THE PROJECT CLUB

Build your own Transistor Radio

PROJECT BOOK 148

RADIO

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RADIO

THE PROJECT CLUB

PROJECT BOOK 148

Build your own Transistor Radio

By R. H. Warring

Illustrated by Peter Loates

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FOR THE DAIRY INDUSTRY

The fact that you have joined The Project Club means that you already have a responsible attitude towards your everyday activities, and that you will read and carry out the project instructions carefully. This will enable you to get the most out of this book and ensure the safety of yourself and others.

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For many years the Dairy Industry has been helping young bodies to grow healthy and strong on milk—one of the most natural and valuable foods we have. With The Project Club it is branching out: young minds will be stimulated by this series of books, each written by an expert in his field. Project Club members not only learn useful techniques and facts, they build up a reserve of information which will be useful to them in later life—whatever they decide to do. Just as a daily 'pinta' is an unbeatable way of feeding your body, and laying the foundations for a healthy life in the future, so the Club provides projects for members which can be the basis for a career or a lifelong interest.

PART ONE

Learning about transistor radios

The first radio receivers for home listening were crystal sets, using a special type of crystal material which could detect radio signals sent out by a broadcast station. They were very crude, difficult to get working at all and only the faintest of sounds could usually be heard in the earphones.

Crystal sets are still made and used today, and their performance has been improved a lot. They work better because the components are so much better than they were 40 or 50 years ago. The crystal set is an important type of radio because many of the simpler designs of radio are nothing more than crystal sets with added components to make the sound louder—loud enough in most cases to be heard through a loudspeaker instead of having to listen with earphones.

These extra components are based around *valves*, or 'tubes' as the Americans call them, which are rather like an electric light bulb but very much more complicated. Instead of just heating up and glowing, they have other parts which take an electric signal and magnify it, or sort it out, and finally feed it to the loudspeaker. A whole string of valves is normally used, connected together in a special way with *resistors* and *capacitors* to produce the required result.

In modern sets, transistors usually replace valves. They are very much smaller components, and not so complicated. More transistors are needed to do the same job as a set of valves, but they still take up much less space. Thus transistor sets can be made smaller. They can also be made cheaper, for transistors cost much less than valves.

There is another great advantage that transistors have. They work off a low voltage, whereas a valve requires a high voltage. This means that a transistor radio can work off a small and inexpensive dry battery. Valve radios can also be worked off batteries, but this time they need both a high voltage battery (which is quite expensive) *and* a low voltage battery. It is the high voltage which makes the valve work, and the low voltage which heats up the valve heater element.

Valve circuits are out of date for home-made radios. A transistor radio is cheaper and easier to make, works just as well, and requires only a single 1.5 to 9 volt battery. This battery will last quite a time for a transistor radio uses little current.

A transistor radio cannot be connected to the mains electricity unless it has an extra circuit designed to cut down the mains voltage from 240 volts to about 10 volts or less. Or you can work one through a 'mains converter' which does the same job. Connecting a transistor radio directly to the mains would 'blow' the transistors and ruin the set. All the transistor radios to be described in later parts are battery sets, so never try to connect them to the mains to save your batteries. Making a battery set is also much safer than making a mains set, for you can never get an electric shock from it.

PROJECT

Make a crystal set

The crystal set is interesting for it uses only a few components and really can be made to work. What is more, it does not even need a battery, unless you want to add transistors to increase the volume of the sound. It is a very good starting point for building your own radio receivers, especially if you have not tackled this sort of thing before.

How to make crystal sets—and how they work—is described in Project Book No. 147. To get a better knowledge of radio sets, read this book first and build some of the designs given in it. You will then find it much easier to make some of the more advanced radio sets described in this book.

PART TWO

Learn to solder

To make radio sets properly, you must be able to solder. Connections between radio components are made by soldering their leads to tags or 'bus bars', and sometimes by additional lengths of wire. All these joints must be soldered if they are to make good electrical connection. Wires which are just twisted together may, or may not, produce a good connection. Then the set will not work. In fact, 99 times out of a hundred if a home-made radio, built to a proper design, does not work, the cause is either:

(i) a component has been connected up wrongly.

(ii) the connections are badly made.

You can easily trace (i) by checking the connections. It is a lot more difficult to find out which connection is causing the second kind of fault. But this fault will not occur at all if all the connections are properly soldered.

PROJECT

Get your equipment

Teach yourself to solder before you start to assemble your first set. This is what you need:

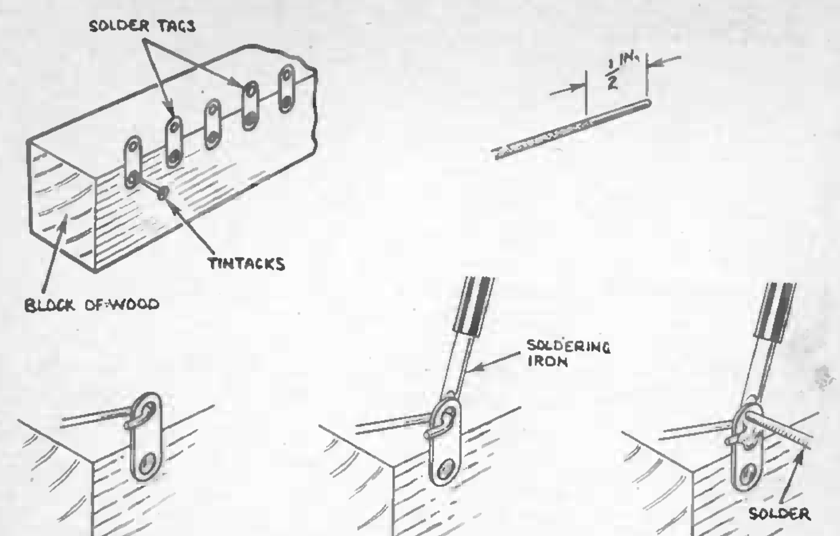


Fig. 1

(i) A 30 or 40 watt electric soldering iron with a $\frac{1}{8}$ in. or $\frac{3}{16}$ in. diameter bit.

(ii) Some electrical quality cored solder. This looks like soft silvery wire, about $\frac{1}{16}$ in. diameter, and is sold in coils (on a spool or in a card box); or in shorter lengths wrapped round a card.

(iii) A small piece of emery paper.

(iv) A dozen or so solder tags.

(v) A dozen tin tacks.

(vi) A block of wood about 2 in. square and 9 to 12 in. long.

(vii) A few feet of 16 gauge enamelled copper wire, or some old radio components (resistors or capacitors).

Mount the solder tags in line along one edge of the block of wood, as shown in *fig. 1*, using tin tacks. Cut off a 6 in. length of wire and clean the enamel off the last $\frac{1}{2}$ in. with the emery paper until bright copper metal shows. If the solder tag looks dirty, clean that as well with the emery paper. Push the bared end of the wire through the hole in the tag and bend back.

Plug in the electric iron and leave it to heat up—making sure that the bit is not touching the table or anything else it could burn. You can tell when the iron is hot enough by touching the tip with the end of the solder. If the solder does not melt, or melts only slowly, the iron is not hot enough. When properly hot the solder should melt and run over the tip immediately.

Now place the tip of the iron behind the solder tag, pressing lightly in place. Count 'one-two', then place the tip of the solder on the other side of the tag. The solder should melt and run evenly over the tag covering the bare wire. Remove the iron and blow on the joint to cool it. If the joint looks bright and even all over, with a good 'flow' of solder, the joint is a good one.

There are really only two things which can go wrong, and it is easy to find out why.

(i) If the solder is slow to melt when pressed on the tag, *the iron is not hot enough*. You have not left it switched on long enough to heat up. You may be able to complete a joint, but the solder will look rough and white instead of spreading evenly. This 'dry joint' is usually a bad electrical connection.

(ii) The solder melts but collects in small blobs, or runs off the tag. This is because the tag is dirty and needs cleaning. Solder will not stick to dirty or greasy surfaces. The answer is simple. Make sure that both tag and wire are bright clean before you try to solder.

You will probably have discovered one other 'fault'. The wire gets too hot to hold by the time you have completed the joint. A good soldered joint should be completed quickly (in a second or so), and then cooled by blowing on it. Leaving the iron in

place too long could conduct so much heat back up the wire that a component connected to it could be damaged.

PROJECT

Keep practising

Having learnt that lesson you can hold the wire in place with pliers next time. Practise soldering wires to all the tags until you can get a good joint every time. If you run out of tags, simply unsolder the wires and start again. To do this, hold the iron against the tag until the solder has softened and pull the wire out. If solder is left filling the hole in the tag, blow this out while the solder is still molten.

Time how long it takes to make a good soldered joint, counting 'one-two-three-etc.'. When you get down to 'one-two-three' and each joint is a good one, you can reckon that you can solder well enough to build any radio set.

PART THREE

Identifying radio components

Here is a list of components used in the construction of transistor radio sets: aerial coils; resistors; capacitors; variable capacitors (tuning controls); variable resistors or potentiometers (volume controls); diodes; earphones or earpieces; loudspeakers. Plus, of course, transistors which will be described separately in Part Four. In addition, to assemble the set we need a suitable base material (usually Paxolin sheet), solder tags, tinned copper wire, and other small parts as described later.

PROJECT

Make your aerial coils

These are wound from fine insulated wire on ferrite rods or slabs, and look like *fig. 2*. They can be bought ready-made in various sizes, or you can wind your own coils on ferrite rod or ferrite slab. Bought coils are usually more efficient for they are machine wound in a special way. However, home-made coils work nearly as well, and we will use these for most of the sets described later.

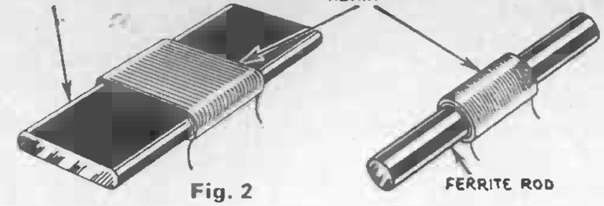


Fig. 2

Resistors

Resistors have a cylindrical body, usually ceramic, with a wire sticking out at each end (*see fig. 3*). They have different *values* from 1 ohm or less up to about 22 million ohms. The values do not go up in tens but in a series like this
10 12 15 18 22 27 33 39 47 56 68 82
100 120 150 180 220 330 390 470 560 680
820 and 1000.

A value of 1000 ohms would be written as 1 kilohm, or 1 KΩ. The next largest value would be 1.2KΩ, then 1.5KΩ, and so on, following the same series as above, up to 1000KΩ.

A value of 1000KΩ would be written as 1 megohm or 1MΩ. The next largest value would be 1.2MΩ, then 1.5MΩ, and so on.

The value of the resistor does not determine its *size*. The size is the same for a resistor with a value of several megohms as it

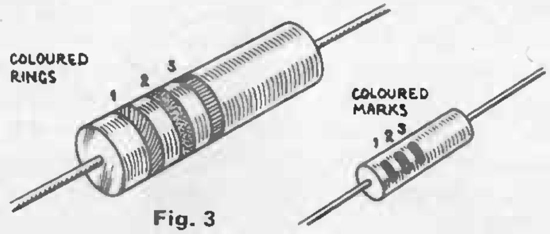


Fig. 3

is for one with a value of only 10 ohms, if the resistor is the same *type* or *rating*. The type we use for transistor radios is a *miniature resistor* with a rating of $\frac{1}{4}$ watt. Even smaller resistors, known as *sub-miniatures* can be used. A miniature ($\frac{1}{4}$ watt) resistor is about $\frac{1}{2}$ in. long by $\frac{3}{16}$ in. diameter. A sub-miniature type is about $\frac{3}{8}$ in. long by $\frac{3}{32}$ in. diameter. Much larger resistors may be used in valve sets, but they are too bulky for transistor sets.

Can you see why resistors for valve sets have to be larger in size for the same value? Because valve sets work on higher voltages the resistors have to have a higher *rating*. It is the rating which determines the dimensions.

PROJECT

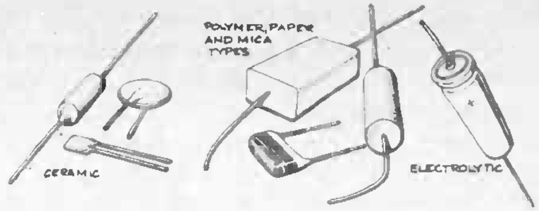
Learn the colour code

The value of a resistor is never marked on it. Instead the resistor has three coloured bands marked around the body near one end (or coloured streaks in the case of some sub-miniature types)—*see fig. 3* again. These rings provide a colour code by which you can tell value of the resistor. If a number of resistors are mixed up in the same packet they will look the same. The only way of finding out their values is to use the colour code.

The colour code works like this. Reading from the end of the body: *The first* colour gives the first number of the resistance value; *the second* colour gives the second number of the resistance value; *the third* colour gives the number of noughts to put after the first two numbers. Here are the colours and the numbers they stand for:

BLACK	0 or nil	GREEN	5
BROWN	1	BLUE	6
RED	2	VIOLET	7
ORANGE	3	GREY	8
YELLOW	4	WHITE	9

Fig. 4



Now let us see how it works. Suppose the three coloured rings were brown, blue and orange.

Brown gives the first number = 1

Blue gives the second number = 6

Orange gives the number of noughts to add = 3 or 000.

The value of the resistor must be

1 6 000

or 16,000 ohms or 16 kilohms.

PROJECT

Make your own table

Use the colour code to write out a complete list of colour rings for resistors from, say 100 ohms up to 22 kilohms. This will cover all the values we are likely to use. You can then identify any resistor quickly from this list instead of having to work out the colour code each time.

Capacitors

Capacitors are made in various types, like those shown in *fig.* 4. This time the value is usually marked on the capacitor itself, so we do not have to work it out. However capacitor values are given in microfarads (millionths of a farad); or picofarads (millionths of a millionth of a farad). To save writing this out, or using a lot of noughts, the value is given by a number followed by pF for picofarads, or µF for microfarads.

Unlike resistors, capacitors *do* vary in size according to their values. This is because the construction has to be different for higher values. Ceramic capacitors, and mica types, are both quite small in size and only suitable for small capacity values. Paper types, which are larger, range from small to fairly high values. For larger values, the electrolytic type of capacitor is the only suitable form of construction. This looks like a paper capacitor but has an aluminium body.

There is also one other important difference with an *electrolytic capacitor*. One end is marked positive or + and it *must always be connected the right way round in a circuit*—positive side connecting to the positive side of the battery. It does not matter which way round you connect other types of capacitors, or resistors.

Variable capacitors

These are capacitors where the value can be altered so as to adjust the tuning of a circuit. *Fig. 5* shows two main types.

The *vane type* is usually quite large and is adjusted by a knob turning a spindle. This opens out or closes a set of vanes spaced

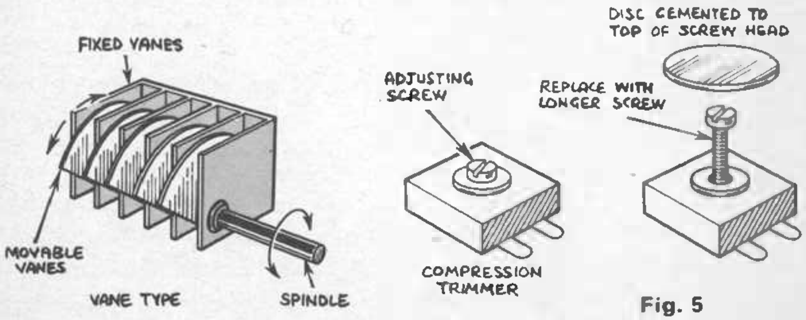


Fig. 5

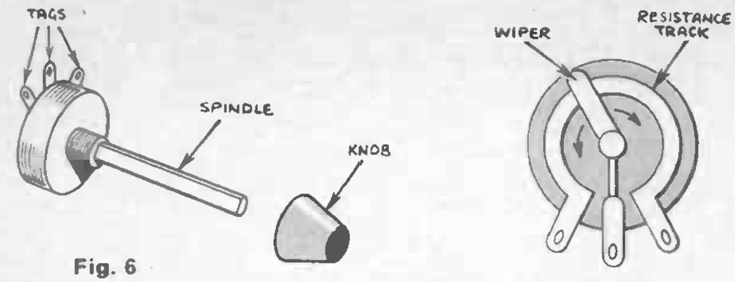


Fig. 6

between a series of fixed vanes. The *compression trimmer* is much smaller, about the size of a postage stamp, and it is adjusted by turning the screw in the centre.

Although miniature vane type variable capacitors are available, many small transistor sets use a compression trimmer instead, which is quite cheap. To make this type of capacitor easier to adjust the centre screw should be removed and replaced with a longer one having the same thread. The thread is almost always 6BA size. The longer screw can be fitted with a knob or small disc, as shown, to make the capacitor easy to adjust. The usual values of variable capacitors used for tuning transistor radios is 0–250 pF or 0–500 pF.

Variable resistors (potentiometers)

A potentiometer has a circular metal case with a spindle sticking out of its centre, and three small tags on the back for making connections—*fig. 6*. It works like this:

Tag 1 is connected to tag 3 by a circular strip of resistance material inside the body. Tag 2 connects to a wiper resting on this strip, and its position can be altered by turning the spindle. Thus if connections are made to tags 1 and 2 and the wiper is turned as far to the left as possible, any current flowing will

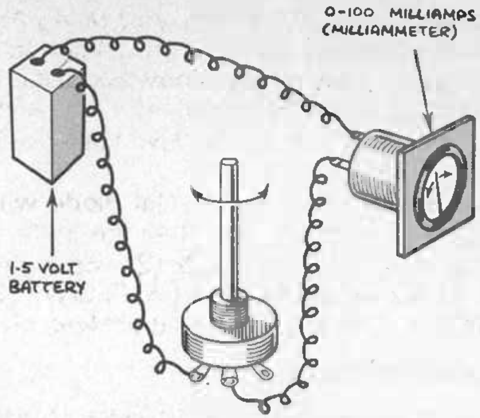


Fig. 7

enter via tag 1 and then straight out again through the wiper and tag 2. Turning the spindle to the right means that the in-and-out path now includes a length of the resistance track, which will reduce the current flow. The further the wiper is turned to the right the more resistance is in circuit.

You can check this working by connecting a potentiometer to a milliammeter and a 1.5 volt battery, as shown in *fig. 7*. See how the reading on the milliammeter falls as the spindle is turned one way (resistance increasing); and rises when the spindle is turned the other way (resistance decreasing).

This property of varying the current flowing through it means that a potentiometer can be used as a volume control in a radio set. That, in fact, is all that the volume control is on any radio or television set—just a potentiometer.

Diodes

A diode is a little glass envelope with a thin wire sticking out of each end for making connections (*See fig. 8*). Inside is a

special crystal which has the property of being able to detect radio signals—the working part of a crystal set, in fact.

The only thing you really need to know about it is that it works only one way round. One end is marked +, or painted red. This end is the one which assumes a positive voltage in a rectifying circuit.

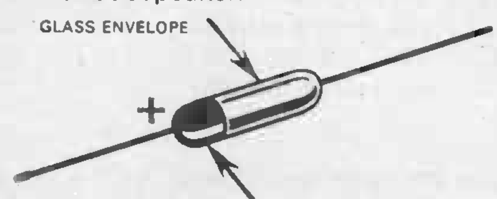
Almost any type of miniature crystal diode will work as a detector in a transistor radio, and they are quite cheap components—about 10p (2s.) to 12½p (2s. 6d.) each. Suitable type numbers to ask for are Mullard 0A70, 0A79, 0A81, 0A90, 0A91, GEC GEX34, BTH CG IOE, or equivalent.

Earphones and earpieces

Earphones or earpieces are used to listen to sets which do not have enough power to operate a loudspeaker (*See fig. 9*). You can, of course, also use an earpiece to plug into a loudspeaker set for 'personal listening', in which case the power of the set must be reduced. This can be done by turning the volume control down; or automatically by building in an extra resistance in the earpiece connection.

Headphones are most useful with crystal sets where the volume is low as they block out other sounds around you. An earpiece, which is plugged into one ear, is much neater to use with transistor sets which have more power, but still not enough power to operate a loudspeaker.

Fig. 8



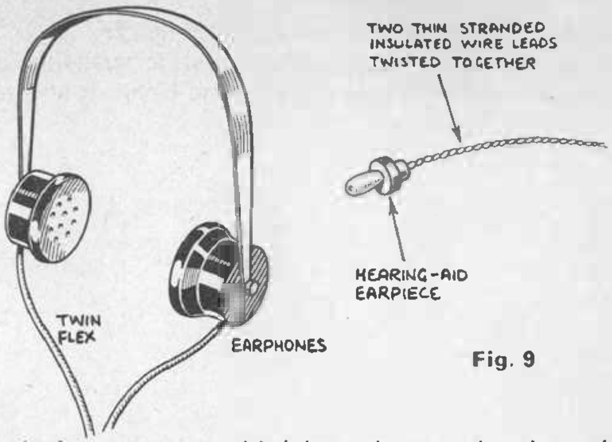


Fig. 9

Either come in two types—*high impedance* or *low impedance*. High impedance earphones or ear pieces are always used on simpler circuits.

PROJECT

Buying a loudspeaker

The bigger the loudspeaker is the more power it needs to drive it, but the better the quality of the sound will be. That puts transistor sets at a disadvantage. They do not develop enough power to drive a large loudspeaker, unless a lot of additional components are added. Also a large loudspeaker looks odd if used with a small set.

The largest size of speaker used with the simpler transistor radios is about 3 in. There are smaller ones, but their performance will not be as good. Also the impedance or resistance of the speaker must match the set. The two important points in buying a loudspeaker for a transistor set are, therefore:

(i) Make sure that it is the correct 'match'.

(ii) Buy the most expensive miniature speaker of this value you can afford. The more it costs, the better it should perform.

PART FOUR

Learning about transistors

The types of transistors used in simple radio receivers are of the size and shape shown in *fig. 10*. The only identification is the make and type number marked on the side (usually), and three thin wires emerging from one end (actually the bottom of the transistor). These connect to the three elements inside the transistor and *it is very important to be able to identify them correctly*. If a transistor is connected up wrongly, it will probably be ruined.

The three elements are the *base* (b) the *emitter* (e) and the *collector* (c). The collector wire (c) is identified by a paint spot marked on the body of the transistor. Having found the collector lead, the other wires can then be identified from *fig. 10*.

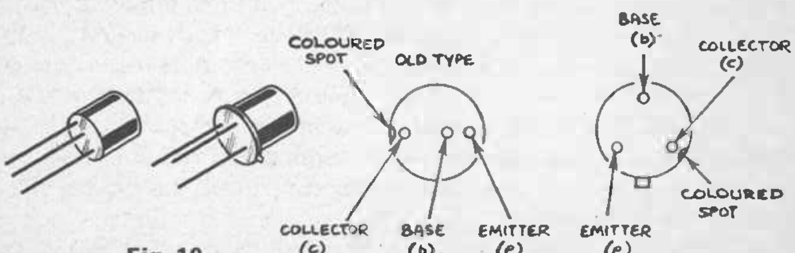


Fig. 10

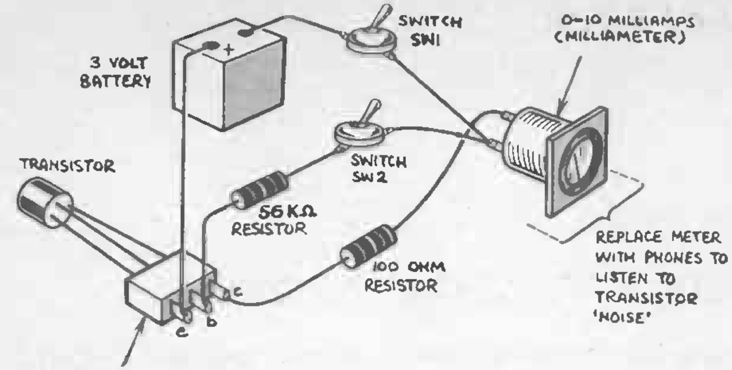


Fig. 11

There are in fact two types of transistor: PNP and NPN. However, all the circuits in this book use PNP types.

PROJECT

Test your transistors

Fig. 11 shows a simple circuit for testing PNP transistors. It could be used for NPN types simply by reversing the battery connections. Using a transistor holder, various transistors can be plugged in and easily removed. Start with both switches off. Now switch on SW1: a very small reading should be obtained on the meter. Now switch on SW2: a much larger reading should be obtained. This larger reading gives an idea of the 'gain' of the transistor: the higher the reading the higher the 'gain'. A very low reading, less than 1 mA say, or no reading at all, would indicate a 'dud' transistor.

If you have a number of transistors, bought cheaply as 'surplus' types, you can select the best ones by testing them in this way. Those with the highest 'gain' will give the best performance in a radio set.

PART FIVE

Learning how to read a circuit diagram

A 'plan' of a radio set is nearly always drawn out using symbols for various components. You must learn these symbols which are shown in *fig. 12*.

The other thing about a circuit 'plan' is that while it shows all the components and how they have to be connected, it is not usually possible to follow it directly as a 'wiring up' diagram.

There are several reasons for this. A circuit plan, or *circuit diagram* as it is usually called, is a theoretical design, drawn in

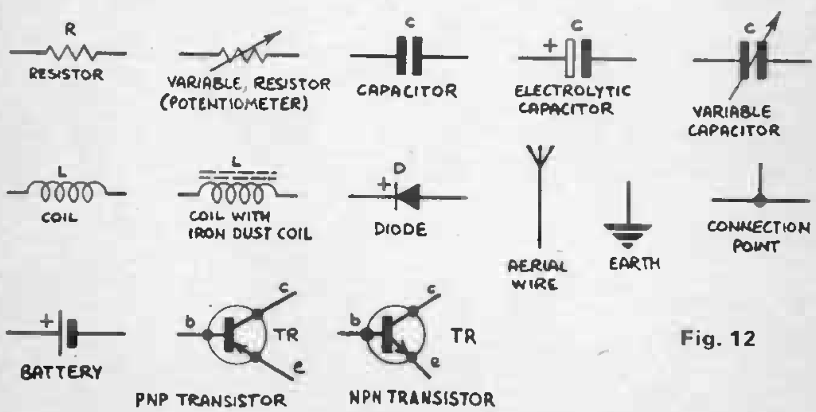


Fig. 12

the simplest possible way to show all the components and where they have to be connected. The same design could be built in several different ways, with the components in different positions, provided all the wiring connections agreed with the circuit diagram. Also when it comes to layout components so that they can be mounted properly on a baseboard, the wiring connections may have to cross each other far more than shown on a circuit diagram. One of the main things with a circuit diagram, in fact, is to avoid crossing connections as much as possible to avoid mistakes in 'reading' the connections required. Also the components are drawn as symbols and not to scale size.

To build a set, therefore, you have to 'translate' the circuit diagram in terms of a practical *wiring diagram*. Sometimes this is done for you—a separate wiring diagram is given in addition to the circuit diagram. Otherwise you have to work it out for yourself. This becomes more difficult the more complicated the circuit is.

The main thing is to try to follow the layout of the circuit diagram as far as possible for the positioning of the components. If necessary spread the components out.

It is also necessary to decide how the components are to be mounted or held in position, and what additional wiring may be necessary to complete the circuit.

PROJECT

Make a plan

Two things you do when starting with a circuit drawing:

(i) Turn it into a *wiring diagram* with a suitable layout and positioning of components.

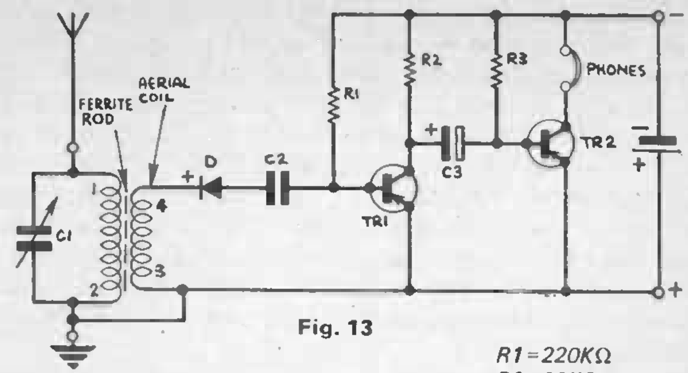


Fig. 13

C1 = 0–500 pF variable capacitor
C2 = 1 μF
C3 = 8μF (electrolytic)
D = diode (OA70 or equivalent)

R1 = 220KΩ
R2 = 22KΩ
R3 = 100KΩ
TR1 and TR2 = Mullard OC71 transistors (or equivalent)
Phones—high impedance type

(ii) Produce a *working plan* for mounting the components in position and provide suitable connecting points for all the soldered connections necessary.

Finally, you might want to fit the set in a cabinet or box. This could have an effect on both (i) and (ii) above, to make the set fit inside the size or shape of cabinet you had in mind.

Starting with a theoretical circuit

Fig. 13 is a theoretical diagram of a two-transistor receiver showing all the components and their connections; and also the values required for the various components. The only thing not specified is the aerial coil 1-2-3-4. Since this is a simple set we will make this instead of buying a ready-made one. The only materials required are a 4 in. length of ferrite rod $\frac{5}{16}$ in. diameter and some 38 gauge double silk and enamelled wire.

PROJECT

Make an aerial coil

Start by winding a paper sleeve around the ferrite rod, using gumstrip. This needs to be only about three or four layers thick, but wind with the gummed side out so that the paper does not stick to the rod (*see fig. 14*). Now wind on 50 turns of the 38 gauge wire, each turn close up against the one before it. Hold the ends of the coil in place with a dab of adhesive or wax and cut the ends of the wires to a length of about 5 in. This is coil 1-2.

Using the same wire, wind a second coil on top of the first, at one end, making it only 16 turns long. Secure the ends of the wire with adhesive and cut off to 5 in. length. This is coil 3-4.

The rest of the components are bought from a radio supply shop (where you get the ferrite rod and the 38 gauge wire).

Since you aim to make the wiring layout follow the circuit diagram, you will need a base panel 4 in. wide to take the components, with the ferrite rod at one end. Assuming that a suitable length for the panel would be 6 in. see how the components fit this space.

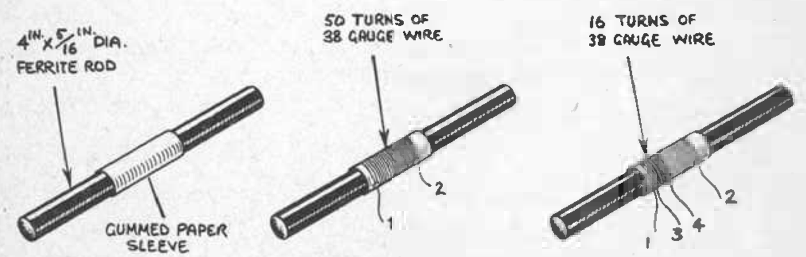


Fig. 14

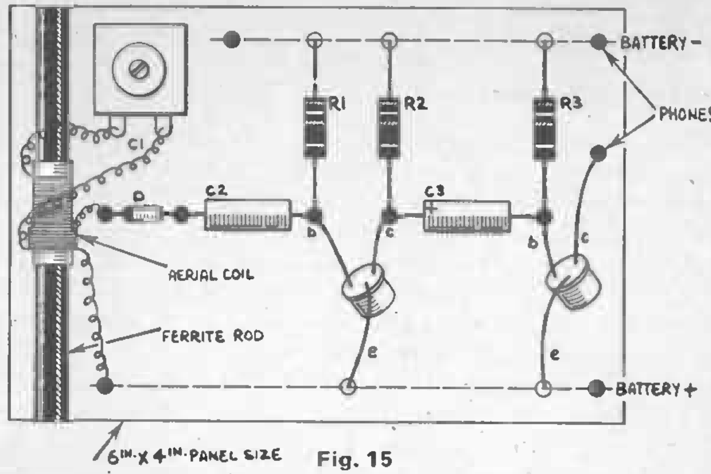


Fig. 15

PROJECT

Draw the wiring layout

Draw a 6 in. × 4 in. rectangle on paper. Lay the aerial coil on its ferrite rod at one end, and then the other component in roughly the same position as in the circuit diagram (*see fig. 15*). The odd component out is the variable capacitor (C1), but we can place this at the top, as shown. There will be space for it here and it will be in an easy position to connect to coil 1-2.

Now draw circles where all the connecting points come. These would be logical positions for fixing a solder tag to the panel. But we can save a bit of work. Five of the circles at the top come in one line and all have to be connected together. We could use one solder tag at each end and solder a bare wire between them. The other three connections could then be made to this wire, saving three tags. Black in only the end two connecting

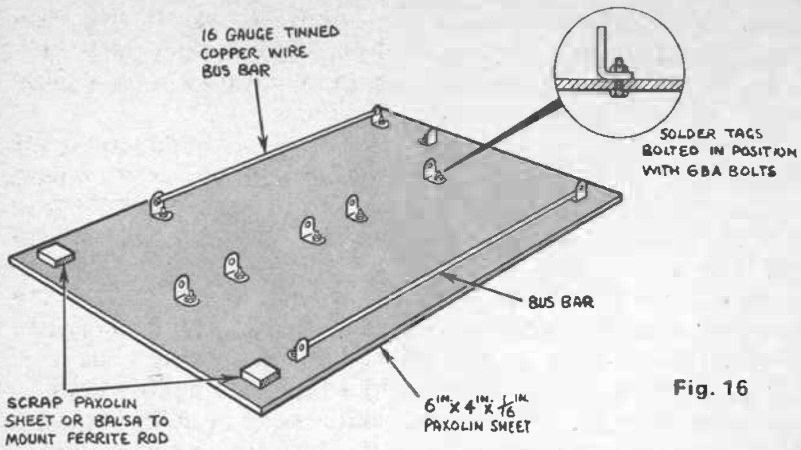


Fig. 16

points to mark as solder tag positions.

The same happens at the bottom. A solder tag is needed at each end, connected by a length of bare wire. Black the two end circles in for solder tag positions.

We cannot save on any of the other positions, so black all these in to show the further solder tag positions required—a total of ten in all. This completes our wiring-up plan.

PROJECT

Make the set

Fig. 16 shows the panel cut to size, marked out and drilled to take the ten solder tags. Each tag is then bolted in position using a 6BA brass bolt and nut. The bare wire connections between the two tags at the top, and the two at the bottom, is made from lengths of 16 gauge tinned copper wire soldered in place. The ferrite rod can be mounted on blocks cut from

scrap Paxolin sheet, or balsa. Glue these blocks to the main panel, and then glue the rod on top, using Araldite or Bostik. The variable capacitor (compression trimmer type) can also be stuck to the panel with Araldite by its base.

Scrape about $\frac{1}{4}$ in. bare on each of the four aerial coil leads bare of insulation. Solder 1 and 2 to the two tags of the tuning capacitor C1. Coil lead 3 is soldered to the bottom copper wire 'bus bar'. Lead 4 is soldered to the first of the middle line of solder tags.

Do not cut these wires short, but leave enough slack for the aerial coil to be slid up and down the ferrite rod. This is necessary to adjust the position of the aerial coil for best results.

To complete the wiring up, solder the other components in place, one by one, between the solder tags, or solder tag and bus bar, as shown. The battery connects to the two end tags, as shown in *fig. 17*, and the phones (a high impedance deaf aid earpiece should be used) to the top (negative) battery connection and the tag to which the collector of TR2 is connected.

To get the set to work well, you may also need an aerial and earth. The aerial can be a length of any thin wire—the longer the better—which can be spread out around the room. The earth is another length of wire connecting to a water pipe. Make sure that the pipe is scraped clean and the wire is properly connected to bare metal.

You should be able to work out from the circuit diagram where to connect the aerial and earth wires. The aerial wire connects to the tag on C1 connected to 1 on the aerial coil; and the earth to the other tag on C1. It does not really matter which way round these two wires are connected.

Try to get your set working without external aerial and earth connections if you can. It is so much more convenient not having these extra wires attached. Remember, if the signal is

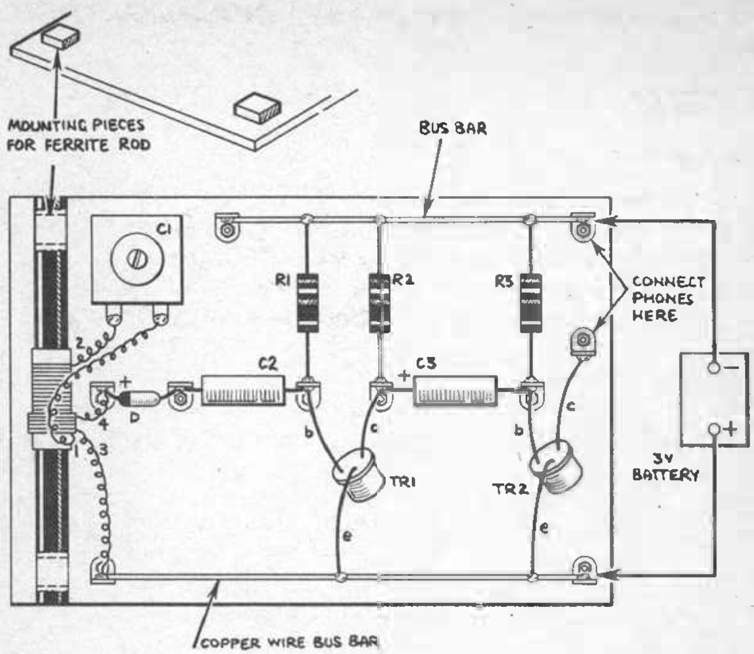


Fig. 17

heard only weakly it may be that the ferrite rod is pointing in the wrong direction. This type of aerial is very 'directional', so turn the set round and see if the signal gets stronger. There will be a different 'best' position for the set to hear each station.

You will probably find, too, that you can hear *more* stations if you slide the aerial coil up and down the ferrite rod. Find the position which gives the most stations over the full range of the tuning control. Glue the coil to the rod in this position.

NOTE: Do not solder with the battery on—the transistors may 'burn out'.

PROJECT

Make a cabinet

You can now make a simple cabinet to take the 'works' complete with battery. In this case, connect a switch in one of the battery leads to switch the set on and off. However, before you think of finishing off the set in this way, we can improve on this circuit and get better results, as described in the next part.

PART SIX

How to make a more advanced receiver

Although the circuit described in Part Five works quite well it is limited to a battery voltage of about 3 volts. If a higher voltage battery is used there is a danger of the transistors becoming 'thermally unstable' and possibly damaging themselves. That is one of the peculiar things about transistors. As they pass current they get slightly warm, which tends to make the current passing through them increase. This means more heating and a still higher current flow, until in the end the current value may become so high that the transistor burns itself out. This is called 'thermal instability'.

To prevent this, additional components are required to cancel out heating effects and make the transistor operate at a constant current. Instead of connecting the emitter lead of the transistor direct to the + battery side of the circuit it is connected through a capacitor and resistor in parallel. Also another resistor is added on the base side of the transistor between the base and + battery side. This treatment has to be applied to each transistor to produce a 'stabilised' circuit.

Fig. 18 shows a circuit design with this feature—really the same as the circuit described in Part Five, but with additional components to stabilise the two transistors. This has also called for some changes in component values.

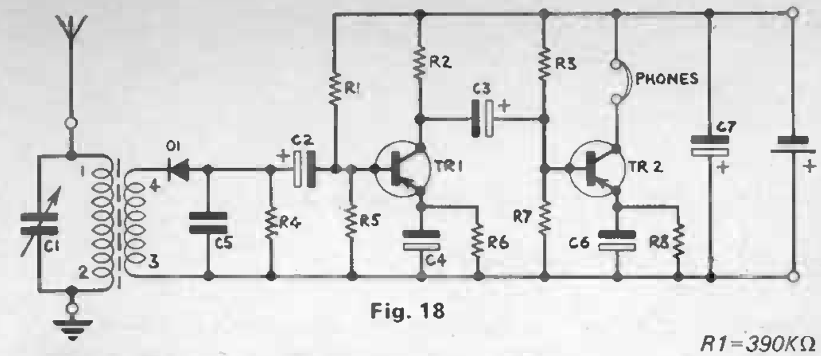


Fig. 18

C1=0–500 pF variable capacitor
C2=8μF
C3=8μF
C4=8μF
C5=.001μF
C6=8μF
C7=30μF

TR1 and TR2=Mullard OC 71 (or equivalent)

D=diode (OA70 or equivalent)

R1=390KΩ
R2=3.3KΩ
R3=390KΩ
R4=2.2KΩ
R5=47KΩ
R6=470Ω
R7=47KΩ
R8=470Ω

At the same time some further components have been added to improve the performance of the whole circuit—a capacitor and resistor (C5 and R4) between the negative side of the diode and positive battery side, and a capacitor (C7) across the battery input.

These additional components will all fit in on the same base panel as *fig. 15*. All we need is two additional solder tags mounted on the panel, as shown shaded in *fig. 19*. You can make this modification to the set already built in Part Five, or start again with a new panel.

If you are going to modify the first set (Part Five) capacitor C2 and resistors R1, R2 and R3 must all be removed because they are of different value in this new circuit.

Fig. 19 shows all the components in position for the new

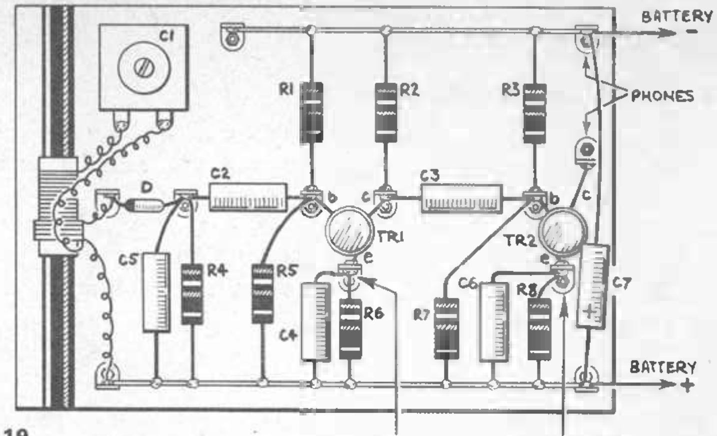


Fig. 19

TWO ADDITIONAL SOLDER TAGS

circuit. The transistor emitter leads are now connected to the additional solder tags fitted. There is plenty of room to fit in all the additional components required. The advantage of using a 'bus bar' for a common connection at the bottom of the circuit is obvious. No fewer than nine connections are soldered to this bus bar, making a common connection to battery positive.

This time a higher voltage battery can be used (up to 9 volts) and this should further improve the performance of the set. You should be able to tune in to more stations, and hear the nearest or more powerful stations quite loudly. Unless you live in an area where radio reception is very poor, you should be able to get at least half a dozen stations quite easily without using an external aerial and earth.

Remember the trick of sliding the aerial coil up and down the ferrite rod to find the best position for reception. Do this again to adjust the set. Here are some further adjustments and experiments you can make with this circuit.

PROJECT

Change the aerial coil

Unsolder the aerial coil connections and remove the ferrite rod and coil. Replace with a professionally made coil assembly of similar size. Make sure that the coil you buy matches the value of the variable capacitor C1. If not, you will have to change this capacitor as well. A bought aerial coil should be more efficient than the one you have made, so you should get better results.

PROJECT

Try altering component values

Try disconnecting C5 and R4. The set may, or may not, work better without these in the circuit. If there is no improvement, or the result is worse, replace C5. Remove R4 entirely and try other resistors of different value in its place. Since transistors can vary quite a bit, you should be able to find a value which will give the best performance with the transistors you are using.

Try disconnecting C7. Does this make any difference?

PROJECT

Fitting a volume control

Remove resistor R4 entirely and disconnect the lead on C2 which went to the same tag. Fit a small 10 kilohm potentiometer on the panel in the space between C5 and R5 and connect up as shown in *fig. 20*. Note that the potentiometer 'breaks' the circuit at this point, the lead you disconnected on C2 now being joined to the centre tag of the potentiometer.

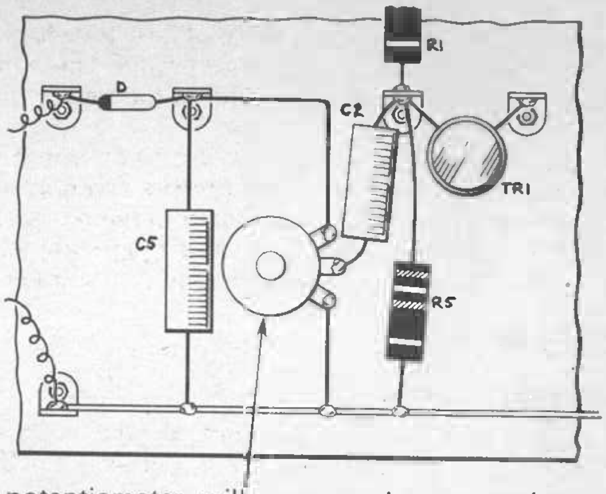


Fig. 20

This potentiometer will now work as a *volume control.* Turning the spindle one way will increase the sound level in the phones, and turning it the other way will decrease the level.

PROJECT

Fitting a loudspeaker

Using a 9 volt battery, this set should have enough power to drive a miniature loudspeaker. You cannot connect a loudspeaker directly in place of the phones, however, as most such speakers are of *low resistance* type which will not 'match' the circuit. So you will need one additional component as well as the loudspeaker—a 9:1 ratio miniature *output transformer.* The loudspeaker should be of 3 to 8 ohms resistance.

Mount the transformer on the panel alongside R3 and connect the input terminals to the points where the phones were connected (*see fig. 21*). Connect the two tags on the loud-

speaker coil to the output terminals of the transformer. You should then have a working loudspeaker radio. The transformer must be connected the right way round or the transistor may be damaged.

There *is* one type of loudspeaker which you could connect directly to the circuit in place of the phones (without using an output transformer). This is known as a *moving iron speaker.* Speakers of this type do not appear to be made nowadays, but you can still find them from time to time on the 'surplus' market.

PROJECT

Fitting a tone control

We can add one further refinement to your radio—a tone control. This requires two more components—a 10 kilohm

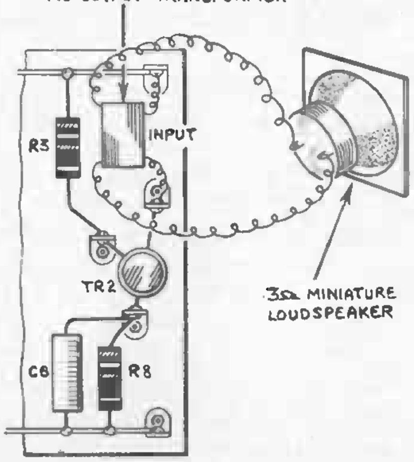


Fig. 21

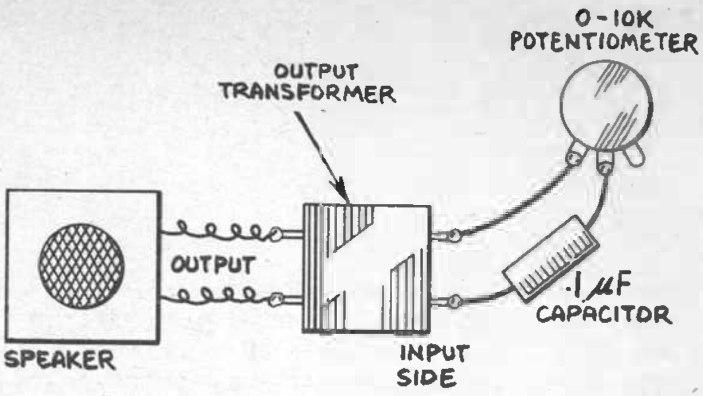


Fig. 22

potentiometer and a 0.1 μF capacitor connected in series across the input terminals of the output transformer, as shown in *fig. 22*. There should be room to mount the potentiometer on the panel between R2 and R3. Capacitor C7 can be disconnected.

Turning the spindle of this potentiometer will vary the tone heard from the loudspeaker. With both volume and tone controls your set has as many controls as most radios.

PART SEVEN

Try a trick circuit

The performance of a simple transistor radio can be improved by a bit of electronic 'trickery' which makes part of the circuit do two jobs. This can have the same effect as adding another transistor stage, but without using any additional components. Apart from saving on the number of components used, the great advantage of this is that it enables you to build a miniature receiver small enough to fit into a cabinet no larger than a cigarette pack (or a bit larger if a speaker is fitted as well).

Fig. 23 is a circuit diagram of such a set which, although it uses only one transistor, has the performance of a two-transistor set. The aerial coil is the same as before, only this time the ferrite rod should be cut down to $3\frac{1}{2}$ in. long. To do this, file a nick around the 4 in. long rod $\frac{1}{2}$ in. in from one end and break off. The rest of the components are bought, except for L1 and L2. These are special coils or chokes which are quite easy to make, as shown in *fig. 24*.

PROJECT

Make your own coil

Buy two $\frac{1}{4}$ in. diameter polystyrene coil formers. Cut two $\frac{5}{8}$ in. diameter circles from stout card or very thin ply and pierce a $\frac{1}{4}$ in. diameter hole in the centre of each. Cement these two pieces on

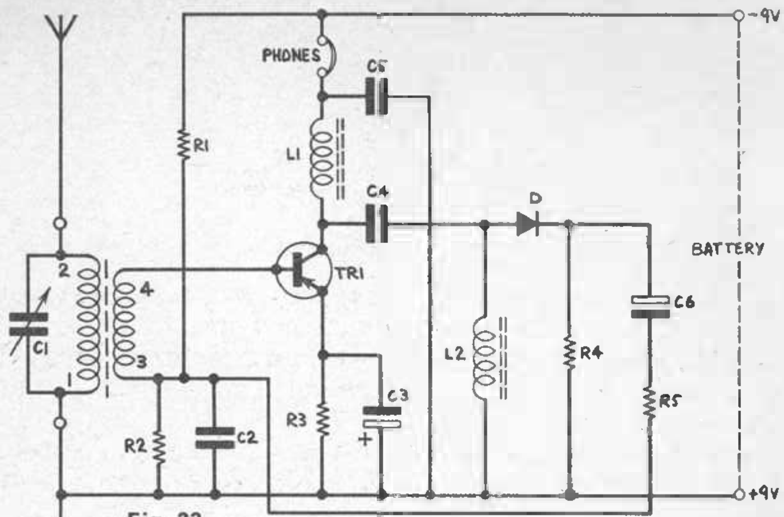


Fig. 23

R1=22KΩ
R2=4.7KΩ
R3=3.3KΩ
R4=22KΩ
R5=1KΩ

C1=0–500 pF
C2=.01 μF
C3=32μF

TR=Mullard OC44, OC45, or equivalent

C4=47 pF
C5=.005 μF
C6=10μF
D=diode (0A70 or equivalent)

to the polystyrene coil former, $\frac{3}{16}$ in. apart, as shown. Now wind 38 gauge double silk and enamelled wire (similar wire as you used for winding the aerial coil) on the 'bobbin' you have made until the space is completely filled up. Secure the ends of the windings to the sides of the bobbin, leaving about 2 in. free length for making connections.

Cut a panel $3\frac{1}{2}$ in. × $2\frac{3}{4}$ in. from $\frac{1}{16}$ in. sheet Paxolin for the base. Mark out and drill as shown in *fig. 25*. This time use small spring clips (or plastic clips) for holding the ferrite rod in place,

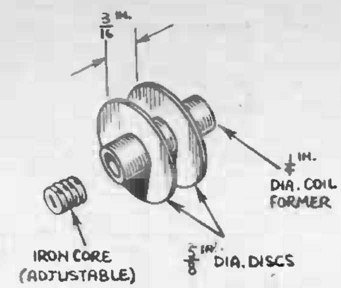


Fig. 24

fastened to the panel with 6 BA bolts and nuts. Mount the seven solder tags with 6 BA bolts and nuts and solder the two bus bars of 16 gauge tinned copper wire in place, as shown in *fig. 26*. The variable capacitor C1 is also mounted on the panel at this stage, where shown.

Adding the various components is quite straightforward, following the circuit diagram (*see fig. 23*). *Fig. 27* shows all the

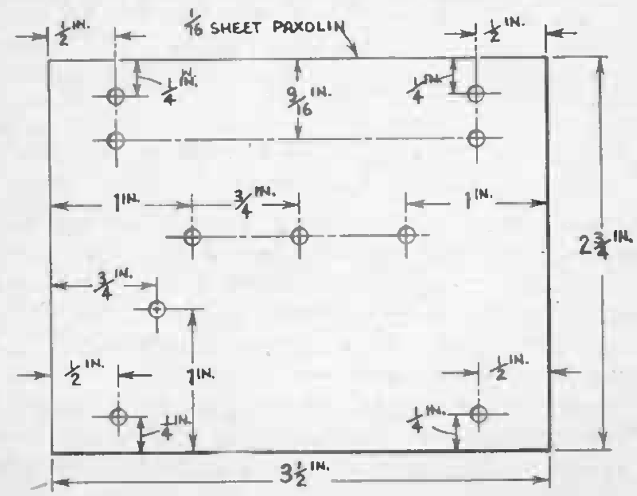


Fig. 25

components soldered in place. You can follow this instead of the circuit diagram, if you prefer.

The phones are a high impedance deaf aid earpiece, with the leads soldered to the top bus bar and one side of the choke LI, as shown. You can also solder battery leads to the top and bottom bus bars, soldering the other ends of these leads to a battery connector to fit a PP3. The battery can then be plugged into the circuit. Make sure that you get the battery leads wired up with the correct polarity as if the battery is the wrong way round it will damage the transistor.

PROJECT

Make a cabinet

A small cabinet about $4\frac{1}{2}$ in. long by $3\frac{1}{4}$ in. wide and 1 in. deep, made in the form of a box from $\frac{1}{4}$ in. sheet balsa, will be big enough to house both the radio panel and the battery. Remove the screw in the centre of the tuning capacitor CI before fitting the lid. Make a hole in the lid immediately above the centre of CI

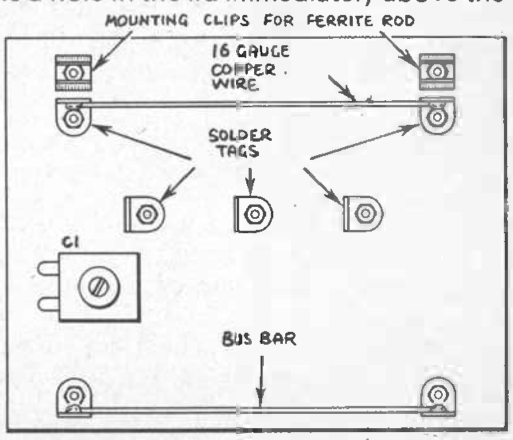


Fig. 26

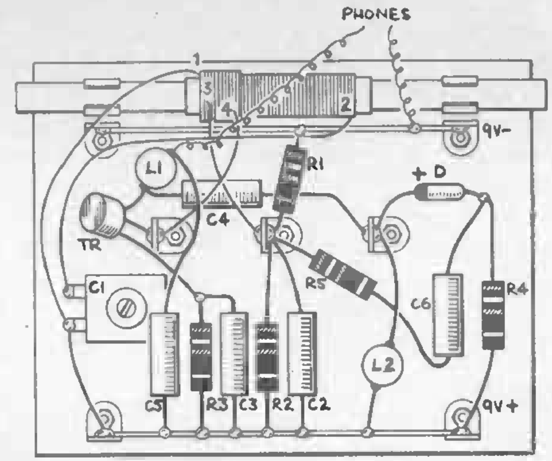


Fig. 27

and replace the screw in CI, making sure that it is long enough to project at least $\frac{1}{4}$ in. above the top. Cement a disc on to the head of the screw to act as a tuning knob. The earpiece leads can be led out through a slot in the side of the cabinet. Finally fit a switch at the battery end of the cabinet, cut one of the battery leads and connect to the switch terminals for switching the battery on and off. You now have a miniature receiver which you can carry round in your pocket.

PROJECT

Adjust the receiver

Tune in to a fairly loud station. Now turn the set so that the sound level falls off, but you can still hear it comfortably. Using an insulated screwdriver, adjust the core positions in coils L1 and L2, turning one way and then the other until the sound is a maximum again. Adjustment of L1 will affect adjustment of L2, so you may have to repeat this operation to get it right.

PART EIGHT

A higher powered receiver

To get more power from the design described in Part Seven a second transistor must be added to provide another stage of *amplification*. The theoretical diagram for this circuit is shown in *fig. 28*. You will notice that this is the same circuit as before with TR2 added together with resistors and a capacitor to provide *stable* working (the reason for this is in Part Six).

Use the same size panel, and layout as *fig. 29*. This layout is the same as *fig. 25* with two more solder tags to take TR2.

The components will be a little more crowded this time, but will all fit in as shown in *fig. 30*. Instead of following this diagram for soldering the components in place, try to work from the circuit diagram (*fig. 28*) as this will give you practice in 'translating' circuit diagrams without having to prepare a component layout diagram. This is what an experienced radio man would do. Having prepared a basic layout from the circuit diagram, he would then work only from the diagram to connect the components in place. There is less chance of making a mistake this way.

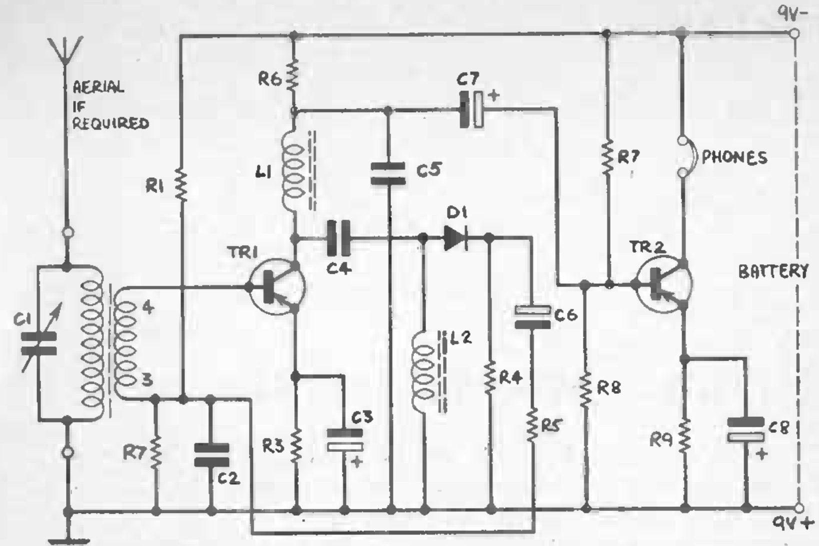


Fig. 28

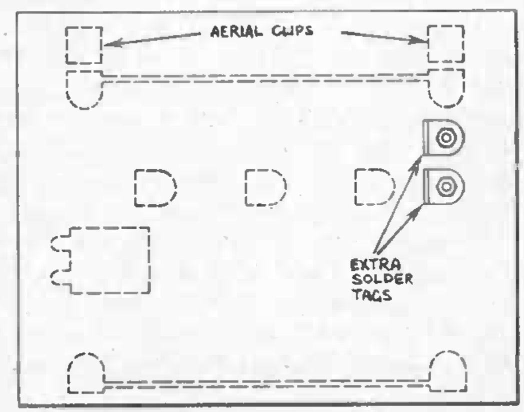


Fig. 29

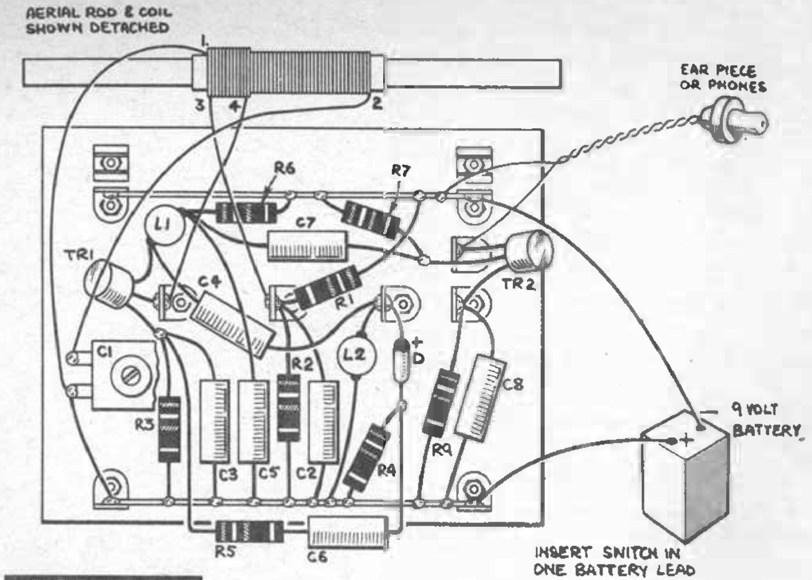


Fig. 30

PROJECT

Watch for mistakes

All radio constructors, however experienced, do make mistakes in wiring up from time to time. A common mistake is to misread a resistor value from its colour code, so that a resistor of the wrong value gets connected into some part of the circuit. As a result the set may work, but not very well—or it may not work at all. Checking the connections will not show where the fault is in this case.

One way of avoiding this is to identify the value of each resistor by its colour code and then mark on the resistor number for the circuit, R1, R2, etc. There is hardly enough room to put this number clearly on the body of the resistor, so mark on a piece of gummed paper which is then stuck to the resistor. You can then pick up the right resistor each time, and tear off the paper before (or after) you have soldered it in place.

The set described in this Part should be powerful enough to work almost anywhere without an external aerial and earth connections. It will be quite 'directional', so it must be turned to get the aerial in the best position for receiving any one station at maximum volume. Turning the set in this way can also be used as a form of *volume control*, making it unnecessary to fit a separate potentiometer as a volume control. If you want a volume control, replace R4 with a 10 kilohm potentiometer.

PROJECT

Loudspeaker working

A balanced armature speaker can be connected in place of the phones to give loudspeaker listening, although the volume will be fairly low. Alternatively you can connect a 3 ohms loudspeaker to the output side of a 9:1 output transformer connected in place of the phones, as described in Chapter Six.

Do not expect too much in the way of loudspeaker performance from a small two-transistor set, though. You will certainly get better listening with a deaf-aid earpiece.

PART NINE

High performance

A circuit diagram of a three-transistor radio receiver of advanced design is shown in *fig. 31*. The performance of this set is equal to that of many domestic radio sets costing a lot more. It has the same sort of 'trick' circuit as used in the designs in parts Seven and Eight, but with the additional transistor stage is capable of working an *80 ohm* loudspeaker direct without using an output transformer.

Here is a full list of components required:

Resistors

R1	50kΩ	linear potentiometer	R8	33kΩ
R2	560kΩ		R9	4.7kΩ
R3	5kΩ	log. potentiometer	R10	1.5kΩ
R4	4.7kΩ		R11	470Ω
R5	150kΩ		R12	680Ω
R6	10kΩ		R13	100Ω
R7	2.2kΩ		R14	10Ω

Capacitors

C1	12pF		C7	10μF/16V	Mullard C426AM/E10
C2	365pF	Jackson type 01	C8	40μF/16V	Mullard C426AM/E40
C3	0.02μF	Mullard C296AA/A22K	C9	100μF/4V	Mullard C426AM/B100
C4	100pF		C10	40μF/16V	Mullard C426AM/E40
C5	10μF/16V	Mullard C426AM/E10	C11	320μF/2.5V	Mullard C426AM/A320
C6	330pF				

Transistors and Diode

TR1 Mullard AF117	TR3 Mullard OC81
TR2 Mullard OC71	D1 Mullard OA70

The aerial coil for this set consists of three windings, L1, L2 and L3, made on a Mullard FX2367 ferrite slab. All the windings are made from 46 gauge double cotton covered wire, but you need two different types of this wire—one 12 strand, and the other 3 strand.

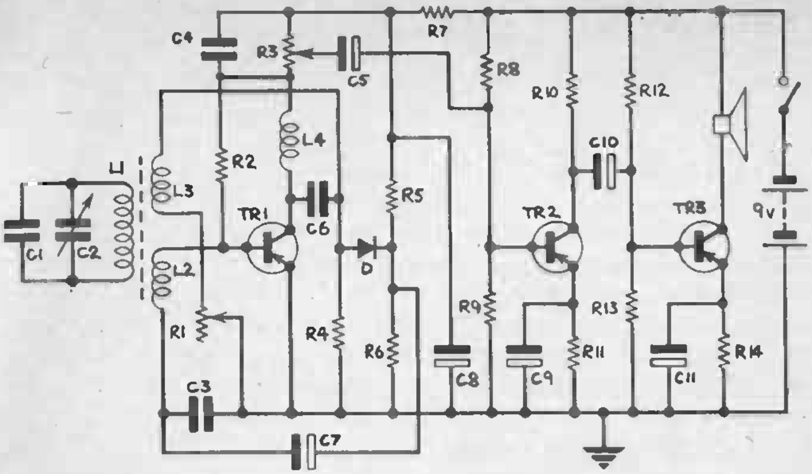


Fig. 31

Make the coils

Make winding L1 first, using the 12 strand wire. Wind 60 turns on the ferrite slab. Winding L2 consists of 3 turns only of 3 strand wire, wound on top of the first four turns of L1 at one end. this end of the coil is the 'earth' end for connection in the circuit. Winding L3 consists of 4 turns of 3-strand wire, again wound on top of section L1, but this time $\frac{1}{4}$in. in from L2.

The other winding that has to be made is the coil, L4. Make up a coil bobbin just like *fig. 24* and wind on 100 turns of 3-strand wire. All the other items in the circuit are standard components that you can buy.

PROJECT

Your own design

This time, no layout diagram or component layout is given. Work this out for yourself, it should not be very difficult. You can use bus bars for the top and bottom common connection lines, noting that the top bus bar will have to be in two separate pieces joined by R7. If you plan a solder tag position for each of the other connecting points shown on the circuit diagram this will give you a satisfactory basic layout to work from.

If you have connected all the components up properly, the set should work as soon as the battery is connected and switched on. It will be directional again (all ferrite rod aerials are), so to adjust for best performance first line the set up for maximum volume listening to a particular station. Then turn the volume control down until the sound is quite weak. Now adjust the core of the coil L4, screwing it in or out, until you get maximum volume. The set is then aligned for best performance.

PROJECT

For better listening

(i) Fit a tone control connected directly across the loud-speaker tags (see Part Six):

(ii) Replace the loudspeaker with an 18:1 miniature output transformer and use a 3 ohm loudspeaker. This may give better listening. (You may find it difficult to get an 80 ohm loudspeaker for connecting directly into this circuit, so this is an alternative solution in this case).

PART TEN

How to make your own printed circuits

The printed circuit has almost entirely replaced 'wired up' circuits in professional radio construction. They are quite easy to make, the main problem being the *design* of the circuit rather than actually making it.

Printed circuit base material consists of copper foil—two, three or five thousandths of an inch thick (or in some cases thicker) bonded to a thermoset plastic base of suitable thickness—e.g. typically $\frac{1}{16}$ in. thick for general work. The base material may be laminated or reinforced phenolic (most common in this country) or polyester reinforced with glass fibre (generally favoured in America and now coming more to the fore in this country). The type of base material is not of primary importance, provided it has the necessary electrical qualities of being a stable non-conductor and has the necessary rigidity and physical strength to act as a chassis plate. It must also be a suitable material for taking the bonded copper surface layer and be capable of being drilled or punched to accommodate component leads, etc. The main advantage of a glass fibre board over 'Paxolin' or a similar material is that it is translucent and so it is possible to see the printed circuit pattern of 'lands' from the other side of the board, making it easier to locate components correctly or trace connections when checking. On the other hand glass fibre boards are usually more expensive and are harder to cut. Also drills used for hole-making are readily blunted by them and need frequent replacement or resharpening.

Etching the pattern

Printed circuit stock is invariably bought in panels which can be cut to the size required. One face of these panels is coated with copper foil and it is on this face that the actual circuit pattern is produced by etching. This involves transferring a drawing of the circuit on to the copper, coating all copper areas which are to remain with a suitable *resist* and then immersing the panel in an acid bath to etch or dissolve away the remaining unwanted copper. The resist is then removed with a solvent, when the printed circuit panel can be prepared for component assembly by drilling, etc.

All this work is well within the scope of the amateur enthusiast, either working from a printed circuit plan or designing a suitable printed pattern equivalent to a theoretical circuit design, although the latter can become quite an involved business. Alternatively, many standard radio designs, etc., are available as kits or in component form for home assembly, including a complete printed circuit, ready drilled as necessary. This latter feature saves a lot of time and effort, and is a point of design on which the less experienced constructor is likely to go wrong. One of the basic essentials of printed circuit design, in fact, is complete familiarity with component sizes, so that mounting holes or holes for leads properly match the component to be accommodated—with each component arranged in logical order, both physically and electrically. Unlike ordinary wiring-up, printed circuit conductors cannot be crossed over each other.

Complex circuit

The typical superhet circuit is relatively complex and, without experience in printed circuit layout, can present an almost unsolvable problem as to how all the necessary conductors can be arranged on a single plane. In general, however, the layout should follow basically the same physical disposition as the theoretical circuit. Where this diagram itself includes crossing conductors it may well be of considerable help to see if it can be replanned so that these are eliminated. If this proves physically impossible, and a solution cannot be found by altering the disposition of the components, it may be necessary to terminate certain connections on the printed circuit lands and interconnect to cross other lands with an insulated jumper wire. While this may be considered bad design, it is perfectly suitable for one-off or amateur construction. Components themselves can be used for bridging over adjacent conductors.

The current-carrying capacity of conductors varies with foil thickness, but, since the current values in transistor receiver circuits are invariably low, conductor size is unlikely to be critical, although recommended minimum figures should be adhered to.

Minimum recommended conductor width is $\frac{1}{16}$ in., with at least $\frac{1}{32}$ in. clear spacing between adjacent conductors to reduce the possibility of accidental shorts of 'bridging' between conductors when soldering. The drawing should also allow for a minimum spacing of at least $\frac{1}{32}$ in. between the outside conductor and the edge of the printed circuit board.

Where holes have to be drilled to take component leads, the hole diameter should closely match the lead size—e.g. with a typical resistor lead of 0.028 in. (22 s.w.g.) the corresponding hole diameter should be at least $\frac{1}{32}$ in. or No. 67 drill. Sufficient

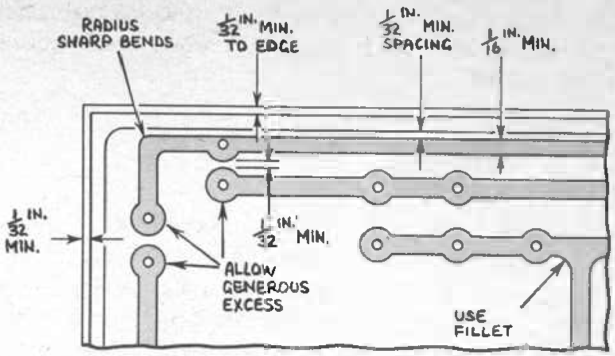


Fig. 32

area of copper 'land' should be provided around each hole for a minimum width of $\frac{1}{16}$ in. (*fig. 32*). Holes should be correctly spaced to match component leads, allowing for a 'finger bend' at each end or down the side of the component, according to whether horizontal or vertical assembly is to be used (*fig. 33*). The former is to be preferred except where a minimum size panel is aimed at, when vertical mounting of resistors, etc., will occupy minimum base area. At no point, however, should spacing between adjacent holes be less than twice the laminate thickness (i.e. normally not less than $\frac{1}{8}$ in. on standard laminate).

Other points to watch are that where conductors join at an acute angle they should be faired in with a generous fillet, increasing the area bonded at the joint and making the copper far less liable to be lifted. Also do not leave unnecessarily wide or large areas of copper as conductors. These may be subject to excessive heating and expansion, with the result that the copper tends to lift from the base. Either cut down the outline of such areas or relieve the surface area with slots to be etched away.

This is not so important on low-voltage circuits, but on mains circuits no copper area of more than about one square inch should be left 'solid'.

PROJECT

Trace from a master drawing

For professional work the printed circuit design is usually prepared as a master drawing two or three times actual size—and sometimes to a very much larger scale where a complex circuit is being designed to be accommodated within minimum area. This is then photographically reduced and printed or otherwise transferred to the laminate. For amateur work an accurate tracing is usually made off an actual-size master drawing, transferred on to the laminate (copper face) with carbon paper. Simple circuits can be drawn directly on to the copper with a lead pencil. All the land areas are then carefully painted in with cellulose paint (or resist ink, as preferred) and allowed to dry. The panel is then ready for etching.

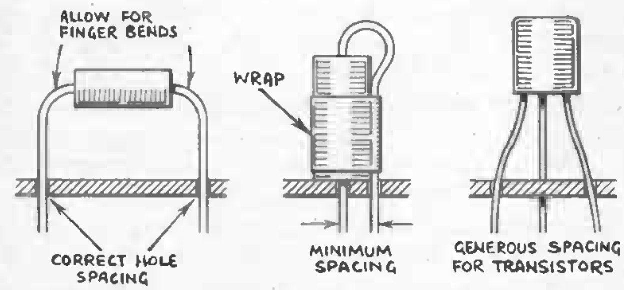


Fig. 33

PROJECT

Start from scratch

Although the majority of home-constructed superhets are built from professionally made printed circuits the technique of preparing a laminate will be described in detail for those who may prefer to work to their own circuit designs.

The first step, having prepared a printed circuit drawing, is to cut the laminate to the required overall size, using a fine tooth saw. The cut edges can then be smoothed with a fine flat file, as necessary. The copper surface has probably become greasy and dirty through handling, and so should now be cleaned thoroughly by washing with a detergent and rubbing dry with a clean cloth. If the copper is discoloured through corrosion, use a domestic abrasive cleaner to bring it up bright clean.

A test of cleanliness is to hold the panel under a tap, copper side up, and allow water to run on to it. If the water wets the whole area and flows smoothly over it, the surface is clean and grease free. If isolated patches of copper stay dry these are still coated with grease and need further cleaning.

Once completely clean the printed circuit pattern is drawn or traced on to the copper. Cellulose paint or resist ink should then be used to paint in all the land areas, using a ruling pen for straight lines and a small brush to fill in and complete the wider sections. The whole of the pattern may be painted on, if preferred, although the result may be somewhat more ragged. Avoid painting on too much paint or resist, as this may overrun the outlines. At the same time make sure that all the land areas are fully covered. The painted pattern should then be left to dry, which may take an hour or more with cellulose paints or 10 to 15 minutes with resist inks.

The solution normally used for etching is ferric chloride mixed with a little hydrochloric acid, or straight dilute nitric acid. The former is generally preferred since it does not 'gas' as much as the acid alone, but either will be equally effective. The etching solution is poured into a suitable shallow container, such as a plastic sandwich case or tray and the laminate slid into it to immerse. Rate of etching will depend on the temperature of the etching solution and also the degree of agitation. Thus at a temperature of 50 °F a ferric chloride bath will etch the copper at a rate of about 1 thou. in 20 minutes—or nearly an hour to etch 3-thou. foil. At 70 °F the rate of etching is increased to about 10 minutes per thou., and at 100 °F is almost twice as active again. The etching rate can also be increased by gentle agitation, e.g. moving the board gently backwards and forwards in the bath, or gently rocking the container to swill the etching solution from end to end. **Acid can be dangerous: use it with great care.**

Etching should be allowed to proceed until all traces of copper have disappeared from the surface. The board can then be removed and rinsed under running water to remove any traces of etchant. The paint or resist ink covering the lands is then removed either with a solvent (e.g. cellulose thinners in the case of cellulose paint) or a cleaner (in the case of resist inks). After this, again wash and dry the board, when it is ready for drilling.

Three basic rules must be observed when drilling printed circuit panels:

(i) Always use a sharp drill (preferably a new drill, or one which has been resharpened prior to use).

(ii) Always drill from the copper side (i.e. with the copper face uppermost).

(iii) Always use a backing of hard material underneath the panel to prevent the drill tearing the Paxolin when it emerges.

PART ELEVEN

Building from kits

A number of firms supply kits for building radio receivers. These are nearly always based on a printed circuit panel which is already made and drilled. Building the set is then simply a matter of inserting component leads through the right holes in the panel and soldering them in place. In some kits, the position and identification letters for the components are printed on the panel as well, to make the job even easier. Kits contain all components necessary to complete the set, and sometimes even a cabinet.

One type of radio receiver which is particularly suited to kit assembly. This is the *superhet*, which has a superior performance to almost any other type of receiver. Practically all domestic radios, for example, are superhets.

Unfortunately, the superhet is a complicated circuit, requiring the use of special transformers which have to be adjusted or *aligned* to get the set to work at all. This can be quite a complicated process. The superhet, therefore, is not a suitable type for home construction—*except in kit form*. A superhet kit will contain *pre-aligned transformers*, a finished and drilled printed circuit panel, and complete instructions both for assembling the set and getting it to work properly.

Kits of this type are not expensive. They cost from about £5 upwards, and are well worth the money. Buying the components separately would cost almost as much and you would have all the trouble of planning a layout and aligning the set.

There is quite a choice of types and designs, and most are supplied with professional made cabinets to take the works.

PROJECT

Make it simple

Buy a simple superhet kit for a start and get it working. Then save up for a more elaborate kit, and build that. It could very well give a better performance than professionally made radios costing twice as much.

FOR FURTHER READING

ABCs of Transistors, by G. B. Mann. *Foulsham,* 20s.

Forty-Nine Easy Transistor Projects, by R. M. Brown and T. Kneitel. *Foulsham,* 16s.

Fun With Transistors, by G. Davey and J. Cox. *Kaye and Ward,* 16s. **(Learning With Fun** series).

Having Fun With Transistors, by. L. Buckwalter. *Foulsham,* 21s.

How to Build the World's Smallest Transistor Radio. *Bernards,* 1s.

Modern Transistor Circuits for Beginners, by C. Sinclair. *Bernards,* 7s. 6d.

One Hundred and One Questions and Answers About Transistors, by L. G. Sands. *Foulsham,* 21s.

Practical Transistor Receivers, by C. Sinclair. *Bernards,* 5s.

Radio Controlled Transistor Circuits for Models, by H. Boys. *Bernards,* 7s. 6d.

Transistor Circuits for the Constructor: Numbers 1–4, by E. N. Bradley. *Price,* 3s. 6d. *each.*

Transistor Pocket Book, by R. G. Hibberd. *Newnes,* 25s.

Transistors, by C. Brown. *Newnes-Butterworth,* 10s. **(Questions and Answers** series).

Transistors, by Egon Larsen. *Phoenix House,* 13s. 6d. **(Science Works Like This** series).

Transistors, by J. A. Reddihough. *Newnes,* 15s. **(Beginner's Guides)**.

Transistorized Amateur Radio Projects, by A. C. Caringella. *Foulsham,* 25s.

(The prices shown were correct at the time of going to press, but are subject to alteration and are intended only as a guide.)

To buy any of the above books, first try your local bookseller. If he does not have it in stock, he will be pleased to order it for you. In case of difficulty, write to the publisher of the book in question.

POSSIBLE CAREERS

BROADCASTING—SOUND AND TELEVISION. There are opportunities with the B.B.C. for graduates in engineering, and for technical operators, who require good 'O' levels, including English Language, mathematics and physics, as well as for technical assistants, who need 'A'-level or equivalent mathematics or physics. There is very little direct entry from school. The Independent Television Authority employs staff ranging from engineers-in-charge to technical assistants, who must be not less than 20 years old and have had practical telecommunications or electronics experience, with a Higher National Certificate or Technological Certificate.

Write to: The Engineering Recruitment Officer, B.B.C. Broadcasting House, London W.1; The Personnel Officer, Independent Television Authority, 70 Brompton Road, London S.W.3.

RADIO ENGINEERING. Entry to a career in radio and electronics engineering is at several different levels. You can begin as a university graduate or professional engineer employed in research, development or production. Then there is the technician level, covering servicing, maintaining and repairing equipment, for which you need 'O' levels in English, mathematics and at least one science subject. Finally, there are skilled craftsmen who train on a five-year apprenticeship and become toolmakers, electricians or radio mechanics.

Read: Careers in Radio and Electronics Engineering (from the Institution of Electronics and Radio Engineers, 9 Bedford Square, London W.C.1; **Electrical and Electronic Engineering—a Professional Career** (1s. 6d. from the Institution of Electrical Engineers, Savoy Place, London W.C.2); **Radio and Television Servicing,** Choice of Careers Booklet No. 66 (from booksellers or Her Majesty's Stationery Office).

Write to: Education Officer, Institution of Electronic and Radio Engineers, 9 Bedford Square, London W.C.1, for a complete list of colleges offering suitable courses in radio and electronics.

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