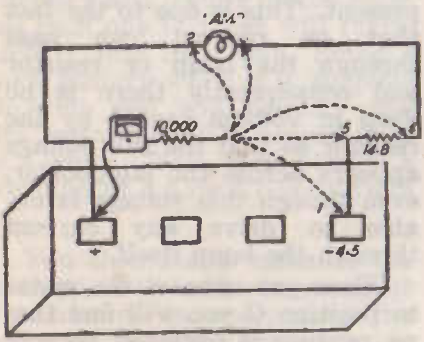


Fig. 5.

point to another as numbered on Figure 5. At position 1, you will check the battery voltage. If all of the other parts in the circuit are in good order, you will find at position 2 that you obtain no reading, at position 3 you will obtain a reading of approximately 1 volt, at position 4 you will obtain a similar reading, while at position 5 you obtain a reading of the full battery voltage.

You can see how the readings would change in the event of the lamp being faulty by unscrewing the lamp slightly in its holder and checking again the voltages at each of the points from 1 to 5.

EXPERIMENT 4.

TESTING FOR SHORT CIRCUITS.

To examine the effect of a short circuit, let us use the 14.8 ohm resistor, lamp and battery in similar fashion to that in diagram 4, with the exception that we deliberately introduce a short circuit in the form of a wire connecting with the right

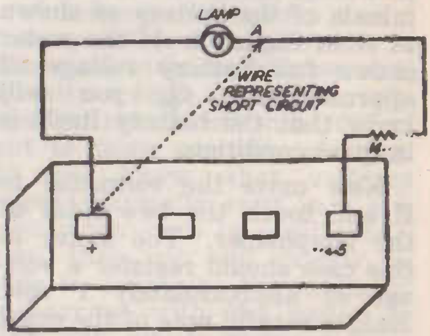


Fig. 6.

hand side of the lamp to the positive terminal of the battery as shown by the wire in Figure 6. When this short circuit is introduced, current from the battery will not pass through the lamp but will take the alternative path through the short circuit to the point marked A and then will pass on back through the 14.8 ohm resistor to the battery.

In this case, when we measure the voltage of the battery as shown at A in Figure 4, we will obtain a normal reading. When the meter is connected, as shown in Position B, to measure the voltage applied to the lamp, we will obtain no reading, and of course the lamp will not be alight. Again, when the meter is connected as shown in position C, we will obtain a reading of full battery voltage because the full voltage of the battery is reaching the 14.8 ohm resistor without having to drive current through the resistance of the lamp.

Previously, when we had an open circuit in the lamp, by unscrewing it in its holder, we obtained full battery voltage when measuring across the lamp in position B of Figure 4. On this occasion, when there is a short circuit across the lamp, as shown in Figure 6, we obtain no reading across the lamp. You will see that the different types of faults reveal themselves by the fact that different voltage indications are obtained when they exist.

EXPERIMENT 5.

CONTINUITY TESTER.

For tracing out the circuits of a radio set or other electrical equipment, and for testing some of the parts, a continuity tester is a very useful instrument. This will reveal when there is a complete path for current through any portion of a complex circuit. A simple continuity tester may be made by employing a 1½ volt section of the battery and the lamp connected together as shown in Figure 7.

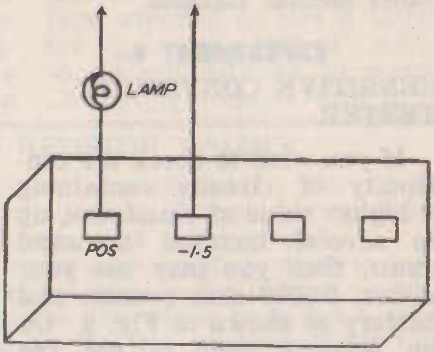


Fig. 7.

By using two lengths of flexible hook-up wire, connect the battery and lamp to any electrical circuit and if there is a continuous path of low resistance, then current will pass through the lamp and cause it to light. If there is a slight amount of resistance in the circuit, the lamp will light dimly. On the other hand, if there is a complete open circuit or a very high resistance path the lamp will not light at all.

The lamp supplied with your kit is rated at 2½ volts and it is permissible to use it for a short period of time with 3 volts applied from the battery. However, it is not advisable to use it for very long under these conditions, and on no account should you connect the lamp across the full 4½ volts of the battery or it will burn out and be of no further use to you.

A continuity tester of this

nature is quite useful for checking the windings in an electric motor or for testing coil windings in radio receivers, and other similar circuits.

EXPERIMENT 6.

SENSITIVE CONTINUITY TESTER.

If you wish to check the continuity of circuits containing a higher value of resistance, up to several hundred thousand ohms, then you may use your meter, 10,000 ohm resistor and battery as shown in Fig. 8. On no account omit to use the 10,000 ohm resistor, otherwise your meter will be damaged.

When the two long flexible leads indicated by the arrow-

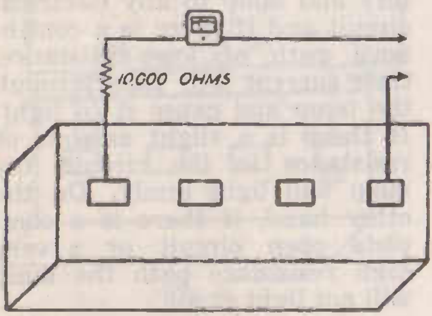


Fig. 8.

heads in Figure 8 are touched to a circuit of low resistance you will find that the needle will move right across to a position corresponding to the full battery voltage, i.e. about 4½ on the scale. On the other hand, when the leads are connected to an open circuit, through which no current can flow, naturally, the meter needle will stay at zero. Again, if the two leads are touched to a circuit containing several thousand ohms of resistance, the needle will take up a position somewhere along the scale.

A continuity tester of this type is quite useful for checking not only resistors in radio receivers but also transformers, coil windings, headphones, loudspeakers and many other parts. If you have an assortment of radio parts on hand, you should test them with the unit and observe the results you obtain. You can also use it for testing the continuity of other electrical appliances such as lamps, irons, electric motors, toasters and other such pieces of equipment.

At this stage, you will not be able to make use of the graduations around the top of your meter face because we have not yet built the instrument up into a proper ohmmeter. Later on, we will, by the use of a slightly more complex circuit, make our meter into an actual ohmmeter for measuring the exact values of these resistances.

In using the continuity tester shown in Figure 8, if you check the continuity of the lamp and the 14.8 ohm resistor you will find that the needle will register almost full battery voltage in each case because both of these items have a very low value of resistance.

A great deal of valuable practical experience can be obtained in using meters and reading meter scales from the experiments outlined above. In order to safeguard your meter, always keep in mind the following points. Never use your meter as it is supplied to you, for measuring values of current higher than 500 microamps. Never use your meter to measure voltage or as a continuity tester without using in addition to it a high value of resistance such as the 10,000 ohm resistor supplied. Even with the 10,000 ohm resistor do not attempt to measure values of voltage greater than 5. A meter of the type supplied to you is suitable for measuring direct voltage, so do not attempt to measure alternating voltages with it.

INDICATION OF RESISTOR VALUES

The number of ohms resistance possessed by the resistors supplied in these kits is indicated either by the value being directly printed on the body of the resistor or by a colour code.

There are two slightly different colour code systems in use although the colours have the same numerical value in both, as shown by the table below. In one system, the whole body has a general background colour which indicates the first number of the value. One end is coloured to indicate the second number and about one third of the way along the resistor from the uncoloured end is a dot or band of colour to show the number of noughts which follow.

In the second system, the body is a natural light brown or white colour and there are three coloured bands around the resistor near one end. Starting from the end near the coloured bands, the first band indicates the first number, the second band the second number and the third band the number of noughts. Occasionally, a fourth band, coloured gold or silver is used to show whether the resistor is within 5% or 10% of its labelled value.

RESISTOR COLOUR CODE

Body Colour or First Coloured Ring	First Figure	End Colour or Second Coloured Ring	Second Figure	Dot Colour or Third Coloured Ring	Remaining Figures
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.

Lesson No. 2

Wherever possible, the College will supply resistors coloured or printed exactly as in the parts lists and diagrams of the various lessons but sometimes, where a lesson mentions a 50,000 ohm resistor you may be supplied with one marked 47,000 or for a 250,000 ohm resistor you may be supplied with one marked 220,000 or 270,000 but in all cases you can be sure that these slight variations from the originally intended values will not affect the results of your experiments in any way.

International Preferred Values.

Instead of continuing to make resistors in an almost infinite range of sizes, manufacturers are now tending to standardise on preferred values each of which is an even ten per cent. or twenty per cent. higher than the one below it. For example, taking just those values between 10,000 and 100,000 ohms, resistors in the ten per cent. series with actual values between 9,000 and 11,000 ohms will all be marked 10,000 ohms. Those between 10,800 and 13,200 will all be marked 12,000, etc. The table below indicates the marked or preferred value and the actual values likely to be experienced.

Preferred Value.	Actual Value.	Preferred Value.	Actual Value.
10,000	9,000—11,000	39,000	35,100—42,900
12,000	10,800—13,200	47,000	42,300—51,700
15,000	13,500—16,500	56,000	50,400—61,600
18,000	16,200—19,800	68,000	61,200—74,800
22,000	19,800—24,200	82,000	73,800—90,200
27,000	24,300—29,700	100,000	90,000–110,000
33,000	29,700—36,300		

The same principle applies for all other values above and below those shown above.

> After a period you may find that the pointer on your meter does not quite return to zero at the left hand end of the scale, or it may drop slightly to the left of the zero mark. This need cause no alarm because the small black button on the front of the meter case allows the pointer to be set accurately to zero. Slight rotation of this button either way will effect the necessary adjustment.

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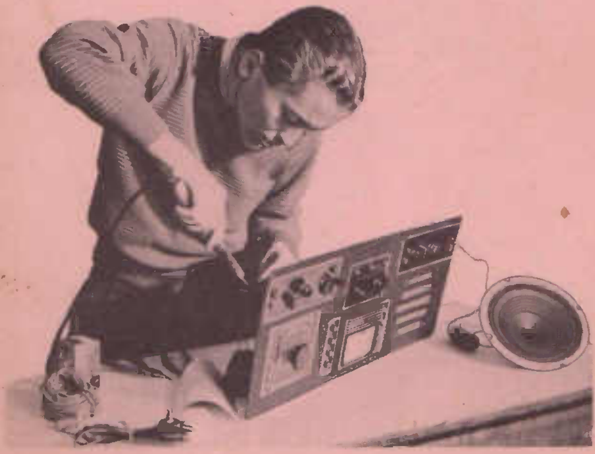
PRACTICAL RADIO COURSE



of

HOME PRACTICAL INSTRUCTION

Lesson No. 3

THIS Radio Course of practical home instruction is the result of many years experience, and months of final experimental work by some of Australia's most competent Radio engineers. It is designed so that you acquire a thorough and most comprehensive practical Radio training by building up the kits which are supplied with these lessons. When the course is finished, and all the kits have been built up into the final unit, you will possess a complete professional outfit of Radio testing apparatus, which in itself is not only worth far more than the money you pay for it, but which will also enable you to earn many times its actual value from the Radio work you can perform with it.

●

CONSTRUCTING A MULTIMETER

This lesson will show you how to:–

HOME PRACTICAL INSTRUCTION

LESSON No. 3

The materials contained in this kit will enable you to partially assemble the Multimeter in its final form.

In some of the Practical Instruction Kits you will receive later on, you will be supplied with the parts to make up a number of receiver, amplifier, oscillator and other interesting circuits. When you are experimenting with these units it will be necessary for you to make a number of tests of current, alternating and direct voltage and resistance. Consequently, it is desirable to build your multimeter into a more permanent form, which is easy to use, so that it is ready when you require it to make tests and measurements as you proceed.

You will receive in this third kit, the main panel upon which the multimeter is mounted, and also a number of parts which will enable you to extend its ranges to directly measure resistance and to measure values of direct voltage. In the next kit, you will receive the remaining material necessary to complete the multimeter and also a valve and other parts, so that you will be able to make a number of interesting tests with it, including the plotting of some of the valve's characteristic curves. In this way you will learn a lot about the behaviour of valves before you actually build them into receiver and other circuits.

As your principal practical instruction in connection with this particular kit will be in the construction of the multimeter, the greater part of this lesson will be devoted to building instructions and a description of the functions of the parts. Only, a small portion will be employed to describe experiments which you can make with the meter. On the other hand, the next lesson will cover only the final construction details and will be mostly devoted to a description of experiments to be undertaken. Contained in this third kit you will find the following materials:—

1 .25 megohm resistor accurate within ∓ 1%.
1 50,000 ohm resistor accurate within ∓ 1%.
1 1,000 ohm resistor accurate within ∓ 10%.
1 200 ohm resistor accurate within ∓ 2%.
1 1,000 ohm potentionmeter.
1 Front Panel.
5 Tipjack socket assemblies.
1 small pointer knob.
1 yd. nylex tubing.

1 pair test prods and leads with push-on clips.

ASSEMBLY.

The first step in assembly is to mount the tipjack sockets, and potentiometer on the main panel.

The positions in which the various parts are to be placed on the panel are clearly shown in Fig. 1. The two black moulded bushings are to be used on the large label, the three red bushings being for the voltage sockets on the narrow label at the right of the meter.

It is most important that the tipjack sockets are insulated from the panel and this is accomplished by means of the moulded insulating bushings provided. If the sockets are not carefully fixed in the centre of the holes in the panel, it is possible for the threaded part of a socket to touch the side of a hole and thus be connected to the panel. Should this occur, it will quite possibly result in damage to the meter when it

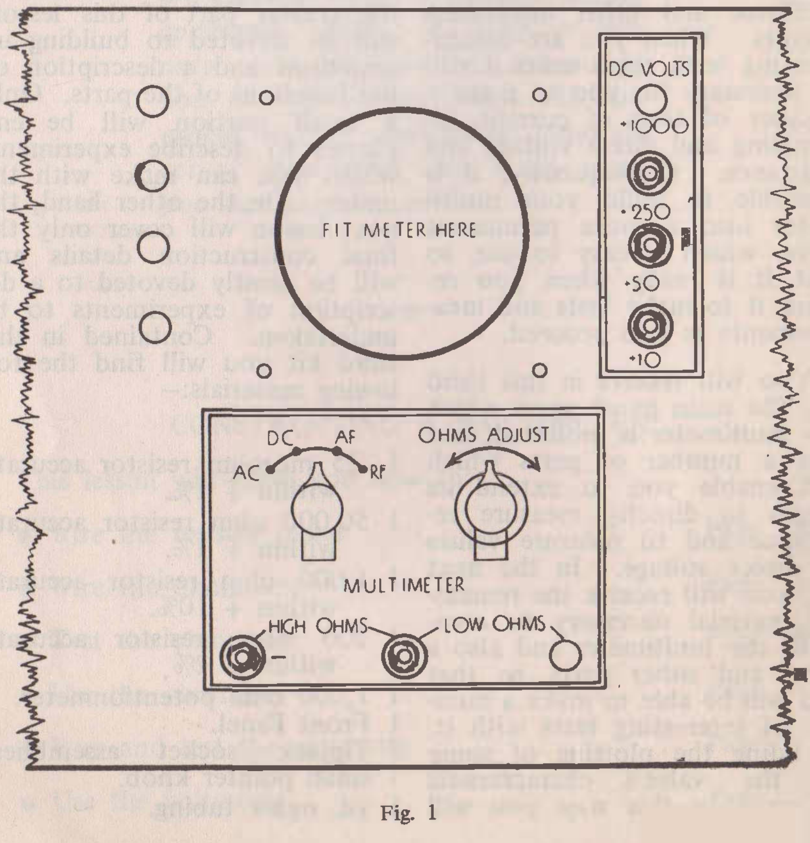


Fig. 1

is used for testing some of the units we will construct later. If you examine the bushings carefully, you will notice that a ridge about three-sixteenths of an inch high is provided on the underneath surface. This ridge is a little smaller in diameter than the holes provided in the panel and consequently, when this ridge is fitted down into the holes, it will prevent the threaded portion of the socket from touching the edges of the hole and thus assure satisfactory insulation. You must be careful, however, to see that this ridge passes through and fits into the hole in the main panel, before tightening up the nut on the socket.

The correct method of assembling the various components on the tipjack sockets is shown in Fig. 2. It will be seen that the long portion of the socket is passed firstly through the ridged bushing, then through the panel, plain bushings metal washer and solder lug, before the nut is finally screwed on. The nuts should be screwed on securely to prevent them from loosening when the instrument is in use.

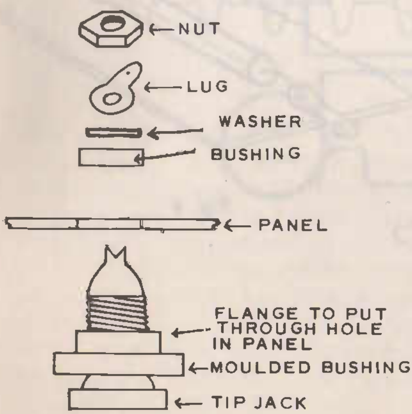


Fig. 2

To make sure that there is no accidental short circuit between the sockets and the panel, it is desirable to make a continuity test. Connect your meter, 10,000 ohm resistor and battery together as shown in Fig. 8 of Lesson No. 2. Scratch a small amount of the lacquer from the rear side of the large panel until you have a small shiny area of bare metal exposed. Connect one of the leads from the continuity tester to this bare spot on the main panel and touch the other lead in turn to each of the sockets. In no case should you obtain a reading on your meter. If the meter gives an indication then this shows that the sockets are not centred in their holes on the panel, and it will be necessary to loosen the nuts, reposition them and then tighten the nuts again. After this, make another test until you find that there is no reading obtained when testing to any of the sockets.

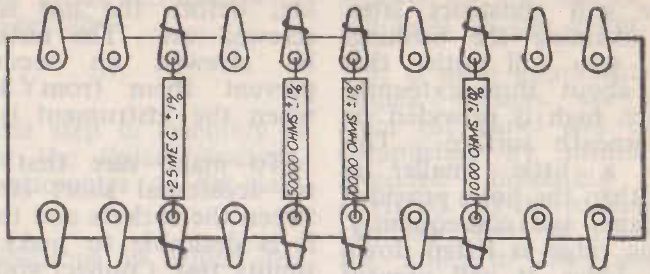


Fig. 3

RESISTOR PANEL.

The next step in the construction of the multimeter is to mount the various resistors on to the resistor panel (supplied in Kit 1) in exactly the positions indicated in Fig. 3. Count along from one end of the resistor panel and leave the number of spaces indicated on Fig. 3 before mounting the resistors in position. These vacant spaces will be used for some of the other resistors which will be supplied to you in your next kit.

To make certain that the resistors are mechanically secure before the soldering operation is carried out, pass the connecting wires from the resistors down through the eyelet holes, securing the various lugs in position, and then bring the connecting wires outward and around the solder lug. The correst method of attaching the resistors to the lugs is shown in Fig. 4. Now use your soldering iron to solder the ends of the wires to the solder lugs.

You may now mount your meter into position on the main panel by means of the four nuts supplied with it.

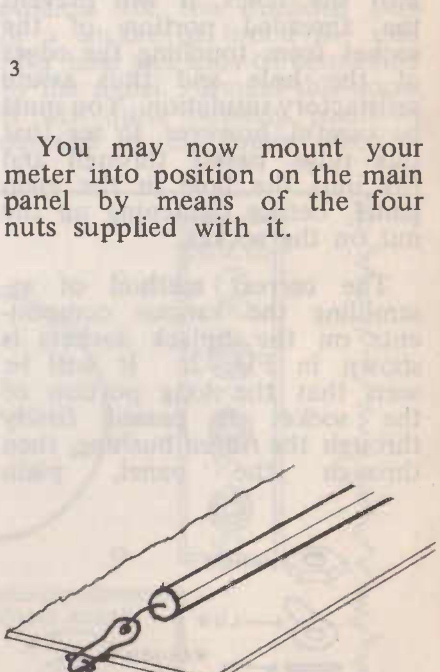


Fig. 4

Now solder the resistor panel to the two lugs attached to the meter as shown in Fig. 5. You will find, if you solder the fourth lug from the left-hand end of the resistor panel to the left-hand meter terminal that the seventh lug from the left-hand end of the resistor panel matches the soldering lug attached to the right-hand meter terminal.

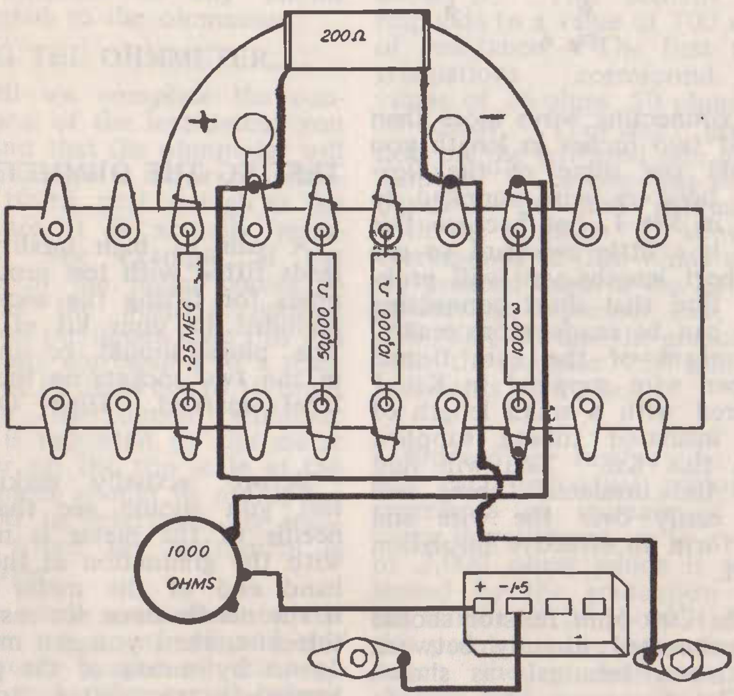


Fig. 5

WIRING THE OHMMETER.

The wiring necessary to complete the ohmmeter circuit is clearly indicated in Fig. 5 and the equivalent electrical circuit arrangement is shown in Fig. 6.

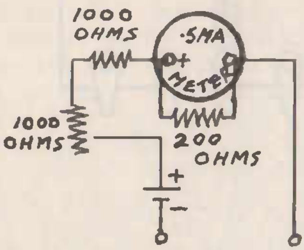


Fig. 6

For connecting wires more than about two inches in length you should use some of the flexable hook-up wire supplied to you in Kit 1, but because this wire is a little awkward to use in short lengths you will probably find that short connecting wire can be made more readily by means of the bare tinned copper wire supplied in Kit 1 covered with a small length of the insulated tubing supplied with this Kit. You will find that the insulated tubing will slip easily over the wire and will form an effective insulation for it.

The 200 ohm resistor should be connected directly between the meter terminals as shown in Fig. 5.

The wires from the centre lug of the potentiometer and from the centre socket in the large label should be left about eight or nine inches long so that they may be connected to the battery supplied to you in Kit No. 2. The wire from the potentiometer should connect to the positive terminal on this battery and the wire from the tipjack socket should connect to the battery terminal marked minus 1.5. Having completed our ohmmeter section we will proceed to test this before proceeding with the construction of the voltmeter.

TESTING THE OHMMETER.

A pair of high quality test leads fitted with test prods and plugs for fitting the sockets is included in your kit of parts. The plugs should be inserted in the two sockets on the large label marked "High Ohms".

Before actually making a test you should see that the needle of the meter is in line with the graduation at the left-hand end of the meter scale. If the needle does not rest over this line, then you can make it do so by means of the plastic headed screw fitted to the centre of the meter case just below the glass. Use a large screw-driver and turn this screw very slowly, one way or the other, until the needle is in line with the left-hand marking on the scale.

Next you should check the position which the needle reaches at the right-hand end of the scale when the two long test wires are touched together. When you touch them, you will find that the meter will move up the scale towards the right-hand end. You should use the knob supplied, fitted to the shaft of the potentiometer, to adjust the potentiometer until the needle just reaches the right-hand end of the scale. If you now separate the end of the test wires they are ready for measuring the resistance of any circuit connected to the ohmmeter.

USING THE OHMMETER.

Until we complete the construction of the instrument you will find that the ohmmeter will only indicate a value of resistance 100th part as high as the resistance it is actually measuring. For example, if the needle of the meter comes to rest at the position marked "10" on the upper scale this will not really correspond to a resistance of 10 ohms but to 10 times 100 or 1000 ohms. Whatever value is indicated by the meter pointer on the top scale of the instrument should be multiplied by 100 to determine the resistance which the instrument is measuring.

The small graduations on the voltage ranges of your meter are evenly spaced all the way across and represent the same value of voltage from one end of the scale to the other. This is not the case with the ohms graduations, however, and you will notice that they are not uniformly spaced and that the value represented by them varies from one end of the scale to the other. Make a careful examination of the graduations on the ohms scale, starting from the right-hand end and working towards the left-hand end. The graduation at the extreme right-hand end is marked zero because the needle should only reach this position when the test leads are directly joined to one another and when there is no external resistance present. Proceeding towards the left you will observe that the fourth graduation has the number "1" above it. This actually corresponds to a value of 100 ohms of resistance. The first three graduations correspond to values of 25 ohms, 50 ohms and 75 ohms. The short graduation on the left-hand side of the number "1" corresponds to 150 ohms. The next graduation, with the number "2" above it, corresponds to 200 ohms so, as we proceed towards the left, the graduations represent 250, 300, 350, 400, 450 and the graduation with the number "5" above it represents 500 ohms.

Proceeding further to the left, each individual graduation represents an increase of 100 ohms in resistance up to a value of 2,000 ohms which is represented by the graduation with the number "20" above it. From this point on, the separation between the graduations again changes and consequently they represent different values of resistance. The next short graduation represents 2,500 ohms, the longer one represents 3,000 ohms, then, in turn, 3,500 ohms, 4,000 ohms, 4,500 ohms and the graduation with the number "50" above it represents 5,000 ohms. The following unmarked graduations will represent 6,000, 7,000, 8,000 and 9,000 ohms and the graduation with the number "100" above it represents 10,000 ohms.

As we continue, the graduations will represent, in turn, 12,500, 15,000, 17,500, 20,000, 30,000, 40,000, 50,000 and the graduation with the number "1,000" will correspond to 100,000 ohms.

The last graduation, which is a symbol somewhat like a figure 8 turned on its side, represents "infinity" and means that there is an infinitely high resistance present between the ends of the test leads. The needle will normally rest on this graduation when the test leads are not connected to any conducting circuit.

To obtain some practice in using the instrument as an ohmmeter, we will proceed to measure the values of the resistors which you have not yet included in the wiring of the instrument.

Included amongst the materials supplied to you with your last kit was a 14.8 ohm resistor. If you touch the two test leads to the ends of this resistor the needle will move almost to the extreme right-hand end of the scale. The needle should take up a position approximately half-way between the end graduation marked "O" and the first graduation to the left which corresponds to 25 ohms. Next, carefully connect the two test leads to the ends of the 10,000 ohm resistor which you have now fitted near the middle of the resistor panel of your instrument. Be careful that the test leads do not touch any of the other solder lugs, especially the one attached to the right-hand meter terminal. When you touch the test leads to the ends of the 10,000 ohm resistor you will find that the needle will move a short distance across the scale and should come to rest somewhere near the graduation which has "100" above it. As previously pointed out, this number should be multiplied by a value of 100 times in order to obtain a correct indication and of course 100 multiplied by 100 represents 10,000, which is the correct value of the resistor.

Because of the wide range of resistance covered on the scale of an ohmmeter it is almost impossible to ever construct an ohmmeter which is absolutely accurate throughout the full length of its scale. For this reason, do not worry if the meter needle comes to rest a little to one side or the other of the graduation marked "100".

Next, you may check the value of the 50,000 ohm resistor by touching the two test leads to the ends of this resistor. Once again, be careful that the ends of the test leads do not touch any of the other solder lugs on the panel. When you have made the connection, you will observe that the meter needle will move only a very short distance up the scale and will come to rest somewhere near the graduation marked

"500". This value of course corresponds to 500 multiplied by 100 or 50,000 ohms.

You now connect the test leads to the two ends of the 250,000 ohm resistor. You will find that the needle will hardly move at all across the scale for the reason that this resistor is so high in value that it prevents any appreciable amount of current passing through the meter and the small amount flowing is hardly enough to move the pointer.

As mentioned earlier, it is impossible to make an ohmmeter which is absolutely accurate across the full length of its range. The degree of accuracy obtained on an ohmmeter will always be greatest near the centre portion of its scale and consequently the needle can be relied upon to come to rest within about 1-16 of an inch of the correct position when checking resistance values which cause the meter needle to come to rest anywhere between 1-3rd of the way across the scale and the right-hand end. The graduations become so crowded together near the left-hand end of the scale that, although the position of the needle may not vary by more than about 1-32nd of an inch from its normal position, this may actually cause it to indicate a value of resistance a little different from the true value of resistance being indicated. In most cases, for practical radio work, any slight error indicated in this fashion is not of sufficient importance to make any noticeable difference to the performance of a radio receiver and the ohmmeter may be regarded as a sufficiently accurate instrument for all radio servicing or constructional testing.

WIRING THE VOLTMETER RANGES.

The connections necessary to complete the wiring of the voltmeter are clearly indicated in Figure 7. The ohmmeter wiring has been omitted from this circuit diagram showing the wiring of the instrument embodying both the ohm and voltage ranges is shown in Figure 8.

When carrying out your wiring be careful to see that the solder, used for attaching the hook-up wire to the solder lugs mounted on the tipjack sockets, does not run underneath these lugs and form a bead which will connect the lugs to the front panel. To minimise the possibility of this occurring, it is a good idea to bend the ends of the soldering lugs upward away from the panel before you commence the soldering. After you have completed the soldered joint, examine the backs of the solder lugs and see that there is not sufficient solder to connect them to the panel.

You may now make some simple tests with the aid of the

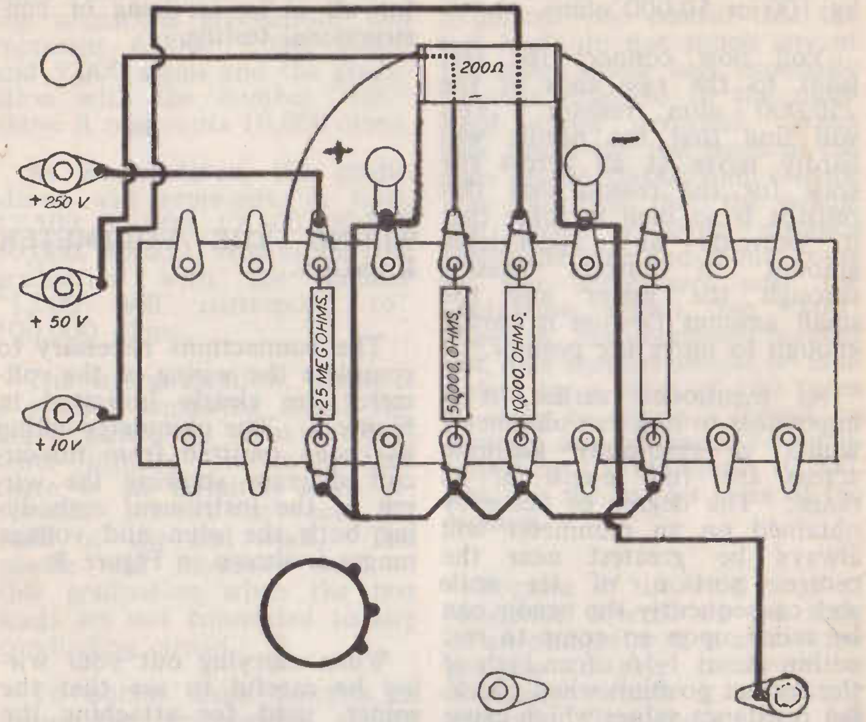


Fig. 7

ohmmeter battery to determine whether the voltmeter has been wired correctly. Insert one of the test leads in the socket mounted in the lower left-hand corner of the main label. This is the socket with the minus sign beside it. The second test lead should be plugged into the tipjack socket marked plus 10 volts. Disconnect the 4½ volt battery from the ohmmeter circuit and instead, connect the ends of the test leads to the two outside terminals on your battery. If your battery has not been extensively used, the meter needle should move almost halfway across the scale. When using the 10 volt range of the instrument, by plugging one of the test leads into the socket marked "+ 10 volts" you should observe the indication of the meter on the DC voltage

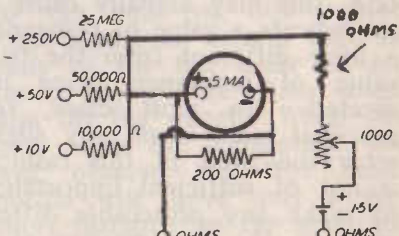


Fig. 8

scale terminating in the number 10 at the right-hand end. The value of 4½ volts from the battery should make the needle move a little less than half-way across the scale to a position about 2 or 3 small graduations beyond the number 4. On this range, each small graduation corresponds to a value of 0.2 volts so that if your battery has its full voltage of 4.5 volts, the needle should move about 2½ small graduations beyond the number "4". The first small graduation would correspond to 4.2 volts, the second to 4.4 volts and the third to 4.6 volts. If the needle does not register approximately 4.5 volts when testing the battery this may indicate either a fault in your instrument or that the battery is discharged. If the needle tends to move more than half-way across the scale this would suggest that the 200 ohm resistor has not been wired directly across the meter terminals; but on the other hand, if the needle does not come up as far as it should, this may indicate that the battery has been discharged or that you have mixed up the resistors and have not connected the 10,000 ohm resistor to the socket marked " + 10 volts".

The 50 volt range of your instrument may be tested by plugging the test lead, which was previously used in the socket marked "+ 10", into the socket marked "+ 50" instead. By touching the two test leads to the end terminals of the battery you will read its voltage on the 50 volt range of your meter. In this case, the needle will move only a short way across the scales. There are 50 separate graduations on the DC voltage scale of your meter so that each small graduation in this case will correspond to one volt and if your battery has its normal value of 4½ volts pressure, then the needle should move 4½ graduations across the scale.

In a similar fashion, we may obtain an indication as to whether the 250 volt range is correctly wired by plugging the test lead into the socket marked " + 250". In this case, the needle will hardly move at all across the scale as each small graduation will represent a value of 5 volts and consequently the needle should move not quite the width of one graduation across the scale from the zero position.

Once you have satisfied yourself that the 3 voltage scales are indicating correctly you may then connect a 1½ volt section of the 4½ volt battery to the ohmmeter circuit again and your instrument is ready to employ as a general purpose voltmeter or ohmmeter for testing radio receivers or electrical appliances. Even though your instrument is now capable of measuring voltages as high as 250 volts, when you employ the test lead in the socket marked " + 250" you should fully realise that the voltmeter will only measure direct voltages and is not capable of measuring alternating voltages. In most districts, alternating voltage power mains are employed and consequently your meter will not be suitable for measuring the voltage of these power mains. If, however, you happen to live in a district where direct voltage power mains are in use, then you may use your voltmeter for checking the value of the actual voltage supplied by these mains. In many cases it will not be exactly 240 volts but your meter will enable you to determine just what voltage is available.

When measuring values of voltage exceeding 100 volts be very careful not to touch the two connections to the source of voltage simultaneously with your fingers or you may receive an unpleasant or even dangerous electric shock. You can quite safely handle voltages up to 50 volts without any fear whatsoever; you should be very careful in handling voltages from 50 volts up to 100 volts and you should be particularly cautious never to touch simultaneously the two sides of any circuit operating with a voltage in excess of 100 volts.

If you wish to use your instrument for checking the voltages present in an ordinary type radio receiver you will find that in most cases you can connect the test lead which is normally plugged into the socket marked "–" to the metal chassis of the receiver and then use only the other test lead, plugged into one of the voltage sockets, for measuring the voltage existing at the plate, grid, filament or other parts of the radio receiver.*

To prevent damage to your meter it is always advisable to start off with the highest voltage range provided, and obtain an approximate indication of the value of voltage before making use of one of the lower voltage scales. If you do not observe this precaution, you may perhaps be using your meter on the 10 volt range and accidently touch a point which is carrying a much higher voltage, say 200 or more volts. If you do this, the 200 volts applied to the meter on its 10 volt range would overload it and might possibly do some damage to it. If, however, you always start with the 250 volt range, you will immediately be given an approximate indication of the value of voltage present and you may, if you find it necessary to do so, safely employ one of the lower voltage ranges for measuring values of low voltage accurately. Do not attempt to measure voltages which may exceed 250 volts until you have wired up the 1000 volt range of your instrument as described in the next lesson.

The ohmmeter range will now enable you to measure directly the value of resistance of any radio parts or electrical device with a resistance between about 25 ohms and 100,000 ohms. In our next lesson we will see how to increase the usefulness of the ohmmeter for measuring very low values of resistance.

* See A.R.C. Service Engineering Course Lessons 7, 12, 20, 26, 44.

If you have a number of radio parts of electrical devices it is a good idea to gain practice in using the ohmmeter scale by measuring the resistance of these units. Do not forget to multiply the value indicated on the upper scale of your meter by 100.

Never attempt to measure the resistance of an electrical appliance or the circuits or a radio set with power applied. Always disconnect the appliance or radio set from the power mains before using your ohmmeter or, in the case of battery-operated sets, disconnect both A and B batteries.

In measuring the resistance of electrical appliances you may in some cases be puzzled by the fact that the resistance you measure appears different to the resistance which you may calculate. The reason for this is that the ohmmeter will measure the resistance of an electrical appliance such as a lamp, radiator, or other unit when the element is cold and the resistance of the element may increase appreciably when it is heated. For instance, the resistance of an electric lamp filament increases by about ten or more times when it is operating at its normal voltage. The resistance of an electric lamp filament when it is heated may be calculated by the formula $R = \frac{E^2}{W}$ This formula is derived from the better known formula

$$W = \frac{E^2}{R} *$$

If we use this formula for calculating the hot resistance of a 240 volt 60 watt lamp we have $R = \frac{240 \times 240}{60} = 960$ ohms. On the other hand, if you actually use your meter to measure the resistance of the 240 volt 60 watt lamp you will only obtain a measured value of about 70 or 80 ohms which is the actual resistance of the lamp filament when the lamp is cold. The lamp's resistance only increases up to 960 ohms when it is heated. This same effect applies to a somewhat lesser degree in the case of other electrical appliances which become quite hot during their operation, such as radiators, toasters, household irons, soldering irons, etc. When testing radio components, however, the parts do not normally become very hot during operation and consequently do not change their value of resistance appreciably, thus the meter will indicate the true value of resistance of radio parts with a fairly high degree of accuracy at all times.

If your instrument fails to perform as it should, carefully check over the wiring and see that it agrees exactly with the illustrations in this lesson.

* See A.R.C. Service Engineering Course Lesson 18A.

Lesson No. 3

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PRACTICAL RADIO COURSE

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HOME PRACTICAL INSTRUCTION

Lesson No. 4

THIS Radio Course of practical home instruction is the result of many years' experience, and months of final experimental work by some of Australia's most competent Radio engineers. It is designed so that you acquire a thorough and most comprehensive practical Radio training by building up the kits which are supplied with these lessons. When the course is finished, and all the kits have been built up into the final unit, you will possess a complete professional outfit of Radio testing apparatus, which in itself is not only worth far more than the money you pay for it, but which will also enable you to earn many times its actual value from the Radio work you can perform with it.

CONSTRUCTING A MULTIMETER (Cont'd.)

This lesson will show you how to:—

VALVE EXPERIMENTS

HOME PRACTICAL INSTRUCTION

LESSON No. 4

The first portion of this Lesson will be devoted to instructions for completing your multimeter unit, while the second portion of the Lesson will describe the operation of some types of radio tubes and will describe a number of experiments you can undertake to determine some of the characteristics of the valve supplied with this kit of parts.

The fourth kit of parts comprises the following material:–

1 75,000 ohm resistor

3 .25 megohm resistors accurate within ± 1%.

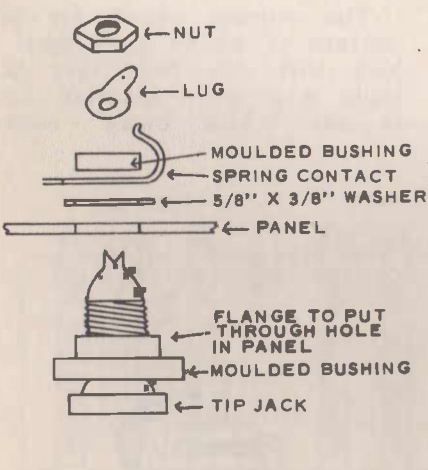


Fig. 1.

1 Multiple shunt for milliamp ranges.

1 Single bank 4 position rotary switch

6 Tip jack sockets and nuts

7 Moulded insulating bushings

1 5/8" x 3/8" x 1/64" bakelite washer

1 Spring contact for low ohms range.

6 Soldering lugs with ¼" dia. holes

2 Small pointer knobs

1 2000 ohm potentiometer

2 1.5 volt dry cells

1 Bantam valve socket

1 Type 3S4 valve

1 Metal switch collar or washer

2 Sheets of graph paper

ASSEMBLY.

Your first assembly operation should be to mount four of the tip jack sockets provided, by means of red insulating bushings, into the vacant holes on left-hand side of the meter. The method of insulating these tip jack sockets was described fully in Lesson 3 and illustrated in Figure 2 of that Lesson.

In a similar fashion a tip jack socket and red bushing should be mounted in position in the vacant hole near the marking "+ 1000" at the right of the meter.

The remaining tip jack socket and black insulating bushings should be mounted in the hole on the right-hand side of the main label. Before placing the solder lug and nut on the rear of this socket there are some additional parts to be mounted on it as illustrated in Figure 1. The tip jack socket is passed through the moulded bushing, the panel, the 5/8'' diameter bakelite washer with the 3/8'' diameter hole, the curved springy low ohms contact, then through the second moulded bushing with its ridge facing the panel, the solder lug and finally the nut. Be especially careful to see that the ridge on the bushing fits snugly into the hole in the spring contact and also in the bakelite washer so that the spring contact is centred around the tip jack socket without any possibility of actually touching it.

After having assembled the tip jack sockets in position it is necessary to test them for short circuits by means of your ohmmeter.

Plug the test lead into the sockets marked "high ohms", connect one test lead to the clean spot you prepared on the back of the panel and touch the other test lead in turn to each of the sockets you have just installed. If you obtain any reading on the meter scale this shows that the bushing is not centring the tip jacket socket properly in its hole so that it is touching the panel. You should then loosen off the socket concerned and re-centre it so that no reading is obtained. You should then apply the same test to the 1000 Volt socket.

The "low ohms" socket you have just installed should also be tested in a similar fashion and then in addition, you should touch one of the test leads to the socket and the other test lead to the springy, curved contact. Before making this test, see that the contact is bent in such a fashion that it does not quite touch the nut on the rear of the socket but yet will press against the side of one of the plugs on the end of your test lead when it is inserted in this socket.

The correct shape for this contact is shown in Figure 2. You will see from this that when a plug is inserted fully in the "Low ohms" socket

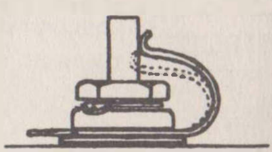


Fig. 2.

it then protrudes through far enough to press against the springy contact. When the plug is pulled out of the socket the springy contact will move slightly but must not move far enough to touch the nut on the rear of the socket.

The position of the springy contact when the plug is withdrawn is shown by dotted lines in Figure 2.

The rotary switch may now be mounted in position. After removing the nut from the threaded bushing in front of the switch, place the thick metal washer or "collar" over the threaded portion of the switch and then pass this threaded portion of the switch. from the rear, through the panel. The toothed lock washer is then placed on the threaded part of the switch and finally the nut is screwed on. Before finally tightening the nut on the switch, rotate the switch so that the bolts and nuts which hold it together are in a horizontal position. If you examine the switch carefully you will see that most of the connecting lugs on it are placed on the rear of the switch but that three are placed on the front side of the switch. Of these three, one is placed directly underneath one of the lugs on the rear of the switch. This pair of connecting lugs should be pointing in the direction of the slotted loudspeaker opening. When the switch has been rotated to its correct position, the nut on the front may be tightened securely, and the pointer knob fitted on to its shaft by means of a small screwdriver. The screw in the knob should be screwed down on to the flattened portion of the switch shaft so that it may grip securely and so that it will point to the four

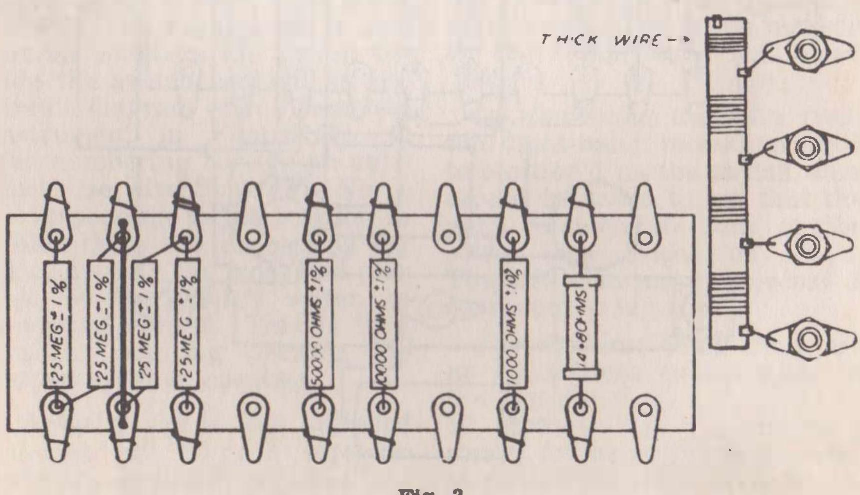


Fig. 3.

markings on the label in turn, as the switch is rotated through its four positions.

The three .25 megohm resistors, the multiple wire-wound shunt resistor and the 14.8 ohm resistor supplied with Kit No. 2 may now be soldered into position as shown in Figure 3. The milliamp shunts now being supplied differ slightly from those shown in Figs. 3 and 4. They are now made in two separate sections joined at the centre. The twisted pigtail wires where the sections join should both be soldered to the 50 ma. socket. Be careful to see that the shunt is placed so that the thick wire on it or .8 ohm section is near the top of the panel and the thin wire or 180 ohm section is near the socket marked "+ 1".

WIRING.

The wiring of the instrument should be carried out as shown in Figure No. 4. Wires which are already in the instrument and which do not have to be changed in any way are shown

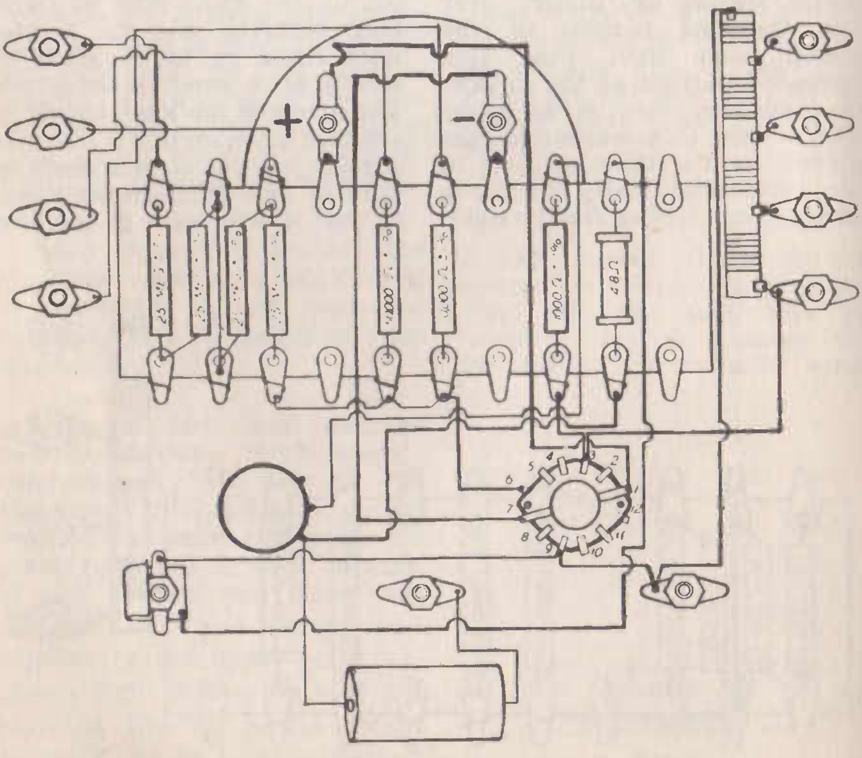


Fig. 4.

in this diagram as thin lines, whereas new wires or wires which must be altered at this stage are shown as thick lines.

Commence by connecting the "1000 volts" socket to the upper left-hand connecting lug on the resistor panel, then by joining the second lug from the left-hand end at the top of the resistor panel to the second lug from the left-hand end at the bottom.

You should also remove completely the 200 ohm resistor soldered across the two meter connections as this resistor will no longer be required, its place being taken by the multiple milliamp shunt which has a total resistance of 200 ohms. You should also disconnect and remove completely the wire connecting to each meter terminal.

To assist in wiring the rotary switch, the various connecting lugs around it have been given numbers in Figure No. 4 and similar numbers are placed beside the switch contacts in the circuit diagram of the complete instrument in Figure No. 5. The numbering runs in an anticlockwise direction with No. 1 corresponding to the position in which there is a connecting lug fitted on both the front and rear side of the switch wafer as described earlier. This is in a position pointing towards the slotted speaker opening.

Actually the switch supplied consists of three separate switches grouped together for compactness and convenience so that all three switches are operated by the one knob. Contacts 1, 2, 3, 4 and 5 form one complete switch. Contact No. 1 is a connection to the moving or "rotor" section which continues any circuits connected to lug No. 1, through to lug No. 2, 3, 4 or 5, depending upon the position to which the switch is turned.

You should slowly rotate the switch and watch the motion of the rotor section so that you may understand just how this section of the switch functions.

Lug No. 7 forms a connection to the rotor section of a second switch. The rotor of this switch may be moved in turn to positions 8, 9, 10 or 11.

The third switch consists of the three lugs mounted on the front side of the wafer. Lug No. 6 is the connection to the rotor and the protruding tooth on this rotor connects to lug No. 12 or to the front lug No. 1, in the switch positions marked on the front label "A.C." and "D.C."

In connecting the wire from the right-hand meter terminal to position 1 on the switch, care should be taken to see that the wire connects to both of the solder lugs in position No. 1. The left-hand meter terminal is connected to lug No. 7.

For the time being there are no connections to be made to the lugs No. 2, 4, 5, 8, 10, 11 or 12, as these lugs will provide a means for using the instrument in conjunction with other equipment for later experiments.

Although you will actually be carrying out the wiring of the instrument from Figure No. 4, it is desirable that you also follow each wire and part in the circuit diagram in Figure No. 5. In this way your proficiency in reading circuit diagrams will be improved.

There are two separate connections to be made to the "low ohms" socket, one to the solder lug and one to the spring contact.

A length of wire should start from the uppermost end of the milliamp shunt and run straight down to the solder lug on the negative tip jack socket immediately below. The wire should then connect from this socket to lug No. 9 on the switch and then across to the solder lug on the "low ohms" socket.

Another piece of wire should be carefully soldered on to the spring contact and should con-

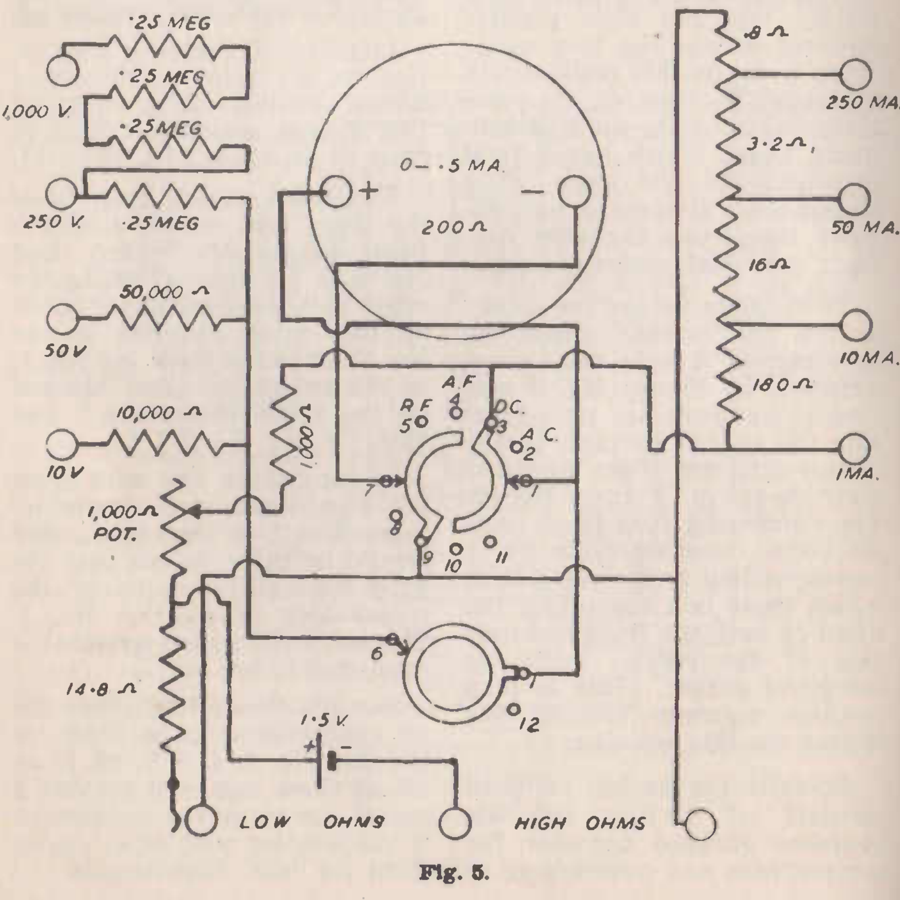


Fig. 5.

nect on to one end of the 14.8 ohms resistor. The other end of the 14.8 ohms resistor is connected to the lower lug on the potentiometer together with one of the flexible leads from the battery.

OHMMETER BATTERY.

The 1.5 volt torch cell supplied with this kit will be used for the ohmmeter in future instead of using one section of the 4½ volt battery. The 4½ volt battery will be needed for other experiments. To connect the 1½ volt battery to the ohmmeter it is necessary to solder the flexible lead from the lower lug on the potentiometer to the small brass cap on one end of the battery. The other flexible lead, from the ohms socket, in the centre of the multimeter label should be soldered to the zinc bottom of the battery. It will be necessary to leave your soldering iron in contact with the bottom of the battery for a matter of four or five seconds before the solder will adhere properly to the zinc can, and it is desirable to scrape the zinc can carefully first before soldering is attempted.

TESTING.

The multimeter will only operate when the four-position switch is turned to the position marked "D.C.", so be sure to turn the switch to this position before attempting to use the instrument.

To test the 1000 volts range, insert the test lead fitted with the black test prod into the socket marked "—", and touch the other end of this lead to the negative terminal of your 4½ volt battery. This battery will not now be connected to the ohmmeter as you will have replaced it by the 1½ volt cell.

The second test lead may be plugged into the socket marked "+ 1000 volts" and its other end touched to the positive terminal of the 4½ volt battery. It is impossible to measure 4½ volts accurately on the 1000 volts range, but if you watch the pointer of your meter carefully, you will observe it move very slightly when connection is made. If the needle moves appreciably across the meter scale it shows that you have made an error in connections and it is necessary to check the wiring carefully. The movement of the meter pointer should normally be only about a quarter of one small graduation.

If you have a radio receiver, you may test the 1000 olts range by measuring some o the high direct voltages present in the receiver.

To test the milliamp ranges, leave the black test lead plugged into the socket marked "—" and plug the red test lead into the socket marked "+ 250 milliamps."

WARNING.

On no account must the test leads be connected directly to the terminals of a battery when the milliamp ranges are in use. A good battery is capable of supplying many thousands of milliamps, and if the two test leads were touched directly to a pair of battery terminals so much current would pass through the meter that it would be certain to be damaged. The milliamp meter must only be connected in series with a circuit in which there is sufficient resistance to restrict the current flowing to a value of 250 milliamps or less.*

To test the milliamp ranges, connect the 75,000 ohms resistor to the 4.5 volts battery as shown in Figure 6. Touch the black coloured test lead to the negative terminals of the battery and the red coloured test lead, which may be plugged into the socket marked "+ 1", to the end of the 75,000 ohms re-

* See A.R.T.C. Service Engineering Course Lessons 7 and 41.

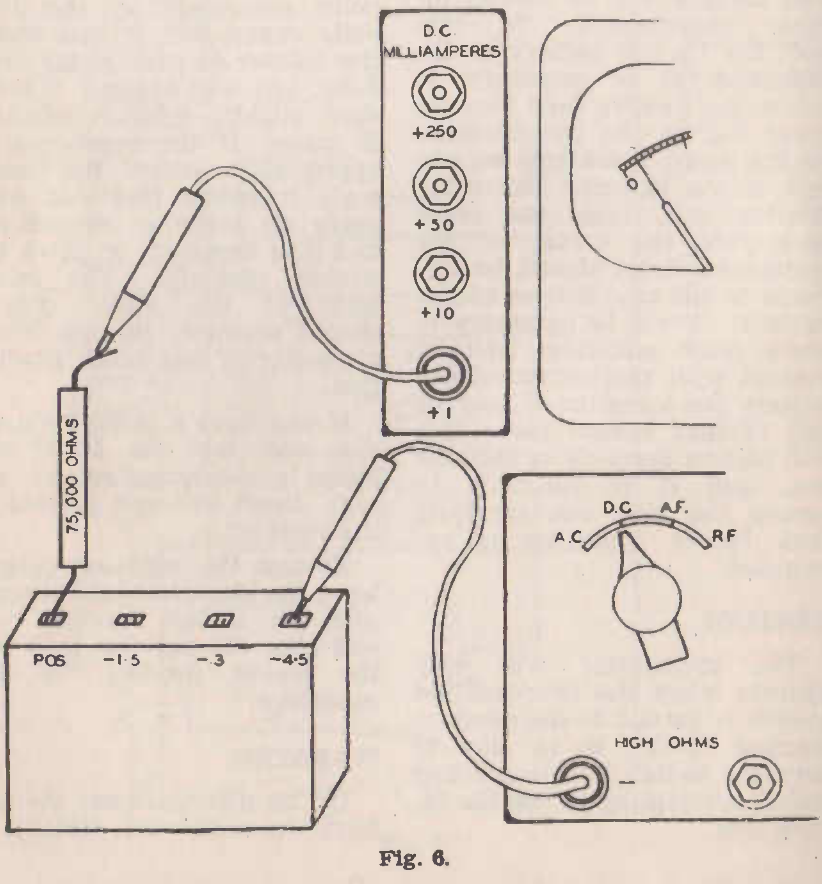


Fig. 6.

sistor. If your battery is in good condition, the 75,000 ohms resistor will limit the current flowing to a value of $\frac{4.5 \times 1000}{75,000}$ which equals .06 milliamps. This should cause the meter to move approximately three small graduations across the scale.

You may then plug the red test lead into the +10, +50 and +250 milliamp sockets in turn and note that the movement of the needle decreases in each case. There will scarcely be any noticeable movement in the +10 position and the needle will hardly move at all in the +50 or +250 position.

If there is as much movement, or nearly as much movement, when any of these three sockets are used as was the case when the +1 milliamp socket was used, then this indicates an error in wiring, or a fault in the multiple shunt, which must be corrected before any attempt is made to measure larger values of current.

If everything appears to be in order before this check has been carried out, you may then connect the 200 ohm resistor to a $1\frac{1}{2}$ volt section of your battery as shown in Figure 7. With a value of $1\frac{1}{2}$ volts applied to a resistor of 200 ohms, the amount of current flowing will be equal to $\frac{1.5 \times 1000}{200}$ or 7.5 milliamps. Obviously this amount of current would be too much to be registered on the 1 milliamp range so that you must not insert the red coloured test lead in the socket marked "+1" when using the 200 ohm resistor for testing.

With the test lead plugged into the "+10" socket, the needle should move about three-quarters of the way across the scale. When plugged into the "+50" socket, the needle should move just past the first heavy graduation on the scale. When plugged into the "+250" socket the needle should move about one and a half small graduations.

The low ohms range may be tested by plugging the test leads into the tip jack sockets between which the words "low ohms" are marked. Before making the test, the ends of the test leads should be touched together and the needle made to register zero ohms at the right-hand end of its scale by means of the knob marked "Ohms Zero". After this preliminary adjustment, the ends of the test leads may be separated and applied to the ends of the 200 ohm resistor. This resistor should of course be disconnected from the $4\frac{1}{2}$ volt battery for this test.

You will recall that when using your ohmmeter with the test leads inserted in the sockets marked "High Ohms", it was necessary to observe the position of the needle on the scale and then multiply the value indicated by 100. When using the "Low Ohms" scale, no such multiplication is necessary. You simply apply the test leads to a resistor or other circuit to be tested and its value will be directly indicated by the graduations on the ohms scale. Thus, when testing the 200 ohm resistor you will observe that the needle takes up a position very close to the graduation marked "200".

You may then apply the two test prods to the connections on the 2.5 volt lamp supplied to you with kit No. 2. You will observe that the resistance of this lamp is only a few ohms.

You have now completed the construction of your multimeter and it is ready for you to employ in making tests and measurements on the units you will construct with later kits.

VALVE TYPES.

Prior to making some tests with the valve supplied with this kit, we will proceed to explain the action of radio, valves in general.

In 1884, when Edison was conducting some experiments with electric lamps, he noted the effect that an electric current could pass between a heated filament in a lamp and an additional piece of metal or wire contained in the lamp envelope. Although he noted the effect in his notebook, he did not pursue the subject any further at that stage. This effect, known as the "Edison Effect", led to the ultimate development of radio tubes, by a series of gradual advancements over a period of many years.

Some years later, in 1896, Fleming commenced to investigate the "Edison Effect" and as a result of his investigations developed what has become known as the "Fleming Valve". This valve was a two-element valve or "diode" consisting merely of a heated filament and an additional metal plate called an anode. When the filament was heated and the anode was made positive compared with the filament, a number of electrons would be emitted or thrown out from the hot cathode and attracted across the space in the valve by the positive voltage applied to the anode. In a simple valve such as this, where the electrons start out from the heated filament, the filament might also be called the "cathode".

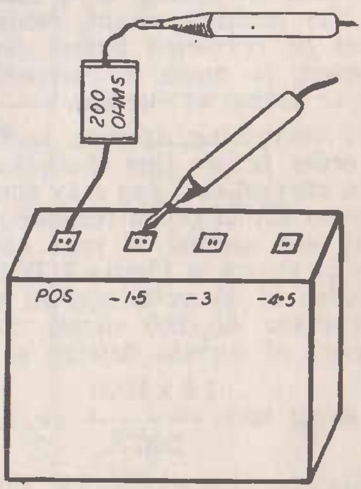


Fig. 7.

If the plate of the valve is made negative compared with the filament, no electrons will pass across the space between the two and the valve will therefore prevent any flow of current in the circuit. If an alternating voltage is applied to a circuit containing the valve, it is thus obvious that only the half-cycles which make the plate positive will be able to cause any current flow and the valve will have the effect of allowing the current to flow only in one direction. In other words, the valve will act as a rectifier or detector. Because of this effect, the Fleming valve was employed as a detector in radio receivers and thus became the first radio valve.

THE TRIODE.

The sole application of the Fleming Diode was as a rectifier or detector and it was not until 1907 that De Forest conceived the idea of introducing a grid into the tube so that amplification could be achieved. With three elements present the tubes were known as "Triodes" and thus made possible the first method of actually amplifying a received signal so that its power could be increased a number of times in a receiver.

In order that a triode tube may be used as an amplifier, it is necessary to apply the comparatively weak signal voltage between the grid and cathode of the tube and to include in the plate circuit of the valve a resistance or impedance which is known as the "plate load". The signals applied to the grid of the valve produce changes in plate current which in turn produce variations in voltage across the plate load and these represent the output signal which may, in many cases, be several times stronger than the input signal. In other words, the signal has been amplified.[1]

Although the triode valve is quite efficient when employed as an amplifier of low frequency signal, it is difficult to achieve much useful amplification from it at high frequencies because of oscillation which occurs due to capacity inside the valve between the plate and control grid.[2]

To make possible the efficient amplification of radio frequency signals, a fourth element, a screen grid, was introduced between the plate and the control grid and screen grid valves or "tetrodes" were made available commercially in 1928.

Whilst the introduction of the screen grid effectively reduced the possibility of oscillation occurring, it still did not provide an entirely satisfactory amplifying valve, and in 1929 a "pentode" valve employing a third grid or, in all, a total of five elements was developed in Europe. This pentode valve proved to be an extremely successful and efficient type of am-

[1] See A.R.T.C. Service Engineering Course Lessons 12 and 18.

[2] See A.R.T.C. Service Engineering Course Lesson No. 21.

plifier and is still the most commonly used form of amplifying valve at the present time. Naturally, in the intervening years many minor improvements in construction and characteristics have occurred but for general amplifying purposes pentode valves are still extremely widely used at the present time. The valve supplied with your kit of parts is a pentode containing a filament, three grids and a plate. However, we will use it in a number of interesting experiments as a diode and triode valve also, to become familiar with the characteristics of these types.

Some radio valves employ even more elements than a pentode but these are special types of tubes developed to perform some particular task such as frequency-changing in superheterodyne receivers and are not used as ordinary amplifiers.[3]

DESCRIPTION OF PENTODE TUBES.

If you examine the valve supplied to you, you will see through the glass envelope a large metal cylinder which is the plate or anode. Across the top and bottom of this cylinder is a perforated disc of mica which is provided with a number of small holes to separate and hold in their correct positions the other elements of the tube.

The three grids are oval-shaped spirals placed inside the plate and therefore not readily visible. If you look at an angle downwards through the top of the plate or upwards from the bottom, you may just be able to see some of the very fine turns of the grid coils. The grid windings are attached to thick upright wires which protrude through the holes in the mica at top and bottom.

The filament consists of two very fine strands of wire which you may just be able to see protruding upwards from the centre hole in the mica disc. These two fine filament wires run down from the centre hole in the top mica disc to the centre hole in the bottom mica disc and are thus held in the centre of the oval shaped grids and plate.

Connection is made to the various elements by means of the prongs protruding from the base of the valve. You can see that these prongs are extended upwards inside the valve and bent over to connect to the various elements.

Connection of the valve to the circuit is made by means of the valve socket supplied. You will see that the valve has seven pins with a wide spacing between two of them so that it cannot be inserted in the socket in the wrong position.

When plugging the valve into the socket, or when removing it, push the valve straight in or straight out and do not wriggle it from side to side. If you bend it from side to side in re-

3 See A.R.T.C. Service Engineering Course Lessons 21A and 32.

moving it from the socket you will probably find that the glass base cracks around one or more of the wires and allows air to enter the valve, making it useless.

Most battery-operated valves simply have two connections to the filament, one to each end, so that they will operate from one particular value of filament voltage only. The valve supplied to you is somewhat adaptable in that the filament is in two separate sections. These two sections can be operated in series with one another from a source of 2.8 volts, that is, the voltage provided by two dry cells, or alternatively, the two portions of the filament can be connected in parallel and may be operated from a single dry cell giving a voltage of 1.4 or 1.5 volts.

To accomplish the change over for series or parallel operation, there are three connections to the filament, a connection to each end and a connection to the centre point. This is illustrated in Fig. 8 at the left which shows the centre tap being disregarded and the voltage from a three volt battery being applied so that current flows through the two portions of the filament in series. Notice that the connection No. 5 on the valve socket, to the centre tap of the filament is not employed and that current from the battery has to flow firstly through one half of the filament and then through the other. To the right in Fig. 8 is shown the method of operating the valve from a 1.5 volt battery. In this case the socket contacts one and seven are connected together and to the negative side of the battery. There are thus two paths for current through the two halves of the filament. If we imagine current as starting out from the positive side of the battery it will flow from contact No. 5 to the centre point of the filament and then portion of the current will flow to the left and back to the negative terminal of the battery through connection No. 1, whilst the other part of the filament current will flow to the right from the centre point through the second half of the filament and back to the negative side of the battery through pin No. 7. In practically all of our tests and measurements we will be operating the valve with the two filament sections in parallel as shown at the right of Fig. No. 8.

TESTING THE VALVE FILAMENT.

Before proceeding to use your valve I suggest that you test each portion of the filament with your multimeter to make sure that both parts of the filament are in good order. To do this, plug the test leads into the terminals marked "Low Ohms" on your multimeter. connect one of the test leads to pin No. 5 on the valve socket and the other test lead in turn to pin 1 and then to pin 7. In both cases your multimeter should give an indication of approximately 20 ohms. At the moment that the test leads are applied, the ohmmeter needle may rise to a value of about 10 ohms but then the needle will rapidly drop back to the position corresponding to about 20 ohms as the filament sections heat under the influence of the testing current. It is due to this heating effect you will find, if you will check the whole filament resistance by measuring between pins 1 and 7, that instead of getting twice 20 ohms or 40 ohms you will only obtain a reading of about 35 ohms. This is due to the fact that the filament does not become quite as hot under these conditions as when you are testing each half individually.

Although the valve filament is rated to operate from a source of voltage providing either 1.4 or 2.8 volts, it is actually quite in order to operate the valve from a 1.5 volt or 3 volt dry battery. There is a permissible variation of plus or minus 10% in filament voltage, and 10% of 1.4 volts amounts to .14 so that it is quite in order to apply up to 1.54 volt to the filament of the valve. Similarly, when the two halves are operated in series, it is permissible to apply 10% more than 2.8 volts, that is, 3.08 volts, without any risk of damaging the valve.

In addition to the filaments, there are, as previously explained, three grids and a plate inside the valve. Grid No. 1, usually called the "control grid"

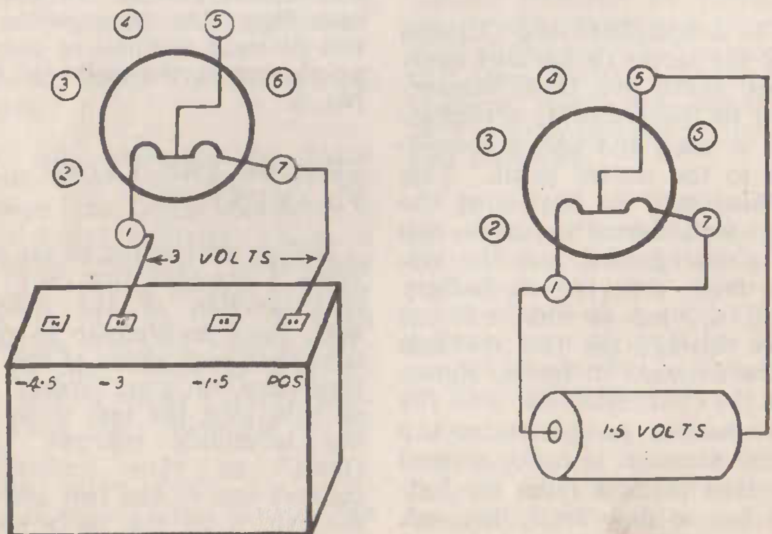


Fig. 8.

and the one to which signal voltages are normally applied, is connected to pin No. 3 on the valve base. Grid No. 2, frequently referred to as the "Screen Grid", is connected to pin No. 4. The third grid, sometimes called the "Suppressor Grid", is connected to pin No. 5 together with a connection to the middle part of the filament. The plate is connected to pin No. 6. These valve base connections are shown in Figure No. 9, which represents the position of the socket connections when viewed from underneath, that is, from the position of the valve socket when it is turned over for wiring purposes.

OPERATION AS A DIODE.

As a first experiment, we will connect our valve so that it acts as a diode and repeat some of the experiments conducted by Edison in 1884.

As previously explained, a diode valve has only two elements, a filament or cathode and a plate or anode. To form the anode in our valve, we will join together the control grid-screen grid and plate by connecting together on the valve socket pins 2, 3 and 4. These three elements all being connected to one another act as one large element which we will regard as the anode in our valve. The suppressor grid is already connected inside the valve to portion of the filament, so that this grid, together with the filament, becomes the cathode. The two portions of the filament are to be connected in parallel by joining together pins 1 and 7 as shown at the right in Figure 8. The centre brass contact on one of the 1.5 volt cells supplied to you should be connected to pin 1 or 7, whilst the wire soldered to the centre of the bottom of the zinc can should be connected to pin No. 5. These connections are also shown to the right in Figure 8. Current from this 1.5 volt cell will then heat the filament of the valve, the 1.5 volt cell being known as the "A" battery.

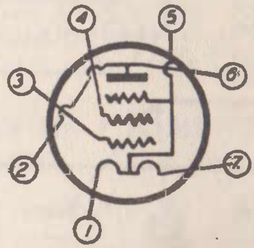


Fig. 9.

We will use our 4.5 volts battery as a "B" battery by connecting a wire from the battery terminal marked "—4.5" to pin No. 5 on the valve socket. Plug one of our test leads into the minus terminal of your multimeter and connect this test lead to the anode of the valve at pin 2, 3 or 4 on the valve socket. The other test lead should be plugged into the "+10 milliamp" socket and its remote end connected in turn to the —3, the —1.5 and the plus terminal on the 4.5 volts battery. These connections are shown in Figure 10.

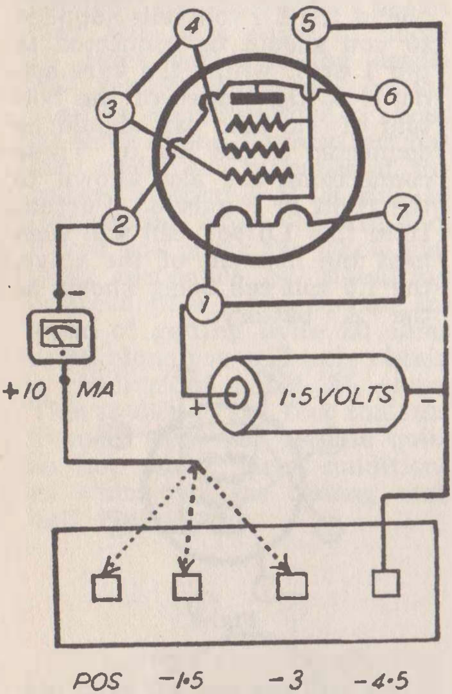


Fig. 10.

You will observe that when the anode of the valve is connected through the meter to the plus terminal of the battery, several milliamps of current are indicated by the meter. Actually this is the result of electrons emitted by the hot cathode being attracted across the space in the valve by the positive voltage applied to the anode. The electrons, once attracted to the anode, strike the anode and flow on around through the wires, through the meter and back to the positive terminal of the battery.

A reduction of positive voltage applied to the anode will have a smaller attraction for the electrons so that fewer of them will reach the anode. This is indicated by the fact that, when you touch the lead from the positive terminal of the meter to the —1.5 terminal on the battery, the anode of the valve becomes 3 volts positive compared with the negative side of the filament and this will result in a current flow of about 1½ or 2 milliamps.

If you still further reduce the positive voltage applied to the anode by connecting the lead from the meter to the —3 volt tapping on the battery, this actually makes the anode only 1.5 volts positive compared with the negative side of the filament and the plate current will be still further reduced to somewhere about .25 milliamps. To obtain an indication of this small value of current it will probably be desirable to remove the positive lead from the socket marked "+10" and insert it instead into the socket marked "+1" on the milliamp label.

Edison noted that current would only pass between the heated filament in a valve and the other elements when the other elements were made positive compared with the filament.

We can confirm Edison's finding by reversing the connection to the 4½ volts battery so that it applies a negative voltage to the anode. This is shown in Figure No. 11. You should connect the lead from pin No. 5 on the valve socket to the positive terminal of the 4½ volts battery. The other three terminals will then provide voltages which are —1.5, —3, and —4.5 volts negative compared with the filament respectively.

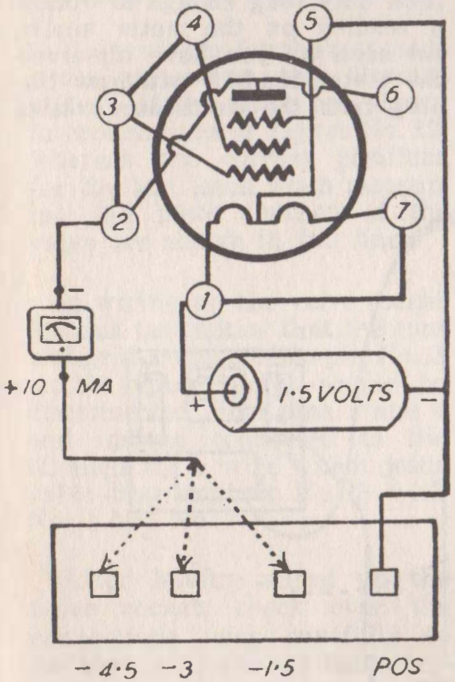


Fig. 11.

If you now touch the test leads from your meter to these three terminals in turn, you will observe that no current whatsoever flows, due to the fact that the negative voltage reaching the plate of the valve, through the meter, does not attract any electrons from the hot filament.

This experiment demonstrates that electrons will definitely only pass in one direction through a valve, that is from cathode to plate; and consequently, if an alternating voltage is applied to the plate, current will only flow in one direction, so that the valve will act as a rectifier. You will see a practical application of a diode valve used as a rectifier in this manner when we use the valve to act as a rectifier for measuring alternating voltages in conjunction with your multimeter later on in this Lesson.

EFFECT OF FILAMENT VOLTAGE.

The strength of positive voltage applied to the anode of a diode valve is not the only factor in determining the amount of plate current which will flow through it. The current is also a function of the temperature of the cathode.

To determine the effect of the cathode temperature, connect the valve as shown in Figure No. 12. It will be necessary to use the multimeter for two distinct purposes in making these tests, firstly, to measure the amount of voltage applied to the filament of the valve and secondly, to measure the resulting strength of plate current. When measuring the filament voltage, the instrument will be used with the positive test lead plugged into the socket marked "+10" on the volts label, and for measuring milliamps the same lead will be withdrawn from the voltage label and plugged into the socket marked "+1" on the milliamps label. The negative test lead will remain in the socket marked "—" on the large label.

A distinct possibility for damage to occur to the instrument exists if one is careless in changing ranges from milliamps to volts. In changing from one measurement to another, it is imperative that the test lead be withdrawn from the multimeter socket before the test prod at the other end of the lead is connected to the plate or filament of the valve. It will probably be found convenient to use one of the spring clips pushed on the end of the test lead, and when it has been connected to the correct position on the valve, the plug may then be inserted into the appropriate socket on the multimeter and left in position only long enough to obtain a reading on the meter scale. As soon as you have observed the meter reading withdraw the plug from the multimeter whilst

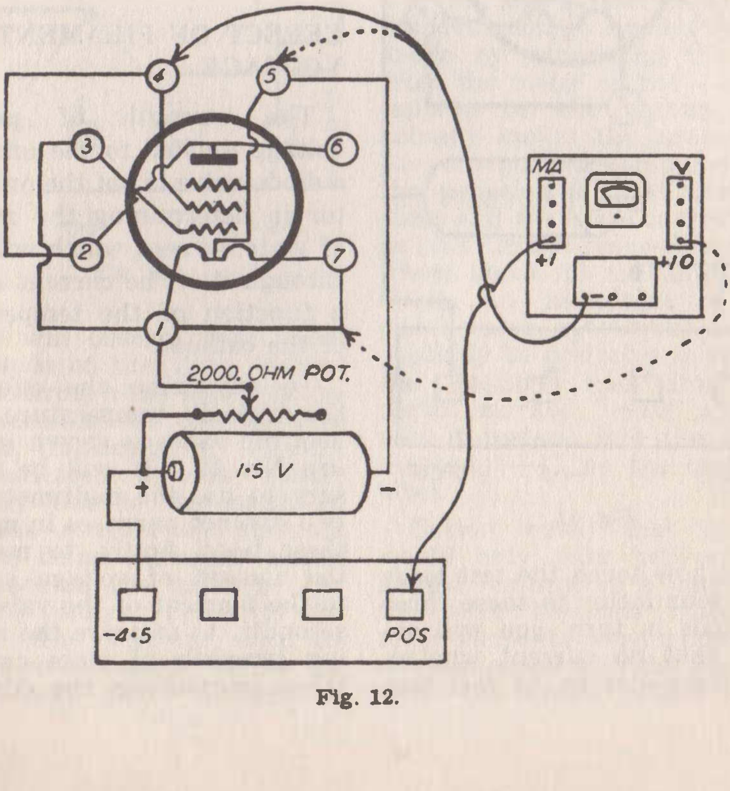


Fig. 12.

you are changing the connections for the following readings. If by any chance you touch the positive test lead of your meter to the filament of the valve while the other end of it is plugged into the "+1 milliamp" socket, you are almost certain to damage the instrument. On the other hand, if you make sure that the connections are correct in the circuit before plugging the plug into the appropriate multimeter socket then no harm will result.

The positions for the test leads when measuring the filament voltage of the valve are shown in broken lines in Figure No. 12, whereas the correct positions for the test leads when measuring the plate current of the valve are shown in full lines.

In wiring up the valve socket for this test notice that the control grid, connected to pin No. 3 on the valve socket should be disconnected from pins 2 and 4 and instead connected to the filament by a wire which joins valve base contact No. 3 with No. 1 and No. 7.

After having wired up the valve socket, check over the connections very carefully to see that you have not made any mistakes. Then, connect the multimeter, set on the 10 volt range, as shown by broken lines, to measure the filament voltage. Adjust the setting of the 2000 ohms potentiometer until the meter reads a filament voltage of .2. This will correspond with the first small graduation on the meter scale.

Now transfer the meter to measure the plate current of the valve. As pointed out before it is imperative to remove the positive test lead entirely from the multimeter before changing any connections, and after changing the points to which both test prods are attached so that the negative test lead connects to the valve socket pin 2 or 4 and the positive lead to the positive terminal of the 4½ volt battery, you may then reinsert the plug on the end of the positive test lead into the "+ 1" milliamp socket and register the plate current if any. With only .2 volts applied to the filament of the valve it is doubtful whether the valve filament will heat sufficiently to allow any electrons at all to be emitted and to reach the plate. Consequently, the milliamp meter needle will probably remain at zero in this first instance.

Next, remove the positive test lead entirely from the multimeter, restore the connection as shown by the broken line in Figure No. 12, reinsert the positive test lead into the "+10" volts socket on the multimeter and move the control shaft on the potentiometer slightly to increase the filament voltage to a value of .4, that is, two small graduations on the meter scale.

Next, following the procedure described previously, convert the meter to measure the plate current and in this instance you will probably observe a very small indication of perhaps one or two graduations on the meter. If the needle moves across two graduations this will correspond to a current of .04 milliamps and you should record this on a table as set out below.

You should then reconnect the meter as a voltmeter, increase the filament voltage to .6 volts, switch over the meter to measure milliamps and again record the value of plate current flowing. In this instance you will find the needle moves considerably further across the scale and will probably register a value of between .1 and .2 milliamps.

Continue to repeat these tests until you have compiled a table something like the one set out below. This table was obtained by testing one particular valve but individual valves vary considerably when operated at such low values of plate voltage and consequently your figures may be considerably different from those in the table.

Filament Volts	Plate Milliamp
.2	0
.4	.04
.6	.2
.8	.36
1	.54
1.2	.68
1.4	.86

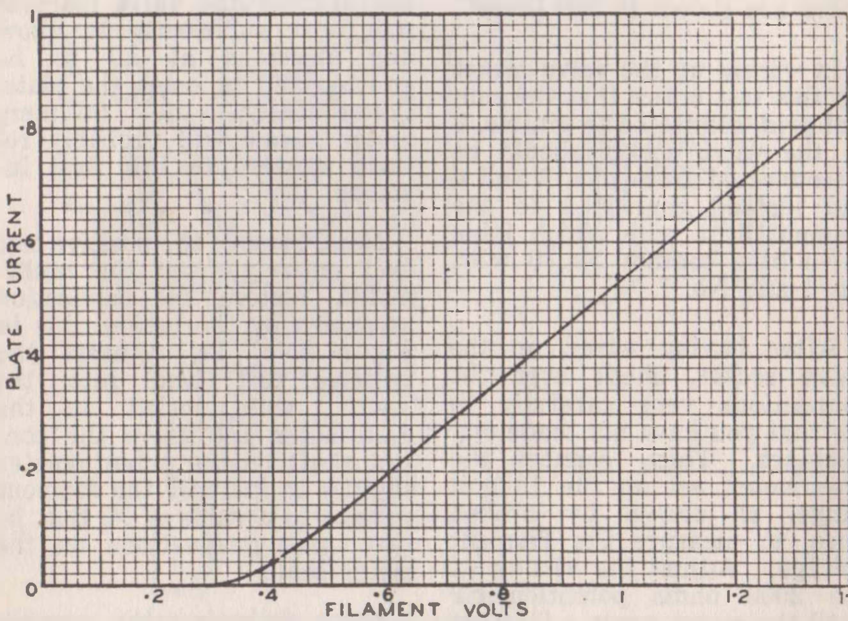


Fig. 13.

Having made a table of the values of plate current corresponding to various filament voltages, it is desirable to set out the information in graphical form. To do this, take one of the sheets of graph paper supplied and draw a rectangle on it, 7″ by 5″. Against the heavy lines on the graph paper mark the values of filament voltage horizontally along the 7″ line and values of plate current vertically along the 5″ side. The form of the graph is shown in Figure 13.

With .2 volts applied to the filament we found the plate current was zero so put a spot on the base line of the graph at a point corresponding to .2 volts.

With .4 volts applied to the filament, we had a resulting plate current of .04 milliamp. To determine the position for this spot, find the vertical line corresponding to .4 volts and follow up this until you reach the second small line which corresponds to a current value on the left-hand scale of .04 milliamp. At the intersection of these two lines place the spot as shown in Figure 13. Of course, if your particular valve had a plate current of some value other than .04 milliamp, put the spot on a horizontal line corresponding to the plate current of your valve instead of on the line corresponding to .04 milliamp, but put it directly above the point marked .4 volts on the base line.

Continue to mark in the spot corresponding to the other values of voltage and current, then join up the seven dots to form a curve somewhat like the one shown in Figure 13.

Do not be disappointed if the spots you obtain when you plot the various values of voltage and current do not lie exactly in the line of a normal smooth curve because it is very difficult to adjust the filament voltage exactly to the values of .2, .4 volts etc., because of the small reading provided on the meter scale. Any slight inaccuracy in setting the filament voltage will of course put the dots out of position on the graph and they will not be in line with one another when the graph is completed. However, it is permissible to draw the line slightly to one side or the other of the dots in order to make it a smooth curve because in practice a valve will always have a smooth curve and if the dots are a little out of position then this is due to an error in reading the meter rather than to peculiar variations in the valve characteristics. An error such as this is shown with the upper part of the curve where the dot for 1 volt appears to be a little too high and the dot for 1.2 volts appears to be a little too low. You will notice that the line has not been drawn through these dots but rather a little to one side or the other because obviously the dots are a little out of position due to an error in reading the meter.

EFFECT OF CONTROL GRID.

The following tests in which we apply a variable voltage to the control grid will reveal its effect in controlling the stream of electrons passing through it from the filament or cathode to the plate. For the purpose of this test, it is necessary to rearrange the connections to the valve sockets and batteries in accordance with Figure No. 14. From this Figure, it is clear that when the moving arm on the potentiometer is moved to one extreme position it will connect the grid of the valve to the negative end of the 1.5 volt cell. When moved to the other extreme it will connect the grid of the valve to the positive end of the 4½ volts battery. Thus, the grid voltage may be varied to any value between —1.5 volts and +4.5 volts.

In making the tests with this arrangement, it will be necessary to again use our multimeter for two purposes, namely, to measure the grid voltage and and to measure the plate current. Once again in changing over the connection to the multimeter so as to enable the grid voltage to be set to a definite value firstly, and then to permit the measurement of the resulting plate current, it is necessary to exercise the same caution and to follow the same procedure as outlined in connection with the filament voltage plate current curve, previously described. In this test, the 1.5

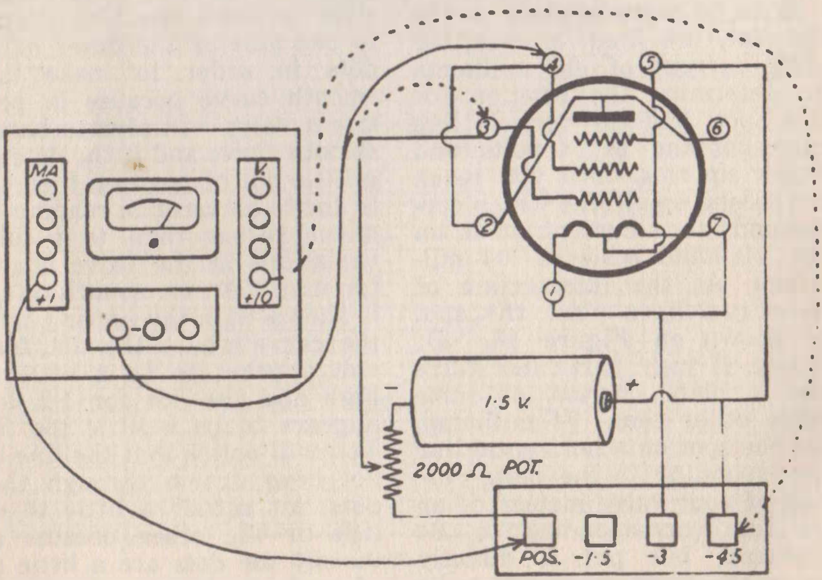


Fig. 14.

volt cells acts as the "C" battery or "bias battery." The portion of the 4½ volts battery between the —4½ and —3 volts tapping is used as the "A" battery, whilst the whole of the 4½ volt battery between the —4½ terminal and the positive terminal acts as the "B" battery.

Commence with the meter connected as a milliammeter with the positive test lead inserted in the socket marked "+1" milliamp, and the other end of the test lead connected to the test circuit as shown in full lines in Figure 14. With the potentiometer set about halfway through its range of travel, there will be a substantial reading on the meter. You should slowly and carefully rotate the potentiometer so that the reading on the milliammeter decreases to zero. You will find that the current will decrease fairly rapidly at first, as the potentiometer is turned, and then, when the current has been decreased almost to zero, the decrease will be very slow until finally the needle drops right down to the zero mark on the scale.

Once the plate current has been reduced to zero, change your multimeter over to measure the negative bias applied to the grid of the valve, by connecting the negative lead of the multimeter to the grid and the positive lead, one end of which is plugged into the socket marked "+10 volts" to the —4½ volt terminal on the 4½ volt battery. You will probably find that the value of negative bias is somewhere between zero and —1 volt. Read the value of bias carefully on the voltmeter scale and mark this on a piece of paper so that you commence another table similar to that set out below, neglecting for the moment the second column of plate milliamps.

Grid Voltage	Plate Mills. at 4.5v.	Plate Mills at 6v.
—1.0		0
— .8	0	.01
— .6	.005	.02
— .4	.01	.04
— .2	.02	.07
0	.04	.11
+ .2	.08	.18
.4	.13	.26
.6	.19	.34
.8	.24	.42
1.0	.31	.52
1.2	.37	.62
1.4	.44	.72
1.6	.51	.81
1.8	.58	.91
2.0	.66	1.01
2.4	.74	
2.6	.82	
2.8	.91	
3.0	1.0	

Next, adjust the negative grid bias to a value a little less negative than before so that the plate current will increase to a value slightly greater than zero. Use a value of bias which comes out to an even fraction of 1 volt such as —.8, —.6, or —.4 volts, the exact value you choose depending upon the particular characteristics of the valve supplied to you. Once you have set the negative bias at an appropriate value, change over your meter connection so that it registers the plate current and mark this value of current down on the table you will compile for your particular valve.

Continue to repeat the process by changing the grid bias a fifth of a volt or .2 of a volt at a time, as suggested by the accompanying table, and record the values of plate current until you reach a plate current of 1 milliamp.

After you have made two or three tests you will find that the negative grid bias has been reduced to zero. To continue to produce further increases in plate current, it will be necessary to move the potentiometer a little further, thus making the grid positive in comparison with the negative terminal of the 4½ volt battery. In order to read the positive values of the grid, reverse the connections to your voltmeter so that the positive test lead will be connected to the grid and the negative test lead to the —4½ volt terminal of the battery. This reversal of connections will enable you to measure the values of bias starting from +.2 volts and going on to a value sufficient to make the plate current increase up to about 1 milliamp.

To determine the effect of a change in plate voltage, we will borrow the 1.5 volt cell from the multimeter and connect this in series with the 4½ volt battery so that the total plate voltage will be increased to 6. The method of connecting this 1.5 volt cell is shown in Figure 15. Of course, you should disconnect the battery entirely from the multimeter by unsoldering the wires to it before connecting it to the 4½ volt battery as shown in Figure 15.

You should now commence again to plot another column of plate current values under these new operating conditions. You

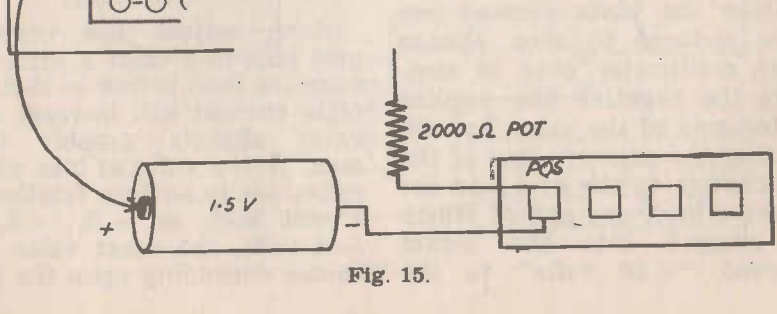


Fig. 15.

will find that it is necessary to use a slightly greater value of negative grid bias, to reduce the plate current to zero, than previously and you will find that because of the greater attraction of the higher positive voltage for electrons, the value of plate current will be higher in each instance, for the same amount of grid bias, than it was in the case of the last set of figures.

Tabulate this second set of figures in a third column as shown above. Once again, the figures you obtain for your particular valve will probably be somewhat different from those shown in the table. The table serves merely to illustrate the manner in which you should undertake the work.

PLOTTING GRID VOLTAGE-PLATE CURRENT CURVES.

It is desirable to set out the information we have just obtained in the form of characteristic curves, from which we may determine the valve's actual characteristics under the operating conditions we have employed.

To draw the grid voltage-plate current curve, draw out a rectangle six inches by 5 inches on a piece of graph paper and mark off values of grid bias along the base and the plate milliamps upwards along one side as shown in Figure 16.

Now, start with the column for grid voltage and the column for plate milliamps at 4.5 volts and mark in the series of points corresponding to the positions on the graph at which these lines intersect as indicated in Figure 16. Once you have plotted all the points corresponding to a plate voltage of 4.5, join these points together to make a smooth curve. If the curve does not exactly pass through some of the points do not worry because, as explained previously, it is difficult to always read the meter accurately, and this will cause some of the points to be placed a little higher or a little lower than should be the case.

Having drawn one grid voltage-plate current curve, you should now proceed to mark on the graph the second row of points corresponding to the values of grid voltage and plate milliamps at 6 volts plate voltage. These points should form a second curve a little to the left of the last one, somewhat as shown in Figure 16.*

DETERMINING VALVE'S CHARACTERISTICS.

An amplifying valve has three important characteristics which will reveal to a radio engineer the manner in which it will perform as an amplifier. These characteristics are known as the "amplification factor", which indicates the maximum possible amplification to be obtained from the valve under ideal conditions, the "plate resistance", which indicates the

* See A.R.T.C. Service Engineering Course Lessons 12 and 18.

internal resistance of the valve to signal currents under operating conditions and thirdly, the "mutual conductance", which indicates how effective a signal voltage applied to the grid is in producing a change in plate current.

The values of these three characteristics are not constant for any type of valve but will change, depending upon the voltages and current at which the valve is operating. The values we obtain from our curve in the following calculation will reveal the characteristics of your particular valve under the conditions you have tested it, that is, with a plate voltage of only 4½ or 6 volts. Naturally, these characteristics will be somewhat different from those which exist when the valve is operated at a higher voltage such as 45 or 67½ volts in an ordinary radio receiver and this accounts for the fact that the characteristics you will determine will be different from those published for the valve in valve data sheets printed by Valve Manufacturers. However, the characteristics you determine from your calculations will be the characteristics of the valve under the conditions of test we have just employed.

To determine the characteristics, is is necessary to mark three points on the set of curves as shown in Figure 16. Point

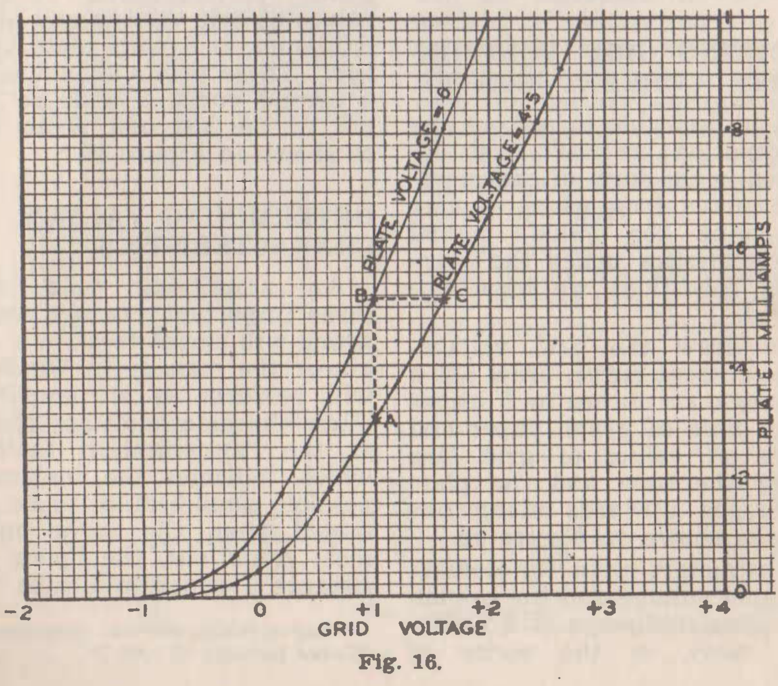


Fig. 16.

"A" should be marked at the position where the right-hand curve crosses the vertical line corresponding to a grid voltage of +1. Point "B" should be marked directly above point "A" at the position where the left-hand curve crosses the vertical line corresponding to a grid voltage of +1. Point "C" should be marked on the right-hand curve exactly level with point "B".

To determine the amplification factor of the valve, we divide the difference in plate voltage between the two curves by the difference in grid bias at a constant value of plate current. The difference in plate voltage will be 1.5 volts, that is, the difference between 4.5 and 6 volts, the two voltages at which we made the tests resulting in the curves. The difference in grid bias is the difference between the bias corresponding to point "B" and that corresponding to point "C" on the diagram. In Figure 16, point "B" corresponds to a bias of +1 and point "C" corresponds to a bias of 1.6 volts. This is determined by following directly downwards from point "C" to the scale of grid voltage at the bottom. The difference between 1 and 1.6 volts is of course .6, so we divide the difference in plate voltage, 1.5, by the difference in grid bias, .6, and as a result have an amplification factor of $\frac{1.5}{.6} = 2.5$.

An amplification factor of 2.5 is not very great but we must remember that this amplification factor applies when the valve is operated as a triode and the amplification factor will be many times higher when it is used in later experiments as a pentode. Further, the low value of amplification factor is accounted for by the very low value of plate voltage employed.

To determine the value of internal plate resistance, we divide the change in plate voltage by the change in plate current at a constant value of grid bias. In this case the change in plate voltage is again 1.5, and the change in plate current is the difference in plate current values between point "A" and point "B" on the curve. In figure 16, the value of current corresponding to point "A" is found by following across horizontally to the scale of milliamps and is .31 milliamps. The value of plate current at point "B" is found from the scale at the right-hand side to be .52 milliamps. The difference is therefore .52 minus .31 or .21 milliamps.

Because our value of plate current is expressed in milliamps instead of amps., our formula for determining the plate resistance becomes $1.5 \times \frac{1000}{.21} = 7143$ ohms.

To determine the mutual conductance, we divide a change in plate current by the change in grid voltage producing it, at a constant value of plate voltage. The change in plate current is the difference in plate current corresponding to points "A" and "C" on Figure 16 and in Figure 16 this difference, as we have already seen, is .21 milliamps. The difference in grid voltage producing it is the difference between the grid voltage corresponding to points "A" and "C", that is, the difference between +1 and 1.6 volts, or .6 volts. Dividing .21 by .6 gives an answer of .35 milliamps per volt for the mutual conductance. Another way of expressing mutual conductance is in "micromhos". To express our mutual conductance in micromhos, we merely multiply the number of milliamps per volt by 1000. Thus, the valve will have a mutual conductance of 350 micromhos.*

APPLICATION OF VALVE.

The experiments we have just completed have revealed a vast amount of information about the characteristics of the valve but so far we have not seen a practical application for it. To employ the valve as an amplifier, it is necessary to have available a source of signal voltage which is applied to the grid of the valve and to put a resistor, coil or transformer in the plate circuit of the valve as shown in Figure 17. The device in the plate circuit is known as the "plate load" and the actual am-

* These characteristics may also be determined from a group or "family" of plate voltage—plate current curves as explained in A.R.T.C. Service Engineering Course Lesson 23.

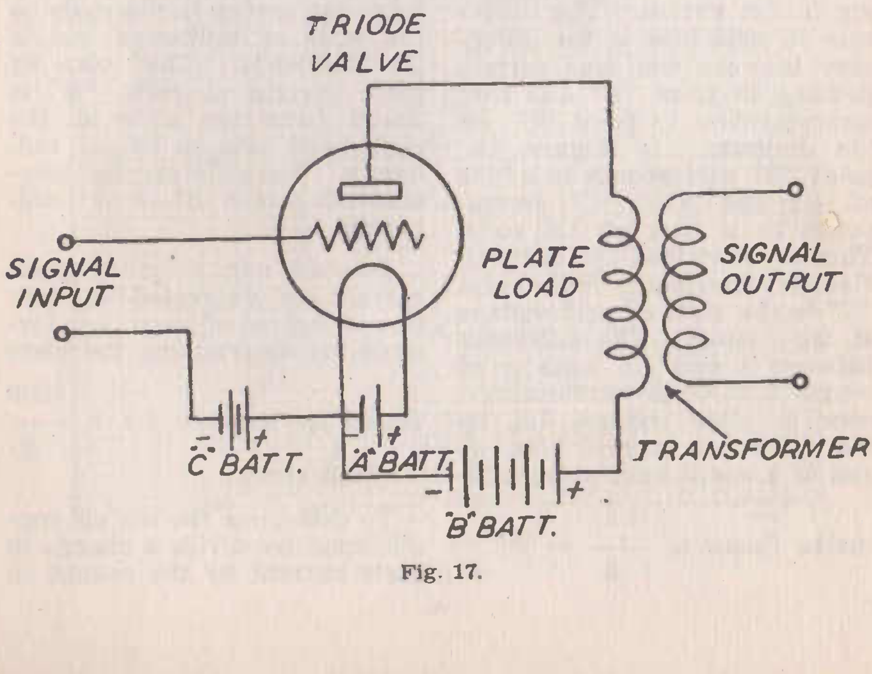


Fig. 17.

plification obtained depends largely upon the value of plate load impedance. The actual value of amplification obtained from the valve is not necessarily equal to the valve's amplification factor but is usually somewhat less than this. We will conduct a number of experiments in a later lesson, with various values of plate load impedance to illustrate this fact.

The curves shown in Figure 16 and the characteristics we have obtained from them apply to the valve when used as a triode. Actually, the valve supplied to you is a pentode and in most amplifier circuits will be used in this fashion. To employ the valve as a pentode it is simply necessary to connect the screen grid to a point of positive voltage instead of connecting it to the plate as we have been doing so far in our experiments. A diagram of a pentode amplifier is shown in Figure 18.

USING THE VALVE AS A RECTIFIER.

One practical application to which we may put the valve at this stage is to use it as a diode and to connect it to our multimeter so that the multimeter may become capable of measuring alternating voltages as well as direct voltages. In this application, the valve will act as a diode rectifier and will cause the alternating voltages to be measured, to produce pulses of direct current which will operate the meter.

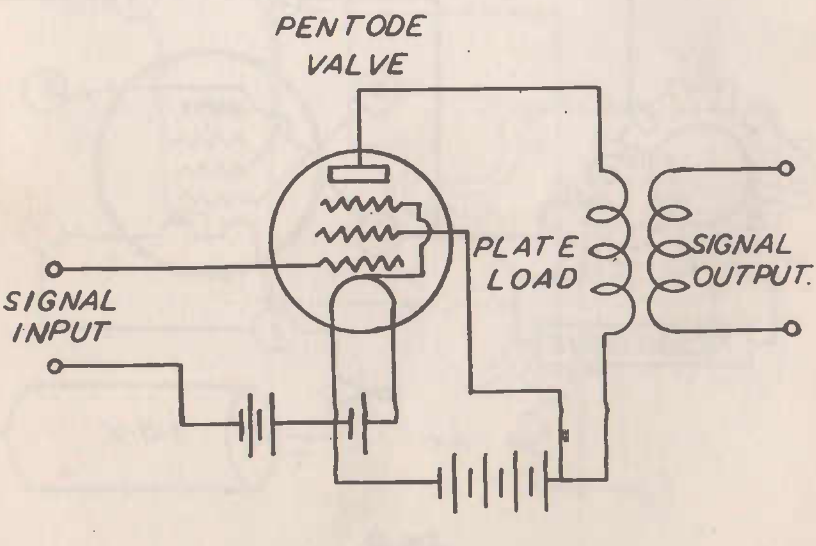


Fig. 18.

Figure 19 shows the manner in which the valve should be wired to contacts 2, 8, 9 and 12 on the multimeter switch.

The 1.5 volt battery used to heat the filament of the valve in this application must not be the one which is connected to the Ohms Range. You have two 1.5 volt cells supplied, so one can be connected to the Ohmmeter section of the instrument and the other one can heat the filament of the valve when it is required as a rectifier. Of course, this battery must be disconnected from the valve filament when the instrument is not actually in use for measuring alternating voltages, otherwise battery current will be flowing constantly through the valve filament and the battery will be discharged in the matter of a day or two. It is not possible to make the multimeter switch disconnect the battery from the valve filament and as you have no other switch yet provided, it will be necessary to employ two pieces of wire, one attached to the battery and the other to contact 1 or 7 on the valve socket, so that these two wires may be twisted together to act as a switch, when the instrument is to be used for measuring alternating voltage and the ends separated to prevent the battery discharging when the instrument is not in use for this purpose.

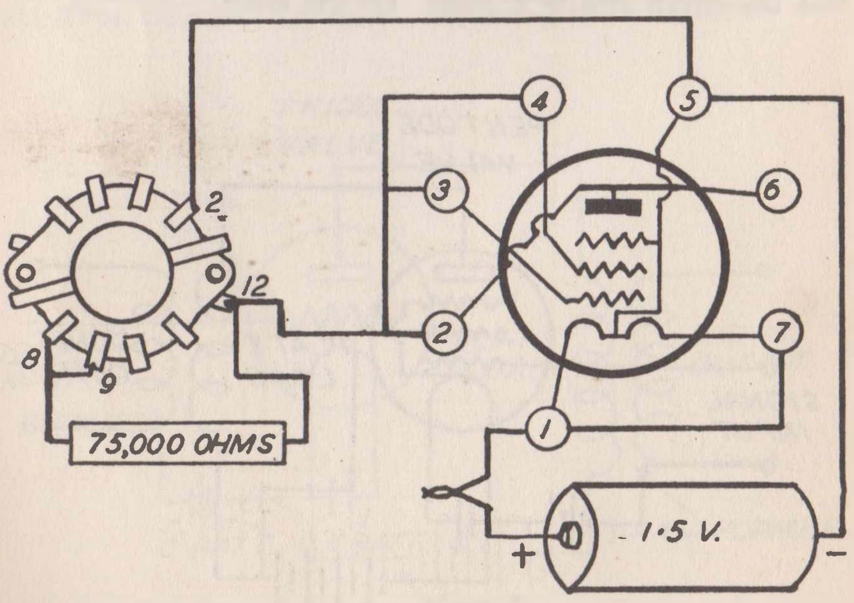


Fig. 19.

A circuit diagram of the voltage section of the instrument incorporating the valve is shown in Figure No. 20. In this diagram, we have deliberately omitted the milliamp shunt and the ohms section of the instrument because these are not in the circuit when the main switch is turned to the position marked "A.C."

If an alternating voltage is now applied to one of the voltage sockets on the multimeter, one half cycle will cause electrons to start at the negative terminal of the multimeter, pass through the meter from left to right, then be emitted by the filament in the valve and pass through the valve from filament to plate and then out, through one of the voltage multipliers on the other side of the circuit. During this half cycle, no appreciable amount of current will

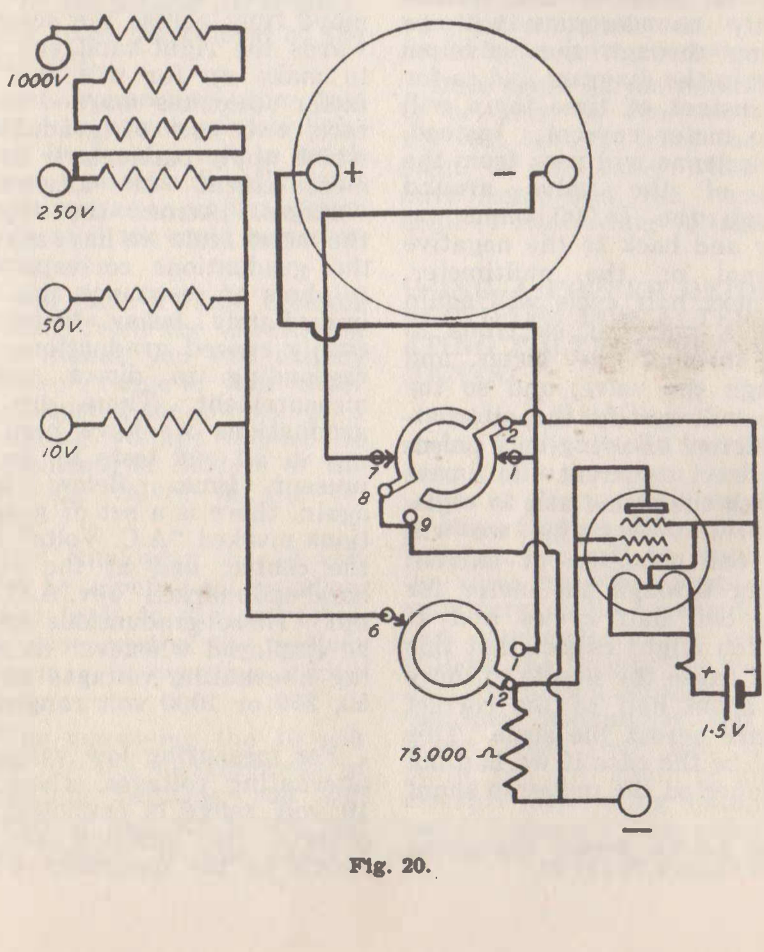


Fig. 20.

pass through the 75,000 ohms resistor because the value of this resistor is so much higher than that of the meter and valve.

On the next half cycle of alternating voltage, a negative voltage will be applied through the voltage multiplier to the plate of the valve. We have already observed, from our experiments earlier in this lesson, that no electrons can pass through the valve when the plate is negative and consequently no electrons will be passing through the valve or meter in the diagram and so for this instant of time there will be no meter current. Instead, the electrons will pass from the plate of the valve around through the 75,000 ohms resistor and back to the negative terminal of the multimeter. The next half cycle will again cause a pulse of electrons to pass through the meter and through the valve, and so the valve will rectify the alternating current allowing only pulses of direct current to pass through the meter and to register on it.* Actually, we will have one pulsation of current passing through the meter for every two half cycles and at first you might expect that this would cause the needle to move only about half of the correct distance across the scale. This would be the case if we had not disconnected the milliamp shunt from the meter in turning the switch from the D.C. to the A.C. position. Because the milliamp shunt is disconnected in the A.C. position, the meter becomes twice as sensitive as it would be with the shunt connected across its terminals, and so the needle will reach nearly to the right-hand end of the scale when the full voltage corresponding to any of the voltage ranges is applied.

Actually, the needle will not move fully across the scale towards the right-hand end, and to make up for this fact the meter scale has marked on its face, two sets of graduations which apply particularly to the measurement of alternating voltages. Across the top of the meter scale we have marked the graduations corresponding to ohms of resistance and then immediately below these the evenly spaced graduations corresponding to direct voltage measurement. These are the graduations we have been using in all our tests up to the present time. Below these again, there is a set of graduations marked "A.C. Volts" near the centre, and at the right-hand end marked "50v. A.C. and up." These graduations are to be employed whenever measuring alternating voltages on the 50, 250 or 1000 volt ranges.

For measuring low values of alternating voltages, where the 10 volt range is employed, we observe the position of the needle on the innermost set of

* See A.R.T.C. Service Engineering Course Lessons 26 and 32.

graduations. These are the graduations marked at the right-hand end "10v. A.C. only."

If you live in a building in which alternating power mains are available, you may test the A.C. ranges of your multimeter by plugging one test lead into the socket marked "—", and the other test lead into the socket marked "250 volts". The other end of the test leads can be applied to the contacts of a power point or light socket and the voltage will be registered on the second set of graduations from the bottom of the meter scale.

When connecting the test leads to the power point or light socket, be careful not to touch the two contacts directly with your fingers as an unpleasant or even fatal shock could be experienced.

If you have a radio receiver operating from the alternating power mains, you can employ the 10 volt range of your meter for measuring the low values of alternating voltage applied to the filaments or heaters of the amplifying valves in the receiver.

When employing the 10 volt range, be careful not to allow the test leads to slip and touch some other part of the receiver which may be carrying a high voltage.

When employing the 10 volt range for the measurement of alternating voltages, you will observe, if you touch the test prods directly to one another without any voltage applied, that the meter needle moves a short distance across the scale. It will probably move up to a reading corresponding to 1 volt on the lower scale on the instrument. This initial movement of the needle will cause a slight error in measuring the value of alternating voltages up to about 1½ volts but for higher values of alternating voltage than this, the initial movement of the needle produces no appreciable effect on accuracy and from 2 volts upwards the instrument will be found to be quite accurate.

Once again let me remind you to be sure to disconnect the 1.5 volt battery from the filament of the valve when you have completed the measurement of alternating voltages.

USING A COPPER OXIDE RECTIFIER FOR ALTERNATING VOLTAGE MEASUREMENTS.

The use of the valve wired as shown in Figures 19 and 20 will permit the accurate measurements of alternating voltages up to the value of 1000 volts, but later on, we will be employing the valve for other purposes in amplifiers, radio receivers, etc., and consequently we will be without the facility for measuring alternating voltages. With the final instrument you construct with your last kit of parts, you will again be able to measure alternating voltages at audio frequency and radio frequency by means of the meter but you will not have a ready means for measuring power mains voltages, etc. For this reason, you may consider it desirable to purchase a copper oxide instrument rectifier which can be permanently wired into your multimeter to make available the immediate reading of alternating voltages at any time. This rectifier is not included with your kits of parts because of the fact that it is not an essential in radio service work but is a luxury which some may think is worth including. If you do decide to purchase one of these rectifiers, you should specify a full-wave 1 milliamp instrument rectifier, such as the Westinghouse type MBS1.

The rectifier will have four terminals or connecting leads, one of which will be marked plus or coloured red. This lead should be connected to contact No. 2 on the multimeter switch. Another of the leads will be

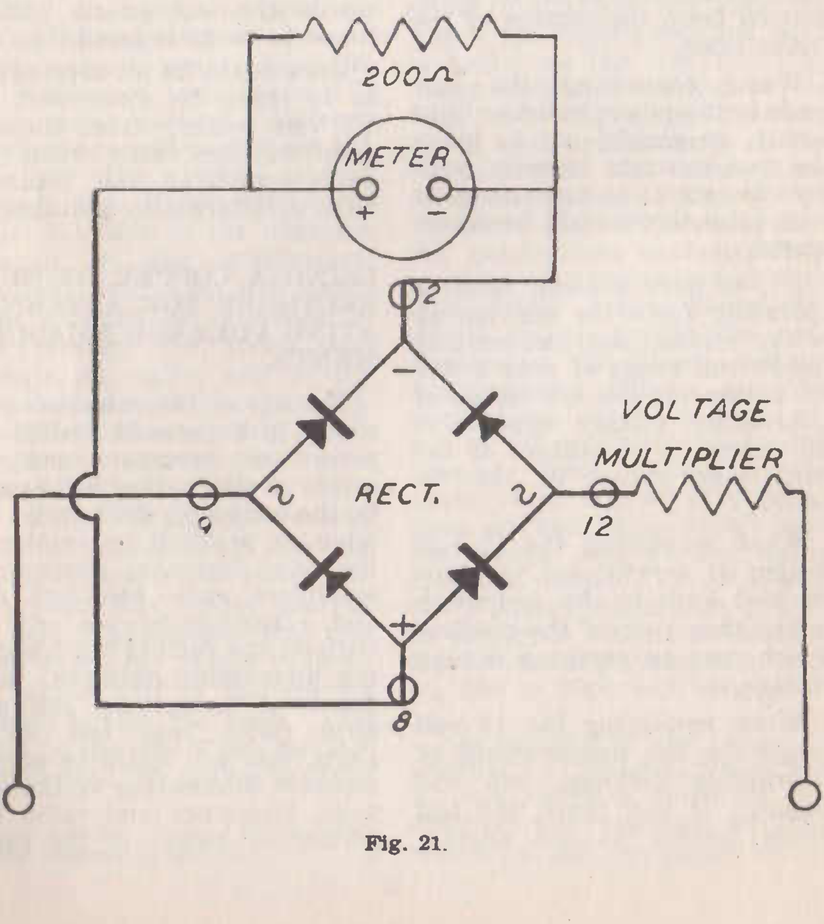


Fig. 21.

marked minus or coloured black. This one should be connected to contact No. 8 on the switch. The other two leads will be marked A.C. or marked with a symbol "~" or may be coloured white. One of these should connect to lug No. 12 on the switch and the other one to No. 9. The leads will probably be long enough to allow the rectifier itself to be bolted onto the right-hand end of the resistor panel. The 200 ohm resistor previously supplied can also be mounted between the two unused lugs at the end of the resistor panel and connected to lugs 2 and 8 on the switch.

One of these instrument rectifiers actually contains four small "copper oxide" rectifiers connected in what is called a "bridge" circuit. The circuit of the voltage measuring section of the multimeter incorporating a copper oxide rectifier is shown in Figure No. 21. You will be able to follow the passage of current through the instrument if you consider that current can only flow through the rectifier in the direction in which the arrows are pointing. Thus, current entering at the right-hand side of the diagram would pass through the voltage multiplier, the upper right-hand rectifier to the positive terminal of the meter and 200 ohm resistor, and then, through the meter and resistor to the negative terminal, back to the bottom of the rectifier, upwards through the lower left-hand rectifier and out through the other test lead. When the alternating voltage reverses, current would enter at the left-hand test lead, pass through the upper left-hand rectifier, again to the positive side of the meter, through the meter and resistor, back to the bottom of the rectifier and through the lower right-hand rectifier back through the voltage multiplier to the other test lead. Thus it will be observed that regardless of which test lead is positive at any instant of time, current will always flow in the one direction through the meter and the meter will register the strength of alternating voltage on its scale.*

As when using a valve rectifier, it is necessary to measure low values of alternating voltage on the 10 volt scale, which is the lower set of graduations on the meter dial. Alternating voltages employing ranges of 50, 250 or 1000 volts should be observed on the second set of graduations from the bottom.

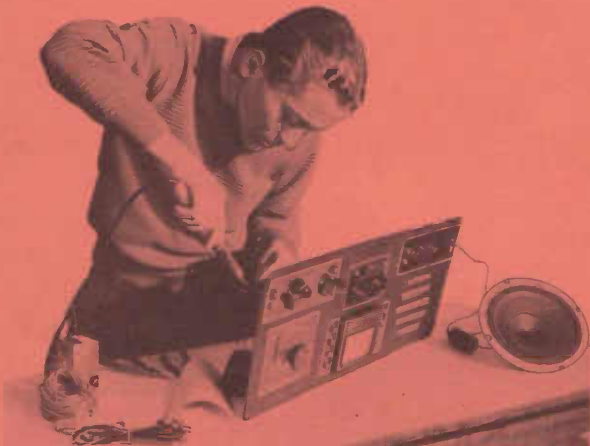
As mentioned previously, it is not essential to purchase one of these copper oxide rectifiers, but the information is given in this Lesson in case you may consider it desirable to do so and in any case, by studying Figure No. 21, you will be able to understand the action of these rectifiers should you come across them at any time.

* See A.R.T.C. Service Engineering Course Lesson 41.

Lesson No. 4

Australian Radio & Television College Pty. Ltd.
206 Broadway, N.S.W.
AUSTRALIA

PRACTICAL RADIO COURSE



of

HOME PRACTICAL INSTRUCTION

Lesson No. 5

THIS Radio Course of practical home instruction is the result of many years' experience, and months of final experimental work by some of Australia's most competent Radio engineers. It is designed so that you acquire a thorough and most comprehensive practical Radio training by building up the kits which are supplied with these lessons. When the course is finished, and all the kits have been built up into the final unit, you will possess a complete professional outfit of Radio testing apparatus, which in itself is not only worth far more than the money you pay for it, but which will also enable you to earn many times its actual value from the Radio work you can perform with it.

CONSTRUCTING AN OSCILLATOR.

This Lesson will show you how to:—

THE MORSE CODE.

HOME PRACTICAL INSTRUCTION

LESSON No. 5.

The material contained in Kit No. 5 will permit you to construct an audio frequency oscillator with which you may test amplifiers or practice the Morse Code if you are interested in learning it.

A list of the material contained in Kit No. 5 is as follows:—

1 Metal chassis.
1 6″ permanent magnet loudspeaker with 5000 ohm transformer.
1 loudspeaker transformer with centre tapped primary winding.
1 small pointer knob.
1 single wafer switch.
2 Plastic terminals.
1 .01 mfd. condenser.
2 ½″ x 5/32 x 1/16″ bakelite washers.
2 dozen ⅜″ x ⅛″ Whitworth bolts and nuts.
4 ½″ x ⅛″ bolts and nuts
2 Soldering lugs.

The circuit diagram of the oscillator which we are about to construct is shown in Figure 1.

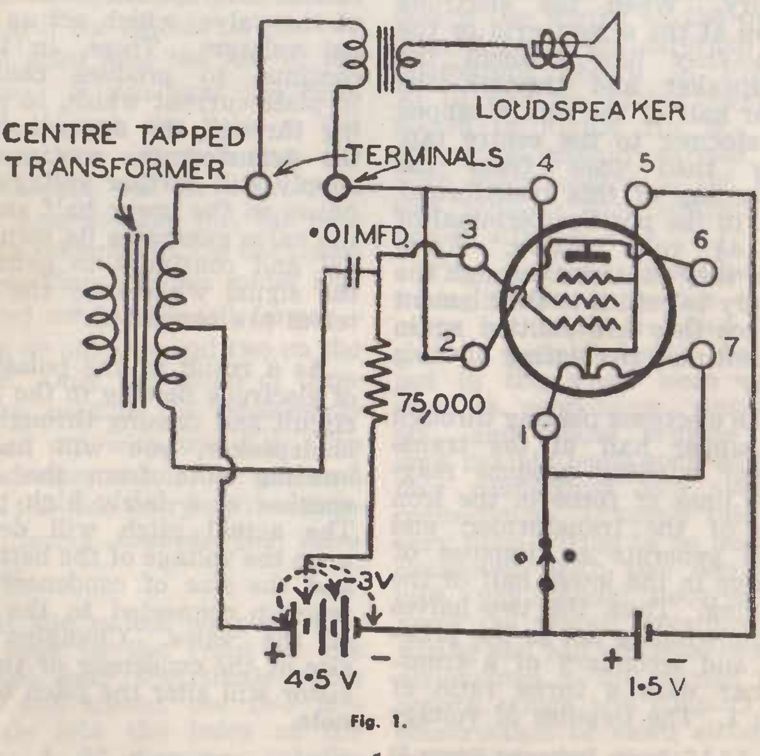


Fig. 1.

The principle of operation is as follows:

When the switch, connected to the filament of the valve, is turned on, electrons from the negative terminal of the 1.5 volt cell flow around through the filament of the valve and back again to the positive terminal of the cell, thus heating both sections of the filament. When the filaments are hot, they emit electrons which are attracted across to the plate and to the screen grid of the valve because both of these elements are connected together and are made positive by the 4½ volt battery. When the electrons arrive at the screen grid or the plate they flow through the loudspeaker and through the upper half of the centre tapped transformer to the centre tap. They then pass from the centre tap of this transformer back to the positive terminal of the 4½ volt battery. From here, they continue through the battery to return to the filament whence they are emitted again to continue circulating in this path.*

The electrons passing through the upper half of the transformer winding produce magnetic lines of force in the iron core of the transformer, and these generate an impulse of voltage in the lower half of the winding. Thus, the two halves of the winding act as the primary and secondary of a transformer with a turns ratio of 1 to 1. The impulse of voltage generated at the bottom of the lower half of the transformer is applied through the .01 mfd. condenser to the grid of the valve. This impulse of voltage, applied to the grid, produces a change in the plate current, and the change in plate current passing through the upper half of the transformer winding produces another impulse of voltage in the lower half, which is again applied around through the .01 condenser to the grid of the valve. Thus, there is a succession of pulsations of voltage, produced in the lower half of the transformer and applied to the grid of the valve, which act as signal voltages. These, in turn, continue to produce changes in plate current which, in passing through the upper half of the transformer, continue to supply still further voltage impulses in the lower half and so the valve generates its own signal and continues to generate the signal while ever the batteries are connected.*

As a result of the pulsations of electrons flowing in the plate circuit and passing through the loudspeaker, you will hear a howling note from the loudspeaker at a fairly high pitch. The actual pitch will depend upon the voltage of the batteries and the size of condenser and resistor connected to the grid of the valve. Changing the size of the condenser or the resistor will alter the pitch of the note.

* See A.R.T.C. Service Engineering Lessons 12 and 18.

* See A.R.T.C. Service Engineering Lesson 47.

ASSEMBLY.

If you examine the metal chassis supplied, you will observe that it has the corners cut away on one edge while the other edge is the full length. The edge of the corners cut away is the front of the chassis and on it will be mounted the switch and potentiometer.

You can mount your valve socket into the hole provided for it near the right-hand end of the chassis, by means of the two small 8BA bolts and nuts supplied.

The transformer mounts underneath the chassis on the two small holes near the rear of the chassis. If you pass the bolts down through the holes in the chassis you will find that the transformer will fit over them and then you can put the nuts on the underneath. On the transformer there are five solder lugs riveted on to the coil former—three on one side and two on the other. Only the group of three lugs is used in the experiments carried out with this Kit. The transformer should be mounted with the side carrying the three lugs facing towards the valve socket.

Fit the switch supplied into the hole in the front of the chassis near the single valve hole and mount the two terminals into the holes at the rear. A ½" diameter bakelite washer should be placed between the terminal nuts and the chassis so that the terminals are insulated from the chassis. The position of the switch is shown in Figure No. 2.

The speaker itself can be bolted by means of four bolts onto the left-hand end of the main front panel with the transformer upwards so that it will be out of the way of the other parts and protected from damage.

WIRING.

You should not experience any great difficulty in undertaking the wiring of the oscillator if you follow carefully the photograph shown in Figure No. 2, and the wiring diagram shown in Figure No. 3. The wiring is actually carried out with short lengths of the flexible hook-up wire supplied to you in Kit No. 1.

The correct procedure in wiring radio apparatus is to carry out what is called "the ground wiring" firstly, then to put in the small loose parts such as condensers, resistors, etc., and finally provide any long flexible leads such as battery connections and speaker connections. Although there is very little wiring to be done in connection with this oscillator unit, you should nevertheless apply the proper procedure for wiring and you will then become accustomed to the correct procedure, which will simplify the construction of more elaborate units later on.

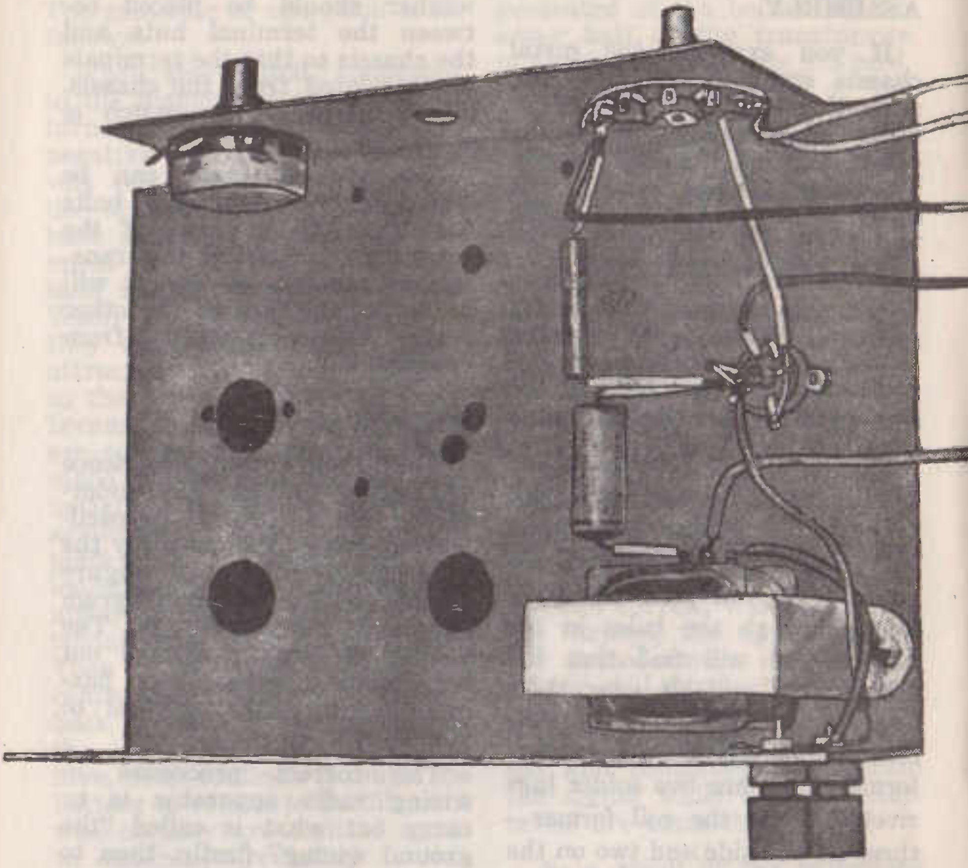


Fig. 2.

In this instrument, the ground wiring consists simply of linking various socket connections to one another, for instance, connect 2 and 4 on the valve socket, also, pins 1 and 7. The wire can then be taken from pin 1 to one contact on the switch. To enable you to follow the connection to the switch contact, the switch in Figure 3 and also the potentiometer have been drawn as though the front flange of the chassis were bent down flat. In this way, you will easily be able to determine the correct switch lug to which to make connection. The lugs have been numbered in an anti-clockwise direction in Figure 3.

If you examine the switch

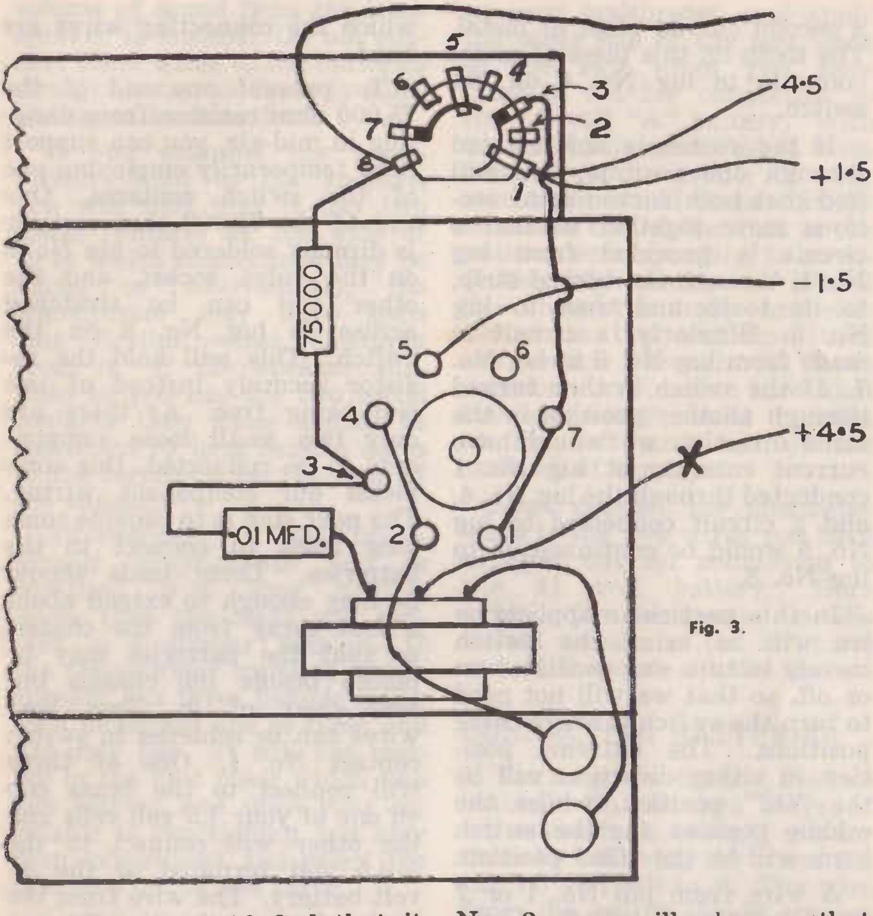


Fig. 3.

carefully, you will find that it is really two switches built together on to the one piece of insulating material or "wafer". In addition to the fact that it is really two switches built together, you will find that the control shaft can be rotated into three separate positions. This means that each switch may be described as a single-pole three-position switch.

If you compare the switch with the diagram in Figure No. 3, you will observe that No. 1 lug is a little longer than Nos. 2, 3 and 4, so that it is able to connect to the curved piece of metal attached to the centre portion of the switch. One end of this curved piece of metal protrudes outward, and, with the switch in the anti-clockwise position, this piece of metal contacts connection No. 2 on the switch.

At the same time, Lug No. 5 is also a long lug connecting to a second curved piece of metal. The tooth on this piece of metal connects to lug No. 6 on the switch.

If the switch is now rotated through one position, you will find that both curved rotor sections move together so that a circuit is provided from lug No. 1, through the curved strip, to its tooth and then to lug No. 3. Similarly, a circuit is made from lug No. 5 to lug No. 7. If the switch is then turned through another position in the same direction we would have current entering at lug No. 1 conducted through the lug No. 4, and a circuit connected to lug No. 5 would be continued on to lug No. 8.

In this particular application we will be using the switch merely to turn our oscillator on or off, so that we will not need to turn the switch through three positions. The extreme position in either direction will be the "Off" position, whilst the middle position for the switch knob will be the "On" position.

A wire from pin No. 1 or 7 on the valve socket should be taken to lug No. 3 on the switch.

The next step in the wiring is to connect in the small components such as the 75,000 ohm resistor and .01 mfd. condenser. In soldering the condenser or any other connection to the transformer, you must make the soldered connections as quickly as possible, otherwise the heat from the soldering iron will melt the plastic material in which the connecting wires are fixed.

To prevent one end of the 75,000 ohm resistor from dangling in mid-air, you can support it by temporarily employing one of the switch contacts. One end of the 75,000 ohm resistor is directly soldered to pin No. 3 on the valve socket, and the other end can be stretched across to lug No. 8 on the switch. This will hold the resistor securely instead of one end being free. As there are only two small loose components to be connected, this completes our component wiring. The next step is to provide some long leads to connect to the batteries. These leads should be long enough to extend about a foot away from the chassis so that the batteries may be placed beside the chassis but well clear of it. Two long wires can be soldered to switch contact No. I. One of these will connect to the brass cap on one of your 1.5 volt cells and the other will connect to the —4.5 volt terminal of the 4½ volt battery. The wire from the centre lug on the transformer will connect to the positive terminal of the 4½ volt battery. For the time being, disregard the "X" shown in this wire in Figure No. 3. A long wire brought away from switch contact No. 8 and therefore from one end of the 75,000 ohm resistor may be tried at different positions on the 4.5 volt battery. You will probably find one particular battery lug on which the volume of sound from the loudspeaker is loudest. Do not connect these wires to the batteries straight away as there is some testing to be done first.

If you examine the transformer fitted to the speaker, you will find that it has two metal contacts on one side of it, to which connections may be made, or alternatively, the transformer may have some long flexible wires emerging from it. If the speaker supplied to you has the two metal contacts then these should be connected by long flexible wires to the terminals on the rear of the chassis.

Alternatively, if the transformer supplied to you is equipped with long flexible leads, then the leads will connect in a similar fashion. If the transformer supplied on the speaker has three flexible leads, then disregard one of them and use only two. It will not matter in the first place which two you employ and once your oscillator is functioning you may then experiment and select the best two out of the three.

TESTING.

Before inserting the valve in the socket and also before connecting the batteries to the battery leads, it is desirable to make some tests to ascertain that you have wired the oscillator correctly as this will prevent any possibility of damage to the batteries or to the valve.

Firstly, insert your test leads into the "High Ohms" sockets on your multimeter, and apply the other end of the test leads to the two wires you have brought out for connection to the 1.5 volt "A" battery. With the test leads connected to these two wires the needle of your ohmmeter should remain at the left-hand end of the scale at the position corresponding to an infinitely high resistance. Whilst the ohmmeter leads are connected to the oscillator, turn the switch through its three positions and make sure that the ohmmeter needle remains at the left-hand end of the scale all of the time.

Next connect the ohmmeter leads to the two wires you have brought out for connection to the 4½ volt battery. Here again, the ohmmeter needle should remain at the left-hand end of the scale all the time.

CONNECTING BATTERIES.

You may now connect the two batteries to the two pairs of wires you have brought out for them by soldering the wires for the 1.5 volt cell to it. The wire from the switch should connect to the centre brass cap on the 1.5 volt cell and the wire from No. 5 pin on the valve socket should connect to the end of the zinc can. The second wire from the switch should connect to the —4.5 volt terminal of the 4.5 volt battery, and the wire from the centre tap of the transformer should connect to the positive terminal. The wire from one end of the 75,000 ohm resistor can be connected at first to the —1.5 volt terminal on the $4\frac{1}{2}$ volt battery.

As a further check on your wiring you should measure the voltage appearing between pins 1 and 5 on the valve socket with the switch turned on. To do this your multimeter test leads should be plugged to the minus socket and to the one marked "+10 volts." A reading of approximately 1.5 volts should be obtained. If the voltage is higher than 1.5 or 1.6 volts this shows that you have connected the A battery leads to the 4.5 volt battery instead of the 1.5 volt battery. As a further test, you should connect the negative test lead to pin 5 on the valve socket and touch the positive test lead to the centre tap of the transformer. In this position you should obtain a reading of approximately 6 volts. Next, touch the positive test lead to pin 2 or 4 on the valve socket and in this position the reading should be between 5 and 6 volts.

If your voltmeter does not show a reading of more than 5 volts when its positive lead is connected to the centre tap of the transformer, then this suggests that either one of your batteries is defective or that you have reversed the connection to one of them. You should check over the wiring very carefully to see that you have them the right way around.

Finally, touch the positive test lead to pin No. 3 on the valve socket. In this position the needle should only move about two or three small graduations across the scale. The small reading at this point is due to the presence of the 75,000 ohm resistor in the circuit.

If all these voltages appear to be in order, then it is safe to firmly insert the valve in its socket. As soon as the valve is inserted you should hear a distinct squealing sound from the loudspeaker. This whistle is known as an "audio frequency oscillation" and is produced by the action explained earlier in this lesson. The pitch of the sound is determined by a large number of factors, particularly the inductance and capacity of the transformer. Other things, however, affect the pitch and you will find, if you make some experiments with the connection from the 75,000 ohm resistor to the 4.5 volt battery, that trying the lead on to various tappings on the battery will not only alter the pitch but also the loudness of the tone.

If no sound is heard when the valve is inserted, then examine the valve itself carefully to see that it is pushed firmly down into the socket and that there are no cracks in the glass. When inserting or removing the valve, it is most important that it be pushed straight down into the socket and pulled straight out from the socket. On no account must the valve be wriggled from side to side, as it is being pushed in or pulled out, as this is almost certain to cause cracks in the glass base around the connecting prongs. Even the slightest crack in the glass of the valve will render it useless. If the oscillator still will not function, even when the valve is firmly in its socket, then remove the valve and test the filament for continuity by applying your multimeter test leads to pins 1 and 7. The other ends of the test leads should be plugged into the sockets marked "High Ohms" on the multimeter. When connection is made you should obtain a reading between 30 and 50 ohms.

If you do not get any reading when you touch the ohmmeter lead to pins 1 and 7, then the valve filament has been burnt out by the application of excessive voltage.

If the valve is in good order, then the next thing to test is the loudspeaker. This may be tested by disconnecting its two wires and touching them momentarily to the positive and minus 4.5 volt tappings on the 4½ volt battery. Just as the connections are made, there should be a distinct click from the loudspeaker, and similarly, at the moment when the connections are broken there should be another click.

By means of the tests described earlier, we have really checked all of the parts in the oscillator and if it still will not function then there must be a mistake in the wiring and you should check this over very carefully.

PENTODE OPERATION.

With the valve socket connections 2 and 4 joined together, this joins the screen and plate of the valve to one another so that the two act as a plate and the valve therefore operates as a triode. You may now see how the valve performs when operated as a pentode. This can be done by removing the wire connecting pins 2 and 4. The lead from the loudspeaker terminal must still connect to pin No. 2, whilst a long lead is connected to pin No. 4. This long lead may then be touched to the various tappings on the 4½ volt battery and the effect of varying amounts of screen grid voltage can be noted. You will observe that the greatest volume is obtained when the wire from pin No. 4 is connected to the positive terminal on the 4½ volt battery and that the signals become weaker when the lead is connected to other points. When the screen is connected to the negative end of the 4½ volt battery or to the minus 3 volt terminal there will probably be no whistle at all because of the fact that with a low screen voltage the plate current is low and oscillation will not be maintained.

LEARNING THE MORSE CODE.

No doubt many of you will have taken up a study of radio with the object of becoming a radio operator. In sending commercial messages to and from ships and to and from aircraft and in various other commercial activities, it is customary to make use of the Morse Code for sending a large number of messages because of the fact that Morse Code communication can be established over greater distances and with greater reliability than is the case with the spoken word. Consequently, if you tune a short-wave radio receiver over the various short-wave bands you will find plenty of Morse Code stations, especially on the 20 metre band, the 40 metre band, the 80 metre band, and, of course, way up on 600 metres. Each one of these series of sounds is conveying some dramatic message from one part of the world to another. It may be battle, murder, or sudden death. Often they may tell of huge dealings in finance, gold—they may carry details of some royal romance or political intrigue. No wonder that Morse Code study is fascinating and is well worth the concentration and effort necessary to be able to unscramble these sounds and determine what they mean.

The oscillator we have just built, especially if operated by a proper Morse Key, provides a most efficient method of learning the Morse Code. All that is necessary is to break the wire from the centre tap of the transformer to the positive terminal of the $4\frac{1}{2}$ volt battery at the point marked "X" on Figure 3. If you insert a Morse Key at this point then you will find that tapping the Morse Key enables you to produce dots and dashes from the speaker. These will sound just like the dots and dashes of Morse Code signals heard on a radio receiver.

Because many of you will want to learn the Morse Code, you will find set out on the following pages a lengthy and thorough description of the Morse Code itself, the symbols comprising it, and how best to memorize them. If by any chance you are not interested in the Morse Code, then you can turn over the next few pages to the heading "Testing Radio Receivers."

THE MORSE CODE.

There is only one code that is used in radio—the International Morse Code. It is used all over the world by radio operators on land or sea. Whether a station is China, France, Germany, Australia, America—the code is the same.

Let us put these sounds in picture form and study them. Here they are:—

A . —
B — . . .
C — . — .
D — . .
E .

F . . — .
G — — .
H . . . .
I . .
J . — — —
K — . —
L . — . .
M — —
N — .
O — — —
P . — — .
Q — — . —
R . — .
S . . .
T —
U . . —
V . . . —
W . — —
X — . . —
Y — . — —
Z — — . .

You can see that each letter has its own group of symbols and that group consists of only two things—dots and dashes. Your first step is to firmly implant those symbols in your brain by studying the picture set out above. Once you have done that your next step is to do it by means of your ears. Learn what the letters of the alphabet look like and then after that learn what they sound like, and your Morse Code proficiency is finished except for practice.

It is important that you study slowly but surely in the beginning. Don't be frightened of the apparent complexity of the symbols. Really, it is very simple and once you study it you will soon find out how easy it is.

Start at the letter "A". Now 'A", as you can see, consists of one dot and one dash (. —). A dot when properly made is just one-third as long as a dash. Let us find out what "A" sounds like. To do this you must make the sound with your mouth.

Letter A sounds like this: DIT DAH. Try it yourself. The I in the word "DIT" has the same sound as the I in "TIN". The A in "DAH" has the same sound as the A in "FATHER." When you say the sound "DIT" it is very short. The word "DAH" is longer. One thing I will warn you of here, and it is very important. NEVER MAKE THE LETTERS BY THE DOT AND DASH SOUNDS. Never make the sound for A as "DOT DASH". Always make it as "DIT DAH." This of course applies to all letters. As you find that your speed increases you will discover that no progress can be made unless you use the DIT DAH method. You can actually transmit with your mouth at the rate of thirty words a minute by using these symbols. This is impossible by saying "DOT DASH".

Now that you know what the letter A sounds like, I want you to practise it at least fifty times. Make these two sounds over and over again, and at the same time picture that letter in your mind. Commence slowly and in this way you will commence correctly.

Now I have written down the whole alphabet in sound. I want you to practise each one of these letters by making their particular group of sounds with your mouth. Forget that they are dots and dashes and think of them as DITS and DAHS. Make the sounds for the letters as you see them written out and practise each letter at least fifty times before you go on to the next. After that, practise them in groups of five or ten at a time. I want you to get them so that you can write down each letter every time you hear the sound. For example, if you hear "DAH DIT DIT DIT", you should be able to write down the letter "B" and not "Dash Dot Dot Dot". Never, under any circumstances, write down dots and dashes when you are sounding words. That is a habit you must not start. These sounds must represent letters to you and not symbols. When you hear "DIT DIT" you must automatically and immediately think of the letter I. Correct practice will soon give you this habit and it is a habit that will always remain with you.

Here is the whole alphabet written out in sound symbols:—

A DIT DAH
B DAH DIT DIT DIT
C DAH DIT DAH DIT
D DAH DIT DIT
E DIT
F DIT DIT DAH DIT
G DAH DAH DIT
H DIT DIT DIT DIT
I DIT DIT
J DIT DAH DAH DAH
K DAH DIT DAH
L DIT DAH DIT DIT
M DAH DAH
N DAH DIT
O DAH DAH DAH
P DIT DAH DAH DIT
Q DAH DAH DIT DAH
R DIT DAH DIT
S DIT DIT DIT
T DAH
U DIT DIT DAH
V DIT DIT DIT DAH
W DIT DAH DAH
X DAH DIT DIT DAH
Y DAH DIT DAH DAH
Z DAH DAH DIT DIT

Right here and now I am asking you to study your code where you will not be disturbed. Go to a place where you can concentrate and put in anything up to an hour on it for the first time. Don't do more than an hour at first because you will soon get tired and in this way your study will be less effective. I suggest anything between thirty minutes and one hour to commence.

Get the sounds set in your mind so that you can write down each letter as you hear the sound of it. After that you can start right in on words. Once you start practising with a key and oscillator you will recognise the sounds because that's the way the oscillator will make them. That also is the way they will sound in your radio receiver when they come from a transmitting station. You can see how important it is to learn them correctly at the very beginning.

Learn a few letters in the beginning and practise them during the day while you are working. You can practise them anywhere—while you are walking or any other place where you have a few moments to spare mentally. Patience is necessary, but you will be well rewarded for this virtue. Naturally you will find that you will stumble over some letters and some you will find are hard to retain in your mind. Perseverance is the only way to overcome this.

NUMBERS.

After concentrating on the letters until you know them thoroughly, I want you to learn the numbers. The numbers that are used in Morse Code are 1, 2, 3, 4, 5, 6, 7, 8, 9, 0. These numbers are surprisingly easy. Look at the diagram set out below. Each number consists of five separate characters. When you study them for a minute or two you will see that the numeral "1" is made up of one dot and four dashes. "2" has two dots and three dashes; "3" has three dots and two dashes; and so on up to 5. When you reach 5 you find that this has five dots. "6" has a dash and four dots; "7" two dashes and three dots and so on. The numerals are arranged in the progressive system. This makes them very easy to remember. What you have to do now is to remember them as sounds and not as little picture diagrams.

1 . — — — —
2 . . — — —
3 . . . — —
4 . . . . —
5 . . . . .
6 — . . . .
7 — — . . .
8 — — — . .
9 — — — — .
0 — — — — —

Get these numbers fixed in your mind as sound. Here they are written down as sounds:

1 DIT DAH DAH DAH DAH
2 DIT DIT DAH DAH DAH
3 DIT DIT DIT DAH DAH
4 DIT DIT DIT DIT DAH
5 DIT DIT DIT DIT DIT
6 DAH DIT DIT DIT DIT
7 DAH DAH DIT DIT DIT
8 DAH DAH DAH DIT DIT
9 DAH DAH DAH DAH DIT
0 DAH DAH DAH DAH DAH

Learn these numbers correctly and use them in combination with the letters you have already learned.

I want you to give the numerals set out in this section about thirty minutes to an hour a day practice just the same as you gave it to the alphabet. Remember, however, that concentration and regular daily study and patience are essential for progress and success.

The final group of sounds which you must learn are those for punctuation. The punctuation symbols are set out in two groups. In conversations between amateurs, many of the punctuation symbols, such as colons, semi-colons, etc., are seldom used. Consequently, the first group comprises punctuation and other signs which are frequently used and which must be memorised just as thoroughly as the letters and numbers. Here they are set out for you, both in symbol form and in sound.

Full Stop	(.) . — . — . —	DIT DAH DIT DAH DIT DAH
Comma	(,) — — . . — —	DAH DAH DIT DIT DAH DAH
Question Mark	(?) . . — — . .	DIT DIT DAH DAH DIT DIT
Hyphen or dash	(—) — . . . . —	DAH DIT DIT DIT DIT DAH
Fraction Bar	(/) — . . — .	DAH DIT DIT DAH DIT
Double Dash	(=) — . . . — .	DAH DIT DIT DIT DAH DIT
Error	. . . .	DIT DIT DIT DIT DIT DIT DIT DIT
Wait	. — . . .	DIT DAH DIT DIT DIT
Commencing Signal to precede every transmission	— . — . —	DAH DIT DAH DIT DAH
End of any one message or Cross	(X) . — . — .	DIT DAH DIT DAH DIT
End of work	. . . — . —	DIT DIT DIT DAH DIT DAH

Learn these in the same fashion that you learnt the alphabet and the numbers.

When practising the code, you will probably be listening to commercial stations sending news items or perhaps you will practise sending articles from a newspaper or magazine. In this work you will come across the other punctuation marks which are set out below. These are not very often used in amateur work, but there are not many of them and you should learn them so that you will recognise them, and so that they will not disturb you when you hear them in listening to commercial transmissions.

Semi-colon	(;) — . — . — .	DAH DIT DAH DIT DAH DIT
Colon	(:) — — — . . .	DAH DAH DAH DIT DIT DIT
Apostrophe	(') . — — — — .	DIT DAH DAH DAH DAH DIT
Quotation or inverted commas	" " . — . . — .	DIT DAH DIT DIT DAH DIT
Brackets or parentheses	( ) — . — — . —	DAH DIT DAH DAH DIT DAH
Underline ——	. . — — . —	DIT DIT DAH DAH DIT DAH

Before we finish this portion on Code, there are some things I want you to know about sending. It will be desirable for you to get a key and connect it to the oscillator shown in Figure 3 at the point marked "X" so that you can do some actual manual practise. When you tap out the letters on the key you will hear the sounds from the speaker just the same as you made them with your mouth. Tap out all sorts of messages on your key and pay particular attention to the spacing between letters and words. The space between words should be three times as long as the space between letters. Try and make each group of sounds clear cut and distinctive. Remember that I told you that a dot is one-third the length of a dash. You can do some excellent practise on a key by yourself by just perfecting your sending and increasing your speed. If you can practise with a friend you can send to each other and improve your receiving speed.

A very important point in transmission is the proper way to hold your sending key and the placing of your arm. Unless you start off right in this respect, you will develop bad habits that will be detrimental to your accuracy and clarity.

The fingers of the right hand should hold the knob of the key. You should not press the key with the tips of the fingers on the top. This may seem easy when you are starting practise, but I can assure you that you will never get real speed and perfect spacing unless you hold the key the right way. Do not grip the key tightly. Take hold of it firmly and lightly. Your arm and hand and fingers must have a feeling of relaxation. You will never get this easy feeling if you grip your key too tightly.

Place the thumb underneath the knob of the key. The index or first finger should rest on top of the knob. The second finger of your hand should rest partly on top but near the outside edge away from the thumb. Raise your wrist just a trifle, so that it will be free to move.

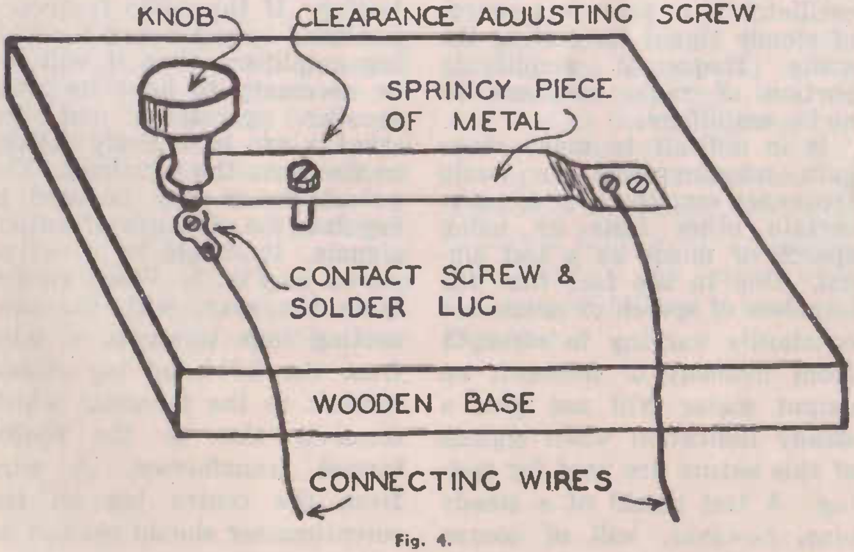


Fig. 4.

The forearm should rest firmly on the table. Now the wrist is free to move up and down. Actually transmission is done from the wrist and not from the fingers. You must hold the key firmly but not grip it.

Keys should be adjusted to fit the hand of the individual user. There are two adjustments on the average key; the spacing and the tension adjustment. The spacing is the distance between contacts. This should be very small to get away from that clicking effect. The tension is adjusted by the lock and spring arrangement to give you just the necessary amount of return action without having to press too firmly on the key to make contact. The easier you have the tension, the easier you will find it to make perfect characters. When you are commencing practise I suggest that you use a little more tension than you will when you are getting up to a respectable speed. If you cannot procure a proper morse key, you will probably be able to make a simple one along the lines shown in Figure 4.

When you begin to feel tired at sending practise, I want you to rest for half an hour or so. It will probably take you some days to get used to consistent sending. Never tire yourself out before you stop.

TESTING RADIO RECEIVERS AND AUDIO AMPLIFIERS.

Apart from learning the Morse Code, another useful application for an audio frequency oscillator is to provide a source of steady signal for testing the audio frequency amplifying portion of radio receivers or audio amplifiers.

It is difficult to make stage gain measurements on audio frequency amplifiers, or to make certain other tests by using speech or music as a test signal. Due to the fact that the impulses of speech or music are constantly varying in strength from moment to moment, an output meter will not give a steady indication when signals of this nature are used for testing. A test signal of a steady tone, however, will of course provide a steady indication on an output meter and this is advantageous in many forms of testing. If the audio frequency oscillator is to be used for testing amplifiers, then it will not be necessary to have its loudspeaker operating, and the speaker can be entirely disconnected from the terminals. The potentiometer may be used to regulate the strength of output signals. It should be wired as shown in Fig. 5. When viewed from the rear, with the connecting lugs upwards, a wire from the left-hand lug should connect to the terminal which connects also to the centre tapped transformer. A wire from the centre lug on the potentiometer should connect to

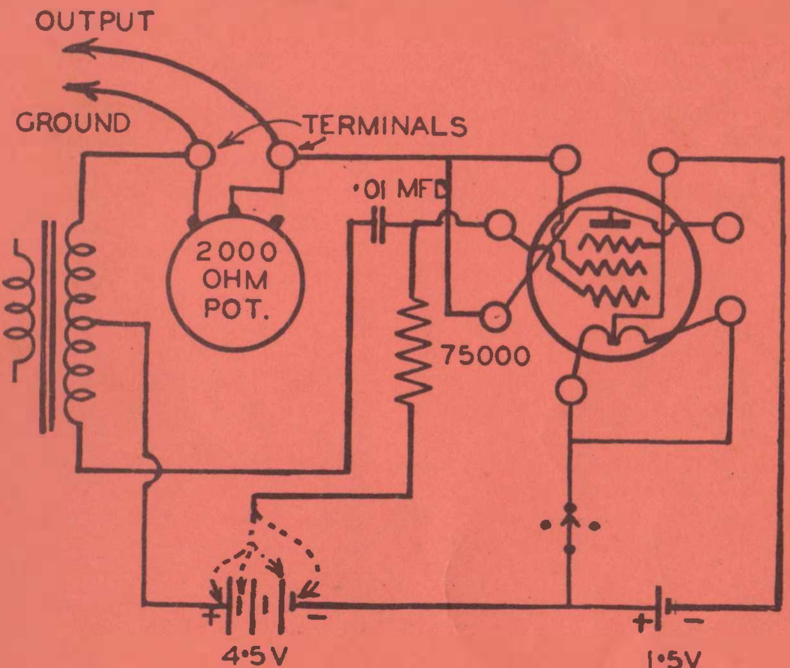


Fig. 5.

the other terminal. Two long "test" leads may be connected to the terminals as shown in Fig. 5. These test leads are then applied, the one marked "GROUND" to the chassis or ground connection on the receiver or amplifier to be tested, and the other one marked "OUTPUT" to the grid of one of the audio frequency amplifying valves. The signals from the oscillator should be heard through the loudspeaker on the radio set or amplifier. You will find that as the control shaft on the potentiometer is rotated, the signals vary in loudness, being zero when the potentiometer is turned fully in an anti-clockwise direction and loudest when it is turned fully in a clockwise direction.

Lesson No. 5

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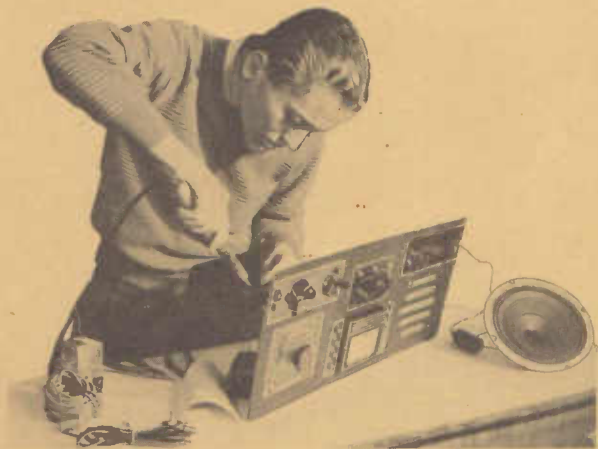
AUSTRALIAN RADIO & TELEVISION COLLEGE PTY. LTD.

PRACTICAL RADIO COURSE



of

HOME PRACTICAL INSTRUCTION

Lesson No. 6

THIS Radio Course of practical home instruction is the result of many years experience, and months of final experimental work by some of Australia's most competent Radio engineers. It is designed so that you acquire a thorough and most comprehensive practical Radio training by building up the kits which are supplied with these lessons. When the course is finished, and all the kits have been built up into the final unit, you will possess a complete professional outfit of Radio testing apparatus, which in itself is not only worth far more than the money you pay for it, but which will also enable you to earn many times its actual value from the Radio work you can perform with it.

CONSTRUCTING A TWO-VALVE RECEIVER, AND WAVE TRAPS.

This lesson will show you how to:—

HOME PRACTICAL INSTRUCTION

LESSON No. 6

Doubtless many of you will have been looking forward eagerly to the time when you would be able to create an actual radio receiver. Although there is a certain satisfaction to be obtained by constructing a multimeter and performing other experiments as we have done recently, this does not by any means match the thrill of hearing radio signals from a receiver we have created with our own hands. This applies especially if the receiver is the first one we have ever built.

I know that for many of you it will be your first attempt at set-building, and consequently I would urge you to read this lesson through very thoroughly before actually commencing construction of the set, so that you will be able to make a thoroughly satisfactory job of it and will not be disappointed by its failure to operate, after you have completed it.

One word of warning. You must not be over-enthusiastic, because after all, this receiver will only contain two valves and as it has to provide enough output to drive a loudspeaker, naturally its sensitivity is somewhat restricted and it will only perform reliably when operated within about 30 or 40 miles distance of a broadcasting station. Alternatively, as described later in the lesson, it is practicable for those living more than about 30 or 40 miles from a broadcasting station to construct an alternative coil which will cover some of the short-wave stations instead of those on the ordinary broadcast band. The range of the receiver when tuned to short-wave stations is much greater than when operating on the lower frequencies between 550 and 1,500 k.c., and it may be quite possible to hear signals from short-wave stations several hundred or even several thousand miles away in a good location with an efficient aerial and earth.

This brings us to another important point, the fact that the receiver will only perform satisfactorily when used with an efficient aerial and earth connection. Many modern radio receivers, operated from power mains and employing a large number of valves, will perform extremely well indeed from a very inefficient aerial and without any earth connection at all. This is possible because of the fact that radio frequency signals from the aerial circuit are able to pass through the aerial coil in the receiver and then back into the power mains through stray condenser effects in the receiver. These signals ultimately find their way to earth through the power mains wiring, and it makes little difference to the performance of a receiver whether an actual earth connection is used with it or not. These conditions definitely do not apply in the case of battery-operated receivers. Because there is no connection to the power mains, it is imperative that a good earth system be employed. The loudness and clearness of signals heard from the receiver will depend on the strength of radio frequency current passing through the primary winding of the tuning coil. This, in turn, is determined by the efficiency of the aerial and earth system in collecting radio energy. The aerial will be efficient if it is as high as possible and as long as possible. However, no matter how efficient the aerial is, no appreciable amount of current will be able to flow through the aerial primary winding unless there is attached to the earth terminal of the receiver a wire which will efficiently conduct the current to the ground itself. This wire, by means of a length of metal piping or a large sheet of metal, must make an efficient connection with moist earth so that the resistance of the earth system will be kept to a minimum and so that it will be possible for radio frequency current to pass freely through the primary coil.

Details of an aerial and earth system are contained further on in the Lesson.

The first thing to do on unpacking your kit of parts is to check the materials supplied against the following Parts List:

1 type 1S5 valve.
1 valve socket.
1 2 megohm ½ watt resistor.
1 .5 megohm ½ watt resistor.
1 .0001 mfd. condenser.
1 .001 mfd. condenser.
1 double gang tuning condenser.
1 large knob.
2 lengths of tubular coil former.
2 metal brackets for mounting coil formers.
1 coil of 34 gauge enamelled copper wire (thin).
1 coil of 28 gauge enamelled copper wire (medium).
1 coil of 19 gauge enamelled copper wire (thick).
1 45 volt B Battery.
6 ⅜″ x 8 BA bolts and nuts.
4 1¼″ x ⅛″ Whit. bolts and nuts.
1 doz. soldering lugs.
1 yd. nylex tubing.

After having unpacked the parts you should carefully examine the valve to see that the glass has not been broken. The valve has been tested thoroughly immediately prior to having been packed in your Kit and definitely left the College in perfect condition. Provided that the glass has not been broken during transport, it is certain to be in good condition when it reaches you. However, you will probably want to satisfy yourself that the filament is intact, and this may be done by using your Ohmmeter with its test leads plugged into the socket marked "Low Ohms". On touching the other ends of the test leads to prongs 1 and 7 on the valve base, these are the prongs with the extra wide spacing between them, you should obtain a reading of approximately 20 ohms. In testing, it is necessary to avoid applying any sideways pressure to the valve prongs, as this may crack the glass base and it would probably be safer to plug the valve into the valve socket supplied before making the test. The multimeter test leads may then be applied to lugs 1 and 7 on the valve socket.

Next, you should carefully examine the two gang tuning condenser. Remove it from its carton and see that the plates rotate freely without the moving plates actually touching the fixed plates at any position.

If you are doubtful as to whether the moving plates do actually touch the fixed plates or not, you may make a simple tester by wiring a flashlight lamp and the 1.5 volt section of the $4\frac{1}{2}$ volt battery in series as explained in experiment 5 of Lesson No. 2. The connections are shown in Figure 7 of that Lesson. The two lengths of wire which act as test leads may be applied one to the frame of the tuning condenser and the other to one of the long connecting lugs protruding from the centre of the end of one section. As the plates are slowly rotated the lamp should not light. If it does so, it shows that a short circuit exists between the two sets of plates of the condenser. Having tested one section you should proceed to test the second section in a similar fashion. Here again, of course, the lamp should not light.

Before making the tests, you should touch the two test leads together for a moment to see that the lamp will glow if a short circuit exists between the test leads.

The only other part which should be tested at this stage is the 45 volt battery. To do this, plug one test lead into the negative terminal of your multimeter and the other one into the socket marked "Plus 50 volts." When the ends of these test leads are applied to the connecting lugs on the battery, you should obtain a reading of at least 42 volts.

TWO-VALVE RECEIVER.

The first unit to be constructed from this kit of parts is a two-valve battery-operated receiver, the circuit of which is shown in Figure 1. Before commencing the actual construction of the receiver, we shall follow the path of signals through it on the circuit diagrams.

Radio waves from broadcasting stations, passing between aerial and earth, have the ability of inducing an alternating voltage in the aerial and earth system so that an alternating current passes to and fro between aerial and earth. In passing through the primary winding of the coil, fluctuating magnetic lines of force are produced around this coil and these spread out through space. The moving magnetic lines of force

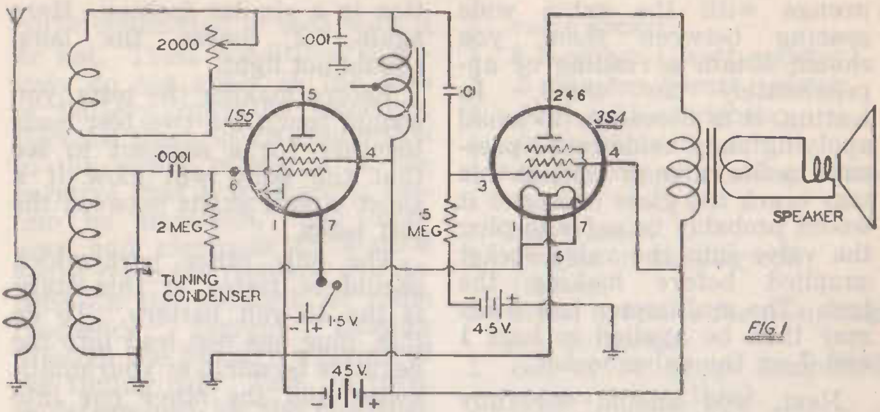


FIG. 1

from the primary winding will pass through and induce a voltage in the turns of the secondary coil. A large number of voltages transfer to the secondary coil at any one time, due to the fact that there will probably be signals from many transmitters received by the aerial and earth system. However, with a tuning condenser set to a certain point, there is only one frequency at which the condenser's reactance will equal the reactance of the coil, and at this frequency only will it be possible for large amounts of radio frequency current to circulate in the tuned circuit composed of the secondary winding of the coil and the tuning condenser. The current circulating to and fro in this circuit will generate a voltage which will be applied through the .0001 mfd. condenser to the grid of the 1S5 valve.

The purpose of the 1S5 valve is to act as a detector, that is, it is employed to remove the audio frequency programme from the radio frequency carrier wave and to make the audio frequency signals available for application to the grid of the second valve.

To enable the 1S5 valve to operate as a detector, it is necessary to have a condenser and resistor in its grid circuit. The .0001 mfd. condenser isolates the grid from the tuning circuit, and the 2 meg. resistor completes the grid circuit back to the filament. This causes the valve to operate as a "Grid Leak Detector".*

The 1S5 valve is really two separate sets of elements in the one glass envelope. The valve is known as a diode-pentode because it contains both a diode section and a pentode section. The diode section consists of a small metal plate surrounding the upper portion of the filament. This small rectangular plate measuring about $\frac{1}{4}''$ by $\frac{1}{8}''$ is probably visible through the upper portion of the glass en-

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

velope of your valve. You may notice a very fine white coloured filament wire extending upward at a slight angle through the diode plate. In constructing this particular receiver, we will not be employing the diode section but will do so in later tests.

The pentode section is contained further down in the glass envelope and consists of three grids and a plate surrounding the vertical filament wire at the centre. It is this pentode section which we will use as a detector in the two-valve receiver.

The radio frequency signals are applied to the control grid of the valve, the screen grid is connected to the positive terminal of the B Battery, to assist electrons in travelling across the space from the filament to the plate, the suppressor grid is already connected inside the valve to the filament, and in the plate circuit we will have pulsations of electrons representing both the radio frequency carrier wave and the audio frequency programme.

In a very simple type of receiver it would be possible to dispense with the radio frequency portion of the plate current by means of a condenser such as the .001 mfd. condenser, drawn near the top of the diagram, and to simply pass the audio frequency signals by means of the choke, .01 mfd. condenser and .5 meg. resistor to the grid of the output valve. However, by employing what is known as "Regeneration" we can substantially increase the amount of amplification provided by the first valve and thus improve the performance of the set.*

REGENERATION.

By passing the plate current of the 1S5 through a small coil winding placed near the main tuning coil, the radio frequency variations in the plate current will produce magnetic lines of force around the "Reaction" winding, and these in turn will spread out and generate a radio frequency voltage in the tuning coil. If the reaction coil is connected correctly, the energy fed back into the grid circuit will add to that already provided by the radio signals and will thus increase the strength of voltage available for the grid of the valve. By this means the strength of the voltage can be increased several times and thus the sounds from the loudspeaker made several times louder than they would be if regeneration were not used.

If too much energy is fed from the plate circuit back into the grid circuit, the valve will provide a signal for itself, and will generate a radio frequency voltage. In other words, it will act as an "oscillator" and will generate a radio frequency voltage at the frequency of the tuned grid coil. This is easy enough to understand because it will be realised that the valve amplifies the signals applied to its grid so that much more

* See A.R.C. Service Engineering Lessons 35 and 36.

energy is available in the plate circuit than is necessary to represent a signal for the valve's grid. If sufficient of this energy from the plate circuit is fed back by means of the reaction coil to the grid coil, a valve can quite easily supply a strong enough signal for its own grid to enable the grid to continue to produce changes in plate current which in turn will continue to feed energy back into the grid circuit. Thus, the valve generates a radio frequency voltage of its own accord. When this happens, the valve is said to be "oscillating" and you will find that if you attempt to tune in any broadcasting station you will hear a very loud piercing squeal which changes in pitch as you alter the tuning condenser slightly. The squeal itself is not the voltage generated by the valve but is the result of the oscillating voltage mixing with the signals from the broadcasting station. When two frequencies combine with one another in this way they produce a third frequency equal to the difference between them and it is this third frequency which is audible as a squeal or howl.*

A loud squeal accompanying a radio signal would not be very entertaining or enjoyable and consequently it is necessary to reduce the amount of regeneration until the energy fed back from the plate circuit to the grid circuit is insufficient to cause the valve to oscillate. Under these conditions the amount of energy fed back will strengthen the signals applied to the grid but will not be great enough to cause any annoying squeal and so we will hear the signals clearly. To control the amount of energy fed back into the grid circuit, you will observe that a 2,000 ohms potentiometer is connected in parallel with the reaction coil. When this potentiometer is turned so that it has no resistance it forms a complete short-circuit across the reaction coil, and all the energy in the plate circuit will pass directly from the plate to the .001 condenser and on through the wiring without having passed through the reaction coil. As the value of resistance in the potentiometer is increased, a greater and greater proportion of the plate energy will be forced to pass through the reaction coil and so the amount of reactance will be increased until eventually oscillation will occur. The ideal setting for the reaction control is at a point just before oscillation occurs, that is, just before squeals accompany the programme.

If no whistles are obtained, even with the potentiometer turned fully on, try reversing the connections to the reaction coil by exchanging the coil wire going to lug 5 on the 1S5 valve socket with the one going to the centre tapped transformer.

The audio frequency changes in plate current pass through the reaction coil or 2,000 ohm

* See A.R.C. Service Engineering Lessons 21, 35 and 46.

potentiometer without causing any appreciable effect, and continue to pass on through the choke. In passing through this they produce an audio frequency voltage drop across it which is applied through the .01 mfd. condenser to the grid of the 3S4 valve.

The .01 mfd. condenser is necessary to prevent the positive voltage, from the B battery, which is present at the upper end of the choke, from reaching the grid of the 3S4 valve. As explained earlier, it is necessary to have a negative voltage or "negative grid bias" applied to the grid of a valve and the .01 condenser provides a means of stopping the positive voltage from reaching the grid but at the same time allows the signal voltages to act through it and to be applied to the valve's grid. The 3S4 valve then amplifies these signals and passes them on to the loudspeaker, where they are converted into sounds.

The purpose of the .5 megohm resistor connected to the grid of the 3S4 is to allow a negative voltage from the 4½ volt battery to act through the .5 megohm resistor and to reach the valve's grid. This is the negative bias referred to earlier.

AERIAL AND EARTH CONSTRUCTION.

As pointed out earlier in the Lesson, the loudness of signals produced by this set and the distance from which signals may be received will be determined almost entirely by the effectiveness of the aerial and earth system. Therefore, you should endeavour to make your aerial installation as high as possible and as long as possible.

In Kit No. 1 you were supplied with a coil of aerial wire, 25 ft. long. You were also supplied with a coil of thicker wire with heavy installation, to be used as a lead-in for joining the aerial itself to the receiver. This lead-in wire was 30 ft. long, which will permit the construction of an aerial up to about 20 ft. in height, leaving

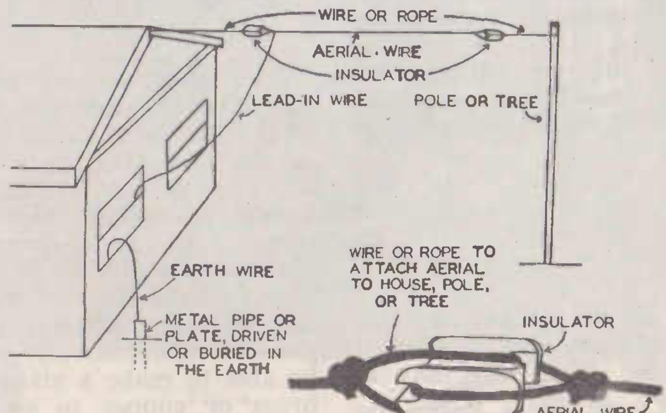


FIG. 2

some for an earth wire. Of course, it may not be possible for you to make your aerial as high as this but you should endeavour to make it as high as possible.

The ends of the aerial will, of course, be attached to an insulator, one at each end, and then short lengths of hook-up wire, lead-in wire, aerial wire or rope, can be used to join these insulators on to two masts, two trees, or portion of your dwelling and a tree or mast. The general arrangement of the aerial system should be as shown in Figure 2.

Details of the method of attaching a lead-in wire to the aerial and also to the insulator are shown in Figure 7 of Practical Lesson No. 1, and it is desirable that you refer back to this to make sure that you connect it in the proper fashion.

In running the lead-in wire from the aerial wire down to the receiver's aerial terminal, it is desirable that you keep it clear of any trees or bushes or portion of the building itself as far as possible. If it is hanging near any of these objects, the wind may blow it backwards and forwards so that the insulation becomes scraped off the wire. You will find then that, when the bare wire touches any other object in wet weather, the signals will vary considerably in strength.*

Just as important as the aerial installation is an efficient earth wire. This wire may be portion of the lead-in wire which may be attached to the receiver's earth terminal at one end and its other end soldered or clamped to a piece of metal piping or metal rod driven down into the earth. This metal pipe or rod should preferably be about six feet long, but if you cannot procure such a long piece you may be able to do with a shorter piece about three or four feet long.

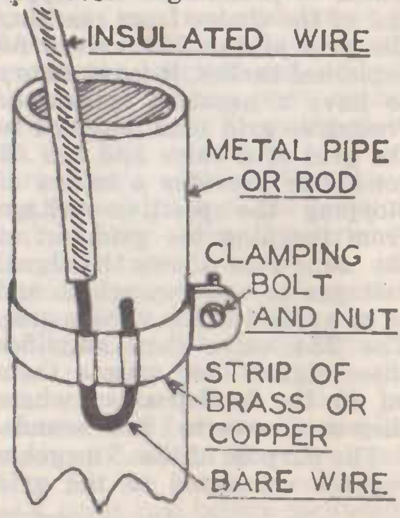


FIG. 3

You may experience some difficulty in soldering the end of the wire to such a heavy rod, as the soldering iron supplied to you is not really large enough to heat up such a large piece of metal. If you have a blow lamp available, you may be able to heat the rod with this and form an effective soldered joint, or alternatively, you may be able to make a strap out of brass or copper to clamp the bare portion of the wire to the

* See A.R.C. Service Engineering Lessons Nos. 4 and 5.

metal rod. Figure 3 shows how this may be done.*

You can proceed with the installation of your aerial and earth system at the same time as you are constructing your receiver so that the aerial and earth will be ready when your receiver is completely built.

* See A.R.C. Service Engineering Lesson No. 4.

ASSEMBLING THE RECEIVER.

You will be able to follow the location of the various parts from Figures 4, 5 and 6. You will observe that the controls and centre tapped choke remain in the same position as in the audio oscillator described in Lesson 5. The valve socket, however, should be moved to the other side of the chassis as shown in Figure 4.

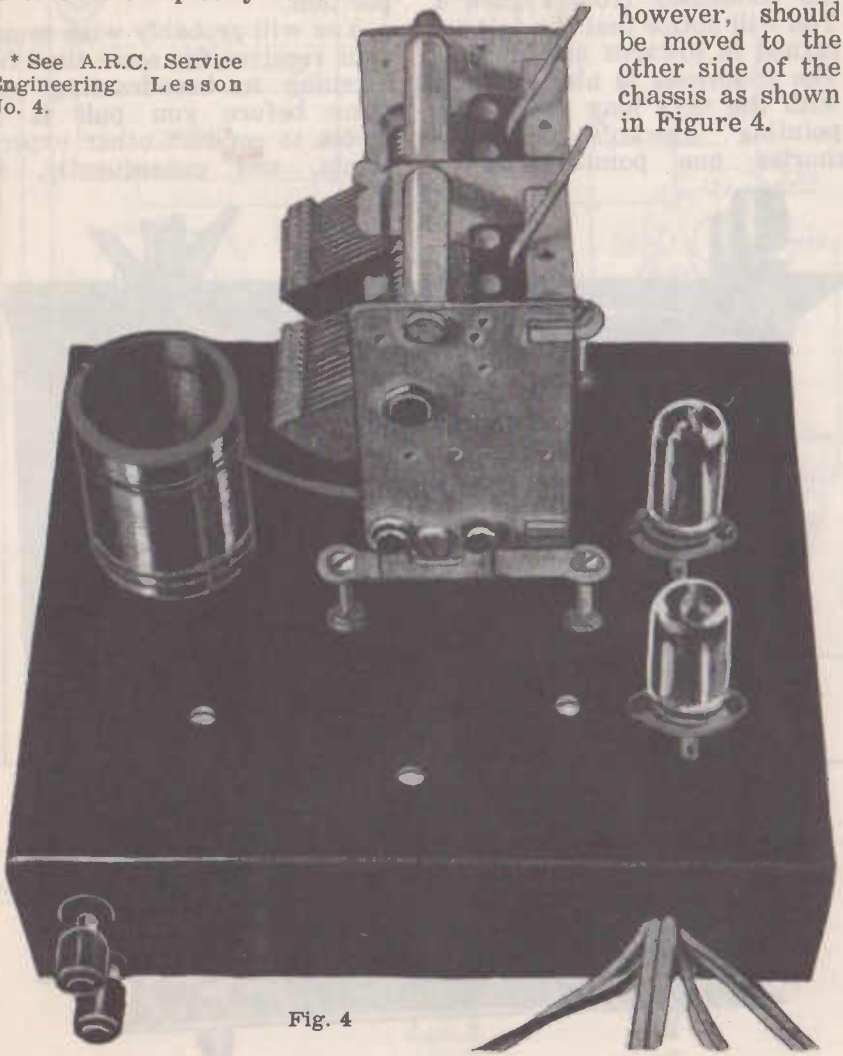


Fig. 4

When you unpack the tuning condenser, you will find that the box also contains two metal mounting feet and four screws for attaching these to the condenser. You will be able to see the way in which these mounting feet are attached to the condenser from Figure 4. You will notice that the feet are turned in towards one another. The condenser is also mounted with the very long solder lugs pointing upwards and the shorter one pointing downwards. After attaching the mounting feet to the ends of the condenser, place the condenser on the chassis and see that the holes in the mounting feet are in line with those on the chassis, but do not actually bolt the condenser directly into position.

You will probably wish to use your receiver for some time for listening to broadcasting stations before you pull it to pieces to conduct other experiments, and consequently, to

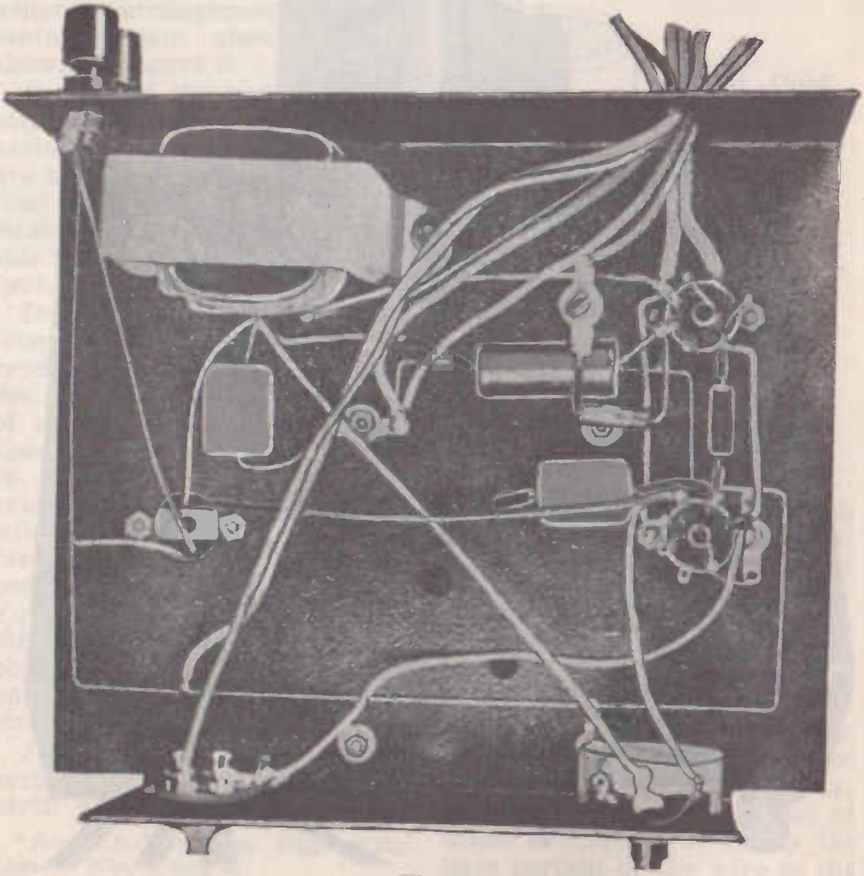


Fig. 5

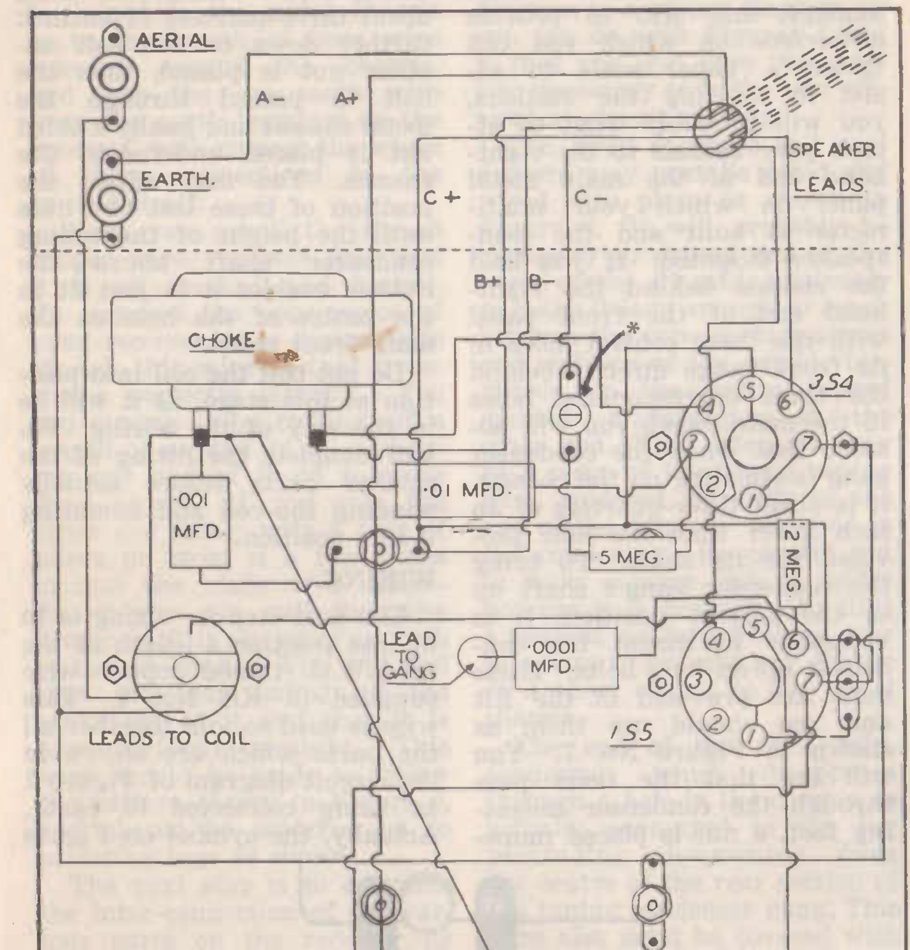


FIG. 6

*INSULATE FROM CHASSIS

protect the receiver from damage, and also to provide a surface on which you can fasten a paper scale to assist in locating the stations, you will probably want to attach your chassis to the right-hand end of the main metal panel on which your multimeter is built and the loudspeaker mounted. If you hold the chassis behind the right-hand end of the front panel with the three control holes in its front flange directly behind the three corresponding holes in the main panel, you will observe that when the condenser gang is standing on the chassis, it is about three-quarters of an inch lower than the hole provided for its shaft. To bring the condenser gang's shaft up to the correct position, it is necessary to mount the condenser up on long bolts. These bolts are provided in the Kit and you should use them as shown in Figure No. 7. You will see that the bolts pass through the condenser mounting foot, a nut is placed immediately under this, and then, about three-quarters of an inch further down on the bolt another nut is placed, then the bolt is passed through the metal chassis and finally a third nut is placed underneath the chassis. You may adjust the position of these last two nuts until the height of the tuning condenser shaft above the chassis enables it to just fit in the centre of the hole on the main front panel.

Do not bolt the coil into position at this stage, as it will be in the way of the wiring. We will complete the fitting of the smaller parts before actually winding the coil and mounting it into position.

WIRING.

The first step in wiring is to fit into position a length of the 18 S.W.G. tinned copper wire supplied in Kit No. 1. This wire is used to join together all the parts which are shown in the circuit diagram of Figure 1 as being connected to earth. Actually, the symbol on Figure

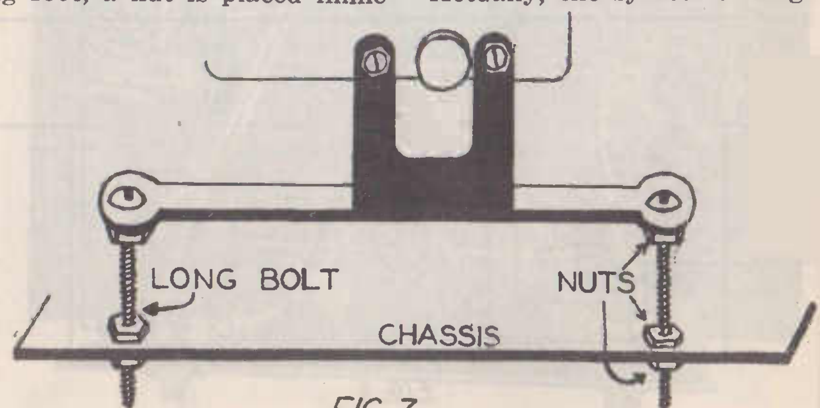


FIG. 7

No. 1 means that they are all to be joined to the metal chassis or to the length of bare wire running around the chassis, and then the one earth wire from the earth terminal on the receiver, will connect the whole of these connections to the ground itself.

When you uncoil the tinned copper wire you will find that it is all crooked and kinked. To improve the appearance of your receiver, it is desirable to stretch this wire so that it becomes perfectly straight. You can stretch it by cutting off a length of a yard or so, and tying one end of it on to some fixed object. If you grip the other end firmly with a pair of pliers or twist it a few times around the blade of a screwdriver you can pull the wire firmly until it stretches an inch or two in length. You will find that this has pulled all the kinks out of it and that it is now perfectly straight. This wire should be made to follow the pattern shown in Figure 6, and should be soldered on to soldering lugs as shown.

The next step is to complete the inter-connection of the various parts on the receiver by means of lengths of hook-up wire, with the exception of the coil and the small resistors and condensers. In carrying out this wiring, you should follow the wiring diagram of Figure 6 but also follow the wiring on the circuit diagram of Figure 1. It is essential for you to become thoroughly proficient at reading circuit diagrams, and it is only by relating a circuit diagram to a wiring diagram, as you can do with Figures 1 and 6, that you will gain the practice necessary to make you efficient at circuit reading.

The small resistors and condensers may next be fitted and wired into place as shown in Figure 6. It will probably be necessary to extend one of the wires of the .01 mfd. condenser to make it long enough to reach between the valve sockets at one end and one of the outside terminals on the centre tapped speaker transformer at the other end. This extension may be a piece of the tinned copper wire, soldered carefully to the end of the "pigtail" attached to the condenser. Be careful not to make a large blob of solder because it is necessary to slide a piece of insulating tubing over this wire to prevent any chance of a short circuit to the metal chassis.

The end of the .0001 mfd. condenser, which disappears through a hole in the chassis, is actually connected to the lug protruding downwards from the centre of the rear section of the tuning condenser gang. This wire also must be covered with insulating tubing.

Near the centre of the tuning condenser, you will see a brass wire "wiper" which presses against the shaft. Solder a length of tinned copper wire to this near the bottom end and solder the other end of the wire to the 18 gauge tinned copper wire running around the underneath side of the chassis.

COIL WINDING.

If you examine the two coil formers supplied, you will see that one has a number of small holes distributed over its whole length. This is the one on which we will wind the broadcast coil. The two large holes near one end are for bolting the former to its mounting bracket. A little further in from the end you will see two small holes side by side. Take the thinnest wire provided (34 gauge) and thread about four or five inches down, from the outside to the inside through one hole, then up through the other, then down through the first hole again. This will secure one end in place. Now wind 15 turns of wire neatly, side by side; cut the wire, leaving 7 or 8 inches for connecting and thread the end down one of the small holes near where the winding ends, up through the neighbouring hole, and down again.

This winding is the aerial primary winding, the point from which you started will later be connected to the bare tinned copper earth wire and the end where you finished will be connected to the aerial terminal on the rear of the chassis.

The best method of winding the coil neatly by hand is to unwind about 8 feet of the wire and, after threading the first end through the former as described above, fasten the other end to some fixed object such as a door handle or nail in the wall. If you stretch the wire taut (be careful not to break it) any kinks will be drawn out of it. Now roll the former around in your hands, rotating it so that the top of the former turns towards you and see that the turns of wire fall neatly side by side. Of course, you will have to walk slowly towards the fixed end of the wire as you wind it. When you have wound the 15 turns, hold the wire in place with one thumb while you cut it and thread the end through the other holes. Be careful that the end does not slip, allowing the coil to unwind or become loose on the former.

The centre winding is the "grid coil" or "tuning coil". Take the middle sized wire (28 gauge) and thread it through, back, and through the next pair of holes, leaving about 3 or 4 inches projecting on the inside. It is necessary to wind 90 turns of this wire; a length of about 36 feet. As you will probably not have sufficient room to stretch out 36 feet of the wire in one straight length, it will probably be necessary to stretch out a shorter length, wind on some turns and then stretch a further length. Of course the wire must be in one continuous length throughout this winding. Do not attempt to join the wire part of the way along the coil. If the wire should break unwind it and start again.

After winding 90 turns neatly side by side the winding will spread over about 1¼ inches and you will find another pair of holes through which the end may be threaded. Pass this wire down through one hole and up through the other so that it protrudes outward from the coil instead of finishing inside the former as the other ends have done. This end only has to reach over to the lug protruding downwards from the centre of the rear section of the tuning condenser, where the .0001 mfd. condenser connects so it need only be about 3 or 4 inches long.

The third winding is the "reaction" coil and is wound near the top of the former, between the remaining pairs of holes. It consists of 45 turns of the thin wire and its ends should finish on the inside and should be 7 or 8 inches long. Be especially careful to wind this in the same direction as the tuning coil. That is, if you look at the top of the former and the top turn of the turning coil is in a clockwise direction then the top turn of the reaction coil should also be in a clockwise direction. It does not matter whether both coils are wound in a clockwise or anti-clockwise direction as long as they are both wound the same way.*

MOUNTING AND WIRING THE COIL.

One of the coil-mounting brackets can be bolted over the large hole near the right-hand end of the chassis by means of two of the 8BA bolts and nuts provided. Leave these bolts and nuts loose for the moment. The coil should be placed gently over the bracket, the ends of the wires passing down each side of the bracket. When the coil is in position so that the large holes in it are in line with the holes in the bracket, it can be fastened to the bracket by means of two $\frac{1}{8}''$ Whitworth bolts, supplied with Kit 5. Nuts will not be needed as the bracket is threaded. Do not make the screws too tight or the former may crack. Now tighten the 8BA screws holding the bracket in place.

Commencing from the bottom of the coil, the lower end of the aerial coil and the lower end of the tuning coil should have the enamel covering carefully removed by means of a small piece of the sandpaper supplied with Kit 1. These ends are then soldered to the 18 SWG tinned copper earth wire under the chassis. The upper end of the aerial coil should be threaded through a 5-inch length of insulating tubing, to prevent it short circuiting to the edge of the hole in the chassis or to the coil bracket, the end cleaned and soldered to the aerial terminal.

The upper end of the tuning coil should be threaded through a piece of tubing, cleaned and soldered to the lug on the tuning condenser to which the .0001 mfd. condenser also connects.

* See A.R.C. Service Engineering Course Lessons No. 35.

The lower end of the reaction coil is passed through tubing, cleaned, and soldered to pin 5 on the 1S5 valve socket. The upper end of this coil is threaded through tubing, cleaned, and soldered to the end of the centre tapped transformer to which the .01 and .001 mfd. condensers connect. The connections to the coil are shown in Figure 8.

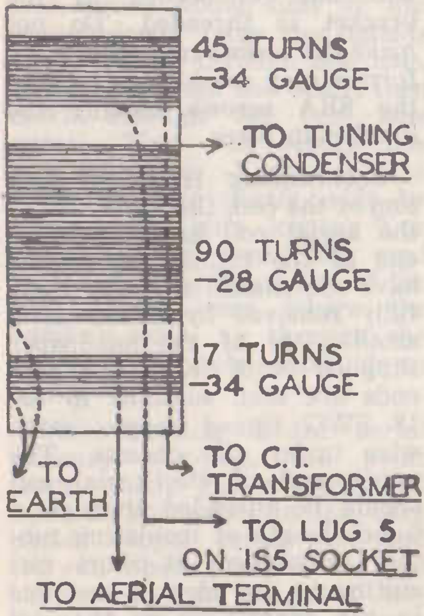


FIG. 8

BATTERY LEADS.

Having now completed the construction of the set itself, it is necessary to make provision for connection to the batteries. You will require three pairs of leads to connect to the three batteries and a fourth pair to join the output valve to the loudspeaker. These pairs of wires can be made by cutting off lengths of hook-up wire about 18 inches long. One wire of each of the three pairs of battery leads will connect to the bare tinned copper earth wire running around the chassis. These wires will be the wire connecting to the negative side of the 1.5 volt A battery, the wire connecting to the negative side of the 45 volt B battery, and the wire connecting to the positive end of the 4½ volt C battery.

The wire for the positive side of the A battery should be cut a little longer than the rest because it has to have one end connected to the On-Off Switch mounted on the front flange of the chassis. The wire for B plus starts from pin No. 4 on the rear socket, that is, the socket to the 3S4 valve and the wire for C-4½ starts from one end of the .5 meg. resistor connected to the grid of the 3S4.

The six wires should be twisted together to form three definite pairs and paper or cardboard labels should be fixed to the ends of the wires so that there will be no chance of confusing them when connecting them to the batteries.

If you do not label these wires carefully, you may find that at some later time, when you are connecting them to the batteries, you may make a mistake and connect the wires for the A battery on to the B battery. In this case, the 45 volts from the B battery would be applied to the filaments of the valves and would burn them out.

A pair of wires for conveying signals to the loudspeaker should be joined one on to pin 4 and the other on to pin 6 of the 3S4 valve socket. Their other ends, of course, will connect to the transformer mounted on the loudspeaker.

CONTINUITY TESTING.

Before actually connecting the battery leads to the batteries, it is desirable to make tests to see that there are no short circuits in the wiring which would ruin the batteries. Turn the switch on the front panel to the "ON" position and plug your test leads into the socket marked "High Ohms" on your multimeter. Before using the multimeter, touch the ends of your test leads together and adjust the needle to zero, at the right-hand end of the meter scale, by means of the zero adjuster. Now separate the ends of the test leads and firstly connect them to the two wires you have labelled for connection to the A battery. The needle should not move away from the zero position on the scale. If it does do so, it shows that there is a short-circuit between the wires and this must be rectified before you connect the wires to the battery. If a reading is obtained, the short-circuit could be caused by a mistake in connecting the wires to the wrong position in the receiver, by your choosing two of the wires which connect to the chassis of the receiver for the A battery instead of one of these wires and one from the switch or defective insulation, allowing the wire itself to touch the metal chassis where it passes through the hole in the back flange of the chassis.

After having tested the A battery wires, repeat the test with the test leads joined to the two wires you intend connecting to the B battery, and again to the two wires you intend connecting to the C battery. In all of these tests there should be no movement of the meter's pointer.

The tests outlined above should, of course, be made without the valves plugged in their sockets but with the loudspeaker connected.

Having satisfied yourself that no short-circuit exists in the wiring, you may now attach these wires to the terminals on the batteries. The wires to the C battery should connect one to the positive terminal and the other to the terminal marked "—4.5".

TESTING VOLTAGES.

Before inserting the valves in their sockets, there are some further tests to make to confirm that the wiring is carried out correctly, and that there is no chance of damaging the valves. These tests are made with one of the test leads inserted in the socket marked "+ 50 volts", and the other inserted in the minus socket of your multimeter.

Touch the negative test lead to pin 1 on the 1S5 valve socket and the positive test lead to pin 7. You should obtain a reading corresponding to 1.5 volts. As this voltage is measured on the 50 volt scale of your instrument, the needle will only move about 1½ graduations away from zero.

Next, touch the negative test lead of your meter to pin 5 on the 3S4 valve socket and the positive test lead in turn to pins 1 and 7. In both positions you should obtain a reading of approximately 1.5 volts.

Touch the positive test lead to the bare earth wire running around the chassis, and touch the negative test lead to the end of the .5 meg. resistor away from the valve socket. The meter needle should move about 4½ graduations across the scale. If by any chance the meter needle moves backwards, to the left of zero, this indicates that you have reversed your connections to the C battery, and you must change them so that the needle moves up the scale. Now touch the negative test lead to pin No. 3 on the 3S4 valve socket. Here the meter needle should move very slightly up the scale but only for a distance of about one-quarter or half of one division. If by any chance the needle moves to the left of zero instead of moving up the scale, this would indicate a faulty .01 mfd. condenser or a strand of wire or an excessive amount of flux joining pin 3 on the 3S4 valve socket either to pin 4 or to pin 2. If the needle does move to the left, firstly examine the valve socket carefully and see that no flux or strand of wire is bridging the socket lugs just mentioned, and if everything appears to be in good order there, disconnect the .01 mfd. condenser from socket lug No. 3. If the needle moves in the correct direction when this condenser is disconnected, this definitely confirms that the condenser is faulty, and a new one must be procured before you attempt to use the receiver.

For the remainder of the tests, the negative test lead from your multimeter may be attached, by means of one of the push-on alligator clips, to the 18 gauge tinned copper earth wire. The positive test lead should be moved from one point to another as outlined below, and should give the following approximate readings. On socket lug No. 4 of the 3S4 valve socket, the meter should indicate the full voltage of the B battery. As this battery has not been used, it should have a voltage of at least 42 volts. On pin 6 of the 3S4 socket, the reading should be about 1 volt less than that at pin 4. As you connect the meter to this point, you should hear a very faint click from the loudspeaker. If no reading is obtained at point 6, this would show that you have forgotten to connect the wires to the loudspeaker transformer.

On lug No. 4 of the 1S5 valve socket you should obtain the same reading as at lug No. 4 on the 3S4 valve socket. At lug No. 5 of the 1S5 valve socket you should obtain a reading about 1 volt less than that at lug No. 4. With the test leads touching pin No. 5 of the 1S5 valve socket, rotate the 2,000 ohm potentiometer on the front panel. As you turn the shaft, the meter pointer should not move. If it moves back about two further divisions on the scale, this would show that there is a break in the reaction winding of the coil.

Having confirmed that all the voltages are correct, you may now insert the valves in their sockets. Take especial care to see that the 1S5 valve only fits into the socket near the front of the chassis and the 3S4 into the rear socket. If you accidentally plug the valves into the wrong sockets it is almost certain that the 1S5 valve would be ruined and it is quite possible that the 3S4 valve also would be spoilt. The aerial and earth wires may now be connected to the terminals on the back of the chassis.

The final test is to touch pin No. 6 on the 1S5 valve socket with your finger. As the filament switch is already turned on, as soon as you place your finger on pin No. 6, you should hear a peculiar squealing or humming sound from the loudspeaker. If there is no sound at all, not even a click, there is a fault in the set, and you must carefully check over the wiring and, if necessary, repeat the tests outlined above with the voltmeter, to determine where the fault exists. If you do hear a squealing or humming sound when you touch pin No. 6, this shows that everything is in order and that there is every probability of the receiver picking up signals from a broadcasting station.

TUNING.

Turn the potentiometer on the front panel, about two-thirds of the way in a clockwise direction. Slowly rotate the tuning condenser, listening carefully at the loudspeaker for any sound from broadcasting stations or for any whistle. If you hear a shrill whistle which changes in pitch as the tuning condenser is moved slightly, set the condenser to a point where the whistle is loudest and deepest in pitch. Turn the potentiometer in an anti-clockwise direction until the whistle just ceases. As soon as the whistle ceases you should hear a programme from the broadcasting stations clearly. The potentiometer is used as a volume control, and if the signals are unpleasantly loud you can reduce them in loudness by turning the control further in an anti - clockwise direction. The loudest signals will be obtained when this control is set into a position just before the whistle starts.

If you live within about thirty or forty miles of a broadcasting station, you should receive the signals quite clearly. If, however, you live further away you may experience some whistles as you slowly turn the tuning condenser, but on turning the potentiometer shaft until these whistles just cease, the speech or music may be so soft that you can hardly hear it or you may not even hear it at all. In this case, the receiver is probably working quite well, but because of the fact that it employs only two valves, its range is restricted, and as the radio signals are so weak it will not operate correctly until we have added an extra valve to it, as explained in a later Lesson.

Another method of obtaining reception in remote locations is to replace the tuning coil with another one containing fewer turns so that short-wave stations can be received. The range of the receiver when tuned to short-wave stations will be much greater than when tuned to the ordinary broadcasting stations. The method of winding a short-wave tuning coil is explained a little further on in the Lesson.

If the receiver will pick up signals from a broadcasting station, you must not expect them to be as loud as those received by radio sets operating from the power mains. This receiver you have just constructed employs only a 45 volt battery to operate it, and only two valves, and consequently with these limitations it cannot produce very loud signals. The signals from nearby stations should be almost as loud as those provided by any other battery-operated set but, of course, no battery-operated sets will produce signals as loud as those produced by sets working from power mains.

OPERATING THE 1S5 as a TRIODE.

Once your receiver is operating correctly, it is interesting to try the effect of operating the 1S5 valve as a triode. This will confirm that triode valves are not capable of producing as much amplification as are pentode valves. As the receiver was originally constructed, the 1S5 was employed as a pentode, but you can easily alter the connection to make it work as a triode by disconnecting the wire from socket lug No. 4, and instead joining Lugs 4 and 5 together. When you do this, you will find that the receiver will still function but the signals will not be quite as loud. You should then restore all the connections as they were originally.

When operating the receiver from the small 1.5 volt battery as an "A" battery, the current drain imposed by the valves on this battery is rather heavy, and the battery would only last for about eight hours of operation before becoming completely discharged and useless. If it is your intention to make use of this receiver for listening to broadcasts for long periods of time, it would be desirable for you to purchase locally, or have supplied to you, a much larger size of 1.5 volt battery. The larger battery must, of course, have a voltage of 1.5, otherwise it will damage the valves, but the larger the battery is physically the longer it will last before becoming discharged. One type of battery which is quite suitable is the large round type of cell measuring about 6 inches high and about 2½ inches in diameter. This type of cell should last for about 400 hours of operation.

Although the B battery supplied has a voltage of only 45 volts, it is possible to operate the valves with up to 67.5 volts supplied to their plates and screen grids. If, however, a 67½ volt battery is used in place of the 45 volt battery, it is most important that the C battery be changed for one which will provide 7½ volts bias. This increase in bias may be obtained by connecting another 3 volts battery in series with the 4½ volt battery, or by using a 7½ or 9 volt battery in place of the 4½ volt battery. Under no circumstances should you apply 67½ volts to the receiver unless you increase the bias to 7.5 volts.

SHORT WAVE COIL.

As mentioned earlier, the range of the receiver, when operated with the coil you have already constructed, will vary, depending upon the efficiency of the aerial and earth installation and also to a large degree on the nature of the country surrounding the receiver. On the ordinary broadcast band of frequencies one can expect a range of about 30 to 40 miles, but, if you do not live within about 30 or 40 miles of a broadcasting station, then it will be desirable to construct a short wave coil, which will permit reception from stations at a much greater distance, due to the higher carrier frequencies involved.

A short wave coil is very similar to the coil you have already constructed with the exception that the numbers of turns on the windings and the spacing apart of the windings is different.

A suitable coil which will permit tuning from approximately 30 meters, which is equivalent to 10 megacycles to approximately 90 meters, which is equivalent to 3.3 megacycles, is illustrated in Figure 9.

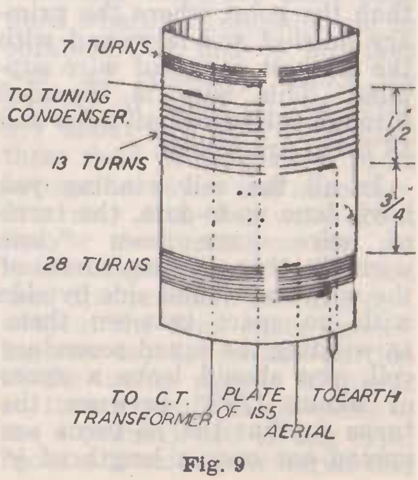


Fig. 9

On the second coil-former supplied to you, you will find a number of holes in slightly different positions from those on the former you have already used.

Again, at one end you will find two fairly large holes for attaching the coil-former to the bracket which mounts it on the chassis and near these, two small holes close together at which you can start the aerial primary winding. This coil is wound with the thinnest gauge of wire supplied in the kit, that is, No. 34 gauge. The method of winding is similar to that for the earlier coil you constructed and the primary winding consists of 28 turns of wire wound closely side by side. After you have finished winding the 28 turns you will find that there is a pair of small holes provided, through which you can thread the wire to secure the end.

The secondary coil commences ¾″ further along the former than the point where the primary finishes and is wound with the thickest gauge of wire supplied. This wire is threaded through the two small holes and 13 turns are wound.

In all the coil winding you have done up-to-date, the turns of wire have been "close wound", that is, the turns of the wire are wound side by side with no space between them. In winding the tuned secondary coil, you should leave a space of about 1/32″ between the turns so that the 13 turns are spread out over a length of ½″ and so that the last turn finishes level with the small holes which are provided ½″ away from where the coil started. If you unwind about 6′ of this wire and attach one end of it to some firm object, as described earlier, pass the other end through the two small holes at the points at which the winding commences and then, keeping the length of wire taut and straight, rotate the former slowly in your hand, you will be able to wind the turns parallel with one another, leaving a small space between the adjacent turns and you will not experience any great difficulty in spreading the 13 turns over the ½″ length. It is necessary to keep the wire fairly tight when winding, otherwise, when you finish off, the turns will be loose and will move together or away from one another, so that the spacing is not regular and even. If you experience any difficulty in winding the turns tightly enough, so that they remain evenly spaced apart on the former, then you may move them into their correct positions and cement them in place with a few small drops of glue, liquid cement, melted wax or other such substance. However, to keep losses to a minimum, it is desirable to use only a very small amount of any of these substances and, rather than paint the whole winding with glue or some cement, it is preferable to apply only small spots of it here and there, if it is necessary to use it at all.

After completing the secondary winding, there should be a space of $\frac{1}{8}''$ before the third coil, known as the reaction coil, is wound. This coil consists of 7 turns of the thinnest wire and will finish a little over $\frac{1}{8}''$ from the other end of the former.

The method of connecting the coil to the receiver is exactly the same as that for the broadcast coil you have used. On substituting this coil for the other coil you will find that the receiver becomes capable of tuning in short wave stations and you will doubtless be able to receive signals from stations great distances away.

AERIAL COUPLING.

Once you have the receiver working satisfactorily with the short wave coil, you can undertake quite a number of experiments with various types of aerial primary coils to obtain the best possible results from the particular aerial and earth installation you are using. The use of a primary coil of 28 turns spaced $\frac{3}{4}''$ away from the secondary will give good results with most aerial and earth systems without the receiver failing to oscillate when the 2,000 ohm potentiometer is turned fully on. The closer the aerial primary coil is moved towards the secondary coil, the louder the signals will become, but if the primary is moved too close to the secondary, you will find that at certain positions of the main tuning condenser, the receiver will not break into oscillation when the 2,000 ohm potentiometer is turned fully on and consequently there will be weak or "dead" spots across the tuning range.

To enable you to experiment with other aerial primary windings, you will find two additional sets of small holes placed between the position occupied by the primary winding you have already wound and the 13 turn secondary winding. You can use a further link of the thin wire to wind up primary coils of varying numbers of turns between these sets of holes. The closest set of holes is only $\frac{1}{8}''$ away from the secondary, and I suggest that you commence with 15 turns of wire placed between these holes. This will probably be too many and you will possibly find that although you can obtain good reception at certain points on the tuning condenser there are other positions where no reception can be obtained. If this is so, then you can gradually reduce the number of turns on the primary about two at a time until these dead or insensitive spots become narrower and narrower. You may find that with about five or six turns you can get louder signals than when you used the previous 28 turn coil, without the dead spots spreading over any appreciable portion of the tuning range. If this is so, then it would be advisable to use a primary coil of this type, because it suits your aerial and earth system better than the 28 turn coil. Of course, in experimenting with this alternative primary winding, you should disconnect the two ends of the 28 turn coil from the aerial terminal and from the 18 gauge tinned copper earth wire and connect the two ends of the newly wound primary in their places. The end of the primary nearest the secondary winding should be connected to the 18 gauge earth wire and the end remote from the secondary should be connected to the aerial terminal.

Whilst you are experimenting with the number of turns on this new primary winding, you will probably find it much easier to hold the aerial end of the primary in place with a piece of adhesive paper, sticking plaster, a drop of molten wax or similar means, instead of threading the wire laboriously through the small holes in the former every time, then passing it down through the hole in the chassis and soldering it to the aerial terminal. If you temporarily hold the last turn of the wire in place you can scrape the enamel from the end of the wire and twist or solder it to the lead-in wire from your aerial without resorting to the use of the aerial terminal until you have determined the best number of turns. Once you have arrived at the best number of turns, then you can solder the wire in the normal fashion to the aerial terminal.

TUNING TO OTHER FREQUENCIES.

By using a secondary winding of 13 turns, the tuning will cover from approximately 30 meters to 90 meters, as previously explained.

If you wish to experiment with secondary windings containing other numbers of turns, you will be able to extend the tuning range to either higher or lower frequencies.* By winding more than 13 turns on the secondary, you will be able to tune to lower frequencies or longer wave lengths, but if you wind more than about 20 turns on the secondary you will find it necessary also to increase the number of turns on the reaction coil, otherwise the receiver will not oscillate and will not be sensitive when the 2,000 ohm potentiometer is turned fully on.

Similarly, if you are experimenting with fewer than 13 turns in an endeavour to tune to shorter wave lengths than 30 meters or higher frequencies than 10 megacycles, then you will also need to reduce the number of primary turns and the number of reaction turns approximately in proportion. The number of turns on the reaction coil should normally be about half the number of turns on the tuned secondary coil for best results.

* See A.R.C. Service Engineering Course Lessons 15 and 17.

WAVE TRAPS.

The purpose of a wave trap is to absorb some of the energy produced by an extremely powerful nearby station, which, under certain circumstances, may cause interference with the reception of other stations. For example, if you happen to live within about two or three miles from a powerful broadcasting station, you will probably find that its signals spread over a considerable distance on the tuning dial and its programme is heard at the same time as the programme from other stations which you may wish to receive.

Probably the most effective cure for this form of trouble is to purchase a more efficient type of receiver, in which the tuning circuits are sufficiently selective to reject the powerful interfering signals and permit the reception of weaker signals from more distant stations on nearby frequencies. Another remedy, which is often very effective, is to construct a simple wave trap which will absorb a considerable amount of energy from the carrier wave of the powerful, interfering station without seriously weakening the strength of signals from other stations. As you will learn further on, there are several different wave trap circuit arrangements which can be employed, but all of them operate on the same fundamental principle of absorbing or reducing the signal energy from the powerful interfering station to which they are tuned and leaving the signals from other stations relatively unaffected.*

If you have a radio receiver at your disposal, apart from the one you have just constructed out of the kit of parts supplied to you, it is an excellent plan for you to carry out the following experiments, so as to learn as much as possible about the behaviour of wave traps, whether your receiver suffers from interference by powerful signals or not. Even if you do not experience any interference with the reception of weak signals, it is worth while conducting the experiments, because at some time in the future you may be confronted with this problem, either in your own receiver or some other receiver which you are called upon to repair or adjust.

Of course, if you have no receiver, apart from the one you have just built from your kit of parts, it will not be possible to carry out experiments with the wave traps at this stage, for the reason that it is necessary to use the tuning coil and the condenser supplied to you to construct the wave traps and if you use these for constructing the wave traps, then you will not be able to have the wave trap operative and your receiver functioning at the same time. Therefore, if you do not have another receiver available, on which you can test the wave traps, it is sug-

* See A.R.C. Service Engineering Course Lesson 42.

gested that you leave these experiments with wave traps until some later stage when you do have a receiver available.

TYPES OF WAVE TRAPS.

The type of wave trap which proves most efficient in weakening the signals from an unwanted broadcasting station carrier wave will depend upon the type of coil used in the particular receiver with which it is to be employed and also to some degree on the impedance of the aerial and earth system from which the receiver operates.

Many radio receivers designed for the reception of broadcasting stations employ an aerial coil with a primary winding consisting of only a small number of turns. One often finds about 10 to 25 turns employed as the primary winding. This type of primary winding is known as a "low impedance" primary and usually operates most effectively in conjunction with a wave trap when the wave trap is a type known as a "rejector circuit".

On the other hand, some radio receivers are equipped with aerial coils in which the primary winding consists of a very lage number of turns, usually several hundred, wound in a bobbin or "pie" and spaced ¼" or more from the secondary. These primary windings are known as "high impedance" primaries and usually operate best in conjunction with a wave trap known as an "acceptor circuit". However, four types of wave traps are described in the following pages and it is suggested that you construct each type and observe the effectiveness of each.

For our first wave trap we will employ the tuning coil we constructed to enable our receiver to tune to broadcast stations, together with one section of our tuning condenser. As only the tuning condenser and coil are involved, it does not matter whether you have both the coil and tuning condenser mounted on the chassis or whether you remove the coil and tuning condenser from the chassis and use these two parts on their own. If you already have the short wave tuning coil mounted on the chassis and intend to continue using the set as a short wave receiver after completing your wave trap experiments, it will probably be better at this stage to remove the tuning condenser from the chassis and employ it together with the broadcast coil, on their own, for making up the wave trap. On the other hand, if the broadcast coil is already mounted in place on the chassis, then it will be easier to leave it there and to perform the wave trap experiments with both the coil and tuning condenser mounted on the chassis. If you intend using the coil and tuning condenser alone, then the coil can be attached by means of one of the mounting brackets, to any one of the spare holes appearing in the back plate of the tuning condenser.

The connections for our first wave trap are shown in Figure No. 10. The main tuning coil consisting of 90 turns of 28 s.w.g. wire is connected to the

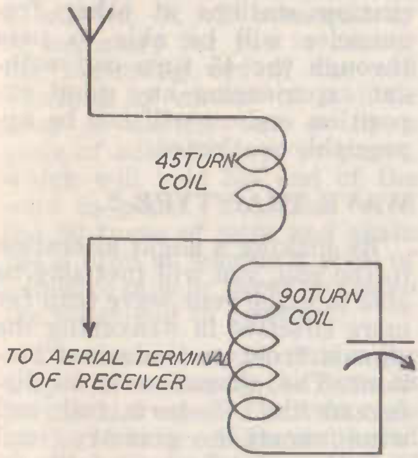


Fig. 10

rotor and stator plates of one section of the tuning condenser. No other connection is made to the tuning condenser or to the 90 turn winding of the coil.

The aerial is connected to one end of the 45 turn coil which was previously the reaction coil when used with the receiver. The other end of the 45 turn coil should be connected to a wire long enough to reach to the aerial terminal of an ordinary radio receiver. The original aerial primary winding of 15 turns is not required in this experiment, but need not be removed from the former.

Tune the radio receiver to some broadcasting station operating on the frequency band between 550 and 1,500 kilocycles. Notice carefully the loudness of the signals, then slowly rotate the shaft of the tuning condenser connected to the wave trap. As you gradually rotate this shaft you will find one setting of the tuning condenser where the signals from the broadcasting station are reduced considerably in strength. If you leave the tuning condenser at this particular setting, it will reduce the strength of signals from that particular station, but will not appreciably affect the strength of signals from any other stations. If the station's frequency to which you have tuned the trap is one which has been previously causing interference with the reception of other stations on your receiver, then the inclusion of the wave trap should reduce the amount of interference. The amount by which the loudness of the signals decreases, when the trap is tuned to resonance, will depend, as previously explained, on the type of aerial coil fitted in the receiver and on the aerial and earth systems. It will also depend on whether the receiver you are employing is equipped with an automatic volume control system or not. If the set has an A.V.C. system, then the reduction in loudness will not be very noticeable, but the reduction of interference with stations on nearby carrier frequencies will be effective.

When you first connect the aerial to the reaction winding on the wave trap coil, it should be connected to the end furthest away from the 90 turn coil. The end of the 45 turn coil nearest to the 90 turn coil should connect to the receiver's aerial terminal. After trying the wave trap with these connections, quickly reverse the connections to the ends of the 45 turn winding, so that the aerial is connected to the end nearest to the 90 turn coil and the receiver's aerial terminal is connected to the end furthest from the 90 turn coil. Notice carefully whether the performance of the wave trap is more effective in reducing signals from stations with this method of connection.

The principle of operation of this type of wave trap is that, when the 90 turn coil is tuned to resonance by the tuning condenser, current produced by signals from the station you are attempting to weaken will circulate readily in the tuned circuit consisting of the 90 turn coil and the tuning condenser. As the current flows to and fro around this circuit, it produces magnetic lines of force which spread out from the 90 turn coil and develop a voltage in the 45 turn coil. This voltage will act in such a manner that it will oppose the flow of current from the aerial through the 45 turn coil to the aerial terminal of the receiver and so will weaken the strength of the signal current reaching the receiver. This current can only flow in the circuit consisting of the 90 turn coil and tuning condenser at the frequency at which the circuit is resonant. This current will only develop a high voltage in the 45 turn coil at that one particular frequency and consequently this voltage will oppose and weaken the signals at this frequency only. Current produced by signals from broadcasting stations at other frequencies will be able to pass through the 45 turn coil without experiencing any great opposition and so will not be appreciably weakened.

WAVE TRAP TYPE 2.

By making a slight alteration to the coil, you will probably be able to make your wave trap far more effective in weakening the signals from an undesired station. The alteration is to disregard the 45 turn coil and wind another primary coil directly over the top of the 90 turn winding as shown in Fig.

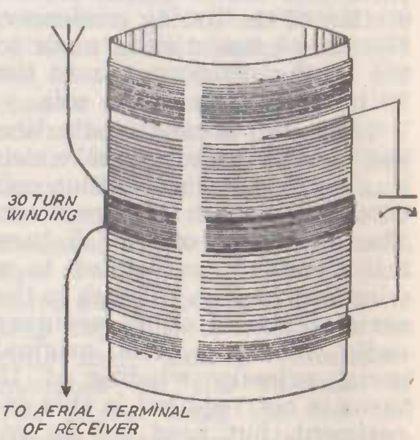


Fig. 11

11. This primary coil should consist of 30 turns of the fine,

34 s.w.g. wire wound side by side exactly over the centre of the 90 turn coil. Because the coil is wound over the centre of the 90 turn coil, it will not be possible to provide any small holes in the coil-former through which the ends of the wire may be started. It will consequently be necessary for you to anchor the beginning end of the coil winding by means of a little drop of molten wax or by a piece of adhesive tape or paper, which will hold the end of the wire in place. You then wind the 30 turns of wire and again use a drop of wax or a piece of adhesive tape or paper to fasten the other end in position.

The connections to this wave trap will be exactly the same as in the last case. The two ends of the 90 turn coil are connected to the rotor and stator plates of the tuning condenser section, the end of the 30 turn coil nearest to the reaction coil is connected to the aerial, the end of the 30 turn coil nearest to the aerial primary winding is connected to the receiver's aerial terminal. As in the last case, it is a good idea to experiment by reversing the connections to the ends of the 30 turn coil to determine which method of connection proves most effective.

The performance of the wave trap will be similar to the trap described previously. When the receiver is tuned to a broadcasting station, if you slowly rotate the tuning condenser of the wave trap, you will find one setting at which the signals are weakened and you should notice carefully whether this second type of wave trap is effective in making a greater reduction in signal strength than the first one. You will probably find that it is more effective.

This second type of wave trap will probably prove effective regardless of whether it is used with a receiver employing a low impedance or a high impedance aerial primary winding.

WAVE TRAP TYPE 3.

Our next experiment consists of using the same coil, that is, with the 30 turns wound over the centre of the 90 turn coil, the only alteration being to connect a wire from the metal frame of the tuning condenser to the earth terminal of the radio receiver with which the wave trap is being used. If the receiver is equipped with a high impedance aerial coil, then the addition of this earth lead will probably make the trap more effective. As before, connections to the end of the 30 turn coil should be tried firstly in one direction and then reversed and tried in the other direction.

The three wave traps described so far have all been known as "rejector circuits" because the action in each case has been that current, circulating in the tuned circuit, has developed a voltage in the primary winding which has opposed the passage of current from the aerial to the receiver and consequently tends to reject signals at the resonant frequency of the wave traps.

WAVE TRAP TYPE 4.

Our next experiment consists of a wave trap which employs an "acceptor circuit". In this wave trap the 90 turn winding on the coil only is used in conjunction with one section of the tuning condenser. The single coil winding and tuning condenser are connected in series with one another as shown in Figure 12, one end of the coil

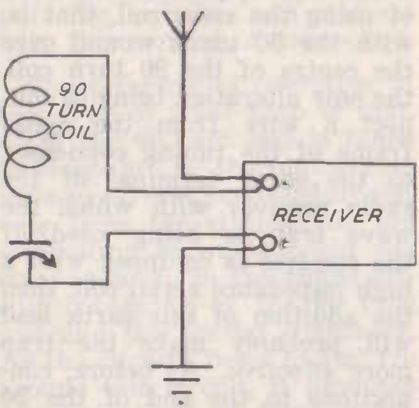


Fig. 12

being connected to the receiver's aerial terminal and the other end of the condenser to the receiver's earth terminal. The aerial itself is, of course, also connected to the receiver's aerial terminal.

This type of wave trap is especially effective with receivers in which the aerial coil has a high impedance primary winding. Its action is that, when the receiver is tuned to a certain station and the wave trap condenser is also rotated to tune the 90 turn coil to resonance at the same frequency, the reactance of the 90 turn coil will be exactly neutralised by the reactance of the tuning condenser in the wave trap, so that there remains no reactance to oppose the passage of signal current from the aerial directly through to earth. The only opposition remaining in the 90 turn coil and tuning condenser is the small amount of resistance present in the coil winding, and this is so low that practically all the signal energy at the resonant frequency will pass through the 90 turn coil and condenser to earth instead of flowing through the aerial coil in the receiver. In this way, the wave trap circuit accepts the signal and the receiver is deprived of most of the signal current.

At other signal frequencies, the reactance of the 90 turn coil and that of the wave trap tuning condenser will not neutralise one another, so there will remain a considerable amount of reactance in the wave trap circuit which will prevent a large proportion of the current passing through the wave trap to earth and consequently, instead, this current will pass through the receiver's aerial coil in the normal fashion and signals from other stations will not be appreciably weakened.

As mentioned earlier, these experiments with wave traps should be executed thoroughly and the results noted carefully, if you have another receiver with which the wave trap may be tested. Although you may not wish to use the wave trap yourself, you will learn quite a lot about the performance of tuned circuits from these experiments and, at the same time, you will then know how to construct an effective wave trap if you need to do so at some time in the future to prevent interference in your own receiver or in some other receiver you are called upon to repair.

The wave trap experiments we have performed so far have all employed the 90 turn coil for tuning purposes, so that the wave trap can be made effective at any frequency within the broadcast band; that is, at any frequency between 550 and 1,500 kilocycles.

If, by any chance, you experience interference in a short wave receiver, due to extremely powerful signals from some nearby short wave transmitting station, then you can construct an effective wave trap using one of the four methods outlined above, but employing fewer turns than 90 for the tuning coil. The exact number of turns on the tuning coil will depend on the frequency at which you wish the wave trap to be effective. The number of turns on the primary winding for use with wave trap type 2 or 3 should be about one quarter of the number of turns on the tuning coil.

REFERENCE, KITS 6, 7 & 9.

NOTE:

Coil winding wires are required for use with Kits 6, 7 and 9. To avoid three separate winding processes,we supply with Kit No.6 all the wire necessary for the three kits. Although it is necessary to use this wire economically, ample is supplied for all three kits.

On the parts lists in Kit instruction booklets 6, 7 and 9, the wires are identified by gauge number and comparative diameter, i.e. No. 34 (thin), No. 28 (medium) and No. 26 (thich).

In Booklet No. 6 parts list a coil of No. 19 wire is shown for which No. 26 has now been substituted. All references in this and other booklets to No. 19 wire should be changed to No. 26.

Lesson No. 6

Australian Radio & Television College Pty. Ltd
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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	Resultant 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.

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 current 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 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

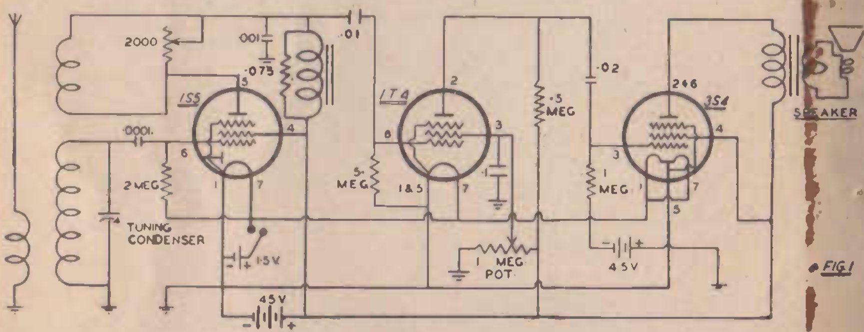


FIG. 1

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

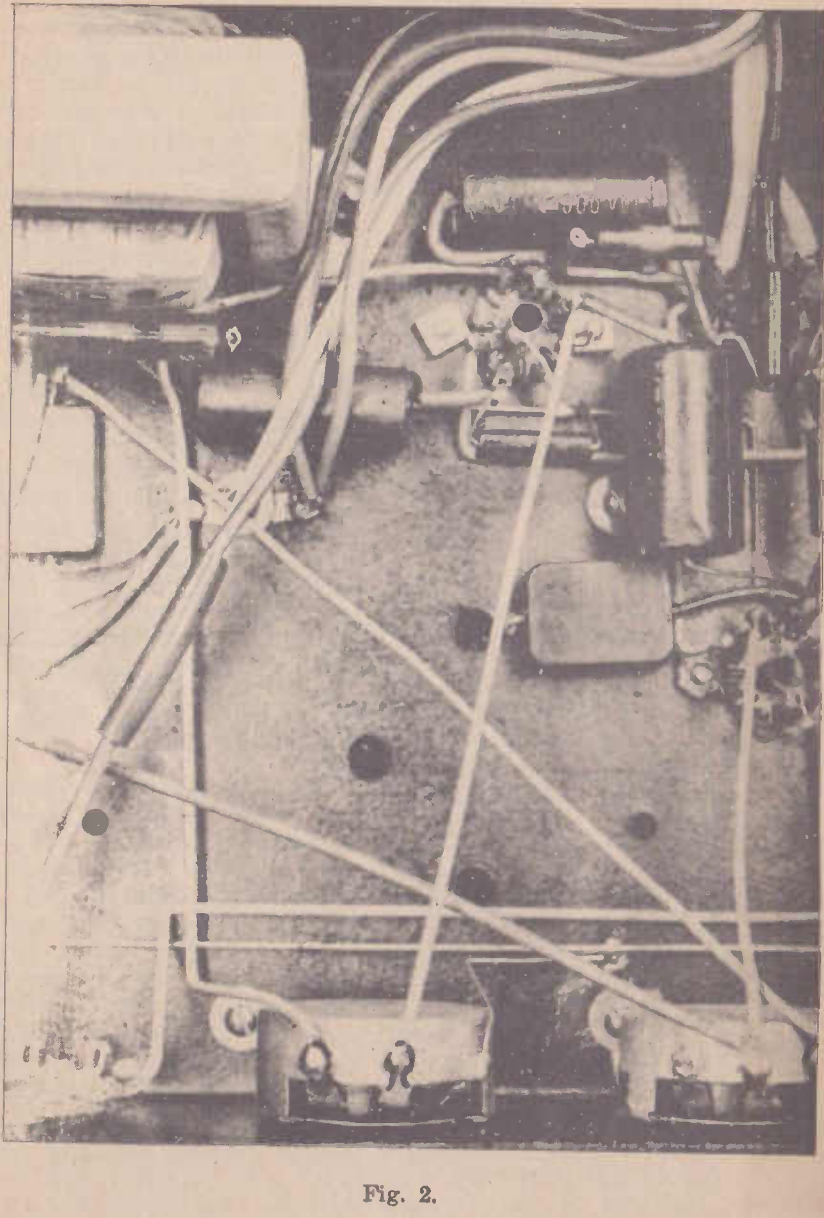
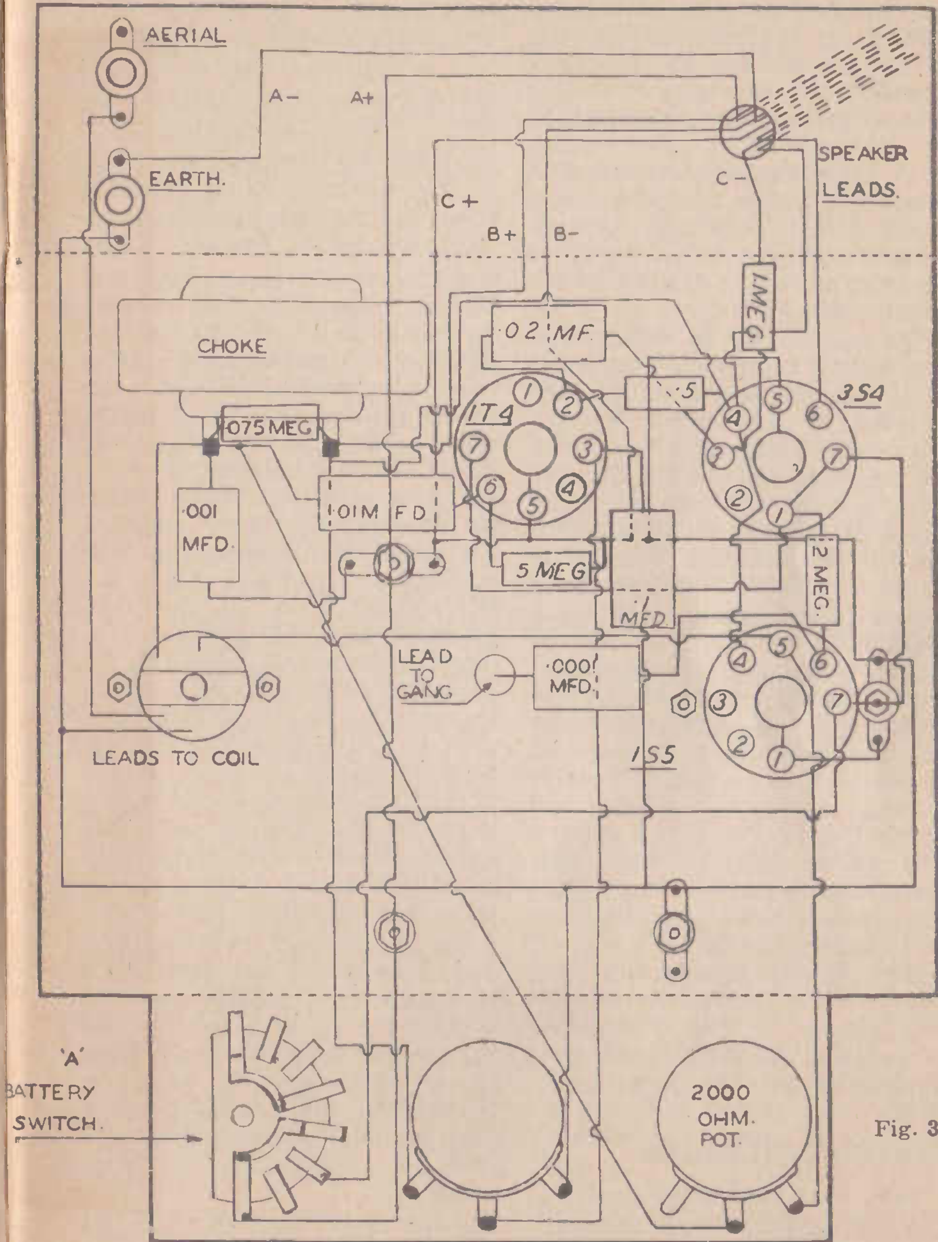


Fig. 2.



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

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 half-way 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

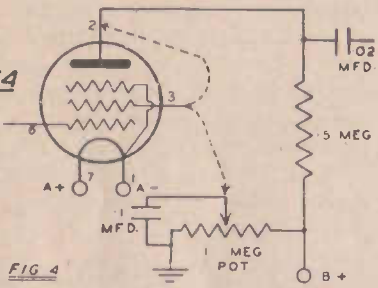


FIG 4

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

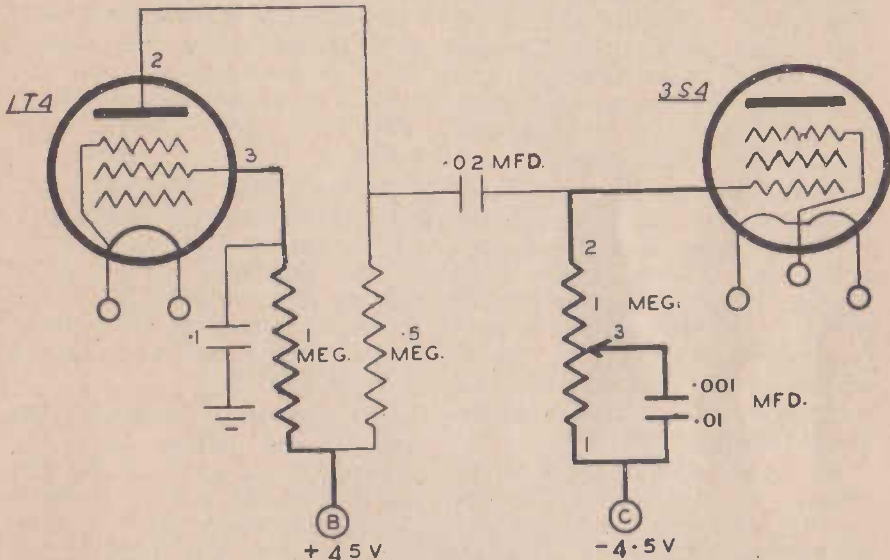


FIG. 5

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 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.

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 removed 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

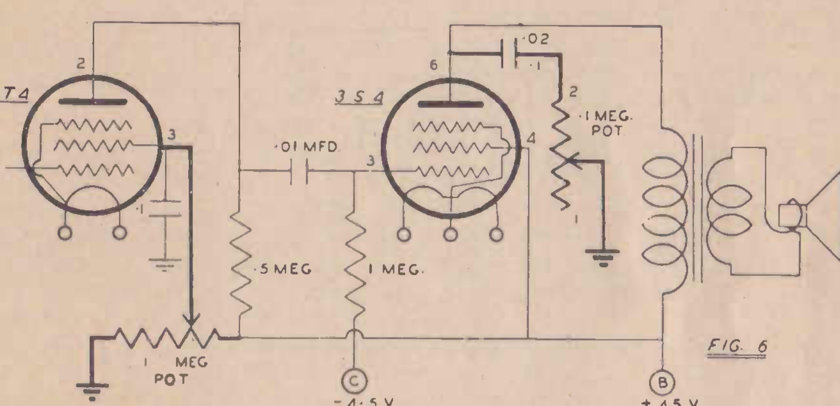


FIG. 6

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.

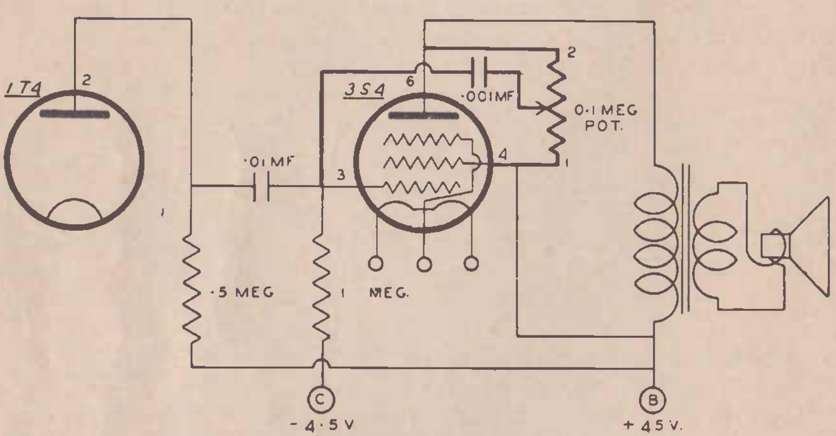


FIG. 7

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.

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.

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 sig-

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

nals 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 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.

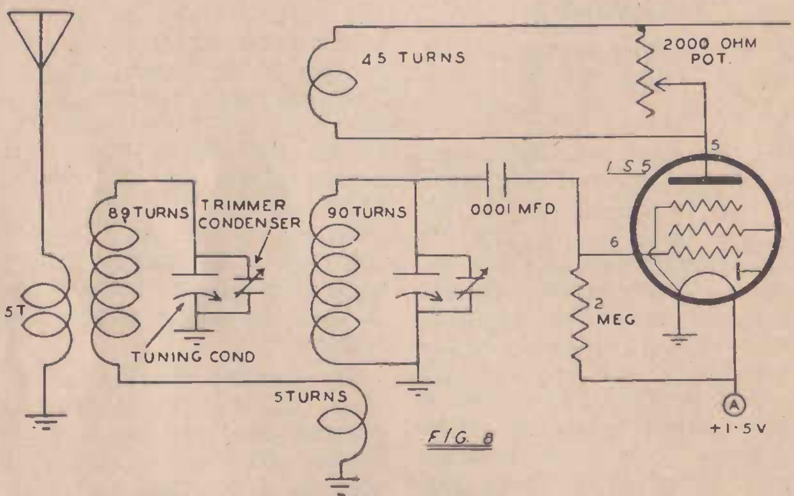


FIG. 8

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 $\frac{3}{8}''$ x $\frac{1}{8}''$ 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 pre-selector 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 $\frac{1}{8}''$ 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 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 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 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.

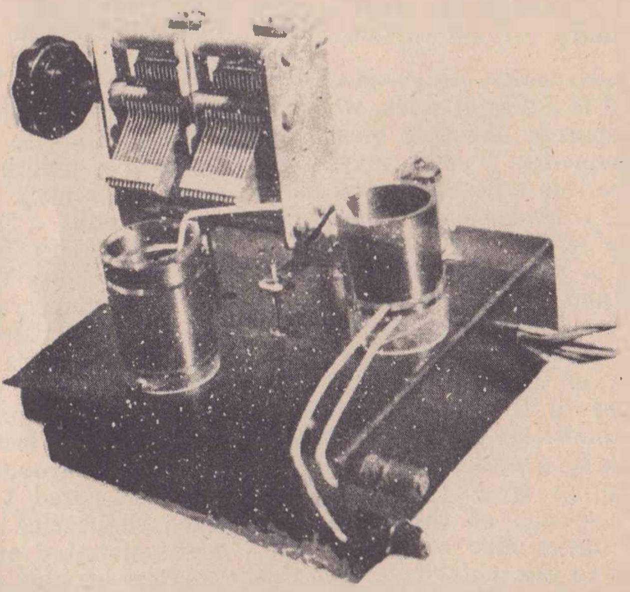


Fig. 9

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.

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

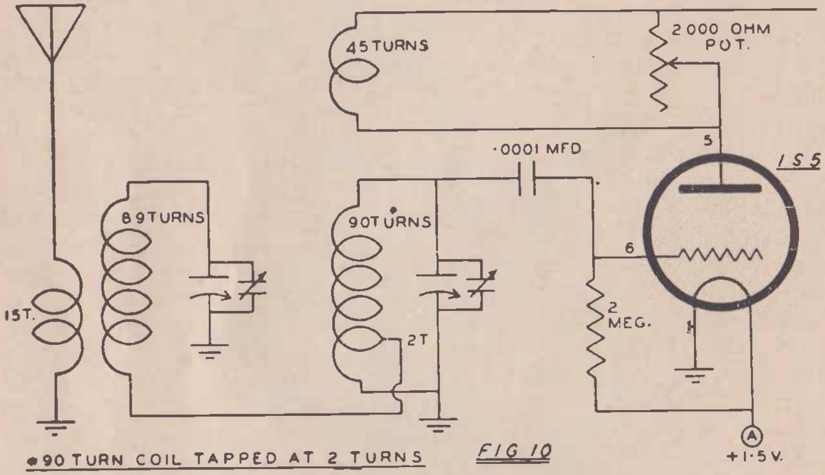


FIG 10

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

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.

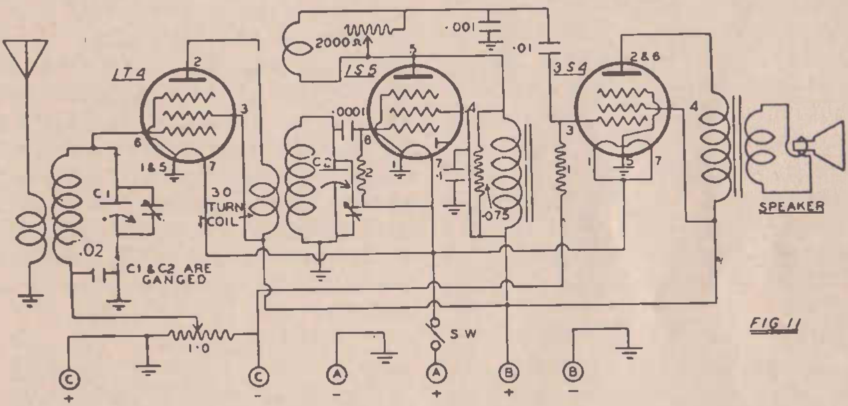


FIG 11

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

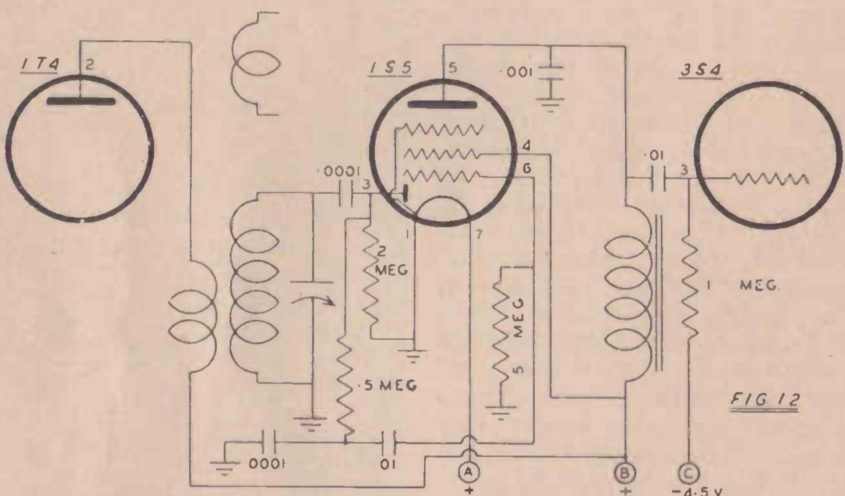


FIG. 12

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 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.

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

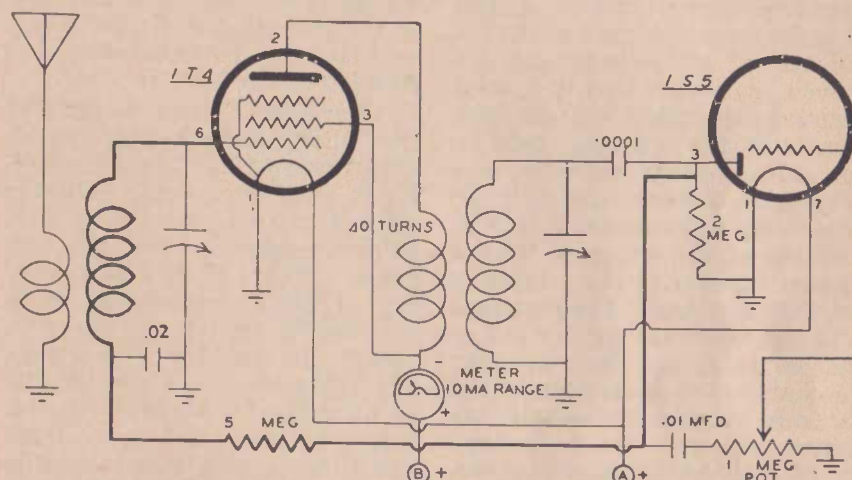


FIG 13

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

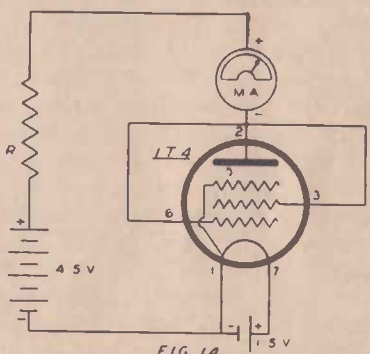


FIG 14

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.

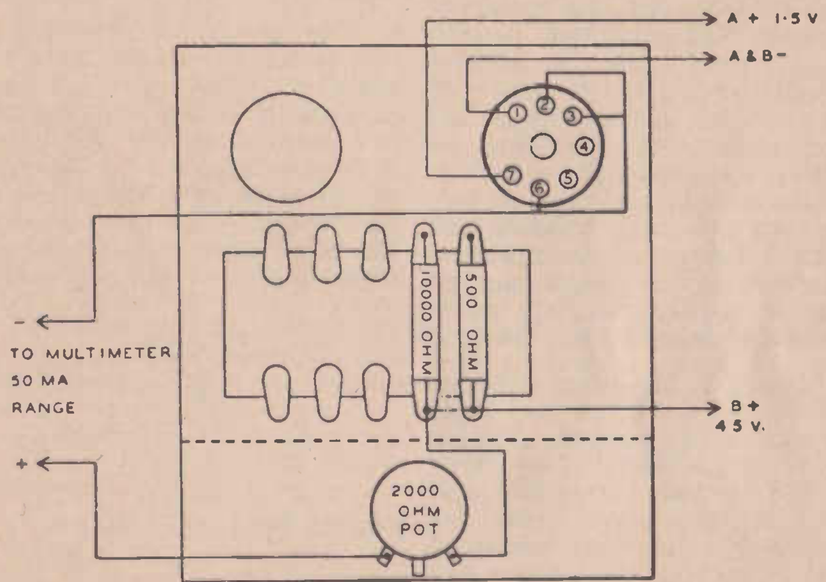


FIG 15

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 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,

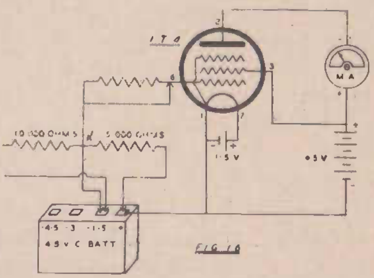


FIG 16

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.

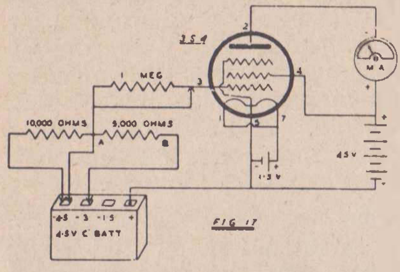


FIG 17

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.

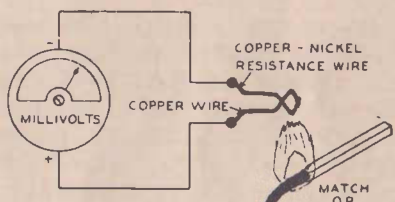


FIG 18

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 nega- meter should be connected to tive test lead from the multi- the 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 "thermo-couple" made up as shown in Figure 19. The thermo-couple consists of a short length of

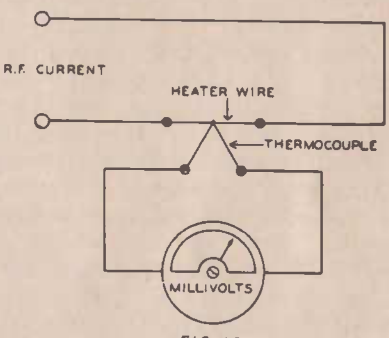


FIG 19

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 thermo-couple 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.

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

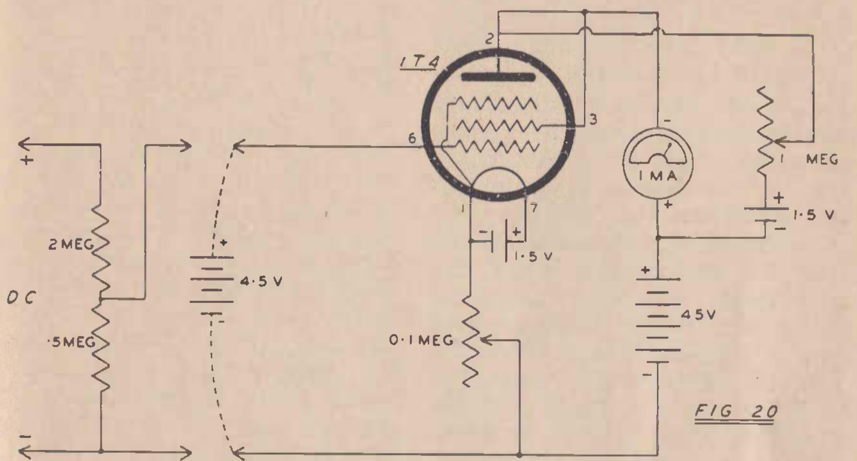


FIG 20

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

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,

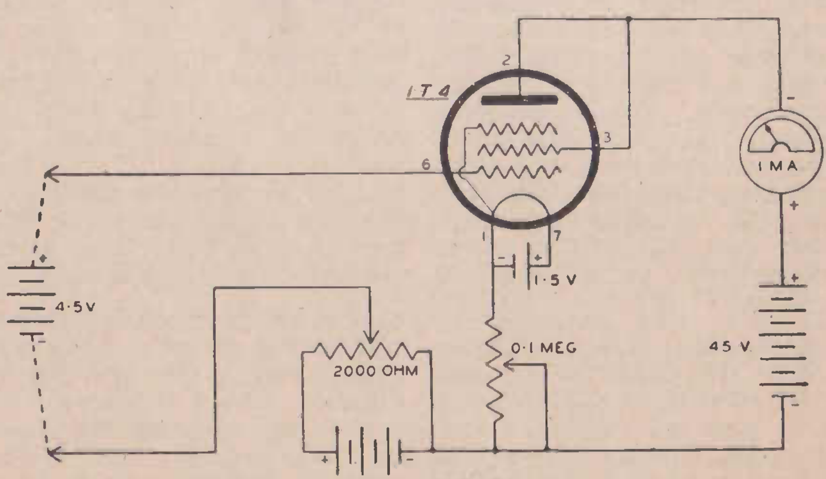


FIG 21

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 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 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 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

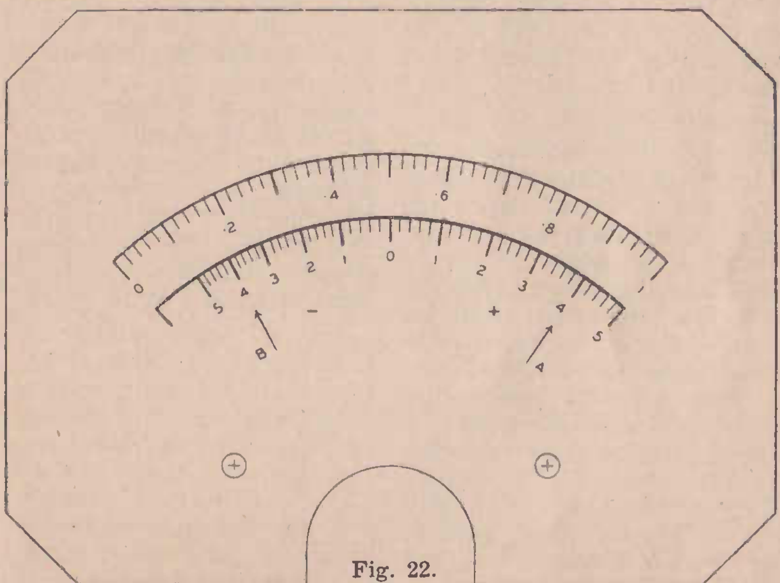


Fig. 22.

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

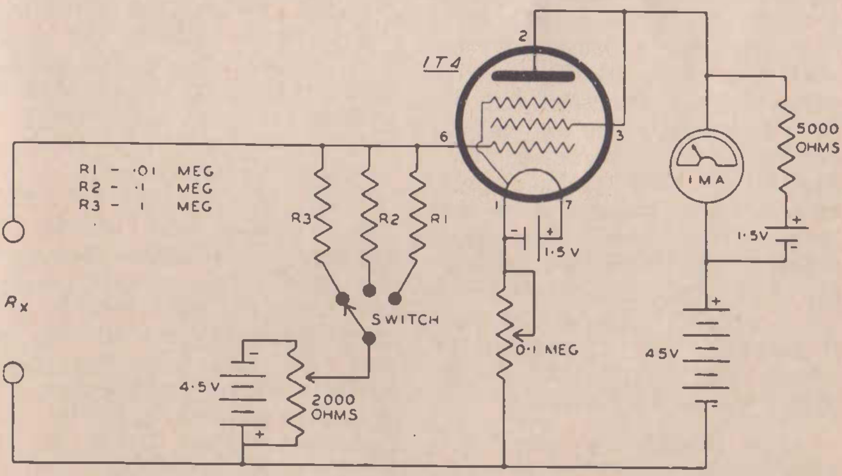


FIG 23

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

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.

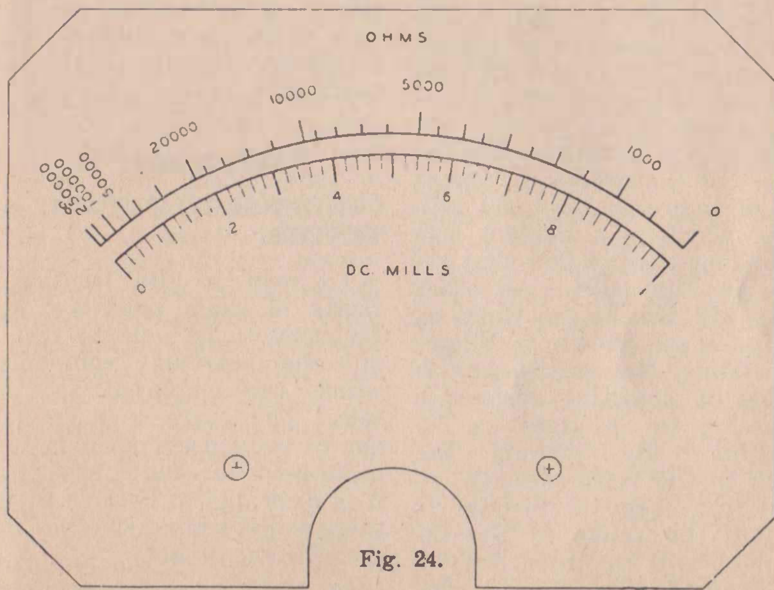


Fig. 24.

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.

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.

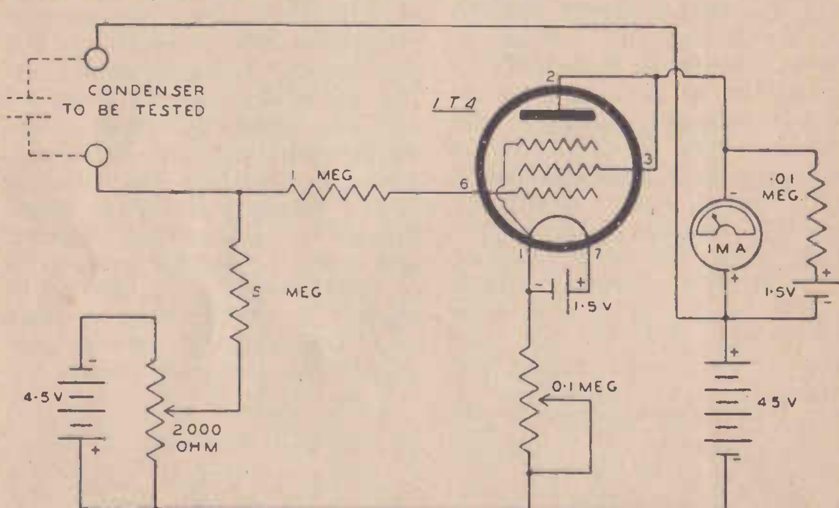


FIG 25

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 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 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, 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.

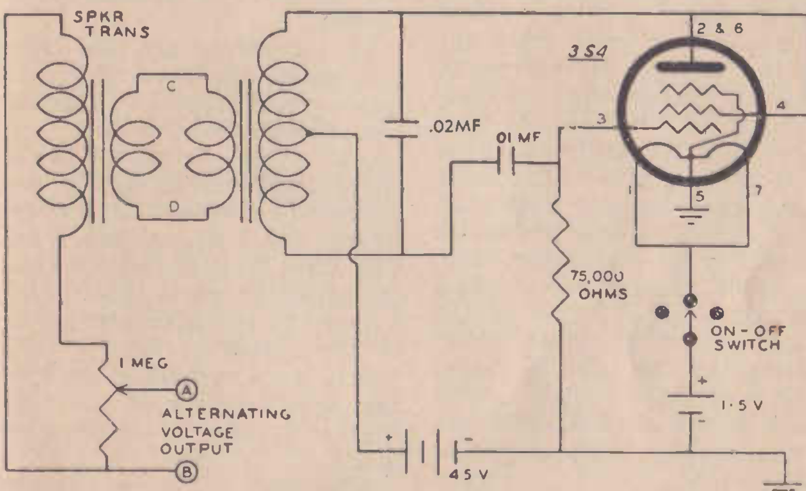


FIG 26

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

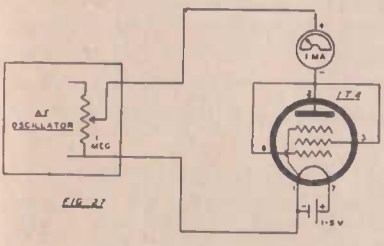


FIG. 27

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.

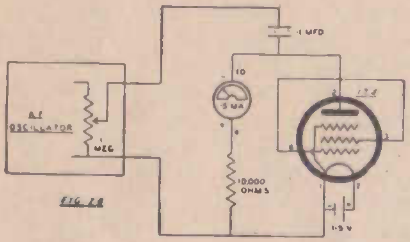
To avoid this irregularity in performance depending upon whether or not direct voltage is present, we may include a condenser in the circuit as shown in Figure No. 28.

* 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



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.

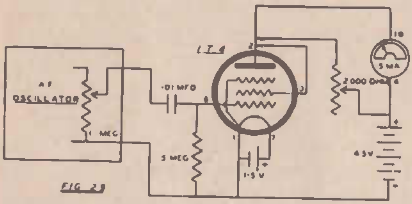
EXPERIMENT 18.

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.

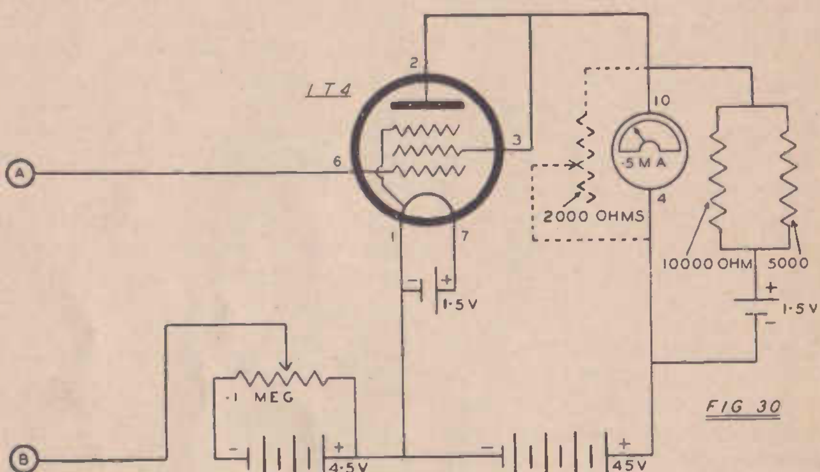


FIG 30

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.

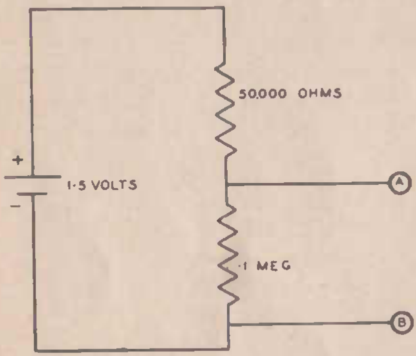


FIG. 31

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-

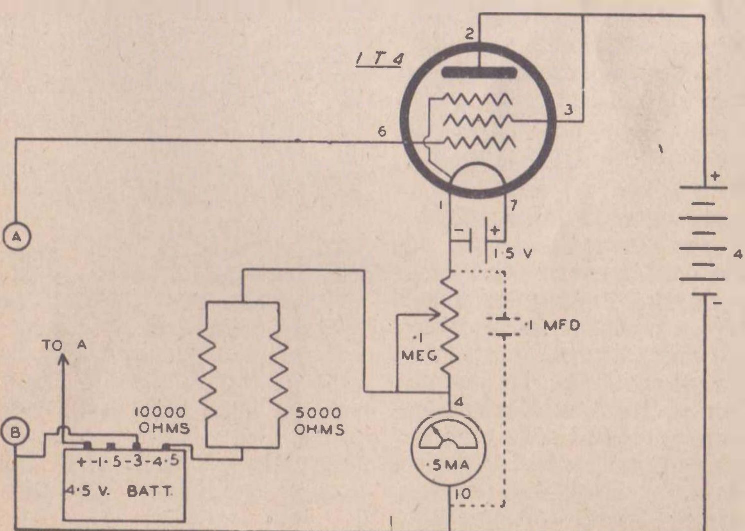


Fig. 32

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.

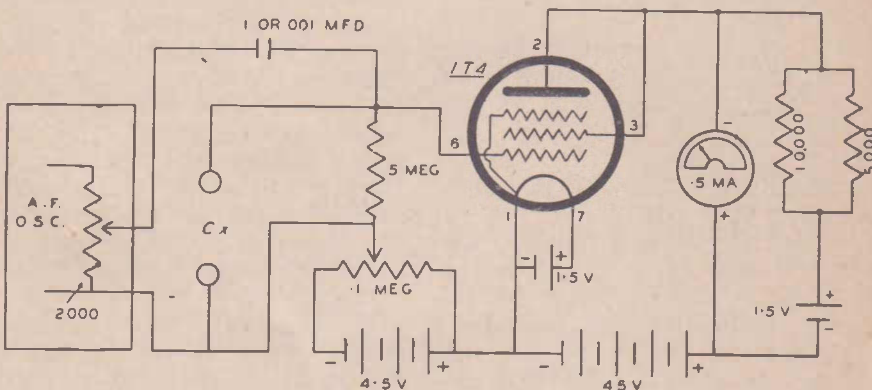


FIG 33

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-

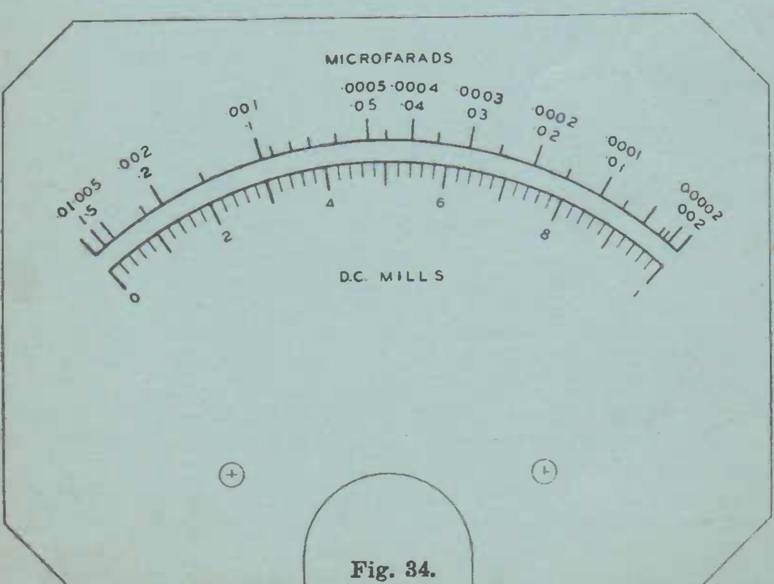


Fig. 34.

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.