# Making and Repairing Transistor Radios

W. Oliver (G3XT)

How to plan, build and service transistor equipment. This new book contains a wealth of very practical information largely based on actual construction, experimenting and servicing experience. It illustrates and describes simple basic circuits from which designs for transistor projects may be developed, including single-diode receivers, reflex transistor circuits, amplifiers, oscillators, superhets, power-supply units, and short-wave adapters or converters for world-wide reception. Other subjects discussed include: winding ferrite-rod aerials and transistor coils; fet and vhf circuits; integrated-circuit modules; tuned-circuit alignment; testing components; systematic fault-tracing; and sources of supply for components and spares. The writing is easy to understand, the technical data is explicit and the diagrams are very distinct.

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# MAKING AND REPAIRING TRANSISTOR RADIOS

by

W. OLIVER
(G3XT)

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# *Preface*

Semiconductors look so simple that you may think the circuits in which they are used must be equally simple to design, build and repair.

This is far from true. The planning, construction and servicing of transistor sets can be fascinating, instructive and rewarding; but not necessarily easy.

In certain cases the work may turn out to be unexpectedly tricky, and the beginner must be prepared for anything from complete success to partial or even total failure.

There are a good many factors which can occasionally result in frustration or disappointment where transistor projects are concerned.

But if you do succeed in getting everything just right, the results with either a newly-constructed set or a carefully repaired one can be so excellent that they make up for occasional discouragements.

It is hoped that the hints in this book will help you to avoid any snags or difficulties and ensure that you will make a good job of any constructional projects or repairs that you may attempt.

In a book of this size there is an obvious limit to the amount of detailed information that can be given in regard to any particular circuit. Therefore some background knowledge of radio theory, and some elementary experience of first steps in practical construction, must be taken for granted.

Various sections of typical basic circuits are illustrated and discussed. They do not include all the refinements and "extras"

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that may be found in detailed project-designs, but they will at least form a useful starting-point for any number of experiments in practical design and construction.

Servicing and maintenance, testing and troubleshooting procedures applicable to home-built and manufactured sets are dealt with, and these sections of the book should be useful to those who are taking up radio as a career, as well as to those who only intend to mend sets as a profitable or money-saving hobby.

Radio is a technology that is constantly changing and progressing. Specific information about all the latest devices and components, sets and circuits can be obtained from up-to-the-minute data leaflets etc, issued by manufacturers or suppliers; and from technical press reviews. The basic facts given in the present book will form useful stepping-stones to understanding and applying more detailed information from these sources.

To start with, the following preliminary hints on safeguards that will help you to avoid disappointment, or even disaster, in dealing with transistors, will be useful.

Make sure that any transistors you use are suitable for the circuit; and that the connections (lead-out wires etc.) are correctly identified.

Check polarities (PNP or NPN as the case may be) and see that battery supplies and electrolytic capacitors are connected "the right way round" to suit the class of transistor that you are using.

Take care that the maximum voltage and current ratings specified by the transistor manufacturer for the particular type in use are never exceeded.

Avoid short-circuiting, or the use of unsuitable test-gear when servicing transistor equipment.

Do NOT ever make any direct connection between any sort of solid-state apparatus and any sort of AC/DC receiver or other equipment with a chassis that may be "live" to the mains.





Never use any sort of add-on device in a way which could result in its exposed metal parts becoming "live" to the mains, not only under normal working conditions but also in the event of a fault-condition occurring.

Avoid overheating any transistor or diode or other semiconductor. Use some sort of "heatshunt", clip or pliers to conduct heat away when soldering semiconductor lead-outs.

Transistor equipment which derives its power solely from low-voltage batteries is inherently shockproof. But transistor equipment which is in any way connected with mains power supplies may not be any safer than mains valve equipment; indeed, it may even be more dangerous.

Isolation from the mains by means of a double-wound step-down transformer at the input of the power-supply unit is the best safeguard against risk of shock.

Never open a transistor or tamper with it in any way that entails breaking the sealed case or encapsulation. This encasing not only protects the transistor but also serves to protect the user against any possibility of risks arising from certain substances which may be found in some types of transistor. Even minute dust-particles from toxic substances could be a hazard, and if transistors are accidentally broken or physically damaged, care should be taken over handling or disposing of them.

If you are in any doubt on any point involving safety, seek expert advice from a competent local technician who is in a position to see what you are proposing to do, tell you whether any risk is involved and if so, how to avoid it.

In storing, using, handling or servicing any unusually sensitive or vulnerable devices, such as certain ones in the "field-effect" class, take any recommended precautions to avoid damage. Useful hints on various safeguards will be found further on in this book.

Care has been taken in the preparation of the text and diagrams in this book, but no guarantees can be given or responsibility accepted. The reader should allow for changes

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in transistor technology and technical practice; availability of semiconductors (discontinuance of some types and introduction of new ones); and any other factors which may affect the construction of home-built projects or the servicing of manufactured sets.

The circuit diagrams in this book are merely for the purpose of illustrating the discussions in the text and in some cases are greatly simplified, so they are not intended to be used, necessarily, as practical working diagrams in actual set construction nor to take the place of the many excellent detailed designs which can be found in radio technical journals. But they will help provide a sound basis for dozens of practical experiments in transistor technique.



CHAPTER 1

# *Transistor Aerial Circuits*

Portable transistor sets for medium and long wave reception normally use a ferrite-rod aerial. If a short-wave range is also included, a telescopic rod antenna will almost certainly be added for use on these higher frequencies

Small table-top experimental projects, including those for short waves, often use an ordinary single wire outdoor aerial, and an earth connection, since this gives a better signal-input (especially from distant stations) to an elementary circuit with little or no amplification—such as a modern version of the oldtime crystal set.

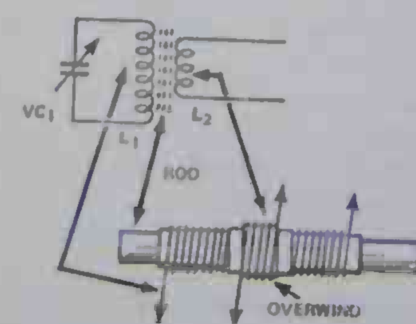


Fig. 1-1

A ferrite-rod may have anything from one to four main windings (L1 in Fig. 1-1) parallel-tuned with a variable capacitor (VC1 in Fig. 1-1). These coils will be for medium; medium and long; trawler-band, medium and long; short, trawler-band, medium and long; or short, medium and long wavebands. The variable capacitor may be a single-section type or it may be a twin-gang, in which two rotors are turned by a single control-knob.

There will probably be no direct connections to the main tuned windings except for leads from the tuning capacitor and from a wavechange switch to select the different wavebands as required. (If the set is for medium-waves only, then of course there will be no wavechange switch).

Signal-transfer to and from the main tuned windings will probably be by means of overwinds (L2 in Fig. 1·1), which are inductively "coupled" to it. Sometimes, in place of one of the overwinds, there is a direct connection, to a tapping on the coil, a few turns up from the earthy end.

This arrangement is a substitute for the overwind in the base circuit of the transistor. Another overwind may be used, especially in straight trf (tuned radio-frequency) and reflex circuits, to give reaction feedback which boosts up the signal-strength and also tends to improve selectivity. Yet another overwind, loosely coupled to the main tuning coils, may be used to feed in signals from an external aerial, such as a telescopic one or a car aerial.

In some cases a small preamplifying stage is inserted between a car aerial and the ferrite-rod circuits; this gives better matching and better signal-to-noise ratio, cutting down interference such as any residual noise there may be from the car's ignition despite the suppressor arrangements which should of course be fitted.

The physical dimensions, and the windings, of a ferrite-rod aerial vary considerably, and are of course interdependent to some extent.

Rods of circular cross-section can be bought in various sizes—e.g., $\frac{3}{8}$ in. diameter x 6, 7, 8 or 10 inches long; or $\frac{5}{16}$ in. diam. x 6 in. long; or $\frac{1}{4}$ in. diam. x 6 in. long.

Another type of ferrite core for this purpose, used mostly in very small personal portables, is a flat type, thin rectangular





cross-section and usually about a couple of inches in length, known as a *ferrite slab*.

The windings are usually of either enamelled copper wire or Litzendraht wire. The number of turns required to cover any given waverange will depend on various factors—the dimensions of the ferrite rod, the position of the winding, the gauge of wire, the spacing of the turns (i.e., close-wound or separated) and the capacity of the tuning capacitor and trimmer connected in parallel with the winding.

As a winding can be put on in a very few minutes, it is just as quick to find the optimum number of turns for any given set by trial and error as by mathematical calculation which will also entail some final adjustment owing to stray capacities etc.

The windings can be put on tubes or sleeves made from gummed paper. The writer has also used thin plastic tubular formers made by cutting the ends off phials in which one make of transistors are packed by their manufacturers.

The following winding details for various typical arrangements will help to give you a rough idea of the number of turns, wire gauge and ferrite rod or "slab" dimensions that can be used, and will show the scope for experiment in this direction.

(1) Slab $2\frac{1}{2}$ in. long, $\frac{5}{8}$ in. wide and $\frac{1}{8}$ in. thick. Approx. 40 turns of 30 SWG enamelled copper wire, close-wound. Tuning capacitor 500 pF. (If the maximum capacity of the latter is much less than 500 pF, the number of turns must be increased proportionately; even so, the waverange covered will not be so wide; but tuning will be easier.) The overwind for the base circuit can be 4 or 5 turns of similar wire.

(2) Rod $2\frac{1}{2}$ in. long, $\frac{1}{4}$ in. diameter. 70 turns of 28 SWG enamelled copper wire, tapped at 10 turns from the earthy end, instead of overwind. Capacitor 300 pF.

(3) Rod 6 in. long, $\frac{3}{8}$ in. diam. 85 turns of 26 SWG enamelled, tapped at 10 turns from earthy end.

(4) Rod 7 in. long x $\frac{3}{8}$ in. diam. 60 turns of 7/45 Litz wire for main winding. 5 turns of thin enamelled wire (30-40 SWG will do) for coupling coil.

(5) Rod $2\frac{1}{2}$ in. long, $\frac{3}{8}$ in. diam. 55 turns of 30 SWG enamelled tapped at 5 turns from earthy end.

(6) Slab $2\frac{1}{2}$ in. long, $\frac{5}{8}$ in. wide and $\frac{1}{8}$ in. thick. 75 to 85 turns of 30 SWG enamelled copper wire, number of turns depending on variable capacitor used. Overwind, 5 to 8 turns, depending on transistor used.

All the foregoing are medium-wave windings. For trawler band, to cover the 80-metre and 160-metre ('top-band') amateur transmitting stations as well, you will need far fewer turns. The exact number will depend on the range of frequencies you wish to cover; for example, whether you want to include some broadcast stations at the top or bottom ends of the range.

To get some idea of the coverage with any particular variable capacitor, you could start with a rough experimental winding containing about half the number of turns quoted for any of the medium-wave windings, and then re-wind with more or fewer turns as required to suit individual ideas.

Long-wave windings will need upwards of double the number of turns in the medium-wave ones, but here again the exact figure will depend on the values of associated components, and it is worth trying a rough experimental winding to form a guide to the final version required. Even a long-wave winding should not take you more than four minutes at the outside to wind by hand, and it is well worth expending this amount of time as an aid to precise "tailoring" of the final winding to suit your individual circuit requirements.

Short-wave windings are quicker still; they contain only a few turns of wire and can be put on literally in seconds. For the main winding, with a variable capacitor of about 300 pF, you could start with about ten turns of, say, 26 or 28 SWG enamelled copper wire, spaced so that there is a gap





of one wire thickness between turns, on a ferrite rod about 2 in. long and $\frac{3}{16}$ in. diameter.

Adding or subtracting one or two turns will make a big difference in waverange at these higher frequencies; and any change in spacing will also affect the coverage by changing the effective inductance of the coil.

Stray capacities etc. play such a big part in the actual frequency range on short or ultra-short wavebands that any attempt at purely mathematical calculation of the number of turns is, in the writer's opinion, a sheer waste of time, when you can arrive at the desired result much more accurately and far quicker by practical experiment.

A simple calibrated wavemeter of some description is needed to give you a close estimate of the coverage; but you would need this even with mathematically-calculated windings to check the final result in practice.

Overwinds for short-wave coils will consist of about 3 or 4 turns, but here again you can experiment a little. The relative positions of overwinds in relation to the main windings will be pretty critical and careful experiment will be needed here.

Ready-made ferrite rod aerials, with windings for normal requirements, can be bought complete if you prefer this alternative.

We have dealt at some length with ferrite-rod windings, because in some popular transistor circuits, notably reflex types, the ferrite aerial contains the only tuned winding in the set, and it plays a very important part in determining the results you can obtain. The writer has experimented in practice with dozens of different ferrite-rod arrangements connected to simple reflex circuits and has found an amazing difference in signal-strength, selectivity, stability and so on, can be produced by what seem to be trivial changes in the design and positioning of the windings on the ferrite rod, and also by the position of the whole assembly in relation to other components in the circuit.

If you are not going to use a ferrite rod, but prefer ordinary small coils (with adjustable iron-dust or ferrite cores) in the aerial tuning circuit, together with an external aerial of some sort, you may prefer to use a complete matched set of ready-made coils.

If the set is a superhet, where correct matching and alignment of all tuned circuits are vital, you may find it very much easier and more effective to use ready-made coils, or a complete coil-pack with wavechange switch for both the aerial and the local-oscillator circuits.

Suitable coils for all purposes can be found in the ranges marketed by Denco Limited, and other firms. Addresses and other particulars may be found in the advertisement pages of latest radio technical journals.

Some transistor circuits are for single-waveband use; for example, medium-wave only. Some types use a wavechange switching arrangement built-in to the variable capacitor, this permitting reception of the BBC Radio 2 transmitter only, on long waves, but normal variable tuning on medium waves.

In home-built sets, several different arrangements for wavechange switching can be tried.

Sets using FET devices may employ wavechange switching very similar to that used in valve sets, since the input impedance of the FET is not lower than, but usually higher than, that of a valve.

With ordinary transistors, the overwinds for matching the base circuit will generally have to be switched, as well as the main tuning circuit, in the aerial-circuit section of the set.

The oscillator section of a transistor superhet mixer may not have any coil-switching, the wavechanging from medium to long may merely switch a suitably-chosen additional fixed capacitor into use across the tuned circuit. The capacity is such as to enable the oscillator section of the ganged capaci-





tors to tune over the long waveband, when the switch is in LW position, instead of over the medium waveband.

The easiest wavechange switching is, of course, in a receiver employing only one tuned circuit; this is one of the attractive features of a reflex arrangement.

Some miniature personal-portable transistor sets dispense with a conventional on-off switch for battery supplies and use a phone jack to switch on automatically when earphones are plugged in.

CHAPTER 2

# *Diodes, Transistors and Simple Circuitry*

The family of semiconductors or solid-state devices is a big one. The oldest branch of the family comprises diodes, and the most famous, transistors.

There are many types of diode, almost innumerable types of transistor (nominally, at any rate) and new descendants of both are constantly being developed.

The crystal detector used in the early days of broadcasting was a form of diode. It could detect or rectify signals but not amplify them. Where signal-strength was concerned, you got out of the crystal detector a little less than you put into it, instead of a great deal more.

When transistors came along the scene began to change, slowly at first, then suddenly a landslide. Semiconductors or solid-state devices started to supersede valves, fast. In some spheres of electronic work valves are now treated as obsolete; but in other fields, such as colour television, at the time of writing valves for certain purposes are still considered to be almost indispensable. From this situation we get a certain number of "hybrid" sets, containing valves in the stages where valves are still best, and semiconductors in the stages where transistorization really pays.

Portable radio receivers form a field where solid-state is now the universal fashion and valves are things of the past. Gone are the heavy batteries that made the word "portable" in some cases rather a misnomer, and here to stay are sets that can be not only portable but so light that you could be unaware that you have got them in a pocket or handbag.

The advantages of the typical transistor are many. Small size; feather-weight; low cost; high efficiency; long life; modest power requirements and simple circuitry—these are just a few of the assets to be found in many transistors and allied types of semiconductor.

You can build a whole transistor set in the space occupied by an early valve, and power it with a battery far smaller and lighter than the little grid-bias battery, which was the smallest and lightest of the three batteries (HT, LT and GB) which were needed for non-mains valve sets in the early days of broadcasting.

Of course, semiconductors have a few snags which must be offset against their advantages; but mostly unimportant ones.

After this brief introduction to the semiconductor "family," let's start working with them!

The diode is the simplest of these devices, though it is very versatile and comes in many forms. We will start with the ordinary detector diode which is equivalent to a modern version of the ancient crystal-detector, but much more reliable.

Just about the simplest (and, in a sense, perhaps the least efficient) receiving circuit you can build is shown in Fig. 2-1. It consists of a mere handful of components, and it will work effectively only in an area where strong signals are to be had from a fairly local or very powerful broadcasting station.

Moreover, under most conditions it will only work an earpiece or headphones. Having only one tuned circuit and no form of regeneration or reaction, its selectivity (i.e., the ability to separate one signal from another) is relatively poor.

When you consider its cheapness and simplicity, and the fact that it will reproduce beautifully clear signals of reasonable earphone strength if used close enough to any sort of transmitter (including even low-power amateur transmitting stations if you are near enough to one), this tiny receiver brings home to you the real miracle of electronic communica-





tion in a way that big, expensive and elaborate apparatus cannot do.

You expect something worth seeing and hearing from a colour television set costing maybe a couple of hundred pounds or more; but the results from such a ridiculously inadequate-looking circuit such as that in Fig. 2-1 are, in their way, more miraculous!

Although this set is so limited in performance, it is not really a waste of time for the beginner to start with it, as every item in it, if undamaged, can be re-used in much more ambitious circuits later.

If you are more than a few miles from a broadcasting station, an external aerial, preferably a good outdoor one, will be needed; and a good earth connection is a great asset. Main water pipes were once a favourite earth, but the introduction of plastic pipes in some districts has spoilt this. Gas pipes must NOT be used.

This leaves us with virtually only two other alternatives. a metal plate or earthing-rod or piece of metal piping buried in moist ground and connected to the set by a length of plastic-covered copper wire. Or, the earthing socket on a mains plug. The latter is correct procedure for mains-operated sets running a loudspeaker. But the writer hesitates to suggest its use for any set on which headphones are going to be used, or which may not be totally insulated inside a cabinet, because there is a risk that a beginner might plug into the wrong socket on a three-pin outlet. This could be dangerous.

So if you are a beginner it would be wiser to stick to the outside earth-connection which you can make yourself by burying a metal plate or driving a metal rod or pipe into moist garden soil just outside the window. (But you live in a high-floor flat? Well, in that case the signal-strength should be better than at ground level, and the earth connection may not be needed anyway!)

In Fig. 2-1, L1 is a medium-wave or long-wave coil (according to which waveband you want) with a tapping towards the earthy end of the winding, to match the low impedance of the diode. C1 is a variable capacitor which can be about 350 or 500 pF maximum capacity. C2 is a fixed capacitor which can be 1000 pF (0.001 μF).

The output terminals Y and Z can be connected to the headphones or earpiece if the set is to be used as it stands.

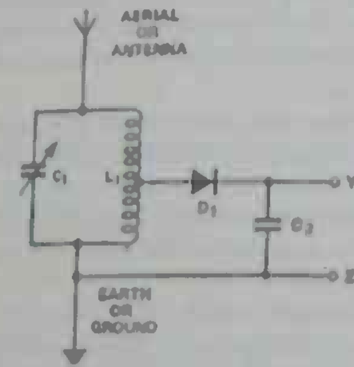


Fig. 2-1

But if you want to add a stage or two of transistor amplification, you can connect a 2,000-ohm potentiometer across these terminals with the slider connected to the input of the amplifier, as in Fig. 2-3.

The headphones or earpiece should be of a sensitive magnetic type having a resistance of not less than 1,000 and preferably 2,000 ohms.

The best position on the coil-winding for the diode tapping can be found by practical experiment; it may differ a bit with different diodes.

Various modifications can be made to the simple circuit of Fig. 2-1 to improve its performance—for example, the selectivity can be improved by using a double-wound coil or radio-frequency transformer. The coil windings can be on a





ferrite core, and the secondary can comprise only a few turns so as to match the low-impedance diode. The primary, to which the aerial and earth are connected, contain the number of turns normally used in a medium or long wave coil. The primary is tuned, the secondary is untuned—i.e., the variable capacitor is across the primary.

Fig. 2-2 shows how to make a ferrite-rod aerial assembly. You can buy one ready-made if preferred; but it will naturally cost you a little more and you will learn a little less than you may learn by making it yourself. Moreover, your home-wound one can be made in an experimental manner which will enable you to try out different windings for different wavebands

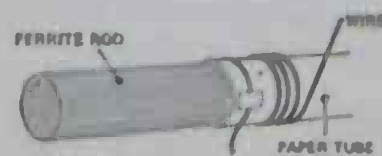


Fig. 2-2

and for any circuits of a more advanced type that you may build later.

As the windings shown in the diagram are put on paper tubes or sleeves that can be slipped on or off the rod at will, the same rod can be used for any set you build. All you have to alter are the windings, which cost next to nothing if you are able to salvage the necessary wire from old coils, discarded transformers or other electronic junk.

The number of turns of wire in L1 determines the wave range or frequency-spectrum that you can cover in conjunction with a given tuning-capacitor. You can experiment with any number of turns from two to two hundred! A coil of only a few turns, space-wound, will tune to short-wave stations. More turns will tune to the trawler band, amateur 80 and 160 metre ("top-band") transmissions, etc. More turns still—

say between 50 and 80—will bring in medium-wave broadcasting stations, and upwards of 150 will bring in long-wave stations. Experiment with the number of turns to cover whatever waveranges you want.

This simple circuit needs only a single-gang tuning capacitor. But this will have limited uses, and if you are going on to build more ambitious circuits such as superhet receivers it is more sensible in the long run to buy a twin-gang capacitor which will do for these as well when the time comes. Meanwhile you can use just one section for the present project; or you can connect the two sections in parallel to give you a wider range of frequencies in one sweep of the tuning-control. (This may tend to weaken signals a trifle and make the tuning a bit more critical. On short waves you should use one section

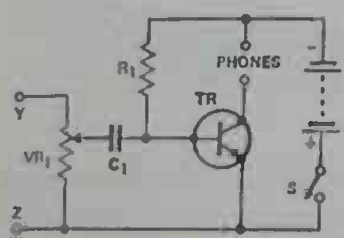


Fig. 2-3

only, and if there is one section with smaller capacity than the other, use the smaller one. If tuning is still too "sharp" and critical, you can get a "bandspread" effect by connecting a fixed capacitor in series with the variable one, but this of course reduces the effective overall capacity and restricts the tuning-range.)

Earpieces or headphones used with this simple circuit will need to be a sensitive type, and a 2000-ohm kind will do. It is possible to get a pair of imported high-resistance headphones at the time of writing for about a pound. Ex-Government surplus ones are also available, but make sure they are suit-





able; some kinds are very low-resistance and are more suitable for other circuits than the present one.

If you want something which will give louder signals than the unaided diode receiver, you can easily add on any suitable amplifier; for example, a transistor audio amplifying stage, such as that shown in Fig. 2-3. With this, you may even be able to work a small loudspeaker if you are using the set in a very strong-signal area, with a good aerial. If the local field-strength is very high, you may be able to get good results with just the ferrite rod aerial and no outside wire at all. This makes the receiver truly portable and self-contained.

Almost any audio-amplifying type of transistor will give good results in this circuit if the input signal is adequate; and other types of transistor can be tried as well.

A small battery of 9 volts, or less, is required. Be sure to

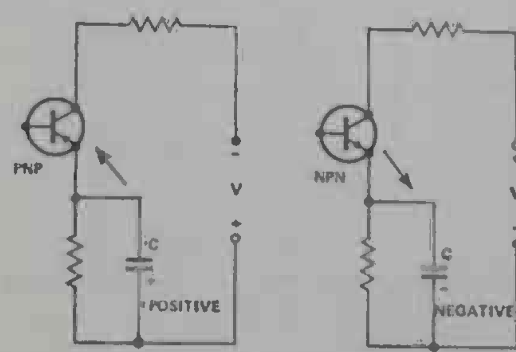


Fig. 2-4

connect it the right way; that is, with correct polarity. Don't reverse the connections or you may damage the transistor permanently, possibly ruin it completely.

There are two main classes of transistor; PNP and NPN. The polarities of these are opposite to one another. Therefore the right battery polarity for one is quite wrong for the other.

We have said "Don't reverse the connections" if you are using one type—say, a PNP type such as the OC44 or the AF117. But if you change to an NPN type such as the NKT733, then of course you *must* reverse the connections since this class of transistor is of opposite polarity to the PNP type.

If the battery connections are reversed, for a changeover from PNP to NPN transistors, certain electrolytic capacitors in the circuit which are polarized (i.e., with positive and negative terminals or wires marked + and − respectively) must also be reversed.

Fig. 2-4 should help to make all this clear. It is quite an important point and applies to much more complicated circuits as well as to the present one, so you will need to get fully conversant with this basic requirement right at the outset, or you will be damaging transistors galore!



CHAPTER 3

# *RF/AF Amplifiers and Oscillators*

RF means radio-frequency and AF audio-frequency. Very broadly speaking, radio-frequency amplifiers are used in the front end of a circuit, that is, between the aerial and the detector (or discriminator), and audio-frequency amplifiers in the later stages between the detector and the loudspeaker.

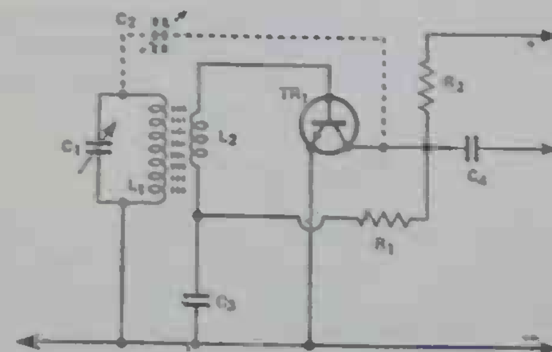


Fig. 3-1

Valve amplifiers in most sets follow rather conventional lines; but where transistors are concerned there is perhaps more scope for circuit variation and more reason to take advantage of configurations that are rather out of the ordinary.

The present book is a practical rather than theoretical one, and we cannot go too deeply into how everything works. We must assume that you have a background of electronic theory which you can get from any elementary handbooks which explain the basic principles of diodes, transistors, amplifying, oscillating and rectifying circuitry, and so on.

In these pages we must therefore be content with only brief references to any theoretical considerations and stick mainly to the practical problems which arise in making and mending sets, which after all is what this book is about.

Fig. 3-1 shows a fairly typical example of an RF transistor amplifier. (Note that this is shown for an NPN transistor, but could be converted for use with a PNP type). You could interpose something on these lines between your ferrite antenna (or aerial) and the diode detector. This would increase the range and sensitivity of the set, but of course it would still have only one tuned circuit, which would make it still rather lacking in selectivity.

Some small degree of positive feedback or regeneration may be introduced at this stage which will help slightly to improve both strength and selectivity. But it must not be overdone or the circuit will become unstable.

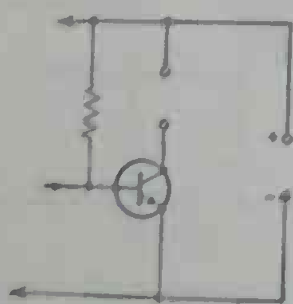

Fig. 3-2

We have already used one transistor for audio amplification after the diode. Now we can take a look at some slightly more advanced audio-frequency amplifying and output stages, though still in the simple and straightforward class.

The diagrams accompanying this chapter will help you to





experiment with this kind of amplifier, and there are many, many different type-numbers of transistors which can be used quite successfully in these elementary circuits.

Results will inevitably vary with different types and there may also be some variation between different individual specimens, even though they bear the same identification-markings. Transistors are not as uniform as valves in this respect, and for some purposes you may find quite a difference between samples that are theoretically supposed to be identical!

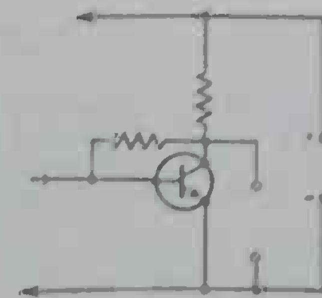

Fig. 3-3

Figs. 3-2 and 3-3 show alternative biasing and output arrangements. (The transistors are NPN types.) Fig. 3-3 incorporates some negative feedback.

Fig. 3-4 shows a low-powered audio amplifying and output stage. TR1 can be an OC71 and TR2 an OC81, but other types—including any updated types superceding those mentioned—can be tried, provided of course that component values, particularly those of resistors, are selected to suit the individual transistors, and that the correct polarities are observed (according to whether you use PNP or NPN types).

VR1 can be a 5K volume-control (though the value is not critical); C1 can be almost anything from, say, 0.04 $\mu F$ tubular to an electrolytic of several microfarads. Resistors will depend on choice of transistors as already mentioned, but as a rough guide you could say 100-120K for R1, 3.3K to 4.7K for R2, and 150 to 330 ohms for R3. C2 can be 25 to 50 μF and C3 100 to 200 μF, both electrolytic.

Fig. 3-5 shows a more powerful, but less economical, amplifier using an absolute minimum of components. The first transistor should be a high-gain type; an OC44 would do, unless you have a suitable alternative of more recent type; and the output transistor can be an AD140.

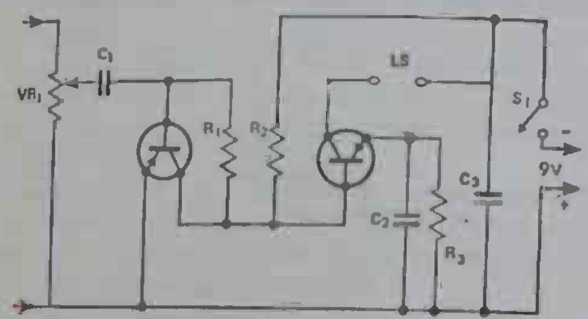


Fig. 3-4

R1 can be about 6.8K, and R2 about 33K or 39K, but a little experimenting can be tried here, within limits. The input capacitor can be up to about 10 μF electrolytic, but is not critical and tubular paper types of lower capacity can be tried.

If you are running this amplifier from batteries, it is important to keep the voltage down, otherwise current consumption will be excessive. A 4.5 v. battery is suggested. This amplifier will work a fairly large loudspeaker and should give quite nice quality if you get everything just right.

Near-equivalents for the AD140 could be tried if you have suitable ones handy; but the current consumption should be watched.

Other examples of audio amplifier circuits are shown in





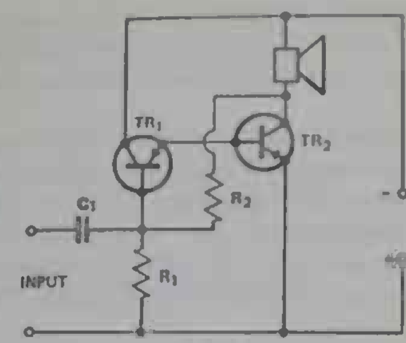


Fig. 3-5

Figs. 3-6 and 3-7. (In actual practice some modifications are often made to the basic circuit in Fig. 3-7.)

Amplifiers on the lines of the Fig. 3-6 example are pretty "safe" types for a beginner to experiment with, as the capacity coupling between the stages makes them more or less independent, rather than interdependent, and therefore any error or fault in one stage is not likely to cause trouble in the other stage as would be the case with direct coupling.

There is a fairly wide choice of transistors for amplifiers such as these two; and the choice of values for the various

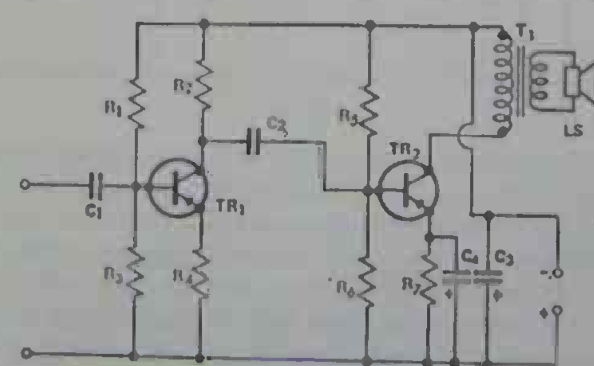


Fig. 3-6

associated components will depend on the transistors chosen. You will find suitable designs based on these circuits in various transistor-project books and in radio technical journals from time to time.

The actual example in Fig. 3-6 uses PNP transistors, but similar circuits are available for NPN transistors, remembering of course to reverse the battery and electrolytic polarities.

Where a "complementary pair" of transistors is used in an output stage one will be a PNP and the other an NPN.

For example, an AC187 (NPN) and AC188 (PNP) form a suitable pair.

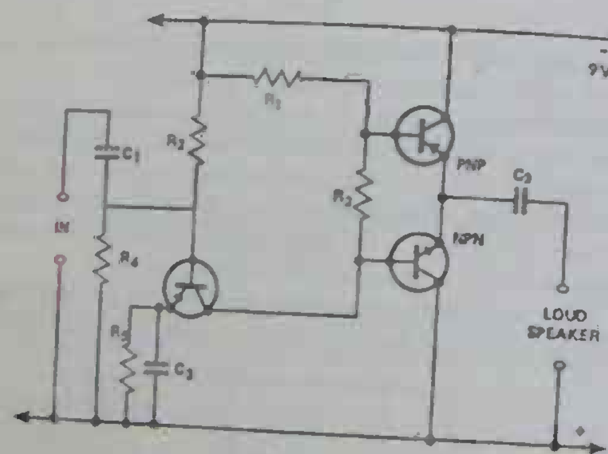


Fig. 3-7

An important precaution with power transistors is the provision of heat-sinks where necessary. But you must be careful to bear in mind that the metal cases of transistors such as an AD140 are in contact with one active element of the transistor—in this case, the collector—and it is imperative to insulate the case from the heat sink (in the electrical, not the thermal, sense), or else to have the heat sink in contact with the case (which gives better heat dissipation) and insulate





the heat-sink electrically from everything except the one necessary connection to it.

Failure to take these precautions is likely to be disastrous and costly.

The AD140 and AD149 are both suitable for the output stage in a car radio. They can be used as replacements for other similar transistors in almost all car radio receivers, if not in all.

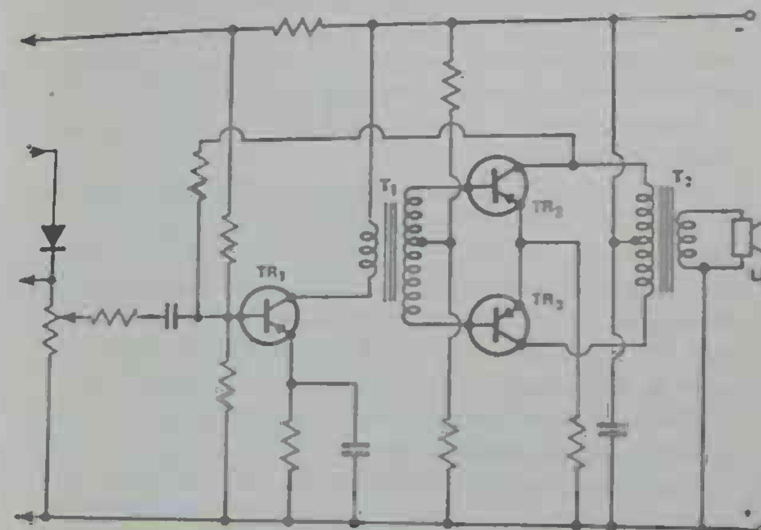


Fig. 3-8

When selecting replacements for any set, always make sure about the polarity of the existing transistors. It is not always safe to trust entirely to the type-number of the transistor as sole evidence; if you have access to the maker's service data, check this also as confirmation. If the set has been tampered with or serviced carelessly or incompetently there is always the chance that someone has fitted a *wrong* type of replacement transistor! If you inadvertently copy their error you will probably damage the new transistor and the set will *still* not work.

Not only output transistors but also driver types need careful choice, both in building sets and in fitting replacements to existing receivers.

Although transformerless audio amplifying stages are commonly used in present-day sets, transformer-type circuits can still be very useful.

Fig. 3-8 will give you some idea of a basic circuit arranged to give push-pull output. TR1 is the driver transistor, TR2-TR3 form the push-pull output pair, while T1 is the input audio transformer with centre-tapped secondary and T2 the output transformer with centre-tapped primary.

Resistance values, etc. (not marked) will depend on the choice of transistors.

As a rough guide, the emitter resistor of TR1 will probably be about 1K, with a 50 or 100 μF electrolytic across it. The emitter resistor for TR2-TR3 will be of a very low value, say just under 5 ohms. The upper and lower resistors feeding the bias to the centre tap of T1 secondary may be about 4.7K and 100 ohms respectively; but various designs differ, and more than one kind of negative feedback arrangement is used.

Several different arrangements are commonly used in transistorized and fet oscillator circuits.

Oscillators serve many different purposes. In a superhet receiver, one oscillator, known as a local oscillator, forms an essential part of the frequency-changer or mixer stage, as we shall see in the next chapter.

If the superhet is a communications-type receiver, such as amateur and professional transmitting operators use for getting replies from other stations to their signals, the circuit may well include another oscillator, known as a bfo (beat-frequency oscillator).

The purpose of this oscillator is to 'heterodyne' incoming continuous-wave (cw) Morse signals and make them readable. The dots and dashes formed by keying the carrier-wave at the





transmitting station "beat" with the continuous oscillation from the bfo and thereby produce signals at an audible frequency.

The pitch of the beat-note, which is heard as audible dots and dashes, can be adjusted to a comfortable level for easy "reading" by tuning the bfo circuit.

Another use for the bfo is for resolving ssb (single sideband) radio telephony transmissions. In this case the bfo generates a local oscillation which replaces the carrier-wave of the transmission, suppressed at the sending end, and helps to restore intelligibility to the speech.

Without the bfo, ssb speech sounds more like a duck quacking than an operator speaking!

Apart from these applications in the receiver itself, transistor oscillators are very useful in test-equipment for alignment of tuned circuits, set-testing and troubleshooting, and such like purposes.

An r-f oscillator can be used as a radio-frequency signal generator which can take the place of broadcast signals for the purposes of tuned-circuit alignment and set adjustment.

To enable you to distinguish the signals from the r-f oscillator and pick them out among any other oscillations that may be present in the set, they can be modulated at audio frequency.

A second oscillator, working at af instead of rf, will superimpose an audible tone at a comfortable pitch on the output from the rf section of the signal-generator.

The type of oscillator known as a multivibrator is very useful as an audio-frequency signal-generator for test purposes of various kinds.

Multivibrators and other oscillators are widely used in all sorts of electronic equipment, including computers; but in the present book we are concerned only with the oscillators that are used in, or with, radio receiving equipment.

CHAPTER 4

# *Superhet Circuits*

In the previous chapter we looked at amplifiers and oscillators. Now we come to the superhet circuit, which is in a sense a combination of both. The frequency changer in a superhet acts as a radio frequency amplifier, but it also contains a local oscillator which generates an internal signal at a different frequency from that of the incoming broadcast.

In the frequency-changer or mixer stage, these two different signals are merged; but they still retain their individual existence up to a point. Therefore we have two different-frequency signals going into the mixer, and at the output we have a choice of several different products.

If we tuned to the frequency of the incoming broadcast, we should find it. If we tuned to the frequency of the local oscillator, that would be there too. If we tuned to a frequency which equalled the two added together (i.e., the sum of the two frequencies), we should find a signal bearing the same speech or music or other sound modulation as the original broadcast in the aerial circuit. If, finally, we tuned to a frequency arrived at by subtracting the one input frequency from the other, we should find yet another replica of the original modulated input.

Incidentally, the frequency of the oscillator can be arranged so that it is either a lot below, or a lot above, that of the aerial circuit. In many sets it is above, for reasons of convenience in design. But either arrangement can be made to work.

Now, in a superhet receiver we extract from the output of the frequency-changer or mixer one frequency only, which can be either the sum or the difference of the mixing process detailed above.

In other words, if the signal coming in from the broadcast station is on 300 kHz and the local oscillator is working on 755 kHz, the mixing process will give us two fresh frequencies, 755 + 300 or 755 − 300. If we choose the latter we have a fresh frequency of 455 kHz, which is known as the "intermediate frequency."

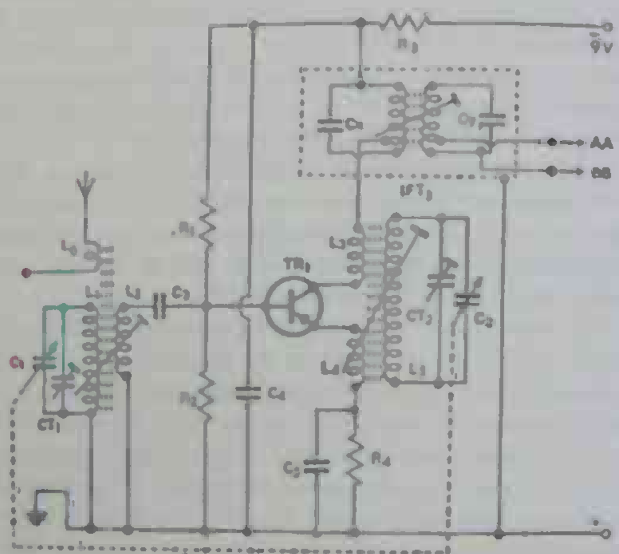


Fig. 4-1

If the signal is on 300 kHz and the local oscillation on 155 we can still obtain a 455 kHz i-f, but the tuning range of the oscillator section is going to be pretty hopeless to line up with that of the aerial section.

If we choose the sum of 755 and 300 we would have an i-f of 1055 kHz. 455 kHz is actually a standard i-f for which





ready-made i-f transformers are easily obtainable; 1055 is not. (But several different i-f standard frequencies *are* available, which can be arrived at by further juggling with the tuning.)

Returning to the practical aspects, Fig. 4-1 shows a simple type of transistorized frequency-changer. There are several other possible designs for f-c and mixer stages in a transistor set.

L0 is a small coupling coil on the ferrite rod which can be used for introducing signals from an external aerial, such as a car aerial or portable telescopic rod such as one sees on certain transistor sets, especially those with a short-wave range in addition to the usual long and medium wave facilities.

L1 is the principal tuning-coil for the input circuit of the frequency-changer. It will most probably take the form of a single-layer winding on the ferrite rod. If there are long-wave or short-wave ranges, these will be catered for by additional coils and the necessary wavechange switching arrangements.

L5 tunes the oscillator circuit, which is completed by the coupling-in of L3 and L4 in the collector and emitter circuits respectively.

L1 and L5 are tuned simultaneously by the two sections of a twin-gang tuning capacitor, C1/C2, with trimmer capacitors for fine alignment, CT1/CT2.

The transistor may be, say, an AF117 or an OC170, but there are various other suitable types for use in this position. The values of the various small components, such as resistors etc., will be chosen to suit the particular transistor in use. R1 should be not less than 10K and R2 not less than 2.7K. R3 and R4 can be around 1K.

IFT1 is the first i-f transformer. Probably this will be working on 455 kHZ; but other intermediate frequencies are also used in some receivers.

Some transistor i-f transformers have only one tuned winding, the other winding being untuned but arranged to match the input impedance of the next transistor. This can also be done by a tapping on the larger inductance needed for the tuned type of winding.

The i-f transformer will normally be enclosed in a metal screening-can, which is earthed. This is shown by the dotted lines surrounding IFT1 in Fig. 4-1. The screening has been omitted, for the sake of clarity, in Fig. 5-1 but will of course be normal design for IFT1 and IFT2 in this circuit also.

The capacitors Cx, Cy, etc., are not numbered because they are not normally included in a list of parts, since they are usually supplied ready-fitted inside the ift cans as an integral part of the i-f transformers.

The connections marked AA, BB in Fig. 4-1 correspond with those similarly marked in Fig. 5-1 (IFT1 is shown again in this diagram as it is really an integral part of the i-f amplifier though the primary winding is equally an essential part of the preceding stage (i.e., the frequency-changer).

There is hardly any basic difference between the circuit of a frequency-changer in a complete, self-contained transistor receiver, and the circuit of a superhet converter or adaptor for use with another MW/LW receiver to provide world-wide reception from short-wave stations.

A number of different circuits can be used for short-wave converter or adaptor units. It is mainly the tuning arrangements which differ. Some have quartz crystals for frequency-control in the local oscillator section.

The very simple arrangement shown in Fig. 4-1 but with smaller-capacity types for C1 and C2, will give quite good results, however, and even with this there is scope for experiment. Several variations on the basic theme are possible and worth trying. Bandspread tuning will be an advantage, substituting a small capacity twin-gang variable instead of the trimmers CT1 and CT2.

Any experimenting you do with circuits like this is an aid towards better understanding of more elaborate arrangements in factory-built receivers, and will help you to cope with these





when you go in for any repair work, servicing or maintenance on them.

Where tuned-circuit alignment is concerned, for instance, the effect of adjustments is more drastic on short waves and therefore more readily observable. Merely turning the ferrite core in or out of the coil-former of a short-wave winding, especially in the oscillator section, will shift the circuit through such a vast range of frequencies that the effect is much more noticeable than in the case, say, of a long-wave circuit.

A question which beginners may ask is: "Can modern integrated-circuit modules be used as a 'heart' for a short-wave adaptor or converter?"

Provided a suitable type of i-c module is selected, the answer is "Yes".

But various circuit modifications are necessary to suit the facilities provided by these modules, and beginners will find it more convenient to refer to an appropriate design giving full specification and constructional details for an i-c version of this circuit rather than to try and adapt the basic arrangement for separate or 'discrete' components shown herewith.

The integrated circuit in this, as in other applications, has the advantage of greater reliability as a rule. Moreover, it tends to cut out the need for experimenting in certain directions.

If, however, you *like* experimenting, you may prefer the separate-component versions of this circuit, and it is true that you can *learn* more from these as the necessary trial-and-error proceedings can be both interesting and informative.

CHAPTER 5

# *Intermediate-Frequency Amplifiers*

Although i-f amplifying stages are not, necessarily, an essential part of a superhet circuit as far as the theoretical principles of the arrangement are concerned, in actual practice you will hardly ever find a superhet receiver that does not incorporate at least one stage of i-f amplification. Often there are two, and sometimes three.

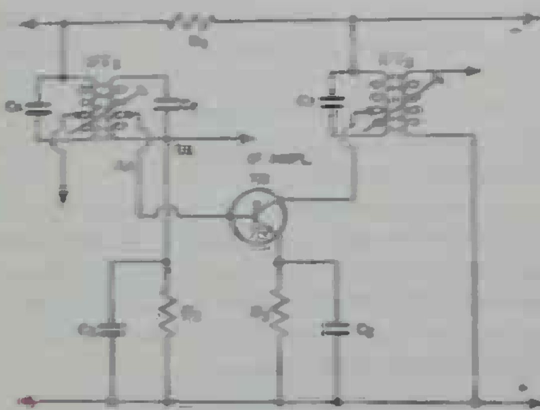

Fig. 5-1

Fig. 5-1 shows a very simple example of an i-f amplifying stage. The transistor (marked "IF AMPL. TR") will probably be an AF117 or some similar type. The first i-f transformer, IFT1, has tapped windings in the primary and secondary positions, with variable iron-dust cores for alignment adjusting, and small fixed capacitors, Cx and Cy, in parallel. (Since these capacitors are normally an integral part of the ift, and are not usually listed in a Parts List, they are not numbered in the diagram; nor is the third such capacitor, across the primary of IFT2, which is also a tapped winding.)

In this particular circuit, the secondary of IFT2 is not tapped, has no capacitor across it, and is of an impedance suitable for matching into the input circuit of the next transistor stage.

IFT1 and IFT2 will normally be almost totally enclosed in metal screening-cans, which are earthed. For the sake of clarity and simplicity, these cans are not shown in Fig. 5-1. In most circuit diagrams, they would be indicated by a rectangle of dotted lines all round them, connected to an earth symbol.

The respective intermediate frequencies used in ordinary a-m sets (for long, medium and short waves) and in vhf-fm sets are, obviously, widely different. 455 kHz and 10,700 kHz are typical. This enormous disparity is most fortunate as it can be put to good account in simplifying design of sets intended for both a-m and f-m reception.

Instead of having to switch in the appropriate ift for each system, all the ift's are wired permanently into circuit and the signals automatically select the right ift for the mode in use! In other words, the difference is so wide that the 455 kHz signals ignore the 10.7 MHz windings, and the 10.7 MHz signals ignore the 455 kHz windings.

The two sets of windings are joined in series.

The choice of intermediate-frequency transformers is quite wide in a number of respects.

First, you have a choice of ready-made or home-made types. For the latter, complete assemblies are available for a few shillings which comprise a screening-can, coil-former, base, "cup core" and screw-core. Another type comprises the can, iron-dust bobbin, screw-core, etc. Yet another, specially de-





signed for transistor receivers, comprises can, ferrite bobbin, ferrite shell, nylon housing, base with terminal-pins, etc.

Winding-data is available for different i-f frequencies in each case. The assemblies in the above-mentioned examples are a product of Neosid Limited.

Where ready-made i-f transformers are concerned, it is important to choose types that are expressly designed for transistor use. (In some circuits it is admittedly possible to use older types which were meant for valve sets, but usually some adaptation is needed and the transformers are bulkier than is desirable for transistor equipment in which miniaturization is a normal aim.)

Transformers are available for a number of different intermediate frequencies. 455 kHz is about the commonest one in the United States. But over here we have a wider choice, though we are gradually settling down to greater standardization in this respect. (Factory-built valve receivers of bygone years have used a great many different i-f's.)

Types available for the home constructor include 455 kHz, 1,620 kHz (often described as 1.6 MHz), and 10.7 MHz. The last-named is for VHF-FM receivers, as you will have gathered.

Although an i-f transformer is the most familiar inter-transistor device in an intermediate-frequency amplifier, there are other alternatives, the most important of which is the ceramic i-f filter.

This is a piezo-electric device, having some features more or less in common with the quartz-crystal used as a frequency controlling device in transmitter or other oscillators.

In a typical i-f amplifier using ceramic filters (such as the Brush Clevite "Transfilters"), there would be one of these between the frequency-changer or mixer and the first i-f transistor; another ceramic filter between the latter and the second i-f transistor; and a conventional i-f transformer between the last named and the detector stage.

At the time of writing, such filters are obtainable through certain retail mail order firms, etc., and are available in types designed for use at several intermediate frequencies—e.g., 455 kHz (the favourite one for American receivers), and 465 or 470 kHz (two commonly-used alternatives in British circuits).

Various set-designs employing this class of inter-transistor coupling in the i-f stages have appeared in the technical press from time to time.

The whole design of this part of the circuit has, of course, to be planned to suit the filters, if best results are to be obtained, since their principles of operation are, naturally, quite different from those of i-f transformers.



CHAPTER 6

# *Detectors and Discriminators*

Some sort of detector is normally an essential part of every radio receiving circuit.

Even the simplest sets incorporate a detector; in fact, the simplest of all is the crystal set or single diode receiver, or one-transistor receiver in which the solid-state detector is the only 'active' component in the circuit.

The function of a detector is to rectify the incoming signals,

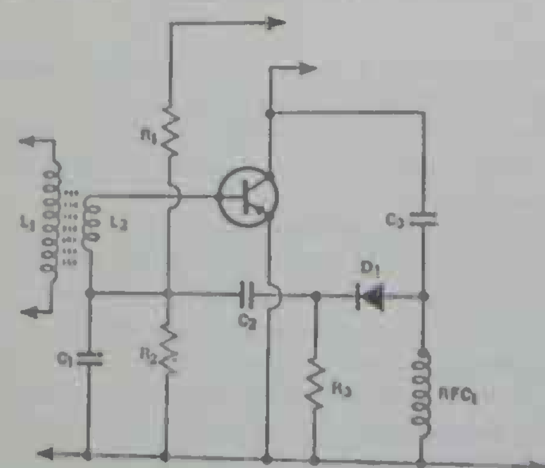


Fig. 6-1

or demodulate them, so that they will (after a-f amplification, except in the very simplest sets) be capable of actuating earphones or a loudspeaker.

In the first chapter we saw the simplest kind of radio de-

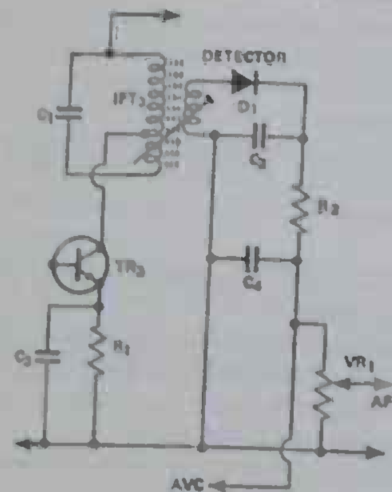


Fig. 6-2

tector circuit, using a single diode. In reflex circuits two arrangements are commonly used. Fig. 6-1 and Fig. 7-1 show these, the former with a single diode and the latter with a pair, which are normally of the same type though this is not absolutely essential.

Several different types of germanium diode are often specified for D1 and D2 in Fig. 7-1. Favourite ones include the OA81, OA91, and sometimes the OA85, or OA71. As with transistors, older types of diode are superceded by new ones, often smaller, which is a help in a miniaturized receiver.

The double diode circuit we have been discussing is a voltage-doubler arrangement. As already stated earlier on, in some reflex circuits only one diode is used, instead of the two that we find in the voltage-doubler.

The kind of demodulator used in a circuit depends very largely on whether it is to deal with amplitude-modulation (am) or frequency-modulation (fm) or both.

For a-m, an ordinary diode detector is usual in most cir-





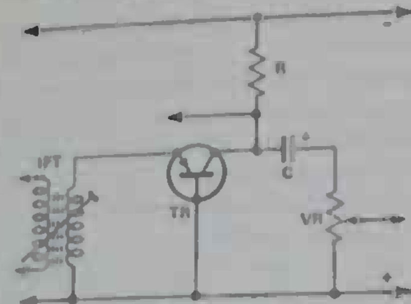


Fig. 6-3

cuits, Fig. 6-2 shows the detector stage of a typical a-m receiver designed for short, medium and long waves. If the set has two i-f amplifying stages, which is quite usual, there will be three i-f transformers, and the diode detector is placed, as you can see, in the secondary circuit of the third i-f transformer, marked "IFT3".

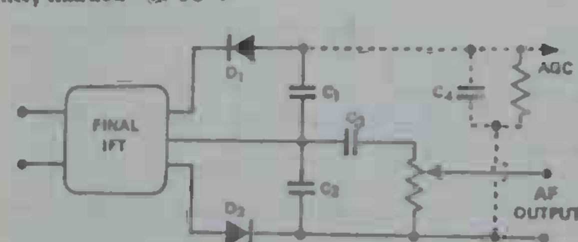


Fig. 6-4

In the particular circuit shown, automatic control of gain is provided by a line going back to the bottom end of the secondary winding of the first i-f transformer in the set. The audio signal developed across VR1, acting as volume-control, is fed to the base circuit of the first a-f amplifying stage. In a typical standard circuit this may be followed by a driver and push-pull pair of output transistors.

In less conventional circuits other arrangements may however be used.

Fig. 6-3 shows the main features of a *transistor* detector stage in a transistorized a-m superhet receiver. This is a very simple arrangement, but diode detection is more often used.

Frequency modulation involves the use of something a bit more elaborate. Diodes, usually a matched pair, are normally employed. Two commonly-used circuits for f-m demodulation are the ratio detector and some form of discriminator. Other methods are, however, possible.

Figs. 6-4 and 6-5 show, in greatly simplified form, the main features of these two systems. The final i-f transformer is shown in block form; within the rectangle marked "final IFT" there would be the usual primary and secondary windings of course, together with other small components. The secondaries are tapped, with perhaps a resistor leading out in the discriminator and an inductive winding leading out in the ratio detector.

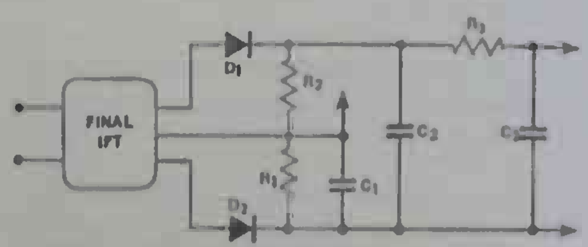


Fig. 6-5

In actual practice the circuitry of a typical receiver in these demodulator stages may well be a good deal more complex than is suggested by these over-simplified diagrams which are intended only to give you a rough idea of the basic arrangement. For servicing purposes you will of course use the proper receiver-manufacturer's circuit diagram appertaining to the actual set you are dealing with; and should you be constructing you would be well advised to refer to a fully-detailed design for this type of receiver.



CHAPTER 7

# *Reflex Circuits*

Reflex circuits are far from new. They were used by some constructors in the early days of broadcasting, when valves and components were neither plentiful nor cheap. Any circuit that would make one valve stage do the work of two was assured of popularity.

When valves and other components became less costly, more efficient and more plentiful, the reflex circuit went out of fashion, except for occasional use in some special receiver.

But when transistors came on the scene, the reflex circuit came back into widespread use again. Early transistors were not very cheap, not at all plentiful and not nearly as efficient as those of the present day. Therefore a circuit that would make one transistor do the work of two had a strong appeal to the constructor.

Although transistors are tiny compared with valves, even the space taken up by one extra transistor and its associated components is a material factor in an ultra-miniaturized set. Moreover, an ultra-miniature set, if it is to be completely self-contained, must have a very small ferrite aerial assembly and very tiny battery. The small aerial necessitates the use of a circuit with very high gain and amplification; and the small physical size of the battery tends (despite the great achievements of miniaturization in cells) to limit the permissible current consumption that is economically feasible.

These, and other, factors all favour the use of a reflex circuit. (About the only other alternative is a micro-miniature integrated-circuit module system.)

Reflexing enables an ultra-miniature receiver such as the Sinclair Micromatic (smaller than a matchbox, complete with built-in ferrite-rod aerial and a battery comprising two Mallory mercury cells) to incorporate a six-stage circuit while using only three transistors and two diodes.

The first two transistors provide two stages of r-f amplification, then the signals are rectified by the double-diode detector stage, and the resulting audio signals are reflexed back and passed through all three transistors now acting as a-f amplifying stages.

This type of circuit not only reduces the number of transistors required but also the number of associated components. The Micromatic provides a six-stage receiver with only 9 fixed resistors and 6 fixed capacitors. Thus reflexing effects a great reduction not only in the number of transistors but also in the number of other components required.

Not only are there fewer items to buy and assemble, but fewer also to test and replace if and when servicing is required.

Reflex circuits are admittedly a little more difficult to design than ordinary straight circuits, and some of them can be a bit tricky to get working properly. But, in the writer's opinion, the advantages of a reflex circuit far outweigh its drawbacks.

In a typical two-transistor reflex circuit, there are only two transistors and one or two diodes to replace in the event of accidental damage or breakdown. There are few associated resistors and capacitors to give possible trouble. There are fewer soldered joints. The whole thing is smaller, cheaper, easier and quicker to service. Current consumption is less, thus prolonging battery life, reducing the physical size of the necessary battery and lowering the running costs.

Fig. 7-1 shows one version of a popular reflex arrangement in which the reflexing action is confined to the first transistor stage. This may be followed by as many a-f amplifying stages as are necessary and practicable to give whatever standard of volume and quality you require.





The majority of published designs using some variation on this basic theme are described for medium-waveband only. This of course simplifies construction and eliminates the need for any wavechange switching. But this kind of circuit will work well over a very wide range of frequencies, given suitable transistors, and can therefore be designed for short and long as well as medium wavebands.

There is a great deal of scope for easy and fascinating

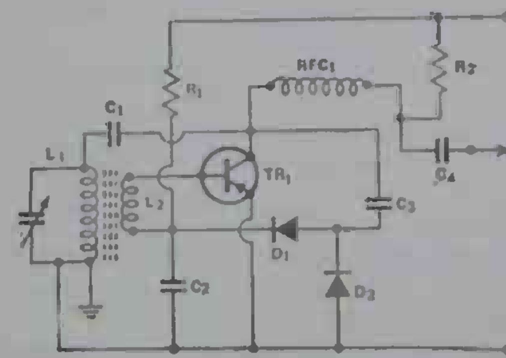


Fig. 7-1

experiments with different versions of the basic circuit shown in Fig. 7-1. It can be used as the first stage of a complete set incorporating a required number of a-f stages to give either headphone or loudspeaker reproduction as desired. Or it can be built as a self-contained unit forming a "front end" for use with a separate audio amplifier or with the a-f stages of an existing receiver.

Yet another application for this simple circuit is to use it as a miniature portable monitor receiver for short-range checking on an amateur transmitter. In this version it can be combined with a field-strength meter circuit.

If you look through past and current volumes of the various radio technical journals catering for home constructors, you will find a number of interesting practical designs based more or less on this fundamental circuit arrangement.

In some of these it is necessary to stick to a prescribed lay-out, while in others there is considerable latitude for experiment and experienced constructors will find it more interesting to plan their own variations on the designer's theme than to copy the suggested prototype version.

Beginners, however, would do better to start by following the published plan, even if they introduce modifications of their own at a later stage.

Apart from the conventional reflex arrangements which are variations on the basic circuit shown in Fig. 7-1, one or two unusual arrangements are possible for special purposes or for use in certain locations—for example, in areas of very high signal-strength.

One such design, published a few years ago, utilized a single a-f type transistor in a very unusual circuit which gave loud-speaker reception of the long-wave BBC station (now known as Radio 2) on 200 kHz.

This shows that there is a great deal of scope for experiment and research with fairly simple reflex circuits. Their possibilities are much greater than one might suppose from a superficial look at the basic arrangements.



CHAPTER 8

# *Short-Wave Adaptors or Converters*

Some transistors work very well in simple adaptor or converter units for short-wave reception.

These are add-on units which are used in conjunction with an ordinary medium-and-long-wave broadcast receiver. They enable you to hear short-wave stations from all over the world, without (necessarily) having to make any internal alterations to the existing broadcast receiver.

The add-on unit can have its own power-supply—a small transistor battery will generally be quite economical for this—and it can be detached from the big receiver in a moment when not required.

A number of different designs for short-wave add-on units of this class have been evolved over the years. Each has its own advantages and snags. Most of them work quite well, and will satisfy anyone who does not expect them to do the impossible by giving results comparable to those obtainable from a proper communications-type short-wave superheterodyne receiver.

The simplest short-wave adaptors can take two main forms. One is a reflex "front end" which can feed into the audio stages of a broadcast receiver, or indeed any kind of audio amplifier, such as that to be found in a record-player. The other is a single-transistor superhet circuit arranged to give an intermediate-frequency output within the broadcast wave-bands.

The latter unit can also be arranged, of course, to give an output on some standard i-f, such as the i-f amplifiers in an ordinary superhet work on. But this is likely to entail some difficulty in feeding into the main receiver, whereas the output in the broadcast bands covered by the ordinary set's aerial tuning circuit entails no difficulties of this sort, nor any alteration to the inside "works" of the big set.

Almost any normal transistor-type frequency-changer circuit can be altered or adapted to form an add-on short-wave unit. The arrangement shown in Fig. 8-1 is a simple and effective one which the writer has used successfully as an external adapter to get short-wave reception on several different broadcast receivers of the LW/MW-only class.

The chief difference between this circuit and the average frequency-changer, as found in a normal superhet receiver, is in the tuned circuit L5 and TC2. This is a medium-wave coil, either plain or ferrite-cored, which, when shunted with the trimmer capacitor TC2, will tune to a convenient frequency within the broadcast wavebands. This frequency should be chosen such that it comes on a spot that is normally unoccupied by any regular broadcast station, in other words, a reasonably clear spot.

The short-wave tuned circuits L2, VC1, TC1 and L3, VC2, VC3, must be so designed and aligned that they give the equivalent of an intermediate-frequency output on the frequency tuned by L5 and TC2. Some experimenting will be needed to find the right number of turns for L2 and L3, and the correct adjustment of TC1. Note that VC1 and VC2 are sections of a twin-gang tuning capacitor, preferably a short-wave type.

TC1 is a pre-set trimmer, while VC3 is a single-section bandspread capacitor for fine tuning. Of course, one could use a twin-gang bandspread capacitor for TC1 and VC3 (TC1 would then be better described as VC than TC1), but this would add a little to the cost and, as the oscillator tuning is more critical than the aerial or base circuit tuning, it is doubtful whether you would gain much by it.





If one is mainly interested in short-wave broadcasting rather than in amateur transmitters' signals, bandspreading may not be necessary if you are able to get hold of a really excellent slow-motion drive for VC1/VC2.

Several different transistors may give good results in this circuit, and the exact values of the various resistors (R1, 2 and 3) should be chosen to suit the transistor you select.

R1 and R2 form a voltage-divider across the power supply and the ratio of one to the other, rather than their actual value in ohms, determines the bias on the base of the tran-

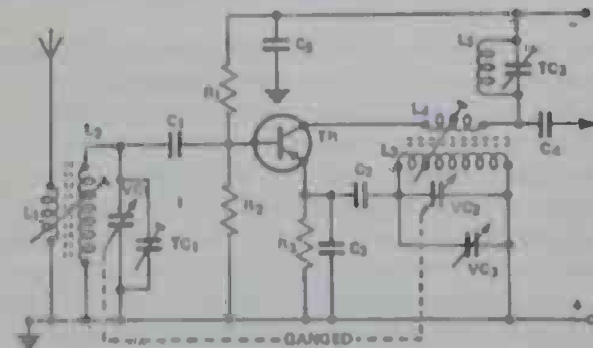


Fig. 8-1

sistor. Thus you will find, in different designs, a wide variation in the specified values for resistors in this position, but their ratio is usually similar regardless of their actual resistance.

For instance, you may find values specified for R1/R2 at say 56K/10K; 33K/6.8K; 15K/3.3K; or 10K/2.7K. R3 could be, say, 1K or more, up to perhaps 3.9K. Practical experimenting and checking current consumption with a milliammeter will help to ensure correct operating conditions for the transistor and optimum performance from the unit as a whole.

C1 and C2 can be, say, 47 or 50 pF silver mica. C2 and

C4 can be about 100 pF silver mica. C5 completes the list of fixed capacitors and can be 0.01 uF tubular paper or some equivalent type; the value here is not critical.

Transistors worth trying in this circuit include the AF115 (recommended by the manufacturers for use as a mixer-oscillator in short-wave a-m circuits), the AF117 (popular in ordinary broadcast transistor sets but also suitable for short waves), the AF125 (recommended for short-wave circuits), the OC44, the OC170 and the OC171.

The power supply voltage is not unduly critical and may be between about 3 and 9 volts; but the fixed resistors may need to be chosen accordingly.

Various modifications can be tried, involving different arrangements of the aerial/base circuit tuning and coupling coils. One could, for instance, use a separate coupling overwind for the transistor base circuit, and a similar one in the emitter circuit, coupling to the tuned oscillator winding.

Another arrangement sometimes used is an untuned coil in the L5 position, connected to flexible leads passing out of the converter case so that this coil can be loosely coupled to tuning coils in the ordinary broadcast receiver with which the converter is to be used. This inductive coupling is in place of the capacitive coupling otherwise provided by C4 in Fig. 8-1.

Apart from the circuits discussed here, there are various other kinds of adapter or converter which have been designed to provide the user of an ordinary broadcast set, or a car radio, with a means of listening to stations not normally receivable on that class of set.

A number of designs for the home construction of short-wave, vhf and uhf converters have been published in various books (including certain titles in the Foulsham-Sams list), and in radio technical journals.

Ready-made converters for certain wavebands are also obtainable from suppliers whose advertisements can be found in some of these journals.





As already stated in a previous chapter, certain types of integrated-circuit modules lend themselves to incorporation in frequency-changer and short-wave converter circuits. It is, however, essential to make sure that you select a really suitable module for this purpose, that you get all the connections right, and that the extra separate or discrete components needed to complete the circuit are also right for the job.

Therefore it is best to follow a complete design as already suggested earlier on. Such designs may be found in various journals, data leaflets, and so on from time to time.

See also the chapter on Integrated Circuits, in the present book.

Some short-wave converters have a transistor operating as a crystal oscillator and r-f mixer. A quartz frequency-control crystal (similar to that used in a transmitter) ensures stability and freedom from drift, on a chosen fixed frequency which is mixed with the incoming short-wave signal frequency. The crystal frequency is such that the output of the converter (at signal frequency minus crystal frequency) will come within the medium-wave band of 550-1600 kHz.

Tuning is carried out on the medium-wave receiver; when the converter is correctly set up between the latter and a suitable aerial, instead of the usual medium-wave stations, short-wave stations will be heard. Adjustable inductance-capacity filters may be inserted immediately after the aerial and ahead of the converter to prevent breakthrough of MW stations.

CHAPTER 9

# *Field-Effect Devices*

FET stands for Field Effect Transistor. Whether this device is accurately describable as a transistor has been questioned; but the initials fet are more often used than the full title anyway.

A fet looks like a transistor but in some ways it behaves more like a valve. For example, its input impedance is as high

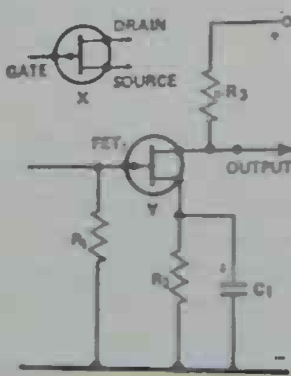


Fig. 9-1

as that of a valve; or even higher. In fact, it can be directly substituted for a valve with a minimum amount of alteration to the circuit, apart from changes inevitably in the power supplies.

The fet's power requirements are as modest as those of a transistor. So in many ways it combines the advantages of a transistor with those of a valve. A fet will do most of the things that a small triode valve will do; and can sometimes be substituted for more elaborate types of valve also.

The simplest type of fet has three electrodes, called source, gate and drain.

These are roughly equivalent to the emitter, base and collector respectively of a transistor; or to the cathode, grid and anode respectively of a triode valve.

Fig. 9-1 shows the circuit symbol used for a fet. Note that the part of the symbol denoting the gate has an arrow which may point inwards or outwards. The outward-pointing arrow is for a p-channel type of fet, and the inward-pointing arrow denotes an n-channel type.

These signs are rather similar to the ones in an ordinary transistor symbol, where the outward-pointing arrow denotes an n-*P*-n type of transistor and the inward-pointing arrow refers to a p-*N*-p type. But in the transistor it is the emitter which is represented by the arrow, whereas in the fet it is the gate which is so represented. This is perhaps a bit confusing.

Note that the polarity of the drain supply is positive for n-channel fet's and negative for p-channel fet's. Thus in Fig. 9-1 fet "X" is a p-channel type, and "Y" (FET 1) is an n-channel type. Therefore the drain of FET1 is connected via the drain resistor R3 to the battery positive line.

The partial circuit shown in Fig. 9-1, incidentally, is that of a simple audio amplifying stage.

If you ever happen to be looking through outdated back numbers of radio technical journals, you may come across an occasional design using a combination of transistors and battery-type valves in a "hybrid" circuit.

An idea worth considering, if you are interested in experimenting for experimenting's sake, would be to try adapting such a design into an updated version by substituting fets for the valves. In some cases this *might* enable you to get the advantages of both transistors and valves without the drawbacks of either! The writer has not tried this, however, and





the idea is just offered in passing on the chance that it might provide you with an interesting line of experiment sometime when you tire of more orthodox arrangements.

It would take a fair amount of working out, and is not recommended for beginners.

Returning to the subject of ordinary, everyday circuits, there are plenty of ways in which fets or their "descendants" can be used with considerable success.

Many designs and circuit arrangements can be found in books specializing in the subject of fet projects (see the Foulsham-Sams list of technical books for these), and in radio or electronic technical journals.

Favourite sources of supply for amateurs buying transistors etc. are mail-order firms which advertise some very genuine bargains at low prices. Naturally, the lowest-priced ranges often include types which have been on the market a long while and which the manufacturers have discontinued producing.

While they may be regarded as obsolete in the commercial sense, this does not necessarily mean that they are in any way inefficient (though they may lack certain advantages of types which have superceded them into current production). They may in fact provide a most useful and economical source of material for amateur experimenting.

But it is essential to remember that you may run into some problems if you try to adapt latest designs, planned around latest transistor-types, and use them with older transistors which may not work well in them—not through any actual defect in the transistors as such, but merely because there are features in the design which are dependent on characteristics found only in the more up-to-date transistor types.

This is just one instance of the many ways in which the technology of the so-simple-looking transistor is beset with problems that the beginner would never anticipate.

Some of these problems have no easy answer and you cannot take any "short cuts" around them. One thing, however, is certain, and that is—the more accurate and comprehensive technical data you can get hold of, the better. Manufacturers' literature appertaining to any devices you are using is a valuable help and should be studied carefully. It will help you not only to get good results but also to avoid damaging delicate semiconductors.

Elaborations of the original fet principle have resulted in the production of various more-sophisticated "descendants" of the plain, simple fet. IGFET, the insulated-gate fet, also known as MOSFET; JGFET, the junction-gate version; and so on.

Some of these are, at the present stage of development anyway, much more susceptible to inadvertent damage than the ordinary transistor or fet. Therefore careful precautions have to be taken to prevent this.

One procedure is to keep all the lead-out wires from the device short-circuited with a bare wire wrapped round them until the device is soldered into circuit. This prevents damage from stray electrostatic charges which may be picked up during storage. The bare wire must, obviously, be removed before connecting up power supplies and trying out the circuit.

It may be advisable to heat the soldering-iron to slightly above normal working temperature and unplug it from the mains before soldering the sensitive-type fet's into circuit, to avoid any charges that may be picked up from the a-c mains if the metal body of the iron is not quite near enough to true earth potential.



CHAPTER 10

# Integrated Circuits

More and more integrated-circuit devices are becoming available to the home constructor in various forms.

The first ones to become available in the amateur market had more limited possibilities than those that followed later. Now, the latest types have a specification so fantastic that it reads more like science fiction than the solid fact that it is!

It is almost impossible to visualize a ten-watt audio amplifier containing 16 active and 18 passive devices in a silicon chip only a twentieth of an inch square! But that is what you get in one monolithic i-c "package" (the IC-10 by Sinclair Radionics of Cambridge).

Although primarily designed as an audio amplifier, the "front end" transistors formed in this chip have characteristics which enable them to be used as r-f or i-f amplifiers, so you can build this module into a complete receiver without using any extra transistors or diodes.

At the present stage of development, there is a strict limit to the different devices that can be incorporated in the silicon chip which forms the heart of an integrated circuit module. Therefore it is necessary to complete the assembly of a whole set or whole amplifier by adding a few separate or discrete components of conventional design externally.

This does not necessarily detract from the advantage of using an integrated circuit, except in so far as it adds to the overall bulk and weight of the complete assembly. In fact, far from detracting it may actually be an asset in some ways, as it allows of greater flexibility than would be possible with an all-integrated arrangement to which you could add nothing of your own choice.

As the majority of integrated circuits at present are based on designs for commercial use in computers etc., the amateur must choose carefully to make sure that a particular module is adaptable to his needs in producing home-constructed projects.

Some of the most suitable integrated-circuit modules come complete with full instructions and details of applications and circuits. There is hardly any point, therefore, in giving such details here, as they could be set out only in a very general way and would not be particularly helpful when you wanted to use a particular module by a given manufacturer. As it is most essential to add all external circuitry correctly, only the makers' instructions should be followed.

As an alternative to the circuit information issued by the actual manufacturers or suppliers, you could of course try one or other of the various interesting designs for amplifiers and similar projects which appear from time to time in the technical journals devoted to radio and electronics.

When i-c's first became available for amateur use, such articles were few and far between, but with the increase in the variety and availability of i-c devices, more and more designs incorporating them are being published.

The use of i-c's certainly simplifies construction (as well as reducing bulk, weight, etc.), and in this respect they have a strong appeal for beginners; but it is important to follow exactly the designer's instructions and to realize that those instructions may apply only to the particular i-c model that is specified in the Parts List.

Any attempt to combine different designs, or use other devices than those actually specified, should be avoided by a beginner or anyone who is not completely conversant with integrated circuits.

Since a good many of these modules or devices are, at present, intended in the first place for industrial or commercial





use, their suitability for amateur projects is apt to be dependent on ingenious adaptation rather than initial design, in some cases at least; and this may be difficult for anyone who is not entirely at home with them.

Some integrated circuit modules are expressly suitable for radio receiver construction. Where these are concerned, of course, it is not a matter of adaptation but of straightforward use in conjunction with a suitable selection of "discrete" components connected in accordance with an appropriate design.

One such device currently available at the time of writing is the TAD100 by Mullards. This is a silicon type i-c and is suitable for amplitude-modulated receivers; but the "front" half of it can be used for 10.7 MHz intermediate-frequency amplification in a vhf-fm receiver also if desired.

The arrangement of the TAD100 is such that it forms the "heart" of several stages in an a-m receiver; i.e., the mixer, oscillator, i-f amplifier and audio preamplifier, together with automatic gain control circuitry.

This particular unit does not include audio output transistors, so you can make your own choice of transistors for the "final", according to what audio power etc. you require, and also according to what battery or mains-unit facilities you have available.

Any data you can get hold of from suppliers or manufacturers of integrated circuits is well worth collecting, for future use in any projects you may decide to experiment with, as of course it is most important to possess accurate detailed information about the circuitry and connections of any module before you attempt to use it.

A good many firms are now engaged in the manufacture, distribution and retailing of integrated circuit devices. The number of such concerns is likely to increase steadily in the future, and therefore it would be no use to attempt to give an exhaustive list here. It would probably be far from complete by the time you read these lines.

It may, however, be of some help to mention a few typical examples of businesses that are currently concerned with handling these devices.

On the manufacturing side, names that come to mind include Mullard, Plessey, Sinclair, General Avionic Associates, RCA, Fairchild, Motorola, General Electric, etc. Some of these firms are American in origin but their products are available over here.

On the distributing or retail sides, more and more firms are likely to be carrying stocks, and therefore a comprehensive list cannot be attempted here.

But, again, it may be helpful to mention a few typical suppliers to whom enquiries may be addressed. Stocks are constantly changing, of course, and up-to-date information should be obtained in every case. Current advertisements in radio technical journals should be consulted to verify locations in case there has been any change of address since these lines were written.

General Electric i-c units: enquire from Jermyn Industries, Vestry Estate, Sevenoaks, Kent.

Mullard, Plessey, etc. i-c's: LST Components, 7 Coptfold Road, Brentwood, Essex.

Lasky's Radio Limited, 3-15, Cavell Street, Tower Hamlets, London, E. 1.

Sinclair, etc., G. W. Smith & Co. (Radio) Limited, 3 and 34, Lisle Street, London, W.C.2.

Fairchild, General Electric, Mullard, Motorola, RCA etc. A. Marshall & Son, 28 Cricklewood Broadway, London, N.W.2.

General Avionics: Dart Electronics, P.O. Box No. 47, Witham, Essex.

Peak Sound (Harrow) Ltd., 32 St. Judes Road, Englefield Green, Egham, Surrey.

Kinver Electronics Ltd., Stone Lane, Kinver, Stourbridge, Worcestershire.



CHAPTER II

# *Testing Before Building*

Most constructors, having selected a circuit and made up their minds to build some project or other, are probably so eager to begin actual construction that they can hardly wait for the soldering-iron to heat up!

The idea of stopping to test every single component in the Parts List before attempting to use it in the new set is decidedly unattractive because it involves a little delay.

But the delay involved in such preliminary testing is time well spent and is negligible compared with the hours that can be wasted afterwards in the exasperating task of trying to find and cure some elusive fault in the completed set, if it fails to work in the way that it should, after completion.

Although one can invariably succeed in getting transistor projects to work very well eventually, complete silence or poor results at the first attempt seems to be an experience that is by no means uncommon.

One often reads, or hears, complaints that transistor projects attempted by various home-constructors have failed to work on completion.

There are several possible explanations of such failures. But one thing is certain: the risk of failure can be minimized by simply testing each component separately before assembling into circuit.

*In situ* testing of components in a completed project is often very difficult and unless one has extremely accurate and advanced test equipment, the results may be misleading to say the least.

But the majority of components can be tested separately, before use, with very little difficulty and often with simple, inexpensive test-gear.

A reasonably accurate volt-ohm-milliammeter will suffice to test components for most of the circuits discussed in the present book.

If you establish that every component is in good order before you start building the project, and it subsequently fails to work on completion, you can be pretty sure that the cause of failure is either a mistake in connections or damage due to overheating in the course of soldering.

But if you build a set with untested components, you cannot tell whether failure is due to the two causes just mentioned, or to a multiplicity of possible faults in anything from a dozen to a hundred components, according to the complexity of the set.

Even brand-new, unused components are occasionally faulty. This may be from a variety of causes: defective material, faulty workmanship, damage in transit, damage in storage, careless handling and so on.

Such components, if under guarantee, are much more likely to be replaced without question by the supplier if you are able to point out the defect in the component as received from him, rather than after it has been soldered into circuit, tried out, found faulty, unsoldered and returned.

In the case of secondhand, salvaged, ex-Government or manufacturers' surplus components, preliminary testing is always strongly advisable. Many such items turn out to be in perfect condition (even if they have been stored for years); but to build them into a set without bothering to check their condition beforehand is certainly asking for trouble.

When one considers that a minor fault in one trivial component can result in a complete set being reduced to silence, the importance of testing every single item is obvious.

Sometimes one reads or hears of an individual constructor





having a succession of failures with transistor equipment. One cannot help feeling that the most probable explanation of this is the re-use over and over again of one particular item which, unknown to the constructor, is faulty.

He probably tests all the more important and complicated items in the set, but when it comes to some very simple, straightforward part such as a connector or a very elementary switch, he assumes that it is in working order. If it isn't, and he re-uses it again and again, then he will get a succession of failures.

Proper systematic testing of the finished circuit should of course enable one to pinpoint a fault of this kind; but in any case it is far easier to test the components separately out of the set than to do so once they have been soldered into circuit.

In the latter condition, it is only too easy to get false or misleading meter indications due to components being shunted by other parts which provide a parallel current-path, thus upsetting the accuracy of, say, an ohmmeter reading.

Where, for example, you have a fixed capacitor and a fixed resistor in parallel, it is almost impossible to tell, from *in situ* testing with an ohmmeter, whether the resistor is slightly off nominal value, or whether the capacitor is seriously leaky. But if you tested each component separately with the same meter, before set-assembly, you could tell at a glance where the fault lay.

In troubleshooting a set that is brought to you for repair, it is quite impracticable to disconnect each individual component for test, and you will be obliged to do most of your preliminary diagnosing with the components *in situ*. Having formed a rough idea of whereabouts the fault or faults must be located, you can disconnect any component that is strongly suspect, and test it out of circuit.

But when you are building a set from scratch, it is far better and quicker to test each component separately by itself, before you attempt to connect it into circuit.

How should you test individual components; and what faults should you look for?

The method and scope of the tests must depend on what test-gear you have available. You should carry out as many as possible of the following tests:

For fixed resistors: check the actual resistance-value in ohms of the resistance element. See that there is no visible external damage to the component. If it is a re-used part, look for any signs of it having been overheated in use—i.e., discolouration, scorching, molten wax, etc.

For variable resistors (potentiometers, volume controls, tone controls, etc.): check the resistance-value of the element. Examine for any signs of mechanical defects, physical damage, corrosion or dirt in the spindle-bearing; etc. Connecting the ohmmeter between one end of the resistance element and the slider, notice whether the change in resistance as the control is rotated is smooth and steady or erratic and jerky (shown by the meter needle flickering instead of moving steadily across the scale).

For variable capacitors, use ohmmeter to check for short-circuits between fixed and moving vanes as the control is rotated. Hold component up to light (if it is an air-spaced type) and see if there are any specks of dust, powdered metal, etc., between the rotor and stator vanes. Check the contact to the rotor and see if the spindle-bearing and ball-race are clean and adequately lubricated.

For fixed capacitors: measure capacity if suitable equipment is available; check for leakage or short-circuiting by using ohmmeter; look for any physical damage, signs of overheating, etc.

Verify polarity of transistors, diodes and other semiconductors. Be careful not to carry out any tests of a kind which might cause any damage to the components under test. In the case of very sensitive semiconductors, such as certain types of





fet, it might be better to avoid testing unless you have good reason to believe the component is faulty.

Even if the transistors etc. are eventually going to be soldered into circuit, in the preliminary stages of construction —i.e., up to the point where the first "trial run" is carried out—it may be best to use transistor holders, so as to rule out any possibility of overheating through soldering.

Continuing with the methods of testing components:—

For transformers, check the windings for continuity and d-c resistance; check for insulation; examine for any sign of physical damage; and if any means is available to do so, check for shorted turns.

For r-f and a-f chokes, and for coils, the procedure is similar.

For switches; check for contact, smooth movement, and correct mechanical operation. Check insulation on wavechange switches and mains switches. Check speed of operation on quick-make-and-break types.

CHAPTER 12

# *Experimenting and Designing*

A beginner is well advised to follow the instructions in published designs for transistor projects rather than attempt to initiate designs of his own.

How far it is possible to duplicate the results obtained by the designer of a published circuit with his own prototype will depend a great deal on the type of set and on the quality of the components and transistors you use in your own copy.

Some circuits are not particularly critical and allow considerable latitude both in the characteristics of the transistors used and in the tolerances of the associated components.

Others, however, are critical in both respects. Reflex circuits sometimes come within this category; and they can also be tricky in regard to layout.

In dealing with a tricky or critical circuit, you may have to do quite a bit of experimenting and re-designing before you achieve results that are one hundred per cent successful. This calls for quite a lot of patience and, if you realize beforehand that a circuit is likely to prove at all tricky, it will probably be best to hook it up roughly for a preliminary test before attempting to finalize the construction in permanent form.

One word of warning, though: do not hook it up *too* roughly, or you may find the result is a case of "more haste, less speed." If the wiring or connections are made carelessly, poor contact may give misleadingly impaired results, or short-circuits may cause costly damage to expensive transistors etc.

Some designers have stated that they have found greater discrepancies in performance between individual samples of a given type of transistor than they have found between different types of transistor!

So you can well appreciate, from this, the difficulty of exactly duplicating the performance of a designer's original prototype even if you use the transistor types specified.

But, fortunately, the difficulty can often be overcome to a great extent by adjusting the bias etc. on the transistor to compensate as far as possible for individual differences.

In making any alterations to your version of a designer's circuit, however, it is vitally important to make sure that you do not exceed the maximum voltage or current ratings laid down for the particular transistors you are using. You will find these figures in the manufacturers' technical literature or in the data given in various published transistor lists.

Perhaps the safest plan is to use variable resistors in series with fixed ones for any experimental changes in bias etc. The fixed resistor should be chosen such that it will prevent a voltage or current rise above the recommended maximum. Adjustment to an optimum value below that maximum can then be made by simply turning the control-knob of a variable resistor joined in series with the fixed one.

If you watch the resulting current-changes on a suitable test meter you should be able to arrive at a setting which will give best results without hazarding the transistor in any way.

When you have found the correct setting of the variable resistor, you can disconnect the battery supply, and use the ohms range of your multimeter to measure as accurately as possible the total resistance of the fixed resistor plus the portion of the variable resistor track which is actually in circuit. The resultant figure will give you a guide in choosing a suitable fixed resistor to replace permanently the temporary combination of fixed and variable ones.

If you cannot get a single fixed resistor accurate enough to serve the purpose, you can build up the required value by joining two resistors in series, checking the result with the





meter before making the final choice and wiring the components into the circuit.

In designing and experimenting, it is important to remember that certain factors in a set tend to be interdependent. Altering the value of one component may necessitate changing the value of another one as well.

One of the tricky things about experimenting with transistors is the fact that, although modern semiconductors are very robust in some respects, they are easily damaged in others. Moreover, damage or destruction can occur almost instantaneously. So take care not to let the transistor or diode overheat either through excessive current or through excessive heat from a soldering-iron.

Often it is the length of time the iron is applied, or the absence of a proper heatsink, which does more damage than the actual temperature of the iron. A small, hot, clean, well-tinned bit, applied briefly, may be much safer for the transistor than a larger, cooler, badly-tinned bit held on the connection too long.

Gripping the transistor leads with a pair of fine-nosed pliers will usually serve as a heat-sink to conduct away any excess heat in the soldering-process. It is necessary to apply the heat-sink between the point of contact with the hot iron (or "bit") and the body of the transistor.

With very sensitive devices, notably some types of fet, special precautions have to be taken when soldering.

Special miniature loudspeakers are avilable for use in very small personal-portable transistor sets.

Although some of these give surprising volume in view of their size, and also reproduce speech very clearly, they overload if the volume exceeds a moderate level and their reproduction of music is decidedly limited in tone and quality.

If one wants really good-quality reproduction combined with ample volume a much larger speaker is necessary, and something in the nature of a baffle. Obviously this means that the overall dimensions of the cabinet will put the set right out of the pocket-size category; and the bigger speaker will also tend to be a good deal heavier, making the set a little less easily portable.

Can you combine miniature size, powerful volume, light weight and excellent quality in one transistor set? At first glance this would seem to be impossible; but a possible solution to the problem is to use a miniature set for use when a self-contained portable is required, but to provide facilities for linking it to a separate extension speaker when the set is in use indoors. The latter speaker can be almost any size you like, within reason, and can be in a properly-designed cabinet which will bring out the full tonal quality of the speaker-unit, including adequate bass response.

Of course, a miniature portable has rather severe limitations as regards volume and quality; it is not exactly in the hi-fi class anyway. But it is nothing like as bad as the tiny built-in speaker tends to make it sound!

Provided that the extension speaker is correctly matched to the output circuit of the little set, you will probably be astonished at the vast improvement in volume and tone, especially tone, which results simply from the use of a decent-sized speaker.

Various developments of this idea can be tried out experimentally. For instance, it might be worth trying the effect of a separate push-pull output stage built into the extension speaker cabinet and provided with a separate battery for power supply. It may be most convenient to use transformer coupling between the small set and the outboard push-pull "final," but the output to the speaker can be a transformerless arrangement if preferred.

Various different configurations can be used as the basis for this add-on output stage feeding the big speaker.

The various stages of a typical superhet have been discussed individually earlier on. To give beginners some idea of how





these individual building-blocks fit into the complete circuit, Fig. 12-1 shows their relative positions and the main signal-paths etc. between them.

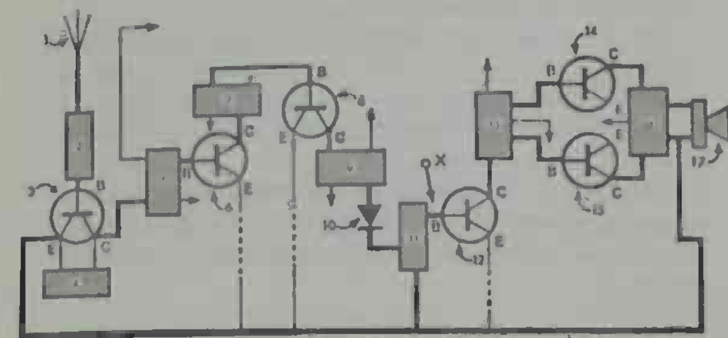


Fig. 12-1

This is a greatly simplified block diagram, from which much wiring, many components and a good deal of detail will be seen to have been omitted, for the sake of simplicity.

The usual arrow-heads denoting the polarity of the transistors—PNP or NPN—have been intentionally left out of this diagram, as the information contained in this drawing is common to either class of transistor. Battery or power supply unit details have also been omitted.

The following items are shown:

1, aerial (if used); 2, ferrite rod aerial or aerial tuning coil; 3, mixer or frequency-changer transistor; 4, oscillator coils; 5, first i-f transformer; 6, first i-f transistor; 7, second i-f transformer; 8, second i-f transistor; 9, third i-f transformer; 10, diode detector; 11, volume control for audio amplifier; 12, driver transistor; 13, push-pull input transformer; 14 and 15, matched pair of output transistors in push-pull configuration; 16, push-pull output transformer; and 17, loudspeaker.

Transformer 13 has a centre-tapped secondary winding, and transformer 16 has a centre-tapped primary winding.

There will probably be a pre-amplifier stage interposed at point "X" in the diagram—i.e., between the volume-control and the base of the driver transistor.

In planning your own designs, studying published projects, and servicing existing receivers, you will need to know the three commonly-used circuit configurations known as grounded, or common, base, grounded or common emitter and grounded or common collector.

Each consists of an input circuit, output or load, and a grounded element that is common to both the input and output. The common element may be either directly or indirectly grounded.

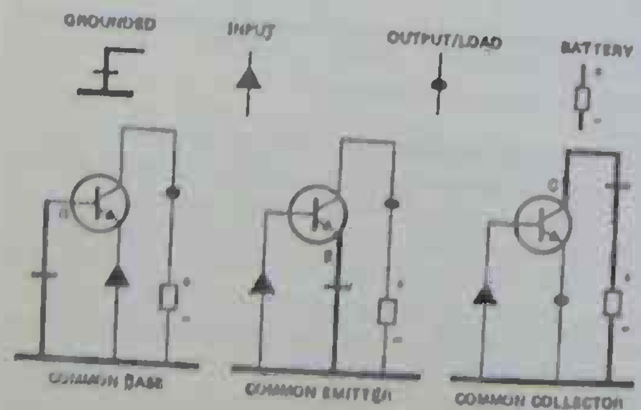


Fig. 12-2

Fig. 12-2 may help you to visualize and remember the chief features of these three configurations. (Note that the symbols denoting grounded, input, output or load and battery in this diagram are NOT accepted conventional symbols but are purely impromptu ones invented on the spur of the moment to aid in the understanding of this particular drawing!)





With grounded base, the emitter becomes the input circuit and the collector the output circuit. Incidentally, the transistor detector in Fig. 6-3 is in the grounded base mode.

Grounded emitter is the most popular mode for most purposes. Broadly speaking it gives more power gain than the other modes. Grounded base comes next and grounded collector lowest; but the latter is useful for impedance-changing. Grounded base is useful in high-frequency circuits, in which it performs well and has a high cut-off frequency, but it has limitations in that it must be combined with another mode, say grounded emitter, where more than one stage of amplification is used. A grounded collector stage can act sometimes as a substitute for a transformer.

CHAPTER 13

# *Construction Techniques*

Modern factory-built transistor sets mostly employ printed-circuit (etched-circuit) boards, except for portions of the assembly where integrated-circuit modules are inserted. Metalwork may also be present where earthed screening, or heat dissipation, is necessary.

The home constructor, not being concerned with any sort of mass production, has a wider choice of techniques. He can build a set in any way he fancies, to suit his own individual requirements.

Also, curiously enough, he may have a freer hand where cost is concerned, because he is not competing with other producers, and the way he distributes his expenditure over different parts of the set is entirely up to him.

Thus he can cut costs on certain items—say, by using ex-Government surplus, manufacturers' surplus, secondhand parts, or even sheer junk—in sections of the circuit where quality is not a vital factor.

This may enable him to spend almost extravagantly on the few items that are really crucial in determining the performance of the set, while still keeping the overall total outlay within his means.

In some critical circuits, one or two of the transistors themselves may be examples of items on which it pays to be rather extravagant in making sure that you get really good samples.

In nearly all circuits that are to be used for musical reproduction, the loudspeaker is an item which can entirely spoil results if a "cheap and nasty" specimen is used. The only exception to the rule of getting the best you can afford is in the case of a set which is to be used solely for Morse code reception.

In a short-wave receiver or adapter/converter, a really good slow-motion dial is a necessity (unless you have very good bandspread with direct control).

Of course, even in non-critical parts of the circuit, it is essential to make sure no actually defective components are employed. A set may work perfectly with parts that are old and battered, though electrically sound; but a single *defective* component (even if it is new and unused) can stop the whole circuit working.

Never use components of doubtful quality in power supply units which have to cope with mains voltages.

Turning now to actual assembly and construction methods, the home constructor can choose between following the conventional techniques used by manufacturers (which are doubtless ideal for factory mass-production requirements) and trying out some very unconventional ideas that lend themselves to "one-off" prototypes.

One method that the writer likes, and has found very efficient indeed for small assemblies, or for sub-assemblies in larger sets, is a skeletonized construction. In this, the small components are entirely self-supported by their own wire-ends or leadouts.

This sounds a flimsy method of construction which one might suppose would lack rigidity. But if properly done, it is surprisingly rigid and not unrobust at all. The complete network, when finished and tested, can be finally mounted on a rigid insulating base of paxolin or Veroboard or other insulating material. If screening is desirable, plain printed-circuit board copper-clad on the underside can be used, the copper cladding being, of course, connected to the earth-line of the circuitry.





An example of skeletonized construction is shown in Fig. 13-1. (This is a simple reflex circuit employing two transistors which the writer has used successfully.) For the sake of clarity the whole assembly has been drawn in an open form, to show all joints etc., but in actual practice it can be made *much* more compact. Components can be mounted as close together as you like, provided you do not overdo it to the extent where unwanted interaction, or any risk of short-circuiting, may occur.

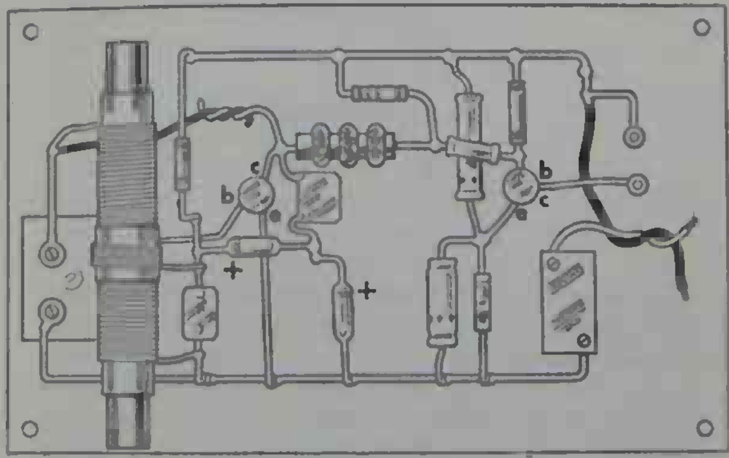


Fig. 13-1

Wires are thoroughly cleaned, joined by wrapping or winding around one another as shown, enlarged, in Fig. 13-2, and finally connected by a touch of solder.

The assembly can be tried out, if desired, before the wrap-around joints are completed by soldering. Contact will be quite good enough for preliminary experimenting and for making sure that the set is working perfectly. If results come fully up to expectations, all you have to do to finalize the job is to touch each joint briefly with resin-cored solder of radio and TV quality, and a well-heated soldering-iron.

Be sure to use heat-sinks to protect each diode, transistor or other heat-sensitive components such as tiny resistors which could be damaged, or change their value, under excessive heat. Spring-loaded tweezers or some similar arrangement clipped on the wire between the soldering-bit and the heat-sensitive components will serve to conduct the heat away.

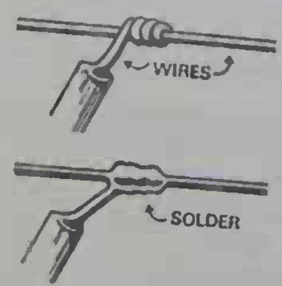


Fig. 13-2

Advantages of the skeletonized method is that components self-supporting in air are freed from unnecessary solid-dielectric losses, and from stray capacities due to conductors running parallel and close together. Testing components *in situ* is greatly facilitated, because you can see and reach every wire, joint and component instantly. You don't have to trace out roundabout conducting paths as in an etched circuit.

As for layout, in most cases this can follow the schematic circuit diagram almost exactly. In the old days of valve sets and big, clumsy components, any attempt to base a practical layout on a theoretical schematic diagram was almost impossible, and if you persisted in attempting it you would end up with a very bulky, untidy and unwieldy set.

But with transistors, solid-state diodes and miniature or even sub-miniature components, instead of the component being many times as big as its circuit-symbol, the reverse may easily





be the case. In the average circuit diagram of to-day, the symbols are often considerably larger than the actual components they represent, unless the diagram is reproduced so minutely as to be more or less illegible!

Therefore you will usually find that the various items can be laid out on the actual schematic and wired up in the relative positions that their symbols occupy in the drawing. If desired, the items can even be closed up into more compact grouping still, to save space where this can be done without detriment.

For those who prefer to use more conventional methods, such as printed circuit boards, Veroboard, Cir-kit, etc., it will be necessary to translate the theoretical circuit diagram into a practical layout which will permit all of the conducting connectors being in one plane, more or less, except where cross-overs can be tolerated by the use of jumper-wires or (for Cir-kit) slips of insulating material between the cross-over conductors.

While printed-circuit methods are ideal for factory-built sets, and useful also for permanent final assemblies of home-made projects, other methods are preferable for purely experimental layouts in which one wants to keep changing the components and their relative positions.

For tentative experiments of this kind, some ingenious "breadboard" systems have been devised. Some are in the amateur improvised category, and some are commercially-produced for sale by mail-order firms and other suppliers. Details will be found in advertisements or catalogues which should be consulted for the latest information on these products.

In mounting transistors, say on printed-circuit boards, do not bend the leadouts too close to the seal. The manufacturers usually recommend keeping at least 1.5 mm. straight; but the writer prefers to allow about 4 or 5 mm. if possible, as he has found that this gives a greater margin of safety against breaking the seal or even breaking the leadouts off right against the seal if the transistor is accidentally knocked at any time. In fact, he finds that the longer the leads can be left, the less risk of such damage there will be.

If the leadouts are of any appreciable length, however, they should be sleeved with thin plastic sleeving to prevent risk of accidental shorting.

Unlike valves, transistors and other solid-state devices can be mounted in any desired position—upright, sideways, even upside down. About the only restricting factors are the space available and the question of adequate heat dissipation. You may have to allow much more space for essential heatsinks than for the transistors themselves.



CHAPTER 14

# *VHF Transistor Receivers*

Some notes on simple transistor receivers for use on very high frequencies, such as the 2 and 4 metre amateur wavebands, BBC f-m broadcasts in Band II, etc., may be of interest to some experimenters.

The construction of receivers for such high frequencies presents a number of practical problems and difficulties not met with to any appreciable extent in tackling sets intended for use on much lower frequencies.

Therefore vhf receiver construction is not a task that a beginner can be recommended to attempt. It is better to make a start on something easier, and postpone vhf work until you get more experience.

Very skilful soldering is required in vhf circuits, because wiring must be virtually eliminated; connections have to be so short that they are almost non-existent; components must be soldered into circuit with negligible amounts of wire between them; and at the same time this must be done without overheating any heat-sensitive parts such as small resistors, diodes, transistors and so on. If you succeed in getting first-rate results the work will have been very worthwhile, but unless you have plenty of skill, dexterity, patience and technical knowledge, you are more likely to end up with a set that fails to work at all.

One thing that is important in vhf construction, and is also helpful though less essential in ordinary short-wave sets, is to connect all earth-returns in a given r-f, f-c or detector stage to one common earthing point, and not to random points on the chassis.

The correct choice of transistors is also vital. Alloy diffused types are available which work very well on these very high frequencies.

Field-effect devices are also available which will work on these frequencies. For example, the MPF102.

Be careful about the connections to the lead-outs of this device. Some retailers have inadvertently issued incorrect data about his particular type, which has caused quite a lot of confusion, with the result that constructors have wasted much time in trying to get the MPF102 to work with the connections wrong, and probably damaged the device into the bargain.

Other transistors etc. are occasionally sent out wrongly marked or with misleading data leaflets, through trade errors. So always bear this possibility in mind if a new purchase won't work.

A simple superregenerative receiver is perhaps a good project for a newcomer to vhf construction to start with; and it is possible to get a kit of parts for this.

Ready-made transistor receivers are available which in some instances offer other vhf wavebands as well as those used for broadcast programme transmissions.

The best and most versatile of these sets are, necessarily, rather more costly than those with more limited facilities.

Various designs for vhf and uhf projects have appeared from time to time in the radio technical journals; a useful source of information on amateur-band apparatus for use on these frequencies is "Radio Communication," the official journal of the Radio Society of Great Britian. Anyone seriously interested in short wave transmission and reception would be well advised to become a member of the RSGB. Particulars of subscription, etc., are available on application to the Society headquarters in London.

The address is now as follows:—

RSGB Headquarters, 35 Doughty Street, London, W.C.1.



CHAPTER 15

# Tuned Circuit Alignment

Correct alignment of tuned circuits is essential for best results in any superhet receiver. In a transistor model, accurate re-alignment during servicing may be even more vital than in the case of a valve model.

Replacing faulty valves with new ones of the same type may not necessarily entail any drastic realignment of the tuned circuits. The characteristics of the replacement valve may well be so similar to those of the original that there may be hardly any difference in stray interelectrode capacities etc., and the tuning of associated circuits may not be upset at all by the change.

Transistors, however, tend to differ much more than valves, and one often finds that realignment is essential after fitting new transistors in certain stages if one is to get optimum results.

So the importance of alignment where transistor sets of the superhet class are concerned will be obvious.

Realigning an ordinary a-m type of transistor set is usually quite easy and can be carried out successfully with fairly inexpensive, elementary equipment. A reasonably accurate a-m signal-generator covering the r-f and i-f frequencies involved in the circuit, and a suitable testmeter, should be enough to enable alignment or realignment to be carried out.

Realigning a transistor set which includes vhf-fm facilities is quite a different matter. This is not a task to be tackled lightly unless you have adequate experience and suitable equipment. Some vhf-fm sets are easier to align than others;

but hit-or-miss methods are seldom entirely successful where this class of circuit is concerned.

So unless you have the knowledge, experience and test-gear which will enable you to tackle vhf-fm realignment with some reasonable chance of complete success, it may be wiser to avoid the job altogether if possible.

The test equipment needed for the best methods of vhf-fm alignment is apt to be costly, and the expense may not be worth while unless you are going to do a lot of servicing on this class of receiver.

A beginner can learn a good deal about correct alignment of vhf-fm circuits by simply listening, very critically and attentively, to a vhf-fm set which *is in* perfect alignment, while tuning right across the waveband.

Finding a set that is in perfect alignment may not be as easy as one might think. Vhf-fm sets of the portable variety tend to get out of alignment rather easily, unless the adjustments are securely sealed, because in being carried about and dumped down, they are usually subjected to quite a lot of mechanical vibration.

If, however, you have access to a vhf-fm set which has been expertly aligned either by the manufacturer's service department, or by a fully-equipped repair workshop, the tuning-and-listening procedure mentioned above can be very instructive.

First, tune in a vhf-fm station as precisely as you can, by ear if no other means is available, or by any visual indication that may be fitted—e.g., a "magic eye" tuning indicator, or a tuning meter.

Signals will be at maximum strength and, above all, at optimum quality of tone and clarity, when the set is accurately tuned to the "centre" of the transmission.

If, now, you begin to tune away to the left or right of the optimum setting, you will notice rapid changes in the strength and clarity of the signals. Not merely a gradual weakening, as





if one were turning down a volume-control, nor just a change of tone as if one were adjusting bass-lift or treble-lift controls, nor simply distortion, nor complete loss of signal.

No, what you will find—if the set is correctly aligned—is a combination of these phenomena, one after the other in succession.

Various inaccuracies in alignment can alter these effects in different ways. If the set is not perfectly aligned, you will probably notice that the different effects or phenomena are not uniformly balanced on both sides of the centre point, but are "lop-sided."

One thing that can have a particularly marked effect on vhf-fm results is misalignment of the i-f transformer secondary feeding the detector or discriminator.

But all the tuned circuits in a vhf-fm set are important as regards alignment, and correct procedure is essential. As this varies with different circuits, it is not very helpful to give general instructions, and by far the best plan is to study the manufacturer's alignment instructions for the particular receiver being serviced and follow them as closely as your skill and available equipment permits.

The sort of equipment used in the best repair workshops for rapid realignment of a large number of vhf-fm sets is costly and specialized. It includes a sweep-generator and oscilloscope.

Those who have to do without these expensive items cannot expect to realign vhf-fm sets very quickly and easily; but, if they follow the right procedure, they can usually get almost, if not quite, as good a final result (though it may take more time, skill and patience), by using more everyday test-gear including an ordinary (amplitude-modulated) signal-generator and multimeter.

Attempting to realign vhf-fm i-f stages without any equipment at all, just by ear and trimming-tool, is not advisable. The chances of complete success are pretty slender; but a lot depends on one's "ear" for how the signal should sound when it is just right.

Sometimes, however, is is only the crucial secondary winding of the i-f transformer immediately preceding the detector which is slightly out of alignment. A judicious touch on the adjustment of the core in this transformer will effect a great improvement without the use of proper instruments at all. It is seldom quite as difficult as some experts allege; but it is decidedly a gamble and it is up to you whether to chance it or not!

We have already referred to what you can learn from tuning "across" a perfectly aligned f-m signal. In the centre of the band of frequencies occupied by a transmission, you get loud and superbly clear reception, with minimum background noise and no distortion.

On either side of this fairly broad "strip" of peak signal you will find a "null" point where the signal drops almost to nothing. Further still from central tuning-point, the signal reappears but with considerable distortion, and as you tune further and further away from the central frequency, the signal gets weaker until it finally disappears altogether in background noise between stations.



CHAPTER 16

# *Set Repairs—Worthwhile and Otherwise!*

Before attempting to repair any transistor set, it is strongly advisable to stop and think whether the job is really worth doing, or whether it will turn out to be a waste of time and money.

One cannot lay down any hard-and-fast rules on this. Each individual case must be judged on its merits. Moreover, a great deal depends on the repairer and his resources.

For example, a cheap imported set that has developed several elusive faults may be time-wasting, and even when you have succeeded in tracing the faults, the defective parts may be of a size and type that cannot be easily obtained in this country. In such a case the job may not be worth doing. But if by chance you are able to get hold of an identical model with different faults altogether, you may be able to remove sound parts from the second set to replace faulty ones in the first.

This may make all the difference to the task being worth attempting.

Unfortunately, some components in ultra-miniature sets are very difficult to remove successfully for re-use without damaging them. So, even if you are able to get hold of two identical receivers, it is not necessarily as easy as it looks to use one as a source of spares for the other.

Another snag is that a given model may have certain weak points in it which tend to cause similar breakdowns in different individual receivers. For instance, you may have one set with a faulty volume-control, and another identical set which you are breaking up for spares. But when you come to try the volume-control in this spare set you may find that it, too, is faulty.

Generally speaking, any receiver of good quality is worth repairing with brand-new components rather than re-used ones, except in cases where you can be quite sure that salvaged parts are in good-as-new condition and are likely to remain so.

A ferrite-rod aerial may be in perfect condition for re-use; but an electrolytic capacitor may be on the point of breaking down and any attempt to re-use it in another set would turn out to be a waste of time. A transformer, provided you can remove it without damage, may be well worth re-using, but a very tiny subminiature resistor, with leads cut short, may be almost impossible to remove without damage, and a new replacement is so cheap that it would be absurd to use a secondhand one in doubtful condition.

Before attempting any repairs on a transistor set for a friend or customer, it is wise to make sure that you have a reasonable prospect of completing the job successfully. If you get a set to pieces and then find that you cannot get suitable replacements, you will have been wasting your own time and running the risk of having to return the set to its owner in worse condition than it was when handed to you for repair.

This is disappointing (or even infuriating) for the customer and embarrassing for yourself.

Some transistor sets are so intricate and miniaturized, so badly designed or so flimsily constructed, that it is almost impossible to carry out any servicing on them without risk of causing fresh damage. On the other hand, there are some models so well thought-out by the designer and so well constructed by the manufacturer that they are easy to test and foolproof to repair.

Suitable tools are a great help in tackling difficult or intricate repairs. The right type of soldering-iron, for instance, will enable you to remove faulty components and replace with new ones in crowded or inaccessible spots on a printed circuit





board. With a larger or clumsier iron such a task would be quite impossible.

A strong magnifying-glass suitably mounted, so as to leave both your hands free for working, is a great help when testing or repairing sub-miniature assemblies. Not only does this aid the work but it also reduces eyestrain.

An adjustable desk-lamp or table-lamp, with a suitable opaque or reflecting half-shade, is another item which will help in this respect.

Some of the very cheapest imported transistor sets are hardly worth repairing if they develop any very elusive faults, or contain defective components of a type for which suitable replacements are almost unobtainable in this country. In such cases it may be actually cheaper to get a new set than to repair the old one.

Remember that the bare cost of the components is not the only item to consider. If you have to send away for parts, there are postages, cheques, or money order or postal-order charges to be considered, as well as the value of your time.

Sometimes it is not the set itself but the case which is damaged. Perhaps the owner has dropped the set and smashed the plastic case beyond repair. If the electronic assembly inside is not seriously damaged and can be got back into working order quickly and easily, it may be worth while refitting the printed-circuit board assembly into a new plastic case of some sort. If the set is an imported one you may not be able to get an exact-replacement case. But the writer has often found it possible to adapt some small plastic box to form a new container for the set.

Sometimes, with the owner's consent, one can fit the set into a case that is larger than the original one, and this permits the use of a larger, higher-capacity battery, giving much more economical running-costs.

CHAPTER 17

# *Testing Transistor Sets*

Before you start any systematic fault-finding with test instruments, it is worth while spending a few minutes just using your eyes and ears: looking at the inside of the set, and listening to it—if there is anything at all to hear.

Faults can be roughly classified according to their symptoms. These range from dead silence, through faintly perceptible background sound, or weak signals, or distorted signals, to signals that are loud and clear in themselves but spoilt by interference or electrical noise of some sort.

These effects can be detected by ear. In some cases, their causes can be detected by eye, if you examine the whole of the set's "works" with a good magnifying-glass and in a good light.

An inspection such as this may reveal hairline cracks in the printed circuit board and its fine copper conductors. Or it may reveal a break in fine wires such as those from the ferrite rod aerial windings. Lead-out wires from a transistor may have broken, either close to the transistor capsule or close to the holes where they pass through the circuit-board. Wire-ends from resistors or capacitors may have broken. Soldered joints may have "come unstuck" so to speak. Tiny resistors may show signs of scorching through overheating. Air-spaced variable capacitors may have become damaged, their vanes slightly bent and short-circuiting through the rotor ones touching the stator ones at some point, as they are rotated.

If there is nothing visibly wrong with the set, the next step is to test sytematically with whatever means or troubleshooting equipment you may have at your disposal.

Test equipment can cost a few shillings or several hundred pounds. Naturally its efficiency is more or less proportionate to its cost. But you can do a great deal of fault-tracing quite effectively with very inexpensive gear. It does, however, take a good deal longer than it would with more costly instruments.

Some faults, of course, are so obvious that no testing is necessary to establish the cause. Anyone who has had a little experience of diagnosing faults can make a guess with almost a hundred-per-cent certainty of being right.

For instance, if you have ever heard a set suffering from the defect termed "motor-boating" (because it sounds like a motorboat engine) you can recognize it in a moment. (The cure is usually a new electrolytic capacitor in the right spot.)

If you are not sure which of the electrolytics is at fault, simply shunting a good one (or adequate working voltage and anywhere near the right capacity) across each suspect one in turn will usually reveal the culprit easily and quickly.

Sometimes failure of a decoupling resistor, associated with the electrolytic capacitor, will produce motor-boating, so if a new capacitor fails to help, the resistors should be checked.

Generally you will find it a sheer waste of time to attempt the tracing of a fault in a set as a whole. You must somehow split it up into manageable units. This narrows down the field of search and reduces the chances of wasting time and effort on sections that turn out to be working perfectly.

The most sensible and logical way to analyze the circuit is to treat each stage as a separate unit. But at the same time you must bear in mind that some of the stages may be interdependent (apart from such obvious links as sharing a common power-supply).

Avc (automatic volume control) or agc (automatic gain control), negative feedback, and reflexing are three actions that may start in one stage and end in another. If you take the





advice about splitting up the circuit into separate stages too literally you may nullify these arrangements and upset the normal working of the receiver to an even greater extent than the fault itself has done!

For example, breaking one connection in a reflex circuit could leave the set still working—after a fashion—but with the amplification cut down to a small fraction of normal level.

So the first thing to do is to take a quick look at the circuit diagram and see whether there are any essential interacting links between the different stages. Look for reflex systems; note how the avc or agc is arranged; and see if there is negative feedback in the audio or output stages.

It is quite a good idea to make sure at the outset that there is no fault in these arrangements. Avc systems can sometimes give rise to fairly baffling symptoms, for a start. In a reflex circuit, failure of one unimportant-looking component can have a most drastic effect on results. A negative-feedback resistor so small that you could overlook it will cut down volume greatly if it lowers in value. If, on the other hand, it rises in value it may cause quality of reproduction to deteriorate quite a lot.

Fortunately you can separate a circuit into sections for test purposes without literally cutting it up! You can inject a signal at the input of a stage, and intercept it at the output of that stage, without *necessarily* disconnecting anything. But this depends, to some extent on the nature of the test equipment available and the design of the set.

Having made sure that the fault or faults cannot be found in any interacting links such as those mentioned above, you can go right ahead with stage-by-stage testing.

Some people prefer to start at the aerial end of the circuit and work towards the loudspeaker; others prefer to check the output stage first, then the audio stages, and so on, working back through the detector, i-f, frequency-changer or mixer stages to the aerial tuning circuit.

A favourite short-cut with a good many technicians is to start with the "top" end of the volume-control. This is a key point, in most transistor sets, which will help you to make a quick assessment of the results that are being given by the whole audio section of the receiver from volume-control to loudspeaker.

A transistor set that seems insensitive and lacking in volume, without any obvious or specific fault, may be rather a difficult problem.

It is of course helpful if you can track down the lack of power to one particular stage; but if it is a vague, overall weakness it may take a lot of finding and more than one component may be at fault.

You could start by making sure that the i-f and r-f tuned circuits are perfectly aligned. Check that the windings on the ferrite aerial rod have not been accidentally moved out of their correct positions for optimum signal-strength.

Check voltages, and if these are all within normal limits, check continuity of windings where this is not already established by the voltage readings.

A signal-tracer and probe should help you to find any stage where noticeable lack of amplification is present. You could try substituting spare transistors of suitable type if you have any handy.

Defective capacitors, possibly in more than one part of the circuit, are another possible cause of weak signals.

The diode or diodes in the detector or demodulator circuit should also be checked. It is generally quick and easy to confirm the condition of these by substituting samples known to be in good working order.

Where noise-faults are concerned, the first thing is to make sure whether the trouble is in the set itself or is being picked up from outside interference. If the set has an external aerial, disconnecting this will usually show whether the noise is inside or outside the set. If it stops, or greatly diminishes, on dis-





connecting the aerial, it is sure to be from outside sources of interference. But if it goes on unabated, it is pretty sure to be in the set itself.

If the set has a ferrite rod aerial, as most transistor receivers do, you cannot very well disconnect this. But, being strongly directional, simply turning the set around will usually indicate whether it is picking up external interference or whether the noise is coming from the receiver circuit.

Incidentally, a transistor portable can be used very effectively in this way as a direction-finding device to locate the actual source of any electrical interference picked up by it. Even if the line of maximum interference is too broad to be much use, the position of minimum pick-up is invariably quite clearly defined and will of course be at right-angles to the maximum.

If the noises are definitely traced to the set itself, you will next need to discover which stage or stages in the set are generating the noises. Turning down the volume control is the first step; if the noise abates, it is in the front half of the set. If it continues unabated, it is in the back half or audio section, or in the power supply unit. This is a rough-and-ready way of checking, but is generally dependable.

Defects in components could be divided into two main classes: parametric changes and catastrophic failures.

The former will usually have an adverse effect on the performance of the set; they may not be easily detectable unless they reach a very obvious stage; and they may not *necessarily* do any damage to other associated components.

The latter will usually stop the set, or at least one section of it, working. Therefore they will probably be much more easily found than any parametric changes. But if the set is run after the catastrophic failure of one component has occurred, other parts may suffer consequential damage.

So if you think there has been a "disaster-type" failure in any component, it is best to switch off the set instantly and not switch on again until the faulty component has been found (by meter-tests etc.) and disconnected.

Transistors and the like are much more easily and quickly damaged by failure of associated components than are valves. About the only thing that is likely to destroy a valve instantly is either application of HT voltage across the filament or heater; or violent vibration—and with a robust type of valve, it has to be surprisingly violent to cause instant destruction.

With transistors, voltage or current rises or other kinds of overheating can, in some cases, cause instantaneous destruction, and of course this occurs as a rule quite invisibly. There is not the spectacular flash of a burning-out valve!

Systematic fault-finding "boils down" to this:

Narrow the field of search all the time.

If you are able to do this, then eventually you must reach a point where the "suspect" area is so small that it contains only one or two components. Replacing or repairing these should cure the fault.

You start by ascertaining which stage of the set is defective: r-f amplifier (if any), frequency-changer or mixer, i-f amplifier stages, detector, pre-amplifier, audio and output stages and finally the loudspeaker or earphone itself.

If you can definitely establish the faulty stage, this is about half the battle! The next step is to see which part of the stage is giving trouble: the input, biasing or output portions or the transistor or diode?

If this analysis is positively and successfully carried out, you are nearly home. The field of search has now become so narrow that the fault must lie in one or two individual items, which can be removed and tested if you have suitable equipment, or even, if the worst comes to the worst, replaced on chance, assuming that you have or can get suitable replacements.

Even if you have not got any exact replacement handy, you may at least have something that is "near enough" to give a





final proof that the fault is in the part you are now suspecting. This is enough to confirm that replacement with the correct component will effect a cure (though some final adjustment, such as re-alignment of tuned circuits or minor alterations to biasing may be necessary, even with a perfectly new and suitable replacement, to restore reception to a "good as new" state).

Of course, in the foregoing account of fault-tracing procedure, we have conveniently ignored two possibilities: one, the intermittent fault; and two, the multiple fault—a simultaneous breakdown of two or more components.

Intermittent faults are the most exasperating things of all. It is hard to tell when they are cured, whether they have "cured" themselves and will recur later, or whether you have really succeeded in getting rid of them for good.

Multiple faults may sound unlikely; the beginner may think that the chances of two or more faults occurring simultaneously must be a remote coincidence.

Unfortunately this is not so. In some circuits, the occurrence of one fault can directly cause another to occur either a little later or even instantly. Sometimes it is possible for even a sort of "chain reaction" to be set up causing a sequence of breakdowns, not necessarily confined to any one stage of the set.

Where this happens, your fault-finding procedure may not work out quite as planned, and you may have to do a lot more testing of individual components before you get any success.

The most likely area for multiple faults to be set up is the audio amplifier. Direct coupled stages are rather prone to this sort of thing, because the effect of breakdown is not confined to one small section of the amplifier.

A few hints, more or less at random, may help you to locate or diagnose faults in transistor superhet receivers. We may as well start with the mixer or frequency-changer stage, since an r-f amplifier preceding this stage is so easily isolated that it presents few problems.

Perhaps the set is working on one waveband only, out of two others—as the case may be—are inoperative? This can be due to several possible causes. If the tuner is the first stage following the aerial, there may be broken connections to the ferrite rod winding or there may be faulty contact in the waveband change switch (this is a very common fault in some transistor sets, due to the type of switch used being a somewhat flimsy one). Sometimes it is possible to cure the trouble by cleaning or adjusting the contacts (the former with a suitable switch-cleaner fluid), but sometimes complete replacement of the switch is necessary.

Alignment of tuned circuits getting "out of focus," so to speak, on one waveband only can of course make that waveband seem to be inoperative although it is in fact working after a fashion—i.e., there is no actual breakdown or defective component, only maladjustment which re-aligning will cure.

Short-circuits in tuning capacitors and also in trimmer capacitors can cause a number of rather baffling tuning faults if you do not realize what has happened. These items should be checked if you get some puzzling lack of results in this section of the set.

If you suspect a fault in the i-f amplifying stages, the first thing to do is to check the alignment. A slight movement of each core in turn will indicate whether the tuning of each winding is peaking correctly. But remember that some sets are slightly "staggered" in their i-f transformer tuning, i.e., they are not all adjusted precisely to the nominal i-f ([illegible] kc/s or whatever the specification lays down), but one winding is peaked slightly below nominal frequency and the next slightly above it.

If you eliminate this staggered tuning by adjusting each winding to precisely uniform in frequency, the result may be



that you will get i-f instability, and the i-f stages may start to oscillate, causing squeals or whistles in reception.

If the i-f's are all aligned correctly, but the overall gain is too low, check the resistors associated with the i-f transistors, and any capacitors also. If all these are o.k., then the transistors themselves could be checked.

Some idea of how the i-f stages are performing can be got by simply disconnecting one side of the diode, i.e., the lead that goes to the secondary of the last i-f transformer, and temporarily joining it, in turn, to the secondaries of the preceding i-f's.

If a pair of earphones happens to be handy, you can check the rectified output from the diode, when restored to its normal position. If you can hear good signals in the 'phones, but nothing from the loudspeaker connected to the output stage in the normal way, the fault will be somewhere in the audio or output stages.

These are generally the easiest to test for complete breakdown, but where signals are being distorted, without being interrupted altogether, diagnosis may be harder, especially for the beginner.

But, more often than not, distortion in the output stage is simply due to incorrect bias resistor values, either through inaccurate choice if one is building the set, or from change in resistor value if one is dealing with a set that has been working all right until the present fault condition started.

Bias-line resistors for a push-pull output stage, for instance, are pretty crucial and should be accurate to within 5% of the specified value.

Incidentally, in the case of persistent trouble at this point, it is well to verify the specification for these particular resistors from some other independent source if possible, just in case there is an error or misprint in the Parts List if you are building the set from a published design.

Another common source of distortion is from incorrect inpedance-matching. Make sure that the output transformer is suitably matched to both the transistor or transistors in the final stage and to the speaker itself.

Poor quality due to the loudspeaker's speech-coil getting "crooked" or misaligned in its very precisely-engineered magnet-gap is usually quite easy to detect, but not so easy to cure. Sometimes, if the speaker is a cheap one, the most sensible thing is to scrap it and fit a new one.



CHAPTER 18

# *Transistor Power Supplies*

The necessary power for transistor sets can be obtained either from battery or mains sources.

The majority of ordinary transistors at the present time are very modest in their power requirements. Some will work on voltages as low as one-and-a-half; the majority however need about nine volts to perform normally; and some kinds are designed for higher voltages.

Several types, and many sizes, of dry battery can be had for transistor sets. Most of these are stocked by local radio dealers and you should have no difficulty in getting replacements for your own set, for any sets you may be repairing for other people and for any constructional projects in the transistor category such as the circuits described in this book.

First there is a wide range of ordinary dry transistor batteries, in various sizes and weights. If there is space in the set to accommodate it, and you do not mind a small increase in weight, you will find it much more economical to use a large 9-volt battery rather than a very small one. The bigger battery will cost a few pence more, but its life, at the same discharge rate, will be far longer and therefore it works out much cheaper.

Apart from ordinary dry batteries, there are various special types, both rechargeable and non-rechargeable. Cadmium nickel cells come in the rechargeable category.

A wide range of cells and batteries for various purposes, including transistor radio receivers, tape recorders, amplifiers etc., comes in the Mallory series, consisting of mercury types.

Transistor car radio receivers, of course, are normally designed to run off the car battery. But some designs permit of portable use with self-contained batteries as an alternative when the set is not required in the car.

The great advantage of battery operation, in any form, is of course that this type of power-supply makes the set entirely self-contained and completely portable. You can use it *anywhere*.

Running the set from a mains power supply unit can of course be much more economical. But it does restrict the mobility of the set. You can only use it, obviously, where there is a mains outlet available.

It is quite practicable, however, to arrange matters so that there is a choice of battery or mains unit operation as desired.

Mains power-units vary greatly in design. There are all kinds from extremely simple, unregulated ones to quite complex types with elaborate voltage-regulating arrangements. Indeed, some of these circuits seem to employ a larger number of solidstate devices—diode rectifiers, zener diodes, transistors, etc.—than are in the average receiver itself!

The usual kind of rectifier employed nowadays in power supply units is a silicon diode of suitable design; or a combination of these in a bridge configuration.

In some circuits it is necessary to use a surge-limiting resistor in series with the silicon rectifier. A 1,000 pF fixed capacitor of sufficiently high a-c working voltage rating is connected across the rectifier, also for protection purposes.

Diagrams accompanying this chapter will give you some idea of typical power supply units designed for use with transistor equipment.

Perhaps the simplest possible mains power supply unit, compatible with reasonable safety, is the circuit shown in Fig. 18-1. (There are dangerous types that are simpler still; but we will forget about them!) Fig. 18-2 employs two diodes.





A slightly more elaborate kind is shown in Fig. 18-3. This, as you can see, employs four diodes in a "bridge" arrangement.

Rectifiers can be either full-wave or half-wave. Voltage-doubling arrangements constitute another possibility; but with the low voltages normally used in the majority of transistor circuits, voltage-doubling may not be needed.

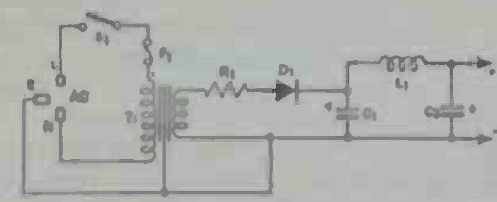

Fig. 18-1

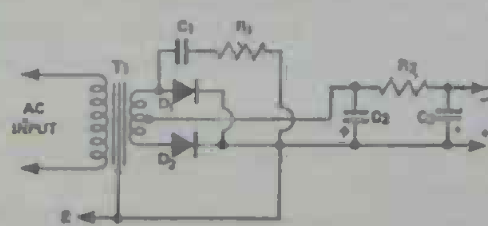


Fig. 18-2

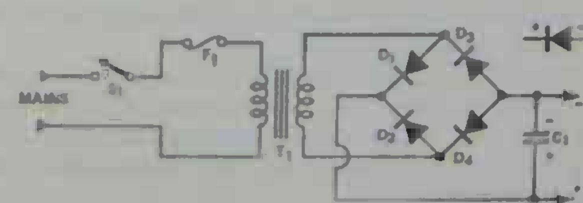


Fig. 18-3

Other refinements, however, can be very necessary. The rectified current needs filtering or smoothing, stabilizing or regulating. Various circuits are available to give almost any desired result.

Ready-made units can be bought; and many designs for building regulated power-supply units have been published.

A filter may consist of either a smoothing choke or a suitable fixed resistor in combination with fixed capacitors.

Zener diodes are commonly used for voltage stabilization in stabilized and regulated power supply units. Power transistors also figure frequently in the arrangements.

The subject of safety in transistor sets is one which may only too easily be misunderstood by beginners.

Transistor sets are commonly regarded as being inherently safe. This idea has grown up because early transistor equipment was generally powered only by low-voltage dry batteries, which were quite incapable of causing even the slightest shock.

But when any sort of mains power supply unit is joined up to a transistor circuit, the latter may be just as dangerous to handle as a valve receiver which is similarly powered from the high-voltage mains.

The safety or otherwise of a transistor circuit powered by a mains unit depends entirely on the design of the set and of the power-supply unit.

If the power-supply unit incorporates a good-quality double-wound mains transformer, to isolate it from the high voltage supply lines, and also, usually, to step down the mains voltage to a much lower level suitable for transistor requirements, the safety factor should be excellent.

With any less stringent precautions, the safety factor may be very doubtful; and in some cases, the whole set may become lethal to handle, through exposed metalwork on the receiver being in electrical continuity with "live" conductors in the mains power supply unit.

Imported mains units should be checked carefully by a com-





petent electrician before being used; some types may be dangerous on our mains.

Remember that our mains run at about 230-240 volts a-c, whereas those in some other countries, including the United States, run at only about half this voltage and are therefore very much safer from the shock aspect.

Designs for power units to work off these lower voltages may not lend themselves to adaptation for our high-voltage mains, without drastic re-designing of the whole unit. So you would be well advised to check carefully before attempting to adapt any design which was not originally intended for British use.

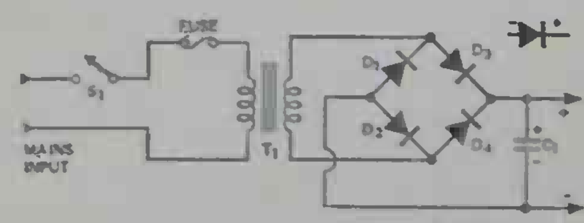


Fig. 18-4

CHAPTER 19

# *Chasses, Cases and Cabinets*

In transistor sets, the conventional metal chassis has been very largely superceded by printed-circuit boards. One cannot very easily combine the two, though it is possible.

The absence of an earthed metal chassis, with its inherent screening effects, may tend to make a set less stable, and the layout will need to be very carefully designed to compensate for this loss of screening.

In short-wave circuits, another snag arises, namely, the tendency for hand-capacity effects to become troublesome if there is no metal screening. The front panel is the critical factor here, but you can provide an earthed screening effect without having an actual sheet of metal for this panel.

Plain printed-circuit board, copper-clad on its rear surface, lends itself well to this use. As the majority of transistor sets are so much smaller than corresponding types of valve receiver, the front panel need not be a large one, and therefore the cost of the printed-circuit board for this purpose will not be unduly high.

A convenient point about it is that earth-returns can be soldered direct to the copper surface behind the panel if desired. The non-metallic front surface can be treated in any way you like. It can be enamelled in any desired colour, and while the enamel is still very slightly tacky, lettering-transfers can be applied to it if you wish.

It can be french-polished like wood; or it can be lightly sandpapered with a very fine-grade sandpaper to give a pleasing, smooth matt effect. Or it can be coated with aluminium paint to look like a metal panel.

Yet another alternative is to cover the front surface with one of the many attractively-patterned self-adhesive sheetings such as Fablon in imitation woodgrain finish. This gives an effect which is very popular in factory-built equipment at the time of writing.

The case or cabinet can be similarly treated to match or to contrast with the finish you have chosen for the front panel.

In the days of valve sets, the vast majority of cabinets for either factory-built or home-built receivers were made of either wood or bakelite—or, in the case of short-wave sets and car radio receivers, metal.

Sometimes other types of moulded plastic were used; but wood, bakelite and metal were the normal favourites.

The small physical size of transistor sets opens up a far wider field of choice for cabinets or cases where the home constructor is concerned.

For really small receivers, amplifiers and the like, there are many attractive-looking ready-made plastic boxes to be had. Apart from any that are actually designed and made to be used for this purpose, there are a great many more that were originally intended to contain various commercial commodities but which, when emptied of their normal contents, can be very easily adapted for radio use.

Several makes of typewriter ribbon are packed in neat circular boxes of transparent plastic. A tiny transistor set could be built into one of these. A hand-drawn tuning scale (on paper or white card) could be fixed behind the transparent lid of the box, and a small pointer-knob fitted to the tuning capacitor. Fig. 19-1 shows the general idea.

If you prefer a rectangular box, there are the soap cases for travelling, which you can buy at most chemists etc. for a shilling or two. These are often made in nicely coloured plastic. They are just about the right size for a miniature receiver.





In some cases the plastic is of a virtually unbreakable kind, which is an advantage if you accidentally drop the set!

For larger receivers there is a good range of transparent or pastel-tinted plastic food containers—sandwich boxes and the like—which again make good little cabinets for a transistor set.

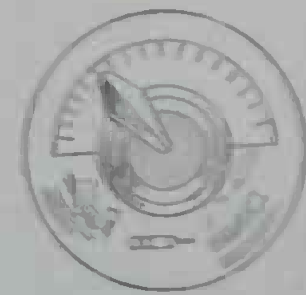

Fig. 19-1

Fig. 19-2 shows an example of a "one-off" improvised case or cabinet which the writer recently assembled for a transistor set presently under construction.

The case itself is a food-container box (made by Addis) in a semi-flexible, translucent plastic material, complete with lid. When adapted for housing a transistor project, the lid forms the back of the case, and the bottom forms the front, which is in the writer's prototype embellished with a chromium-plated decorative grille or front panel salvaged (in perfect condition) from a very old personal-portable receiver by a famous manufacturer.

This ancient set—one of the first on the market with miniature 7-pin valves—had been discarded years ago, but stored carefully in a cupboard, consequently the chrome was immaculate.

A telescopic aerial or antenna rod was passed through a hole punched in the top surface of the case and secured inside the bottom, making a good firm mounting.

This design is mentioned and depicted merely as an example of what can be done by ingenious combination of materials, new or salvaged as the case may be, in devising containers for home-built transistor projects.

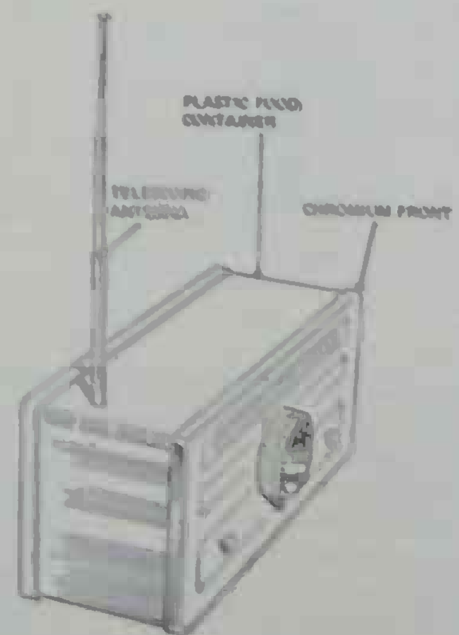


Fig. 19-2

One can use either the soft plastic cases, such as the Addis type mentioned above, or the hard transparent ones. The latter need careful drilling to avoid cracking. The softer ones can be perforated neatly with a leather-punching tool, if this is preferred to drilling.





Apart from the vast range of plastic cases, there are many kinds and sizes of metal boxes which lend themselves to the housing of transistorized equipment of one kind or another.

Tobacco-tins are a favourite kind of case for a good many of the small constructional projects described in some of the popular radio journals catering for amateurs.

Some small biscuit tins (*not* the old-fashioned standard size, which are ten times too big for modern transistor projects) can come in handy for projects which need overall metallic screening.

If instead of improvised cases you prefer a commercial range of accurately-made diecast boxes of aluminium alloy, there is a range of 9 sizes made by Electroniques. These have divider-slots to facilitate the fitting of printed-circuit board (such as Veroboard) or metal screens.

The same firm markets many other boxes, cases and cabinets for electronic equipment. These include aluminium mini-boxes, ready-painted in two-tone finish; others ready-painted in hammer-grey enamel; others again in self-finish aluminium alloy, including perforated casing; and a range of vertical Dinkicases in grey enamel. Horizontal types, and types with sloping panels, are also available.

With cases, cabinets, chasses etc., as with components, the stocks held by different firms are liable to change from time to time, and therefore you should verify from latest information whether any particular cabinet, etc., is still available before you plan a set which you intend to house in it.

In fact, if you are designing a layout from scratch, it is usually wisest to select the case or cabinet first, otherwise you may find you have committed yourself to a design which, in its completed form, simply will not fit into any standard-sized case nor any readily-available improvised case, except of course one of needlessly bulky overall dimensions.

Remember that it is not only the set itself that has to be accommodated but also the battery, loudspeaker, etc., if these are to be included. Even if you intend to run the set most of the time off a mains power supply unit, or—in the case of a mobile or portable receiver—a car battery, it is advisable to allow room for an ordinary dry-battery of normal transistor type to be used as an alternative when you may want to use the set as a completely self-contained portable away from mains or a vehicle.



CHAPTER 20

# *Supplies and Suppliers*

Shopping is nearly as important in radio as it is in housekeeping!

There are bargains to be had in the radio shop just as there are in the supermarket.

But to get the best value for money you have to be careful and discriminating in choosing semiconductors, components and accessories.

Where transistors are concerned, cut-price offers may include a number of unmarked and untested samples. Some of these may be virtually unusable; the price of the whole parcel is usually based on this assumption, anyway. Most firms advertising such packages frankly state an estimated percentage of usable items in the collection.

But the value you get from such assortments depends mostly on your own testing-facilities and your own enterprise or ingenuity.

Some cut-price transistors are partially faulty and cannot be used as transistors at all, but, using two lead-outs instead of three, will form perfectly good diodes.

In other cases, the transistors may be good but unmarked, and have to be identified as best one can; how accurately this can be done depends largely on one's resources in the way of test-gear and so on.

Occasionally one comes across cheap transistors that are incorrectly marked, by inadvertence. These can be very baffling, unless one is prepared for the possibility. If an alleged PNP transistor definitely will not work at all, always check it to make sure that it isn't an NPN type wrongly marked, before throwing it away as useless. Better still, check the polarity before trying it at all; if you have subjected it to power supplies of reversed polarity, you may have damaged it beyond endurance before you discover the marker's mistake!

Another category of cut-price transistors is that which consists of samples with untypical characteristics. These may be unsatisfactory if used in the ordinary way, but can be made to work quite satisfactorily by adjusting the bias, etc. Altering associated resistors to values which suit the individual sample of transistor is all that is needed to get it working properly.

In non-critical circuits one can often use up quite a large proportion of the transistors in a mixed "bargain" parcel.

In a circuit where the choice of semiconductors is very exacting and critical, however, it is usually false economy—a waste of time and money—to try very cheap and doubtful "bargain" transistors or diodes. It pays best in the long run to pay a little more and get first-rate examples from a thoroughly dependable source of supply.

It may be a little difficult for a beginner to judge whether the choice of transistor in a given circuit is a critical one or not. The writer has known of cases where a beginner has gone to a vast amount of trouble to get some uncommon type of transistor for use in a published design, only to find, too late, that there were a couple of dozen different easily-obtainable substitutions that would have given equally good results.

Some writers and designers state clearly whether the choice of transistors for their project is critical or not. Where a designer says emphatically "DO NOT SUBSTITUTE" it invariably means that the transistor type specified really *is* the only one that will give the desired results in that particular circuit.

Some transistor suppliers issue, free or at nominal cost, some very useful data leaflets, booklets, catalogues and substi-





tution lists. These are a tremendous help in choosing semiconductors for home-built projects.

Among semiconductor manufacturers whose advertisements are worth watching for offers of catalogues or data publications the following are a few examples:

AEI Semiconductors Ltd., Garholme Road, Lincoln.

Mullard Ltd., Mullard House, Torrington Place, London, W.C.1.

Newmarket Transistors Ltd., Exning Road, Newmarket, Suffolk.

Sinclair Radionics Ltd., 22 Newmarket Road, Cambridge.

There are also, of course, a number of leading American semiconductor manufacturers whose products are now marketed over here, and they, too, issue some very useful technical data from time to time.

Such publications are often announced or described in technical journals such as the *Wireless World*.

Some of the booklets give very useful guidance on transistor applications—i.e., which types are recommended for f-m receivers, which types for output stages, which types are particularly suitable for car radios, and so on.

Also of course the nature of the transistors themselves is indicated; whether they are germanium or silicon, PNP or NPN, and more precisely whether they are, say, silicon planar or silicon planar epitaxial; and, most important, the identity of the lead-out wires is usually shown in clear diagrams viewing the transistor from its underside.

The first reaction of a beginner when confronted with a comprehensive list of transistors is likely to be utter bewilderment. There are thousands of different type-numbers; how does one start to select a suitable transistor for any given purpose?

Well, first of all one must realize that the choice is not nearly as wide as it looks. Different manufacturers use different type-numbers for what are virtually the same sort of transistor. Even in the range produced by any one firm, there are often several different types which give very similar results in any ordinary circuit.

It is only in the case of fairly critical circuits that the exact choice may be extremely crucial. Sometimes in such projects there is virtually only one type of transistor which is ideal for the job, and no substitutions or equivalents are practicable.

One of the most difficult problems in writing for amateurs on the subject of transistors or other semiconductors is this:

When new types of semiconductor, offering special advantages and design facilities not found in earlier types, first come on the market they are apt to be expensive. In special instances, the price has been prohibitive at first; but afterwards, with increased mass production and wider use, it has fallen to a level well within the reach of the average amateur.

By that time, of course, the device is no longer in the category of "latest" types.

Due to this time-lag, if one writes about the latest transistors the information one gives may be of academic interest only, as far as the majority of amateurs are concerned.

If one writes about the types that are available at extremely low prices and in plentiful supply, one is open to the criticism that the information is about outdated stuff that the makers have ceased to produce!

A very large proportion of queries that radio writers get from readers are about supply problems. Substitution of alternative types for any items that are hard to get can often produce fresh problems in critical designs, and one must be prepared for some difficulties in this direction. Simple basic circuits, however, are usually quite docile to deal with.

Although there are so many different types of transistors, and prices vary so greatly, some excellent up-to-date types for the majority of applications are available from reputable sources of supply at very reasonable prices.





You should be able to get suitable semiconductors for most, or indeed for all normal, purposes from one or other of the firms that advertise regularly in the leading radio technical journals. It is of course up to you to ensure that your choice of types is correct for any particular set, but it is up to the supplier to make sure that each transistor is up to the specification stated in his own publicity.

If you have a genuine complaint of failure to do this on the part of an advertiser in one or other of the leading technical journals, you will generally find that the journal will take up the matter on your behalf if you send them accurate and complete details as soon as possible after the transaction in question.

Hundreds of firms nowadays supply electronic equipment, and it is impossible to give a representative list in the space available. So we must be content with mentioning a few typical examples and referring you to advertisements in the technical press, directories, etc., for the many others.

For complete kits of components, with which to build transistor sets, test-gear, etc.: Daystrom Limited of Gloucester. Their free illustrated catalogue shows the range of sets and instruments available.

For separate components of all kinds, accessories, test-gear, transistors, etc.: Home Radio (Components) Limited of Mitcham. Comprehensive catalogue can be bought for a few shillings, at the time of writing.

For components, transistors, test equipment, kits, etc.: Electroniques (Prop. STC) Limited, in the ITT Electronic group, of Harlow. Comprehensive catalogue can be bought.

For transistors, diodes, and other semiconductors: L.S.T. Electronic Components Ltd. of Brentwood; Electrovalue of Egham; Bi-Pre-Pak Limited of Westcliff-on-Sea; Bentley Acoustic Corporation Ltd. of London and Littlehampton; and many others.

Full addresses are not given above because these are liable to change from time to time and should always be ascertained from up-to-the-minute sources such as latest advertisements, telephone directories, trade lists or other reliable sources.