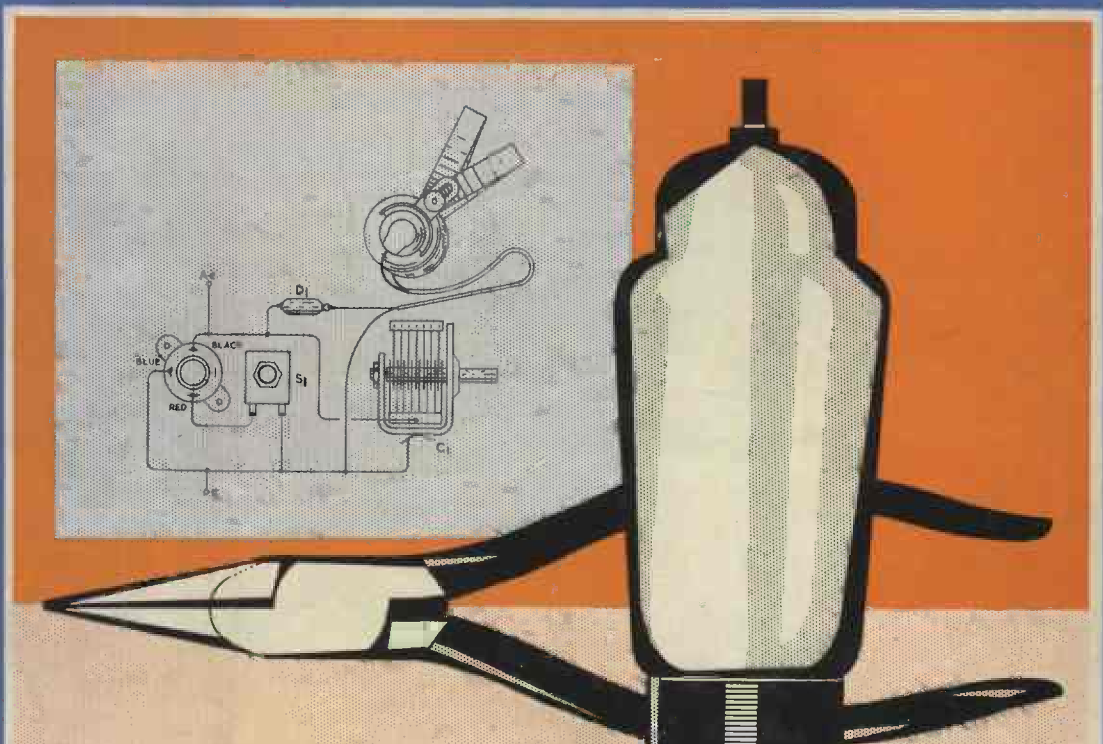
RADIO



EDWIN N. BRADLEY

A JUNIOR TEACH YOURSELF BOOK

RADIO

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 book has an introduction written in three parts. 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 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 by building the Crystal Set shown in Chapter 1 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.

There are also details for building a One Valve headphone receiver which grows, in stages, to a Four Valve loudspeaker set, and a whole section on Transistors, showing how they work and how to build transistor amplifiers and receivers.

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Junior Teach Yourself Books

EDITED BY LEONARD CUTTS

RADIO

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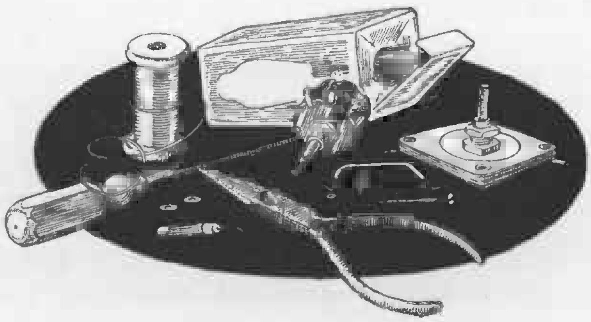
BY

EDWIN N. BRADLEY



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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.

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Part III gives a list of tools required and some hints on construction. Chapters I to IX 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, circuits using both valves and transistors being shown, 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 described 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 licence.

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.

PART II

Electricity

ALTHOUGH we still have a good deal to learn about atoms and electricity we now know that an ordinary 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, pass a current only 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.

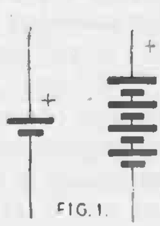


FIG. 1.

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.

(Since the last paragraph was written for the first edition of this book developments in junction diodes and transistors have forced us to think once again about current flowing from positive to negative. Special materials have been produced in which a lack of electrons give rise to 'positive current carriers'—you will find more about this on page 34).

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!

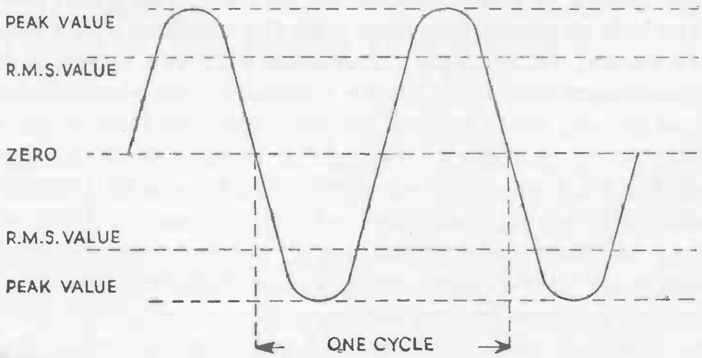


FIG. 2

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.

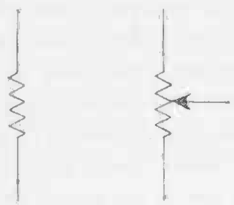


FIG. 3.


FIG. 4

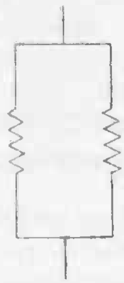


FIG. 5

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 potential 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.

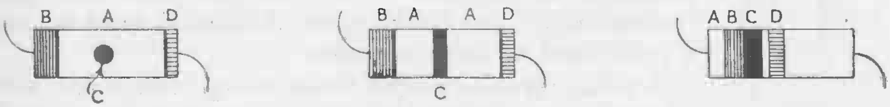
The resistance value is taken from the three colours A.B.C. in that order. D, not present on all resistors, shows the "tolerance" of the component. Resistors used in normal radio receivers do not need to be extremely accurate, so for ordinary work resistors which have values within 20% of the marked 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 I have come across 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.

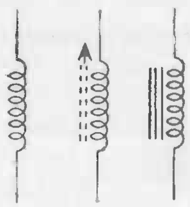


FIG. 6.

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 ferrite cored coil; in this type the core is of a special non-metallic magnetic material. 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 power supplies; it would have an inductance of perhaps 10 or 20 Henrys. The air and ferrite-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.

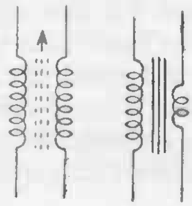


FIG. 7

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 later on 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 (kc/s. for short), which are thousands of cycles, and megacycles (mc/s. 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.

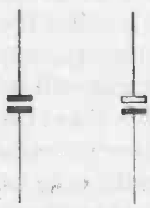


FIG. 8.

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 thin insulating layers set up by chemical action. If the capacitor is connected up incorrectly the layer is destroyed and the capacitor passes a heavy current. Since these capacitors are often 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 waveband a large coil is switched in, for the Medium waveband a smaller coil is employed, and so on, until for the Short waves coils with only a few turns of wire are needed.

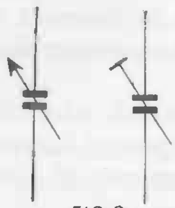


FIG. 9.

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 exciting 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.

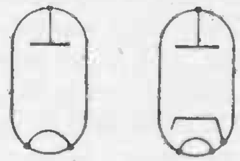


FIG. 10A. DIODE

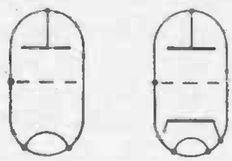


FIG. 10B. TRIODE

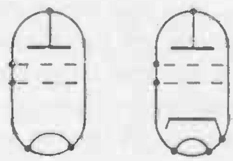


FIG. 10C. TETRODE

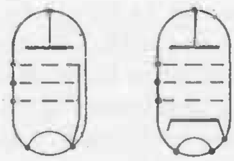


FIG. 10D. PENTODE

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 cathode 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 B7G types and fit into a 7 socket holder. On the circuit diagrams the valve electrodes are coded with a number from 1 to 7, a small "key" diagram showing the 7 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, but this arrangement is not used with B7G valves.

Valves must always be handled with care, and inserted and withdrawn from their holders very gently. Be careful not to bend the soft metal pins of the B7G valves. If a pin does get bent, straighten it very gently with small pliers.

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 diagonal 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. You will only need these if you intend to build large receivers.

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.

Another grand present would be a solder-gun, which is the modern type of soldering iron. The bit is a length of tinned copper wire or strip which is heated by a transformer, and which can easily be renewed as it wears out. In the most convenient form of gun the transformer is mounted in the handle, and this type of iron obviously can be used only on A.C. mains.

Its advantages are that it is switched on only when it is required for use, by a press-switch in the handle, the bit warming up in a few seconds. It can be put down practically anywhere without a rest, and the bit can be bent, if necessary, to enable it to reach awkwardly placed joints without heating or burning nearby components.

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 plastic-covered flexible wire. This can be obtained with various coloured coverings and it is a good scheme to use different colours for different jobs—all the filament wiring in green, for example, with black and red for the H.T. circuits. The plastic is stripped from the wire for a ¼″ or so to expose the wire, which is tinned ready for jointing, and care must be taken not to burn the plastic with the soldering iron whilst the joint is being 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 1

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 older portables the first tuning coil was made large enough to serve as an aerial by being wound over a frame, but in modern portable sets the aerial coil is wound on a ferrite rod or slab. Ferrite is a non-metallic magnetic material which is used to concentrate the surrounding field, due to radio waves, through a suitable aerial coil wound on the rod. This coil therefore receives much more strongly than would a similar coil with no ferrite rod, and passes on good signals to the rest of the receiver. The aerial required for a crystal set is usually 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 wavelength 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 called a 'theoretical' diagram, and in *Fig.* 2 the same arrangement of parts is shown in a 'practical wiring' diagram. A comparison of the two illustrations shows how much neater and clearer the theoretical diagram can be, and all radio circuits are drawn in this way. The symbols can be read after a very little practice:—it is clear from *Fig.* 1, for example, that only 5 components are needed for the crystal set. These are L1, the coil, which tunes over both the medium and long wavebands, C1, the tuning capacitor, which is variable, a switch S1 for selecting the waveband, the crystal detector itself, D1, and a pair of headphones, H.

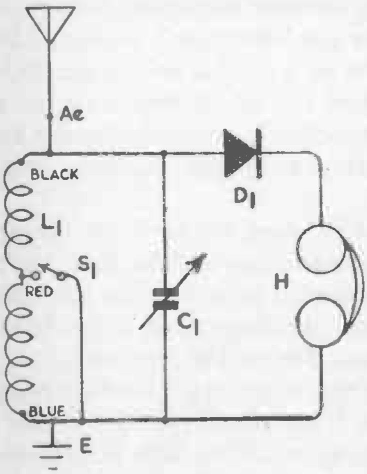


FIG. 1.—THE CRYSTAL SET (Theoretical Diagram)

The straight lines of the diagram indicate wires between the components and where these lines meet in a dot an electrical connection is meant. If one wire 'jumps' over another by means of a small bridge (this can be seen in *Fig.* 5) the wires do not connect at that point, and are insulated one from the other. Some diagrams do not use 'bridges' to show that there is no connection between wires; in these diagrams dots mean connections and lines running one over the other with no dot mean that the wires are insulated. This system is used chiefly in large and complicated circuits and does not appear in this book.

The aerial or input end of the circuit is almost always shown on the left, as in *Fig.* 1, and the output end on the right. A heavier or thicker line at the base of the diagram is known as the 'earth' line and it will be seen in later diagrams that a great number of components are connected, on one side, to this line. In the actual receivers it is very convenient to make this earth line the metal chassis.

The symbols for aerial and earth are also shown, the aerial connection being Ae and the earth connection E.

Components for the Crystal Receiver, Fig. 1

L1 Repanco Crystal Set Coil Type DRX1
C1 500 pF. variable tuning capacitor.

D1 Germanium detector, Mullard OA70 or G.E.C. GEX34 or equivalent.
S1 Single-pole wavechange switch.
H High impedance headphones, or deaf-aid earpiece.

In valve and transistor receivers the tuning capacitor is always of the 'air-spaced' type, and an air-spaced capacitor is indicated in *Fig.* 2. In such a tuning capacitor the fixed vanes are held firmly in the main frame, and are insulated from it by small ceramic pillars whilst the moving vanes swing freely through the fixed vanes and are connected electrically to the main frame. The more the moving vanes are meshed into the fixed vanes so the greater is the capacitance. There is, however, another type of variable capacitor, known as the 'solid dielectric' type, in which the insulator (or 'dielectric') between the vanes is not so much air as thin sheets of paxolin or a similar substance. This allows the vanes to be made closer together and the whole capacitor, as a result, is much thinner. Such a solid dielectric capacitor is quite satisfactory for use in the crystal receiver, a suitable type being a Messrs. Jackson Bros. 'Dilecon' capacitor.

We have already seen that different sized coils must be used for tuning different wavebands. L1 therefore consists of two windings and for long wave tuning both of these coils are used together, connected in series. For medium wave tuning only the smaller coil is needed and the larger coil is therefore 'short-circuited' by the switch S1 so that it has no effect on the receiver.

The crystal detector used in this receiver is of the modern germanium type, and more is written about this in the next section, 'How the Crystal Set Works'.

Make sure you have high impedance headphones, or a fairly high impedance earpiece. If you are buying headphones the impedance or resistance should be stamped or marked on them, and you require headphones of about 2,000 ohms. 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.) The resistance of the headphones depends on the number of turns and thickness of wire in the coils, and for many purposes low resistance headphones are employed. For use with crystal receivers these are not nearly so satisfactory as high impedance headphones.

If you intend to build a transistor receiver later on you may prefer to buy a miniature earpiece instead of headphones. Once again a fairly high impedance component is required and a suitable earpiece is the Ardente ER 250. You will also need to obtain, at the same time, a flexible cord, Ardente E6/E6, and a two-pin socket, SK1255, whilst the earpiece must be fitted with a plastic 'ear-pip' by means of which it is fixed into the ear.

All the components can be obtained from a good radio shop, but it is possible that those of you in smaller towns and villages will have to send away for most or all of your parts. This is where magazines are a great help; look through as many as possible (you should find at least one in the reading room of your local library) and study the advertisements for names of dealers who supply components by post and who advertise the type of components you require. By taking a little trouble in this way you can often save money and time.

When you are buying the components also buy some plastic-covered flexible connecting wire. A good reel may seem rather expensive at first but is cheapest in the long run.

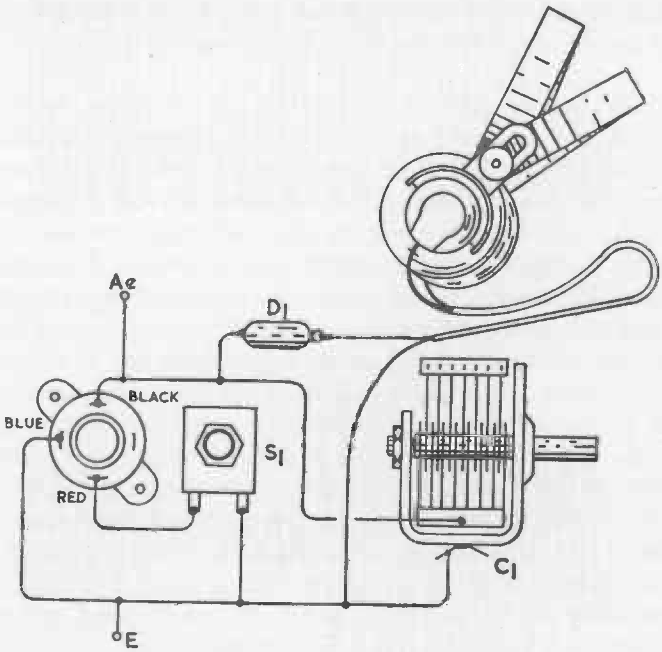


FIG. 2.—THE CRYSTAL SET (Practical Diagram).

Unlike other receivers the crystal set can be built up 'anyhow'. You could arrange 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, and you can also practice your soldering on them, though great care must be taken not to overheat the germanium detector. When this is being soldered its wire ends must be gripped gently by broad-nosed pliers, as suggested on page 25, so that excess heat passes into the pliers and not into the body of the detector. You will find that the same precaution must be taken when you use transistors.

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.* 3. 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

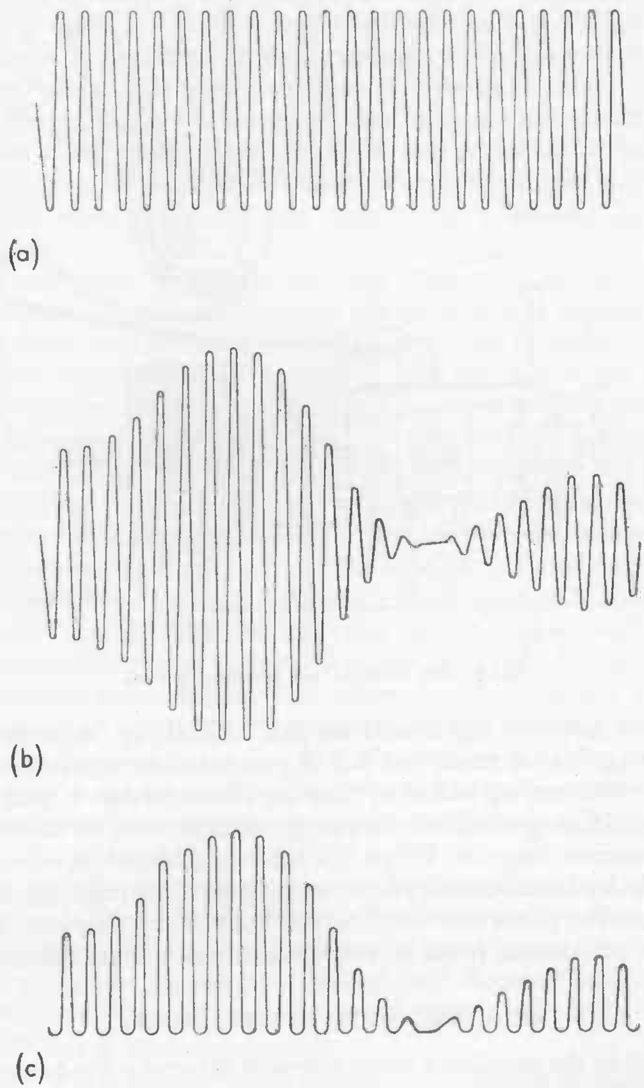


FIG. 3

the fraction of a second. This is an amplitude modulated (A.M.) wave. A frequency modulated wave is drawn as at (a) but with some of the cycles cramped up together and others stretched out. This type of signal cannot, of course, be received with ordinary radio apparatus and requires the use of special circuits.

The alternating currents are fed in the crystal receiver to the tuned circuit made up of L1 and C1. C1 is adjusted to tune in the required signal. The currents are flowing, therefore, in a resonant circuit (see page 20) and a voltage is set up across the tuned circuit alternating in time with the tiny aerial currents. This voltage is applied to the crystal detector and, from there, to the headphones.

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 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.* 3 (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.* 3 (c), and it is the job of the crystal detector to provide this from the full modulated wave of *Fig.* 3 (b).

Old-fashioned crystal detectors consisted of a piece of mineral held in a metal cup at one end of a glass tube, a 'cat's-whisker' being mounted on a small control handle at the other end of the tube. The cat's-whisker, a pointed springy wire, was moved about over the crystals in the mineral until a 'sensitive spot' was found and the receiver worked.

Modern crystal detectors are made of the element germanium; silicon and some other materials are also used for special purposes. Germanium is a black crystalline substance which, when highly purified, conducts electricity very poorly. If a trace of impurity is added, however, the germanium becomes what is known as a semi-conductor. The impurity, which may be a trace of antimony or indium, to name two suitable substances, affects the atomic structure of the germanium. If antimony is added there are spare electrons in the germanium and, since electrons are negative charges, the germanium is then called 'n-type' germanium. If indium is added an even stranger state of affairs is caused. Some of the 'valency electrons' (which hold the atoms together) break loose leaving what can only be called 'positive holes' and the material is then called 'p-type' germanium since it contains positive current carriers.

The idea of a 'hole' being able to move about and carry current may be a little difficult to grasp but those of you who have had to sit in a hospital waiting room may have seen something of the sort happen. When you entered you took the last empty chair at the end of the queue, and waited for the first patient in the line to be called to the consulting room. When this happened he left his chair empty, and everyone moved up one space. You, on the end of the queue, moved up one too, a step nearer to the consulting room. You moved, in fact, rather like an electron in a conductor, from space to space.

But what about the empty chair which the first patient left? The patient next in turn moved into it, so leaving his chair empty, then the next patient moved, leaving his chair empty, and so on all along the line until you moved up one too, leaving your original chair empty and waiting for the next newcomer. Whilst the patients—or 'electrons'—moved forwards, therefore, it would be just as simple to say that the empty chair—or 'hole'—moved backwards. In the same way if an electron, in p-type semi-conductor material, fills a positive hole it must leave just such another hole behind it, the space from which the electron came. In this way, electrons moving in one direction cause positive holes to move in the opposite direction.

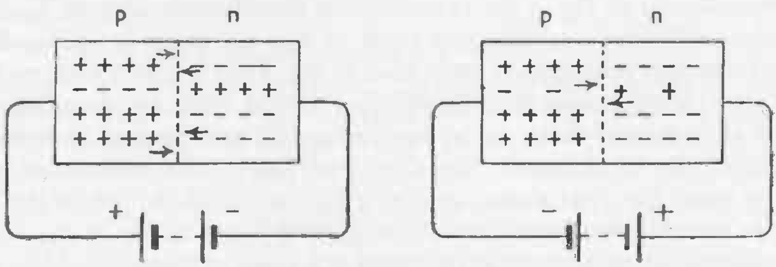


FIG. 4.—THE GERMANIUM DIODE.

A germanium crystal detector (or, a better name, a germanium diode) is made by arranging a junction between p-type and n-type germanium. In *Fig.* 4 such a junction is represented with, at (a), the p-type germanium made positive and the n-type germanium made negative. Holes flow from the p-type side and electrons from the n-type side, these two flows adding together to give good conduction across the junction and so through the diode. If, however, as at (b), the p-type side is made negative and the n-type side is made positive, electrons from the p-type side are attracted over to the positive pole of the battery and holes are attracted from the n-type material to the negative pole of the battery. But p-type material has very few free electrons, just as n-type material has very few holes, and the current flow in this case is very small.

At (a) in *Fig.* 4 the junction is said to be biased in the forward direction—current flows. At (b) the junction is said to be biased in the reverse direction—very little current flows.

The form of the junction varies with different types of diode. In some diodes it is an actual junction between p-type and n-type germanium, made in a way which will be explained later in the section on transistors, whilst in other diodes a pointed wire, similar to the old cat's-whisker, presses on to a suitable piece of n-type material. The exact manner of operation of this type of diode is still not completely known, but it would seem that a small p-type section of material is formed under the sharp point, once again giving a junction.

The two types of diode are known as 'Junction Diodes' and 'Point-Contact Diodes'. Point-contact diodes are generally used as detectors and demodulators, and are the type you will be using.

At all events the junction is all that is required for a 'rectifying' action. If an alternating current is fed to such a germanium junction the diode will pass the current only when it makes the p-type side positive; that is, when the current is rising from zero to a positive value. During the half-cycles when the current is falling from zero to a negative value the diode fails to conduct and the current is cut off.

This is what has happened to the modulated carrier in *Fig.* 3 (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 to which the diaphragm can respond, 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 flows through the headphones to earth. It is quite common practice to connect an 0.001 mF. capacitor across the headphones of a crystal set to provide an easy path for the high frequency currents and you could try this on your own receiver. It is possible that you might improve reception slightly by doing so.

Another point at which you might try inserting a capacitor is at the connection of the aerial to the receiver. If you live near to a broadcasting station which transmits both the Home and Light programmes the signals may be strong enough to 'break through' one on the other. A small capacitance between the set and the aerial will weaken reception but will also sharpen the tuning and help to separate the stations. Suitable values to try are from 50 pF. up to 200 pF.

In the crystal receiver the diode can be connected either way round and will work equally well but in some receivers, to be described later, it is essential to connect the diode in one particular way. In the diode symbol shown in *Fig.* 1

the upright bar is often marked + and is indicated on the diode itself by a red ring or red dot.

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 has 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.* 5 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 C3 the circuit of *Fig.* 5 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. 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 C3 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.* 3 (b).

This current consists, of course, of electrons which flow into C3. Since one side of C3 is connected to the earth line through the tuning coil L1, the side connected to the valve grid is therefore charged negatively, and this charge tries to leak away through the resistor R1. Each following half-cycle, however, recharges the capacitor, the degree of charge depending on the strength of the half-cycle—and this, remember, depends in turn on the modulation of the carrier wave. The result is that the negative charge on C3 follows the modulation and thus controls the grid of the valve with a voltage which would look like the detected half-wave shown in *Fig.* 3 (c) except for the fact that the peaks would be negative instead of positive.

Both C3 and R1 must have carefully chosen values if the best possible results are to be obtained. If either were of too high a value the charge would leak away too slowly, and the sound output of the valve would be muffled. Since the leak effect is so important the circuit is called a 'leaky-grid detector'.

It is clear that both radio and low frequency components are present at the grid of the valve, and both are amplified and appear at the valve anode. The H.F. (high frequency) component is taken down or 'by-passed' to earth through a winding on the tuning coil and then through C4, whilst the L.F. (low frequency) component flows through R2, R3 and R4, finally reaching earth through the H.T. battery.

R2 assists in filtering out the H.F. and C5 is another small by-pass capacitor which provides a path for any remaining H.F. The varying L.F. current flowing through R3 sets up a voltage which varies in time with the current, and it is

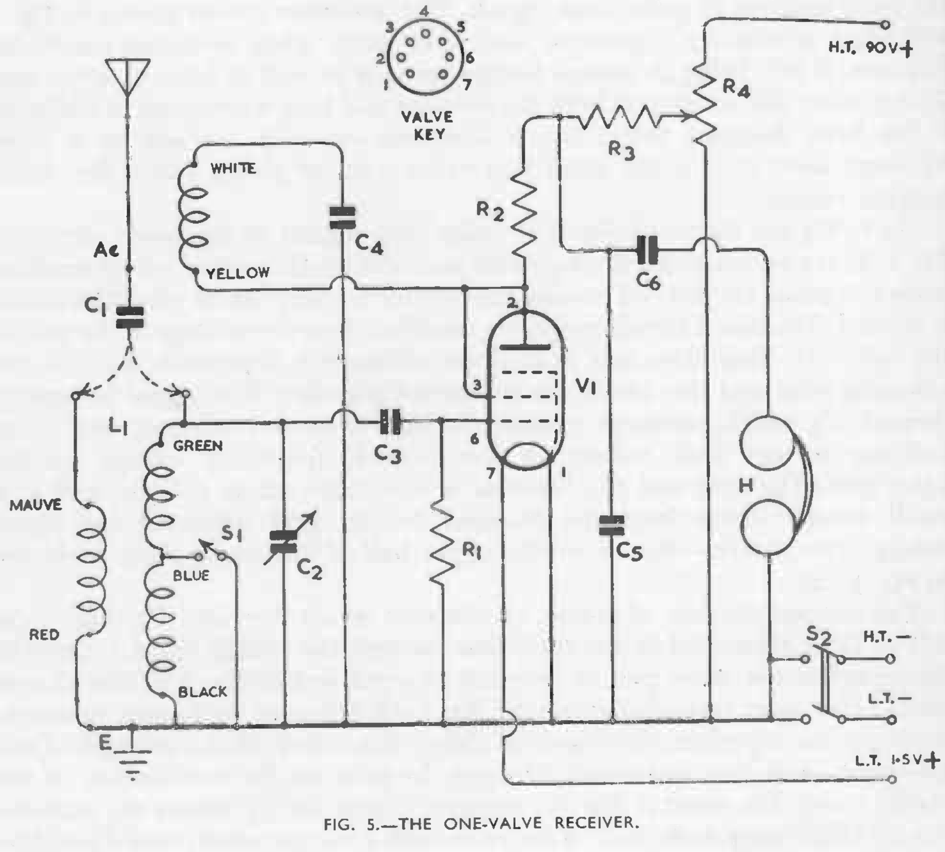


FIG. 5.—THE ONE-VALVE RECEIVER.

this voltage which operates the headphones. These are connected on one side to the earth line and on the other to R3 by means of C6. C6 has a capacitance high enough to pass the low frequencies but it insulates the headphones from the steady high voltage of the H.T. battery.

R4 is a control which allows any voltage from zero to the full H.T. supply to be fed to the valve anode, and so serves as both a volume and a 'reaction' control.

You will see in *Fig.* 5 that the aerial can be connected either to a winding on the tuning coil (Mauve and Red tags) or to the tuned coil (the Green tag). The actual connection used, together with the value of C1, depends to a great extent on your reception area. If you are fairly close to a strong station C1 can be about 100 pF. and taken to the Mauve tag on L1. This gives the greatest selectivity and assists the receiver to tune the powerful signal fairly sharply so that it will interfere less with other signals. If your local station is not particularly strong C1 can be increased up to 500 pF.

If, on the other hand, you live in a poor reception area a long way from any broadcasting stations selectivity will be less important than sensitivity. C1 can then be made 50 or 100 pF. and the aerial connection made to the Green tag on L1. It is well worth while to make tests with the value of C1 and the connection of the aerial to the receiver; note how different values of C1 and different connections cause the tuning of the receiver to alter. This is caused by the aerial 'loading' the tuned circuit by differing amounts.

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 C4—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 R4, 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, R4, must be turned back immediately for the receiver will then be sending out energy and very probably interfering with nearby receivers.

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 neatly, 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 to give good results, and therefore good makes of components must be used. Only the specified coils are suitable; there are, of course, many excellent coils on the market and probably some of these would work well in the circuit without any other component changes, but the design was built up round Repanco coils and these should be obtained. They can be had from all good radio stores or, in the event of difficulty, by post from the makers, Messrs. Radio Experimental Products Ltd., 33, Much Park Street, Coventry.

There are so many types of tuning capacitors, valveholders, capacitors, resistors, volume controls and so on that makers' names are not given—so long as the component is new, of good quality, and about the right dimensions it will be suitable.

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 List for the One-Valve Receiver, Fig. 5

L1	H.F. coil from a pair of Repanco Coils Type DRM3. See below.
C1	50 to 500 pF. See page 39.
C2	One section of 500 pF. variable two-gang tuning capacitor. See below.
C3, C4	100 pF. silver-mica.
C5	0.002 mF. ceramic tubular.
C6	0.1 mF. paper tubular, 250 v.w.
R1	2.2 megohms, $\frac{1}{4}$ or $\frac{1}{2}$ watt.
R2	10 k, $\frac{1}{2}$ watt.
R3	220 k, $\frac{1}{2}$ watt.
R4	1 megohm potentiometer, with 2 pole on-off switch.
S1	2 pole 2 way rotary wavechange switch.
S2	2 pole on-off switch (on back of R4). See below.
V1	Mullard DF96 or equivalent.
H	High impedance headphones.

4 Insulated sockets and plugs.
1 plug to suit L.T. battery.
1 plug to suit H.T. battery.
1 B7G valveholder.
2 Small knobs.
1 Large knob.
Chassis, 7 in. x 4 in. x $2\frac{1}{2}$ in. See below.
L.T. battery, 1.5 volts, Ever Ready A.D. 35 or equivalent.
H.T. battery, 90 volts, Ever Ready B. 126 or Port 61 or equivalent. See below.
Sundries:— 6 B.A. nuts and bolts, soldering tags, connecting wire, plastic or rubber covered flex for battery leads. Short 4.B.A. bolts for tuner. 2 3-way mounting tagstrips.

Notes.

The DRM3 coils are sold in pairs and even though only one coil is required for the receiver in its present state you will need the second coil when you add the next stage to the set. The coil used in the one-valve circuit is the one with four windings on it, and is known as an 'H.F. coil' or sometimes an 'H.F.s transformer'. Rewrap and box up the Aerial coil—the one with three winding on it—and store it carefully till you decide to add the next valve stage to your set.

As already described, the value of C1 is chosen by trial when the receiver is working.

C2 is one section of a two-gang tuner. Here again the second section will be used when the receiver is enlarged. As in the case of the smaller tuning capacitor

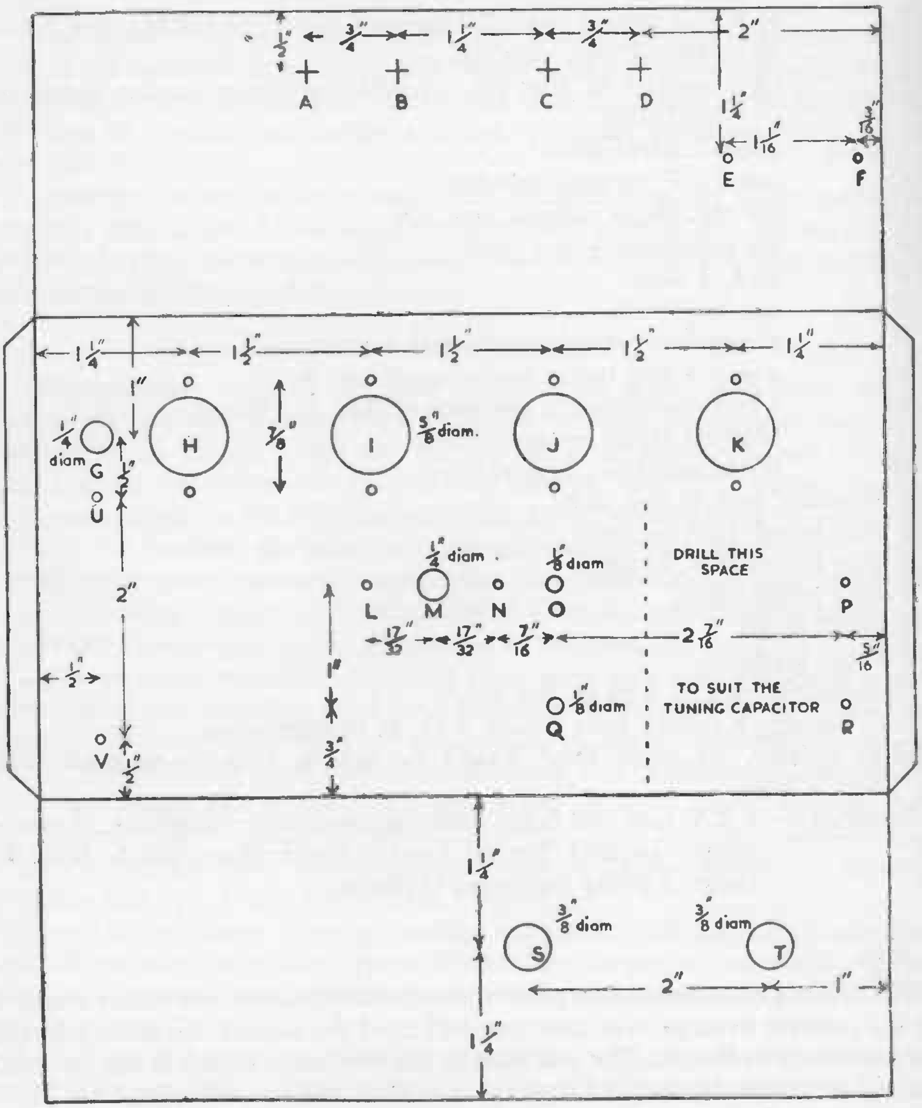


FIG. 6.—TOP VIEW OF THE CHASSIS, SHOWING HOW TO DRILL IT.

used in the crystal receiver, the two sets of fixed vanes are supported by insulators in the main frame whilst the two sets of moving vanes are directly connected to the main frame of the capacitor, and so are automatically connected to the earth line when the tuner is bolted on to the chassis.

There are many sizes and types of tuner obtainable, and you need a component not too large in size which will fit nicely into the space on the chassis. A top view of the chassis, showing the way in which it is drilled, appears in *Fig.* 6 with the tuner space marked. A view of the completed receiver is shown in *Fig.* 15 from which you can see the appearance of the tuner on the original test receiver. With any luck you should find a quite small tuner which has 4 B.A. bolt holes already tapped into the bottom of the main frame or body, so that to mount it all that is needed are suitable holes drilled through the chassis, and some 4 B.A. bolts. Note, however, that these bolts must be no longer than is needed to screw into the tuner body. If long bolts are used they will screw into the tuner, and then protrude above the base of the main frame and touch the fixed vanes. This would short the fixed vanes to earth and the set would not work.

When fixing this type of tuner, therefore, check very carefully that the bolts pass through the chassis and only into the main frame of the tuner, no further. Choose short bolts and, if these are too long, place washers on them until the remaining length of screw is correct.

To find the correct drilling positions on the chassis, place a piece of paper over the bottom of the tuner, hold it up to the light and prick with a pin the centres of the screwed bolt holes you are going to use for fixing. The paper can then be placed on the chassis and the drilling positions marked through the pin pricks—but make sure the paper was the right way round, and in the right place, before drilling the holes.

The correct position for the tuner is that which brings its spindle directly above the mid-point between the S1 and R4 spindles which protrude from the front wall of the chassis. This gives the chassis a neat and tidy appearance. The line which the tuner spindle should follow is shown dotted in *Fig.* 6.

Some really small two-gang tuners are available, and could be used for this set, but they often have no tapped mounting holes in the base of the frame—in their case the mounting holes are spaced round the spindle on the front of the body. It is important to know how to mount these tuners, as you will meet them sooner or later in transistor receivers where the smallest possible components are generally used. To fit such a tuner to the present set you would need a small panel of fairly stout aluminium which could be bolted to the front of the chassis, thus supporting the tuner above the chassis. The panel should be drilled as shown in *Fig.* 7 which shows the layout for the fixing holes in this type of capacitor.

Once again really short 4 B.A. bolts are needed; if the bolts are too long they will pass into the body of the tuner and short-circuit the front fixed vane to earth—they would also distort and damage the vane. Padding out the bolts with washers is not very convenient in this case, and it may be necessary to cut some bolts to size by means of a hacksaw—a fretsaw will deal with brass bolts very well if the cut is made steadily and not too fast. Before sawing off part of a bolt run a nut down the thread up to the bolt head. The bolt can then be gripped in a vice by means of the flats on the nut, and after the bolt has been cut to size running the nut off clears any slight damage to the thread and removes any roughness.

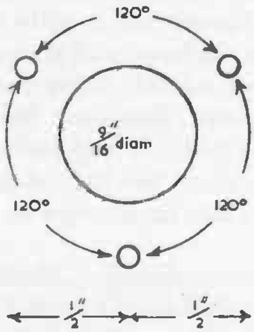


FIG. 7.—MOUNTING HOLES FOR MINIATURE TUNERS.

Those of you who have not done any metal work may be wondering how to deal with the chassis shown in *Fig.* 6. The size chosen, 7 in. x 4 in. x $2\frac{1}{2}$ in. high is quite a common size and suitable aluminium chassis can be bought almost anywhere, or by post from advertisements in the radio magazines. These chassis usually have 4 sides, but the present chassis does not need completely filled-in ends and it can easily be bent up from a flat sheet of aluminium. The 'tabs' along the ends of the chassis top, shown in the diagram, are bent down to stiffen and strengthen the top.

Before any bending is done the chassis is drawn on to the sheet aluminium, cut out with tin snips (or old scissors, if your hands are strong, or even with a fretsaw) and all the holes marked out as shown. The chassis should be of about 18 gauge aluminium. 16 S.W.G. makes a very strong chassis, but is rather thick for drilling and cutting, and while 20 S.W.G. is easily worked, and can be used, the metal is a little thin for our purpose.

All the holes are marked with a centre punch and the small ones are drilled with a twist drill. A $\frac{1}{4}$ in. hole is drilled in stages—start with, say, a $\frac{1}{16}$ in. hole and then, with this as a centre, drill out with the $\frac{1}{4}$ in. drill. The $\frac{3}{8}$ in. holes are made in the same way if your drill will take this size bit—if not, drill a $\frac{1}{4}$ in. hole and carefully enlarge it with a round file until the size is correct. Check from time to time, using the screwed mounting section of S1 or R4 as a gauge.

A great advantage of B7G valves is that the chassis holes required for their valveholders are only $\frac{5}{8}$ in. in diameter, and this is a size which can be tackled without an expensive chassis punch. Either drill a $\frac{1}{16}$ in. hole, enlarge to $\frac{1}{4}$ in. and then very carefully file out to the required size, or drill a number of $\frac{1}{16}$ in. holes, almost touching, round the edge of the large hole. The 'webs' between the small holes can then be cut by small snips or a fret-saw and the hole finally cleaned up with a file.

If you use this method the small holes must not, of course, be drilled on the actual finished diameter of the large hole since then the finished hole would be over-sized. Inside the $\frac{5}{8}$ in. diameter hole scribe, with dividers or compasses, a $\frac{1}{2}$ in. circle, using the same centre point, and drill the small holes with their centres on this circle. After the webs have been cut and the edges filed the hole will then be brought to the finished size quite easily.

If you are patient and have a steady hand the valve holes could even be cut out with a fret-saw, using blades with fine close teeth. Metal-cutting fret-saw blades can be bought from a good tool shop.

Even if you intend to build only the one-valve set at first, cut out all the holes shown in *Fig.* 6. The chassis will then be ready for further work whenever you decide to go ahead—the larger holes cannot be drilled and cut safely when components are mounted on the chassis.

All drilling should be carried out with the metal supported on a block of wood so that the drill point can enter the wood without damaging the bench or table on which the work is being done.

The small holes shown in *Fig.* 6 are to take 6 B.A. bolts and should be made with a $\frac{7}{64}$ in. drill. Holes for 4 B.A. bolts are drilled with a $\frac{5}{32}$ in. drill. The small bolt holes for securing the valveholders are best marked and drilled after the valveholder holes have been cut and trimmed. Drop a valveholder into each hole in turn, marking the bolt holes through the holes in the valveholder mounting tags, first making sure that the valveholder is facing in the right way (this is determined by making the gap between tags Nos. 1 and 7 face as shown in the under-chassis diagrams).

The holes for the aerial, earth and headphones sockets are shown at A, B, C and D on the rear chassis wall. No diameters are given since these will depend on the sockets you obtain. Centre drill each position with a $\frac{1}{16}$ in. drill and then enlarge, with larger drills and a round file, if necessary, until the threaded insulated portion of the socket passes through.

All the holes drilled will have burrs on their back edges. These can be cleaned away either with a round file or, in the case of the small holes, by gently twisting a $\frac{1}{4}$ in. drill in the hole. The cutting faces of the drill will rest on the burred edges and cut them clean.

Once all the holes are made the front and rear walls of the chassis are bent down into place, with the end stiffening tabs being bent down last. If you have a large vice clamp the chassis between two straight clean lengths of wood in the vice so that the join between a wall and the chassis top falls along one edge of the wood. The bend can then be made neatly by pressing down the metal either by hand or with a further piece of wood.

If you have no vice the chassis wall can be bent down by hand using the edge of an old table, or, better, the sharp corner of a thick, square, block of wood as a guide and support.

The end tabs can be bent down by broad pliers. Make the bend a little at a time and pad the pliers jaws with a piece of old felt or cloth so that the metal is not marked. You will have to run up and down the bend, making it a little at a time, if the metal is to look nicely worked and not twisted.

All the drilling has been described as though the chassis were opened out and flat. If you buy a ready-bent chassis the drilling is carried out in just the same manner but the metal will be a little trickier to support from behind. A nice block of 4 in. x 4 in. timber in a bench vice makes an excellent support but you

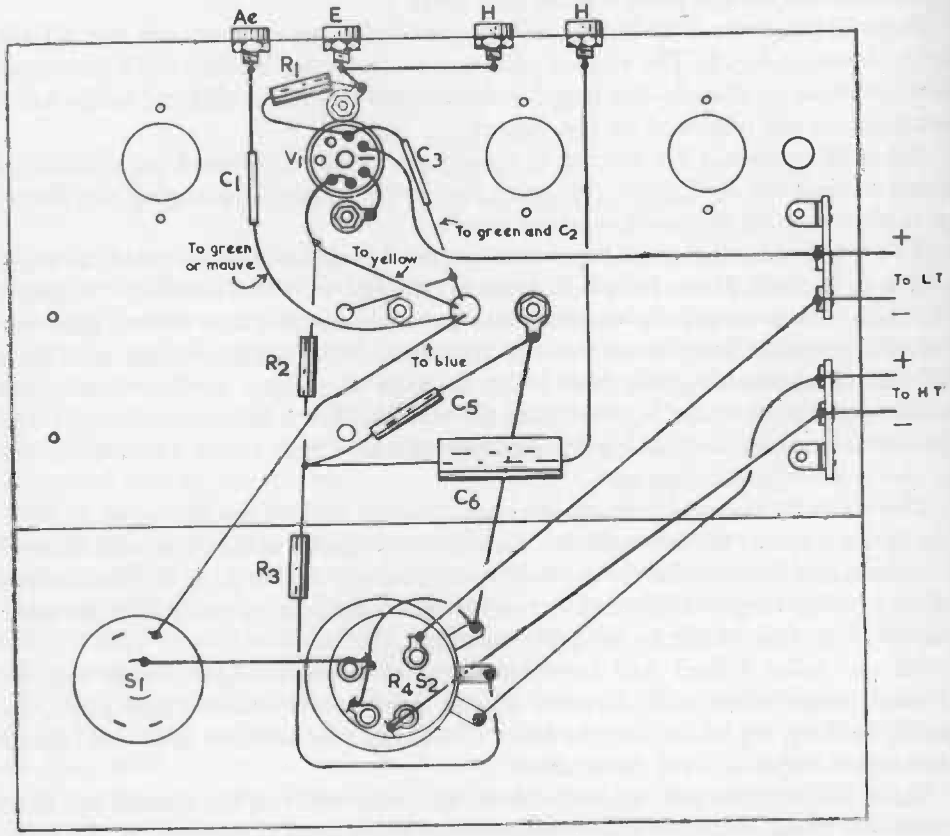


FIG. 8.—UNDER-CHASSIS VIEW OF THE ONE-VALVE RECEIVER.

will probably have to make do without a vice. Do try to support the metal from behind, however, and ask a friend to steady the chassis for you—it makes the work easier and the finished job much neater.

And do try, very hard, not to drill your friend.

Once the chassis work is finished the main components can be bolted in place. An under-side view of the chassis is shown in *Fig.* 8 and from this it can be seen that the aerial, earth and headphone sockets fit in holes D, C, B, A (in that order), the valveholder fits J, L1 is mounted over hole M, the tagstrips are fixed by holes U and V, and S1 and R4 fit in holes T and S respectively. Note that in *Fig.* 8 the front wall of the chassis is drawn as though not bent down. This is done simply to assist in making the diagram clear.

The valveholder is dropped into its hole from above the chassis. Each of the valveholder bolts has, under the chassis, a soldering tag securely clamped down by the nut. These tags provide good electrical connections to the earth line, or chassis—ordinary solder will not make connections to aluminium.

The three-way tagstrips are bolted under the chassis with 6 B.A. nuts and bolts to holes U and V. These strips make very convenient anchoring points for the battery leads. Make sure, when buying the strips, that only one of the tags is lengthened into a mounting foot, and that the other two tags are insulated from the chassis.

The coil L1 is bolted down to holes L and N, the Black earth connection on the foot being over hole L. The coil is, of course, mounted on the top of the chassis. A soldering tag is secured under the nut on the bolt through hole L to provide another earthing point.

The way in which the two-gang tuning capacitor is mounted on the top of the chassis has already been described. Leads to the fixed vanes pass through hole O in this receiver and also through hole Q when extra stages are added.

When S1 and R4 are fitted to the front chassis wall you may find that they have small lugs or 'pips' which press against the metal as though they should fit into it. These lugs are provided to help in securing the components and prevent their turning round should their nuts work loose. If your components have such lugs or pips mark the chassis where they fall when the components are properly placed, and drill $\frac{1}{8}$ in. holes in these positions to accept the lugs.

S1 and R4 will probably have long spindles. These can be shortened, if you think it necessary, by cutting off the excess length with a hack-saw or a metal-cutting fret-saw. The end of the spindle should be gripped in a vice or clamped down to a bench and the body of the component steadied in one hand as the spindle is sawn. Remember to leave sufficient spindle for a control knob.

If you intend to fit the receiver into a cabinet it is best to leave the spindles long.

The receiver can now be wired up, using plastic covered flexible connecting wire. The leads can be followed easily from *Fig.* 8 but a little care is needed over the connections to S2, the main on-off switch on the back of R4. The drawing shows the usual connections to this type of switch, but it is as well to check it for correct connection before starting to wire up. A mistake here could short-circuit one of the batteries, or even 'blow' the valve.

To check the switch use the 1½ volts dry battery and a small torch bulb. Connect one side of the battery to the tag on S2 which is shown, in *Fig.* 8, as going to L.T.— Take the other side of the battery, by a short length of wire, to the bulb, and the other side of the bulb to the tag on S2 which is shown as going directly across to a tag on S1. Rotating R4 clockwise will switch on S2 and the bulb should light.

If by some chance your S2 should have different connections find out, by means of the bulb, which pairs are in contact with the switch closed. Then one side of one pair must go to L.T.—and one side of the other pair must go to H.T.—The remaining switch tags are connected together and to earth like those on the left side of S2 in the diagram, so that with the switch closed both the L.T.—and H.T.—leads are connected to the chassis and with the switch open both leads are disconnected completely from all other points of the circuit.

Whilst the underside of the chassis is being wired it is as well not to allow the weight of the receiver to bear on the tuner and the coil on top of the chassis. When the chassis is turned over support its end on two blocks of wood or on some old books so that the top chassis components are clear of the workbench.

The various leads to the coil pass through hole M and up through the coil former to the tagboard at the top of the coil. When making the coil connections use the soldering iron carefully and avoid burning off the colours on the coil tags. Before starting it would be a good idea to read up once more the tips on soldering on page 24. Measure the length of each lead required, allowing an extra ½ in. for joints, and clean off the plastic for ¼ in. from each end before connecting up the wire. Do not solder on one end of the lead and then tug away at the plastic on the other to clear it for the next joint—in that way the tags and fixings on components are bent or broken.

The resistors and capacitors have fairly long wire ends by means of which they are mounted directly in the circuit. These wires are best insulated, except for the small length exposed for the joint, and for this purpose you will need a little insulating sleeving, which you can buy when you buy your connecting wire. First cut the component lead to the correct length to fit between the connecting points, then snip off a slightly shorter length of sleeving and put this over the component lead. Where the wire is very short, such as that from R1 to the soldering tag beside V1, no sleeving is needed.

In the case of C3 note that one end goes to both the Green tag on the coil and also to the fixed vanes of C2 through hole O. The best plan here is to trim off the lead of C3 to about ½ in. long, then to solder to this lead two plastic covered connecting leads, one to go up to the coil tag and the other to go to the tuner.

The connection to the fixed vanes of the tuner is made to a small tag or eye on the side of the tuner and it is as well to make sure you can reach this tag with the soldering iron before bolting L1 into place. The soldering iron must not get too close to the foot or former of L1 as these are made of polystyrene and easily melt if touched with a hot iron.

Some component leads may also need to be lengthened in the same way as that of C3. C6, for example, may need some extra wire connected to its leads. Remember, however, that the wires drawn in *Fig.* 8 are shown neatly curved, and taking the long way round, to make the connections clear. In actual wiring the leads should be kept as short as possible and follow as direct a path as possible from point to point. This does not mean, though, that the wires should be taut and twanging like bowstrings—tight wiring will eventually damage the components, especially the fixed capacitors.

Note that C4 is not shown in *Fig.* 8. C4 is wired in above the chassis and is supported between the White coil tag and the Black earthing tag on the foot of the coil. Check that C4 does not foul the vanes of C2 when these are fully opened. The Red tag on the coil is also earthed by a short lead to the Black tag.

The leads from the tagstrips to the batteries are best colour-coded and can be of either plastic or rubber covered flex. The usual colours are

L.T. (1½ volts) Positive,	Pink.
L.T. Negative,	Black.
H.T. (90 volts) Positive,	Red.
H.T. Negative,	Black or Brown.

When buying your first set of batteries obtain at the same time two battery plugs. The plug for the L.T. battery has one thick and one thin pin and the L.T. leads are soldered into these pins, the thicker pin being the positive plug.

Two types of H.T. battery are mentioned in the components list. The B126 is quite small and is the cheaper, whilst the Port 61 is larger and, naturally, a little dearer. The main difference is in battery life—the larger the battery the longer will be its life, other things being equal. The current taken by this receiver is very small, however, and the B126 battery is perfectly satisfactory for not only the One-Valve but also the Two- and Three- Valve circuits as well.

If you use the B126 battery you will need a small three pin plug for the connections. The centre pin is only a locator and, with this as the top of a triangle, and looking at the top of the plug, the negative lead goes to the left, and the positive lead to the right, hand pins. Check this against the battery to make certain of correct connections.

If you use the Port 61 battery you will need two wander plugs, usually red and black. The red plug is made the positive, and the black plug the negative, connections.

For this receiver a combined H.T. and L.T. battery could be used, of course, but I prefer to keep the batteries separate. One usually runs down before the other, and can be replaced by itself with less expense.

Some of you may use a chassis with four walls—that is, with the ends completely filled in. In this case you will have to drill two holes in the left hand end to pass the L.T. and H.T. battery leads, and these holes should be protected by rubber grommets so that there is no chance of the leads rubbing on the metal and cutting the insulation. Grommets can be obtained when you buy your other components. They are rubber rings with a slot round the outer edge. A hole smaller than the grommet is drilled in the metal and the ring pushed in so that the slot fits round the rim of the hole.

You must also make certain that there is no chance of the tagstrips slipping or bending round and so short-circuiting against the chassis end wall, but well-tightened nuts and bolts will ensure safety here.

Fitting a Fuse

Commercially built sets and, indeed, most home constructed receivers are not fitted with fuses, but one can be included in the circuit if you would like to have the extra protection this gives. Obtain a small paxolin type fuseholder such as a 'Radiospares' "Single Fuseholder" and mount this on the back of the chassis, drilling two 6 B.A. holes to suit the fuseholder fixing holes and bolting it in place with 6 B.A. nuts and bolts. The H.T.—lead from the H.T. tagstrip is taken to one side of the fuseholder, and a lead from the other side of the fuseholder goes to the H.T.—pin on the battery plug. A 60 mAs. fuse must be obtained and plugged in to the fuseholder, a standard 1¼ in. glass fuse being required. The valve filament takes only 25 mAs. from the L.T. battery and if it were accidentally connected across the H.T. battery it would 'blow' at a current not much higher than this. A 60 mAs. fuse is quite a fair protection, but make sure that the fuse is not rated any higher than this—a 1 or 2 amps fuse such as is used in a television receiver would be no protection at all.

No fuse is shown in the circuit diagrams or layouts of the receiver and the set will, of course, work perfectly well without it, provided, naturally, it is correctly built. Remember, if you decide to have a fuse—it must be rated at not more than 60 mAs. and it is connected into the lead to the H.T. negative battery socket. It should hardly be necessary to remind you that the connections to the fuseholder must be insulated from the chassis, and carefully made.

Finishing and Testing the Set

With all the components in place and the wiring carefully checked it now remains to fit the knobs and to try out the receiver. The large knob is used on the spindle of the tuning capacitor as a tuning knob; it was found with the original receiver that whilst tuning is nice and sharp a slow motion drive was not needed. The small knobs are fitted to S1 and R4. These two controls may have 'flats' on their spindles and in this case the grub screws of the knobs should be located to grip on these flats.

Fit the headphone leads with their plugs and connect them in to their sockets at the back of the receiver. One 'phone lead will be striped or marked differently from the other and this lead goes to the socket connected to C6. In this circuit this is not really important, but the marked lead is the positive lead and in circuits where the headphones have a direct connection to the H.T. battery the marked lead should be taken to the H.T. positive line. Current from the battery will be flowing through the headphones, and would, in time, weaken the magnets if the leads were connected incorrectly.

In the present circuit the headphones are isolated from the battery by C6 and so there is no direct battery current flowing.

Carefully plug in the valve. When a new valveholder is stiff it sometimes requires a little patience to get the valve in and out but just go gently at it, and avoid bending the valve pins.

Plug the two pin plug into the L.T. battery and rotate R4 to switch on S2. It may be possible, in a darkened room, to see a faint glow from the filament of V1. Put on the headphones and then plug the H.T. battery plug in and out (if you are using a B126 battery; with a larger battery insert the H.T. negative plug and then tap the H.T. positive plug in and out of its 90 volts socket). There should be a click in the headphones every time the plug is inserted in the battery. If there is only one click when the plug is inserted the first time, with no more clicks afterwards, check whether the fuse has blown. If it has there is something wrong with the wiring which must be found and put right. The same is true if there are no clicks at all.

If all is well, and there is no reason why it shouldn't be, leave the battery plug in place. There should now be a gentle hissing in the headphones.

Switch S1 to the medium waves (to the left), and turn up R4 slowly. At some point the set will be heard to go into oscillation by a louder hissing in the headphones; possibly there will be a squeal if R4 is turned up further. You should have no difficulty in making the receiver oscillate—indeed until the aerial and earth are connected up there may be too much oscillation. If, however, there is no oscillation at all, switch off, disconnect the batteries, and check the wiring carefully. Make sure that C4 has not been forgotten.

If the wiring is all correct connect up the batteries again, switch on, and connect in the aerial and earth to see if that helps oscillation. If not, switch off once more and change over the connections to White and Yellow on the coil: that is, take the lead from White to the Yellow tag and change the lead from Yellow over to the White tag. Switch on again, and check. If there is still no oscillation change back the leads to the White and Yellow coil tags to their original positions and try increasing the value of C4 by connecting another 100 pF. capacitor across it. If there is still no oscillation a very thorough check of the wiring and components must be made.

Such troubles are very unlikely however, and the set should work correctly as soon as it is switched on. For the first test C1 can well be 200 pF., and connected to the Mauve coil tag. Connect the aerial and earth leads to their sockets, turn the vanes of C2 to the fully open position, and turn up R4 until the set is almost oscillating. Now turn C2 slowly, keeping R4 at just below oscillation point. You should receive your local stations without any trouble, and as you become experienced with the feel of R4 you will be able to receive distant stations as well, especially at evening time when reception over long distances becomes better.

Now switch S1 to the long waveband and you should find that the Light programme is readily received, together with some foreign stations.

You will need some sort of tuning indication, and this is why a large knob is suggested for the tuner. It is quite a simple matter to make a neat paper dial to stick on the front face of the knob, with a pointer on the chassis. The scale can be calibrated in wavelengths or with station names.

And now—well, it's your set! See how much fun you can have with it. But do remember not to let it oscillate, and don't forget to switch off when you have finished listening, 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

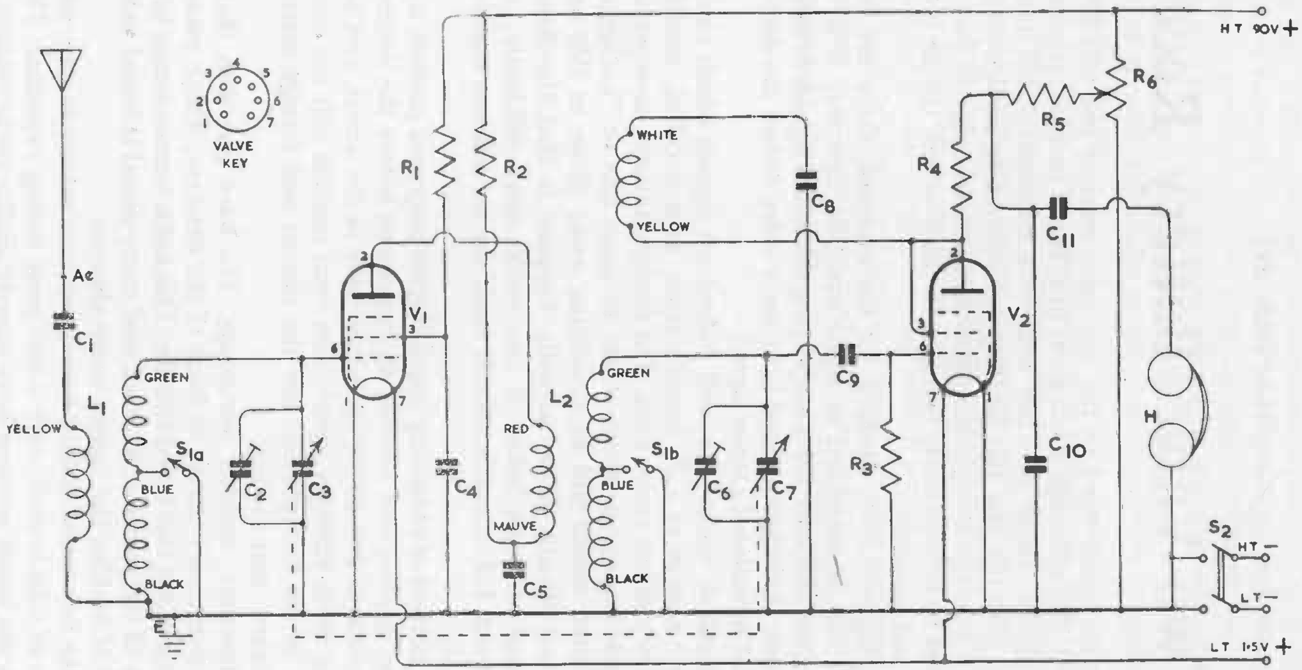


FIG. 9.—THE TWO-VALVE RECEIVER.

two sections, C3 and C7, in *Fig.* 9, indicate the ganging and show that both sections work together.)

The two small semi-variable capacitors, C2 and C6, shown in *Fig.* 9 are also very important to the correct operation of the ganged tuning circuit. These capacitors, called 'trimmers', are mounted beside the two-gang tuner and are connected to it, one in parallel with each tuning section. The wiring, switches and the valve and valveholder 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 two trimmers.

It may not be easy, at first, to see how the new stage, V1 in *Fig.* 9, 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 present some 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 C5.

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 C4.

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.* 5 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.* 5 is now L2, R1 has become R3 and so on. The original C1 is still used in that position, and the new capacitors are numbered, in *Fig.* 9, from C2 to C6.

In the following components list only the extra parts needed for the H.F. stage are shown. (The new L1 is the Aerial coil of the DRM3 pair.)

Extra Components required for the Two-Valve Receiver, Fig. 9

C2, C6	50 pF. 'postage stamp' trimmers.
C4, C5	0.1 mF. paper tubular, 250 v.w.
R1	100 k, ½ watt.
R2	10 k, ½ watt.
V1	Mullard DF96 or equivalent.

1 B7G valveholder.

Sundries:—Connecting wire, 6 B.A. nuts and bolts.

To prepare the One-Valve receiver for the addition of the new stage, disconnect the aerial and earth, the headphones and batteries, and remove the valve. From the coil on the chassis top, which now becomes L2, remove the lead from the Red tag to the earthed Black tag, and also disconnect C1 from the coil.

The two trimmers are mounted on the top of the chassis by 6 B.A. bolts to holes P and R. The trimmers have adjusting screws which must be placed

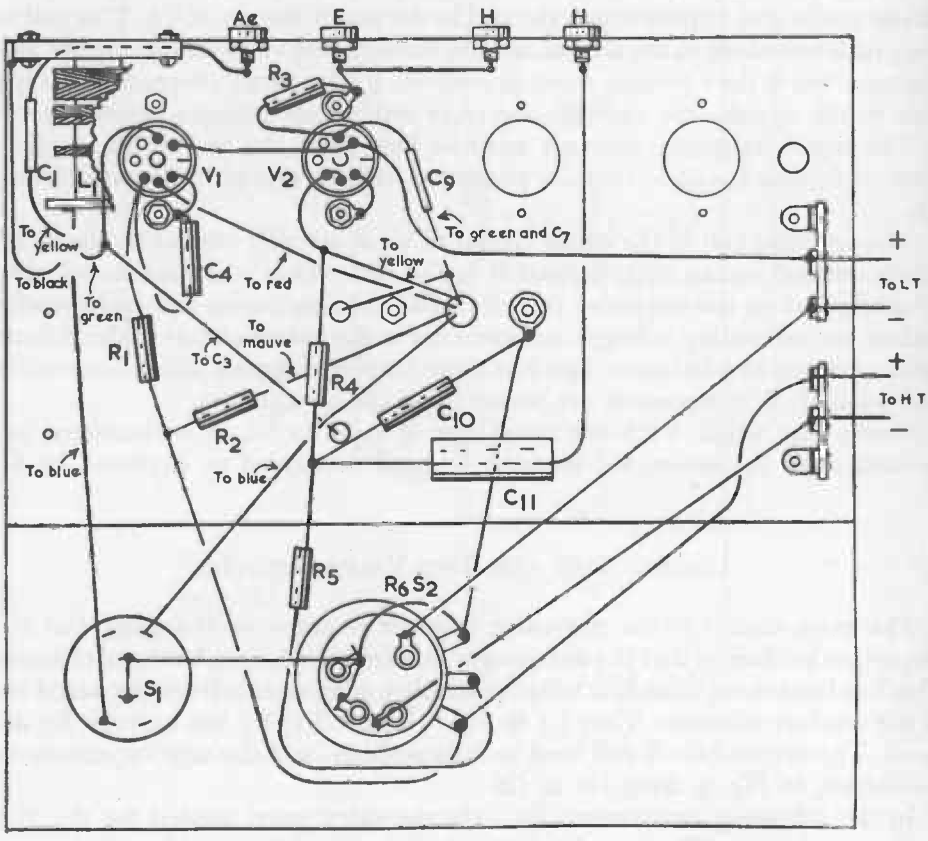


FIG. 10.—UNDER-CHASSIS VIEW OF THE TWO-VALVE RECEIVER.

towards the right hand end of the chassis so that they can easily be turned by a screwdriver. These adjusting screws are in contact with the top springy plate of each trimmer, and the mounting lug connected to this top plate is the lug which must be used for bolting each trimmer down. In this way the adjusting screws are connected to the chassis and so are earthed. If the trimmers were mounted the other way up the adjusting screws would be connected to the 'live' side of the tuned circuit and merely approaching them with a screwdriver would alter the tuning and so make it almost impossible to adjust them correctly.

Mount the new valveholder next in hole K, and wire it up before bolting in the Aerial coil. Note from *Fig.* 10 that one soldering tag is required under one valveholder nut.

Connect tag No. 7 of the new valveholder to tag No. 7 of the existing valveholder to complete the filament positive supply line. Be careful not to burn the insulation on the wire already in place on the old valveholder. Earth tag No. 1 of the new valveholder to the soldering tag, and wire up tags Nos. 2 and 3 as shown in the diagram. Solder on a lead to tag No. 6 sufficiently long to reach the Green tag on the new coil.

L1 is then bolted to the rear wall of the chassis. A soldering tag is secured under the nut nearest the end of the chassis, as shown in *Fig.* 10, as an earthed point for a connection to the Black coil tag. C1 is brought round and connected to the Yellow tag of L1. The value of C1 will be found less critical in this receiver and in a poor reception area it may be made quite large—say 0.001 mF. A suitable starting value would be 200 pF.

L1 is tuned by the front section of the two-gang tuner and is connected to the fixed vanes of this section of the tuner by a lead from the Green tag through hole Q. When this lead is soldered to the capacitor also make the connections from the two trimmers across to the two sets of fixed vanes of C3 and C7. These connections can be seen, along with the trimmers, in *Fig.* 15.

C4 in the original circuit is now C8 and is still in place beside the coil on top of the chassis. The new C5 is also connected up across the coil, and so does not appear in *Fig.* 10. One end of C5 is connected to the Mauve tag of L2 and the other end is taken to the Black earthed tag on the foot of the coil.

Remember that the previously unused pole of S1 must now be connected to the pole already earthed, and that a lead from S1 is taken to the Blue tag on L1.

With the wiring finished and very carefully checked the receiver is ready for testing. As before, plug in the valves and the headphones, plug in the L.T. battery plug, and rotate R6 to operate S2 and switch on. As before it may be possible to check that the valve filaments are glowing if the room is darkened. Plug the H.T. leads in and out of the battery, making sure that there is a click each time, then leave the H.T. plug in and connect up the aerial and earth. Adjust the two trimmers so that they are both about half-open, and tune the receiver to the medium wave Light programme on 247 metres, setting R6 for best results. The calibrations on the tuning knob may now be slightly different.

Using a small insulated screwdriver adjust C2 for best results. A point should be found at which the signal is best received, falling off if the trimmer is opened or closed from this position. If C2 is opened, or unscrewed, to its fullest extent, the signal improving all the way but without the best point being reached, screw up C6 a turn or to and try again. If, on the other hand, C2 needs screwing in fully to improve the signal open C6 a turn or to and again try the setting of C2. Balance the two trimmers in this way until the best possible results are obtained.

Now switch to the long waveband, and check on the Light Programme. Do not alter the setting of the trimmers, however—these are set on the medium waveband and then left.

On both wavebands signals should be both stronger and sharper, tuning in and out with less movement of the tuner knob, and as foreign stations begin to come through at evening more of them should be heard and 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 3/6.

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.* 11 and 12 is connected up.

An output stage could be fitted in place of the new stage round V3 and would give quite good results on local stations, especially if used in a good reception area. In a poor reception area, however, the receiver would not work as well as it should, and it has been found by trial that a stage of extra amplification is very well worth while. The added stage uses another DF96 pentode working as a voltage amplifier, and the resulting Three-Valve receiver gives first-class headphone reception which will be very satisfactory until the final output stage is added.

Very little work has to be done to include the new valve and only one or two extra parts are needed. These are listed below.

Extra Components required for the Three-Valve Receiver, Fig. 11

C11	0.01 mF. paper or ceramic tubular, 250 v.w.
C12	0.1 mF. paper tubular, 250 v.w.

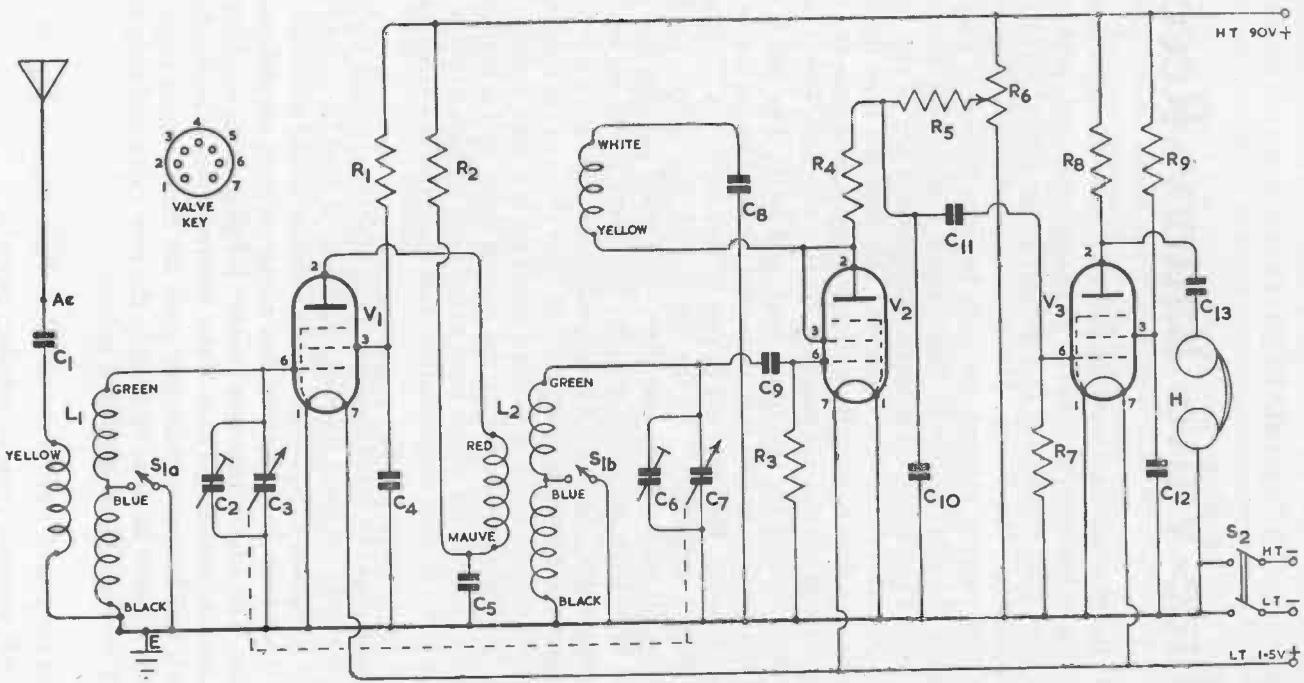


FIG. 11.—THE THREE-VALVE RECEIVER.

R7 2.2 megohms, $\frac{1}{4}$ or $\frac{1}{2}$ watt.
R8 560 k, $\frac{1}{2}$ watt.
R9 2.2 megohms, $\frac{1}{2}$ watt.
V3 Mullard DF96 or equivalent.
1 B7G valveholder.

As before, commence work by unplugging the aerial and earth, the headphones, the batteries, and removing the valves.

Note that the new C11 replaces the original C11 which now becomes C13. Turn the receiver over, supporting the ends as before, and disconnect the original C11 from its junction with R4, R5 and C10.

Insert the new valveholder in hole I and bolt it home with a soldering tag under one nut, as shown in *Fig.* 12. Disconnect the lead from tag No. 7 of V2 from the L.T. tagstrip, trim it to length and bare its end, and connect it to tag No. 7 on the new valveholder, running a new supply lead from this tag to the positive tag on the tagstrip. Make sure that insulation on the filament line is perfect, without any burnt plastic or bare wire.

The headphone capacitor, now C13, is taken, with one end of R8, to tag No. 2 of the new valveholder. Tag No. 1 is earthed to the soldering tag. C12 and R9 both have one end taken to tag No. 3 of the new valveholder, and the grid leak, R7, is taken from tag No. 6 across to the earthing tag beside V2.

The new C11 is also connected to tag No. 6 and is taken to the connection of R4 and R5. Keep the leads of C11 as short and direct as possible.

The free ends of R8 and R9 are anchored to the positive supply point on the H.T. tagstrip and the free end of C12 is earthed at the soldering tag under hole L.

The receiver is now ready to have its valves plugged in. Once again a check can be made to see that the valve filaments glow when the L.T. battery is plugged in and the switch S2 is closed. The headphones can then be plugged in and the H.T. battery click test tried—the clicks should now be really loud, and when all is found to be in order and the aerial and earth connections made, reception should be very good indeed.

The receiver should be perfectly stable in its new form but if there is any tendency to hissiness, or whistling, especially as the headphone leads are moved about, try connecting a 500 pF. silver mica, or a 0.001 mF. tubular capacitor directly across the headphone sockets under the chassis. Instability is caused by stray H.F. currents being amplified in the new stage, and such a capacitor would provide them with an easy path to earth.

Now that your receiver has extra L.F. amplification you may hear a rustling or slight hissing noise as the reaction control is adjusted, or this may later appear as the control wears. This can be prevented by connecting an 0.1 mF. paper tubular capacitor of 250 v.w. rating between the slider—that is, the centre tag—of R6 and the earth line in *Fig.* 11.

It is interesting to learn that the new valve just added to the receiver is

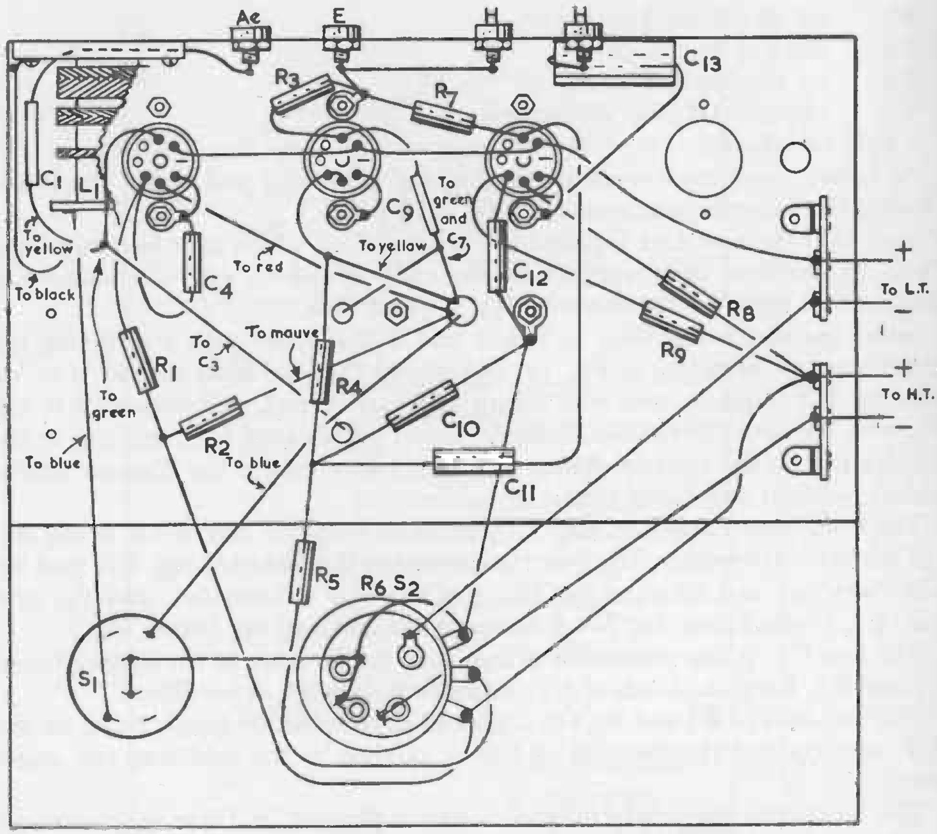


FIG. 12.—UNDER-CHASSIS VIEW OF THE THREE-VALVE RECEIVER.

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.

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 last stage can be seen in *Fig.* 13.

There are one or two important facts to notice in the diagram. In the first place 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 DL96, is 5.2 volts negative, and this is provided automatically by the flow of current through R12. 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 9 or 10 mAs. which through a 560 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 5 or 6 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 R11 and R12.

R12 is by-passed by a large capacitance, C15, and it will be seen from *Fig.* 13 that an electrolytic capacitor is used. Whilst we require the H.T. supply current to flow through R12 and so set up a bias voltage, an alternative path must be provided for the varying H.F. and L.F. currents if these are not also to set up other, unwanted voltages across the bias resistor. C15 provides such a path.

Note, next, the changes in the supply to the reaction and volume control. This has now become R7 and is separated from the H.T. positive line by a new resistor, R6. The junction of R6 and R7 is by-passed to earth by another electrolytic capacitor, C12, and R6 and C12 together decouple the detector from the H.T. supply. The presence of V4 in the circuit means that quite heavy L.F. currents are now circulating through the receiver and battery. If the supply to V2 were still taken directly from the H.T. line there would be undesirable

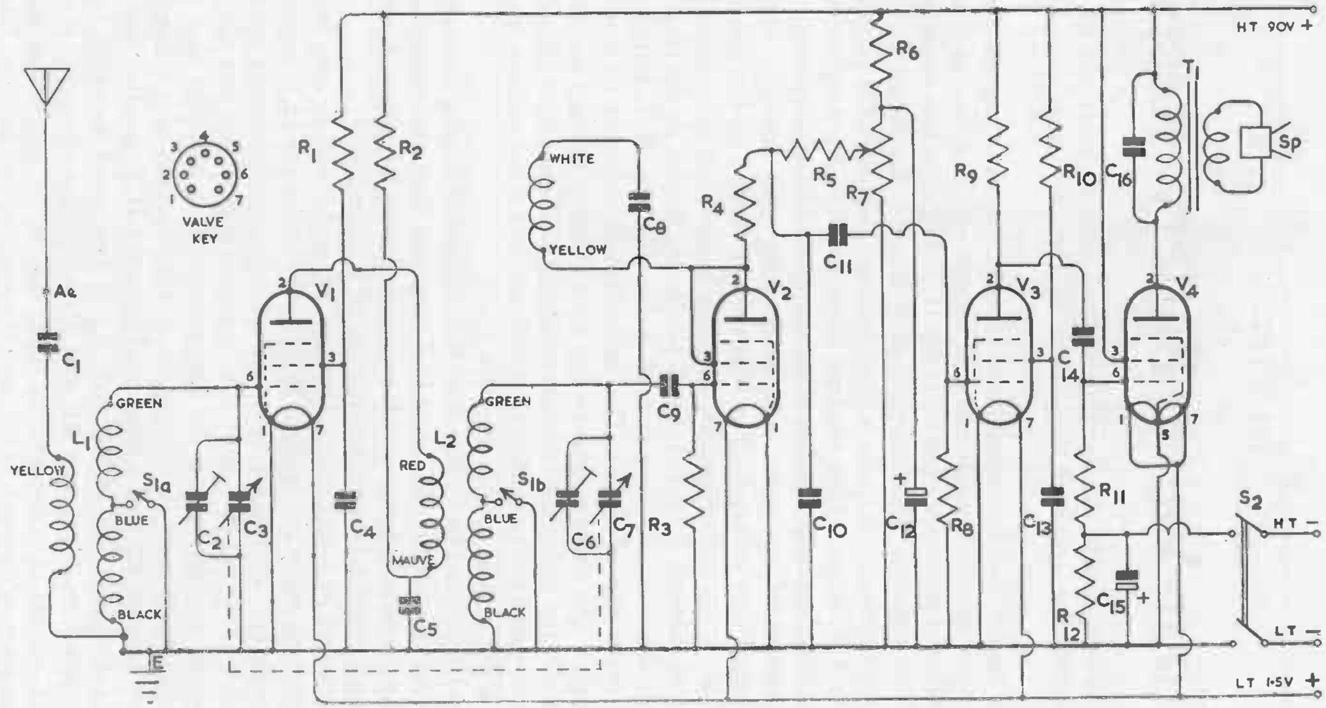


FIG. 13.—THE FOUR-VALVE RECEIVER.

coupling between V2 and the rest of the circuit, causing a form of instability known as 'motor-boating' since it takes the form of a slow plopping or low humming. Decoupling circuits like R6 and C12 are sometimes said to 'filter' the supply, and called 'filter circuits'.

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 impedance; in the case of the present valve the anode needs a load of 13,000 ohms. The impedance of the loudspeaker moving coil (often called the "voice coil") is about 3 ohms, and it is the job of the transformer to match these two impedances together. 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 impedances 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 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 wavelength and so for good low tones, or good bass 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.

Extra Components required for the Four-Valve Receiver

C12	2 mF., miniature electrolytic, 150 v.w.
C15	8 mF. miniature electrolytic, 15 v.w.
C16	0.005 mF. ceramic or paper tubular, 250 v.w.
R6	47 k, $\frac{1}{2}$ watt.
R11	1 megohm, $\frac{1}{4}$ or $\frac{1}{2}$ watt.
R12	560 ohms, $\frac{1}{2}$ watt.
V4	Mullard DL96 or equivalent.

1 B7G valveholder.
T1 Output transformer, to match 13,000 ohms to 3 ohms loudspeaker.
Sp, Loudspeaker, 3 ohms speech-coil.
Sundries:—Connecting wire, 6 B.A. nuts and bolts.

Notes

There are now many types of miniature electrolytic capacitors on the market and it is quite in order to vary the specifications given above, depending on what you are able to buy. C12 can have any value from 2 mF. upwards, with any working voltage of 100 or upwards, whilst C15 can have any value from 8 mF. upwards with any working voltage from 10 upwards. Keep as close as possible to the values given and obtain small capacitors which will fit easily into the available space. Make sure they have insulated bodies.

C16 is connected across the primary of the output transformer. Pentode valves tend to accentuate the higher audio frequencies and C16 is a form of fixed tone control, by-passing some of the high frequencies across the transformer. It also assists in preventing any chance of instability in the output stage.

The output transformer could quite easily be mounted on the loud-speaker but in the original receiver it was bolted above the chassis as shown in *Fig.* 15.

One foot was secured under the bolt holding the H.T. tagstrip whilst a fresh hole had to be drilled for a bolt to secure its other foot. If you need to drill this hole for your transformer disconnect everything from the receiver first, and remove the valves. Drill the hole slowly and carefully and be careful not to damage components or wiring under the chassis. Clean the burr from the underside of the hole and make sure that all the swarf (the drilled chips of metal) are cleaned away from the chassis. When the transformer is bolted on use a short bolt and make absolutely certain that it cannot touch any part of the L.T. tagstrip.

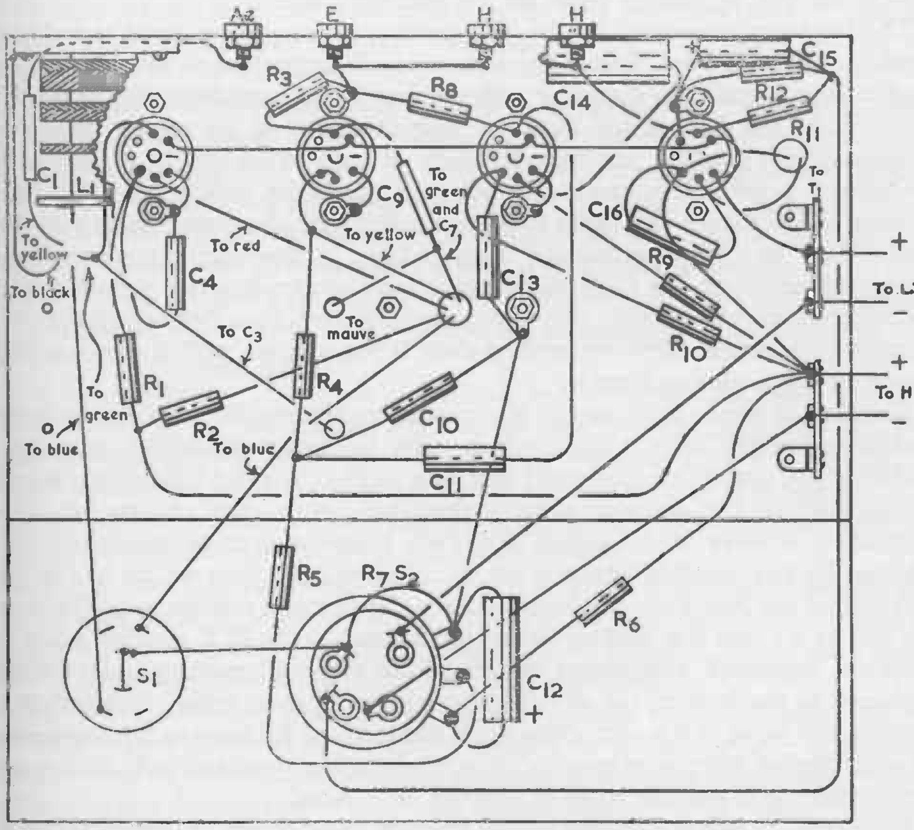


FIG. 14.—UNDER-CHASSIS VIEW OF THE FOUR-VALVE RECEIVER.

A miniature output transformer is quite satisfactory for this receiver and there are many types which may be offered you, including 'universal' transformers. This kind of transformer has three or four wires coming from the primary, coded with different colours, and the instructions with the component will state which coloured leads should be used for Battery Pentodes—these are the leads you connect up. Coil up the other wires, if any, and make sure they are insulated from one another and the chassis. Other transformers have tag-boards with numbered tags but here again the instructions with the component will show which tags to use.

The secondary of the transformer is taken to the loudspeaker tags. If the transformer secondary has two enamelled wires coming out it would be as well to obtain a three-way tagstrip and bolt this down under one of the transformer bolts. This would then serve to anchor the two wires, and two heavier leads could be taken to the loudspeaker. If the transformer has a tagboard this will serve as its own anchoring point for the speaker leads.

The loudspeaker should be the best permanent magnet 3 ohms speech-coil speaker you can afford. Size is not tremendously important so long as it is not smaller than 6 inches in diameter; this receiver is not intended to be a portable set so make the best of the available output and tone by using a fair-sized speaker. Quite possibly you may be lucky enough to be offered an old radio containing a good loudspeaker, when you might be able, too, to make a speaker cabinet from the radio cabinet. In this case, however, make sure the loudspeaker is of the permanent magnet type. A few mains receivers have 'energised' speakers—in these the magnet is an electro-magnet, powered from the receiver power supply, and therefore of no use in a battery circuit. An energised speaker is easily recognised since it has a large 'pot' at the rear with insulated leads coming from it.

Commence work on the output stage by disconnecting the leads and batteries and removing the valves; then bolt in place the new valveholder, securing a soldering tag under one fixing nut as shown in *Fig.* 14. Next bolt on the output transformer in the manner already described. Now turn the chassis over, supporting it clear of the bench as before. Disconnect or cut away the lead joining the two earthed contacts on S2, the left-hand tags on S2 in *Fig.* 14. Disconnect the lead from the bottom tag of the reaction control, now R7, from the join of R1 and R2, and take this lead instead to the H.T. positive point on the H.T. tagboard. Disconnect the lead from the H.T. positive point on this tagboard to the bottom tag of R7 and connect R6 in its place. Remember to insulate the wires of R6 with sleeving. If the leads of R6 have to be lengthened by soldering on extra wire remember to insulate these joints as well. If they are neatly made it is possible to push sleeving over them.

Connect C12 across the tags of the reaction control, R7. Be very careful to connect the positive lead of C12 to the positive tag—that fed by R6. If the leads of C12 are measured and cut carefully the capacitor will be securely anchored by R7 and need no other support.

When wiring the new valveholder note carefully the different filament connections to V4. The valve contains two filaments which can be operated either in series or parallel, depending on the type of circuit in which it is used. In this case parallel connection is needed, when the filament takes 50 mAs. at

1.4 volts. In the series connection the current demand is halved to 25 mAs. but then the required voltage is 2.8 volts.

Tag No. 5 is the centre-tap on the filament, and is earthed to the soldering tag. Tags Nos. 1 and 7 are connected together to join the two ends of the filament in parallel.

The positive filament supply lead from tag No. 7 of V3 can be disconnected from the filament tagboard, trimmed, and taken to the No. 7 tag on the new valveholder, with a new lead from tag No. 1 of this holder to the L.T. positive point on the tagboard, as shown in *Fig.* 14 but this is not really necessary. The old lead to V3 can be left in place, and another lead run from the L.T. positive supply point on the L.T. tagboard to either tag No. 1 or No. 7 on the V4 valveholder.

C16 has its leads trimmed to size and insulated by sleeving, and is supported between tags Nos. 2 and 3 on the valveholder. A lead from each of these tags is taken up to the primary of T1—if T1 is the type with wire leads ready fitted these will of course be taken down through hole G to the valveholder. Make sure that the edges of hole G are smooth and not likely to cut through the insulation on the leads—it is as well to bush the hole with a small rubber grommet.

A lead from tag No. 3 on the V4 holder is also taken to the positive supply point on the H.T. tagboard. This supplies the screening grid and, through T1, the anode.

Tag No. 6 is connected to the headphone socket fed by C14—the capacitor shown as C13 in *Fig.* 12. This means that the headphones can still be used—if V4 is removed you will be able to do some quiet listening since V1, V2 and V3 will be working in just the same way as before. The battery consumption will be much less too, so that it is quite a good scheme to make use of the headphones whenever loudspeaker reception is not really wanted.

R11, R12 and C15 are mounted between tag No. 6 on the V4 holder and the soldering tag as shown in *Fig.* 14 and a lead is run from the joint of R11 and R12 round to the disconnected tag on S2. The H.T. negative supply is now taken through the switch and through R12 to reach the chassis.

Turn the receiver over and connect the loudspeaker to the secondary of T1. The loudspeaker will have two soldering tags on an insulating bar; make neat joints to these, do not overheat the tags, and leave sufficiently long leads between the speaker and the receiver to avoid any chance of straining the joints. Twisted lighting flex makes quite good speaker leads.

Never use the Four-Valve receiver without the loudspeaker connected up. (Unless, of course, you have removed V4 and are listening with headphones. In that case always connect the loudspeaker again before putting back V4 and switching on). With the loudspeaker disconnected the anode of V4 is not working into its correct load and the valve could be damaged.

The set is now ready for testing. Plug in the valves, connect up the aerial and earth, plug in the L.T. battery leads and switch on. Check the filaments for glow if the room can be darkened enough, then tap the H.T. battery plug in and out of the battery socket. Each tap should give a good loud plop or crackle from the loudspeaker. If all is well plug in and try out the set. If your results are as good as those from the test receiver you should feel very pleased with it.

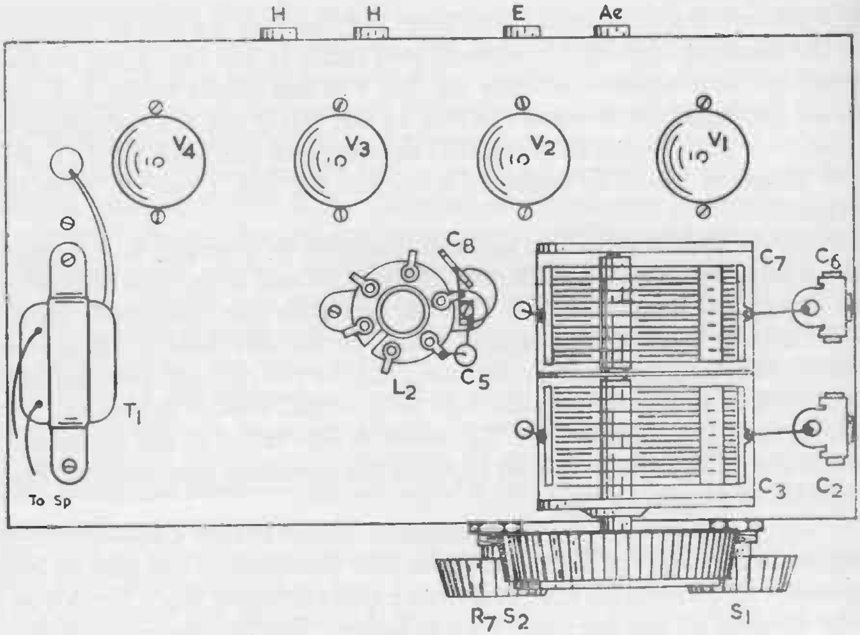


FIG. 15.—TOP VIEW OF THE FOUR-VALVE RECEIVER.

CHAPTER VI

Transistors

YOU probably already know that transistors are the modern substitute for valves. They will perform practically all the tasks which valves carry out for they will amplify at low and high frequencies, detect, rectify, switch, transmit and operate in output and power stages. They are far smaller than valves and are far more efficient since they have no filaments and therefore require no filament battery, whilst in place of the fairly high H.T. required by normal valves the supply to the average transistor circuit is no more than between 6 and 12 volts. They are very strong mechanically since they are usually encased in plastic which in turn is covered by a metal tube, and when used under the correct conditions they would appear to have a very long life.

Transistors were developed at the Bell Telephone Laboratories in America by J. Bardeen and W. Brattain, and further improvements were made by Dr. Shockley.

Perhaps one of the most amazing things about transistors is that in the quite short time since they were first announced in June, 1948, they are being produced and used in literally millions every year, and are found in electronic apparatus ranging from miniature portable radios to space rockets.

The first transistors to be developed arose from experiments with crystal diodes and were known as 'point-contact' types. A piece of n-type germanium had a point-contact applied to it, so that it behaved as a point-contact diode or rectifier. If another pointed wire was pressed on to the surface of the semi-conductor close to the first point-contact it was found that under certain conditions signals applied across one point contact could be obtained in an amplified form from a load impedance connected to the other diode. Such transistors were made and sold in large numbers but were difficult to construct as the contacts to the semi-conductor had to be controlled and fixed within very fine limits.

The junction between p-type and n-type materials which we have already learnt about in the chapter on the crystal receiver was developed by Dr. Shockley and practically all transistors now made are of the junction type. They are described as being either p-n-p or n-p-n since they consist of two junctions with either p-type or n-type germanium (or silicon) in the centre like the meat in a tiny sandwich, with the bread on either side being made of the opposite type of semi-conductor.

All the transistors used in the circuits which follow, and almost all those used in portable radios and other equipment which you are likely to handle for some time to come are of the p-n-p germanium type.

A representation of such a transistor is shown in *Fig.* 16 and you may care to compare this with *Fig.* 4. The two junctions mean that the transistor is really a pair of germanium diodes back-to-back, each diode having its own source of bias voltage. The letters 'e', 'b' and 'c' stand for 'emitter', 'base' and 'collector' and give a very fair idea of the work which each part of the transistor does.

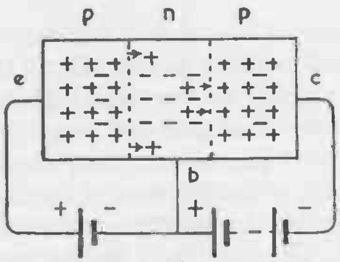


FIG. 16.—THE JUNCTION TRANSISTOR.

The emitter and base diode is biased in the forward direction—the p-type material is made positive and the n-type material is made negative so that positive holes pass from the emitter to the base, giving a current flow. Electrons, of course, also pass from the base to the emitter but the electron current is kept small by careful control of the impurities in the semi-conductor.

The base and collector diode is biased in the reverse direction, so that if this were a simple diode there would be almost no current flow. In the transistor, however, positive holes are being passed into the n-type base from the emitter and these diffuse across the base until they come under the influence of the negative collector, which attracts them strongly so that they enter into the collector circuit. A few positive holes are lost in the base by combination with electrons so that there is a slight difference between the emitter and collector currents, this difference appearing as a very small base current.

The emitter to base junction is biased in the forward direction and this means that small variations in the voltage across this junction cause relatively large changes in the emitter to base current, compared with the behaviour of the collector. The collector, being negative, attracts—or 'collects'—every available hole regardless of the voltage.

The amplification given by a transistor is 'current amplification'. If the emitter and collector currents are compared there is a slight loss in the transistor, because the collector current is always slightly less than the emitter current. If the base and collector currents are compared, however, it can be seen that there is a considerable gain or amplification, because a quite small base current can control a quite large collector current.

A voltage amplification can be obtained by passing the currents through impedances or resistances.

By now you are probably beginning to see the similarities between the transistor and the valve. In the valve a small control voltage set up across the cathode (or filament) and grid influences the anode current through the valve which in turn is made to flow through an anode load, setting up amplified voltages across the load.

The emitter of the transistor is, therefore, rather like the valve cathode, the base is rather like the valve grid and the collector is rather like the valve anode. There are also many similarities between the circuits round a transistor and round a valve, but it is wise not to compare them too closely.

The input impedance of a valve is normally very high—a valve can be connected straight across a tuned circuit without seriously loading it, as we have seen. This is not the case with a transistor, however—the junction between the emitter and the base is a conducting diode and if this were connected across a tuned circuit it would almost short-circuit it. The circuit has to be matched into the transistor by means of a form of step-down transformer.

Again, the anode of a valve is fed from the positive side of a high tension battery. The collector of a transistor is fed from the negative side of a low voltage battery, and if too high a voltage is applied the transistor may break down and be damaged. If the anode of a valve is made negative the valve suffers no harm—it simply refuses to pass current. In the case of a p-n-p transistor, however, if the collector voltage is reversed—that is, if the collector is made positive—the collector to base junction will conduct heavily and the transistor may very easily be ruined.

The first rules for using transistors, therefore, are these:—

Always check the battery polarity before connecting up the circuit.
When using p-n-p transistors, the collectors must always be negative.
Never use too high a battery voltage.
Never reverse the battery polarity.

There are several different types of transistor already available and several more are in development. At the present time almost all those used are of the two junction (or triode) type but tetrode transistors are already used for special purposes. A transistor has been made in the laboratory containing its own batteries in the form of small deposits of radio-active material which supply the operating current by atomic energy. Semi-conducting germanium is light sensitive; when light falls upon it more current carriers are released and the currents increase. For this reason all ordinary transistors are enclosed in light-proof cases but some types are made into photo-electric cells and these are useful in photo-electric exposure meters for photography, in warning and control systems and the like.

The earliest transistors were suitable for use only at low frequencies. The frequency to which a transistor will respond is controlled largely by the thickness of the base material, and methods had to be found of making the central n-type wafer thin enough for the transistor to work at radio frequencies. This has been overcome in various ways and transistors are now working at up to 200 Mc/s. and more.

One way in which transistors are made is shown in *Fig.* 17. Construction starts with a wafer of n-type material, cut from a large crystal which is 'grown' under special conditions. The size of the wafer may be less than $\frac{2}{10}$ in. long by less than $\frac{1}{10}$ in. wide whilst it may well be no more than 5 thousandths of an inch thick. On each side of the wafer is placed a bead of indium, one larger than the other, and these are held in place whilst the whole unit is heated up in hydrogen, until the indium becomes molten (indium melts at a lower temperature than does germanium). Under the indium some of the germanium is dissolved and on cooling a crystal of germanium containing indium is formed under the indium. Since germanium containing indium becomes p-type semi-conductor the p-n-p pair of junctions is thus formed in the wafer of n-type material, whilst the indium beads become the emitter and collector terminals. The base connection is soldered on to the wafer in the form of a nickel wire or strip, and the whole is mounted on a base which supports the lead-out wires.

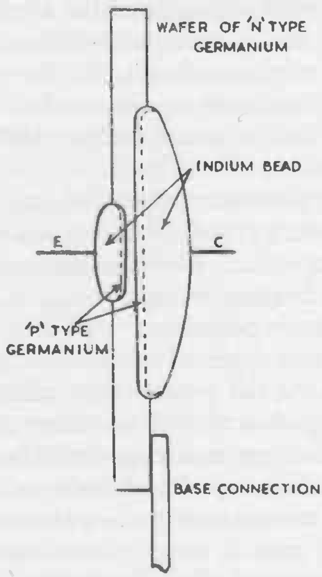


FIG. 17.—AN 'ALLOY' JUNCTION TRANSISTOR.

Transistor Circuits

Transistors can be connected into circuit in three different ways, depending on the type of circuit required. The most common type of connection in a typical transistor stage is shown in *Fig.* 18, where the transistor is acting as a simple amplifier. Note the transistor symbol, a circle with the base shown as a bar and the collector and emitter as two straight lines joining the bar. The emitter has an arrowhead pointing into the bar which shows that the transistor is of the p-n-p type. The symbol for an n-p-n transistor has the emitter arrowhead pointing out of the bar.

Whilst two circuits are shown they are both basically of the same sort, and are known as 'Common Emitter' or 'Grounded Emitter' or 'Earthed Emitter' stages, because the emitter is taken to the earth or positive line and held at a steady positive potential whilst the input signal is taken to the base and the amplified output comes from the collector. When used in this way the transistor gives high amplification but is not too good at handling high frequencies; as a result the common emitter stage is found in audio and similar low frequency amplifiers. The two different circuits show the two main ways in which the bias is supplied to the base. This bias is very important to the correct working of the stage—if the bias current is of the wrong value the transistor may be cut-off, when the collector will pass practically no current, or, on the other hand, it may be damaged by the collector's passing too high a current.

Remember always that the transistor is a current operated device. In the case of valves we are chiefly concerned with voltages: in transistors we are concerned with currents.

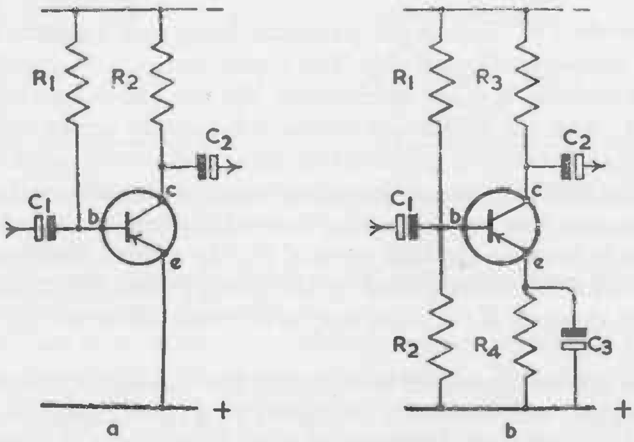


FIG. 18.—A TRANSISTOR COMMON EMITTER AMPLIFIER STAGE.

At (a) in *Fig.* 18 the simplest biasing arrangement is shown. The signal is fed to the base by C1 which passes L.F. but is an insulator to D.C. The bias resistor, R1, is connected to the negative supply line, and a quite usual value for R1 would be 220 k. Across a 3 or 6 volts supply such a high resistance would pass only a minute current; nevertheless this current, flowing through the resistor and the base-emitter junction serves as the base bias. The collector is connected to the negative supply line through a much smaller resistance, R2, which may have a resistance of about 2 or 3 k. Amplified signals are obtained from C2 which again passes L.F. but blocks D.C. from the next stage. The collector current in a simple amplifier stage would be between 0.5 and 2 or 3 mAs.

You will see that C1 and C2 are electrolytic capacitors. Their physical size is very small in most transistorized apparatus since they require a working voltage rating of only 6 volts or so, but a coupling capacitor is often of 2 mF. value and may be much higher. The reason for this lies in the fact that, at audio frequencies the transistor behaves like a resistance connected in series with the coupling capacitor. If the reactance of the capacitor, in ohms, was much higher than the apparent resistance of the transistor the amplification of the stage would be greatly reduced.

Now we come to one of the disadvantages of the transistor—it is very sensitive to heat, and as it is warmed up passes more current through the collector junction. The fact that it is passing current at all tends to warm it, of course, and the situation can arise where, if the transistor is placed in a hot situation, it can 'run away'—the heat will cause more current to flow, this extra current helps to heat up the transistor, this causes even more current to flow and so on until the junction is damaged. If the battery voltage is low, or if the collector load is high, 'running away' cannot easily happen, but in output stages or other circuits using transformers precautions have to be taken to prevent such overloading.

The best method of biasing the transistor base, and a system of controlling run-away, is shown in *Fig.* 18 (b). The input and output capacitors and the collector load resistor, R3, are unchanged, but the bias is now drawn from the junction of R1 and R2 which are connected directly across the supply lines. This forms what is called a potential divider, and providing that R1 and R2 do not have too high resistances the voltage at their junction will remain almost constant no matter how much the bias current through the transistor base may increase. This is because the bias current is only a mere fraction—probably a tenth or less—of the current passed by the battery through R1 and R2, and so whilst it flows through R1 it does not have much effect on the voltage drop across R1.

The emitter is now connected to the earth line through a resistance R4, often about 1 k in value. This resistor is by-passed by a large capacitance, C3, which provides an easy path for L.F. The collector current must flow through R4.

If, through heating effects, the collector current now tries to increase, this causes an increase in the voltage drop across R4. The base is held at a constant voltage, however, so that the bias across the emitter-base junction is reduced and the flow of bias current is reduced. This in turn causes a reduction in the collector current and so the circuit is self balancing within quite wide limits.

In *Fig.* 19 are shown the two other ways in which a transistor can be connected into circuit. At (a) the stage is of the 'Common Collector' type, the collector being taken to the earth line through the battery. The input signal is applied to the base and the output is taken from the emitter. This circuit is fairly similar to a valve circuit known as a 'cathode follower' and which you will meet in radio and electronic circuits as your experience grows. We shall not be using a common collector stage in the circuits to be described, but it can be very useful, especially in audio and gramophone amplifiers, since it gives high gain and has a much higher input impedance than that of the common emitter circuit. This makes it suitable for connection to modern crystal pickups.

At (b) is shown the 'Common Base' stage. By now you will expect this name to mean that the base is taken to the earth line and so is common to the other two electrodes. This is indeed the fact, although the connection between the base and earth is via C1, with R1 and R2 providing the base bias.

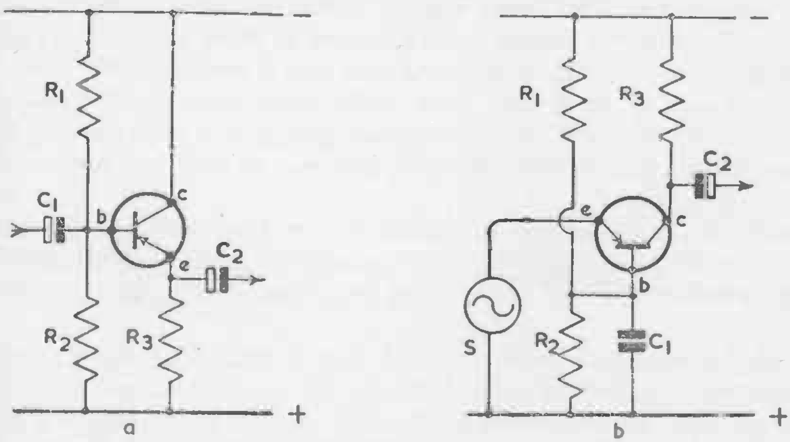


FIG. 19.—COMMON COLLECTOR AND COMMON BASE TRANSISTOR AMPLIFIER STAGES.

'S' represents the signal source which in this stage is fed into the emitter, the output being taken from the collector.

The common base connection is valuable since it is in this type of stage that a transistor gives its best high frequency performance. This does not mean, of course, that a low frequency transistor such as the OC71 will work well at radio frequencies if it is connected up in a common base stage, but it does mean that a high frequency transistor such as the OC45 will give its best performance and work at its highest possible frequency in such a stage. There are disadvantages to the common base type of connection, since amplification is low and the emitter input impedance is low, but if a step-down transformer is used to feed the input and a high efficiency output circuit is provided, this type of stage can be most valuable in transistor receivers.

Two common base stages are used in the superhet, to be described in Chapter IX.

If you have managed to read this far you must be eager to stop thinking about the theory of transistors and to start using them. You will find them fascinating to work with and capable of giving remarkable results. But remember to keep on with the theory, and read whatever you can find on the subject; transistors have a great future and in these few pages we have barely scratched the surface.

CHAPTER VII

A Simple Transistor Amplifier

THE best type of transistor circuit for the beginner to build is a simple audio amplifier. There is very little to go wrong, very few components to buy, and the parts can all be used later in more complicated circuits. The first thing, of course, is to have a signal to amplify and so in *Fig.* 20 is shown a crystal receiver amplifier. If you have built the crystal receiver described earlier in the book, or have any other type of crystal set, the amplifier can be used with it. Even if you can barely hear the crystal set signals the two-transistor circuit will make them loud and clear in the headphones, whilst if you are near to a strong station the amplifier will allow you to use a smaller aerial and thus do something towards sharpening up the tuning of your set.

Note, first, that the crystal set is fitted with a volume control in place of the headphones, Rc, connected straight across the headphone terminals of the set by its two outer tags. The centre tag is taken to the base of Tr1 and feeds in the signal.

A suitable value for Rc is 50 k and if you intend at some time to build up the superhet described in Chapter IX you could buy a small 50 k potentiometer with a single pole on-off switch. This would serve now for both Rc and the amplifier on-off switch, and could be used later on when you build up the superhet.

C1, a 2 mF. capacitor, passes the signal to the transistor but isolates the base bias from the volume control. An amplified signal is set up across the collector load R2 and is passed by C2 to the base of the second transistor. The headphones are connected directly between the collector of Tr2 and the supply line, and high impedance headphones should be used, or else a fairly high impedance deaf-aid type earpiece.

The battery can have a voltage between 3 and 6 volts. A 4½ volts flat torch battery gives good volume and is easily connected up.

A simple circuit like that of *Fig.* 20, containing only three resistors, two capacitors and two transistors could be built up in the corner of a matchbox, but there is no point in miniaturising this sort of amplifier, besides which you will want to be able to change the values of resistors and capacitors to investigate the working of the circuit. A very good way of building up transistor circuits is shown in *Fig.* 21—it is a splendid idea and I wish I had thought of it myself, but I didn't. All the components are mounted in a terminal block—the sort that is called a 'Barrier Strip Connector'

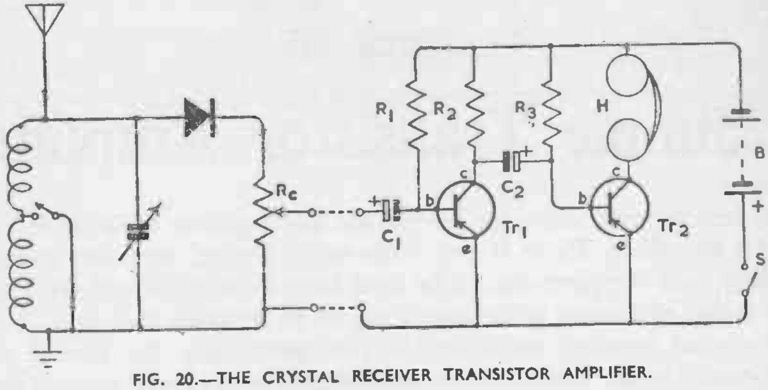


FIG. 20.—THE CRYSTAL RECEIVER TRANSISTOR AMPLIFIER.

or, very often, a 'Chocolate Block Connector' because each section is separated by a furrow from its neighbours, like sections of a block of chocolate. Metal tubes fitted with screws run through the block so that in any tube a wire or wires can be run into one end and held under one screw whilst further wires can be run into the other end and gripped by the second screw. Each tube is, of course, insulated from its neighbours.

Chocolate block connectors can be bought from any good radio or electrical shop, and are usually made in strips of 12 sections. The outer cover may be of porcelain but hard bakelite and semi-flexible plastic covers are more common. If possible obtain one of the semi-flexible type; this will not break if you should accidentally drop it.

The diagram in *Fig.* 21 shows that only 9 sections of the strip are needed for the crystal set amplifier, but do not cut off the remaining three sections since

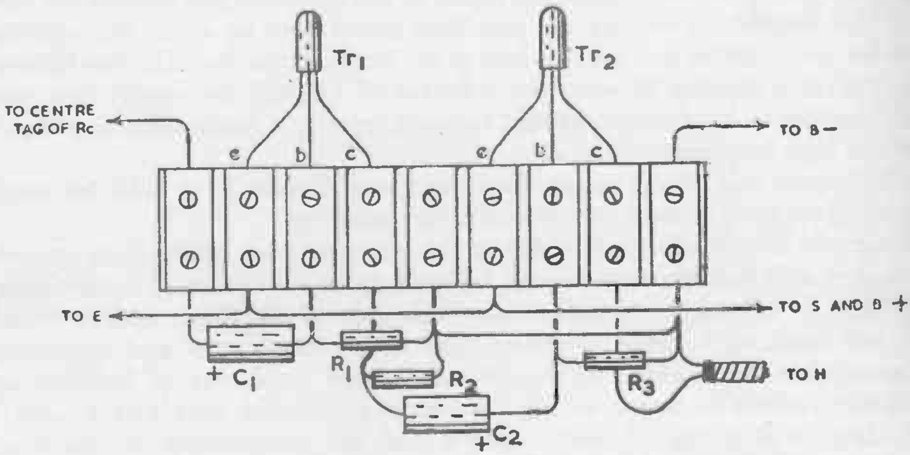


FIG. 21.—WIRING THE CRYSTAL RECEIVER TRANSISTOR AMPLIFIER.

you may be glad to have the whole length available for building the receiver in the next chapter.

The best thing about this method of connecting up a transistor circuit is that it does away with soldered joints. We have already seen that transistors are very heat sensitive and it is therefore necessary to be extremely careful when soldering their leads in place. A heat shunt *must* be used; this was mentioned in Chapter I where it was suggested that broad-nosed pliers should be used to grip the wire ends of the crystal detector to conduct away excess heat.

In your first circuits you will want to take transistors in and out of the equipment and it would hardly be safe to solder and unsolder them every time.

Some typical transistors are shown in *Fig.* 22 and the method of coding the leads is shown—it is now standard practice to have the leads in the order emitter-base-collector, with, usually, an indicating dot or spot of colour beside the collector lead. There is very often another spot of colour on the transistor, on the top of the can. This may be red, blue, white, yellow and green, or yellow and red. Transistors carrying these colours, and without any name or type number on them, are known as 'surplus' types and are sold a good deal more cheaply than 'first-grade' transistors. The surplus types are those which are not quite up to the standard of the named and coded transistors, but you will probably be glad to use them to save money and as a general rule they perform very well indeed. The colour coding is as follows:—

Red, or Yellow and Green	Suitable for L.F. and audio work.
Blue	Suitable for the lower radio frequencies and especially for I.F. circuits in superheterodynes. (To be described later.)
White, or Yellow and Red	Suitable for radio frequencies from 1.5 to 8 Mc/s. or more.

In some cases the spot of colour by the collector lead is the coding colour of the transistor—thus, if the component has only one red spot on it, near to a wire, it is an audio transistor with the collector lead next to the spot.

Prices of these 'surplus' transistors vary but if you study the advertisements in the radio magazines you will soon see that there are a number of mail order shops who specialise in supplying these transistors and the miniature components to go with them, and you can then compare prices.

When it comes to named and coded transistors the situation is rapidly becoming as complicated as that connected with valves. In time you will probably select one main firm whose products you like and you will know their type numbers off by heart. Until then do not try to learn off all the available types, but watch the announcements, advertisements and articles in your magazines and you will soon have a good working idea of what is available.

Although transistors are so strong, mechanically, you must be very careful when handling the connecting wires. Never snatch or tug at them and never bend them sharply, or too close to the base of the transistor. The leads from the base should be left straight for at least ¼ in. outside of the transistor case before they are bent, or they may snap off and there is no way of repairing them. This does not mean that you must be too scared of a transistor to touch it—just handle it sensibly.

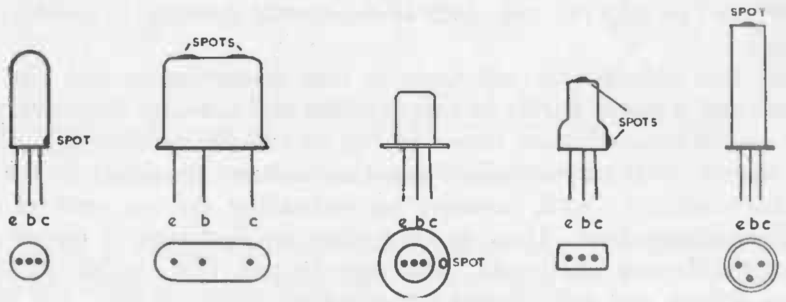


FIG. 22.—SOME TYPICAL TRANSISTORS.

Another safety precaution which I always take when wiring transistor circuits is to use Black covered thin connecting wire for the negative supply leads, Red covered wire for the positive supply leads, and Green covered wire for the base leads. There is no need to go quite so far as this but you should use Red and Black battery leads at the very least, so that you can always be absolutely certain which is the correct sense of battery connection.

Components List for the Crystal Set Amplifier, Fig. 20

C1, C2	2 mF. miniature electrolytic capacitors, 6 v.w.
R1, R3	220 k, $\frac{1}{10}$ or ¼ watt.
R2	3.3 k, $\frac{1}{10}$ or ¼ watt.
Tr1, Tr2	Mullard OC71 or Red Spot transistors.
H	High impedance headphones or deaf-aid type earpiece.
I	12-way Chocolate Block strip connector.
S	Single-pole on-off switch. (Can be part of Rc.)
B	4½ volts flat torch battery.
	Red and Black connecting wire.

When wiring up the circuit leave the transistors until last and fit the small components to the chocolate block as shown in *Fig.* 21. Remember that most capacitors used in transistor audio amplifier circuits are electrolytic and must be connected with their polarities correct. If the component leads are not too long there is no need to put insulating sleeving over them since they are held quite firmly in the strip connector with little chance of short-circuits. The positive supply line going to the Earth terminal of the crystal set, to sections Nos. 2 and 6 of the block (numbering from the left) and to the switch must, of course, be insulated from the rest of the wiring. Strip off only as much of the plastic covering as is necessary to make the connections.

With the components and wiring in place the transistors can be put into circuit. Gently bend their leads to fit into the correct connectors in the block and whilst turning down the screws make sure that each transistor lead is right under the screw, and has not slipped over to one side. Do not screw up too tightly, just enough pressure to hold the leads securely is all that is needed. When the transistors are in check the circuit over. Make sure that the transistors are the correct way round—the spot indicating the collector lead should be on the right in *Fig.* 21. Check that the Red, positive, battery lead is coming from the bottom of section No. 6 to the switch, and the black, negative, lead is coming from the top of section No. 9. Connect in the headphones if you have not already done so, and make the connections from the amplifier to the crystal receiver. If the crystal set is working and you have very strong signals in your area you may hear something in the headphones even before you connect up the battery and switch on.

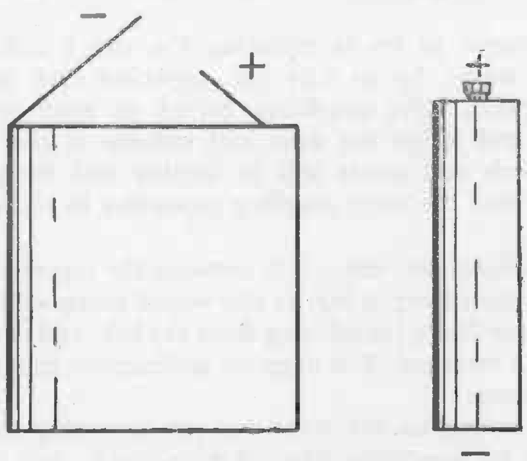


FIG. 23.—THE POLARITY OF TORCH BATTERIES.

You may not be too certain of the polarities of ordinary torch batteries so these are shown in *Fig.* 23. The zinc case of a cell is the negative pole and the brass cap on the central carbon rod is the positive pole. Ordinary paper clips make quite good battery connectors for the flat strip terminals of a $4\frac{1}{2}$ volts battery, since the battery leads can be soldered to them and they can then be pushed on to the strips to make a good connection. Round torch batteries need a built up clamp both to hold them and to make the connections, and a suitable design is shown in *Fig.* 27.

If you are using a flat battery with paper clip connectors the circuit does not really need a switch—simply slide the clips on to the battery to switch on, and slide them off again to switch off.

You should be ready for switching the amplifier on now. Make a final check on the wiring and the battery polarity, then switch on and turn up the volume control. When the crystal set is tuned in you should hear the signals strongly amplified in the headphones.

Things to Try

There are some experiments you can carry out on the transistor amplifier, but with this as with any other transistor circuit, never disconnect or connect up a component with the battery switched on. This was a lesson I learnt the hard way with my first transistors, by connecting in an 0.01 mF. capacitor to an oscillator circuit. The charging current drawn by such a capacitor from a low voltage is not very great but I drew it from the wrong point—through a junction—and ruined a transistor.

The first experiment to try is replacing C2, the 2 mF. coupling capacitor between the stages, by an 0.01 mF. capacitor such as would be used for a coupling between valve amplifiers. Switch on again when the changeover is complete and judge the tone and volume of the signal. The low frequencies in speech and music will be weaker and the whole signal less powerful, proving that the large coupling capacities in transistor circuits are really necessary.

If you have a milliameter, connect it between the top end of R2 in *Fig.* 20 and the negative supply line; in *Fig.* 21 this would mean withdrawing the lead of R2 from connector No. 5 (numbering from the left) and connecting it to the positive milliameter terminal. The negative milliameter terminal is then taken to the No. 5 connector.

Switch on. Depending on the transistor you are using the current shown by the meter will be something like 0.5 to 1.5 mA. and is, of course, the collector current of Tr1. Switch off again, and change the value of R1 to 330 k, using either a 330 k resistor in place of the present R1 or by adding 100 k in series with the present R1 (the odd 10 k does not matter in a total value of over 300 k). Switch on and see what has happened to the collector current, and also judge by ear whether the signal in the headphones has altered. You may not be able to detect a change in the volume; on the other hand it may go up or down. The collector current, in any case, will have been reduced.

The effect on the headphone volume will once again depend on the transistor, and it is not unusual, especially when surplus transistors are being employed, to choose bias resistors by trial to give the required collector current. If increasing R1 improves results leave the new value in place, and make the same test on R3 to see if a further improvement is obtained. If the volume falls, however, or becomes distorted, replace the original R1 to try an even lower resistance—say 150 k—in place of the original 220 k.

Try a 1.5 volts cell in place of the battery at B, remembering to check the polarity before connecting up. The amplifier will still work even with such a low supply voltage.

CHAPTER VIII

A Transistor Receiver

NOW that you have handled transistors and made them work in the crystal set amplifier you will be wanting to build a real transistor receiver. In *Fig.* 24 is shown a two-transistor circuit which will give good results anywhere, usually without an external aerial and earth, though a small aerial and an earth connection will be needed for proper reception in the worst signal areas.

L1 and L2 are ferrite slab aerials, L1 covering the long, and L2 the medium, wavebands. We have seen earlier in the book that ferrite has the power of concentrating the surrounding fields through a coil wound upon it. A radio wave has an electric and a magnetic field, and it is to the magnetic field which the ferrite responds. These fields radiate outwards from the radio transmitter and the ferrite aerial receives most strongly when the length of the rod or slab is running along the face of the magnetic field—that is, when the slab is at right angles to a line joining the receiver and the transmitter. This 'directional' property can be very useful, since it assists in reducing interference from unwanted stations. It is also of value in direction finding, although here the weakest signal point, rather than the strongest signal point is used, by tuning in the required station and then turning the aerial until the signal is weakest or fades right out. At that point the length of the aerial is pointing directly at the station.

Either aerial is connected, depending on the switching, to the base of Tr1 which is connected as a common-emitter amplifying stage. A step-down transformer is needed therefore, as we have already seen, to match the aerial coil to the transistor, and the small windings on the aerials between the Green and Blue tags are the step-down secondaries of these transformers, the main aerial coils between the Red and Black tags being the primaries.

Signals are passed by C3 to the base of Tr1 which amplifies them but does not 'detect' (or, a better word, 'demodulate') them. The amplified signals are passed on to a crystal detector which does the demodulation, through C5 to D1. C3 and C5 do not need to be large electrolytic capacitors since here we are dealing with H.F., not audio signals.

The positive half of the modulated signal passes through D1 whilst the unwanted negative half of the modulated signal is passed through D2 to earth. R3 filters out the H.F. component and also prevents signals from the aerial through C3 being lost in the detector circuit. Theoretically there should be a resistor and a capacitor in parallel connected between the junction of D1 and R3 on one side and the earth line on the other, but in the original receiver adding these components made no difference. If you live in a strong signal area, however, you may find these components help to keep the set stable and prevent whistling. Connect a 220 k. resistor across a 500 pF. silver-mica capacitor, and take one side of the pair to connector section No. 6 and the other to section No. 7 in *Fig.* 25 (numbering from the left). You could also try connecting the same resistor and capacitor in parallel between connector sections No. 6 and No. 5—that is, directly across D2. If you find either connection improves results the components can be left in place.

Tr1 amplifies the audio signals and these then pass through R6 and C6 to the base of Tr2; C5 is too small in value to provide an easy passage for them. R6 is connected in circuit to prevent the original H.F. signals from reaching C6 but does not interfere to any great extent with the L.F. signals. The audio is amplified again by Tr2 to appear as a strong signal across R8, to be fed by C7 to the earpiece H. The earpiece or headphones could be connected directly to the transistor collector and the negative supply line but it is better, if a deaf-aid type of earpiece is used, to use the system shown, so that direct current is not passed through the earpiece.

You will have realised that Tr1 is dealing all the time with two signals—the original H.F. from the aerial and then the audio from the detector or demodulator. For this reason it is said to be in a 'Reflex' circuit, one meaning of the word reflex being 'directed back upon itself'. In the early days of radio, when valves were very expensive, reflex circuits were developed so that one valve could carry out two or more tasks for the sake of economy. The present reflex circuit also saves the cost of one transistor.

Tr1, besides amplifying the H.F. and audio, also has a third function. Part of the amplified H.F. signal is fed through R1 and C4 to the primary or main tuned winding of whichever ferrite rod aerial is switched in circuit by S1. The base bias is controlled by R5, a potentiometer across the supply lines, the amplification of Tr1 increasing as R5 is turned up, and a point is reached on R5 where the gain is sufficient to cause reaction, or regeneration, over the H.F. circuits. This, of course, gives a further great increase in amplification of the original radio signal, and R5 is therefore both a regeneration and a volume control. By setting it correctly the receiver can be made very sensitive and also very selective.

Components List for the Two-Transistor Receiver, Fig. 24

L1	Ferrite Long Wave Aerial, Repanco Type FS4.
L2	Ferrite Medium Wave Aerial, Repanco, Type FS3.
C1	47 pF. silver-mica. See page 89.
C2	208 pF. tuning capacitor. See page 89.
C3	0.01 mF. ceramic tubular.
C4	27 pF. silver-mica.

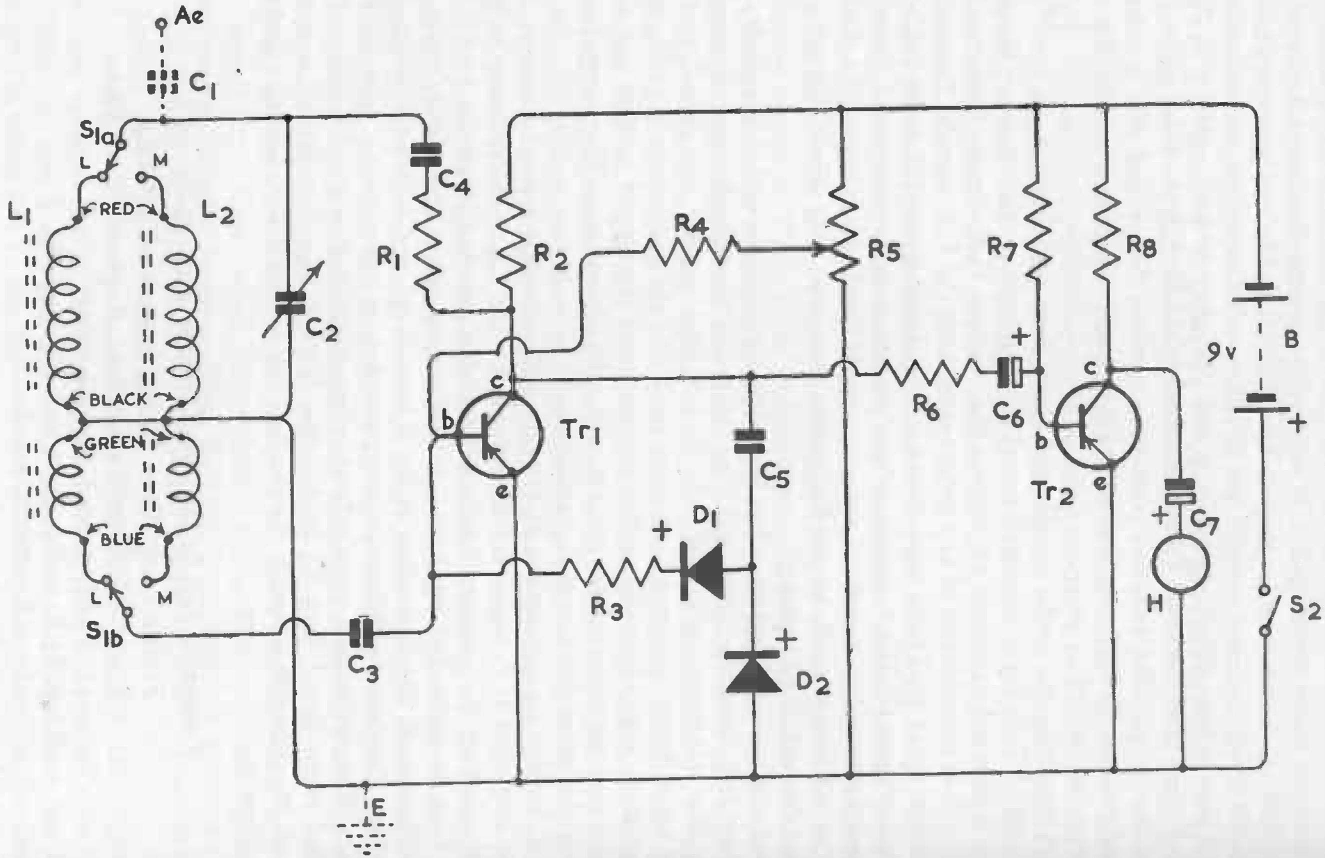


FIG. 24.—THE TWO-TRANSISTOR RECEIVER.

C5	0.002 mF. ceramic tubular.
C6, C7	2 mF. miniature electrolytic capacitors, 12 v.w.
R1, R2, R6	4.7 k, $\frac{1}{10}$ or $\frac{1}{4}$ watt.
R3	10 k, $\frac{1}{10}$ or $\frac{1}{4}$ watt.
R4, R7	220 k, $\frac{1}{10}$ or $\frac{1}{4}$ watt.
R5	500 k, potentiometer, with s.p. on-off switch.
R8	8.2 k, $\frac{1}{10}$ or $\frac{1}{4}$ watt.
Tr1	Mullard OC45 or White Spot or Yellow/Red transistor.
Tr2	Mullard OC71 or Red Spot or Yellow/Green Spot transistor.
D1, D2	Mullard OA70, G.E.C. GEX 34, or equivalent.
H	High impedance headphones or deaf-aid type earpiece.
Sla, b	2 pole 2-way miniature rotary wavechange switch.
1	12-way Chocolate Block strip connector.
S2	On-off switch (on back of R5).
Container or case. See below.	
3	Control knobs.
B	3, 4½, 6 or 9 volts battery. See below.
Sundries:—	Short 4 B.A. bolts for tuner, Red and Black connecting wire, etc. Aerial and Earth sockets and plugs if required.

Notes.

The receiver can be built up in many different ways, and can be made into a very small pocket set, but for those of you who are still rather new to radio construction the layouts shown in *Figs.* 25 and 26 are recommended. Here a 12-way chocolate block strip connector is again used to hold the transistors, diodes and small components, whilst the ferrite aerials, tuner, switch and regeneration control are all mounted in a case, or on a panel fixed to a case, about 6 in. x 4 in. x 1½ in. deep. Plastic cases with lids can be bought at some radio stores and are advertised in magazines, or a cigar box could be used, or the case could be built from hard balsa wood. The case must be non-metallic; the set cannot be built into a tin box or a case bent up from sheet aluminium since then the ferrite aerials would be screened and would receive very little signal.

C1, and the Aerial and Earth sockets are only needed if the set is to work in a poor reception area. You can test the set without them and carefully add them later, if you like. The sockets can be placed anywhere convenient on the receiver panel or side of the case.

C2, the tuning capacitor, should have a value of 208 pF. but a different value can be used. If you intend, later on, to make up the superhet described in the next chapter, you can buy a suitable tuner for that receiver, a Jackson Bros. Type 'OO' Midget Two-Gang Tuner, and temporarily use it for the present receiver. The front section of the 'OO' tuner has a maximum capacity of 208 pF.

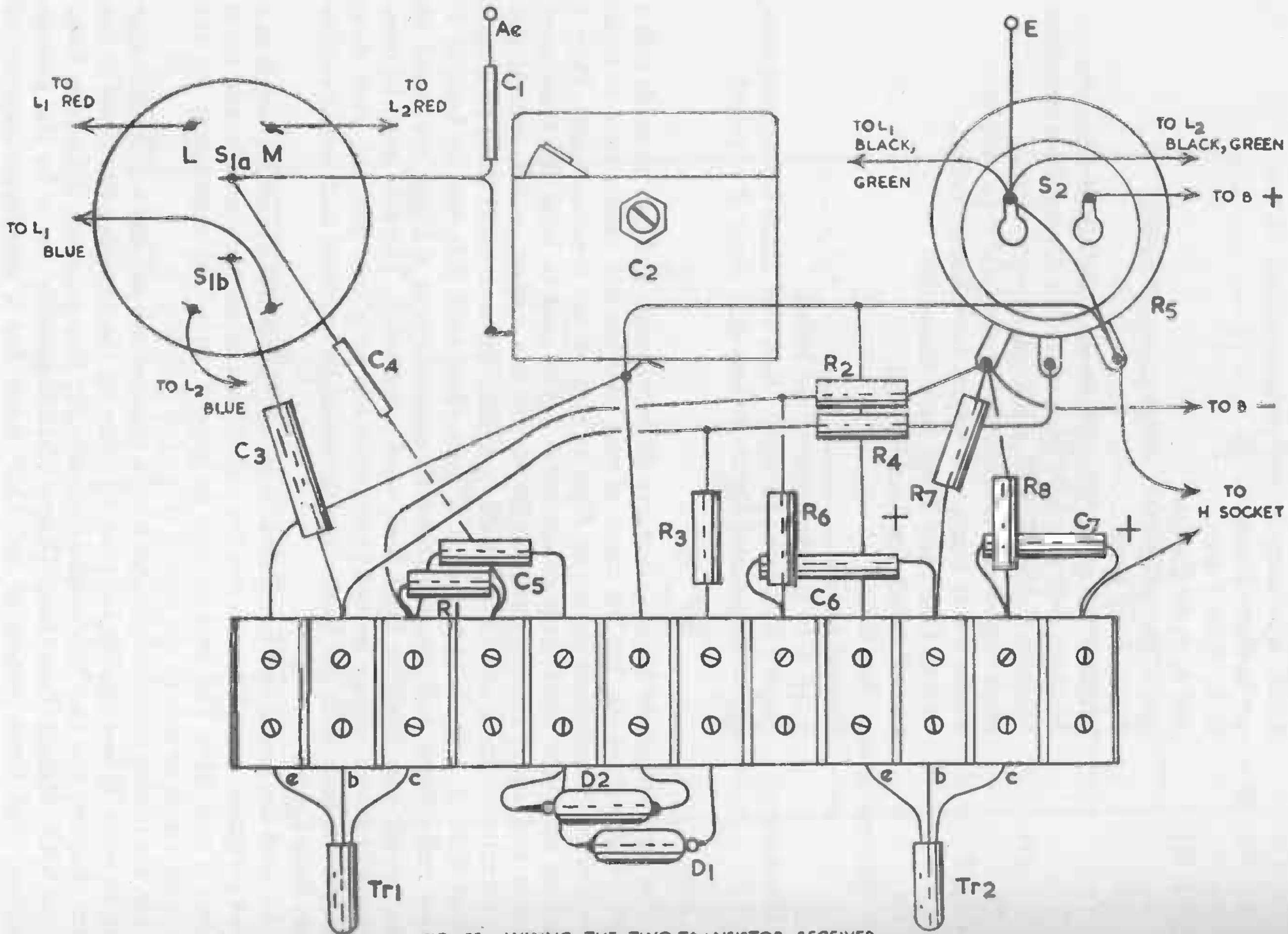


FIG. 25.—WIRING THE TWO-TRANSISTOR RECEIVER.

Another miniature single-gang tuner which can be used for the Two-Transistor receiver is the Jackson Bros. Type 'O' tuner. This has a value of 365 pF. and the effect of using this greater value is simply to bring the stations a little closer together on the tuning dial.

Both the 'O' and 'OO' tuners are mounted as shown in *Fig.* 7 by means of short 4 B.A. bolts. It would be as well to read page 43 again before fixing C2.

The currents in the circuit are all low and $\frac{1}{10}$ watt resistors are suitable. If you can only obtain $\frac{1}{4}$ or $\frac{1}{2}$ watt resistors these are, of course, perfectly satisfactory.

The original set was built using White Spot transistors, and various other types were also tried. All worked well and provided that an R.F. transistor is used in the Tr1 position you should be able to use whatever types are most easily obtained. Good diodes must be used for D1 and D2, but several advertisers sell cheap diodes often stated to be 'specially selected for crystal receivers' and such types were used with good results in the test receiver.

Although a 9 volts battery is shown in the circuit diagram the set will work well on lower voltages down to 3 volts. If you decide to use a 3 volts battery change R4 to 100 k. If the receiver will not oscillate reduce R1 as well, to 2.2 k. Volume will be less if a lower voltage is used, naturally, and a 9 volts battery is recommended—do not use a higher voltage. A suitable small battery is an Ever Ready PP3—when buying the battery for the first time also buy the two snap connectors needed for the battery leads, and be careful, when soldering these to the supply wires, to get the polarities correct.

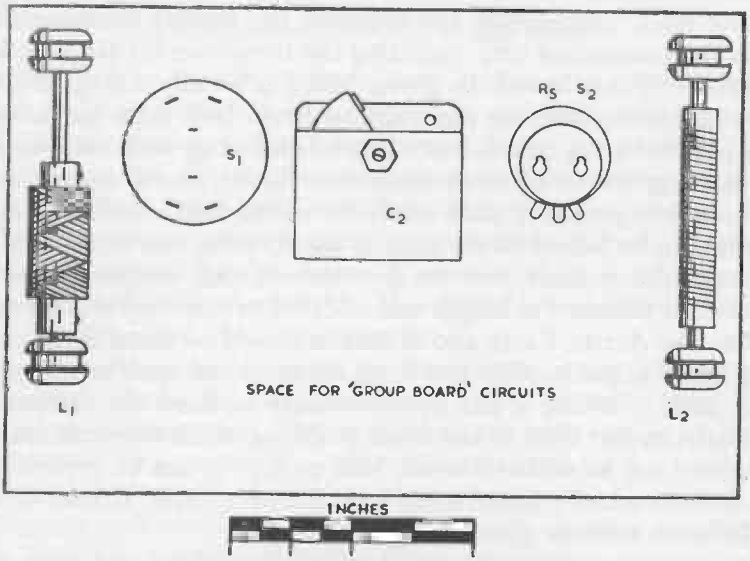


FIG. 26.—A CASE FOR THE TWO-TRANSISTOR RECEIVER.

The main layout shown in *Fig.* 26 is intended more as a guide than as a final design. Before drilling your case or panel put the components on it and check their positions, making sure that they have sufficient space and that the tuner will open without the moving vanes touching the case or other parts. The two aerial slabs can be fitted either to the front of the case, or to the panel, or to the sides of the case. Each aerial has a rubber grommet at either end and these can be used to hold the aerials—strips of scrap aluminium or other metal can have slots cut at their ends into which the aerial grommets will slide, the strips being bent up and bolted to the case or panel, or the aerials can be secured by a turn of *insulated* wire taken round the grommet and through two holes in the panel or case. The wire must be insulated since if it were bare and were passed in a single turn round the aerial slab with its ends twisted together it would form a 'shorted turn'—that is, it would act as a very low impedance secondary winding on the aerial, absorbing a good deal of power and thus spoiling reception. In the same way, if the grommets are held in slots in metal strips the slots (shaped like long 'U's) must remain open at their ends—if the ends were brought together to enclose the grommet, and were in electrical contact, there would again be formed a shorted turn.

Remember, when spacing out the components, to leave room for the battery, which must be clear of all other parts and with no possibility of a short-circuit between it and any wire or component. If possible it is a good plan to divide off a part of the case, using strips of balsa wood and balsa cement, to form a battery box. The best place for the battery is at the bottom of the case, well away from the aerials.

Once the main components are mounted the smaller components can be secured in the connecting strip (omitting the transistors for the time being) to make a sort of 'group board'. A group board is usually a strip of paxolin or other insulator with soldering tags running down both sides (as shown in *Fig.* 29). This is called a tag board, but when it is wired up with components fixed between the tags the name often changes to 'group board' to indicate that it contains complete groups of parts ready for wiring into a main circuit.

The strip can be bolted to the case or panel, using two or three of the bolt holes between the sections, and the free ends of such components as C3, C4, etc. can then be trimmed to length and soldered to their correct tags on S1, C2, R5 and S2. The Aerial, Earth and H sockets should be fitted to the case before the group board is put in place and these too are wired up. The wiring is shown in *Fig.* 25 and, as usual, it has been necessary to show the components and wiring clearly, rather than in the exact positions which they can take. R3, for example, need not be soldered to the lead to R4—it can be mounted directly between sections 2 and 7 (numbering from the left), whilst R6 can be mounted directly between sections 3 and 8.

With the wiring completed carefully check every lead and connection and make certain that the battery leads are fitted with the correct polarity connectors. If a 3 volts battery is to be used it is very conveniently held in a pair of clamps as shown in *Fig.* 27. No dimensions are given since these must depend on the type of battery you decide to use—this again depends on the amount of space available. Both clamps are cut from a flat piece of sheet metal, using tin snips or old scissors—they can be made of tinplate cut from an old tin if nothing better offers. The metal is cut to the shape at C, the fixing tab or foot being drilled with two holes for 6 or 8 B.A. bolts. The side pieces of the clamp should be spaced so that they hold the battery between them, and the clamps are bolted down on a piece of paxolin or plywood as at A and B, with a soldering tag at each end to take the battery leads. The negative clamp has a small 'tongue' cut and bent down which presses on the bottom of the battery. The spacing between the clamps on their mounting board should be arranged so that the battery is gripped fairly tightly between them and is unable to slide out unless the clamps are gently eased apart.

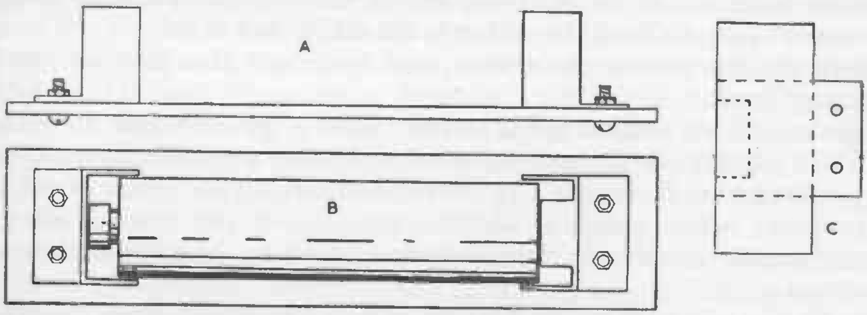


FIG. 27.—A BATTERY CLAMP FOR 3 VOLTS BATTERIES.

The battery holder should be fixed firmly in the case before the wiring is carried out—it must not be left loose since the metal clamps might touch some part of the circuit causing a short-circuit or damaging a transistor.

The transistors and diodes can now be mounted in the strip connector or group board. Check their leads and make sure that the emitter, base and collector in each case are taken to their correct sections. Check the polarities of the diodes; the positive ends are coded in most cases by a red ring or by red paint where the positive lead enters the glass case. Note that the positive end of D2 and the negative end of D1 go to section 5.

Plug in the headphones, connect up the battery, make a final check on battery polarity and turn R5, S2 to switch on. Switch S1 to the long waveband.

Slowly go on turning up R5. The set will become more and more 'lively' and should finally oscillate smoothly, with a hissing sound in the headphones or earpiece. Turn R5 back to just stop oscillation and rotate C2. Unless you live in a bad signal area the Light Programme should be received. Try various settings of R5 for best results, adjusting C2 as necessary.

If the receiver oscillates but the station is not heard, or heard only badly, connect an aerial—a few feet of wire will do—and earth. The Light Programme should then be received at good strength.

Now switch to the medium waves, readjust R5 and tune C2 until the Home Programme is found. Again check on whether the aerial is needed. If the aerial is connected up it should be possible to tune in at least a few foreign stations by day, and quite a number under evening conditions.

The circuit is so straightforward that you should have no trouble in making it work correctly the first time it is switched on, and a little practice with C2 and R5 will soon have you tuning in stations in fine style. There is, however, always that odd set that doesn't seem to work properly, so the following hints are included.

If, after switching on and turning up R5, you hear nothing, not even a hiss, switch off and check the battery polarity and all the wiring and components. Check that the transistor connections, the diode leads and the electrolytic capacitor leads are all the right way round, with the positive leads going to their correct points. Check the wiring to the aerials and to S1.

Check the headphones or earpiece, and make sure that they are not low impedance types.

If the set will not oscillate either increase C4 to 47 pF. or reduce the value of R1. Make sure that R4 is 100 k if you are using only a 3 volts supply. R4 may also need reducing if you use a $4\frac{1}{2}$ volts flat battery supply, again to 100 k.

Remember, when tuning in stations, especially if you are not using an external aerial, that the set must be turned about for best results since it is directional.

Finally, you will want to add a tuning scale to the receiver. With this type of set probably the easiest way of doing this is to draw up a scale on paper, shaped to fit round the tuning knob. A pointer knob, or a plain knob with a line or dot engraved on it as a pointer, will then indicate on the scale the wavelength, or the station name, to which the receiver is tuned.

CHAPTER IX

A Transistor Superhet

THE receivers so far described in this book are known as Tuned Radio Frequency (T.R.F.), or 'straight' receivers because their tuned circuits are adjusted to the frequency of the station to be received and, where there is more than one tuned circuit, as in the Two Valve receiver, the signal goes 'straight through' the receiver. Practically all commercially made receivers today are, however, superhets or, to give them their full name, supersonic heterodyne receivers.

Heterodynes we have already met—they are the beat notes, heard as whistles, obtained in a receiver which is allowed to oscillate whilst tuning in a station. A supersonic heterodyne is, obviously, a beat note or whistle too high in frequency to be heard by the ear. A superhet is, therefore, a receiver in which an oscillator is allowed to beat with the required station signal to produce another quite high frequency. And how, you are probably saying, does *that* help?

We found with the crystal set and the One Valve receiver that having a single tuned circuit was hardly sufficient for reception under the present conditions where many stations are crowded into the medium waveband—the receiver is not selective enough to give good sharp tuning. Adding regeneration helps considerably, and so does adding a further tuned circuit, since both selectivity and sensitivity are then greatly improved. At the best of times, though, a regeneration control is a tricky thing to handle, and it would be a good plan, if possible, to do away with reaction altogether and to use in its place a whole series of tuned circuits, each in a stage which would amplify the signal and increase the sharpness of tuning. This in turn, however, would mean a very large variable tuner, with several gangs. It would be difficult to keep all the tuned circuits in step, whilst at the same time a number of tuned circuits all on the same frequency would be very likely to burst into uncontrollable oscillation—they would be unstable.

Now look at *Fig.* 28 which shows the circuit of a transistor superhet receiver. A ferrite slab aerial, similar to those used in the Two Transistor receiver, is tuned to the required station on either the long or medium wavebands, and the signal is fed to the first transistor, Tr1. A second tuned circuit consisting of L3, C8, C6 and C7 is also connected to the transistor (by C5 to the emitter) and this tuned circuit has a secondary or regeneration winding connected into the collector of Tr1. L3 and its capacitors form a oscillating circuit. There is no regeneration control, the circuit oscillates steadily, and its frequency is varied by C6 which is ganged with C2, the aerial tuner. The two circuits are not tuned

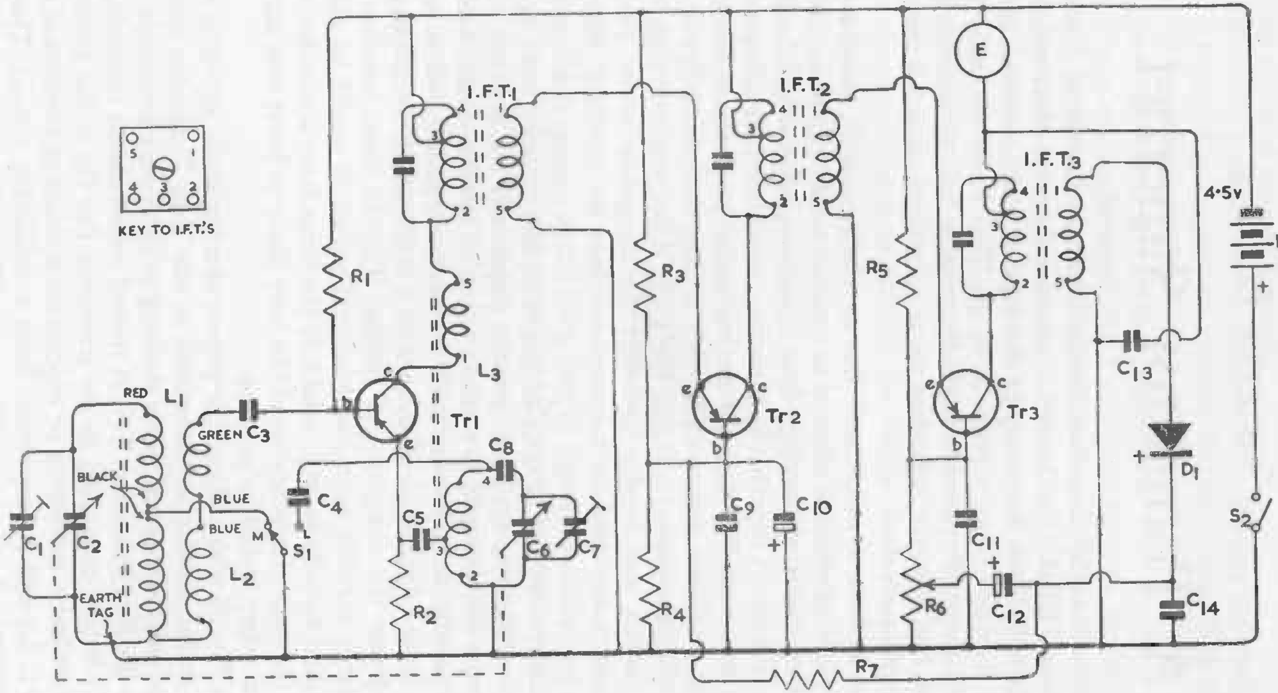


FIG. 28.—THE TRANSISTOR SUPERHET.

to the same frequency; the oscillations provided by L3 are always tuned to a frequency 455 kc/s. higher than the frequency of the station which is being received. The tuning capacitor, aerial and oscillator coils and C8 all have to be arranged to have the correct values in order that the frequencies shall keep in step over the wavebands since it is essential that the difference of 455 kc/s. is always accurate.

When two signals are fed into a suitable circuit they can be made to combine (to 'beat together' or to heterodyne) and so there are a number of outputs from Tr1, consisting of the original signal, a steady signal from the oscillator, and two heterodynes, one consisting of the signal frequency plus the oscillator frequency and the other consisting of the oscillator frequency minus the signal frequency. This last heterodyne will always be at a frequency of 455 kc/s. and is called the Intermediate Frequency or I.F.

It is fed to one winding of the first I.F. transformer, I.F.T.1. This winding is tuned to 455 kc/s. so that the unrequired signals pass through it with little effect. It resonates at the frequency of the required signal, however, so that the I.F. is passed on by induction to the second winding of the transformer and an amplified signal is supplied to the emitter of Tr2, the first I.F. amplifier. This transistor is connected in a Common Base circuit (see *Fig.* 19), which gives good high frequency operation and makes a stable and easily adjusted stage. From Tr2 the signal is fed through another I.F. transformer to another I.F. amplifier, Tr3. Yet another I.T. transformer couples the signal into the demodulator, D1.

Following Tr1, which is know as the 'Frequency Changer' since in it are combined the two frequencies giving the Intermediate Frequency, there are therefore no fewer than six tuned circuits, all adding to the selectivity and sensitivity of the receiver. Once they are adjusted to the correct frequency when the set is aligned they require no further tuning, and since the coils can be made small and efficient, and screened in miniature metal cans, the circuit can be kept stable.

Once again a reflex stage is used in the receiver, Tr3 being made to perform as an audio amplifier as well as an I.F. stage. The two components from the demodulator separate, the H.F. component at the intermediate frequency of 455 kc/s. passing to earth through C14 and the L.F. or audio component being coupled through C12 to the volume control R6, which is part of the biasing circuit for the base of Tr3. As the slider of R6 is turned up an increasing proportion of the audio signal is fed to the base of the transistor, and therefore an increasing amplified output is heard in the earpiece E. C13 decouples the earpiece from the I.F. signal.

The receiver also has Automatic Volume Control or A.V.C. which reduces the gain of the first I.F. stage on strong signals but allows the stage to work at full amplification on weak signals. When a signal is demodulated in a diode or germanium crystal the carrier wave is rectified and so sets up a steady D.C. voltage, the strength of the voltage depending on the strength of the carrier wave. In the present circuit the diode is connected to make this voltage positive and the positive supply is fed to the base of Tr2. A strong carrier wave therefore reduces the negative bias on the base of this transistor, causing it to give less amplification. Audio signals must be prevented from reaching the transistor, and these are filtered out by R7 and C10.

Components List for the Transistor Superhet, Fig. 28

L1	Ferrite Medium Wave Aerial, Repanco, Type FS3.
L2	Long Wave Loading Coil, Repanco, Type XL1. See below.
L3	Medium Wave Oscillator Coil, Repanco, Type XO8.
I.F.T.1	I.F. Transformer, Repanco, Type XT6.
I.F.T.2	I.F. Transformer, Repanco, Type XT6.
I.F.T.3	I.F. Transformer, Repanco, Type XT7.
C1, C7	50 pF. 'postage stamp' trimmers.
C2, C6	208—176 pF. variable two-gang tuning capacitor. Jackson Bros. Type 'OO'. See below.
C3, C5, C14	0.01 mF. ceramic tubular.
C4	250 pF. silver mica, 5%. See below.
C8	300 pF. silver mica.
C9, C11, C13	0.1 mF. tubular.
C10, C12	2 mF. miniature electrolytic capacitors, 12 v.w.
R1	330 k, $\frac{1}{10}$ or $\frac{1}{4}$ watt.
R2	10 k, $\frac{1}{10}$ or $\frac{1}{4}$ watt.
R3	82 k, $\frac{1}{10}$ or $\frac{1}{4}$ watt.
R4, R7	4.7 k, $\frac{1}{10}$ or $\frac{1}{4}$ watt.
R5	1 meg. $\frac{1}{10}$ or $\frac{1}{4}$ watt.
R6	50 k, potentiometer, with s.p. on-off switch.
Tr1	Mullard OC44 or White Spot or Yellow/Red Spot transistor.
Tr2, Tr3	Mullard OC45 or White Spot or Yellow/Red Spot or Blue Spot transistor.
D1	Mullard OA70 or G.E.C. GEX34 or equivalent.
E	Deaf-aid type earpiece. See below.
S1	Single pole 2-way wavechange switch.
S2	On-off switch (on back of R6).
1	12-way tagboard. See below.
Container or case. See below.	
3	Control knobs.
B	$4\frac{1}{2}$ volts flat torch battery.
Sundries:—	Short 4 B.A. bolts for tuner, 20 S.W.G. tinned copper wire, Red and Black connecting wire, etc.

Notes.

You have by now read enough constructional notes, and seen enough diagrams, to be able to decide for yourselves how to build up this receiver, and so there is no illustration of the case layout. Plastic food boxes sold at multiple and hardware stores make good receiver cases, cigar boxes are almost as good and, once again, you could make up a case from balsa wood.

I have built up this circuit in several different ways, but the most convenient and quickly constructed is shown in *Fig.* 29 where all the small components and transistors are mounted on a 12-way tagboard. This, in turn, is mounted in the case and so it is as well to obtain the tagboard first, with the components, before looking round for a suitable small container. The tagboard used for the original receiver had the fairly standard size of 4½ in. long and 2⅛ in. wide.

The oscillator coil and I.F. transformer are secured to the tagboard by short lengths of 20 S.W.G. copper wire. In *Fig.* 29 the coil cans are shown slightly separated from the tags along the side of the board for the sake of clarity but in fact the cans fit up against the tags, and are held in place by the wires which are soldered to the two nearest tags on the board and to the two small holding lugs on the coil cans. Be careful not to use too much heat when soldering the oscillator coil and I.F. transformers, either on the cans or on the pins when making the connections. The coils are wound on polystyrene formers and these can be melted or damaged. You should be able to make a quick, neat soldered joint by now. When connecting components to the coil pins gently shape the leads round the pins so that everything is held steadily in place before applying the solder and iron.

When the four coils are mounted on the tagboard you should find them very secure, and a good foundation for the components and transistors which are wired to them. When wiring up be sure to keep the coil and transformer cores clear since these will need adjusting when the receiver is first switched on.

Note that all the tags on the coil can side of the tagboard are connected together and taken to the positive or earth supply line. This helps to screen the circuit and make it stable.

R6 is shown, not to scale, to illustrate the connections to its three tags and those to the switch tags. Very probably R6 in your completed circuit will not be in this position—simply use leads long enough to reach it, and extend the lead of C12 if necessary.

You will see that in this circuit the transistors are shown soldered in place, which means that a heat shunt must be used on their leads, and on those of the diode, D1, when the connections are made. It would be as well to use a heat shunt on the capacitor and resistor leads also, especially if miniature $\frac{1}{10}$ watt resistors are used. If you are unable to obtain these or ¼ watt resistors you may of course use ½ watt components.

Remember to check the polarities of C10, C12 and D1 before making their connections.

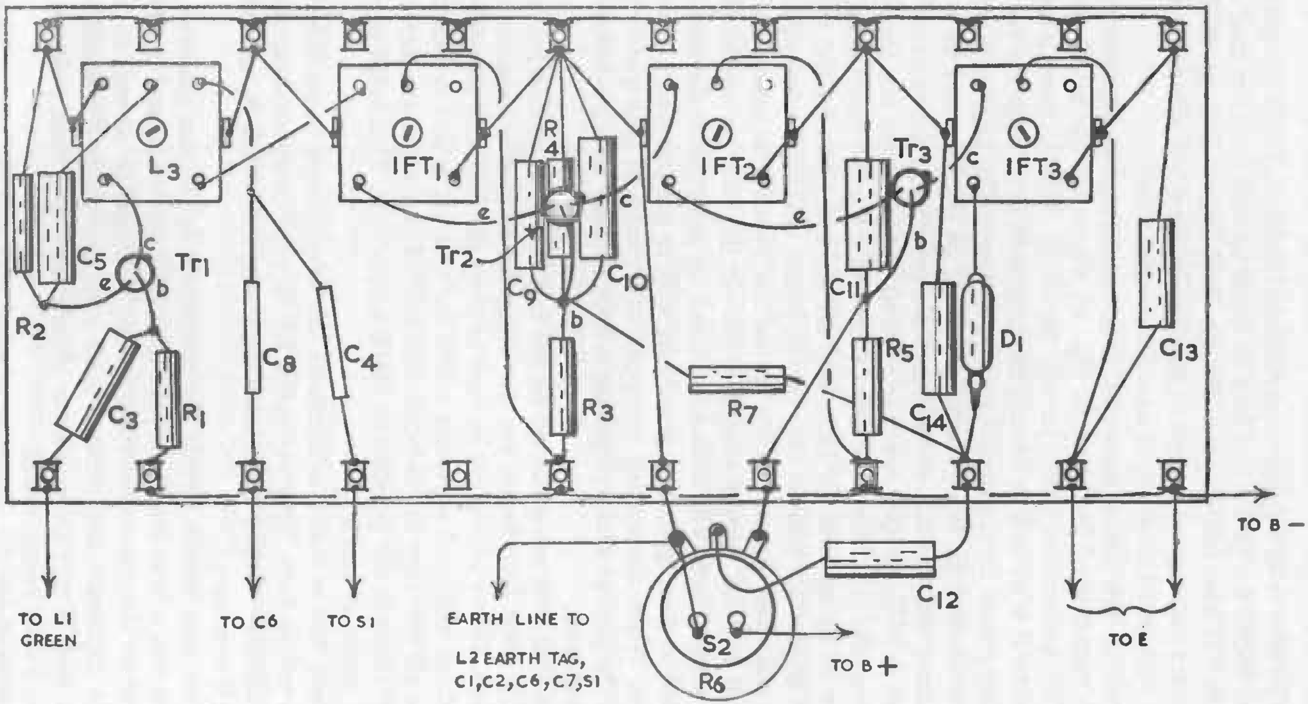


FIG. 29.—WIRING THE TRANSISTOR SUPERHET.

Transistor holders may be used in place of the direct transistor connections if you can obtain these, and would like to try them out. There are various types of holder, some specially designed for transistors and others which are really midget 5 wire valve holders; in these you can use the two end and the middle contacts and ignore the other two. The holders can be mounted on the tagboard with a spot of glue or cement or they can be supported in the wiring if they are suitable. It is as well to code the collector socket on each holder with a spot of paint so that the transistors can be inserted without accidents taking place.

The tuner, the two trimming capacitors C1 and C7, the volume control and on-off switch and the wavechange switch are mounted on the front panel or inside the case, depending on how you are housing the receiver. The three mounting holes can be arranged in much the same way as is shown in *Fig.* 26. The Type 'OO' tuner requires a three hole fixing as shown in *Fig.* 7—remember that the three 4 B.A. bolts must be only sufficiently long to grip the capacitor and must not foul the plates. The front section has the larger capacitance and is C2, the rear section being C6.

The trimmers can be mounted directly on the tuner or on a small tagstrip mounted beside the tuner. On each trimmer the tag connected to the top plate, and thus connected to the adjusting screw, is the earth connection.

The ferrite aerial used is the FS3 with an extra coil used to give reception of the long wave Light Programme, and if you normally receive the medium wave Light Programme without difficulty you can omit all the long wave tuning arrangements if you like. To omit the long wave tuning alter the circuit of *Fig.* 28 as follows:—

Omit L2. Omit S1. Omit C4. (In other words you need not buy these components, and there will be only two controls on the case, the tuner and the volume and on-off control.)

Join the Black and Blue tags of L1 together and connect them to the earth line. Since there is no S1 there is, of course, no connection from the L1 Black tag to S1, and since there is no C4 there is, of course, no connection from C8 to C4. The circuit is now a medium wave receiver only.

If, however, you require the long wave Light Programme, as I certainly do in my part of the country, the loading coil L2 must be connected up to L1 and fitted on to the ferrite slab. To do this, very carefully remove the two rubber grommets from the ends of the FS3 aerial slab and move the winding, on its former, up to one end of the slab, leaving a length of ferrite clear below the Black and Blue tags. On to this part of the slab slide the XL1 loading coil with the earthing tag towards the medium wave coil. The XL1 coil has two leads coded Black and Blue. Connect these to the Black and Blue tags of the FS3 coil, Black to Black and Blue to Blue. (See *Fig.* 30). The aerial is then ready for connection into the rest of the circuit.

The aerial coils are wound with Litz wire, which is formed of many strands of fine insulated wire and which works more efficiently at H.F. than does a single, thicker, strand of wire. When making connections to the aerial ensure that each fine strand of wire is included in the joint.

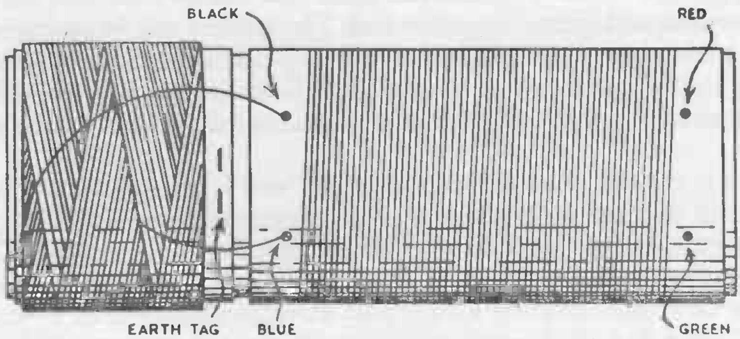


FIG. 30.—THE MEDIUM AND LONG WAVE AERIAL WINDINGS

It is as well to connect the aerial with leads sufficiently long to enable it to rest outside the case until the receiver is aligned. It can then be mounted in the case and the leads shortened. The leads must not be over-long, however, otherwise the receiver might be unstable and difficult to align; use just sufficient wire to permit of easy adjustment of the windings on the ferrite slab.

Since the rubber grommets have to be removed from the aerial when the long wave coil is included, some different method of mounting the aerial must be worked out. The best place for the aerial is usually a horizontal fixing under the top of the receiver case and it is quite a simple matter to make two grooves or rebates from bits of scrap hardboard and glue or cement into which the aerial can slide when the receiver is completed.

The action of the extra coil on the aerial is to increase the inductance of the winding when S1 is switched to 'L' so that C1, C2 and the whole aerial winding tunes to 200 kc/s. With S1 switched to 'L' the capacitor C4 is connected right across the tuned winding of the oscillator coil, thus reducing the frequency of the oscillator. C4 must have the correct capacitance if the circuit is to work correctly and so a 5% capacitor is specified—that is, the value of C4 must be 250 pF. plus or minus 5%. When buying C4 simply ask for a '250 pF. 5 per cent' capacitor.

Ordinary high impedance headphones can be used with the receiver but if it is to be a small and portable set a deaf-aid earpiece as mentioned in earlier chapters is much more convenient. The original circuit used an Ardente earpiece type ER250, connecting cord E6/E6 and two pin socket SK1255, the earpiece being fitted with a plastic 'pip' to fit the ear. In this circuit the collector current of Tr3 passes through the earpiece but the current is quite small.

A flat $4\frac{1}{2}$ volts battery will fit fairly easily into most receiver cases—remember to take precautions to prevent the battery connecting strips from touching any part of the circuit, preferably by building a suitable battery compartment into the case. The set will work well on 3 volts, however, and a really tiny 3 volts battery such as the D22 can be used if the receiver is to be made in midget size.

Double check the wiring once the set is made and before switching on. Check transistor leads, the polarities of the electrolytic capacitors and D1 and, above all, the battery polarity. When you are satisfied that everything is in order you can put in the earpiece, switch on, turn up R6 and hear—probably nothing but a slight hiss. A newly-built superhet is an annoying thing, which has to have all its tuned circuits adjusted correctly before it will show off its paces.

The first task is to make a trimming tool to suit the tiny cores of the oscillator coil and I.F. transformers. These little cores must be treated with care, and must not be touched with an ordinary screwdriver blade. A suitable tool could probably be carved from an orange stick but I have found a copper blade to be best. Take 3 or 4 inches of 20 S.W.G. tinned copper and either squeeze the end in a vice, or gently hammer it on a flat surface, to spread the round wire into a thin, flat blade. The edges of this blade will probably be wavy, and they should be trued-up with a fine file. Carefully try the blade in the core of one of the I.F. transformers, and if necessary file the little blade until it slips down through the core and will, when turned, screw the core in and out of the coil. Do not move the core more than a half-turn either way until you are ready to start the alignment.

If you know a friendly radio engineer or experimenter who has a signal generator he will probably carry out the alignment for you, using the instructions provided with the Repanco coils, but most of you will have to make the adjustments without a signal generator. This means that the signals from ordinary broadcasting stations must be used, so that the work is best carried out during the evening when reception conditions are best.

Start by setting the trimmers C1 and C7 to roughly their half-way capacitances, switch the receiver to the medium waveband and switch on, turning up R6 for full volume. Tune over the whole range of the tuner, and, remembering that the aerial is directional, turn the set about, in an effort to hear the local Home Programme. If no station can be heard connect in an aerial to L1. Use, at first, a fairly short length of wire connected to a 50 pF. capacitor, and connect the other side of the capacitor to the junction of L1 with C2, i.e. the Red aerial tag. If a station still cannot be heard even weakly try lengthening the aerial wire and adding an earth connection to the earth line of the receiver. If it is still not possible to receive a signal make adjustments to the core of the oscillator coil, L3, tuning C2, C6 round the band after each adjustment. First screw out the core of L3, half a turn at a time, turning round after each half turn, until the core is level with the coil base. If there is still no signal screw the core back into L3 until it is well down the former—be very careful not to screw it to a full stop against the coil can at the other end of the coil former as it might jam.

At some point in this series of operations you should hear at least the local station, and quite possibly some more distant stations as well.

Choose a fairly weak signal, if you can hear more than one station, and adjust the cores of the three I.F. transformers. Once the station is tuned in leave the tuner set, and commencing with the core of I.F.T.3, screw this in and out slowly with the copper trimming tool, leaving it at the position where the signal is loudest. Adjust the core of I.F.T.2 in the same way, again tuning it for best results, and finally tune the core of I.F.T.1 to give any improvement possible on the signal. If the signal should become very loud as the I.F. transformer cores are tuned, turn down the volume control; slight improvements cannot be heard on a loud signal.

The receiver should be perfectly stable but if, as the I.F. transformers are brought up to tune, the circuits go into oscillation this will be heard as a 'plop' and a hiss, the station signal either disappearing, or becoming distorted. The fault is unlikely but if it should occur reduce the value of R4 to 3.3 k or 2.7 k by trial, after first checking that D1 is connected correctly and that C9, C10, C11, C13 and C14 are in place and in good order.

If all is well, as it should be, the three I.F. transformers are now tuned up correctly to a frequency near to 455 kc/s.

It should now be possible to hear quite a few stations as the tuner is rotated, and if signals are strong, and an aerial was added to assist in the first stage of alignment, try disconnecting the aerial—and earth, if used—to see if signals can be received without them. If not, reconnect the aerial, but if stations can still be received leave the aerial disconnected.

Turn the tuner so that the vanes are fully open, then slowly start to turn the vanes in until a signal is heard. Leave the tuner set at this position and tune C1 with a screwdriver until the signal is at the best volume obtainable. This will make a further improvement in results and the next step is to find the correct setting of the oscillator coil core.

Carry on slowly tuning C2, C6 so that the moving vanes mesh into the fixed vanes and the receiver tunes towards the low frequency end of the medium waveband. Stations will be heard at first but probably they will become weaker and weaker as the tuning progresses until nothing is heard and the tuner is only about half in mesh. Leave the tuner set at that point and, with the copper trimming tool, adjust the core of L3 either in or out until signals are heard. Open the tuner to the starting position again and again turn the vanes into mesh—it should now be possible to hear signals further round the tuning range. If the core of L3 was moved some considerable amount it may be necessary to adjust C7 to improve results at the high frequency end of the tuning range, with the vanes practically out of mesh. If the core of L3 was turned into the coil open C7 slightly; if the core of L3 was turned out of the coil close C7 slightly. If C7 is adjusted in this way make a slight adjustment to C1 whilst listening to a weak signal with the tuner vanes almost fully open.

If necessary, repeat this process with the core of L3 until signals can be heard all round the tuning range as C2, C6 is rotated.

If an external aerial and earth are still in use these must now be disconnected. C1 will need a slight readjustment when the aerial is removed.

It now remains to align the aerial circuits and to adjust the tuning range of the receiver. The best signals to use are either the West Home Service on 206 metres or Luxembourg on 208 metres. Open the tuner fully and try to find either of these signals with the vanes only slightly in mesh. If the signals are found with the vanes more than a few degrees in, increase the value of C7, opening C2, C6 at the same time, until the signal is positioned at about the right spot on the tuner arc. If the signals cannot be heard at all, and if the Light Programme on 247 metres is found with the vanes almost fully open, C7 is too high in value, and should be unscrewed until the required signals are heard with the tuner turned to the correct spot. Whenever C7 is adjusted C1 will need a similar adjustment to keep the signals at best volume.

With either the West Home Programme or Luxembourg marking the high frequency end of the tuning scale, turn the tuner round so that the vanes are fully meshed, and make sure that signals are heard right round the dial. If C7 has required a considerable adjustment the core of L3 will need further adjustment, and then it will be necessary once more to reset the tuning positions of the West and Luxembourg stations. Once signals are heard right round the dial the aerial winding on the ferrite slab can be adjusted for best results. Try moving the FS3 winding, on its former, up and down the ferrite slab. A position will be found where signals at the low frequency end of the tuning range are improved. Open the tuner and adjust C1 for best volume on the medium wave Light Programme at 247 metres, and repeat these two adjustments, first the aerial winding, then the setting of C1, until results are good all over the tuning scale. Select a weak signal, and check the settings of the I.F. transformer cores, starting with I.F.T.3 and working back to I.F.T.1 to see if any further improvement can be made, making only small adjustments, however.

Now switch the receiver for long wave reception. With any luck the Light Programme will be heard as the tuner is turned, and all that is necessary is to move the XL1 loading coil on the ferrite aerial slab until the station is received at the best volume obtainable. Switch back to the medium waveband and check that the adjustment to the XL1 coil has not upset the FS3 coil positioning. If necessary make corrections to both the FS3 coil and the XL1 coil until one ceases to have any effect on the other. Both coils should then be secured to the ferrite slab with a dab of glue or polystrene cement, and left alone until the glue has set. The aerial can then be fixed into the receiver case. If the leads are shortened a further adjustment to C1 will probably be needed to compensate for the change in the circuit; if the leads are folded up into the case make sure they do not come too close to the I.F. circuits as coupling between the aerial and detector circuits may lead to instability.

To finish off the receiver, add a tuning scale either to the tuning knob itself, if a large diameter knob is fitted, or a paper scale round the knob as described in the last chapter.

And that is that. There are, of course, quite a number of things you could try in this circuit—you could vary the value of R1, try adding a small resistance in series with C5 (see the Repanco instructions with the oscillator coil), try various extra amplifying stages after Tr3 and, finally, build a loudspeaker output stage to follow D1 instead of using the present reflex circuit—again, the Repanco instructions give a suitable circuit. So far as this book is concerned, however, it has to be Goodbye and—

GOOD LISTENING!

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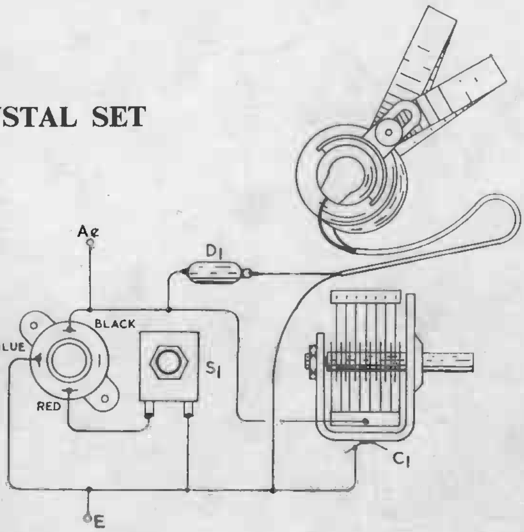

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