Junior Teach Yourself Books

EDITED BY LEONARD CUTTS

RADIO
FOR BOYS

Junior Teach Yourself Books

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Ballet for Boys and Girls
Model Railways for Boys

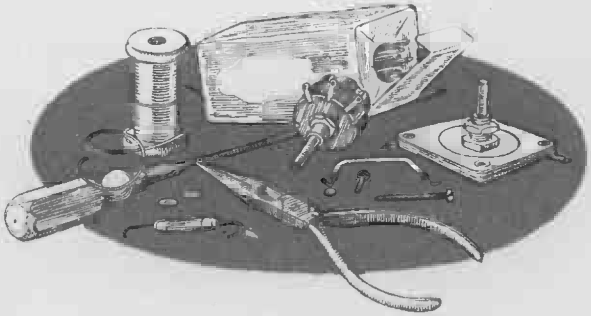
A Junior Teach Yourself Book

RADIO FOR BOYS

BY

EDWIN N. BRADLEY

A.I.P.R.E.



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Contents

Why Radio?

"IT was about half-past twelve when I heard three little clicks in the ear-phones. Several times they sounded, but I hardly dared believe. Can you hear anything, Mr. Kemp? I asked, handing the receivers to my assistant. Of course (he told me); the letter S in Morse. And then I knew that I was right. Electric waves were being sent out from Poldhu and were spreading over the Atlantic, serenely ignoring the curvature of the earth, which so many doubters had told me would be a fatal obstacle. And in those moments I knew that the day was not far off when I would be able to send full messages, without wires, across continents and oceans."

That experiment of Marconi's, described in his own words, was not the first wireless transmission but on that day, December 12th, 1901, when he heard in Newfoundland the signals which were being transmitted from Cornwall, a new chapter of history commenced.

Today even the beginner in radio knows more than Marconi knew at that time—he knows, for example, that wireless waves travel round the earth's curvature by bouncing or reflecting from an electrified layer of air high up in the atmosphere and the surface of the earth itself, whilst on any ordinary radio receiver with short wave tuning, signals from America and even further afield can be heard at almost any time of the day or night. The beginner is used to the idea of television and knows that television in natural colours is somewhere on the way, and he knows something, too, of radar and of radio navigation which can guide ships and aircraft through fog and cloud.

But those of us who have chosen radio for a hobby know something even more important than all these remarkable inventions—we know that there is still a good deal to learn, and still more remarkable inventions to be made, and to judge from the past it might well be the amateur and the home constructor who helps to make them.

Just as you have to get wet before you can learn to swim so, in radio, you have to learn one or two things before you can start building sets, and that is why this Introduction is written in three parts. This, the first part, is very short; its chief job is to tell you that if you are thinking of making radio your hobby you have had a very good idea indeed. In fact wireless is more than a hobby for after a while it turns into a sort of lifelong friend, and might easily become your job, as it has for thousands of us.

The second tells you just a little about electricity and the parts you will be using in your receivers. If you want to, you can forget Part II for a while and after reading Part III you can start building the Crystal Set shown in Chapter I straight away; as soon as you want to know what is happening in the capacitors and coils and wires you can come back to Part II to find out.

Part III gives a list of tools required and some hints on construction. Chapters I to VII show you how to make a selection of sets and take you, step by step, through the whole business of construction.

Where Do We Go From Here?

After getting wet and learning to swim, the wise man starts to specialise. He develops one stroke, he learns to dive and probably develops one particular dive, too; perhaps he goes on to make life-saving his chief interest, and so on. Nevertheless, the person who is satisfied when he can plop in off the second board and do a length without too much splashing has a lot of fun too, and it is much the same in radio. The receivers described are of the "broadcast" type—they receive the medium and long wave bands and, in the last two circuits, the general short wave band too, and many home constructors are very happy to go on building this sort of receiver, learning more and more about them, and finding their own pet circuits. Others begin to specialise. Some work for their "ham" transmitting licences (you cannot transmit without passing a written exam. on transmitter and receiver theory and a practical test in Morse transmission and reception), and others, like myself, spread our interests far and wide over the whole great range of radio, until we find pleasure in any apparatus that uses a valve or what is called an "electronic" circuit. Others again concentrate on the fascinating study of television, not only building, but designing, their own receivers and, in some cases, their own transmitters as well, even running little television shows with their friends as actors and artistes.

And—this is the point—practically every one of them started where you are starting as you read this; with the construction of simple broadcast receivers. There is always something new in radio, always another step to take and another valuable fact to learn, and that, for most of us, is its real and deepest charm. I have never yet found a "radioman" who has grown old and stale.

Before you start specialising after you have successfully built some or perhaps all of the receivers shown in this book, there is something else to learn, with yourself as the teacher. This next step is to work and construct from circuit diagrams only, without guidance from chassis drilling diagrams and under-chassis views. At first this may seem difficult but, like other things, it is a knack which comes with practice; in this case a "feeling" or sense of layout. You will notice in the receivers you build that the signal is carried from the aerial to the loudspeaker or headphones in a series of stages, step by step, and that these steps are actually built one after the other on the chassis. In each stage the parts or components are kept neatly together, the wiring as short as possible, and the signal is taken both to and from the stage by the most direct routes. If you become interested in short wave working and eventually build very short wave receivers, or television sets, you will find that layout and arrangement of the components is then one of the most important points in the whole receiver. A stray inch of wire, or a misplaced component, can cause serious trouble in a televisor which is, as a result, a most interesting challenge to its designer.

Wireless receivers work properly only when they are built properly, and there is no room in them for carelessness. I remember a visit I once paid to the workshop of a well-known designer who showed me a little broadcast receiver built by one of his readers. Despite the fact that the set had been constructed from carefully prepared blueprints it looked nothing at all like the designer's own original set which stood next to it—capacitors and wires were draped about it everywhere, even round the frame of the loudspeaker, and quite naturally all it produced were howlings and screechings. It was, as we say, full of "feedback," because the signals, instead of being taken directly from stage to stage were being lead about anyhow. The person who built it was highly indignant, of course, and blamed the poor designer, quite ignoring the fact that the designer's correctly built original worked beautifully.

Always follow the design when it is supplied, for that is the first step towards learning to make your own layouts.

Remember, too, that you are dealing with delicate gear and handle your parts with care. Bare wires badly placed, or impatiently made connections to batteries can cause serious damage to valves, but there is no need to feel worried about this, or to think that there is anything really difficult in building a good receiver. It is simply a case of realising that carelessness brings its own rewards—unpleasant ones—and so working carefully and unhurriedly.

When you can make your own layouts, take the next step and design your own receiver. A simple one, at first, with, perhaps, only one or two valves. Choose your own valves, your own component values, and make up your own circuit. You will realise, of course, that you will not reach this stage without studying your subject, but here again radio can be far more interesting and, indeed, exciting, than many other hobbies. Not only are there dozens of good books to dip into but as soon as you have managed to collect a spare valve or two, and some odd components, you can experiment and prove what you have read. As an example there are a tremendous number of experiments to carry out on the subject of oscillators alone (we shall be describing an oscillator later on) with no more gear than a valve, one or two capacitors and resistors, and a coil or two which you could wind yourself, with perhaps a cheap voltmeter or milliameter as an indicator.

So far as meters and many components are concerned you could not be starting in radio at a better time, for there is still a great amount of "war surplus" material on the market. You will not use any of this when building the receivers in Part III but when you commence experimenting on your own account you will soon find some very useful bargains.

Magazines

In radio the amateur can be as far advanced in technical knowledge and skill as the professional, and so there are several magazines which cater for radiomen of all types. A complete list of them here would not be very helpful for the majority would be much too advanced for you. You would do well to start, though, by reading *Practical Wireless* which month by month gives many circuits of all kinds, some of which you could build and others of which might give you ideas for experiments. There are many articles, too, to help on your knowledge of component operation, testing and repairing, measuring instruments and several other subjects which cannot even be mentioned in this book.

If you feel interested in television *Practical Television* will start you off on TV. circuits with, once again, articles which explain how the television signal is built up, how pictures are received and so on.

You could also try a little magazine called *The Radio Constructor* which is published each month.

You will not understand everything you read in these magazines all at once, but if you keep on patiently reading and fitting your bits of knowledge together you will be surprised at how fast you learn, and the number of ideas which come to you. I started by reading *Practical Wireless* myself, understanding about one word in five at first, but when I was fourteen I made two quite interesting inventions both connected with impressing sound on wireless waves. Two or three days later, after more reading, I discovered that both my inventions had been made long before and, worse still, that neither system was much use and so had gone out of fashion, but at least I had been using my mind!

American magazines also deserve some mention, though at present you will not find them easy to come by, and they are rather expensive. They are extremely practical, however, and much bigger than our own. The best known are *Radio-Electronics* and *Radio and Television News* with *Q.S.T.* for those who are aiming at a transmitting license.

Radio Clubs

Another grand way of learning more and sharing your experience with others is to join a radio club. Perhaps you have one at School—if not, why not start one? It could be quite small at first, but if it was well run and did good work you might be able to obtain permission to meet at the School—in the laboratory, for example—and you might find a master or two who would be interested and give talks and demonstrations.

To run such a club properly you should have an inaugural meeting to elect officers—at first a Chairman or President would be sufficient but later on a Secretary and a Committee could also be elected. Once you were established you could begin to branch out and to arrange visits to manufacturers and, possibly, radio stations, though you will generally need a "sponsor"—a grown-up—to make these arrangements.

Those of you who are Scouts might ask your Scouters about Scout Troop transmitting licences, which permit a Troop to have a system of "walky-talky" transmitter-receivers. There are, of course, many requirements to fill, as for any other transmitting licence, but if you are interested these should be no more than a spur to encourage you on.

We started with Marconi and have reached Scouting so perhaps we might finish with a mixture of the two. My own Troop (unofficially we call ourselves the "First and Last" since the Land's End is only two miles from our H.Q. and we are the Troop nearest to it), has a little week-end camp site perched steeply over a wooded valley on the Cornish coast where Marconi often visited and walked, and we swim in the bay where his yacht "Elettra" often anchored. There's no getting away from radio!

PART II

Electricity

ALTHOUGH we still have a great deal to learn about electricity we are now fairly certain that an electric current is made up of electrons—tiny negative particles. All atoms contain electrons rotating like planets round a core, and when a voltage is set up across the ends of a conductor, such as silver or copper wire, electrons leave their own atoms and jostle along to other atoms, their places being taken by other electrons in turn. This movement of electrons is an electric current, and the greater the voltage the more electrons move along at the same time.

Some materials such as porcelain, cotton, paper and many others do not allow their electrons to move even though a very high voltage is connected across them, and these are called insulators. Other materials, like iron and carbon, only pass a current poorly, and these are said to show resistance. All conductors show some resistance, but the resistance of good conductors is very low.

The electrical units, volts, are named after the Italian Count Volta whilst the unit of current, the Ampere, is named after a French scientist. In radio the ampere, or amp. is too large for most applications and so we deal chiefly with milliamperes or mAs., for short, which are thousandths of an ampere.

Volts are a measure of the "Electro-Motive-Force" or E.M.F. across a cell or battery or other supply, or of the "Potential Difference" or P.D. across points in an electrical circuit.

A voltage can be obtained and a current set flowing in two different ways—chemically and inductively. A cell or battery sets up a voltage chemically—two different materials, generally zinc and carbon, are surrounded by an "electrolyte" which is a chemical solution and chemical action sets up a voltage across the two materials or "electrodes" of the cell. A battery is a collection of cells, joined positive to negative to step up the voltage, and the technical signs for a cell and a battery are shown in *Fig.* 1. Most cells these days are "dry cells"—the electrolyte is made in the form of a paste so that there is no loose liquid in the cell.

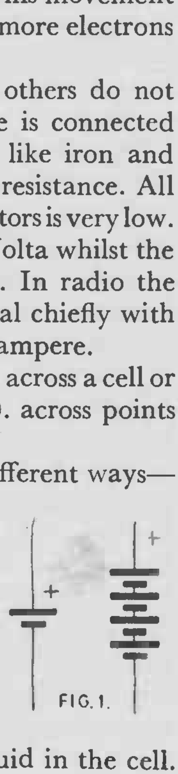


FIG. 1.

In ordinary batteries the zinc case is the negative electrode and so when this is joined by a wire to the carbon or positive electrode electrons flow from the zinc, round the circuit, and back to the carbon. Electrons are like magnet poles, and repel each other; you will know that two north poles of magnets try to push each other apart, but that a north pole is attracted strongly by a south pole? In a similar way electrons will flow from a negative battery pole and be attracted towards a positive pole—electron flow is thus from negative to positive.

This may bother some of you who are learning electricity in school for you may have been told that current flow is from positive to negative, the exact opposite. Unfortunately very little was known about electricity when it was first used, and this old idea of current flow was no more than a guess, and a wrong one at that. Nevertheless the idea of current flowing from positive to negative has remained and is still used by many electrical engineers.

Before going on to see how electrical currents are generated by induction it is necessary to understand the difference between Direct Current and Alternating Current. These are not two different types of electric current, but simply currents acting in different ways. A direct current—known as D.C.—is current flowing as it would from a battery, steadily and in one direction. Alternating Current or A.C. flows first in one direction, then reverses (that is, alternates), and flows in the other direction. This means, of course, that the voltage signs at the ends of the circuit change too, the current always flowing from negative to positive.

The graph of an alternating current is shown in *Fig.* 2—the same curve also serves to show an alternating voltage. Note that the current changes are not abrupt; the current starts at zero, rises to a maximum, falls back to zero then reverses its direction and again rises to a maximum and so on. A complete round of operations from zero current to reversal at zero back to zero current is called a "cycle" and the alternating mains have a "frequency" of 50 cycles per second or 50 c.p.s.

You will see that two different values for the wave are shown in the diagram, "Peak" and "R.M.S." values. Since the peak value is only reached for a tiny fraction of a second in each half-cycle this cannot be taken as the actual voltage or current and it is found that the "Root Mean Square" value gives a true indication of the voltage or current as compared with D.C. As you might guess the term R.M.S. refers to a mathematical method of discovering the voltage and current values along the wave, but the method is not nearly so important as one or two simple facts about A.C.—

1. The R.M.S. value of alternating current has the same heating effect in a conductor as an equal direct current.

2. The R.M.S. value of a wave is always taken for granted unless the peak value is specially mentioned. When we say 230 volts A.C. mains we mean 230 volts R.M.S.

3. The peak value of the wave is 1.414 times the R.M.S. value, so that the peak value of a 230 volts supply is actually 325.22 volts. All the more reason to avoid electric shocks!

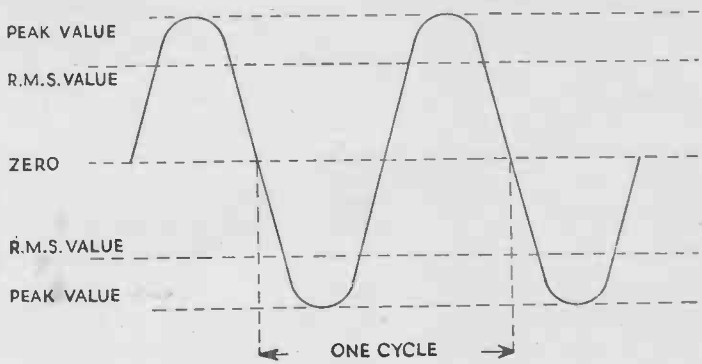


FIG. 2

4. For mathematical and mechanical reasons the shape of the wave in *Fig.* 2 is called a "sine wave", and these facts refer only to sine waves. There are other wave shapes of various kinds, but in radio work we are concerned chiefly with smooth, regular sine waves or very irregular waves such as are produced by a microphone. These irregular waves are called "speech" or "sound waves," or "low frequencies," and their shapes are really electrical copies of sound waves in air.

Resistors

Before we reach the method of generating electricity by induction we must understand the behaviour of D.C. and A.C. in a resistance. A body which exhibits the property of resistance is called a "resistor" and practically all radio receivers use a good many resistors of different values. These resistors are made by depositing a thin film of carbon on an insulating rod, or by mixing a little carbon with an insulating compound.

Resistance is measured in "ohms" after the Bavarian scientist Ohm who discovered Ohm's Law. This law states that voltage, current and resistance are coupled by the simple formulae

$$V = I \times R \quad \text{or} \quad I = \frac{V}{R} \quad \text{or} \quad R = \frac{V}{I}$$

where V is the voltage across the resistance R, and I is the current in amperes flowing through R. Therefore if a steady current is made to flow through a resistance it causes a voltage to be set up across the ends of the resistor, the voltage depending on the current and the resistance in ohms. The resistor is using up power, too, and so tends to get warm.

The values of radio resistors vary from a few hundreds to some millions of ohms. A one million ohms resistance is called a Megohm, and sometimes a one thousand ohms resistance is called a Kilohm. The symbols for a fixed resistor and a variable resistor or potentiometer are shown in *Fig.* 3 and you will often see similar symbols in circuit diagrams with the numbers and letters showing the resistance values; for example the symbol with 10K beside it indicates a 10,000 ohms resistance.

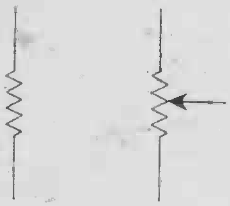


FIG. 3.

FIG. 4

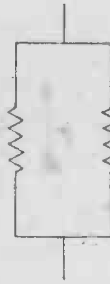


FIG. 5

Variable resistors—the symbol with an arrow touching the zig-zag track—are used for many purposes and especially as volume controls. They are circular and have a rotating spindle which moves a contact arm over a carbon track to make contact at any point required between the ends of the resistor. Suppose, for example, that a resistor of this type had a D.C. voltage of 10 volts set up across it. Voltage drops steadily across a resistor, and so by moving the contact arm we could tap off any voltage or potontial we required between 0 and 10 volts. This type of resistor is therefore known as a potentiometer.

Resistances in series are added together to discover the final value. Resistances in parallel follow a rather complicated law which you can find for yourself, with many other interesting facts, from any good electrical text book—your local library will probably have several which you could borrow. Resistors in series and parallel are shown in *Figs.* 4 and 5.

Radio resistors, besides being rated in their values in ohms, are also rated by their "wattage"—that is the power which can be used up or "dissipated" in them. Most of the resistors you will employ will be of the half-watt type. A watt is a measure of electrical power and wattage is discovered by multiplying the volts across a circuit by the amperes flowing. If too much current is forced through a resistor it will overheat and break down, and so a radio designer must choose the correct power rating of a resistor, as well as the correct resistance.

Resistors, in radio sets, have two chief tasks—to provide correct currents and voltages for valves, and to pass on signals from one valve to another, or one stage to another. Tiny varying currents due to radio signals are made to flow through resistors, so setting up voltages across them, and these varying voltages are then passed on to further sets of valves, resistors, coils and so forth for more amplification. Remember that if quite a tiny current can be made to flow through a high resistance it will set up a surprisingly high voltage.

The Resistor Colour Code

Most resistors have their resistance values marked in a code of colours, each colour having a particular meaning, depending on its placing in the code. In the diagrams the three most usual methods of marking the resistor are shown.

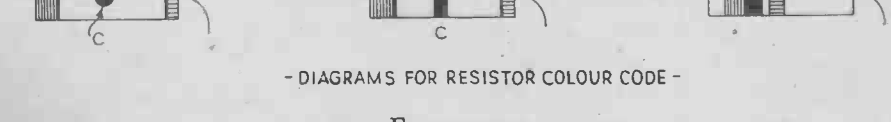
The resistance value is taken from the three colours A.B.C. in that order. D, not present on all resistors, shows the "tolerance" of the component. Resistors used in normal radio receivers do not need to be extremely accurate, so for ordinary work resistors which have values within 20% of the marked value are quite suitable. For more accurate work the type of resistor is generally specified in the components list; the next degrees of accuracy are 10% and 5%. For measuring instruments and very accurate work 1% resistors can be obtained.

In all the receivers to be described 20% resistors may be employed.

The Colour Code.

Colour.	*Meaning of Colour in Position:—* A	B	C
Black	0	0	—
Brown	1	1	0
Red	2	2	00
Orange	3	3	000
Yellow	4	4	0000
Green	5	5	00000
Blue	6	6	000000
Violet	7	7	Rarely used
Grey	8	8	Rarely used
White	9	9	Rarely used

At position D a Gold band shows a 5% resistor, a Silver band a 10% resistor and no extra colour at position D shows a normal 20% resistor.



- DIAGRAMS FOR RESISTOR COLOUR CODE -

Examples

First Diagram.

Brown body (1), Red tip (2), Yellow dot (0000) = 120,000 ohms.

Second Diagram.

Orange body (3), Orange carried on over tip (3), Brown centre band (0), =330 ohms.

Third Diagram.

First band, Brown (1), Second band, Black (0), Third band, Green (00000), =1,000,000 ohms or 1 megohm.

Tricky resistors which you will not come across at first are those with Black as the first or A colour. For example in some war surplus gear there are resistors coloured as follows (with bands as in the second diagram).

Black body (0), Green tip (5), Black centre band (Ignored), =05- ohms or 5 ohms. This is what this arrangement of colours should mean, but in some cases these resistors when tested are found to have actual values of 50 ohms.

All being well, however, you should have no trouble at all in being able to read off the values of the resistors which you will be using.

Induction

When a direct current is passed through a coil of wire wound on an iron cylinder or "core" the iron becomes magnetised. This effect was studied by Faraday, from whose experiments finally grew the electric motor, the dynamo, the telephone and, eventually, radio. Faraday's greatest discovery, after years of work, was to prove that the reverse is also true—when a magnetic field is set up in a coil of wire, a voltage appears across the ends of the coil and a current flows through the coil if its ends are joined to complete an electrical circuit. This "induced" voltage appears only when the magnetic field is varying in strength—we say that the lines of magnetic force must "cut" the wires of the coil. One obvious way of causing this to happen is to rotate a coil in and out of a steady magnetic field, as in a dynamo.

Now imagine two coils of wire wound on the same core, one beside or on top of the other. When a current is passed through one coil the core becomes magnetised and the growth of this magnetic field causes a voltage to appear across the ends of the second coil. If the first coil is fed with alternating current the magnetic field will always be varying and so an alternating voltage will appear across the ends of the second coil. An alternating current will flow through a circuit connected to the second coil. Two such coils make up a "transformer," and transformers of different types are used a great deal in radio receivers.

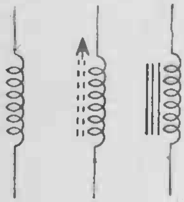


FIG. 6.

A voltage is also induced across a single coil of wire when a current is passed through the coil for the wire is cut by the magnetic field which it is itself producing. The induced voltage always opposes the original potential across the coil, and so is called a "Back E.M.F." When a coil is supplied from a source of direct current the Back E.M.F. appears only when the current is switched on and off for only then does the coil's magnetic field vary in strength, but in a coil fed with alternating current the Back E.M.F. is always present and the coil then acts as a sort of energy store—current flows in and out of the coil yet no power is used up apart from the small amount of energy needed to overcome the resistance of the coil.

A coil used in this way can be said to act as a "choke" for it will pass D.C. easily and yet oppose A.C. Choke-coils, or chokes, are used in several radio circuits.

In *Fig.* 6 are the symbols for various types of coils or inductances. On the left is an air-cored coil; this has the turns wound on an insulating former with a hollow centre. The next symbol shows an iron-dust-cored coil; in this type the core is of tiny particles of iron held in a plastic compound. On the right is an iron cored coil, wound on a former which has inside it a core built up of sheets of special iron, called laminations.

Inductance is measured in units called Henrys after an American professor who lived at the time of Faraday and who carried out similar experiments. The iron-cored coil is a type used in mains receivers as will be described; it would have an inductance of perhaps 10 or 20 Henrys. The air and iron-dust-cored tuning coils have much smaller inductances, generally measured in micro-henrys or millionths of a Henry.

Transformer symbols are shown in *Fig.* 7, that on the left being of a high frequency transformer and that on the right being the symbol of a low frequency transformer. As you will see, the only difference in the symbols is in the core, although in actual fact the windings themselves would be very dissimilar in the actual components. Many tuning coils are actually high frequency transformers, whilst low frequency transformers are used for such purposes as supplying various voltages and currents from the mains, and passing sound frequencies from a valve to a loudspeaker.

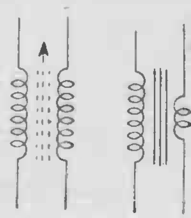


FIG.7.

It is important to know that the size of the windings on a transformer control the induced voltage and current. Suppose that the coil to which energy is supplied—this is called the "primary" coil—has ten times the number of turns on the coil in which current is to be induced—this is called the "secondary" coil. If alternating current at, say, 10 volts, is fed to the primary, only 1 volt will be drawn from the secondary, though the secondary current will be ten times as great as the primary current. If the secondary coil has ten times the number of turns on the primary, 10 volts across the primary would give 100 volts across the secondary, though in this case the secondary current would only be one-tenth of the primary current. It is easy to see, then, how valuable a transformer can be when a source of A.C. is available—the mains transformer in an A.C. receiver can have a primary to suit the 230 volts mains and secondaries which will supply all the different voltages and currents required in a receiver.

Remember that transformers do not work on D.C.—the current must be varying or alternating so that the magnetic field round the primary is also varying or alternating.

Frequencies

The word "frequency" has already been used a good deal and it will occur often throughout the rest of the book. We have seen that the A.C. mains have a frequency of 50 c.p.s. because the current goes through two complete alternations at that speed—we shall see in Part III that a radio wave induces alternating currents in an aerial and that these currents have far higher frequencies. The slowest alternating wave used in Great Britain for broadcasting has a frequency of 200,000 c.p.s. whilst radar waves have frequencies of 10,000,000,000 c.p.s. A quick glance through the *Radio Times* will show you that radio stations are listed by both a frequency and a wavelength. The wavelength is actually the distance, in space, between complete cycles or oscillations, of the radio wave, and it and the frequency are connected by a simple formula:—

Wavelength x Frequency = 300,000,000 where wavelength is in metres and frequency is in cycles per second. For convenience we deal in kilocycles (kcs. for short), which are thousands of cycles, and megacycles (Mcs. for short), which are millions of cycles.

The figure of 300,000,000, is actually the speed of light in metres per second (and it is now slightly incorrect, for recent work has shown that light travels even faster than we thought!) and from this we see that radio waves also travel at the speed of light—at least in free space; they slow down when travelling along wires or cables. Electrons themselves do not travel at these high speeds—an ordinary electric current, it has been said, travels along a wire at no more than walking speed, about three miles per hour.

Capacitance

In most radio receivers there are as many condensers as resistors, and these components play very important parts in the working of all radio gear. Condensers or—a better name, capacitors—exhibit capacitance and consist in one way or another of sets of conductors near one to the other but insulated. The symbols used for capacitors are shown in *Fig.* 8.

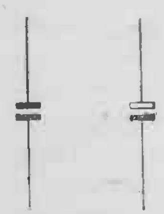


FIG. 8.

Most capacitors have two sets of metal plates interleaved and separated by waxed paper, mica, porcelain or similar insulators. Air can also be used as an insulator, and capacitor construction can most easily be seen by studying a variable or tuning capacitor which you will find in any normal radio receiver.

Since the two sets of plates are insulated it is clear that if a capacitor is connected across a battery a steady current cannot flow. Nevertheless there is a short, rapid flow of current, fairly high at first but soon falling, then ceasing, as the capacitor "charges up." One set of plates becomes rich in electrons, the other set becoming correspondingly poor, so that if a capacitor is charged up by being connected across a battery for a few moments, it can be discharged by connecting a wire between the two sets of plates. If the battery voltage was sufficiently high and the capacitance sufficiently large, the discharge will take the form of a vigorous spark.

If A.C. is fed to a capacitor it will commence to charge on one half-cycle but will then find the voltage falling and will therefore discharge, endeavouring to charge up once more on the next half-cycle, and so on. As a result a capacitor appears to pass current when connected to a source of alternating current, though in actual fact it is rather like the coil mentioned earlier—no power is consumed. A capacitor can thus pass alternating and varying waves whilst "blocking" direct current, and it is used for this purpose in many radio circuits.

The unit of capacitance is the Farad, after Faraday, but for ordinary purposes this is far too large and we employ millionths and million-millionths of Farads in radio work. A millionth of a Farad is called a micro-farad (mfd. for short) and a million-millionth of a Farad is called a pico-farad (pfd. for short). The Greek symbol μ is often used to express the "micro" in mfd. thus, μfd.

The symbol mF. would properly mean a milli-farad or thousandth of a Farad, but since this value of capacitance is hardly ever used it is becoming quite common to employ the term mF. in component lists to stand for mfd. or μfd. This symbol is used in the component lists later in this book, where, for example, 8 mF. is read as "eight micro-farads."

Small capacitors are sometimes stamped with their values in decimals of mfd. two common values being 0.0001 and 0.0005 mfd. If you remember that these are the same as 100 and 500 pfd. you will not go wrong.

All capacitors have a working voltage which must not be exceeded, otherwise the insulator between the plates might break down and the component become worthless, besides damaging other parts or valves. New capacitors of good make should always be used.

Tubular capacitors—the name describes their shape for they are enclosed within a cardboard tube—have a black ring at one end; this end is generally connected to the negative side of the circuit. Electrolytic capacitors must always be connected up with great care, for these have their plates separated by a chemical solution and thin layers of gas set up by chemical action. If the capacitor is connected up incorrectly the gas layer is destroyed and the capacitor passes a heavy current. Since these capacitors are generally employed in circuits where there are fairly high voltages and currents this might well cause serious damage. All electrolytic capacitors have their polarity clearly marked, and in circuit diagrams the positive plate is shown by a hollow bar, the negative plate by a solid bar, as in the right hand symbol of *Fig.* 8. Electrolytic capacitors must never be used in purely A.C. circuits—there must always be some D.C. across them to maintain the correct polarity.

Tuning

A radio set is tuned to the frequency of the desired signal by a capacitance and an inductance. A coil presents a "reactance" to alternating current—because a Back E.M.F. is set up—and this reactance, which is measured in ohms, since is it rather like a resistance, increases as the frequency of the A.C. rises. A capacitor also has a reactance but the reactance of a capacitor to A.C. falls as the frequency rises. If a coil and a capacitor are connected in parallel, therefore, there will be some frequency at which they both have the same reactance and then the energy stored up in the magnetic field round the coil will combine most efficiently with the energy stored up in the capacitor. The whole circuit, which is said to be "resonant" to that particular frequency, will act rather like a pendulum which can be kept swinging strongly with very light taps at the correct moment. A current swings back and forth through the tuned circuit of the coil and capacitor if the circuit is excited at the correct frequency by tiny currents from, for example, an aerial.

In ordinary receivers the capacitor is made variable so that the tuned circuit can be adjusted to any required frequency. Generally more than one coil is used, the correct coil being chosen by a switch, so that for the Light programme on the Long wave band a large coil is switched in, for the Medium wave band a smaller coil is employed, and so on, until for the Short waves coils with only a few turns of wire are needed.

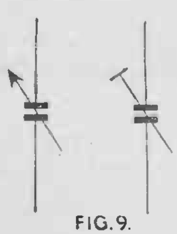


FIG. 9.

A variable capacitor symbol is shown in *Fig.* 9; it is a normal capacitor symbol with a sharp-topped arrow through it. A blunt arrow indicates a very small variable capacitor called a trimmer or padder; you will find more about these in later Chapters.

Most receivers use more than one tuned circuit and then "ganged" variable capacitors are used. Two variable capacitors are built together so that the moving sections move on the same spindle, and these two capacitors are connected to two identical coils. In this way both tuned circuits work at exactly the same frequency.

A circuit which contains both reactance and resistance, or two reactances, is said to have an "impedance." Two reactances, or a reactance and a resistance, in series cannot have their values in ohms added together to give the final impedance; a special mathematical formula must be used and this you will not need to know for quite a time.

Valves

The first components noticed in any radio receiver are the valves. Everyone knows that they are important, and do strange things, and also that there are a great number of different sorts all coded by various sets of letters and numbers, but once you know just a little about electrons and the way they flow you will find it quite easy to understand the principles, at least, of valve operation.

The first work on valves was carried out by our own scientist Sir Ambrose Fleming. He was experimenting with electric lamps at the time, and was puzzled by the darkening of the glass after the bulbs had been used for a period. (It still happens now and then, even with modern bulbs and their improved filaments.) After a while he decided to put a small plate of metal into the bulb along with the filament so that he could test electrically what was going on inside the bulb in which, of course, there was a vacuum, and as he expected he found that tiny particles of the filament were being carried over to the glass. He found that the hot filament actually "boiled off" electrons, and by making his plate positive with a battery, the negative end of the battery being connected to the filament, he could set up an electric current through the vacuum itself between the filament and the plate. This was very promising, for up to that time radio detectors had been rather insensitive and peculiar gadgets, and this new type of lamp, called a diode because it had two electrodes, could be developed into a detector. As you will see when we reach the crystal set in Chapter I a radio detector must be able to turn A.C. into D.C. (we call this rectification) and a diode would do this easily. The electrons coming off the filament would only travel to the plate when it was positive—if it became negative it would repel electrons. If, then, an alternating voltage was put on the plate the electrons would only travel to it on each positive half cycle, and to all intents and purposes this is changing A.C. to D.C.

A further great advance was being made in America. Dr. Lee de Forest was also experimenting with lamps in which he had introduced metal plates, but he went further and put in a third electrode so that his new bulbs were called triodes. This third electrode was a grid or mesh of wire between the filament and the plate, so that electrons had to pass through this grid on their way from the negative filament to the positive plate. Very few hit the grid and so whilst the grid had no voltage of its own it had practically no effect on the current through the valve.

The grid, however, could be given a voltage which could be either negative or positive with respect to the filament. A positive voltage attracted more electrons from the cloud of electrons round the filament, and although some of these electrons were captured by the grid, the majority of them shot through and reached the plate. The plate current thus increased when the grid was made positive, and, in the same way, it fell quite rapidly as soon as the grid was made negative. The grid then repelled electrons so that very few could pass through it; instead they remained in a cloud by the filament.

But best of all was the fact that it needed only quite a low voltage on the grid to bring about these important effects, and so the triode valve was a most important invention—it was an amplifier, which could take practically any small electrical effect and amplify it, or strengthen it, many times. It meant that weak signals, only just audible in headphones, could be amplified up until they could work loudspeakers, but more important still was the fact that broadcast—that is, sound—transmission became possible. Until that time all radio transmission was in Morse code with transmitters often relying on spark coils, but it was found that the triode valve would "oscillate" in a simple circuit giving out continuous high frequency energy which could be made to carry speech and music.

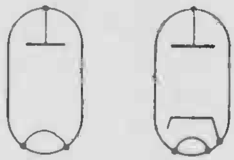


FIG. 10A. DIODE

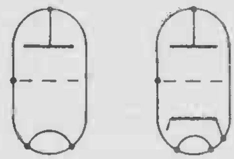


FIG. 10B. TRIODE

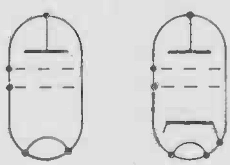


FIG. 10C. TETRODE

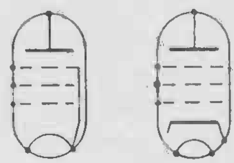


FIG. 10D. PENTODE

Other valves were developed from the triode which was discovered to be rather poor at amplifying radio frequencies. This was because the valve acted in a sense as a collection of small capacitors—there is capacitance between a filament and grid, and between grid and plate, and so on. These capacitances gave quite low reactance paths to radio frequencies, and so the valve worked inefficiently unless very special circuits were used. Eventually a "screen" grid valve was developed with an extra grid between the first grid, or control grid, and the anode, the new grid being called a screen grid since it broke up the unwanted grid to plate capacitance. The screen grid was made almost as positive as the plate, but was connected to the filament by a large capacitance.

The screen grid or tetrode valve (tetrode means four electrodes) was used for years, but was still not so efficient as could be desired and it eventually gave way to the pentode or five electrode valve now employed to a very great extent in all types of radio gear. The pentode has a further grid, called a suppressor grid, placed between the plate and the screen grid, and connected to the filament. This new, third, grid suppresses a stray emission of electrons from the anode to the screen grid which sometimes occurred in the tetrode; this "secondary emission" was caused by electrons from the filament being speeded up by the positive potential on the screen grid to such an extent that they knocked or "bombarded" electrons out of the plate, these secondary electrons then being drawn to the screen grid. The suppressor grid turns these secondary electrons back to the plate so that in the pentode they can no longer reach the screen grid.

Whilst the Americans still use the term "plate" for the positive electrode, we now employ the term "anode." In the same way we call the filament the "cathode," anode and cathode meaning positive and negative electrodes. In mains valves the filament is no longer the cathode but instead heats up a metal tube which acts as a cathode. Battery filaments and the tube cathodes of mains valves are coated with special compounds which give off clouds of electrons when heated.

Different types of valves are shown in *Fig.* 10, starting with the diode—note the cathode in the second diagram, drawn as a line over the filament, and the anode at the upper end of the valve. Then comes the triode with the control grid between the cathode and anode, the screen grid and finally the pentode valve—sometimes the suppressor grid is connected to the filament within the valve, and sometimes it is brought out to its own connecting pin.

There are, of course, different types of triodes, pentodes, etc., to carry out different jobs; for example one type of pentode you will use is designed to give a highly amplified voltage output while another type, called an output valve, is designed to give a high current output to operate a loudspeaker. The output from a valve is almost always taken straight from the anode. The anode is connected to the H.T. line through a "load"—a resistor or coil—and the varying currents in this load set up varying voltages across it which can be led off to further stages. The H.T. line is the High Tension positive voltage supply whilst the Low Tension filament supply is known as the L.T. line.

Some valves, especially output valves, also require a third voltage supply known as G.B.—Grid Bias. This is a steady potential on the control grid of a few volts negative, which prevents the grid ever becoming positive and so passing grid current. Except for special reasons, one of which you will meet in the one valve receiver soon to be described, a valve's control grid is not allowed to pass current as this leads to distortion and incorrect working of the valve.

Connections to the valve's electrodes are made by inserting the valve into a holder which connects with the valve pins. The valves you will use are called "International Octal" types and fit into an 8 socket holder. The valve base has a leg or spigot which fits into the valve holder in only one way, and the connections to the valveholder are made to suit the valve to be used. On the circuit diagrams the valve electrodes are coded with a number from 1 to 8, a small "key" diagram showing the 8 sockets, with their numbers, on a valveholder. The key diagram and numbering are always given looking at the valve pins and the underside of the valveholder. Many valves have a further connection—the control grid is brought out to a small top cap so that it is far from the anode connection and the grid-anode capacitance is kept low.

Valves must always be handled with care, and inserted and withdrawn from their holders very gently. Always hold the valve base, never the glass bulb, when handling valves and especially when taking them from the holders.

The various numbers and letters given to valves are simply a means of identifying them, and they are chosen by the valve manufacturer to indicate the type of valve, its filament voltage and current, and so on. As you gain experience you will learn several valve numbers but there is no point in storing them up in dozens in your head. There are several excellent "Valve Data Books," some quite cheap, and one of these will give you all the information you need about ordinary valves.

PART III

Tools and Soldering

A GREAT deal could be written about tools but perhaps the best way to learn how to use and treat them is by practice. For radio work you will not need many tools at first and a few hints may help you to choose and use them well.

Screwdrivers—use a screwdriver whose blade is as wide as the screwhead, so that it fits the slot well. Make a collection of different sizes as you can afford them.

Pliers—start off with 5 in. flat-nosed pliers, then obtain some small round nosed pliers. You can collect pliers for years.

Cutters—*old* scissors will do at first. Buy a pair of top or side cutters when you can.

Spanners—never use pliers on nuts. Buy a set of Terry spanners, sizes 0-8 B.A.

Files—collect one or two small flat and half-round files for cleaning holes and the edges of chassis.

Drills—a good twistdrill and a set of drills is a valuable tool and makes a fine present. Use a "centre-punch" for marking the spot where a hole is to be drilled; a punch can be made from a stout nail. Lightly tap this on the drilling spot to leave a small pit for the drill to start off in.

Chassis punches—used for cutting out large holes in aluminium chassis; a chassis, of course, is the shaped metal sheet on which a receiver is built. See Chapter II.

Soldering—you will need a soldering iron and unless you have no mains electricity supply, buy the best electric iron you can afford; a "Solon" with a pencil bit is a good choice. Those of you without mains will have to use a small copper-bit iron heated in a flame. Such an iron needs a good deal of practice to use properly, as the bit must be kept at the correct temperature. Frequently wipe the bit with a pad of rag to keep it bright and clean.

Make a soldering iron stand with two strips of tin plate cut from an old tin and bent into W shapes. Turn these upside-down and nail them down to a block of wood so that the handle and bit of the iron each rest in the middle dip of the W at each end of the block.

Soldered joints are made by flowing molten solder over the jointed wires—they must be firmly made before the solder is applied. The solder makes an alloy with the metals which provides a good electrical path. The metals being soldered must be bright and clean—the whole secret of good soldering is lightly to scrape the metals first. An old razor blade makes a good scraper. The bright surface must be protected from the air and this is done by a "flux"; modern solders ("Ersin Multicore" is excellent and easy to obtain) contain their own fluxes. To make a joint, or to "tin" a metal, bring the soldering iron and the solder to the joint at the same time so that the flux melts and runs out over the metal. The flux then boils and the solder runs after it. Never use more solder than necessary.

The bit of the soldering iron must be tinned before it is used— the iron will have instructions with it and these must be followed exactly. Generally it is necessary to start by filing off a protective layer to expose the clean copper bit.

Connecting wire is sold already tinned and so needs no further tinning, but the tags on components and valveholders should be cleaned and tinned before joints are made to them. To tin a tag, flow a very little solder over it with the iron so that it forms a thin film on the metal, rubbing the tag with the iron if the solder does not flow at first. Avoid blocking up any hole in the tag.

Small resistors and capacitors have wire ends which are soldered directly into place, and not too much heat should be allowed to reach the body of the component. It is a good scheme to hold the wire end in broad nosed pliers, gripping it between the soldered joint and the component's body, to allow some of the heat to escape into the pliers.

The receivers described in this book have connections between components made by a length of tinned copper wire over which is slipped a length of insulating sleeving. The first joint is easily made, but when the sleeving is on the wire it is easily burnt by the iron when the second joint is made. Practice this type of joint, besides joints where rubber-covered flexible wire with several fine strands is connected to a soldering tag. Be careful, when making joints, to leave no blobs of solder which could touch other wires or joints, and clean out any drops of solder which fall amongst the wiring and components.

Once a joint is made, never move the wires or parts until the solder is set—this takes only a few seconds. Poor joints, called "dry" joints, have a brittle grey appearance and will give a great deal of trouble sooner or later. Dry joints must be remade with fresh solder.

CHAPTER I

A Crystal Set

A CRYSTAL set is the simplest wireless receiver that can be built, and for those who live fairly close to a transmitting station it is a good plan to start off on the hobby of radio by making this sort of set. It costs nothing to run, since it needs no batteries or mains electricity, and whilst it is of little use to those of you who live out in the wilds it gives good clear signals up to distances of roughly 50 or 60 miles from a strong station. A crystal set needs a very good earth and the best aerial possible, though often a bed-spring can be used as an aerial, a wire from the metal frame of the bed being connected to the aerial terminal on the receiver. A good earth is made by burying a copper plate two feet deep in the garden, a strong flexible copper wire being soldered to the copper plate, or an earthing rod can be bought and driven into the soil until it is almost completely buried. A flower bed under a window is a good spot for the earth, for then the ground will be kept moist and the earth lead-in can enter the house through the window frame. Ask if you can drill a small hole through the wooden frame, take the stranded flexible wire through and then seal the hole with putty; there is no need to insulate the earth wire. If you are not allowed to drill the window frame, or if it is of metal, a good earth can be made to a water pipe inside the house. Choose the "rising main" (the main pipe which goes up to the roof tank), if possible, clean its surface, and connect the earth lead to it by using a circular hose clip which you can buy for a penny or two at a hardware store. NEVER use a gaspipe or the conduit or earthed lead of the house electricity supply as a wireless earth, it can be dangerous as well as against the rules of the supply companies.

All receivers need an aerial of some sort, even portable sets which appear to have no aerial at all. (In portables the first tuning coil is made large enough, by being wound over a frame, to act as the aerial.) Usually an aerial is a straight length of wire, which draws energy from radio waves by having tiny electric currents induced in it by the waves on their passage through space. These currents flow up and down the aerial lead-in, through the first coil or tuned circuit of the radio set, and through the earth lead-in. They flow up *and* down because they are actually alternating currents at a high frequency.

The length of the aerial of an ordinary broadcast set is not very important, but it is worth while remembering that an aerial can actually be tuned to any wavelength and frequency by cutting it to the correct length—a half wave-length long. For the Long Wave Light Programme this would mean an aerial 750 metres or about 820 yards in length, which would be both unnecessary and ridiculous, but the amateur transmitting on 20 metres or so can quite easily arrange an aerial about 33 feet long to radiate strongly and efficiently, because it is tuned to the correct frequency. Some radar sets use aerials about 2 inches long, these tiny aerials throwing their energy into a curved reflector which sends the waves forward just as a torch reflector gathers all the light from a small bulb and transmits it as a single beam. The frequency of the waves from these sets is so high that it is found better to use specially designed metal tubes, rather than wires, for carrying the power from the transmitter to the aerial, or from the aerial to the receiver, the waves travelling along the tubing rather as though they bounced from wall to wall.

Modern radio receivers for the normal broadcast programmes are so sensitive that in many cases they work quite well from a small indoor aerial, and give all the stations needed at good volume. Nevertheless it is a fact that results would be better still if a good outdoor aerial were used, especially in the case of mains receivers. An indoor aerial must be fairly close to the house electricity wiring, and this wiring carries all sorts of interfering signals which can cause odd noises in the radio set. Any electrical spark sets up wireless waves—the first transmitters were spark operated—so that a refrigerator motor, a poor light switch or even an electric bell can send out waves and signals which travel along the house wiring. These waves affect the aerial and cause clicks, bangs, hissing and other noises to spoil the programmes. At the same time the indoor aerial is generally never very high, and height is important to a good aerial; the higher the aerial can be, the better it is.

To obtain the best results possible from the crystal set, then, an outdoor aerial, as high as possible and, say, 50 feet long or so, is the ideal to aim at, though a great many of you will have to be content with something much simpler. Wherever the aerial is placed it should be insulated at each end with proper aerial insulators which can be bought quite cheaply, and the aerial wire itself, as well as the lead in, should be of stranded copper wire which can often be found at Woolworth's. The lead-in need not be joined onto the aerial, for the end of the aerial wire itself can be brought down to the window where the earth wire enters the house. The aerial lead-in must be taken through the window frame by means of a lead-in tube; this has a brass connector running through an ebonite tube so that the actual connection is insulated. The lead-in should be kept away from gutterings and drain pipes and other metal objects which are connected to earth.

Once again, an outside aerial, like an outside earth, means drilling through a window frame, and if you cannot get permission to do this you will have to make the best of an indoor aerial. Use insulated copper wire for this, and experiment by running the wire along the picture rail in your bedroom. Generally a wire round two of the walls is best; don't forget to try the bedspring as an aerial, it often works well.

When you have an aerial and earth system which will work the crystal receiver you can be sure that it will give very good results with the other sets later on.

The circuit of the crystal set is shown in *Fig.* 1 in what is call a 'theoretical' diagram and in *Fig.* 2 the same arrangement of parts is shown in a 'practical' diagram. A comparison of the two illustrations shows how much neater and clearer the theoretical diagram can be, and all radio circuits are shown in this way. With a very little practice the symbols can be easily read; in *Fig.* 1, for example, it is clear that only 5 or 6 components are needed for the crystal set. These components are L, the coil, which has two windings separated and insulated from each other, C2, the tuning capacitor, which is variable, C3 connected across the headphones, the headphones themselves, and the crystal detector. C1 will be used only in some cases, this is shown by the dotted lines.

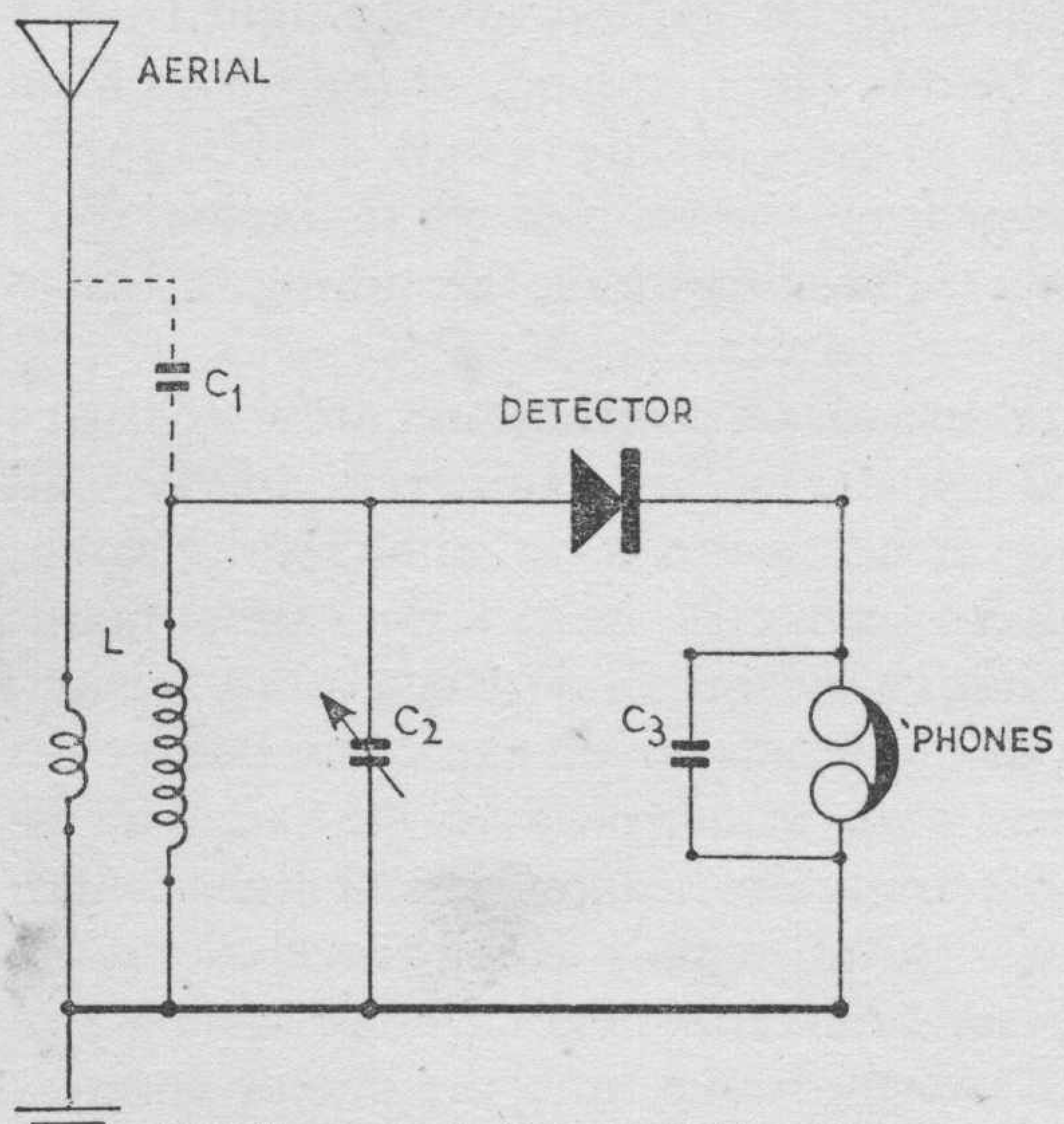


FIG. 1—THE CRYSTAL RECEIVER

The straight lines of the theoretical diagram indicate wires between the components; where these lines join in a dot an actual electrical joint is meant. If the wires meet with one 'jumping' over the other in a small bridge (this can be seen in *Fig.* 6) the wires do not connect at that point, and are insulated one from the other.

The aerial or input end of the receiver is always shown on the left and the output end on the right, and the heavier or thicker line along the bottom of each diagram is known as the 'earth line.' It will be seen in later diagrams that a great number of components are connected, on one side, to this earth line, and in the actual receivers it is very convenient to make this earth line the actual metal chassis.

Components for the Crystal Receiver, Fig. 1.

L Wearite PA2 coil.
C1 See below.
C2 500 pF. variable tuning capacitor. J.B. "Dilecon."
C3 500 pF. Mica. Type T.C.C. CM20N.
Semi-permanent crystal detector.
High resistance headphones.

C1 is used when the set is to operate at some distance from a transmitter, and when C1 is connected into circuit the aerial is no longer taken to the first coil, but goes straight to C1, whose other side is taken straight to the 'top' of the second coil. The value of C1 rather depends on conditions, but 100 pF. is usually about right.

It is a good plan to collect a number of capacitors and resistors as soon as possible, so that different values can be tried out in circuits. The best way to buy these parts is to watch the advertisements in magazines such as *Practical Wireless* and to buy components by post; for those of you who live in villages and small country towns this will sometimes be the only way.

The crystal detector is "Semi-permanent." This means that instead of the old-fashioned catswhisker a second crystal is used to make contact with the main crystal. The main crystal is held in a cup and looks silvery, the movable crystal is usually purple and must be treated with respect as it is not too strong and will not stand a lot of grinding or twisting. Once a 'good spot' is found, however, there will be no need to move the crystal again, whilst it is very easy to find a spot where signals come through clearly.

Make sure you have high resistance headphones. If you take a headphone apart you will find a diaphragm of thin, special, iron under the ebonite cap. Carefully *slide* this off to one side; underneath will be the two poles of a powerful magnet with a coil round each pole. (Some headphones are made differently; if you have a pair where the diaphragm is sealed into a perforated chamber do not try to dismantle them any further.)

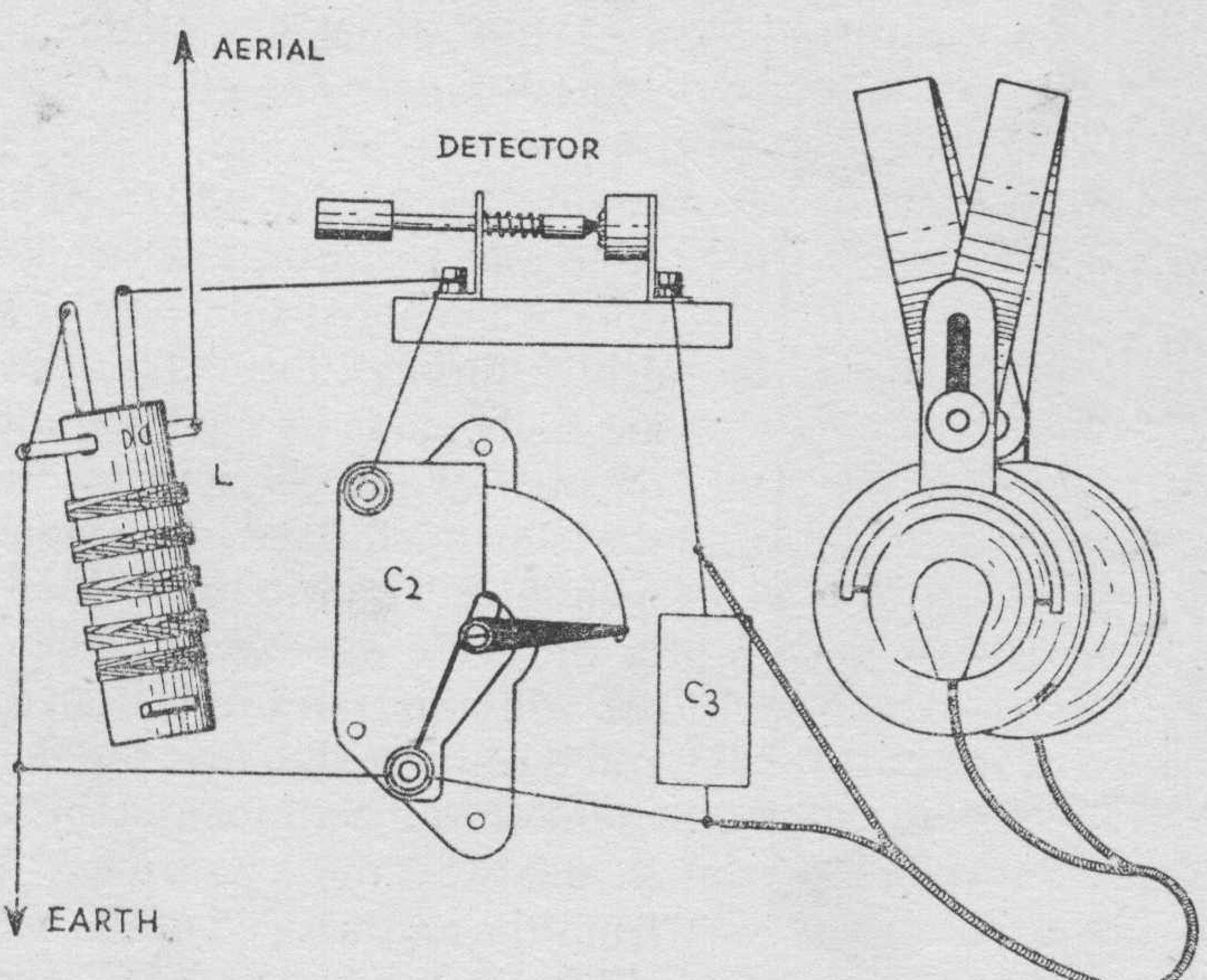


FIG. 2—THE CRYSTAL RECEIVER "HOOKED UP"

The resistance of the headphones depends on the number of turns and kind of wire in the coils, and for many purposes low resistance headphones are employed. For ordinary crystal sets these are not nearly so useful as high resistance headphones.

When you are buying the components, also buy some tinned copper wire for making connections, with some sleeving to slip over it as insulation. Make sure the sleeving is just large enough to run over the wire; good sizes are 22 S.W.G. tinned copper wire (S.W.G. stands for Standard Wire Gauge) and 1½ millimetre sleeving. Although it seems rather expensive at first, buying a good reel or length of each in one go is cheapest in the end.

Unlike other sets the crystal receiver can be built up 'anyhow.' You could build it neatly into a small box, but if you want to experiment with it, the parts can be connected up rather as they are shown in *Fig.* 2; you could also practice your soldering on them.

Things to Try

Fig. 1 shows one way of building a crystal receiver; there are other ways. There is no need to follow the parts list too closely for this set; for example practically any variable capacitor could be used as the tuner. The one shown is known as a "solid-dielectric" capacitor since the moving plates are separated from the fixed plates by thin sheets of insulator instead of air, which allows the capacitor to be made smaller than an "air-dielectric" tuner.

It is certainly worthwhile trying a home-made coil in the crystal receiver, when a different type of aerial coupling can also be tested. The coil is wound on a cardboard, or better still, a paxolin former, 2 inches in diameter and about 2 inches long, using 28 S.W.G. enamelled copper wire. 60 turns, wound neatly side by side are needed, with taps brought out at 30 and 45 turns. Each end of the winding is anchored in a pair of small holes drilled through the coil former. The taps are easily made by doubling the wire back on itself at the correct turn and twisting the loop thus formed into a pigtail about an inch long. The winding is then carried on in the same direction as before, and the tap will stand out firmly from the coil. The coil is connected so that the first turn goes to the crystal detector and the last to earth, in this way the 45 turn tap is 15 turns from the earthed end of the coil. The finished coil is shown in *Fig.* 3, and when this type of coil is used, the aerial is connected on to one or other of the taps, the best connection being found by trial. The effect of a small capacitor between the aerial and the tap can also be tried. The enamel must, of course, be cleaned from the wire ends and the taps with fine emery paper before a connection can be made.

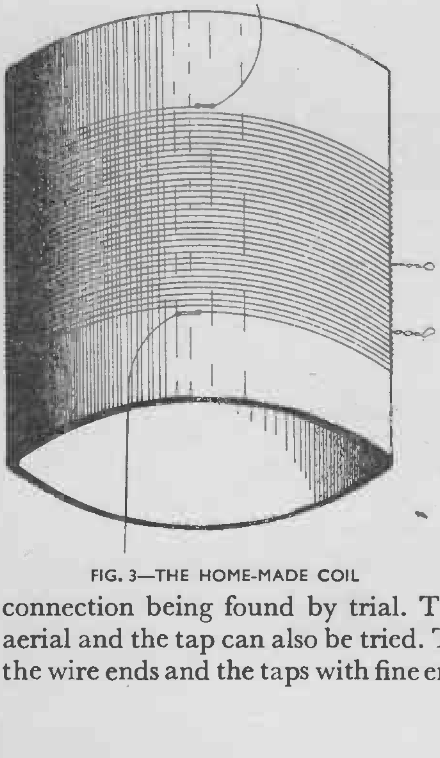


FIG. 3—THE HOME-MADE COIL

It is also possible to try radar crystals in the receiver instead of the ordinary crystals. Two types of radar crystals are shown in *Fig.* 4; in each case the connections are made to the metal ends of the crystal holder. There is no adjustable

FIG. 4—RADAR CRYSTALS

contact; inside the holder a very delicate spring is sealed into connection with a germanium or silicon crystal. Small clamps made from sheet brass can be used to hold the crystal and give contact with its ends; do not try to solder the connection onto the ends of the crystal holder.

How the Crystal Set Works

The currents in the aerial of a radio receiver, set up by the passage of wireless waves, can be drawn as the curves shown in *Fig.* 5. When the wave is not carrying speech or music (it is then called an "Unmodulated Carrier"), it can be drawn as at (a) for the same diagram can be used for both the carrier wave itself, and the aerial currents it causes. When speech or music "Modulate" the wave, its strength varies in time with the variations of the sounds, and so it can be drawn as at (b), which again also serves to show the currents in the aerial. At some points, as you can see, the currents rise to twice the strength of those due to the unmodulated carrier; at other points the wave dies right away for the fraction of a second.

The important point to remember is that the currents are alternating, changing direction regularly at a high speed. This means that when they flow through the first coil in the receiver of *Fig.* 1 they induce similar currents in the second, tuned, coil. If the first coil is not used and the aerial is connected straight through C1 to the tuned coil, or if a tapped coil like the one of *Fig.* 3 is employed, the currents then run through the tuned coil itself. The currents are at so high a frequency that C1 presents only a low reactance to them.

The coil is tuned by C2 to the frequency of the currents set up by the required transmitter; as a result a voltage is set up across the tuned circuit. Once again *Fig.* 5 (b) serves to show the voltage which, like the currents causing it, is alternating. If this voltage were to be connected directly across the headphones currents would flow through their coils. The currents would not, however, cause any sound to be heard as they would be alternating far too rapidly.

A varying current, flowing through the headphone coils, affects the strength of the magnets round which the coils are wound, and thus affects the headphone diaphragm. A current in one direction will strengthen the magnet and so draw the diaphragm further in; a current in the opposite direction will allow

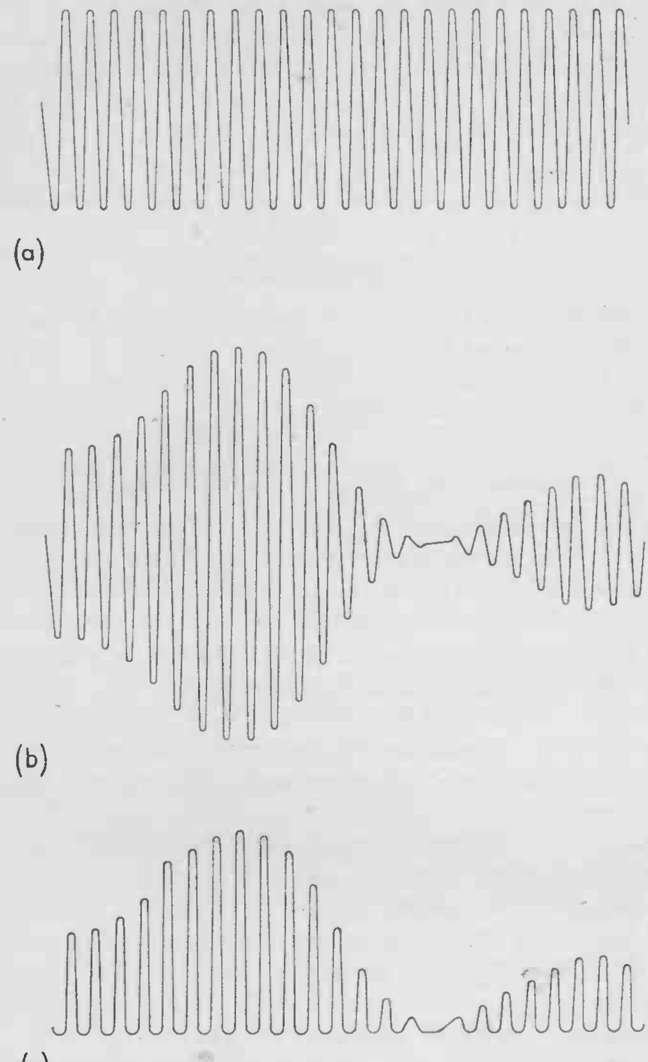


FIG. 5

the diaphragm to spring away from the magnet by weakening the magnetism. These movements of the diaphragm move the surrounding air, and so cause sounds to reach the ears when the headphones are worn. Sounds can be caused by slowly alternating currents or by direct currents of varying strength, but the currents shown in *Fig.* 5 (b) cannot cause sounds because both sides of the carrier are modulated—an upwards peak at any one point is balanced by an equal and opposite downwards peak, and so on. Thus if this waveform were to be fed to the headphones, the diaphragms would each try to move in two directions at once, and finish up by remaining still and causing no sound.

To operate the headphones, therefore, one half of the modulated wave is needed—a wave like that shown in *Fig.* 5 (c), and it is the job of the crystal detector to provide this from the full modulated wave of *Fig.* 5 (b).

Several natural crystals have the strange power of being able to pass electricity quite well in one direction, but only poorly in the other direction—that is, a current can pass through the crystal easily only if it flows in the direction which suits the crystal. If the current reverses, and endeavours to flow through the crystal in the opposite direction, very little current gets through. This is called a rectifier action, and is very similar to the way in which a simple diode valve operates. Obviously, if an alternating current is passed through the crystal only one half of each full alternation, or cycle, gets through, the other half being blocked by the crystal.

This is what has happened to the modulated carrier in *Fig.* 5 (c), so that only one half of the complete wave is left. This consists of many half-cycles or half alternations of current, each of which rises from zero up to a strength which depends on the speech or music with which the carrier was modulated. The total effect of all the currents seems to the headphones like a speech or music current which the diaphragm can copy, and so sound is heard from the headphones.

We sometimes say that the current now has two components, one a high or radio frequency component and one a sound or low frequency component. The low frequency component, as just explained, operates the headphone diaphragms, and the high frequency component can flow to earth through the capacitor C3. The receiver will still work if C3 is removed, but it is best to have it in circuit.

So much, then, for the crystal receiver, though there are still one or two things to be learnt from it. Notice, for example, how "broadly" it tunes compared with the home mains or battery set—a station which tunes in and out very sharply on the big receiver spreads across quite a wide movement of the crystal set tuning capacitor. This is because the crystal set has only one tuned circuit, and also because all the energy which operates the headphones had to come from the wireless signal itself; the rest of the crystal set acts as a load on the tuned circuit which therefore cannot act with full efficiency.

The next step, then, is to use a valve instead of a crystal.

CHAPTER II

A One-Valve Battery Receiver

WE have already seen that the great disadvantage of a crystal receiver is that the wireless signal itself has to supply the energy, after rectification, to operate the headphones of the set; this means that the crystal receiver is insensitive (it will not work on weak signals) and unselective (it does not tune sharply). Much better reception can be obtained from a valve receiver for in this type of set the energy required to operate the headphones comes from a battery whilst the valve does not load the tuned circuit to a very great extent. The tuned circuit merely supplies a voltage which controls the valve and since a greatly amplified signal can be drawn from the valve's anode the set is sensitive to quite weak signals. The one-valve circuit shown in *Fig.* 6 will work practically anywhere, and after dark, when reception conditions improve, it will bring in several foreign stations as well as local programmes. The receiver also tunes over both the medium and long waves, and in addition, it has been designed rather like a Meccano set—you can add to it stage by stage until it is a full sized four-valve receiver giving really fine loudspeaker results.

Up to C5 the circuit of *Fig.* 6 is really very similar to the tuned circuit of *Fig.* 1. S1 is a switch which "short-circuits" part of the main tuning coil for medium wave reception, the full coil coming into use for the long waves when the switch is opened. C2 and C3 are "Trimmer" capacitors and are more important when a further valve and tuned circuit are added to make the set a two valve receiver. Their values are quite small, and the work they perform is described in Chapter III.

The tuned circuit supplies a modulated carrier voltage to the grid of the valve V1. This valve acts as a triode, although it is pentode, because the screening grid and the anode are connected together. The signal is applied through C5 which, although passing the high frequency voltages, acts as an insulator to any D.C. voltage or low (sound) frequency voltage on the valve grid. The grid and the filament of the valve act as a diode, and so a small current flows from the filament to the grid whenever the signal voltage goes positive—that is, on the upper half of the carrier wave as drawn in *Fig.* 5 (b).

This current cannot flow past C5 and so must flow through R1. We have seen already that a current flowing through a resistor causes a voltage to appear across the ends of the resistor, and so a negative voltage appears at the grid of V1, its strength depending on the strength of the signal. This voltage, therefore, must vary with any variation of the signal strength, and as a result the negative voltage on the grid of the valve rises and falls with the modulation of the carrier

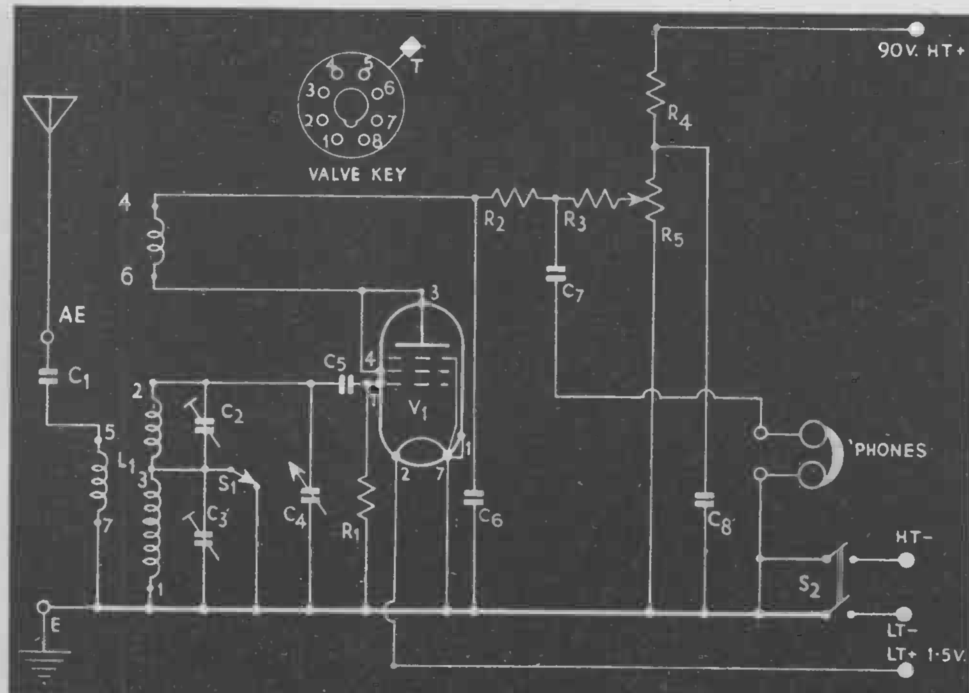


FIG. 6—THE ONE-VALVE RECEIVER

—in other words, it becomes a speech or music voltage. Since it is negative it acts as grid bias and controls the current through the valve from the filament to the anode, this current therefore varying with the voltage. The H.F. (high frequency) component is taken down, or "bypassed," to earth, through C6 and the L.F. (low frequency) flows through R2, R3 and R5, then through C8 to earth.

R2 assists in separating out the H.F. which is no longer required, and the varying L.F. current then flows through R3. Here again a voltage varying in time with the current is set up across the resistor, and it is this voltage which is used to operate the headphones which are connected through C7 to R3. C7 has a capacitance high enough to pass low frequency currents, but it insulates the headphones against the steady high tension or high voltage due to the H.T. battery.

R5 is a control which permits the valve anode to be fed with any value of H.T. voltage, and so serves both as a volume and a 'reaction' control.

Reaction

The one-valve receiver is far more sensitive than the crystal set not only because the valve amplifies the speech and music voltages on its grid, but because it also amplifies the original small voltages in the tuned circuit caused by the wireless signal. This very valuable amplification is obtained through the use of 'reaction' or (a better word) 'regeneration.'

We have already seen that the unwanted H.F. currents flow to earth through C6—this means, clearly, that they must flow through the anode coil first. This coil is coupled to the main tuned coil (generally called the grid coil) and so currents in the anode coil induce similar currents in the grid coil. Note that all the coils shown are wound on the same coil former, and are close to one another.

But the currents in the anode coil are controlled by the signal currents in the grid coil, and therefore the induced currents in the grid coil can be added to those already flowing. This increases the grid voltages at the valve, which increases the currents in the anode coil which increases the induced currents in the grid coil—and so on and so on until, as we say in technical language, all the grid losses are made up, and the valve oscillates. An oscillating valve is really a small transmitter, generating wireless waves in the tuned circuit connected to the valve, and giving out radio power. At first sight this looks like something for nothing, but actually the power is being drawn from the H.T. battery. The valve is really a power inverter, turning direct current energy into alternating energy.

In the receiver we do not want the valve to oscillate, and R5, by controlling the anode voltage, allows the valve to be run up to the "critical point" which is where the valve is about to oscillate and where it is amplifying the signal very strongly.

If the valve is run past the critical point, and the tuning capacitor rotated, stations will be heard as whistles. This is quite a useful way of tuning in, but the regeneration control, R5, must be turned back immediately for the receiver will then be sending out energy and very probably interfering with nearby receivers.

In the circuit of *Fig.* 6 you will find it possible to make the valve oscillate on the medium waveband, but on the long waves it will only just reach the critical point. This is quite satisfactory since long wave stations are, in general, more powerfully received and require less amplification.

Remember—when the set is oscillating, it delivers energy to the aerial and interferes with others. Until you have fitted the second valve, as described in the next chapter, and which will prevent this interference, you must handle the regeneration control carefully.

Building the Receiver

Valve receivers must be built up carefully, with every wire taken directly from point to point and properly insulated, and the components cannot be "hooked up" as in the crystal set. For one thing the valve or valves would be ruined if, by an accidental short-circuit, the 90 volts H.T. battery became connected across the filament circuit which, in the present receiver, needs only

1½ volts; for another, the valve or valves are amplifying tiny currents. Untidy wiring could cause unwanted regeneration by feedback, the currents in one circuit inducing currents in another circuit. One of the most important points in receiver construction is the prevention of feedback.

The receivers described in this book have been very carefully tested. This means that the correct components must be used, especially the correct coils, and where makers' names are given in the component lists every effort must be made to obtain the correct parts. The same tuning capacitor and fixed capacitors *should* be used, and the same coils *must* be used, as must the same valves. Any make of resistors, valveholders and so forth may be employed.

Beside the circuit of each receiver described, an under-chassis view is also given to show where valveholders, switches and other components are placed. This is the real job of these diagrams, and they do not always show the wiring exactly as it will appear in the finished set. The connections shown are, of course, correct, but to prevent confusion in the drawing the wiring has to be drawn in straight lines and large curves. Remember, then, that these under-chassis views are really to show where all the components are placed—where necessary wiring hints are given in the chapters.

Components for the One-Valve Receiver, Fig. 6.

L1	1 pair of Weymouth CT2W2 coils. See below.
C1	See below.
C2, C3	4 to 60 pF. trimmers. Walter Instruments, MS70.
C4	One section of 500 pF. variable two-gang tuner, Jackson Bros. Type E. See below.
C5, C6	500 pF. 350 v.w. Mica. T.C.C. CM20N.
C7	0.01 mF. 500 v.w. Tubular. T.C.C. 543.
C8	0.5 mF. 350 v.w. Tubular. T.C.C. 343.
R1	2.2 megohms, ½ watt.
R2	10,000 ohms, ,,
R3	220,000 ohms, ,,
R4	100,000 ohms, ,,
R5	1 megohm, potentiometer, with 2 pole on-off switch.
S1	2 pole, 2 way switch. Rotary, Messrs. Walters Type B.T.
S2	2 pole on-off switch, ganged with R5. See below.
V1	Mullard DF33

1 Octal valveholder.
4 Sockets and plugs, Belling Lee, L315 and L1021/3.
1 Flex fuseholder, Belling Lee, L1037. See below. Fuse, 1055, 60 mAs.
2 Wander plugs, red and black, Belling Lee, L341. (H.T. Battery Connectors)
1 L.T. Battery Plug, 2 pin.
Tuning Drive, Messrs. Jackson Bros. "Squareplane."
1 Rubber Grommet, ½ in. diameter.

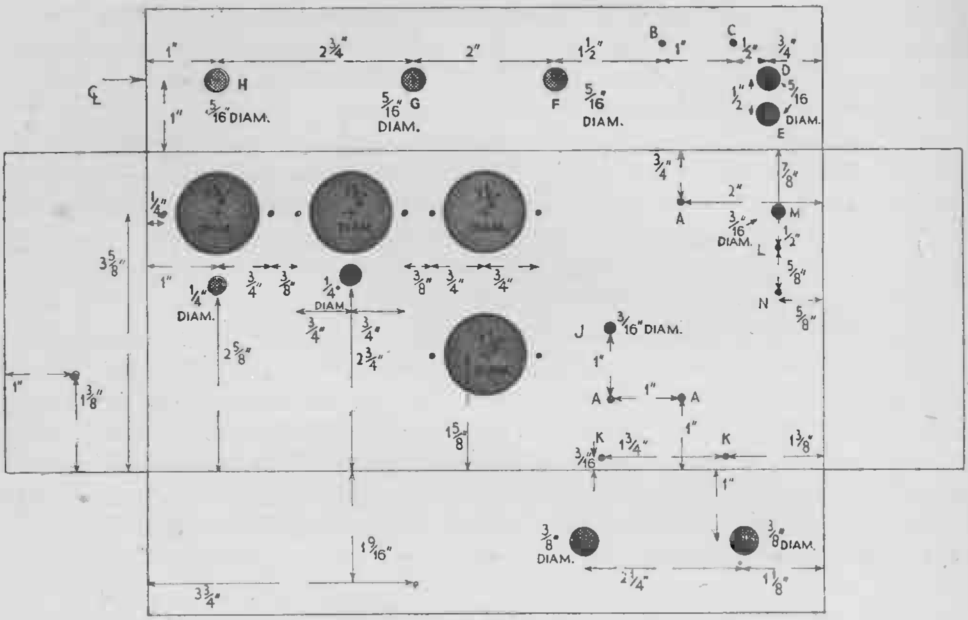


FIG. 7—TOP VIEW OF THE CHASSIS, SHOWING HOW TO DRILL IT

1 Grid clip, octal size.
3 Knobs.
Chassis, 9½ in. x 4½ in. x 2 in. aluminium.
High Resistance Headphones.
Odd lengths metal for clips, etc.
6 B.A. nuts and bolts, soldering tags, connecting wire and sleeving, 3 yards rubber covered flex for battery leads. Washers for spacing tuner from chassis; See below.
H.T. Battery, 90 volts, L5039, Vidor.
L.T. Cell, 1.5 volts, L5049, Vidor.

Notes.

A pair of CT2W2 coils is required, although only one coil is used in the one-valve receiver, since the second coil is used when the next valve is added, later on. The coil to be employed in the present receiver is that marked "H.F. Coil" or "H.F. Transformer." The aerial coil should be carefully boxed up and left for later work. Note that the connections on the coil are numbered; tag No. 7 is at the base of the coil and can easily be found since it is the only bottom tag with a wire going to it.

C1 is chosen to suit the aerial and the distance from the local stations. If the local station is nearby C1 should be fairly small, but if the receiver is to be used some way from the transmitter C1 may be larger. The value for this capacitor

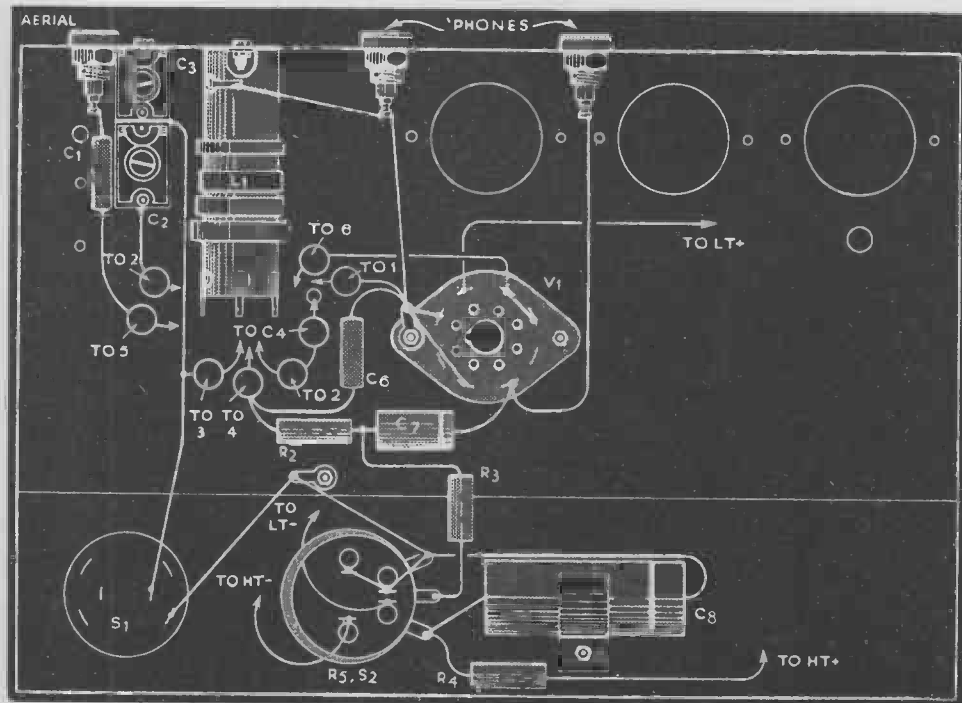


FIG. 8—UNDER-CHASSIS VIEW OF THE ONE-VALVE RECEIVER

must therefore be found by experiment, capacitances of between 100pF and 0.001 mF. being tried. A good all-round value is 200 pF.

C4 is part of a two gang tuner; here again the second section is used when the set is enlarged. The moving plates are connected by a wiper to the capacitor frame or body, and so these are automatically connected to the chassis when the tuner is bolted down.

The way in which the tuner is mounted needs special attention, but first it is necessary to note the way in which the chassis is drilled and punched—this is shown in *Fig.* 7. In this diagram the sides of the chassis are shown as though folded out flat so that the dimensions can be clearly drawn. Notice, too, that in later diagrams of the under-chassis view some of the chassis walls are shown as though bent out flat to allow the components to be seen—the front chassis wall, with volume control and switch, together with C8, is drawn in this way in *Fig.* 8. Naturally the chassis sides are not bent out flat at any time, but are drilled in their normal positions.

Small holes are drilled with twist drills, and the large valve holes with a chassis punch of $1\frac{1}{8}$ in. diameter. There are several sorts of punches, but in each case it is necessary first to drill a fairly large hole—about $\frac{1}{4}$ in. diameter—in the exact centre of what will become the valve hole. The punch spindle is then placed through this hole, and the two sides of the punch are then either screwed together with a special spanner, or one half is hammered into the other with one or two sharp clean blows. In either case the correct size hole is punched cleanly through the chassis. Chassis punches are rather expensive; the best type is a "Speda" which can cut all the usual sizes of valve holes from $\frac{5}{8}$ in. up to $1\frac{1}{2}$ in. diameter. All the valve holes required for the receivers in this book are of $1\frac{1}{8}$ in. diameter.

Valve holes can also be cut with a "tank cutter" which is an adjustable cutter used in a hand brace. This is a cheaper tool to buy, but is a good deal more difficult to manage.

All the holes shown in *Fig.* 7 should be drilled and cut before any of the components are mounted for the chassis can then have further valves and stages added without difficulty.

The tuning capacitor is mounted on the chassis by bolts through the holes marked A in *Fig.* 7. When the tuner is bought it will be found to have three feet; when stood on these feet turning the spindle will open the moving vanes to the left. It has been found better in this design, however, to have the vanes moving to the right and so the feet must be removed and replaced. The feet are riveted to the frame with soft aluminium rivets, and the heads must be filed from these so that the feet can be taken off. This is quite simple, and takes only a minute or so, but every care must be taken not to bend the tuner, or to strain the plates, in the process. The moving vanes should be turned into the fixed vanes and the tuner held by its frame; it can then be supported on the edge of a bench or table for the filing. When the feet are removed they can be bolted onto the frame by boltholes already drilled in the tuner. These holes will be found in corresponding positions to those previously holding the feet, at the opposite sides of the endplates. With the feet bolted to these holes by 6 B.A. nuts and bolts, the tuner will again stand flat and firm, but the vanes will open towards the right. Use short bolts so that there is no chance of the bolt ends fouling the moving vanes as they are rotated.

If you feel a little nervous about filing the rivets and changing over the feet of the tuning capacitor, there is a very easy way out—use three small Meccano brackets. If you haven't a Meccano set, you can the buy brackets quite easily. Bolt these onto the frame and leave the original feet in position.

To make the tuner fit the tuning or slow motion drive it must be raised about $\frac{1}{4}$ in. above the chassis—the exact amount is not important because the drive itself is adjustable in height. A few washers are therefore placed over each bolt, each stack of washers being of the same height, and the capacitor is bolted to the chassis by the holes marked A. Bolts about $\frac{1}{2}$ in. long are needed, again of 6 B.A. gauge. The changes to the feet of the tuner, and the way in which it is mounted, are shown in *Fig.* 9.

Almost all the components and wiring are below the chassis so that with the

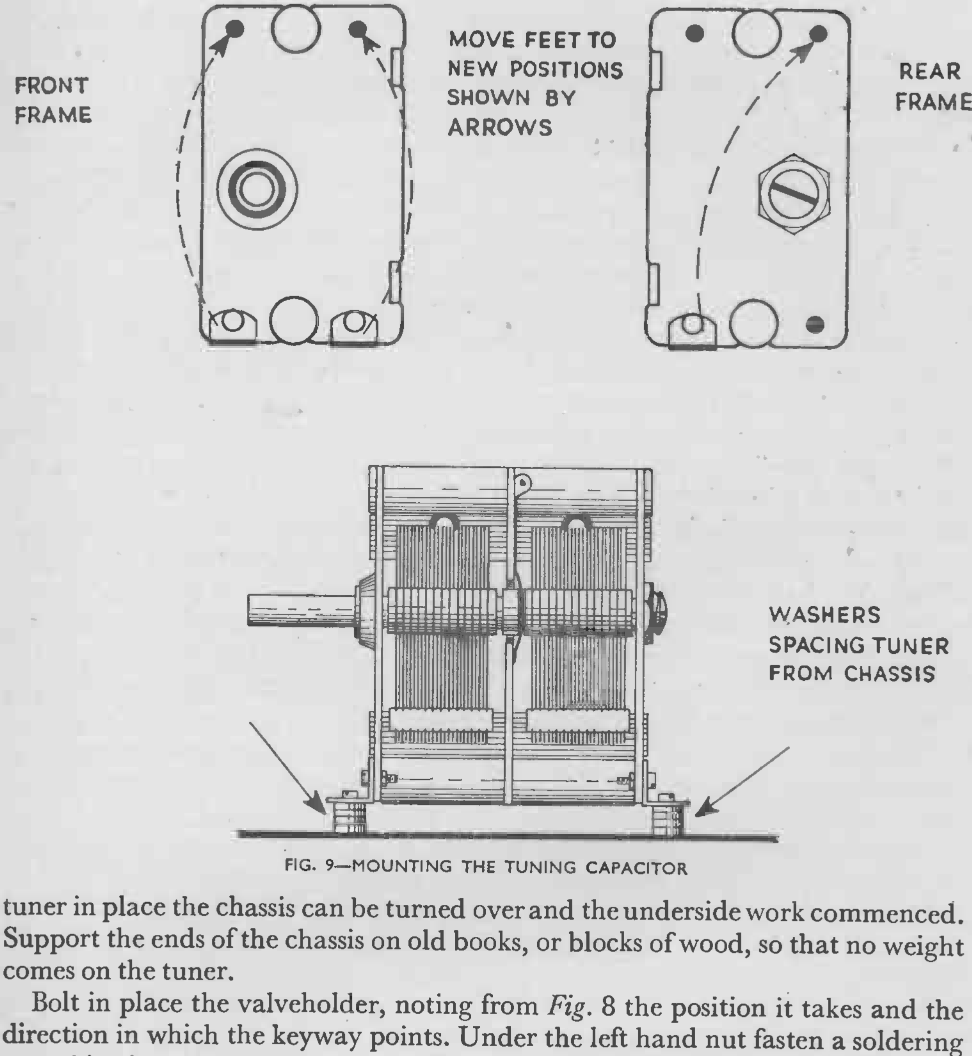


FIG. 9—MOUNTING THE TUNING CAPACITOR

tuner in place the chassis can be turned over and the underside work commenced. Support the ends of the chassis on old books, or blocks of wood, so that no weight comes on the tuner.

Bolt in place the valveholder, noting from *Fig.* 8 the position it takes and the direction in which the keyway points. Under the left hand nut fasten a soldering tag; this gives a good direct connection with the aluminium chassis which, of course, will not take solder.

The coil is bolted to hole B of *Fig.* 7, and the trimmers to hole C. The trimmers are bolted together as shown in *Fig.* 8. If you inspect the trimmers you will see that the adjusting screw contacts the upper plate which then curves round in a spring and becomes the fixing tag. Make sure that this tag—the one in contact with the adjusting screw—is the tag of C3 which is attached to the chassis by the nut and bolt. When the trimmers are bolted together place a soldering tag between them, over the bolt, and again make sure that the plate of C2 which is in contact with the adjusting screw is the one bolted down onto the tag of C3.

This arrangement is necessary so that when the trimmers are adjusted the screwdriver is in contact with the earthed plate; the screwdriver would otherwise add some capacitance to the trimmer and upset the tuning when it touched the screw.

The four sockets are fixed to the rear chassis wall. D in *Fig.* 7 is the aerial socket, E the earth socket and F and G the headphone sockets. Socket E, the earth socket , is connected by a length of wire to the socket at F and thus to the earthed soldering tag under the valveholder nut. This wire cannot easily be shown in *Fig.* 8 so it has been left out of the diagram. Actually socket E is hidden, in the illustration, by the aerial socket.

The front panel components can now be mounted, as shown in *Fig.* 8. The connections to S1 are easily traced but the on-off switch which is a part of R5 needs a little care. This will be found to have 4 contacts on the back, these making up two pairs, but it is not always easy to tell which pair is which. The illustration shows a normal type of switch, but it is always best to test out the contacts with a battery and bulb—you could borrow these from your torch. As the spindle of R5 is rotated from one end of its movement it is easy to feel and hear a click—this means that the switch is closed in the "On" position. Connect the battery and bulb in series with the contacts, using a length of wire, testing the contacts in pairs. The bulb will light when a pair is found, and will also light across the other pair. One pair is used for the L.T.-lead, and the other for the H.T.-lead, one side of each pair being connected together and earthed to a soldering tag near the front edge of the chassis.

This tag is actually held under one of the bolts securing the slow motion drive, but until this is fitted the tag should be held in place by a temporary bolt and nut.

C8 is clamped to the front chassis wall by a strip of scrap metal, drilled with a small hole at one end and bent into a curve to fit the capacitor.

The receiver is now wired up as shown, with special care being taken over the leads to the coil. In *Fig.* 8 each lead is labelled with the number of the coil tag to which it goes.

Remember that the thick base line of *Fig.* 6 represents the chassis, and that contacts to this thick line are actually made to the earthed soldering tags already bolted in place.

One lead from tag No. 2 of the coil goes through hole J in the chassis to the fixed vanes of the front section of the tuning capacitor.

The connection to the fixed vanes of the tuner is actually made to a small brass eye, and it is a good plan to check whether the soldering iron will reach underneath the capacitor, and touch this eye, before finally bolting the tuner down. If the soldering iron is too large for this a length of wire can be soldered to the eye before the tuner is secured, the wire being left about 6 in. long and passed down through the chassis hole. Remember to insulate it with sleeving when it is out to the correct length, for if this connection touches the chassis where it passes through, it will short circuit the grid coil. No damage will be done, but the set will not work.

C5 and R1 are the only components wired in above the chassis, and their positions can be seen in *Fig.* 16 (where they are numbered C10 and R2). The earth connection for R1 is made by bolting a soldering tag to a hole in the end frame of the tuning capacitor; C5 is taken to the front fixed plates where a further brass eye connector will be found. Both components are connected, at their opposite ends, to the clip which attaches to the valve top cap.

C5 and R1, like the other small components, have their own wire ends. To find the correct length of lead needed insert V1 into its holder, making sure that the key on the valve spigot (the rod between the valve pins) fits into the keyway on the base. The components can then be checked and the leads cut to length; remember to leave ¼ in. of wire at each end for the soldered joint.

The small components can then be wired in under the chassis. In *Fig.* 8 the component leads are shown as neatly curved so that the parts and wiring can be drawn clearly—in actual fact the leads should always be kept short and direct. The leads to the valveholder can be checked by observing the small numbers against the valve symbol in *Fig.* 6 and comparing these with the "valve key" shown above the circuit. This key shows the base of the valve, looking at the pins, and also the underside of the valveholder. The connection to the valve top cap is shown by the letter and mark "T." Notice that most valves have pin No. 1 connected to earth; this pin makes contact with the metal coating on the outside of the valve which screens the electrodes inside from stray electrical fields.

Tag No. 6 on the valveholder is used to anchor the lead from C7 and the lead from the right hand headphone socket, and is therefore called an "anchoring point." If you look at the base of the valve you will find that pin No 6 is missing, so that this valveholder tag is spare and can be used safely as an anchoring point.

Rubber covered flexible wire is employed for the battery leads, and it is worthwhile to get four different colours of covering so that the leads can easily be identified. The usual colours are:—

L.T. (1.5 volts) Positive,	PINK.
L.T. Negative,	BLACK.
H.T. (90 volts) Positive,	RED.
H.T. Negative,	BLACK or BROWN.

The two L.T. leads are soldered into the small two pin plug which fits the socket on the L.T. battery. The thicker pin is the positive plug.

All the battery leads leave the chassis through the hole marked H, into which is fitted the rubber grommet. This insulates the edge of the hole so that there is no chance of the leads being cut through and short-circuiting.

Fitting the Fuse

The fuse is not shown either in the circuit of *Fig.* 6 or the layout of *Fig.* 8 since it is fitted in the H.T. negative lead itself. It is not soldered in place; the lead is cut at any convenient point and the ends of the wire bared for about ¼ in. The end cap of the fuse holder is unscrewed and the washers, fuse and spring removed. One bared wire end is passed through the hole in the fuseholder body and secured under the base washer, the spring and fuse are then replaced and the other wire end secured in the top washer which is then pressed down on the fuse as the cap is screwed back in place. A 60 mAs. fuse is used, type Grey, No. 1055, Belling Lee.

Some of you may have difficulty in obtaining this type of fuse. If so, you will have to use a small bulb type fuse, which looks like a torch bulb, with a fuse-holder to suit. The fuseholder can be mounted below the chassis on the front wall in the space between C8 and the end of the chassis, *Fig.* 8, two small holes being drilled to take two 6 B.A. bolts which will secure the bulbholder. The negative lead from the H.T. battery is then taken to one holder contact and the negative H.T. lead from S2 to the other contact. Take special care to see that no bare wire or 'live' metal part of the holder touches the chassis.

Finishing and Testing the Set

It now only remains to fit the slow motion drive on the top of the chassis, and then the set can be tested out. The drive is bolted down to the two holes marked K in *Fig.* 7. Before placing it in position, loosen off the screws which hold the adjustable bottom bracket of the drive. Slip the driving hub over the capacitor spindle, let the bottom bracket slide down to touch the chassis, and bolt it in place, remembering to fasten down the soldering tag holding the S1 and S2 leads under the left hand nut.

Turn the drive spindle so that the pointer reads the lowest wavelength, 200 metres, and then turn the moving vanes of the tuner so that they are right out of mesh, or open—this of course is before the hub screw is tightened. Then tighten the screw, and make sure that both pointer and capacitor vanes rotate together when the front spindle is turned.

Place a knob on each spindle—two switches and the tuner—and tighten their grub screws. When the spindles have flat faces cut along one side, the grub screw of the knob should fall on this "flat" as it is called. Plug in the headphones; one phone lead will be striped or marked differently from the other and this should go to right hand phone socket, looking at the rear wall of the chassis, the socket connected to C7. This marked lead is the positive lead. In some circuits H.T. current flows from the batteries to the valve or valves through the headphones, and then it is important to see that the positive lead goes to the positive side of the battery. If the phones are connected the other way round, the magnets will, in time, become weaker.

This is not very important in the circuits described in this book, because the headphones are always insulated against direct current by a capacitor.

Now plug in the valve. When handling valves always hold them by their bases, not by the glass, and plug them in, and remove them from their sockets, by curling the fingers right over the top of the valve to get a grip on the solid base. Pulling on the top loosens the joint between the glass and the base. When a new valveholder is stiff it sometimes needs a good deal of patience to get the valve in and out, but just go gently at it, slightly rocking the valve from side to side. Always place and remove top cap clips very carefully.

Plug the small two pin plug into the H.T. battery, and rotate S2 to switch on. Check that the valve filament is glowing; this is sometimes not easy to see but in a dark room a pale red or orange light should be seen in the centre of the valve, through the clear glass at the top. Put on the headphones, then plug in the H.T. negative lead. Take the H.T. positive lead and tap it on the 90 volts socket of the battery; there should be a good loud click in the phones at each tap. If there is only one click, or no click at all, check the fuse in the H.T. negative lead. If it has "blown" something is wrong with the wiring, and it must be found and put right.

If all is well, and there is no reason why it shouldn't be, the positive plug can be inserted into the battery. There should be a gentle hissing in the phones.

Turn S1 to the medium wave band (to the left) and turn the volume/reaction control up and down. At one point the set will be heard going into oscillation by a louder hissing; possibly there will be a squeal as the knob is rotated further round.

You should have no trouble at all in making the set oscillate; indeed it is possible that until the aerial is connected up there will be too much oscillation. In one or two cases, however, the set may refuse to oscillate at all, and if this should happen plug in the aerial and earth straight away to see if that corrects matters. If not, remove the battery plugs, headphone plug and the valve and turn the receiver over, then carefully unsolder the leads to tags Nos. 4 and 6 on the coil, and reverse them. That is, take the lead which went to tag 6 to tag 4, and the lead which went to tag 4 to tag 6.

If that does not cure the trouble, put the leads back in their original places, and very carefully check all the wiring and joints, first making sure that all the connections to the coil are made correctly.

With the reaction working, connect the aerial and earth to their sockets, turn the reaction control down, and tune the receiver till the pointer reads the wavelength of the local medium wave station. Turn up R5 to the reaction point; probably the station will not be heard, so turn the tuner one way, then the other, till the station is found. Experiment with R5 for best reception, remembering not to let the set oscillate.

Now the trimmers can be used to make the dial read correctly. Set the pointer to the right spot on the dial, and very carefully turn the set over onto one end, still switched on, so that you can reach the trimmers, then adjust C2 with a screwdriver—do not let the metal blade touch any of the wiring or other components. An insulated screwdriver is best; later on you might afford a proper set of trimming tools.

If it was necessary to turn the pointer up the dial to find the station, screw C2 in; if the pointer had to come down, unscrew C2. In either case it should be possible to tune in the station with C2, and then the dial will read correctly.

Now switch to the long waves and tune in the Light wave programme at 1,500 metres. Set the pointer correctly, then again turn up the set so that C3 can be adjusted to tune in the signal properly.

You may find that the ends of the wave bands, on the dial, do not read quite correctly, but the amount of error will be very small, and not important.

And now—well, it's your set! See how much fun you can have with it. But put the escutcheon (the frame) and the glass of the tuning dial away carefully, till you build the receiver into a cabinet of its own. And don't forget to switch off, or the batteries won't last very long.

CHAPTER III

A Two-Valve Battery Receiver

AS you grow accustomed to the one valve receiver you will decide, sooner or later, that although it is a great deal better than a crystal set it still has some faults. Those who live near to a transmitter will find the signal spreading out over the dial and blotting out interesting foreign stations, whilst those who can hear the foreign stations without this trouble will find that several of them cannot be heard clearly enough. In other words, the set is still lacking in selectivity and sensitivity.

Forgetting the selectivity business for the moment, there are two ways in which signals can be amplified or made stronger. One way is to use a valve after the detector, this new valve amplifying the sound signals before they reach the headphones; the other method is to use a valve before the detector to amplify the whole modulated carrier signal.

The first method works very well indeed on signals which can already be heard clearly—a stage of L.F. amplification, as it is called, would make the local and home stations really loud. The foreign stations, however, would seem to be very little improved; there would be more hiss or "background noise" and the foreigners would still be mumbling away down in this noise instead of speaking out clearly. What actually happens is that the detector needs a certain signal strength before it can work most efficiently, so that no matter how much L.F. amplification is used, the set will not *receive* signals any better.

The other method of obtaining amplification improves matters a great deal. An H.F. stage (a valve and another tuning circuit before the detector), amplifies the tiny voltages due to the signal currents in the aerial, and hands on to the detector a much stronger signal. The local stations will not sound so very much louder in the headphones, but the distant and foreign stations will be very much clearer and louder.

There is, however, another advantage. We have just seen that the H.F. stage has its own tuned circuit in front of the detector, which means that the two valve receiver has two tuned circuits. This helps tremendously in improving the selectivity of the receiver, for each and every signal is tuned twice and this has the effect of making the tuning much sharper.

Of course the two tuned circuits have to operate exactly in step, which is why a special pair of coils is used, with a two gang tuning capacitor. The coils are made so that the tuned sections have exactly similar performances, whilst the two sections of the tuner are also exactly alike. (The dotted line between the two sections, C4 and C9, in *Fig.* 10, indicate the ganging and show that both sections work together.) The small trimmer capacitors are also very important in the ganged tuning circuits. The wiring, switches and the valve and valve-holder connected to each coil add small capacitances to the tuned circuit and naturally these affect the tuning. In a single valve set this is not of great importance, but when two tuned circuits are used the extra small capacitances (known as "stray" capacitances) must be balanced; that is the strays in one circuit must be made equal to the strays in the other. This can be done by adjusting the four trimmers.

It may not be easy, at first, to see how the new stage, V1 in *Fig.* 10, amplifies the signals without rectifying them as does the detector. Notice, though, that the H.F. stage has no grid capacitor or resistor; the grid works without grid bias and so swings in voltage with the alternating signal voltages. These are amplified at the anode and appear across the coil in the anode circuit of V1. This coil has very little resistance to the flow of current through the valve caused by the H.T. battery, but it does have a great impedance to the small alternating currents due to the signals, the currents therefore setting up voltages across the coil.

The signal frequency currents must be kept from the rest of the circuit to prevent feedback, and so they are presented with an easy path to earth through C6.

The coupling coil in the anode circuit of V1 is actually wound on the former of the second tuning coil—indeed it is the coil which was used as an aerial coupling coil in the one-valve receiver. The voltages across this coil therefore induce corresponding voltages and currents in the tuned circuit of the detector with a further amplification, and it is these amplified signals which are rectified and whose L.F. components are passed on to the headphones.

Notice that whilst V1 is the same type of valve as V2, it is connected as a pentode with the screen fed through R1 and decoupled or bypassed by C5.

Constructing the Two-Valve Receiver

The main circuit of the one-valve receiver requires no changing, but it is important to observe that the component numbering of *Fig.* 6 has been changed. This has been done since it is usual to number components from the aerial end of the receiver diagram. Thus L1 in *Fig.* 6 is now L2, R1 has become R2 and so on. The original C1 is still used in that position, and the new capacitors are numbered, in *Fig.* 10, from C2 to C6.

In the following components list only the extra parts needed for the H.F. stage are shown.

Components for the H.F. stage of the Two-Valve Receiver, Fig. 10

C2, C3	4 to 60pF. trimmers. Walter Instruments, MS70.
C5, C6	0.1 mF. 350 v.w. Tubular. T.C.C. 343.
R1	15,000 ohms, $\frac{1}{2}$ watt.
V1	Mullard DF33

1 Octal valveholder.
Wire, sleeving, nuts, bolts, etc.
1 Grid clip, octal size.

The first work to be done is to prepare the existing one-valve set for the addition of the new stage. Disconnect the headphones, batteries, etc., and remove the valve. Turn the receiver over, supporting it at the ends as before, and remove C1 by unsoldering its wire ends. Disconnect the lead between tag No. 7 on the coil and the earthed headphone socket, also removing the lead from the socket to the soldering tag at the valveholder.

Now bolt in the new valveholder in the position shown in *Fig.* 11 with a soldering tag below the left hand bolt. Connect the valveholder tags Nos. 1 and 7 to this soldering tag, and also the nearby headphone socket from which the leads have just been cleared. Next run a carefully insulated lead from valveholder tag No. 2 to tag No. 2 on the other valveholder; in *Fig.* 11, for the sake of clearness, the leads are shown meeting further up the chassis but actually the lead should be run as just described.

R1 is connected between valveholder tags Nos. 4 and 6, so that as before tag No. 6 is used as an anchoring point for the H.T. lead. C5 is held between tags No. 4 and the earthed soldering tag, whilst C6 is held in place with the existing capacitor now numbered C13. The metal clamp must be reshaped to hold C6, or a new metal strip can be bent to hold both capacitors.

Tag No. 3 on the new valveholder is taken to tag No. 5 on the existing tuning coil, whilst tag No. 7 of the coil is now taken to tag 6 on the new valveholder where it meets the H.T. lead. Remember that H.T. leads must be carefully insulated.

The rest of the components are mounted on the top of the chassis, and can be seen in *Fig.* 16. The Aerial coil, saved from the pair originally bought, is bolted down with a 6 B.A. bolt and nut, to the hole marked L in *Fig.* 7, whilst the two trimmers C2 and C3 are bolted together with a soldering tag between them. They are then bolted down to the hole marked N in *Fig.* 8 so that they stand up from the chassis in the same way that the first trimmers stand out from the back wall of the chassis. The lower trimmer is C3, and the tag touching the chassis must be the one in contact with the adjusting screw. In the same way the lower tag of C2 (the one bolted to C3) must be the tag in contact with the adjusting screw.

The earthed lead from tag No. 1 of L1 is taken to the tag which will be found soldered to the frame of the tuner, whilst a lead from tag No. 2 of the coil goes to the upper brass eye of the rear section fixed plates of the tuner, a further short lead from this eye going to the top cap clip of V1. This short lead should be of rubber-covered flex. Tag 2 of the coil is also taken to the top tag of C2, and tag 3 of the coil goes to the soldering tag between the two trimmers. From Tag 3 a further lead is taken down through the hole M, which falls right below the coil. This lead is taken to the switch—remember to connect up the other switch contact as shown in *Fig.* 11.

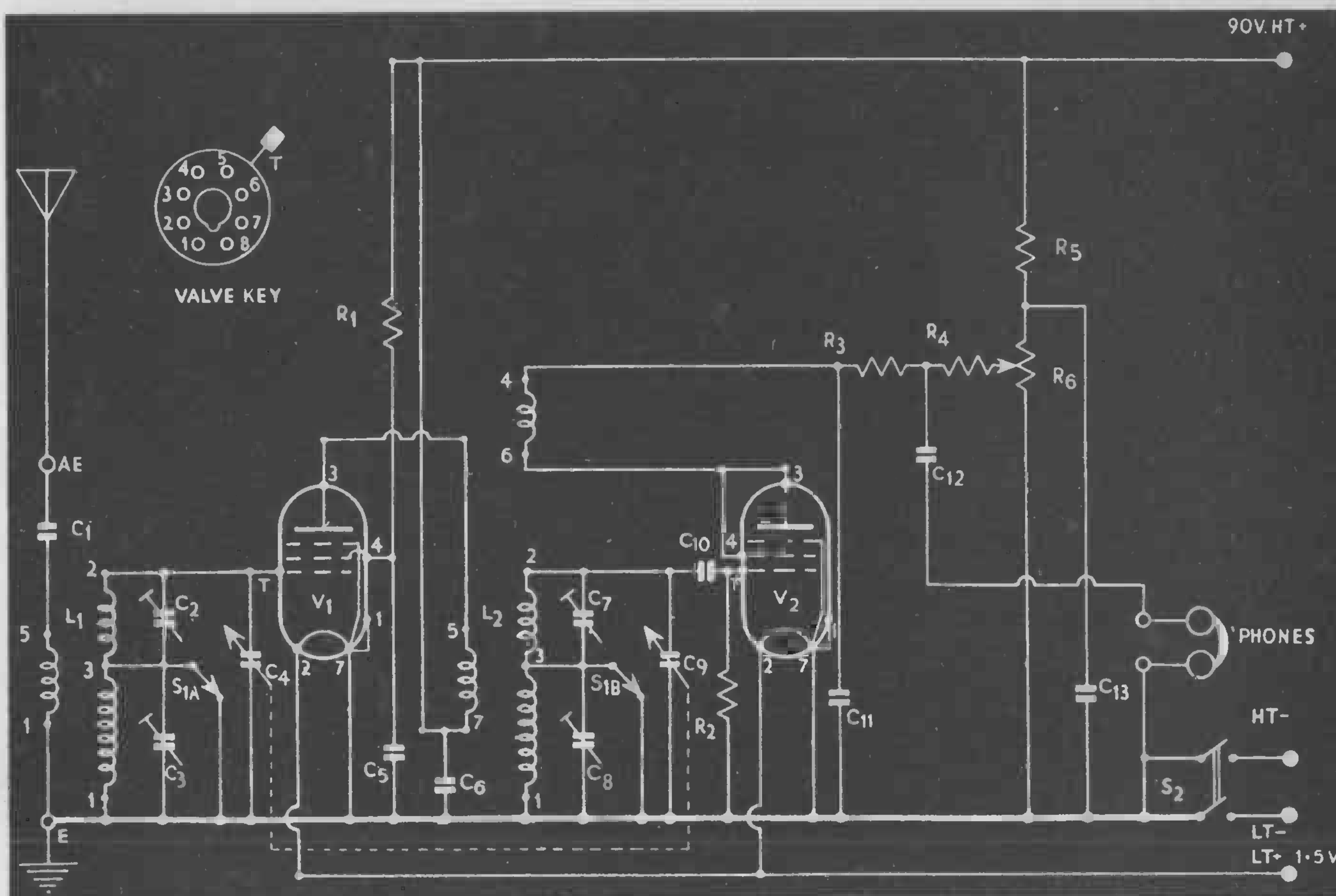


FIG. 10—THE TWO-VALVE RECEIVER

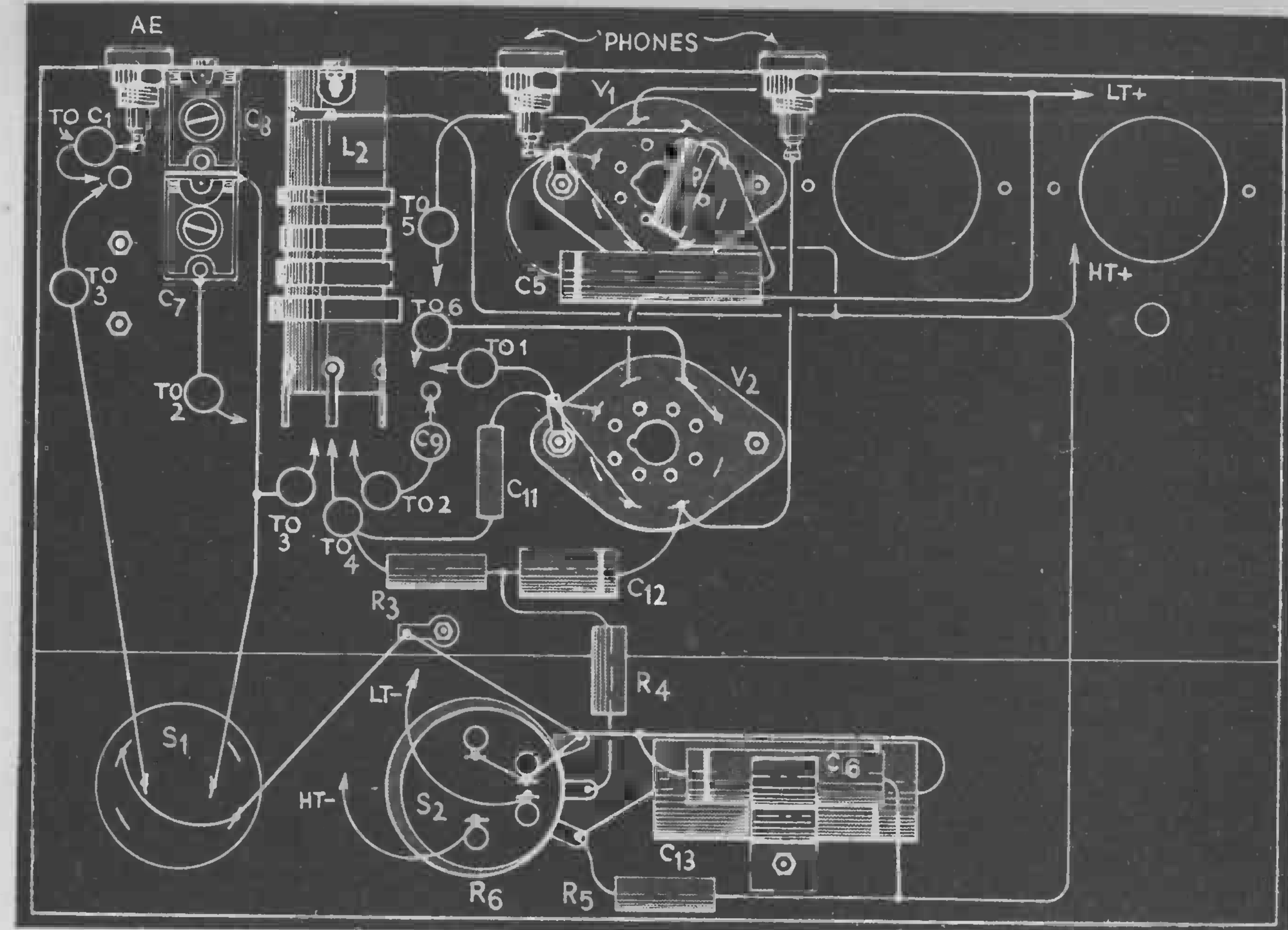


FIG. 11—UNDER-CHASSIS VIEW OF THE TWO-VALVE RECEIVER

C1 is placed inside the coil, with one lead connected to coil tag No. 5, the other lead going down through the hole M to the aerial socket.

The receiver is now ready for testing. As before, plug in the valves and connect up their top caps, plug in the headphones and the L.T. battery plug, then switch on and inspect the filament of V1 to make sure it is glowing. Plug the negative H.T. lead into the H.T. battery, and tap the positive lead on the 90 volts socket, making sure there is a click in the headphones at each tap. The lead can then be plugged in, the aerial and earth connected, and the set tuned round the medium waves. There may be some improvement; on the other hand it may not be possible to hear anything at all, but adjusting the trimmers will soon correct this. Tune the set to the medium wave local wavelength on the dial, then adjust C2 gently, first one way, then the other, until the signal is heard at its best. Make sure that the original trimmers, now numbered C7 and C8, have not been disturbed by turning the tuner; if the station is not received at the correct point on the dial correct C7 and then readjust C2 for best results again.

Switch to the long wave band, and adjust C3 for best results on the Light programme, and then tune round both wavebands. Signals should be sharper, tuning in and out with less movement of the tuner knob, and as foreign stations begin to come through at evening, it should be possible to hear more of them, with much clearer reception.

It is now safe to allow the receiver to oscillate, too, for the coils in which the oscillations are set up are now no longer directly connected to the aerial. Naturally there is no point in letting the receiver oscillate strongly, but tuning will be easier if the reaction control is turned just sufficiently to give oscillation whilst the tuner is rotated. The signals then come in as whistles, at first high pitched with the note rapidly falling as the tuning continues. At the exact tuning point the note drops to a deep growl then ceases altogether—if the tuner is turned further the note is again heard rising in pitch.

This note is called a "heterodyne" and is produced by two radio frequencies beating together, the pitch of the note being decided by the difference in frequency between the station signal and the frequency at which the receiver is oscillating. When the two are exactly in tune the note disappears but it is still necessary to turn the reaction control back to beyond the critical point to allow the station clearly to be heard.

With the two-valve set you should receive enough stations to make a station list necessary, so that you can identify all the signals heard. The best list is *Guide to Broadcasting Stations*, published by Messrs. Iliffe and Sons, Ltd., at 1/6.

CHAPTER IV

A Three-Valve Battery Receiver

WITH the two valve set working properly, you will begin to think about working a loudspeaker instead of headphones and, perhaps, some of you have tried connecting in a speaker to the output sockets. Probably you were disappointed—this is why. Headphones need very little power to work them, even a tiny current through the coils being sufficient to vary the magnetism and allow the diaphragms to move, but a loudspeaker requires a great deal more power. Practically all modern loudspeakers are of the moving coil type, in which powerful currents are needed. The currents flow through a coil with a very few turns, thus making it an electro-magnet, and since the coil is held in the field of a strong permanent magnet, the two magnetic forces operate one against the other, making the coil move back and forth. The coil is connected to the cone of the speaker, so that this moves too, causing sound waves in the air.

When valves amplify, they can act in one of two ways—as "Voltage amplifiers" or as "Power amplifiers." So far the valves and stages we have been dealing with have all been voltage amplifiers—the small voltages due to the tiny aerial currents have been amplified greatly, but there is still no real power to pass on to a loudspeaker. To drive a loudspeaker we must have a power output stage which uses a valve passing more current than those so far employed in the set, but this power output valve in its turn needs quite a high voltage at its grid to control this heavier current. Before the output stage and a loudspeaker are added the small L.F. voltages which have so far been enough to drive the headphones must be given further amplification, and to do this the extra stage shown in *Figs.* 12 and 13 is connected up.

The valve used is a diode-triode, a double valve which can do two jobs at once, but in this receiver only the triode section is employed, the diode anode being connected to earth and forgotten. The stage is again a voltage amplifier, so that it still will not work a loudspeaker properly—though results from the local station might be reasonably good—but it will at least give very good headphone strength until the final stage can be included.

Very little work has to be done to include the new valve, and only one or two parts are needed. The extra parts are shown in the list below.

Components for the L.F. stage of the Three-Valve Receiver, Fig 12

C14	500 pF. 350 v.w. Mica. T.C.C. CM20N.
C15	0.01 mF. 500 v.w. Tubular. T.C.C. 543.
R7	2.2 megohms, ½ watt.

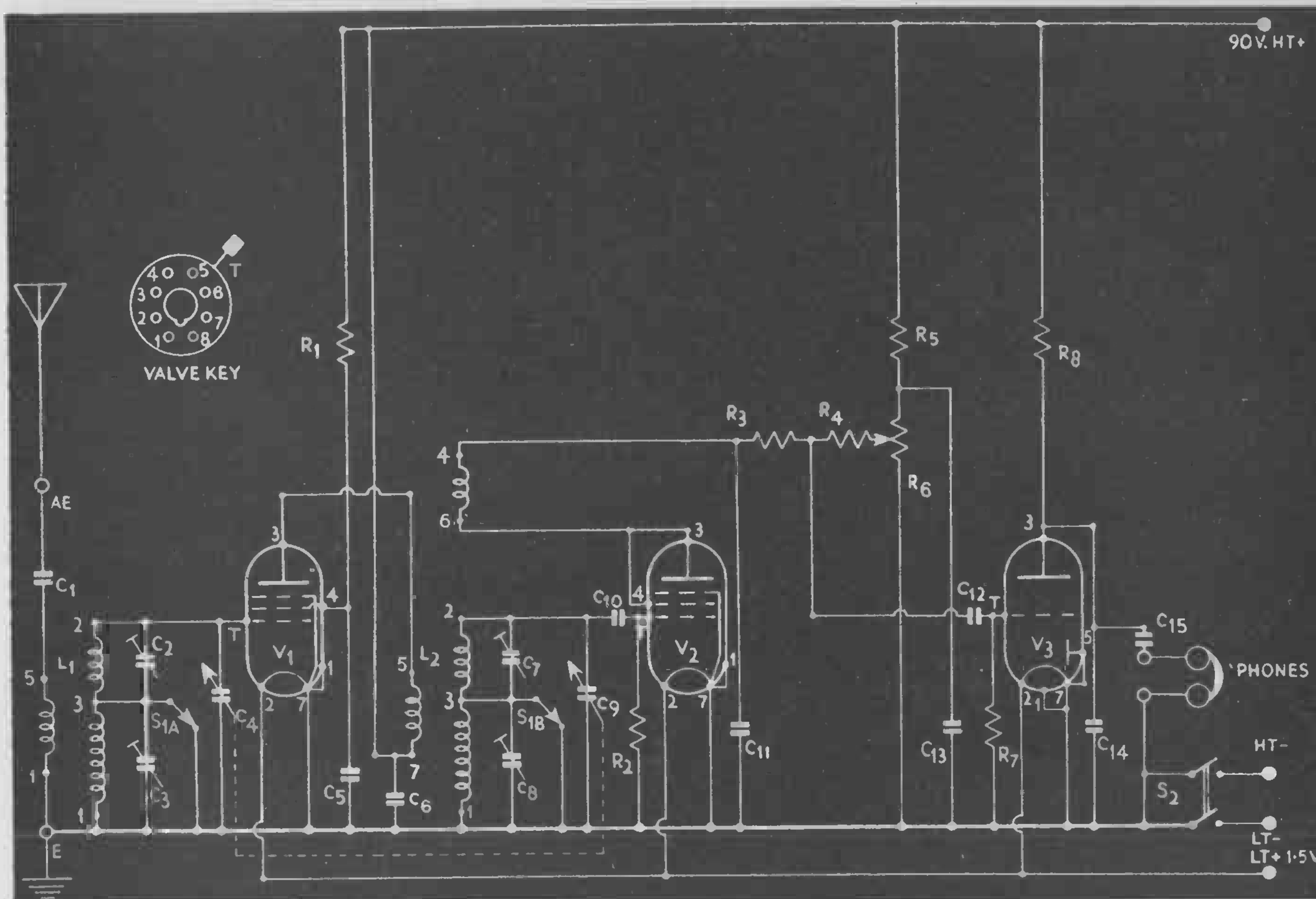


FIG. 12—THE THREE-VALVE RECEIVER

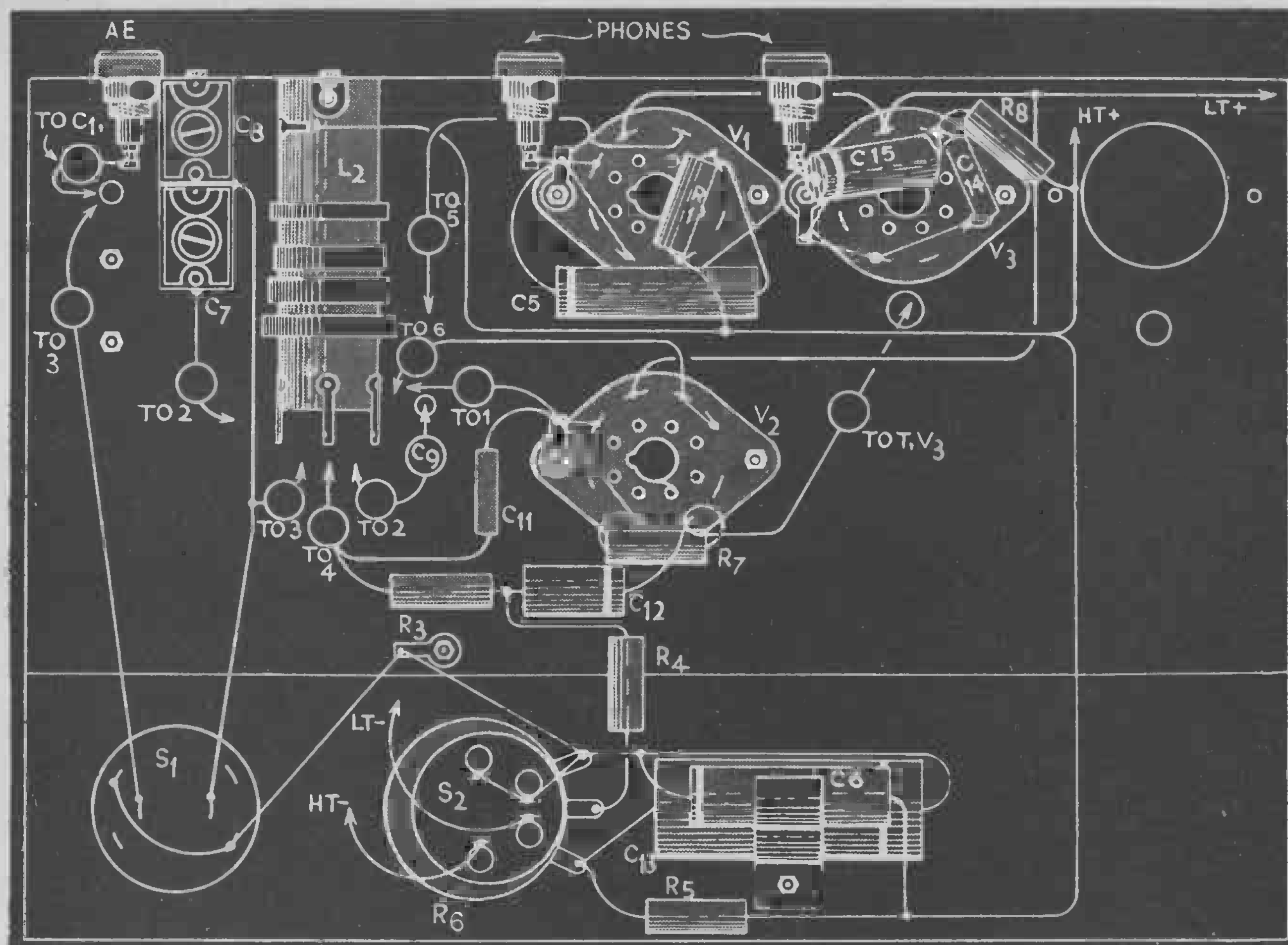


FIG. 13—UNDER-CHASSIS VIEW OF THE THREE-VALVE RECEIVER

R8 1 megohm, $\frac{1}{2}$ watt.
V3 Mullard DAC32
1 Octal valveholder.
Wire, sleeving, nuts, bolts, etc.
1 Grid clip, octal size.

CONSTRUCTING THE THREE-VALVE RECEIVER.

As before, commence the work by unplugging the batteries, headphones, etc., and remove the valves from the chassis. Turn the set over, and support its ends so that it rests clear of the bench or table and unsolder the lead from tag No. 6 of V2 to the right hand phone socket. This is the only lead which must be removed.

Bolt the new valveholder in place in the position shown in *Fig.* 13 with its keyway pointing in the same direction as those of the other valveholders, and remember the soldering tag under the left nut. Connect this soldering tag to valveholder tags Nos. 1 and 7, also to tag No. 5, the diode anode connecting point. Connect tag No. 2 of the new valveholder to tag No. 2 of the V1 holder, to give V3 its filament supply, then solder in C15 as shown from the headphone socket to tag No. 3. Also from tag No. 3 take C14 across to tag No. 5 so that it is earthed at this point; C14 is a bypass capacitor giving a path to earth for any stray H.F. at the anode of V3. If C14 is omitted the receiver may whistle and show other signs of feedback.

One end of R8 is also connected to tag No. 3, its other end being left unconnected for the moment.

R7 is connected in at the holder of V2 between tags Nos. 6 and 7, whilst from tag No. 6 is taken the grid lead to V3. This lead should be of rubber covered flex and should be as short as possible, passing through the chassis by means of the drill hole beside the V3 holder and up to the top cap of V3, where it is fastened by means of the grid clip. It is very important to keep this lead as short and direct as possible, for should it pick up any stray or unwanted signals from the other stages of the receiver these will be amplified and possibly fed back yet again to cause instability, howling and similar troubles. In the original trial receiver this lead was moved into various positions to test for possible stray pick-up without any feedback taking place, but should feedback occur in any case it can be cured quite easily. The cure consists of a screen round the lead made of a mesh of fine wires, this screen, like the metal round a valve, protecting the lead inside against stray fields and signals, and such a screen can be obtained as insulated screened sleeving. This is used in the same way as ordinary insulating sleeving, except for the wire mesh woven around the tubing. A $\frac{1}{4}$ in. of this is carefully unravelled at one end of the screening, and taken to the nearest earthed point—to use such a screen in the circuit of *Figs.* 12 and 13, for example, it would be best to add another soldering tag to the V2 holder, under the right hand nut, and take the screen to this. At no point should the screening touch any other component or connection of course, for this would cause a short-circuit, and care must be taken to see that whiskers of wire at either end of the screen cannot touch the wire inside where it emerges, or the grid clip.

Finally it remains to connect the free end of R8 which must be taken to the nearest H.T. supply point. It may be soldered onto the H.T. lead as shown in *Fig.* 13, but it might also be taken across to tag No. 6 on the V1 holder. In either case the connection must of course be clear of any other connection, component, or chassis.

The receiver is now ready to have its valves replaced, with the new DAC32 in the V3 holder. After plugging in to the L.T. battery, and connecting up the headphones, test the set by watching for the filament glow and by tapping the H.T. plug onto the 90 volts battery tapping as before. The clicks should now be really loud, and when all is found to be in order, and the battery and aerial and earth all connected up correctly, reception should be very good indeed.

It is interesting to learn that the new valve just added to the receiver is amplifying the output from the detector about 50 times—though this doesn't mean that stations will sound 50 times as loud! The ear is a most interesting part of the body, worth looking up and reading about if you can find something suitable in the local library, and roughly speaking it can only judge between quite big differences in volume—for example if the power to a loudspeaker is halved, the ear has the impression that volume has dropped only by about one-fifth. You might try to find out something, too, about decibels and phons. They don't bother us in this book, but later on when you design receivers for yourself, or, perhaps, become a transmitting amateur, decibels are very useful units.

For the moment it is enough to know that the three-valve receiver is taking signals of, perhaps, a few tens of microvolts (millionths of a volt) and giving an output to the headphones of a volt or so, very roughly, depending on the station tuned in. This means an amplification of, say, 20,000 times, again very roughly; not bad for three valves and a few components.

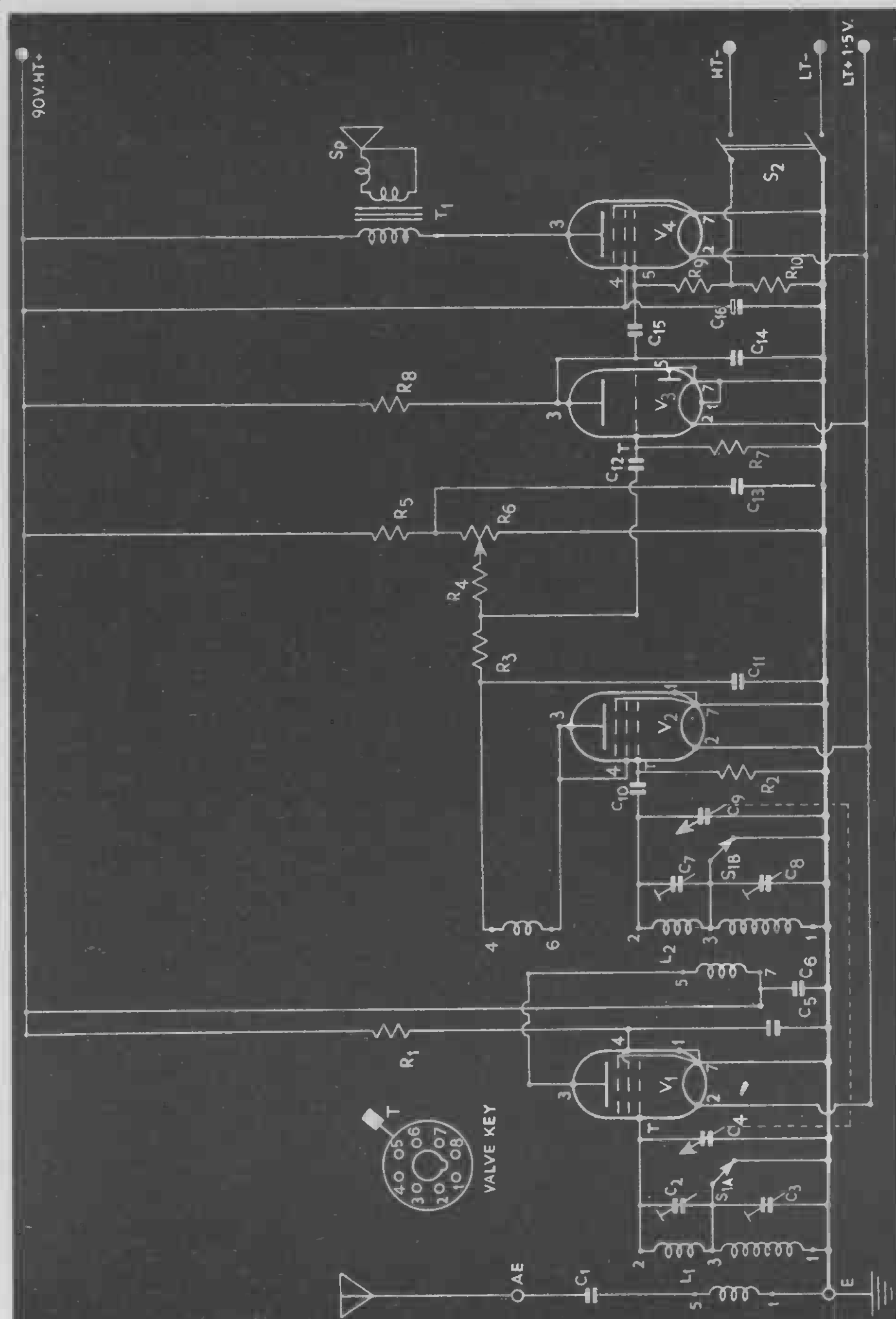


FIG. 14—THE FOUR-VALVE RECEIVER

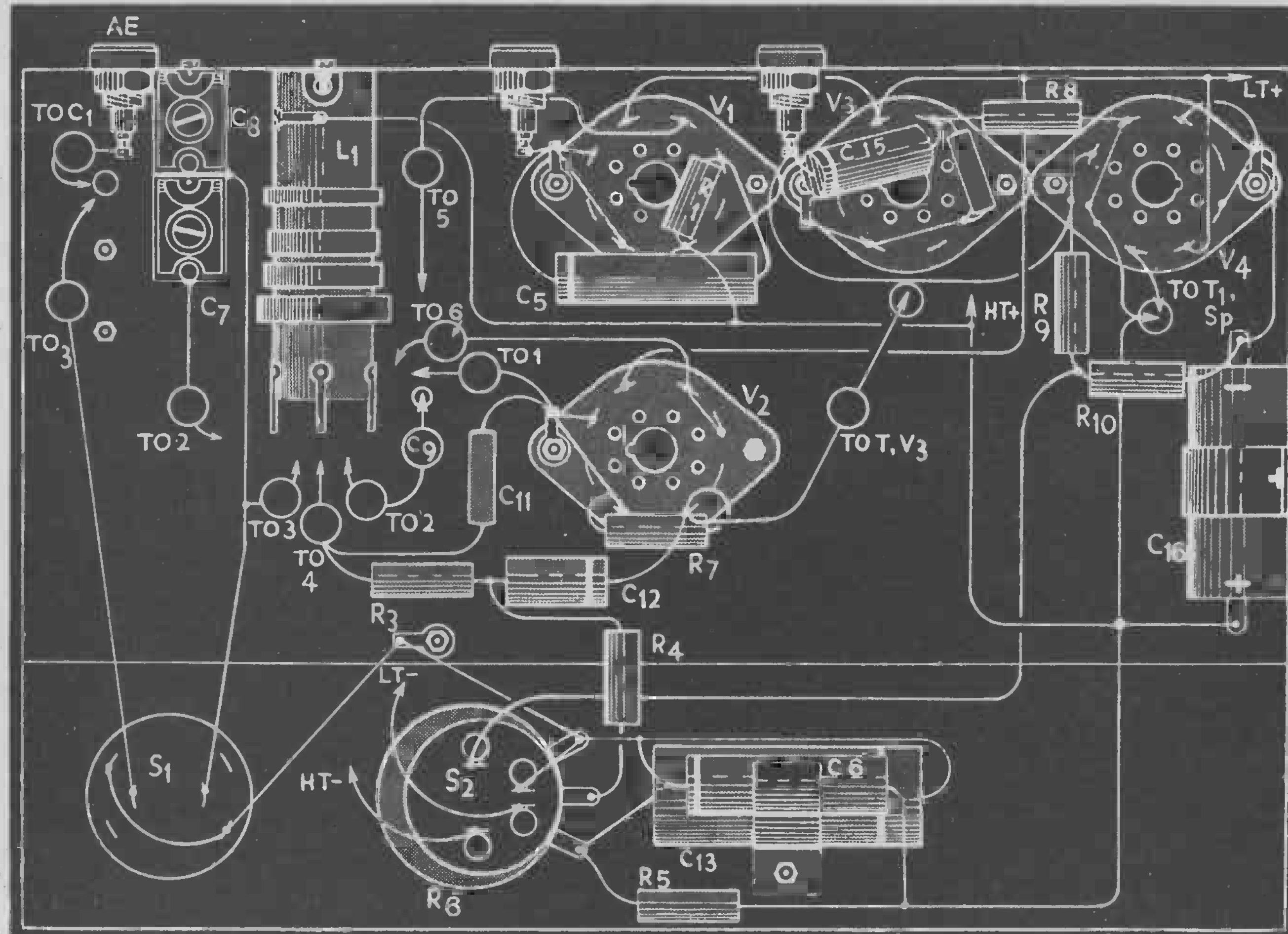


FIG. 15—UNDER-CHASSIS VIEW OF THE FOUR-VALVE RECEIVER

CHAPTER V

A Four-Valve Battery Receiver

IT remains now to add the fourth and final stage to make the receiver into loudspeaker-type set, and the circuit of this final stage can be seen in *Fig.* 14.

There are one or two important facts to notice in the diagram. In the first case the output valve has a different grid resistor circuit from the other valves, for two resistors in series are used with the H.T. negative line coming in to the junction of the resistors. This provides grid bias for the valve.

Grid bias is necessary as quite a large voltage L.F. signal is supplied to the grid from the L.F. stage. Many modern battery valves are designed to operate without grid bias, but output valves must always be biased to prevent their grids becoming positive at any time, and so drawing grid current, which would distort the sound very seriously. The bias voltage needed by the present output valve, a DL35, is 7.5 volts negative, and this is provided automatically by the flow of current through R10. All the H.T. current drawn by the receiver has to flow through this resistor, since it is in series with the H.T. battery and the negative or earth line of the set. This current flow amounts to 12 or 13 mAs. which through a 680 ohms resistance sets up a suitable voltage across the resistance. Naturally the end of the resistor connected to the negative side of the H.T. battery is then 7 or 8 volts negative to the chassis end of the resistor, and the grid leak of V4 is connected to this negative point.

The second important fact arises from this method of biasing the output valve. In the previous circuits the H.T. and L.T. negative lines are connected directly together after the switch, but now this connection must be removed and the H.T. negative switch point taken to the junction of R9 and R10.

Third, it must be noted that C16 is an electrolytic capacitor, and so must be connected into circuit the correct way round. The capacitor provides a path for all the varying L.F. and H.F. currents which would otherwise have to pass through R10 and the H.T. battery; when the battery is new they can do so easily but as the battery ages it has an increasing internal resistance which can finally lead to feedback, loss of volume and howling.

The final important point is the fact that the loudspeaker, as in any other receiver, is fed through a step-down transformer. The moving coil which drives the loudspeaker cone requires, as we have already seen, a fairly heavy current, and whilst the output valve draws more current than the other valves, this anode current is still not large enough to work the moving coil efficiently. The coil is therefore "matched into" the output valve by a transformer—the anode current through the primary induces a heavier current at a lower voltage in the secondary, and it is this current which drives the moving coil.

The matching between the output valve and the loudspeaker must be correct if the whole circuit is to work correctly. All output valves deliver power most efficiently into one certain load or resistance; in the case of the present valve the anode needs a load of 8,000 ohms. The resistance of the loudspeaker moving coil (often called the "voice coil") is about 3 ohms, and it is the job of the transformers to match these two resistances together. (Actually they should be called impedances rather than resistances, since they deal with alternating currents.) Although it is quite easy to see how a transformer can step up voltage or current from one winding to another it may not be so simple at first to understand how resistances can be matched or transformed—however, try thinking of it in this way. Forget for the moment that transformers deal chiefly with A.C. and that we are really talking about impedances, not resistances, and imagine that we have a step-down transformer whose primary is taking 10 mAs. at 80 volts—the primary is then acting like a resistance of 8,000 ohms, for 80 volts across 8,000 ohms would pass 10 mAs. If the step-down ratio were 40 to 1 the secondary of the transformer (ignoring losses and so on) would supply 400 mAs. at 2 volts, and therefore the secondary would act like a resistance of 5 ohms.

The transformer, then, is matching a resistance of 5 ohms to one of 8,000, and it is in this way that the loudspeaker coil is matched into the output valve anode circuit to give the best results.

The loudspeaker should be of the type which has its transformer mounted on it, bolted to the speaker frame, and the loudspeaker itself is mounted not on the chassis with the other components, but inside the cabinet into which the receiver is to be placed. If the set is not to have a cabinet the speaker should be placed in a case of its own, or on a baffle board. The tone from the speaker will be very poor if it is stood alone on a table or bench, and the bigger the case in which it can be placed, within reason, the better.

A baffle board can be used in place of a speaker cabinet, and consists of a large flat board of, say, heavy 5-ply wood with a central hole of the right diameter for the speaker cone. The loudspeaker is screwed or bolted very firmly to its baffle board or case.

A baffle is needed because both the front and the back of the loudspeaker cone give off sound waves, and if you think about it you will see that these sound waves are of opposite sorts—when the cone moves forward the sound wave in front will consist of compressed air, but that at the rear will consist of rarefied air. The same sound is heard either in front or behind the speaker, but the sound waves are out of phase and if they are allowed to mix the tone is affected. The real job of the baffle board (a loudspeaker cabinet is only a baffle folded up into a box), is to make the rear sound waves travel a longer distance than the front waves so that they are in phase when they emerge into the room. The low sounds have the longest wave-length and so for good low tones, or good bass,

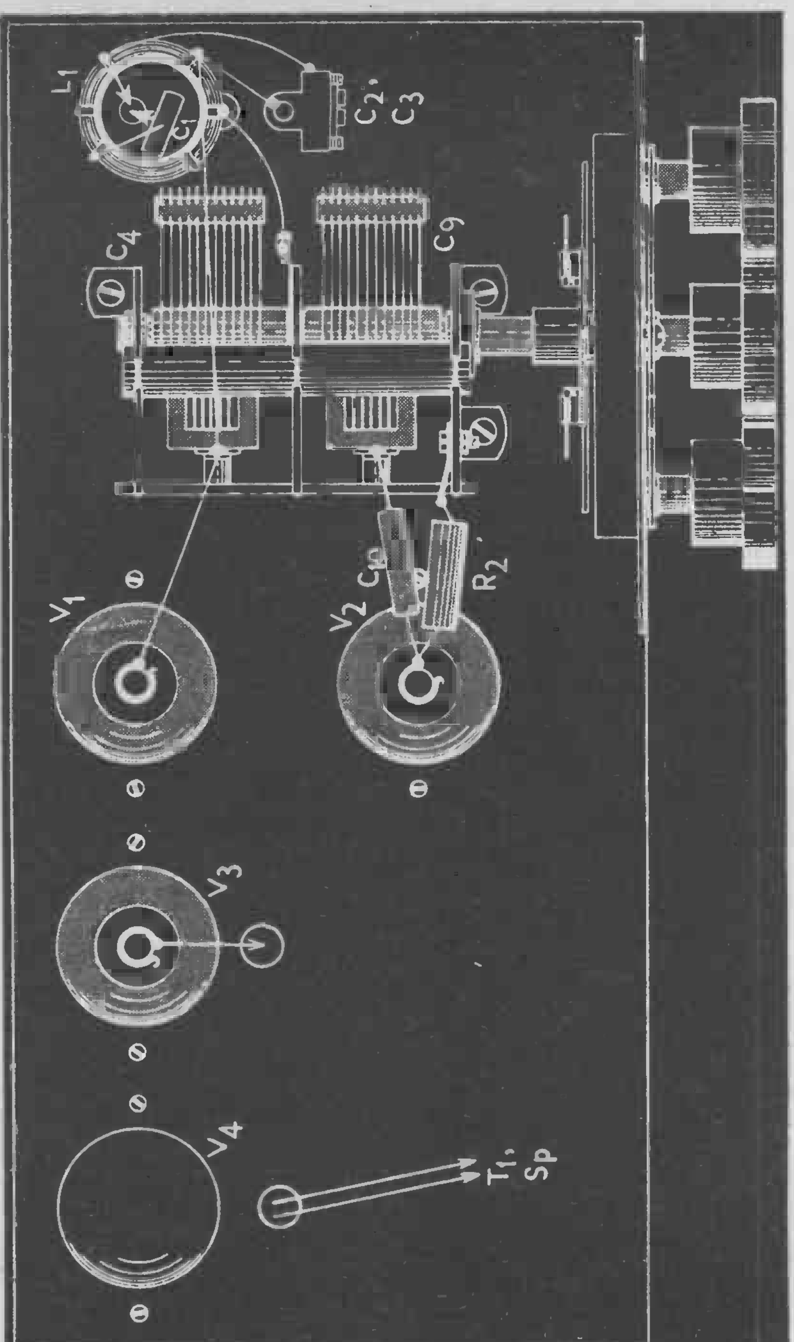


FIG. 16—TOP VIEW OF THE FOUR-VALVE RECEIVER

the baffle needs to be as large as possible. It must be firm and thick so that it will not vibrate and add unwanted sound waves of its own to those coming from the loudspeaker.

Constructing the Four-Valve Receiver

Only a few extra parts are needed for the output stage and these are listed below.

Components for the Output Stage of the Four-Valve Receiver, Fig. 14

C16 8 mF. 200 v.w. Electrolytic. T.C.C. CE18G.
R9 2.2 megohms, ½ watt.
R10 680 ohms, ½ watt.
V4 Mullard DL35
1 Octal valveholder.
T1 and Sp., 5 in. moving coil, permanent magnet loudspeaker, with output transformer to match to 8,000 ohms anode load.
Wire, sleeving, nuts, bolts, soldering tags, etc.

Prepare the chassis as before, so that with the valves removed it can be turned over and supported at the ends. The only wire to be removed is that from the on-off switch which connects the switched H.T. negative lead to the chassis.

The new valveholder is bolted down over the last valve-hole but in this case its keyway points in the opposite direction from the other valveholders and the soldering tag is secured under the right hand nut (*Fig.* 15). Tags Nos. 1 and 7 of the valveholder are connected to the earthed soldering tag.

C16, the electrolytic capacitor, is fastened to the end wall of the chassis by another clip bent out of scrap sheet metal. Make sure that the positive tag is well clear of the front chassis wall. Connect the negative capacitor tag to the soldering tag at the V4 holder, and wire in R9 and R10 as shown in *Fig.* 15, with their junction point connected to the switch contact on S2. From tag No. 5, where R9 meets the valveholder, take a well insulated lead, as short and direct as possible, to the nearer headphone socket to which C15 is connected; this enables the headphone sockets to be left on the chassis and still working, so that if a faint foreign station is tuned in the headphones can still be plugged in to get better reception.

If R8 was connected to the H.T. positive lead without being taken to an anchoring point it can now be supported by tag No. 6 of the new valveholder, to which tag No. 4 is also connected. Tag No. 4, the screen grid tag, acts as a main H.T. positive anchor and is connected to the positive tag of C16, whilst from this tag (4) and from Tag No. 3 a pair of rubber covered flex leads are taken through the nearby hole in the chassis for connection to the two tags which will be found on the speaker transformer. These leads must be left long enough to reach the speaker without stretching or straining, and if the speaker and the receiver are both to be fitted into one cabinet, the leads should still be long enough to allow the set to be taken out of the case for adjustment, and testing.

Tag No. 2 of the new valveholder is connected to tag No. 2 of the V3 holder, to give the output valve its filament supply, and the set is then ready to be turned right way up and tested. First, though, connect up the two leads to the loudspeaker—there are no special connections, either lead may go to either transformer tag. The receiver must never be switched on without the loudspeaker connected to the output valve, for then the anode of V4 would not be able to draw current and the screen grid would pass too much current, which might possibly spoil the valve.

Insert the valves into their holders, plug in the L.T. leads to the L.T. battery, and switch on so that the valve filaments can be inspected. With the H.T. negative plug in the H.T. battery, tap the positive plug on its socket, as before—there should be a loud plop from the speaker at each tap. If all seems well, plug in correctly, and connect up the aerial and earth and tune round the medium and long waves. If results are as good as they were with the test receiver, you should feel very pleased with your set.

Just one more point. Listen carefully to the tone of music and speech. It should be clear and natural, with no hollowness or boom, and no suspicion of whistling or howling. If there are whistles or howls (apart from normal heterodyne whistles when the reaction is too far advanced), this probably means that a grid lead to V3 or V4 has been left too long. If correcting the grid lead does not improve matters, connect a 500 pF. 350 v.w. Mica capacitor from tag 3, the anode, of V4 straight down to the earthed soldering tag. This should not be necessary, however.

To return to the tone of the speaker—not all ears are alike, and what pleases one listener does not always please another. It is very simple to vary the tone of the receiver, within limits, by connecting a capacitor directly across the two tags of the speaker transformer, where the rubber-covered leads are connected, the value of the capacitance being found by trial. Values between 0.001 and 0.01 mF. can be tested, each will have the effect of cutting off some of the higher frequency response, with a slight drop in volume. Capacitances vary the tone in this way—we have already seen that a capacitor "passes" A.C. and so has an impedance to A.C. The impedance depends on the frequency at which the current alternates, the higher the frequency the lower the impedance. In the L.F. signal supplied to the loudspeaker the high notes are, naturally, at a higher frequency than the low notes, and the capacitor, therefore, has a lower impedance to high notes than to low notes. A proportion of the higher frequencies are thus bypassed through the capacitor without affecting the loudspeaker, the proportion growing larger as the capacitance is increased.

CHAPTER VI

Four-Valve Battery Superhet

THE four-valve receiver described in the earlier chapters is known as a "straight" or "Tuned Radio Frequency" set (T.R.F. for short) because both the tuned circuits are adjusted to the frequency of the station being received. If you read a few wireless receiver advertisements, however, you won't find much about T.R.F. sets in them—practically every receiver will be described as "superhet."

Superhets seem very peculiar receivers indeed when you first meet them, because although they have several tuned circuits, only one or two are actually tuned to the station you want.

We have already seen that a simple receiver with a single tuned circuit is not very selective—the two tuned circuits of the final T.R.F. set give much better results, with a great deal less interference between stations. Even so there will still be some conditions where the T.R.F. set will not separate stations—it should always receive the local stations well, with several foreign stations also, but it would be better if it were more selective still. This could be done by adding another R.F. stage, but then it would be difficult to keep the receiver stable; that is there might easily be feedback over the two R.F. stages.

Another trouble with T.R.F. receivers is a change in sensitivity as they are tuned over the medium wave band. Careful listening will show that results are better at the low wavelength end than at the high wavelength end—this is because the tuned circuit has greater efficiency when the tuning capacitance is low. Again, the T.R.F. receiver is not very useful for short wave listening—short wave coils could be added but a superhet will give better results because it can be made more sensitive.

A really good receiver, then, would have (1) several tuned circuits for selectivity, and (2) these tuned circuits would be arranged to work at their most efficient point. (3) There would be long, medium and short wave tuning, whilst, (4) it should be possible to do away with a reaction control, letting the receiver work at the best sensitivity to suit the signal being received. This means (5) some form of "Automatic Volume Control," operated by the signal itself, so that the set is very sensitive for a distant weak station, but much less sensitive for a strong local signal.

The most important points on this list are the tuned circuits. If these are to work at their most efficient point they should not have variable tuning at all, and in fact this is done in a superhet. The required station, whatever its wavelength and frequency, is first tuned in normally, then converted to a standard "Intermediate Frequency" and passed on to sets of coils and amplifiers which work at that one frequency. The intermediate frequency signal (I.F. signal) is then passed to a diode detector, from which the audio is taken to an amplifier and output stage. The important thing to understand, then, is the frequency converter and I.F. amplifier; the rest of the superhet receiver is similar to any other type of set.

The circuit of the battery superhet is shown in *Fig.* 17 and at first the coils and capacitors round V1 may seem rather startling. The 4 windings on L1, however, merely provide tuning over the three wavebands, the correct coil being chosen by a switch, S1b, and the signal, once tuned, is passed to one of the 5 grids of V1, a DK32 frequency changer or frequency converter. This type of valve is known as a heptode since it has 7 electrodes altogether, and since it has so many grids it can act as more than one valve—the first two grids, for example, which are connected through switches to the coils of L2 on the right hand side of V1, act, with the filament, like a triode valve.

In this section of the valve oscillations are generated, the frequency of oscillation being controlled by the tuned circuit of L2 which is switched in by S1c and S1d. In this particular circuit the feedback coil is connected to the grid and the tuned coil to the 'anode' or second grid of the frequency changer, but the oscillations are still generated in the way explained in Chapter 2. There is no regeneration control, and the triode section of the frequency changer is oscillating all the time the set is switched on.

You will remember that when an oscillating detector is tuned to a broadcast signal a beat note or heterodyne is heard, the frequency of the note depending on the difference in frequency between the signal and the detector tuning. A similar effect takes place in V1 of the superhet—the oscillator is automatically tuned to a frequency higher than that of the required broadcast signal and the two carriers beat against each other in the valve to produce a heterodyne. In the majority of receivers, as in the present set, this heterodyne has quite a high frequency of its own, about 465 kcs. which is far above audibility, and therefore it is known as a "Supersonic Heterodyne." From these two words, of course, comes the name "superhet."

The tuned circuits of L1 and L2 are so arranged that no matter what frequency is tuned in the L1-C6 circuit, the L2-C10 circuit always tunes to a frequency 465 kcs. higher; for this purpose L2 has specially arranged windings and the "Padding" capacitors C11 and C12 are added to the circuit. If the oscillator section falls "out of gang" so that the difference frequency is more or less than 465 kcs. the set will tune incorrectly; when the oscillator is in correct adjustment it is said to "track" properly.

The heterodyne caused by the beating of the broadcast modulated signal with the plain carrier of the oscillator carries the modulation, and is now known as the intermediate frequency; this I.F. appears at the final anode of V1 and is passed to the first I.F. transformer. The first tuned winding is, of course, adjusted

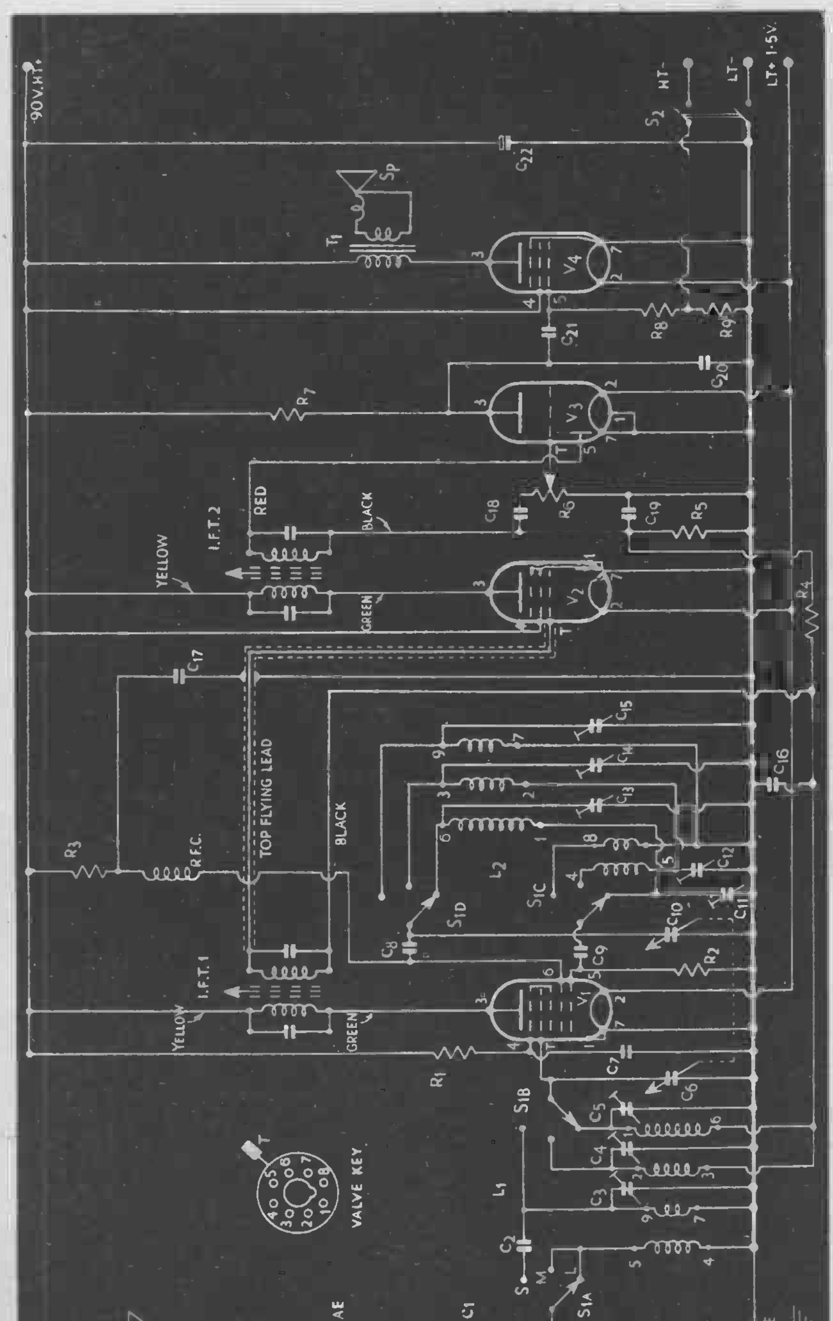


FIG. 17—THE BATTERY SUPERHET

to 465 kcs. and so accepts the heterodyne signal, whilst other beat notes caused by the heterodyne action are discarded. The primary of the I.F. transformer passes the signal on by induction to the secondary and thus to V2 where the I.F. is amplified—V2 is therefore known as the I.F. stage, or I.F. amplifier. Again the signal is taken to a tuned winding of a transformer and again passed on by induction to a second tuned winding—it thus undergoes four separate stages of tuning, which gives the receiver a very high selectivity.

The diode detector (or "demodulator" as it is sometimes called) is part of the diode triode, V3. Besides rectifying the signal, the diode also gives automatic volume control. The secondary of the second I.F. transformer is connected to the diode anode so that the diode passes current over the positive peaks of the modulated carrier wave. This permits a flow of current through R5 so that at its "upper" end appears a negative voltage varying in strength with the modulation. This varying voltage is passed through C18 to a potentiometer from which is fed the grid of the triode; the potentiometer R6 is therefore the volume control, as any proportion of the varying voltage can be tapped off from it. C19 provides a bypass for the R.F. component of the signal.

The automatic volume control, generally called A.V.C., is also obtained from the negative voltage across R5. The medium and long wave tuning coils of L1, beside the secondary of the first I.F. transformer are connected to an "A.V.C. line" instead of to the earthed chassis; C16 provides a return path for the R.F. and I.F. signals but not, of course, for any steady or D.C. voltage on the line. The line is at practically the same voltage as the negative end of R5, although the varying negative voltage due to speech or music is smoothed out by R4 and C16, so that the final voltage on the line is a steady negative one whose value depends on the strength of the signal being received. A powerful signal gives a high voltage, a weak signal gives a low voltage. The voltage, since it is negative, acts through the coils of L1 and I.F.T.1 as a bias on the grids of V1 and V2, each valve giving less amplification as the bias rises. A strong signal therefore reduces the amplification of V1 and V2, whilst it rises again when a weak signal is tuned in.

The audio signal, after amplification by the triode of V3, is passed on to the output stage V4 which operates the loudspeaker. Any stray R.F. is passed down to earth through C20, and this capacitor, if increased in value, can also serve as a simple tone control by passing some of the higher frequencies to earth.

You will have noticed that A.V.C. is not used on V1 when the receiver is switched to the short waves. This is because short wave signals are weaker, and need full amplification, whilst at the same time the frequency converter works better on these high frequencies without any negative bias. You can see, too, from *Fig.* 17 that an aerial coupling coil is not used on the short waves; S1a switches the aerial straight through C2 to the short wave tuning coil and the signal grid of V1. A coupling coil is used for medium and long wave reception.

One unusual component in the superhet circuit is the short wave choke through which the H.T. current reaches the oscillator section of V1. The short wave coils of L2 do not oscillate so strongly as the medium and long wave coils and the choke prevents any oscillatory energy from leaving the circuit. With a new battery the choke could be left out of circuit with practically no effect, but as the battery ages and drops in voltage the short wave section would stop oscillating before the medium and long wave sections if the choke were not in circuit. If the oscillator stops working, naturally, there is no heterodyne or I.F. signal, and so nothing can be heard.

Components for the Four-Valve Superhet Battery Receiver, Fig. 17

L1, L2	1 pair of Weymouth CS3W3 superhet coils.
C1, C18, C21	0.01 mF., 500 v.w. Tubular. T.C.C. 543.
C2	50 pF, 350 v.w. Mica. T.C.C. M.W.N.
C3, C4, C5 / C13, C14, C15	4 to 60 pF. trimmers. Walter Instruments MS70.
C6, C10	500 pF. variable two-gang tuner. Jackson Bros., Type E.
C7, C16, C17	0.1 mF. 350 v.w. Tubular. T.C.C. 343.
C8, C9, C19, C20	500 pF. 350 v.w. Tubular. T.C.C. CM20N.
C11	160 pF. Yellow Spot } double padder
C12	650 pF. Orange Spot } double padder. Walter Instruments Type 356.
C22	8 mF. 200 v.w. Electrolytic. T.C.C. CE18G.
R1	68,000 ohms, ½ watt.
R2	220,000 ohms, „ „
R3	10,000 ohms, „ „
R4, R5, R7	1 megohm, „ „
R6	1 megohm potentiometer, with 2 pole on-off switch.
R8	2.2 megohms, ½ watt.
R9	470 ohms, „ „
R.F.C.	Short wave choke, Eddystone Type 1010.
I.F.T. 1, 2	1 pair I.F. transformers, Weymouth, Type P4J and P4K.
S1a, b, c, d	4 pole, 3 way rotary switch. Walter Instruments, Type B.T.
S2	2 pole on-off switch, ganged with R6.
V1	Mullard DK32
V2	Mullard DF33
V3	Mullard DAC32
V4	Mullard DL35

4 Octal valveholders.
2 Sockets and plugs, Belling Lee L315 and L1021/3.
1 Flex fuseholder, Belling Lee, L1037. Fuse 1055, 60 mAs.
2 Wander plugs, red and black, Belling Lee L341. (H.T. Battery Connectors).
1 L.T. Battery plug, 2 pin.

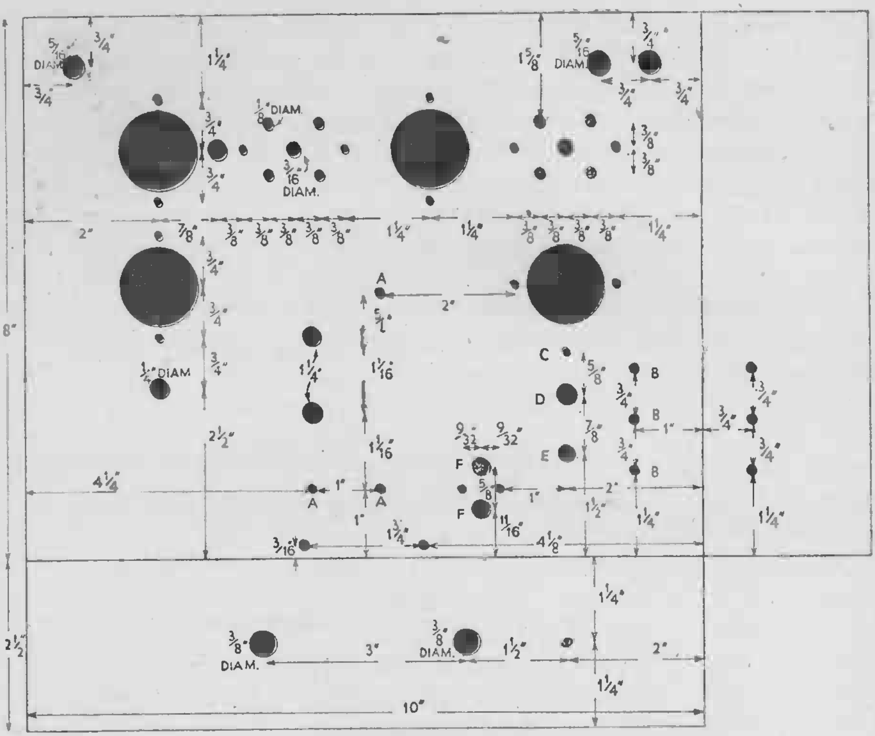


FIG. 18—THE BATTERY SUPERHET CHASSIS, TOP VIEW

Sp. & T1, 5 in. permanent magnet moving coil loudspeaker, with output transformer to match to 8,000 ohms anode load.

1 Tuning Drive, Messrs. Jackson Bros. "Full Vision Drive."

1 Tuning Scale, Messrs. Weymouth Type T.S.1. See below.

Chassis, aluminium, 10in. x 8 in. x 2½ in., drilled as shown in *Fig.* 18. Small piece scrap metal sheet for capacitor clip.

3 Knobs.

1 Rubber Grommet, to fit 5/16 in. hole.

3 Octal grid clips.

Soldering tags, nuts and bolts, wire, sleeving, solder, etc. Length of screened sleeving for grid lead of V3.

H.T. Battery, 108 volts. Ever Ready Winner, 108.

Note.—A 90 volts battery may be used instead.

L.T. Battery, 1.5 volts, Vidor, Type L5049.

Note.—The I.F. transformers have adjusting screws at the top and bottom of their cans. Avoid touching these screws until the receiver is ready to test.

In the circuit diagram the capacitors tuning the I.F. transformer windings are un-numbered. This is because these capacitors are supplied already fitted to the transformers.

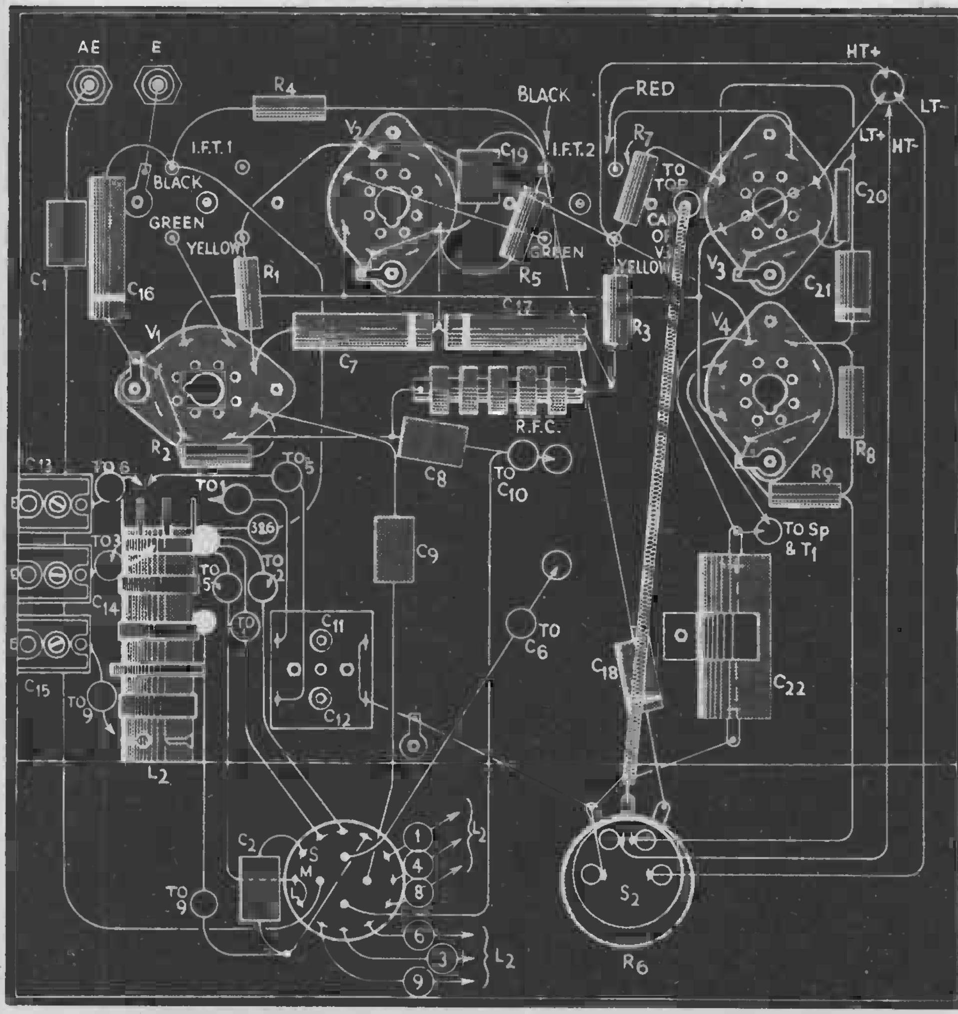


FIG. 19—UNDER-CHASSIS VIEW OF THE BATTERY SUPERHET
TAG NO. 7 OF L2 IS EARTHED TO THE COIL'S FIXING BOLT

Constructing the Superhet

The superhet is not at all difficult to build and wire up, although you should have built at least part of the T.R.F. set first for practice. The chassis is a standard size and can be bought from any good radio store—again, the best way is to buy it by post from advertisements in the radio magazines. The chassis must be completely drilled and punched with valve holes before any wiring up is commenced.

Fig. 19 shows how the parts are mounted below the chassis. On the top of the chassis the tuning capacitor is mounted in the way already described in

Chapter II, its feet being moved, or new feet being fitted, so that it can be mounted with the vanes opening to the right, as shown in *Fig.* 9. Once again the tuner must be spaced by washers to a height of about ¼ in. above the chassis surface. The holes marked A in *Fig.* 18 provide the mounting points for the tuner, whilst those marked B each have a trimmer bolted to them. The trimmers both above and below the chassis should be bolted down, as already described, with their top plates connected to earth.

The Aerial coil is bolted to the top of the chassis at the hole marked C, and the leads to its top tags then pass through the hole D and so up through the coil itself. A soldering tag bolted down with the Aerial coil provides an earthing point for tags Nos. 4 and 7. The lead to tag No. 9 passes through the hole E. The tags at the bottom of the Aerial coil can be easily identified, tag No. 7 is directly below No. 2 and tag No. 9 is directly below No. 5. Remember to connect tags Nos. 1, 2 and 9 to the trimmers bolted on top of the chassis.

On the Oscillator coil the tags must also be correctly identified, for if any of the windings are connected in reverse there will be no oscillation. Tag No. 7 is again below tag No. 2, No. 8 is below No. 4 and No. 9 below No. 5.

Care must be taken, too, with the switch contacts. Before mounting the switch on the front chassis wall, make sure how each of the four moving contacts meet the fixed contacts, and compare the switch with the drawing in *Fig.* 19.

When mounting the padder C11, C12, make sure the two adjusting screws can be reached easily through the holes F, F, and that they will not touch the metal of the chassis. Remember to connect Tag No. 5 to Tag No. 2 on L2.

When the I.F. transformers are placed into position, remember that the one with a lead from the top of the can goes between V1 and V2, the other transformer being placed between V2 and V3. Check the colours on the connecting pins with *Fig.* 19.

Only one lead is wired in above the chassis, apart from the coil leads—a length of rubber covered flex is taken from the top tag of C6, the front section of the tuner, over to the top cap of V1. To find the correct length of wire, plug in V1 for a minute, and solder a grid clip to the end of the wire which should just be long enough to connect to the valve without any strain. Take out V1 before turning the chassis over again, and remember to support its ends on wooden blocks or books whilst the wiring goes on.

Once the coils, trimmers, padders and the wavechange switch are wired correctly, the rest of the work is easy. The component positions are shown in *Fig.* 19, but remember that the wiring should be as direct as possible. Once again it has been necessary in the under-chassis view to show the wires spaced out so that each can be seen clearly, and some can be shorter than they appear in the diagram. Remember that insulation must be perfect. The screened sleeving is used to screen the lead from the volume control up to the top cap of V3. Push back the screening slightly at each end so that there is no chance of its touching the main lead and thus making a short circuit, and note that the screening at the volume control end of the lead is earthed. This joint is made by wrapping one turn of connecting wire round the screening and soldering it. Be careful not to burn the sleeving material inside the screen.

This lead should also be measured for length with V3 in place, and a grid clip soldered to the end of the lead; the third grid clip is soldered to the lead from the top of I.F.T.1.

The rubber grommet is used to bush the hole in the rear left corner of the chassis through which the battery leads pass. Remember to check the switch contacts on the on-off switch behind R6 so that the correct pairs are chosen—the method of testing is described in Chapter 2.

Also described in Chapter 2 is the method of fitting the flex fuseholder to the H.T. Negative lead.

The loudspeaker is not mounted on the chassis, but should be bolted to the cabinet in which the set is placed, or of course it may have its own cabinet or baffleboard. The speaker leads, which should be of rubber covered flex wire, pass through the hole in front of the V4 valveholder.

When the under-chassis work is complete the tuning scale can be fitted to the receiver. The scale already fastened to the Full Vision Tuning drive is not used, and is removed, the Weymouth TS1 scale being used in its place. This must be drilled with a hole for the pointer spindle—to remove the old scale the pointer screw must be taken out and the pointer removed.

The hole in the new scale is drilled at the point marked by a red cross below and between the red letters W and R at the base of the scale. A $\frac{1}{4}$ in. hole is needed and must be drilled carefully so that the celluloid is not cracked. Fit the new scale on the drive and mark where the bolt holes must be drilled, two each side, to allow the scale to be bolted to its framework. These holes are then drilled, the scale bolted on, and the pointer replaced.

Now fit the whole drive assembly to the tuner, first loosening the screws holding the adjustable base of the drive. Lower the base onto the chassis, and bolt it in place with 6 B.A. bolts and nuts, remembering that a soldering tag fits under one of the nuts below the chassis. Tighten up the adjusting bolts, and turn the tuning spindle as far as possible to the right, before tightening the grub screws onto the tuner spindle. Turn the vanes right in, then tighten up the grub screws so that the moving vanes rotate with the tuning spindle on the drive. Finally turn the spindle again to the right as far as possible, and adjust the pointer so that it too lies flat and to the right.

When the set is completely wired up, check every lead and component against the diagrams, then connect up the loudspeaker and plug in the valves. Remember never to switch on without the speaker connected. Plug in to the L.T. battery, and make sure that each filament is glowing. Plug in the H.T. negative plug to the H.T. battery, and tap the positive plug on the 90 or 108 volts socket. At each tap there should be a plop from the speaker. If all seems well, plug in, and then tap the top cap of V1 very gently with a screwdriver, holding the metal blade in the hand. Once again there should be a click or plop. There is not much use in tuning round for stations, for the set has to be aligned, or trimmed up, and that is a job which will need a good deal of care and patience.

Aligning the Superhet.

Before signals can be properly received with a superhet receiver the three different tuned sections must be adjusted correctly. The two I.F. transformers must have their four windings tuned to 465 kcs., the oscillator must be adjusted, on each waveband, to tune 465 kcs., higher than the first tuned circuit or aerial circuit, and this first tuned circuit must be trimmed to tune in agreement with the tuning scale. Receiver manufacturers and radio repair engineers make these adjustments very quickly and easily with the help of "Signal Generators"—small oscillators which can be tuned to give a signal at any required frequency. One or two of you may be lucky enough to know a radio dealer or an experimenter who will show you how to align your superhet with a signal generator, but most of you will have to adjust the receiver using broadcast station signals.

MAKE ALL ADJUSTMENTS VERY CAREFULLY, USING A THIN-BLADED SCREW-DRIVER. NEVER USE FORCE ON ANY OF THE ADJUSTING SCREWS.

Tune the set in the following steps:-

1. Stand the receiver carefully on one end, so that all trimmers, padders, and the top and bottom I.F. transformer screws can be reached.
2. Set the trimmers C3, C4, C5, and C13, C14 and C15 to half capacity. To do this, unscrew each trimmer till the top plate is as far out as it will go, then gently screw it right down, counting the number of turns. Then unscrew it again, half the number of turns counted. Set the two padders, C11 and C12, to about ¾ of full capacity. For the time being, leave the I.F.T. screws in the positions found when the transformers were bought.
3. Plug in a good aerial and earth, and switch on the receiver. Turn the volume control fully up, and switch S1 to the long wave band (over to the right).
4. Tune the receiver to the Light Programme, 1,500 metres on the red scale, and see if the station can be heard. If not, tune on either side of the 1,500 metre point, until the station is found. As soon as the station is heard, trim up the I.F. transformers for loudest volume, starting with the top screw on I.F.T.2. Turn this screw in or out to see if the volume can be increased and leave it at the point where results are best. Then adjust the bottom screw on I.F.T.2, and follow by adjusting first the top and then the bottom screws on I.F.T.1. Once the I.F. transformers have been set this in way, leave them alone during the rest of the adjustments.
5. If the Light Programme is tuned in on one side or the other of the correct 1,500 metres point, turn the tuning knob till the pointer reads 1,500 exactly, and then vary the padder, C11, until the station is tuned in.
6. Now tune to lower wavelength station, such as Kalundborg on 1224 metres. If it is not at its correct tuning point, set the pointer to the correct place and tune in the station by adjusting C13.

   Note—When adjusting either the trimmers or the padders, these should be screwed in to give more capacitance when the station is found *above* its correct setting, and out, for less capacitance, when the station is found *below* its correct setting.
7. If at point 5 the Light Programme was found at the correct point without touching the padder, go straight to adjustment No. 6.
8. Having made adjustment No. 6, retune to the Light Programme. The adjustment made to the trimmer, C13, will probably have moved the station just a little from its correct

setting. Correct the padder C11, to bring it back, then return to adjustment No. 6. The trimmer will now probably need a slight further adjustment.

9. Continue to make adjustments Nos. 6 and 8, one after the other, till one has no effect on the other. Then trim up C5 to give best volume on the Light Programme. If the signal is weak at adjustment No. 5, C5 can be trimmed then to increase volume, and then retrimmed after adjustment No. 8.
10. Now switch to the medium waves (S1 in the central position), and tune to the North Region Home Service, 434 metres on the black scale. If signals are weak trim C4 until they improve and then find whether the North Regional station is above or below its correct point. Set the pointer to the correct position and tune in the station by varying the padder C12.
11. Now tune down to the Light Programme on 247 metres, find on which side of the setting the signal lies, then set the pointer correctly and tune in the station by adjusting the trimmer C14.
12. Tune back to the North Regional station and correct the padder.
13. Tune back to the Light Programme and correct the trimmer.
14. Repeat adjustments 12 and 13 until one has no effect on the other. Finally retrim C4 for best results.
15. Now switch to the short waves, S1 over to the left, and tune over the green stripe beside the 30 metres point. When a signal is heard trim first C15, then C3, for best results. As C15 is adjusted the station will move position, and it will be necessary to retune the main tuner.

    The best way of trimming up the short wave band is to tune to a station giving English programmes and to wait until an announcement is made when the correct wavelength of the signal is given. The pointer can then be set to that wavelength and the station tuned in again by adjusting C15.
16. All the adjustments so far mentioned have supposed that the I.F. transformers were roughly tuned to the correct frequency. If this is not the case, however, the Light Programme will not be heard at all at adjustment No. 4.

    If no signals can be found the I.F. transformers must be roughly set by placing the cores at their mid positions. To do this, unscrew the trimming adjusters on the transformers till they are right out—do not force them or the iron dust cores will be damaged—then screw them in, counting the turns in each case, till the screw slot is level with its holder. Then unscrew the cores for half the number of turns counted, when the cores will be central. It should now be possible to hear a signal on the long wave band, and the I.F. transformers will be corrected during adjustment No. 4.

With the short wave tuning range adjusted, the aligning is complete and the set ready for use, once it is placed in its cabinet.

CHAPTER VII

An A.C. Mains Superhet

ALL the circuits described in this book so far have been battery operated. This is for a very good reason—so that they are completely safe for you to use and experiment with them. A mains receiver is cheaper to run, it can be more sensitive and gives a much greater output, but it can be dangerous until you know something about constructing and handling radio receivers. You *must not* try building a mains operated receiver, therefore, until you are accustomed to battery sets.

There are two types of mains operated receivers—A.C. sets, which work off A.C. mains only, and A.C./D.C. or Universal Mains receivers, which operate either from A.C. or D.C. mains. No. A.C./D.C. receiver is shown in this book, because the circuit and very often the chassis itself of such a receiver is directly connected to the mains wiring, making such a set very dangerous indeed under certain circumstances. In the A.C. receiver the mains are "isolated," as it is called, from the set by the mains transformer. Most of you will have A.C. mains supplies in your homes and so will be able to use the receiver circuit shown in *Fig.* 20; those of you who have D.C. supplies only must be content with battery receivers until you have a lot more experience.

The A.C. mains receiver of *Fig.* 20 is actually a good deal more simple to build and adjust than the battery superhet since a coilpack is used; a coilpack contains all the aerial and oscillator coils ready assembled round the wave-change switch, with all the wiring completed. For this reason there is no need to show the coils, trimmers, switch, etc., in the diagram and only the 5 soldering tags actually connected to the rest of the circuit are drawn. There is also a sixth connection but this is made automatically when the coilpack is bolted by its single large fixing nut onto the metal chassis. Besides being ready built and wired, the coilpack, like the I.F. transformers, is also "pre-aligned," that is the trimmers and adjustable cores in the coils are all set correctly so that if all connections and components are in order the receiver works as soon as it is first switched on, and needs only very slight trimming corrections to suit it to the aerial being used. The adjustable cores act as Padders.

Whilst the mains superhet operates in the same manner as the battery receiver—the received signal is heterodyned to produce a modulated standard I.F. which then passes to a diode detector and an L.F. and output stages—there are some points in *Fig.* 20 which need explanation. In the first case, V1 is not a heptode but a triode-hexode, two valves in one. The aerial signal is supplied to the hexode and the triode provides the oscillator section; notice that the triode grid is extended, in the valve, to behave as one of the hexode grids as well. This gives an "injection" of the oscillator power into the hexode as a grid voltage to heterodyne the broadcast signal. The hexode section is so called as it has 6 electrodes.

Notice that the electrode which supplies electrons to the valve is no longer a filament but a cathode heated by a filament or heater. The cathode is shown as a flat bar at the bottom of each valve in *Fig.* 20 and in each case is brought out at the No. 8 tag on the valveholder. The actual cathode within a mains valve is a metal tube coated with a special preparation which emits electrons when heated; the heater itself is placed inside the tube and insulated from it. This form of construction is needed to allow the valve filaments of heaters to be operated from A.C. supplies. The cathode takes some seconds to heat up to operating temperature but once there it will keep a steady temperature, and emit electrons steadily, even though its heater varies slightly in temperature from time to time. If the electrons were drawn from an ordinary filament operated from A.C. their emission would be governed by the temperature changes in the filament caused by the alternating wave, and any signals applied to the valve would be masked by a 50 cycles hum.

One or two valves, chiefly rectifiers, have heavy strip filaments without separate cathodes for A.C. operation, but all the modern mains valves which you will use in this receiver have cathode tubes—it is easy to see the tube, and the leads to the heater inside it, near the base of unmetallised glass valves.

In the present circuit the heaters of V1 to V4 require 6.3 volts at varying currents, whilst the heater of V5, the rectifier, takes 5 volts at 2 amperes. Some types of mains valves require 4 volts across the heaters, whilst other types, for A.C./D.C. operation, require as much as 30 volts and more across the heaters, since these last valves have their heaters connected in series.

A further point to notice about the cathodes of the valves in *Fig.* 20 is that they are not connected directly to the earth line—the connection is made through a resistor bypassed by a capacitor; R16 and C16 in the case of V4. This arrangement gives the valve automatic grid bias, or cathode biasing as it is usually called. Modern battery valves are, in the main, designed to work without grid bias—in the 4 valve battery receivers only the output valves are biased—but most mains valves require a bias to set their operating conditions correctly. The valve's anode current flows up through the cathode resistor and thus sets up a voltage across it which makes the cathode positive to the earth line. This is exactly the same thing as making the grid negative to the earth line, and so the proper grid bias can be obtained by making the cathode resistor the right value. If the valve passes 10 mAs. and needs 1 volt grid bias, Ohm's Law gives the answer that the cathode resistor should have a value of 100 ohms.

In a pentode the cathode resistor is carrying both anode and screen current, since the screen draws a few milliamps, and, in some cases, even a little grid current as well, if the grid should run positive. The anode current will obviously be varying with the signal, so to prevent the cathode voltage from fluctuating a capacitor is connected across the resistor as a bypass. In R.F. circuits only 0.1 mF. or so is needed, whilst in audio and output circuits 25 mF. is a common value. If the capacitor is omitted the cathode voltage varies in opposition to the grid voltage and reduces the amplification given by the valve; this is known as one form of "negative feedback" and can be very useful in audio amplifiers and similiar circuits, where it is used to reduce distortion, correct tone, and so on.

In *Fig.* 20 V1 and V2 share one resistor and capacitor. This is simply for economy, both valves need the same bias and so R4 and C5 serve for both of them, just as R6 and C9 serve for both screens. Valves cannot always be fed together in this way, but in this case the method is perfectly suitable.

A further difference between mains and the battery circuit is found in the A.V.C. arrangement. V3 in *Fig.* 20 has two diode anodes—it is a double-diode-triode—and so one of these diodes can be used for A.V.C. alone. It is fed by a small capacitor from the anode of V2 instead of from the I.F. transformer secondary. The A.V.C. in this case is delayed for the cathode of V3 is biased by R10 to about 2.5 volts positive so that the diode anode must be more than 2.5 volts positive before the diode current will flow. (The anode must be more positive than the cathode.) The weakest signals will not supply sufficient anode voltage to give current flow and so the A.V.C. does not come into operation on them, it is "delayed" until a signal is strong enough to overcome the bias on the diode section of V3. The weakest signals therefore receive full amplification in the controlled valves, V1 and V2, although of course there is no correction on them if they should fade.

Since, however, this is your first mains receiver, the most important and interesting part is the power pack, which is made up of T2, the mains transformer, V5, the rectifier, L.F.C., the low frequency choke, and C18 and C17, the reservoir and smoothing capacitors.

T2 has its primary fed from the mains through S1, the on-off switch, which is on the rear of the volume control R8. The primary of the transformer is tapped so that it can be adjusted correctly to any mains voltage between 200 and 250 volts—the most usual voltage is 230 volts though some of you may be able to check this by looking at your electricity meters which may have your mains voltage stamped onto their information plates. If you cannot discover your exact mains voltage, it is generally safe to use the 230 volts tapping. The connections to the primary, therefore, are made to the "Common" and to the 230 volts or other correct tapping. The other primary tappings are unused, and must be most carefully insulated—it is a good idea to roll them up, each one separately, and to bind them with a layer of insulating tape. Never pull the wires, or bend them about unnecessarily.

Between the primary and the other transformer windings is a screen, shown

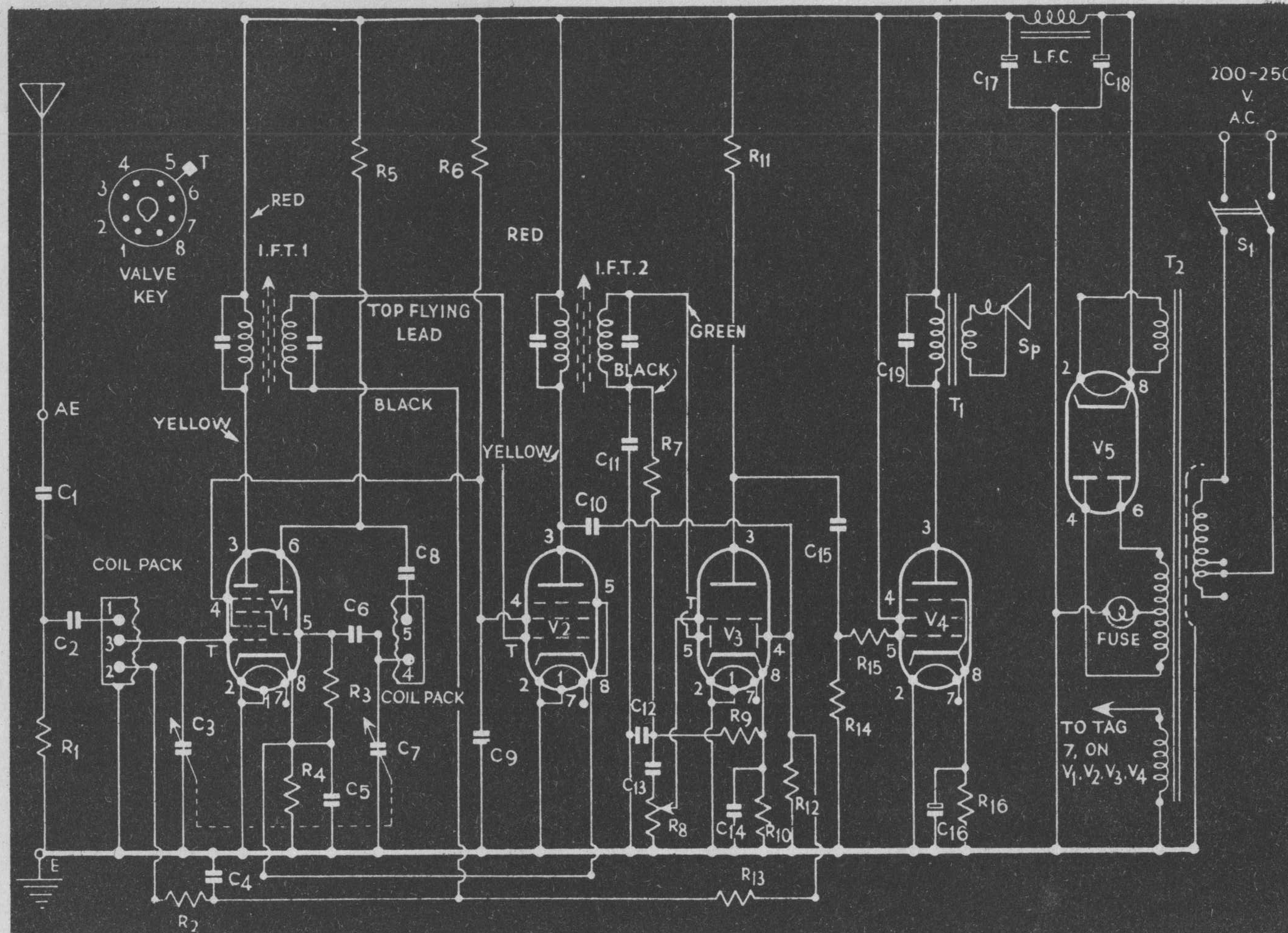


FIG. 20—THE A.C. MAINS SUPERHET

in *Fig.* 20 as a line of dashes connected down to the earth line. This can be identified from the colour code card with the transformer, as can all the other leads. This screen is actually a single layer of thin wire over the primary with a connection at only one end; it prevents noises in the mains lead (electrical noises, of course, caused by poor switch contacts, electric motors, and so on) from being induced into the secondary windings and so interfering with reception.

The two heater secondaries, one giving 6.3 volts and one giving 5 volts are easily identified because of the thick wire used to carry heavy current. Some transformers will have a centre tap to each of these windings, but in this circuit these are not required and can also be rolled up separately and insulated.

Finally the 250—0—250 volts winding, the H.T. winding, will be found. When the transformer is working this winding has 500 volts across it, a really dangerous figure, so that you must never run any risk of touching the two contacts on the V5 holder to which this winding is connected. The centre tap of the H.T. winding is taken to earth through a fuse bulb which is a protection for the transformer if the capacitors C17 and C18, or the rectifier, V5, should ever break down.

The duty of the H.T. secondary of T2 and the rectifier V5 is to convert the alternating output from the transformer into smooth direct current; any trace of A.C. left would cause serious hum, and C17 and C18, with the L.F. choke perform the smoothing. First the A.C. from T2 is rectified or converted into D.C. in the following way.

Since the centre tap of the H.T. winding is connected to the earth line, whenever one end of the winding is 250 volts positive to earth the other end must be 250 volts negative to earth, and since the winding is supplying A.C. each end is positive in turn. Consider the moment when Tag 4 of V5 is positive to earth—it will draw electrons from the rectifier's cathode, these electrons in turn coming from the H.T. supply line, through the L.F. choke, and also from any charge on C18. The electrons flow through the lower half of the H.T. secondary, through the fuse bulb and so to the earth line, where they are available for passage through the circuits and valves.

No electrons are drawn to tag No. 6 anode of V5 since this is very negative.

In the next instant, however, the ends of the H.T. winding reverse their polarity and it is the turn of the tag No. 6 anode of V5 to draw electrons from the cathode. This time they flow round the upper half of the H.T. winding, but still arrive at the earth line to feed the receiver circuit.

Electrons flowing through the valves and into the H.T. line first charge C17, the smoothing capacitor, then flow through the L.F choke to charge C18 and return to the rectifier cathode. The rectifier tries to draw electrons in spurts, as each anode goes positive in turn, but the choke opposes current flowing in spurts by its self-induction—as soon as the current starts to rise the magnetic field around the choke winding varies and induces an opposite current and voltage which practically wipes out the spurt effect. The spurts of current are therefore taken from C18 which recharges after each one, and because of this there is a quite heavy flow of A.C. through the capacitor, although, of course, it does not pass D.C. The reservoir capacitor, therefore, is working under rather difficult and wearing conditions and a good component must always be used in this position. Another point to remember is that the peak voltage across the H.T. transformer secondary is a good deal higher than the R.M.S. voltage, and so the voltage across C18 is more than 250 volts at peaks—it is actually almost 250 x 1.414 volts. The reservoir capacitor in any receiver must therefore have a higher voltage rating than the transformer voltage—a 250 volt transformer must have at least a 350 volts and preferably a 450 volts capacitor, and so on.

Transformers vary their voltage output to some degree with a change of load. If only a few mAs. are drawn from the H.T. secondary the voltage will rise a little, drawing more current makes the voltage fall. A transformer which has a wide variation of this kind is said to exhibit poor regulation.

Note. In some books you will find the action of a power pack described by the old "current flow" theory—you will read how current flows from the rectifier anode to its cathode, so charging up the reservoir capacitor in spurts, these spurts being smoothed out by the L.F. choke and then by the smoothing capacitor. We radiomen, however, have to remember that electrons flow from negative to positive and make up the true current.

In any power pack the smoothing capacitor (C17 in *Fig.* 20), really has two tasks to perform. Whilst it helps to smooth out the direct current H.T. and remove mains hum, it is also very important as a path for R.F. and L.F. variations. Each valve in a circuit has a varying anode current as soon as a signal is applied to its grid and naturally these variations are also found in the H.T. supply lines; just as in any other electrical circuit they must have a complete path to flow round. If these variations of current had to flow through the power pack or through any type of resistance or impedance they would immediately set up voltages which might interact and cause howling or, at the least, distortion and poor tone. C17 provides a low impedance path for these variations which are therefore bypassed straight down to the earth line without having to pass through the L.F. choke or any other part of the power pack.

Constructing the A.C. Mains Superhet.

By this time you will have learned a good deal about constructing receivers and the three diagrams, *Figs.* 20, 21 and 22 will tell you almost everything you need to know about building the mains superhet. Special points are mentioned after the components list.

Components for the A.C. Mains Superhet, Fig. 20.

Coilpack	Osmor "Q" Coilpack, Type H.O., Pre-aligned.
C1, C2, C13, C15	0.01 mF. 500 v.w. Tubular. T.C.C. 543.
C3, C7	500 pF. variable two-gang tuner, Jackson Bros. Type E. See below.
C4, C5, C9, C14	0.1 mF. 500 v.w. Tubular. T.C.C. 543.
C6, C10, C11, C12	100 pF. 350 v.w. Mica. T.C.C. CM20N.
C8	200 pF. 350 v.w. Mica. T.C.C. CM20N.
C16	25 mF. 25 v.w. Electrolytic. T.C.C. CE32C.
C17, C18	8 plus 8 mF. 450 v.w. Electrolytic. T.C.C. CE27P.
C19	See below.
R1, R15	10,000 ohms, ½ watt.
R2	100,000 ohms, ,, ,,
R3, R5, R7	47,000 ohms, ,, ,,
R4	200 ohms, ,, ,,
R6	33,000 ohms, 1 watt.
R8	1 megohm potentiometer, with 2 pole on-off switch.
R9, R12	470,000 ohms, ½ watt.
R10	3,900 ohms, ,, ,,
R11	220,000 ohms, ,, ,,
R13	1 megohm, ,, ,,
R14	330,000 ohms, ,, ,,
R16	270 ohms, 1 watt.
I.F.T.1, 2	1 pair I.F. transformers, Osmor, Pre-aligned.
S1	2 pole on-off switch, ganged with R8.
V1	Mullard ECH35.
V2	Mullard EF39.
V3	Mullard EBC33
V4	6V6GT.
V5	Mullard GZ32.

5 Octal valveholders.

2 Sockets and plugs, Belling Lee L315 and L1021/3.

Fusebulb with holder. Bulb, 250 mAs. See below.

Mains Transformer, T2. See below.

Primary—200-250 volts.
H.T. Secondary, 250-0-250 volts, 60 mAs.
L.T. Secondaries, 6 volts, 3 amps.
5 volts, 2 amps.

Messrs. A. W. Feldman, Type FM1/250.

L.F. Choke. To carry 60 mAs., resistance 360 ohms. See below.

Messrs. A. W. Feldman, Type MC3.

Sp. & T1. 5 in. permanent magnet moving coil loudspeaker, with output transformer to match to 5,000 ohms anode load.

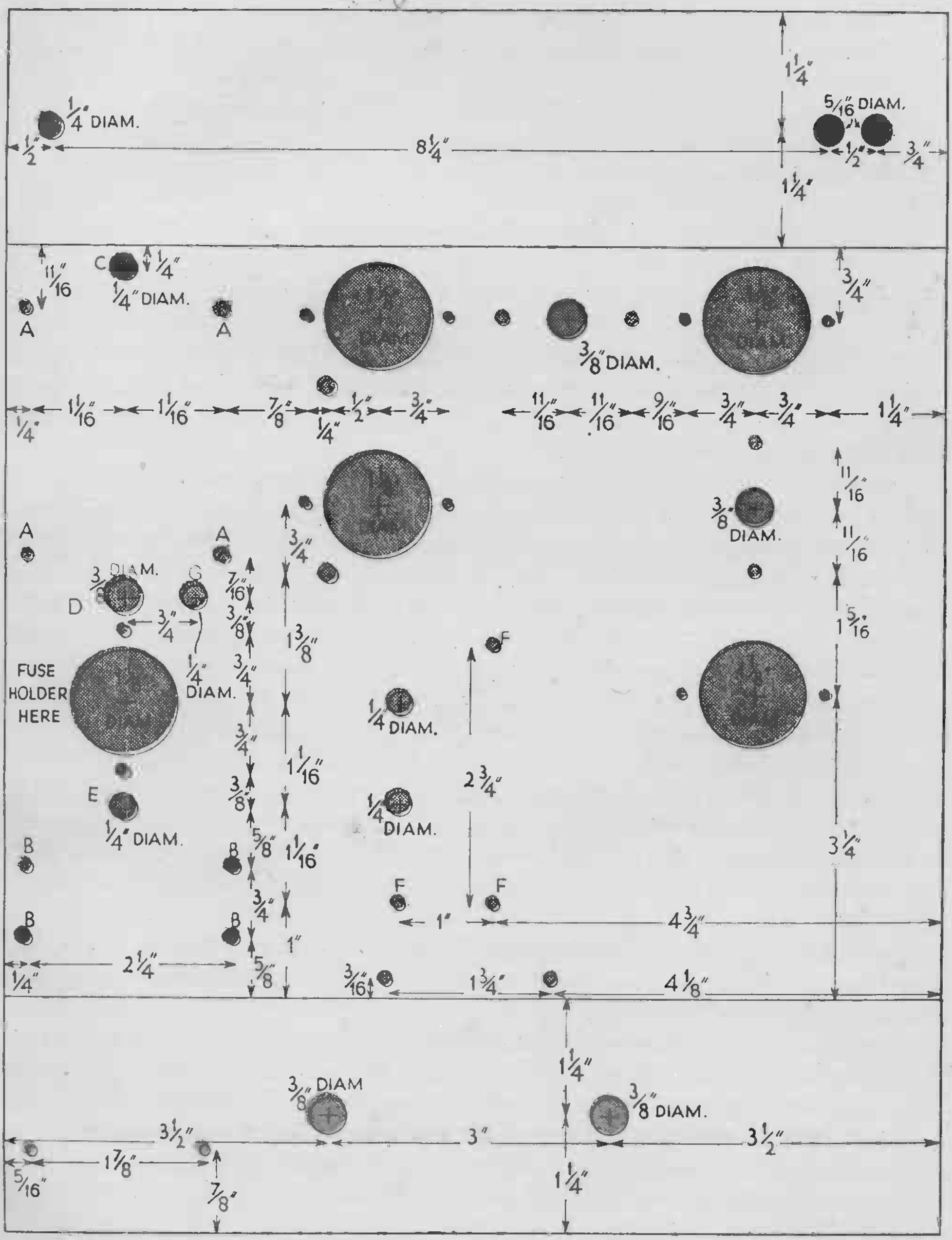


FIG. 21—THE A.C. MAINS SUPERHET, CHASSIS TOP VIEW

1 Tuning Drive, Messrs. Jackson Bros. "Squareplane."
1 Tuning Scale, Messrs. Osmor, square metal type to suit H.O. coilpack. See below.
Chassis, aluminium, 10 in. x 8 in. x $2\frac{1}{2}$ in., drilled as shown in *Fig.* 21.
1 Capacitor can clip, T.C.C. Type V3.
3 Octal grid clips.
3 Knobs.
Soldering tags, nuts and bolts, wire, sleeving, solder, etc.
Length of screened sleeving.
Length of "cabtyre" twin lead cable for mains lead.

The Osmor H.O. coilpack, I.F. transformers, and tuning scale should all be ordered together; make sure that the coilpack and I.F.T.'s are pre-aligned—that is, already tuned. Do not touch any of the adjusting screws on the coilpack and I.F. transformers.

You will see from the components list that in the trial model of this set an Osmor tuning scale was used with a Jackson Bros. "Squareplane" slow motion drive. The white celluloid scale was removed from the drive, and the small lugs holding it were filed away. The pointer, of course, was removed first. Then the large Osmor dial was mounted in place, its central hole falling over the pointer spindle, by means of two strips of aluminium bolted to the front edge of the chassis—the holes for these are not shown in *Fig.* 21 because you may be able to think of some better way to mount the scale. It could quite easily be held by aluminium brackets to the "Squareplane" drive itself. A new pointer will be needed as the old one is not long enough but whilst you could buy this, it can also be made from a straight length of tinned copper wire—use a fairly thick gauge, like 18 S.W.G. To straighten wire off a hank or reel unwind a yard or so, grip the end of the wire in a vice, or by pliers, and put a good strong pull on the other end of the wire. The wire stretches slightly and remains straight and true.

To make the pointer, bend the right length of wire into a loop in its middle, just large enough to hold the pointer fixing bolt. Make sure the ends of the wire do not scratch the scale.

You can, of course, buy a complete Osmor tuning drive with the coilpack and I.F. transformers, but many of you will probably want to use the tuning drive from your old battery set—that is why it is mentioned in the parts list.

The tuning capacitor is again mounted "upside down"—that is, it has its feet moved, or new feet put on, and is bolted down on stacks of washers, with the vanes opening to the right, just as in the other receivers. The tuner is bolted to the holes marked F, *Fig.* 21.

The connection to the top cap of V1 is made above the chassis and as before it is taken from the top soldering lug of C3—the front section of the tuner—over to the valve by a length of rubber covered flex.

C19 is again a tone correcting capacitor, and the final value is best chosen by trial. Wait till you have the speaker properly mounted in its cabinet or on its baffle before choosing C19, for the speaking mounting has a big effect on tone. Probably 0.01 mF. will give the most pleasing results.

Remember, once again, to check the switch contacts on the back of R8 to make sure which are the correct pairs. This is especially important in this receiver since the switch is handling mains voltages. A battery and bulb will soon show which point connects with which when the volume control spindle is turned.

The fusebulb and holder mentioned in the parts list can be found practically anywhere. The fusebulb is the same size as a torch bulb—though it must be bought specially so that it has the correct rating of 250 mAs.—whilst the holder can be a bakelite or metal type which many of you will already have; the sort of bulb holders in your sister's dolls' houses. Don't ask for those, though! The fixing holes in the chassis will depend on the holder itself, and so are not shown in *Fig.* 21. They should be drilled beside the V5 position. A bakelite holder is best. Take out the two small connecting screws which hold the wires, clean the lugs with a small fine file and solder the leads to the bulb holder when you are wiring up. Make sure that no blobs of solder get between the lugs and the chassis, and check that when the bulb is screwed into place the bottom contact arm is not bent down to touch the chassis. If there is any danger of this a circle of cardboard can be cut and fixed beneath the bulb holder when it is bolted down.

The transformer and L.F. choke used in the trial receiver are given in the parts list, but there are so many makes of these components that it may not always be possible to obtain exactly the ones mentioned. However, this is not too important—so long as well made parts are used, there are several types of transformers and chokes which will work perfectly in this circuit. The important points are that the voltage ratings are correct—a 250-0-250 volts secondary at 60 mAs. with 6 volts 3 amps and 5 volts 2 amps windings—and, in the case of the choke, the current rating must be for 60 mAs. at least, with not too low a resistance. Either a 10 or 20 Henrys choke may be used; these are the two most common values.

The next important point is to ensure that the transformer and choke will fit the chassis. The drilling points in *Fig.* 21 are, of course, for the transformer and choke mentioned in the list and if you have to obtain different makes of these drill the holes to suit them. The transformer is bolted down to the holes marked A, and the choke to the holes marked B. Use 4 B.A. bolts for this purpose, 6 B.A. are not large enough.

The mains lead from the switch to the primary passes up through the hole C. If the transformer leads are long enough these of course can be used; if not they will have to be connected to longer leads and great care must then be taken to see that the joints are perfectly insulated.

Perfect insulation of all the secondary leads from the transformer is also necessary. Once the leads have been identified from the colour coding supplied with the transformer, they are wired in as follows:

6 volts heater leads. Take both through the hole G. Earth one to the nearer soldering tag of the V4 valveholder, and take the other to tag No. 7 on the V4 holder. Connect this tag No. 7 with the No. 7 tag on the V1, V2, V3 holders.

5 volts heater leads. Take these through the hole D, and connect to tags Nos. 2 and 8 of the V5 holder.

250-0-250 volts. Take the 0 or centre tap lead to one side of the fusebulb holder. From the other side of the fusebulb holder take a rubber covered wire, pass this down through hole D and connect it to the nearby earthing tag of the V5 holder.

Take the 250 volt leads, pass these down through hole D, and connect them to tags Nos. 4 and 6 of the V5 holder.

The screen lead can pass through either hole to the nearest earthed soldering tag.

The choke leads pass through hole E and can be anchored at the two capacitor tags on C17-C18. These tags must be identified as the third capacitor tag is earthed. This is generally coloured black but the earthed capacitor tag may also have a slightly different shape from the two positive tags, with a little "snick" or cut-out on both sides of it.

The rest of the wiring is quite straightforward, and with the help of *Fig.* 22 you should find this quite a simple set to build. Remember to identify the coloured leads of the I.F. transformers and to connect them up properly—it is clear that the transformers are mounted over the holes between the V1-V2 and the V2-V3 positions. Mount the transformers so that the adjusting screws face outwards.

The coilpack must also have its adjusting screws within reach, and so it is placed as shown in *Fig.* 22, with the coils and trimmers pointing downwards. Handle the pack with care when it is being bolted in. The potentiometer is shown in the diagram as if the chassis front were bent outwards, this is simply to make the connections clear.

The leads from V4 to the loudspeaker are passed through the hole beside the V4 holder. Rubber covered leads should be used, and the speaker must be connected up before the set is switched on. C19 is not shown in *Fig.* 22 since the capacitor is connected across the tags on the output transformer which should be mounted on the speaker itself.

When all the wiring has been completed and carefully checked the slow motion drive and tuning scale should be mounted in the manner already described. Make sure that the pointer lies straight across the scale with the tuning capacitor vanes fully open.

The receiver can now be tested. To do this, plug in V4 only, connect the mains lead to the mains and switch on. The mains lead, of course, should have a proper mains plug to fit the socket you are using. V4's heater should glow after a second or so, coming up to a good brilliance. If all is well so far, switch off,

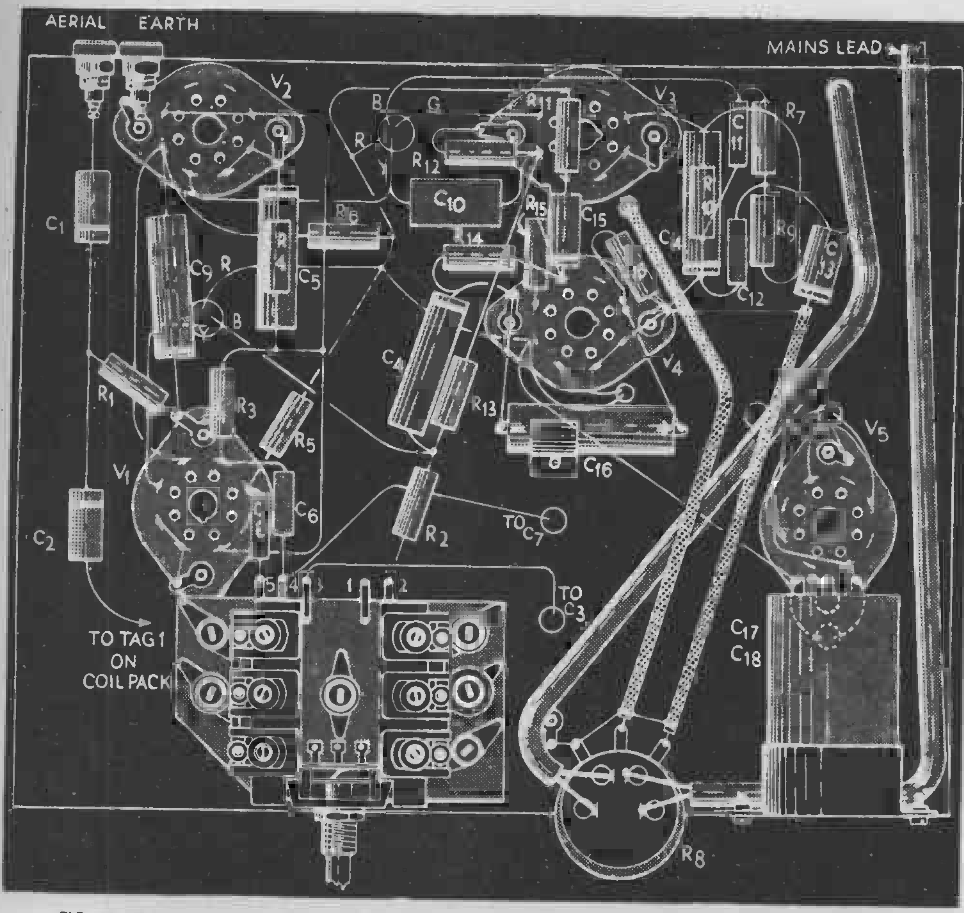


FIG. 22—THE A.C. MAINS SUPERHET, UNDER-CHASSIS VIEW, HEATER WIRING NOT SHOWN

plug in V1, V2 and V3 and switch on again, to make sure that all heaters are connected correctly and are glowing. Switch off once more, make sure the loudspeaker is connected up, and plug in V5; also screw in the fusebulb. Switch on again—after about half a minute there should be a gentle hissing or rustling in the speaker, also possibly a little hum. The hum should be very slight, bad hum indicates power pack troubles or something wrong in the receiving circuits.

Now plug in the earth plug. This may reduce any slight hum. Follow this by plugging in the aerial plug, there should be a loud click from the speaker and it is best not to have the volume control turned up too far.

Switch to the medium wave band, the central switch position on the coilpack, and tune over the band. At least the local Home Programme should be received, and probably many other stations as well. On the long wave band the Light programme will be received with possibly other Continental programmes (switch to the right) and on the short waves (switch to the left) once again there should be several stations.

It now remains to give the receiver its final trimming. Switch off, and stand the chassis carefully on its left hand end, with the transformer and choke supporting it on their sides. Switch on again, and remember to keep the hands clear of the power pack.

The iron dust cores of the coils and I.F. transformers must be adjusted with the greatest of care, and a metal screwdriver must on no account be used for this will cause them to crumble. An old plastic knitting needle, with one end filed into a screwdriver blade, makes a very good trimming tool.

In the following instructions the capacitor and coil numbers refer to the coil pack diagram which you will receive with the coil-pack itself. The coils are numbered from L1 to L8 on this diagram, with the trimmers numbered from C22 to C27.

1. With the set on end and all trimmers and cores easily reached, switch on and set the wavechange switch to the medium wave position. Tune from the low wavelength end (200 metres) to the London Home service on 330.4 metres, setting the pointer at its proper tuning point. All being well the station should be heard near the 330 metres position.
2. If the station is heard, turn the core of L6 for best results and bring to the station right onto its tuning point.
3. If the station is not heard near the correct tuning point, tighten up C23 and C26 (use only light pressure and do not crack the white ceramic washers) then slacken them off half a turn. Retune to 330.4 metres once more, and adjust the core of L6.
4. With the set still tuned to the London Home Programme, adjust the core of L3 for greatest volume.
5. With the receiver still tuned to the London Home service, test the setting of all four I.F. transformer cores. Tune each core, starting with I.F.T.2, using the tool made from a knitting needle, to the position giving best volume.
6. Now tune to the Light Programme on 247.1 metres. It will probably fall on one side or the other of the correct position. Correct the tuning by adjusting C26 till the station tunes on the 247 metre point. Then adjust C23 for greatest volume.
7. Now tune to the Northern Home service on 433.5 metres, and bring the station on to its correct tuning point by adjusting the core of L6. Adjust the core of L3 for greatest volume.
8. Repeat Nos. 6 and 7 until one adjustment fails to have any effect on the other and the stations are found in their correct tuning positions with no further adjustments.
9. Finally correct the setting of C23 on a weak signal near the 225 metres point for greatest volume. Then adjust the core of L3 on any weak signal near the 450 metres tuning point for greatest volume.

   The medium wave range is then adjusted. During all further adjustments the I.F. transformers should not be touched again.

The long wave range can now be adjusted in the following way:—

1. Switch the wavechange switch to the long wave band and tune the capacitor to 1,500 metres, the Light Programme. Set the signal to its correct position by adjusting the core of L5.
2. Adjust the core of L4 for greatest volume.
3. Tune to any station at about 1,000 metres and adjust C24 for greatest volume.

The short wave range really requires careful tuning with the assistance of a signal generator, but very good results can be obtained without a generator so long as the coil cores of L1-2 and L7-8 are not touched. Set the trimmers C25 and C22 half open, and tune in a station at the 19 metres point; then adjust C22 for greatest volume. (On the pre-aligned coilpack it *should* be sufficient just to adjust C22 slightly once a station at about 19 metres has been tuned in without touching C25.)

CHAPTER VIII

Cabinets

WHATEVER type of receiver you build, once it is made and working correctly there is still some work to do—it has to be fitted into a cabinet. The crystal set can be made up in a simple small box, but loudspeaker receivers need something rather better than this.

In some cases you may be able to find an old radio set cabinet which will house the chassis, but whether you already have a cabinet or decide to build one, the first point to settle is the position of the chassis and the loudspeaker. As you know, there are two main types of radio cabinets, one low and long, with the loudspeaker to one side of the cabinet, and the upright type where the speaker is placed above the tuning dial.

The long cabinet is especially useful for battery sets for then the batteries can be placed behind the loudspeaker; an upright case suits most mains receivers quite well, though sometimes, when a large tuning scale is used, it is rather a job to find room for the speaker. It is worthwhile looking at several different types of radio sets, and studying those in shop windows, for ideas about cabinets. Sometimes plastic cabinets are advertised in the radio magazines at quite reasonable prices and when you are really experienced you will find it possible to buy a cabinet first and then design a set to fit into it.

For the time being, however, you will have to rely either on old cabinets or build simple new ones. The best materials are good plywood and wood battens for joints, with something like leatherette for a covering. If you feel brave you can experiment by rubbing the cabinet down with a fine glasspaper till it is really smooth and then enamelling it with two or three coats of bright colour—make sure, though, that it will fit in with the colour scheme of the room where the radio is to go.

Deciding the cabinet size is not difficult although it is a job over which you must spend a little time and trouble—it calls for some work with the chassis and loudspeaker, a ruler, and pencil and paper. Building a case is not hard, either, especially if you are going to cover it over with leatherette. The points to remember are that the loudspeaker needs a really firm mounting, and the chassis needs to get well up to the front of the cabinet, so that plenty of spindle remains to carry the control knobs. The only tricky jobs are drilling the spindle holes in the right places, and cutting out the tuning dial space. This is harder on an old cabinet than with a new one, for an old case will already have drilled holes of various sizes, and almost certainly these will not fit the new chassis

The best way out of the difficulty is to fit the old case with a new panel of thin ply, and, when this is finally drilled and cut, to cover the old cabinet completely with a new surface of material or to enamel it.

The hole or grille for the speaker is easily positioned and cut on a new cabinet. Either a circular hole can be sawn right away with a fretsaw, or a decorative grille can be designed and cut out in pieces. On old cabinets the speaker grille may look old fashioned, and then the new plywood panel can be taken right up the face of the cabinet and a new grille cut in that. One very neat method of decorating either a new or old cabinet is to use a heavy weave of cloth, such as tweed—a plain colour without a pattern is best. This has the advantage that only a plain round hole for the speaker is necessary; the cloth is taken right over the hole and a decorative grille is not necessary.

Behind the speaker hole (which should be slightly smaller than the diameter of the loudspeaker cone) a piece of thicker wood should be firmly glued into position. This small baffle must, of course, have a similar hole cut in it before it is mounted. It gives a firm base for the speaker which can be screwed down onto it—make sure the screws used are not long enough to go right through the wood and the panel. Good hot carpenter's glue is really needed, but a lighter glue will serve if some small brass tacks are tapped through the panel into the baffle—this is supposing that a further covering or enamel will be used to hide the tacks.

The best way of marking the drilling positions for the control spindles is to let them do their own marking. Rub a layer of ordinary chalk on the end of each spindle, then put the chassis into the cabinet at the right point and press the ends of the spindles onto the back of the panel. Each spindle end will leave a white mark showing where the hole must come. Drill through the centre of this mark with a small drill, then, from the front of the panel, drill through again with a $\frac{3}{8}$ in. drill, using the small hole as a guide. If one spindle should be longer than the others drill the hole for that one first. It will then pass through the panel and allow the other spindles to make their marks.

Once the spindle holes are drilled through the panel the cut-out for the tuning scale can be drawn onto the panel by taking measurements from the spindles to the scale on the chassis and marking these off on the wood. Before taking any measurements check the escutcheon against the tuning scale, and cut the hole to suit the escutcheon—it will have to be slightly smaller than its outside measurement, with small drill holes to take the escutcheon fixing bolts.

In the case of the A.C. mains superhet some of you will consider the escutcheon to be too small for the larger Osmor dial fitted to the "Squareplane" drive. In this case you can obtain a square piece of glass the same size as the scale, and mount this into a hole in the panel. To hold the glass in place use strips of plywood along the edges of the hole, slightly overlapping the sides of the glass. The strips on the outside of the panel could be of some other wood to give a decorative effect, being left uncovered if the rest of the panel is covered with material or enamelled. Thin strips of oak or mahogany are useful for making such a frame round the scale, though the wood must of course be chosen to suit the style and colour of the cabinet.

When the panel is drilled the next point to decide is how the chassis is to be fixed firmly into the cabinet. One method is to set the chassis in place with its front face against the back of the panel, and then to screw down a wooden batten on the floor of the cabinet so that it presses lightly against the back of the chassis, but the best way is to fit the chassis with feet or brackets. These can be two small Meccano brackets bolted to the rear wall of the chassis so that their flat portions rest on the cabinet floor. The floor is then drilled with two holes, one under each bracket, so that they can be bolted down firmly—this means that there will be bolt heads protruding on the underside of the cabinet which must therefore be fitted with feet to allow room for the heads so that they will not scratch furniture. The feet can be made from small blocks of wood tacked and glued into place, and it is a good plan to stick a layer of felt or baize on the underside of each foot.

Before the chassis is finally fixed into the cabinet put the knobs onto their spindles to see if they stand out too far from the front of the case. If they do, or if the spindles are of unequal lengths, they must be trimmed—measure them first before cutting them, so that enough is left to hold the knobs firmly and mark the trimming point on each spindle with a small file notch. Then take the chassis out of the cabinet and cut each spindle down to the correct size. A fine toothed hacksaw is best for this, but a fretsaw will do the job perfectly well if it is worked gently and not forced. Make sure that the metal dust from the sawing is kept away from the switches, coilpacks and so on, and also keep the loudspeaker clear especially if any of the spindles are of steel. Never saw or file metal near the loudspeaker for there is always a chance of the metal dust getting into the narrow gap between the magnet and the speech coil, and causing grating noises. Most control spindles are of brass, and are easily cut. Grasp the spindle firmly in the left hand so that it cannot rotate with the saw and also support it against the downwards cutting pressure. When the spindles are trimmed, lightly file their ends to remove any burrs or rough metal, and then mount the chassis in the cabinet and fix it into place.

When the knobs are screwed onto their spindles (choose a screwdriver which fits the small grubscrews really well, as they are easily damaged or jammed into the knobs if you are not careful) the set can be connected up and tested for tone. This is really the time to choose the capacitance which in some circuits is shunted across the primary of the output transformer, for you will find that the speaker tone is different in the cabinet. If the case is made of light wood there may be a resonance or "boom" on some notes which can be bothersome, but it is not too hard to cure this. If your cabinet resonates take some odd lengths of wood batten and with good glue stick them into various positions on the inside walls and roof of the cabinet. Choose places where they will not be in the way of the chassis when you require to take it out, but apart from that stick them anywhere and at odd angles across the walls. These battens will stiffen the wood of the cabinet and break up the resonances and boom.

The cabinet will require a back to keep out dust and this can be made of plywood or even of good cardboard. Cut it out with a pattern of holes rather like the back of a commercial radio set, and remember to allow for the aerial and earth sockets and plugs, battery or mains leads, and so on. The holes in the back are needed for ventilation which is quite important even with a battery set and very important in the case of a mains receiver. Mains valves generate a good deal of heat and plenty of air must be able to circulate round the valves and chassis, the transformer, and other components to keep their temperatures down.

Once again, battens can be used to form a mounting for the back of the cabinet, the inside rear edge of the case being framed with wooden strips into which screws can be driven through the ply or cardboard back. Use 6 or 8 small wood screws so that the back cannot vibrate. When the whole set and cabinet is complete experiment by placing it in different positions in the room for the best tone and effect. Try it with the back tight against the wall, then bring the cabinet forward an inch or so and notice the difference—try the set at an angle across a corner, too, which is a good position if it can be managed.

GOOD LISTENING!

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