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Transistorised Test Equipment and Servicing Manual

by

CLIVE SINGLAIR

REPLACING FAULTY COMPONENTS
SPECIALISED TECHNIQUE FOR PRINTED CIRCUIT REPAIRS
TRACING BIASING FAULTS
TRANSISTOR LOUDSPEAKER REPAIRS
TRANSISTOR I.F. TRANSFORMER ALIGNMENT
SERVICING TRANSISTOR SUPERHETS
ALIGNING TRANSISTOR SUPERHETS
TRACING TRANSISTOR AUDIO AMPLIFIER FAULTS
FAULT-FINDING CHARTS
SERVICING AND ALIGNING TRANSISTOR REFLEX RECEIVERS
DESIGN AND CONSTRUCTION OF TRANSISTORISED ALIGNMENT OSCILLATOR
DESIGN AND CONSTRUCTION OF TRANSISTORISED SIGNAL GENERATOR
DESIGN AND CONSTRUCTION OF R.F. PROBE
DESIGN AND CONSTRUCTION OF MANY OTHER PIECES OF TRANSISTOR TEST EQUIPMENT

BERNARDS RADIO MANUALS

TRANSISTORISED TEST EQUIPMENT AND SERVICING MANUAL

BY

CLIVE SINCLAIR

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We invite all authors, whether new or well established, to submit manuscripts for publication. The manuscripts may deal with any facet of electronics but should always be practical. Any circuit diagrams that may be included should have been thoroughly checked by the author. If you are considering trying your hand at writing this type of book we suggest that you let us have a short summary of the subject you intend to cover. We will then be able to let you know the size of book required and perhaps give you some advice on presentation.

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CONTENTS

List of Illustrations

Introduction

The servicing of transistor radios, as opposed to valve sets, requires special techniques. The relative reliability of the various components is different and their small size makes special treatment necessary. This book, then, is intended to cover the subject of servicing purely from the transistor receiver angle and should be equally useful to the service engineer experienced in the use of valves and the complete newcomer to the field.

The vast majority of radios on the market follow a very similar circuit pattern and these are relatively easy to service once the general principles have been learnt. There are, however, quite a few unusual radios, particularly amongst those imported from abroad, which do not fall into this category. Because they are unfamiliar they often present quite difficult servicing problems when met for the first time. Coverage has been given to these sets and the text includes explanations of the ways in which they work.

Many of the service instruments required may be home-made using transistors, and a range of designs for such items as signal injectors and probes is included. The low cost of these devices compared with their commercial counterparts make them ideal for the amateur who can rarely afford to spend a great deal on his equipment.

Naturally, a book of this size cannot hope to cover every single detail of servicing transistor radios. It can, however, lay down the basic principles which enable the engineer to extrapolate where necessary. I sincerely hope that this book achieves this.

CHAPTER 1

GENERAL FAULT-FINDING PRINCIPLES

Later in this book the particular types of set will be discussed in detail, but this chapter will cover methods that are common to all of them.

For comprehensive servicing the following equipment is required.

(1) Light-weight soldering iron: this should have a power rating of not more than 25 watts because many miniature components, particularly transistors, will not withstand high temperatures. Furthermore, printed circuit boards are hard to cope with when using a large iron. Ideally, two irons should be used; one very small one of 10 watts or under for normal use and a larger one for soldering and unsoldering larger components, such as loudspeakers and volume controls, where the extra unit is essential. If only one iron is used, however, a 25-watt unit is a reasonable compromise. In any case, all solder joints must be made as quickly as possible and leads should be tinned beforehand.

(2) A signal generator: this should provide an A.F. signal of 400 or 1,000 c/s and an R.F. signal from 100 Kc/s to 2.5 mc/s modulated by a 400 or 1,000 c/s tone. It is possible to service sets and align them without a signal generator by using a simple signal injector of the type shown further on in this book, but a signal generator is a great help.

(3) A multi-meter: this should have a wide range of current, voltage and resistance scales and should, preferably, have a resistance of at least 10,000 ohms per volt. The well-known and popular Avo Multiminor is ideal, being both fairly cheap and light. This has the following scales:

D.C. Volts	*A.C. Volts*	*D.C. Current*	*Resistance*
0—2.5	0—10	0—0.1mA	0—20 K ohms
0—10	0—25	0—1mA	0—2 Meg ohms
0—25	0—100	0—10mA	
0—100	0—250	0—0.1A	
0—250	0—1,000	0—1A	
0—1,000			

Anyone purchasing a meter for this purpose should look for something of this sort.

(4) A valve voltmeter: this is by no means so essential as the last item but is definitely very useful and should be used by anyone doing a lot of servicing. The type chosen should either cover R.F. volts or should have an R.F. probe. The input resistance should be at least 10 megohms shunted by a maximum of 10 pf. The maximum sensitivity should be at least 10mV with a frequency range extending to 5 mc/s

(5) An oscilloscope: this is also not essential but is extremely helpful in ensuring that the audio part of the receiver is not distorting.

(6) Signal tracer: this may be home-made and consists of a high gain A.F. amplifier with a high input impedance. The amplifier may drive a loudspeaker or an earpiece. A useful addition to the signal tracer is an R.F. demodulator probe which extends its usefulness to the R.F. and I.F. parts of the circuit. Several signal tracer circuits are given in the chapter devoted to test equipment construction.

Printed Circuits

The vast majority of modern transistor radios use printed circuits. These replace the wires previously used to join the various components in receivers together. In some cases, as yet very few, one or more components may form part of the board.

Printed circuits increase the compactness and normally improve the reliability of a receiver. They simplify manufacture and, when well designed, can also help the serviceman. The principle is a simple one: the components are mounted on one side of a thin board ($\frac{1}{32}$"—$\frac{1}{4}$") made of laminated paper, plastic, glass fibre or some similar material. The leads of the components pass through the board and are connected on the other side to very thin (1/100—1/1,000 of an inch thick) copper strips which are bonded to the board. These copper strips form the connections between the components and, in most cases, are the only means of holding the components in place. In some cases small components are mounted on the copper side of the board and some boards have copper on both sides.

In the manufacture of printed circuits a thin, continuous sheet of copper is bonded to the laminate base or board. The required pattern of conductors is then printed on to the board, using a resistive (to acid) ink. The board is then placed in a bath of solvent, such as copper nitrate or a diluted acid, and the uncovered and unwanted copper is dissolved. Finally the ink is removed by means of another bath of solvent, which does not attack the copper, and the board is punched or drilled. In some cases the ink also acts as a solder flux, in which case it does not have to be removed.

New types of printed circuit board are constantly being developed and will be finding their way into sets. For example, transparent boards and flexible ones are already available. It is also becoming quite common to print, in white or coloured ink, on the component side of the board

This printing normally indicates the positions of the components and gives the reference numbers as shown on the service sheet. This development is very helpful to the service engineer, since it makes circuit tracing very much simpler.

With opaque, unprinted boards, it is possible to see the connections and the components at the same time by holding the board to a strong light. The conducting wires will then appear in silhouette behind the components. This method may also be used to look for breaks in the copper, but for this it is far from foolproof.

As has been mentioned, printed circuits are generally very reliable but they are prone to their own occasional faults, which are sometimes hard to track down. Tiny, virtually invisible, cracks sometimes occur in the copper strips and these cause intermittent operation of the set, or, in some cases, complete failure. The existence of such a crack can be established by gently flexing the board backwards and forwards with the set switched on. This should cause the crack to open and close, thereby breaking and making circuit. The line in which the crack occurs may then be found by keeping the board bent, so as to open the crack, and then measuring the resistance of each conducting copper strip. The resistance of a strip should normally be zero, but a strip with a crack in it will show a high resistance. Once found, the crack should be bridged with solder, care being taken to ensure that the solder flows smoothly on both sides of the crack.

The printed circuits of very tiny receivers are prone to another fault due to the very close spacing of the conducting leads. Metallic dust, from solder and clipped leads, can bridge the gap between two conductors, causing a short circuit. This fault may be cured by brushing the board with an old toothbrush or a small nailbrush. As a precaution, this may be done with every set that comes in for repair, whether or not it is immediately necessary.

Sometimes tiny filaments of solder or wire cause the same trouble, but these cannot be removed so easily, since they are often firmly stuck to the board. If the existence of such filaments is suspected, the conducting strips joined can be found by making resistance measurements between the various strips and by finding the part of the circuit that is not working properly. Once it is known which strips are joined, the filament of wire can be found with the aid of a magnifying glass and removed with a pair of tweezers.

The replacement of faulty components can often pose problems with printed circuits, particularly when they are closely packed and when the leads are very short. Fig. 1 shows a useful technique for replacing a horizontally mounted resistor which has been found faulty. The resistor is cut in the middle using a pair of wire clippers (b)

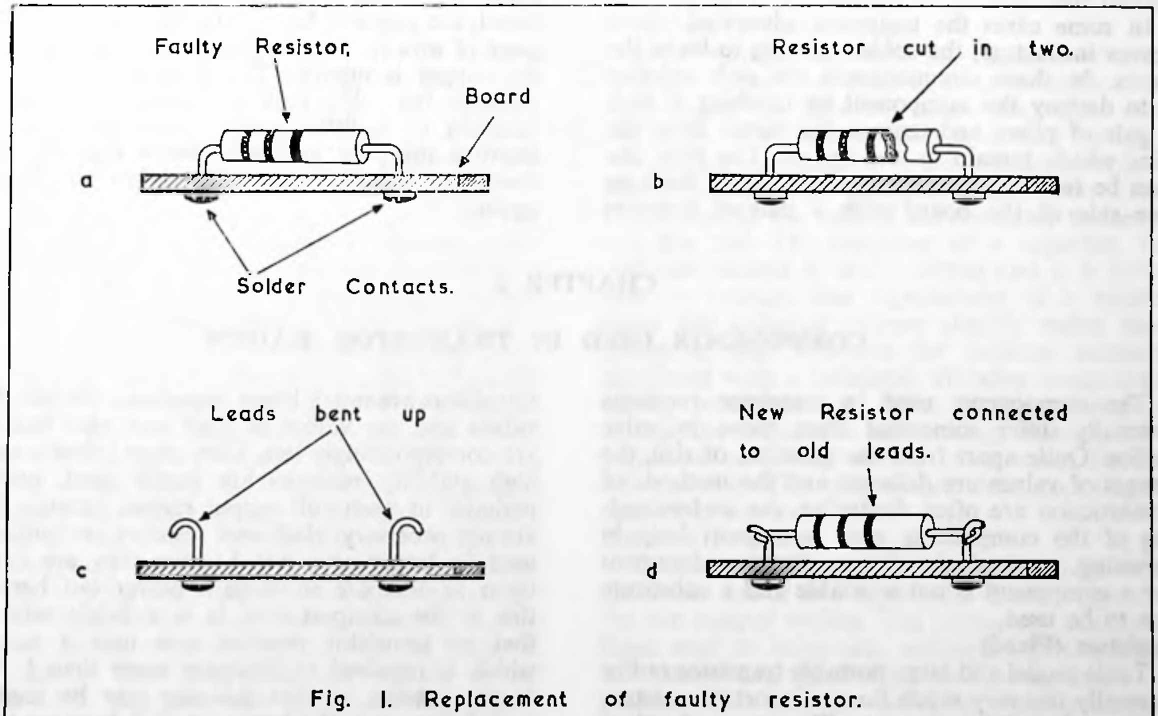


Fig. I. Replacement of faulty resistor.

and the two halves are bent up. The broken halves are then cut from the wires, leaving the wires as in (c). The replacement resistor may now be soldered to the wires. Care must be taken when soldering to ensure that the heat from the iron is not conducted along the wire to such a degree that it unsolders the joints on the board. This technique is far simpler than removing the old resistor from the board along with its leads and is much less likely to cause damage to the board and to nearby components. Fixed capacitors may be treated in the same way. In the case of electrolytic capacitors, which are frequently used in transistor sets, special care must be taken to ensure that the component is not overheated and that the correct polarity is employed.

Removal of components with several pins or wires such as I.F. transformers and volume controls can often be rather tricky because it is difficult to free all the pins of solder at the same time. The best way to remove the solder from a pin is to hold the board with the copper side downwards and to let the solder run on to a clean iron. When all the solder that can be has been removed by this method the contacts should be brushed to remove small particles. The components can now be removed from the board by gently wobbling it backwards and forwards until it is free. Before inserting the new component the holes should be slightly enlarged, using a fine rat-tail file.

In some cases the treatment advocated above proves ineffectual, the solder refusing to leave the joints. In these circumstances the only solution is to destroy the component by crushing it with a pair of pliers and remove the pieces from the pins which remain in the board. The pins can then be removed one by one by holding them on one side of the board with a pair of tweezers and freeing the joints on the other side with the soldering iron.

Transistor should always be replaced very carefully. Their sensitivity to heat is frequently grossly exaggerated and they can, in fact, withstand quite a lot of harsh treatment but, since they are quite expensive, there is no point in taking unnecessary risks. When soldering a transistor into place, grip the lead being soldered with a pair of needle-nosed pliers between the transistor and the board. This will prevent the heat from the iron from being conducted along the wire to the transistor junction. In some cases this may be impossible, because the transistor has to be mounted flush with the board. If this is so, the joints should be made as quickly as possible with a small iron. Using an iron that is not at full heat will not help, because the joint will take longer to make. It is far better to make the joint quickly with an iron at full heat, in which case the transistor is most unlikely to be damaged.

Sometimes, when several components have been replaced, the copper on the bottom of the board will peel off slightly. This poses something of a problem, since glueing it back into place is virtually impossible. If the piece of copper that has pealed is still available it may be held in place by soldering it to the component contact that it is supposed to be connected to. If, on the other hand, the copper is completely separated from the board, the gap will have to be replaced by a short piece of wire joining the two points between which the copper is missing. The wire will be held in place by the solder contacts at each end, but the addition of a little cement over the wire will improve the joint and will ensure that the wire does not drop off when the joints are heated again.

CHAPTER 2

COMPONENTS USED IN TRANSISTOR RADIOS

The components used in transistor receivers naturally differ somewhat from those in valve radios. Quite apart from the question of size, the ranges of values are different and the methods of construction are often dissimilar. An understanding of the components used is a great help in servicing, particularly when a direct replacement for a component is not available and a substitute has to be used.

Resistors (Fixed)

Table model and large portable transistor radios normally use very much the same sort of resistors as those found in valve sets. The range of values employed, however, is somewhat different because transistors are much lower impedance devices than valves and the values of load and bias resistors are correspondingly less. Very close tolerance and high stability resistors are rarely used, except, perhaps, in push-pull output stages, because they are not necessary. Half-watt resistors are normally used in larger sets, not because they are called upon to dissipate so large a power but because this is the cheapest size. It is a fairly safe bet that no transistor receiver ever uses a resistor which is required to dissipate more than $\frac{1}{4}$ watt at the outside, so that this size may be used as a replacement in the larger sets if it happens to be convenient.

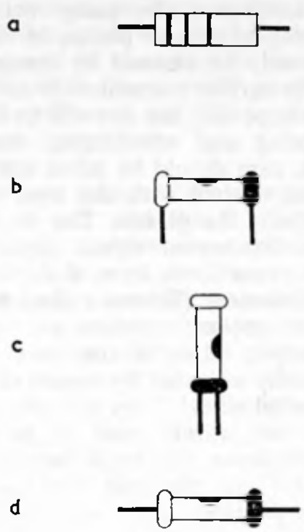


Fig. 2. The four types of resistor found in miniature receivers.

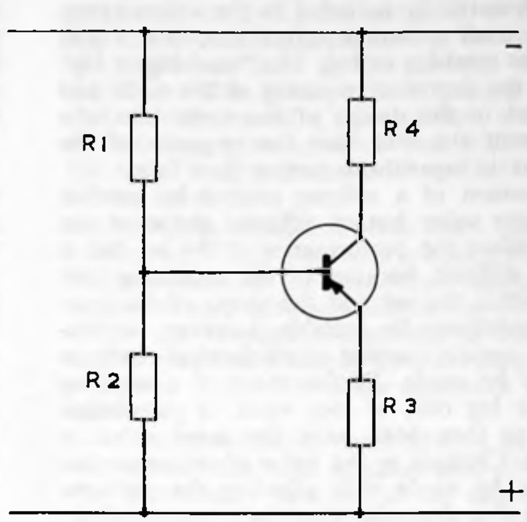


Fig. 3. Transistor bias resistors.

In the very small pocket radios now on the market special sub-miniature resistors are normally used. These have power ratings ranging from 1/8 to 1/50 of a watt and go down to about 1/4″ long by 1/10″ in diameter, or even smaller. These resistors come in four shapes, as shown in Fig. 2. The most common in Great Britain is shape a. On the Continent, types b and d are widely used, and type c, with both leads leaving from the same end, is popular in Japanese sets. Any one of these types may be used as a replacement for any other, assuming that sufficient space is available. Replacement of a resistor by one of a lower wattage rating is unlikely to cause any trouble since most resistors in a pocket radio only dissipate a milliwatt or two. Care must be taken, however, over the resistors used in the output stage and the driver stage.

Some of the small types of resistor are poorly insulated, and this can lead to trouble. The type shown in Fig. 2 (d), for example, is sometimes insulated only by a coat of paint, and if this wears off, as it often does, the metal and terminations are laid bare. If the resistor is mounted vertically, so that the top wire is parallel with the body of the resistor, this may cause the resistor to be shorted out. The fault may be remedied by painting over the metal ends of the resistor, but it is then liable to recur. A better solution is to replace the resistor by the type shown in Fig. 2 (a), which is far less prone to trouble.

Some foreign receivers use resistors of non-standard values and these have to be replaced by resistors having different values than their own. Naturally, a resistor should be chosen having a value as close as possible to that requiring replacement, the deviation being not more than about 5 per cent. In the case of the converter transistor and the first I.F. transistor of a superhet, the collector current is fairly critical and it is advisable to arrange that replacement of a resistor raises the collector current slightly rather than lowers it. Fig. 3 shows the resistors normally associated with a transistor, all other components having been left out. When it is necessary to change the value of a replacement resistor, use a higher value for R2 and a lower value for R1, R3 and R4. This will ensure that the collector current is not reduced.

Variable Resistors

Variable resistors or volume controls in transistor sets are of two types: the spindle type and the rim control variety. The former are similar to those used in valve sets, although often smaller. The latter are generally used in miniature or pocket radios and are varied by rotating the rim of the control, the centre remaining stationary. They have an overall depth of about 1/4″ and a diameter of about ⅝", although even smaller types are sometimes used. The on/off switch for the receiver is normally included in the volume control. The most common values used are 5 and 10 K ohms semi-log or log. The "semi-log or log" refers to the degree of tapering of the track and is included in the design of the control to take into account the fact that the response of the human ear is logarithmic rather than linear.

Replacement of a volume control by another of the same value but of different shape or size will not affect the performance of the set but is normally difficult because of the mounting provisions within the set and the shape of the case. It may sometimes be possible, however, particularly if a certain amount of mechanical readjustment can be made. Replacement of a semi-log type by a log one, or vice versa, is permissible so long as they both have the same value of resistance. Changes in the value of resistance can sometimes be made with affecting the performance, but this depends upon the circuitry of the set. With a normal size transistor superhet a change of 2 : 1 will not normally cause trouble, but with reflex sets, especially the very cheap ones, such a change may not be possible.

The track of the volume control is normally made of carbon composition. Any dirt on the track will cause the set to crackle as the control is rotated. This fault can only be cured by cleaning the track with a liquid such as carbon tetrachloride. Unfortunately, many volume controls are not easy to take to pieces, in which case the track can only be cleaned by immersing the entire control in carbon tetrachloride and swirling it about in the hope that the dirt will be dislodged.

When soldering and unsoldering rim control potentiometers, care should be taken not to touch the body of the control with the iron, since this can easily deform the plastic. The contact pins should not be overheated either, since this can cause them to come loose from their mountings.

Pre-Set Potentiometers (Trimmer Resistors)

Trimming or pre-set resistors are sometimes used in the output stages of transistor receivers. They are normally adjusted by means of a screwdriver or a knurled wheel. They are not very prone to faults and very rarely need to be replaced. Occasionally, however, the track breaks and the component has to be replaced. The replacement need not have precisely the same value as the original resistor, because the amount of resistance in circuit is only a fraction of the total track resistance. Values up to three or four times the original value may be used before adjustment becomes too delicate to be effective. If a suitable pre-set resistor is not available, a fixed resistor may sometimes be used instead. The value re-

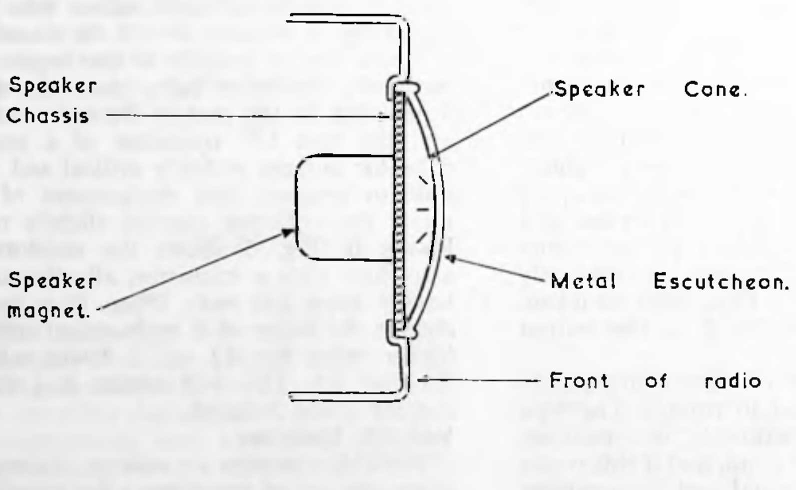


Fig. 4. Method used to mount inverted cone loudspeakers.

quired is determined by temporarily wiring a volume control into the circuit and adjusting it until the correct position is found. The volume control is then removed carefully to avoid varying its setting and its resistance is measured. A fixed resistor is then found with precisely the same measured resistance, and this is wired in place of the pre-set component.

Thermistors

Thermistors (temperature sensitive resistors) of both the N.T.C. and the P.T.C. type (negative and positive temperature coefficients) are also found in transistor output stages quite frequently. They are used to prevent the collector currents of the output transistors from changing too much with temperature. Very little latitude in the value of these components is available and it is not normally advisable to alter the type used. A direct replacement should be used whenever possible. If the thermistor is replaced by an ordinary resistor of the same value the set will probably work perfectly well at normal room temperatures, but at slightly higher temperatures it will start to distort and, in the extreme case, the output ransistors may be destroyed. This course should not, therefore, be taken. Fortunately, thermistors very rarely fail.

Fixed Capacitors

The fixed capacitors used in transistor radios may be broadly divided into two classes : electrolytic and non-electrolytic. We will deal with the latter first.

These cover a range of from a few pf. to about 0.1 microfarads and their use is generally confined to the R.F. and I.F. sections of the circuitry. Apart from the I.F. transformer tuning capacitors, which are normally polystyrene or ceramic close tolerance types, they are not particularly critical in value. Metallised paper capacitors were and still are used quite extensively but, now that subminiature ceramic types are becoming available, these are replacing them. A faulty paper capacitor may be replaced by a ceramic type of the same value.

Where a replacement capacitor of the precise value required is not available, one of a slightly larger value can normally be used. In the case of reflex receivers, however, this may not apply, since some of the capacitors in a reflex set are critical.

The maximum working voltages of metallised paper capacitors are rarely less than 125 volts, so this can normally be ignored. Some ceramic capacitors, however, have working voltages of as little as 3 volts, so that care must be taken when replacing these that the working voltage is not exceeded.

Electrolytic capacitors are also not particularly critical and may be replaced by higher value units when necessary, so long as the maximum voltage rating is observed and the physical size is not greater. Electrolytics are normally used as coupling and decoupling capacitors in the audio stages of a receiver and as the battery decoupling capacitor. This latter capacitor must never be replaced by one of a lower value, even though the set may seem to work well with one, since this may lead to motor-boat oscillations as the battery ages.

Electrolytic capacitors often suffer from leakage as they age. This results in a sharp drop in the D.C. resistance of the capacitors, normally many megohms, and adversely affects the performance of the set. Whether a capacitor is leaky or not may be established simply by measuring its resistance, and if this is low the capacitor should be replaced.

Correct polarisation must always be observed with electrolytics. The negative lead of the capacitor is normally attached to the can or casing. This casing is frequently uninsulated, particularly with very small types, and care must be taken to ensure that the casing does not touch other components.

The capacitors used in I.F. transformers have already been mentioned briefly. They are normally mounted inside the I.F.T. can or in a recess beneath it. Two types are common, polystyrene and ceramic. The overall size may be as little as 5 mm. long by 2 mm. in diameter and their value is most frequently 200 pf., although values up to 1,000 pf. are sometimes used. The ceramic variety are sometimes liable to drift if overheated, so this should be avoided. If an I.F. transformer with a ceramic capacitor in it has been replaced in a receiver it should be given time to cool before alignment is begun. Replacement of a faulty capacitor in an I.F. transformer can be made, but great care should be taken to ensure that the very thin wires used for the windings do not come loose from the pins. A polystyrene capacitor may be used as a replacement for a ceramic one if one of the correct size is available, but any replacement must be a close tolerance type. If a sufficiently small capacitor for mounting inside the I.F.T. can is not available, a larger one may be mounted externally as an emergency measure. This may lead to instability and the best position should be found by trial and error. If sufficient space is available, mounting the capacitor under the printed circuit board is often the best solution.

Tuning Capacitors

Air dielectric tuning capacitors similar to those used in valve radios are found in the larger transistor radios and these need no description. For the smaller sets special miniature tuning capacitors with solid dielectric have been developed. These use very thin sheets of plastic such as P.V.C.

(Poly-Vinyl-Chloride) and polythene for the dielectric material. Three sizes have been made, their dimensions being 25 × 25 × 12 mm., 20 × 20 × 10 mm., and even 15 × 15 × 10 mm. This latter size is, as yet, very rare, because of the difficulty in manufacture, but it is likely to become more popular as the demand for very tiny radios increases.

An ordinary superhet tuning capacitor has two sections, one for the aerial and the other for the oscillator circuit. The former has a maximum value of about 200 pf. and the latter of around 100 pf. A trimmer of about 15 pf. for each section is mounted on the back or built into the casing. Most of these little capacitors are protected from dust by a plastic casing which is sometimes removable.

If a miniature capacitor develops a fault there is rarely anything that can be done about it, but possible faults are worth describing anyway since they may not be immediately apparent. The most common trouble is the main spindle coming free from its rear mounting. This often happens in the cheaper types which use only a plastic mounting for the back support. If this fault occurs it may be detectable by a looseness of the spindle, but sometimes the component appears to be perfect and the only result is that the set is impossible to align. Another form of trouble that occurs quite frequently is the breaking of the pins that prevent the spindle from turning further than it should. This also upsets the adjustment of the plates and makes the component useless.

Replacement of a tuning capacitor must always be made by one of the same size and value and usually of the same make. Substitution of a capacitor by one of only a slightly different value is most unlikely to be successful.

If the trend towards ever smaller tuning capacitors continues, new types are likely to appear. It seems improbable that smaller tuning capacitors than those at present in use will employ the same form of construction because of the difficulties involved in production. One likely alternative is the voltage variable capacitor in conjunction with a variable resistor. The voltage variable capacitor is a junction diode with a high capacitance in the absence of a bias voltage. When the diode is reverse biassed its depletion layer increases in size and its capacitance is reduced.

Thus all that would be required in a superhet receiver is a pair of junction diodes and a variable resistor to vary the voltage across them and hence the capacitance. Such sets have already been made experimentally and it may not be long before they are used commercially. Incidentally, variable capacitance diodes make automatic frequency control possible on the medium wave band and this is likely to lead to push-button tuning even on very small sets.

Loudspeakers

The loudspeakers used in transistor sets are very much the same as any others except that particularly small and compact types have been developed. These normally employ extremely flat cones and the speaker chassis follows the contours of the cone very closely. To save space, some sets use inverted cone loudspeakers with the cone protruding from the front of the case and protected by a metal escutcheon. This metal is often very thin and is easily dented. Since the metal is not far from the cone it may then touch it on part or all of the cone's movement. This will cause distortion which sometimes sounds like a fault in the audio circuit. The cure, of course, is to remove the speaker and to push the escutcheon back into position very carefully.

Loudspeakers used with normal output transformers usually have voice coil impedances of 3 or 10 ohms, as in valve sets, but special direct coupled circuits are often used and these require higher impedance speakers. Centre tapped loudspeakers with impedances in the region of 30 to 150 ohms are used in transformerless symmetrical push-pull output stages, and untapped, high impedance speakers are often used in single-ended output stages.

The impedance of a loudspeaker is always just slightly more than its D.C. resistance, which is easy to measure. A speaker must always be replaced by one of the same impedance, although a slight difference may not matter. Replacement by a unit of a different make is quite permissible so long as the second unit fits, but care must be taken to ensure that the replacement is as well shielded as the original. Speakers of a particular make, size and impedance are often made with different strength magnets. A loudspeaker should not be replaced by one having a weaker magnet, since this will reduce the overall sensitivity of the set. Higher strength magnets may be used to advantage however.

The vast majority of loudspeakers in transistor radios are moving coil types, but one or two American sets employ moving iron or balanced armature speakers because of their sensitivity and light weight. With these the D.C. resistance is considerably less than the impedance and they cannot be satsfactorily replaced by moving coil units.

Earpieces or Ear Speakers

Many pocket radios are equipped with a socket into which an external earpiece or ear speaker may be plugged. In some sets the earpiece is the only speaker employed, there being no loudspeaker inside the case.

The earpiece is normally connected to the set by means of a jack plug which may be 2½ or 3½ mm. in diameter. This plugs into a matching socket and automatically disconnects the loudspeaker. The earpiece may then be driven from the output stage or, less often, from the driver transistor.

Two types of earpiece are used; crystal and magnetic. The former have impedances of around ½ megohm and the latter range from 3 to 7,000 ohms. The magnetic types are most common and they vary enormously in sensitivity and quality. Those made in Japan are usually of very low sensitivity because they are designed to be driven from the output stage where more than sufficient power is available. Low sensitivity does not mean poor quality and the Japanese units range from very poor to excellent in this respect.

Failure of an earpiece to operate is usually due to one of the leads coming loose inside the plug or the earpiece itself. Some cheap plugs and earpieces cannot be taken to pieces, so that if they develop this fault they are useless. Others, however, may be taken to pieces and reconnected.

Sets in which the earpiece is driven from the driver transistor, such as those made by some British firms, normally require high impedance (around 1,000 ohms) high sensitivity earpieces. With other sets, the requirements are less stringent since the output power available is vastly more than that required by the earpiece. The impedance of the earpiece need not match that of the output stage for the same reason, and even a 0.5 megohm crystal earpiece will work well with a 10 ohm impedance output. The only satisfactory way to determine whether or not an earpiece is suitable for use with any particular set is to try it, there being far too many unknowns for any form of calculation.

Receivers which have only an earpiece for their output normally require a sensitive earpiece for satisfactory results. The impedance of the earpiece must also match the output impedance of the radio accurately because the output power of such a set is rarely more than a milliwatt or two. Most earpiece only sets, which are, as yet, rare in Great Britain, will not work properly with a crystal earpiece because the earpiece often acts as the sole load for the output transistor and crystal types do not conduct D.C.

Aerial Coils

Aerial coils in transistor radios are almost invariably ferrite rod aerials, at least for the long and medium wavebands, these having outmoded the frame aerials that used to be used in valve portables. The ferrite rod concentrates the signal in the aerial coil and increases it by as much as 100 times because the rod offers a path of lower resistance to electro-magnetic radiation than does space. A ferrite rod with an aerial coil wound in it therefore provides all the aerial that a set normally requires. The longer the rod is, the greater its signal pick up, and the larger its diameter, the greater the "Q" factor of the tuned circuit. For this reason, manufacturers use as large rods as their sets will accommodate. The efficiency of a ferrite rod aerial is impaired by the presence of any large pieces of metal nearby.

Ferrite rod is very brittle and if a set has been dropped and, as a result, no longer works, there is a good chance that the rod has been fractured. The coil is often sealed in position on the coil by means of wax. If this is heated and wiped off the rod may be replaced by another of the same diameter and length.

If the coil itself is damaged but the rod is still intact another coil may be wound of roughly the same inductance. The turns ratio between the primary and secondary is normally about 10 : 1 and this is not very critical. Nor is the inductance of the coil critical, because a 3 : 1 variation can easily be obtained by sliding it along the rod; maximum inductance being obtained with the coil in the centre.

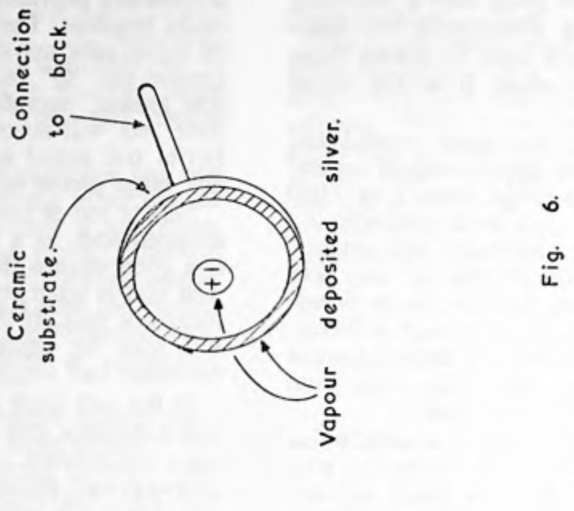
A receiver should never be aligned with its ferrite rod in any but its operating position because of the considerable effect of the nearby components.

I.F. Transformers and Oscillator Coils

I.F. transformers have already been discussed in connection with their tuning capacitors and only the main body need be described here. Two sizes are now more popular than any others, those 10 × 10 × 13 mm. and those 7 × 7 × 10 or 12 mm. Naturally the products of different manufacturers vary somewhat, but these sizes are closely approximated by most of them.

One popular form of construction is shown in Fig. 5. A ferrite cup covers the coil and the inductance is varied by raising and lowering it. The cup has a screw thread on its edge which grips on to a threaded plastic former and is adjusted by means of a screwdriver. The tuning capacitor is mounted at the bottom between the pins.

Too much heat on the connecting pins at the bottom can cause the wires of the coil windings to become disconnected. If this happens the can may be removed and the wire or wires reconnected, but this requires a very small soldering iron and a steady hand. The ferrite slug or cup may become stuck to the plastic former and this may be loosened by a drop of glue. Many manufacturers seal the position of the slug, after final alignment, with a drop of wax. When readjustment becomes necessary the wax may be melted



Ceramic resonator I.F transformer. Fig. 6.

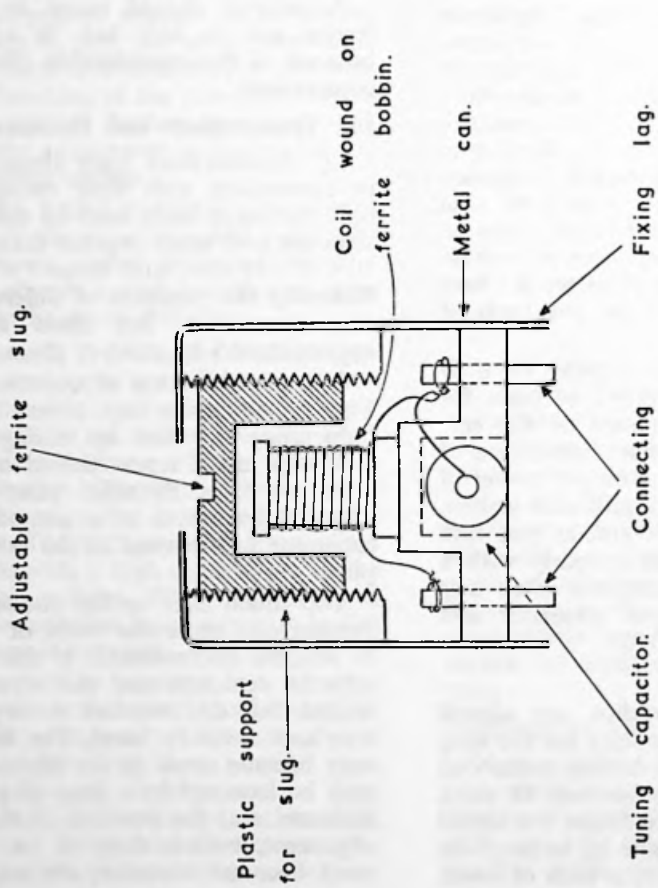


Fig. 5. Cross-sectional view of typical I.F. transformer.

by touching a soldering iron to it for a few seconds. The slug can then be turned with the wax soft. The wax should then be re-melted to ensure that it seals the slug efficiently.

It is very rarely possible to replace an I.F. transformer or an oscillator coil by one of another type because so many factors are involved. Most I.F. transformers are designed around a centre frequency of between 450 and 480 Kc/s. American and Japanese sets usually use an I.F. of 455 Kc/s. In England 465 and 470 Kc/s are more common.

As with tuning capacitors, I.F. transformers have been made as small as they can be conveniently with normal techniques, and new types are likely to appear if sets become any smaller. One promising possibility is the ceramic resonator with a complete coating of metal on one side and a ring of metal on the other side with a spot of metal in the centre. The metal is in the form of vapour deposited silver (see Fig. 6). The ceramic is piezo-electric and resonates at the intermediate frequency. The back and the ring contacts form the high impedance primary and the secondary is formed by the spot and the back. The overall size of such a unit can be made extremely small and it never needs any adjustment or alignment. These I.F.T.s are already in production and are likely to appear in receivers fairly soon.

A.F. Transformers

The A.F. transformers in transistor sets are miniaturised versions of valve equivalents but with lower D.C. inductances and resistances. Very small A.F. transformers tend to be inefficient because their D.C. resistances have to be rather high. They also distort because the saturation point of the core is easily reached. For these reasons the latest pocket sets are using circuits which require no A.F. transformers at all. This is quite possible with complementary symmetry output stages and with Class A single-ended output circuits.

The main causes of failure in A.F. transformers are shorted turns, which degrade the performance, and broken wires which prevent the set from working altogether. Neither of these can be cured and transformers with these faults have to be replaced.

Replacement of a transformer must usually be made by one of the same type because of the difference in physical shape between different types. If a replacement is available of the same size but slightly different characteristics, however, this may normally be used. The most important characteristics are the inductance and d.c. resistance of the windings and the turns ratio between them.

In some sets, where it is necessary to mount two transformers close to one another, special shielding is used. This must not be removed.

Batteries

Most transistor radios are designed for a specific type of battery and so choice is possible as far as size is concerned. There is sometimes a choice of types, however, because new types in standard shapes are becoming available. For example, zinc-carbon batteries the size of the Ever-Ready PP3 are in common use all over the world. Two alternatives are now possible: the more expensive Mercury battery made by Mallory is one and this has the advantages of a far longer life and more constant voltage with life. The other is a re-chargeable battery which is now becoming available. This is more expensive still, but lasts indefinitely. It seems probable that sets will be made with built-in re-chargeable batteries and small chargers so that they can be plugged into the mains overnight for re-charging.

Zinc-carbon batteries may leak if they are left in sets too long, and for this reason they should be removed as soon as their useful life is ended. If one does leak in a set, any liquid should be removed entirely because it is extremely corrosive. When dry it is best removed by a small stiff brush such as a toothbrush. Preferably one reserved for the purpose.

Mallory mercury cells differ from zinc-carbon cells in the way they discharge. The voltage of a zinc cell starts to decline immediately it is used and it drops steadily until the life of the cell is ended. Mercury cells, however, maintain an almost constant voltage until they are completely expired. This means that a radio operating from a mercury battery will give a far more constant performance, there being no loss of output power until the battery becomes useless.

Some small radios are specifically designed for use with mercury cells. They may employ re-generation, the level of which is normally dependent upon battery voltage, and their output is not designed to cope with much voltage drop. This type of set will work perfectly well with a zinc battery, but only when the battery is new. As soon as the battery ages slightly and its voltage begins to drop the set will lose sensitivity and the output may be distorted.

When the metal of a battery clip is different from the metal of which the battery contacts are made, electrolytic action may occur at the point of contact. This may result in intermittent operation or complete failure. The fault may be cured, of course, by cleaning the clips.

In radios which use Class B output stages the life of a battery can be extended by keeping the volume level to a minimum. In sets with Class A outputs, however, the consumption from the battery is the same whatever the volume level and no economy is possible.

The latest development in radio batteries is the use of silicon solar cells. A batch of these large enough to power a radio is still very expensive, but the price is likely to drop soon. Solar cells take up very little volume, since they are extremely thin, so pocket radios of the future may be powered by solar cells during the day and by a very small internal accumulator at night time. The accumulator would be charged by excess power from the silicon cells.

Diodes

The diodes used in transistor radios are normally point contact germanium types. They are used for two purposes; for detection of the R.F. or I.F. signal and for provision of A.G.C. voltages. In addition, some transistor radios use a second diode in an auxiliary A.G.C. circuit, in which case the diode acts as a switch and shunts one of the tuned circuits on strong signals. This shunting reduces the "Q" of the tuned circuit thereby reducing the sensitivity of the set and broadening the response.

Diodes are prone to damage by overheating just as transistors are, and they should be protected when being soldered by the use of a heat shunt. They are not normally prone to failure but, since they are encapsulated in glass, they may break if the set is dropped. When a diode is replaced correct polarity must be observed. An incorrectly connected diode will normally result in considerably reduced volume and rarely in complete failure of the set.

When a direct replacement for a diode is not available one of another make or type designed for the same purpose may be used because the precise values of forward and backward resistance are not critical. A good general replacement diode is the Mullard OA70.

Some of the very small sets now on the market use sub-miniature diodes. These may be replaced by the Mullard OA91.

Whether or not a diode has become faulty may be tested by measuring its forward and reverse resistances. The reverse resistance should be at least several hundred kilo-ohms and the forward resistance should not be more than a few hundred ohms.

If transistor radios are made with built-in chargers for a re-chargeable battery, these may also use germanium diodes.

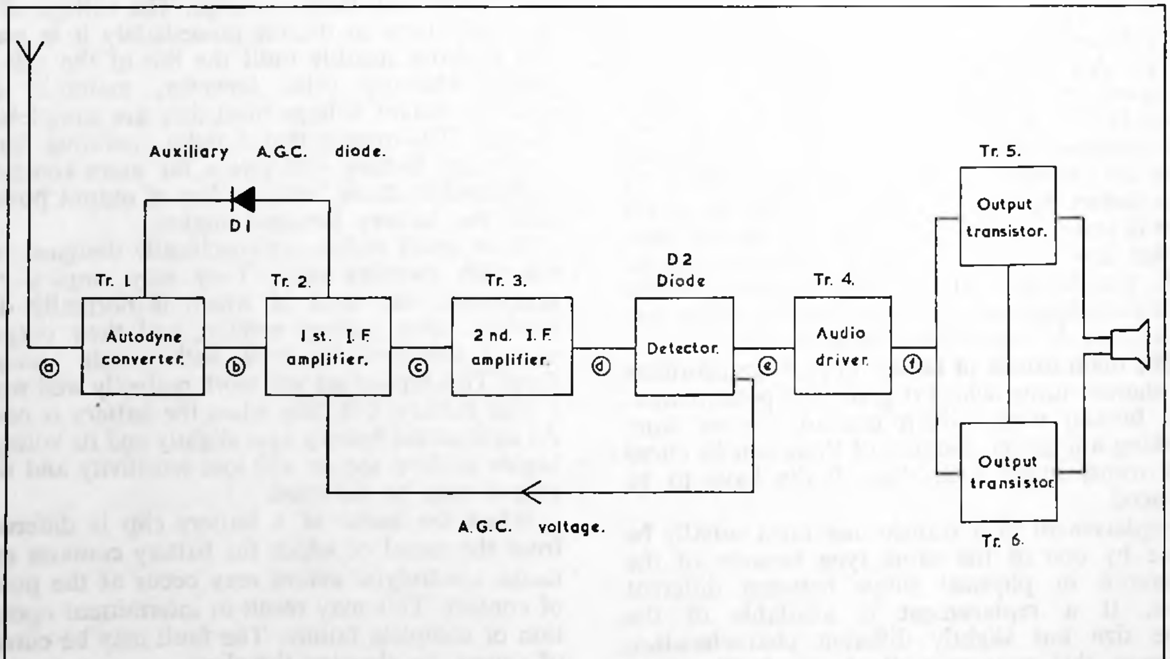


Fig. 7 Block diagram of a typical 6—transistor Superhet.

CHAPTER 3

SERVICING TRANSISTOR SUPERHETS

Far and away the majority of commercial radio sets are superhets, and most of these at present use six transistors in a circuit that varies only in detail from one manufacturer to another. Broadcast band superhets using anything from three to nine transistors are also made, however, and these often make use of circuitry that is unconventional in one way or another.

The six-transistor superhet will be discussed first, and detailed servicing information provided. The other types of superhet can then be seen in relation to this and only the points of difference need be considered.

Six-Transistor Superhets

The way in which a superhet works will not be discussed here, since this is fully covered by many other books, including "Transistor Superhet Receivers" published by us.

Fig. 7 shows the block diagram of a typical receiver of this type and the circuit diagram is shown in Figs. 8 and 9. Since the key to the operation and correct functioning of the receiver are the transistors and the diodes, these will be discussed individually.

Tr1. This transistor operates as a self-oscillating mixer or autodyne converter. The collector current is usually in the region of 0.5mA, but may be anything from ¼ to 1½mA, depending upon the design of the set. The magnitude of oscillation from the oscillator section should be between 50 and 500mV right across the band. The input signal to the base of the converter for 50mW output from the set should be about 5 to 10 microvolts if the set is functioning properly.

A converter transistor must be a good high frequency type and should normally have a cut-off frequency of at least 10 mc/s, since it is required to oscillate at frequencies of up to 2 mc/s. Too low a cut-off frequency is indicated by a lack of oscillator amplitude at the high frequency end of the band.

In Fig. 8 the emitter of Tr1 is coupled to the oscillator coil by means of a capacitor, C2. In some cases a third winding on the oscillator coil connected in the emitter lead may be used.

When an auxiliary A.G.C. diode such as D1 is not used, C2 and C4 are unnecessary. A double tuned I.F. transformer is often used for the output of this stage to increase selectivity.

In some Japanese receivers the oscillator coil is coupled to the base instead of to the emitter, but since this entails the use of a transistor with a better high frequency performance than is necessary the circuit is not used as often as that shown here.

Surface barrier transistors are sometimes used for Tr1, in which case the collector current is likely to be lower than normal and the collector voltage will not be more than about 3 volts.

Alloy-diffused or drift transistors are used for Tr1 in some of the latest sets and these have the advantage of increased gain. They normally operate at a collector current of around 1mA.

Tr2 and D1. Tr2 is the first I.F. amplifier. This transistor also operates with a collector current of around 0.5mA but, since the A.G.C. voltage is applied to it, this may drop to only 50 microamps for a strong signal. For this reason the collector current should only be measured in the absence of a signal. The voltage at the base of Tr1 for 50mW output will usually be around 100 microvolts, but it may vary considerably from this figure.

A.G.C. is achieved by lowering the base bias voltage of the transistor on strong signals. This reduces the collector current and the gain. Some sets have tuning indicators on them, and these are normally connected in the collector or emitter of Tr1, since they thereby register the strength of the signal received. The diode D1 is sometimes included in sets of this type to increase the efficiency of the A.G.C. system. When the signal strength is low D1 is reverse biassed, there being more voltage dropped across R7 than across R4. With a strong signal, however, the voltage across R7 will drop to below that across R4 and D1 will become forward biassed. It will then act as a low value resistor across the primary of the first I.F. transformer, shunting it and reducing the gain of the set.

Other types of transistor may be used as with Tr1, and these may operate at different collector current values.

Tr3 and D2. Tr3 is the second and final A.F. amplifier and normally operates with a collector current of around 1mA since no A.G.C. is applied, and this level provides approximately maximum gain. The input required for 50mW output will be in the region of 2.5mV to the base of this stage.

Tr2 is coupled, by means of the final I.F. transformer, to the diode detector, D2. The load for D2 is VR, which is usually around 5 to 10K ohms. C11 returns any surplus R.F. to earth. The D.C. output from the diode is fed back to Tr2 via R8, the A.F. being grounded by C5.

In receivers that use N.P.N. transistors for Tr1, Tr2 and Tr3, the battery connections will be reversed and D1 and D2 will be the other way round. Electrolytic capacitors will also be reversed. N.P.N. transistors are not used in the R.F.

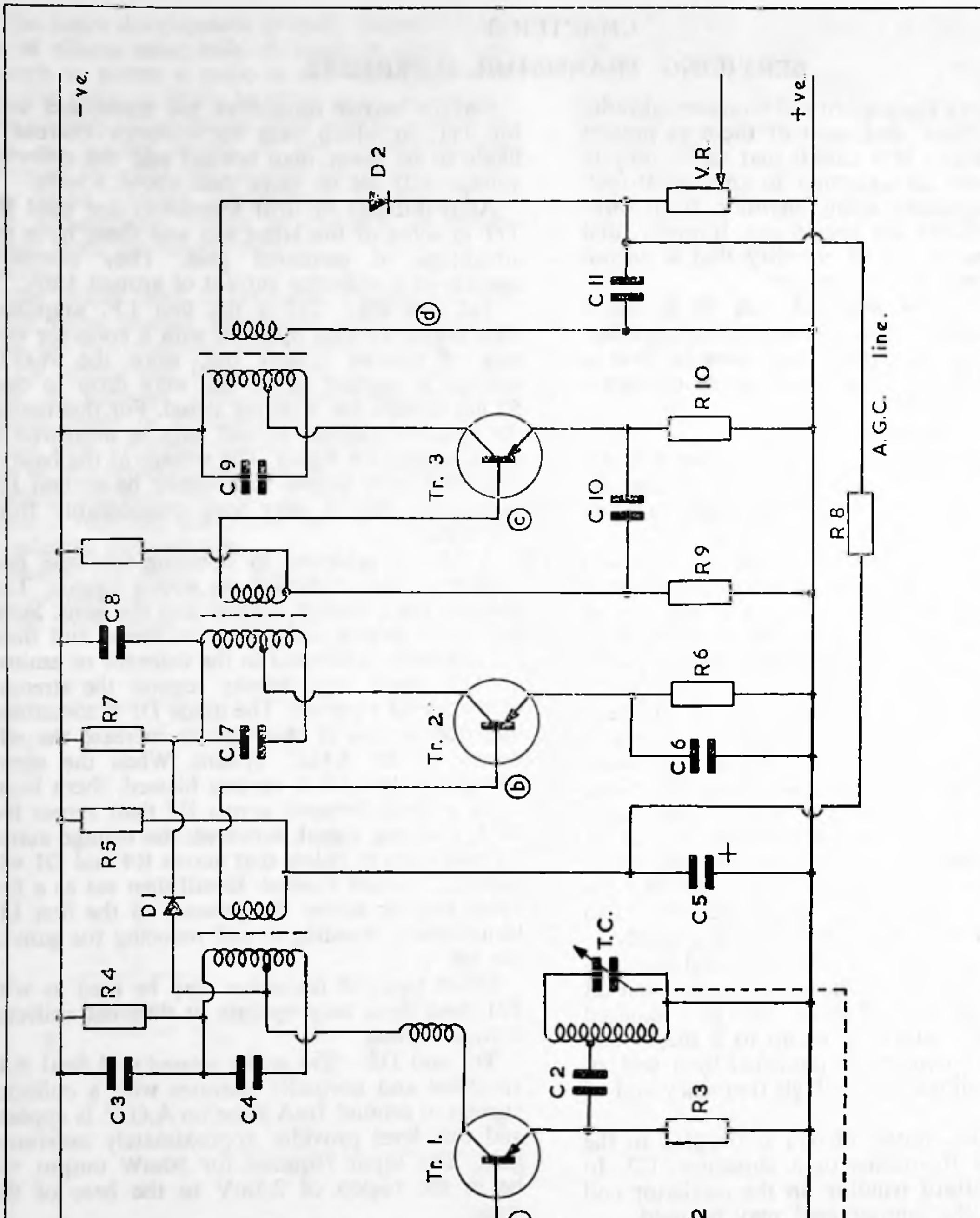


Fig. 8. The R.F. section of a typical 6—transistor Superhet.

sections of any British sets, but both Japanese and American sets sometimes use them. It is as well to determine which types are used before attempting to make any measurements or to take any readings.

Some American companies are experimenting with several transistors in a single encapsulation. In future, therefore, Tr1, Tr2 and Tr3 may all be in one case and will have to be replaced together. This is still rather far off, however, and may never occur.

The A.F. Transistors

The A.F. amplifier of a typical transistor superhet consists of a driver stage followed by a Class B push-pull output stage. The output power may range from about 40mW to 1 watt or more but the most popular level is around 200mW with 100mW for very small sets.

The collector current of Tr1 will depend upon the maximum output power for which the set is designed and on the battery voltage, but it is usually around 3mA. The stage operates, therefore, at close to the maximum gain of which the transistor is capable.

Since the output transistors are operated in the Class B mode their collector currents will depend upon the volume to which the set is adjusted. In the absence of any signal the transistors have a slight forward bias which is provided to prevent cross-over distortion. This results in a quiescent collector current level of around 3mA.

For distortion free output it is essential that Tr5 and Tr6 be matched accurately. That is to say, they must both provide the same current gain over the operating range. For this reason it is normally necessary to replace both audio output transistors by a new matched pair when one of them becomes faulty.

C13 and C15 are battery decoupling capacitors and their function is very important to the operation of the A.F. amplifier. They compensate for the increase in internal resistance which occurs as the battery ages. Should one or both of these become faulty, positive feedback is likely to occur through the battery and cause motor-boat oscillations.

Some receivers use a form of single-ended push-pull output stage which requires no output transformer. There is insufficient space available here, however, to give a detailed coverage of all the types of A.F. amplifier possible. Readers requiring this information can obtain it from "Transistor High Fidelity and Audio Amplifiers" published by us.

Servicing Procedure with a Six-Transistor Superhet

With valve receivers and equipment that have become faulty, the most suspect components are

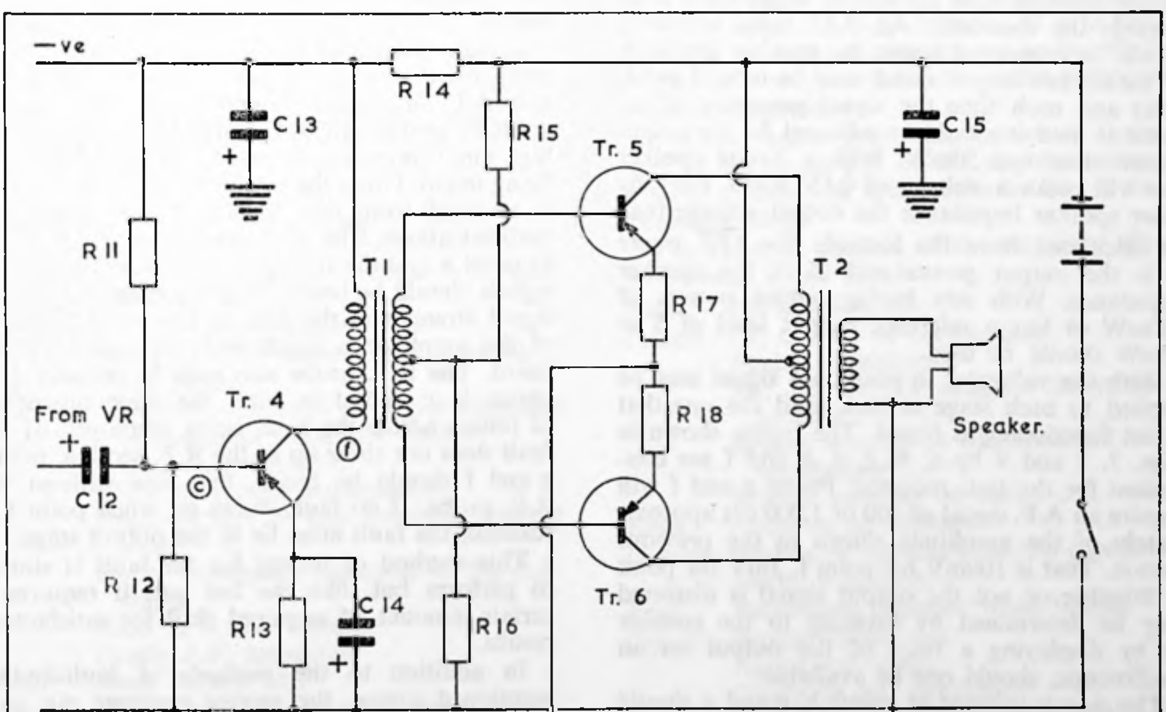


Fig. 9. The A.F. section of a typical superhet.

the valves themselves. Since these are easily removed, the common procedure is to test them first before considering any of the other components. With transistor sets, however, the position is reversed for, far from being one of the most delicate components in a radio, a transistor is one of the most robust. Furthermore, transistors are normally soldered into position and it is not convenient to replace each one in turn.

When a radio is brought in for repair, the first thing that should be tested is the battery. In a remarkable number of cases, radios supposed to be faulty merely require a battery replacement. The reason for this is that transistor sets tend to distort as the battery voltage drops, usually due to cross-over distortion in the output stage. Valve sets, however, on which most people base their experience, normally continue to play satisfactorily but with reduced volume and sensitivity.

First of all, then, the battery voltage should be measured with the set switched on. Most sets are designed to operate well down to between half and two-thirds of the nominal voltage of the battery, but some sets start to distort long before this point is reached. If the battery proves to be other than almost new it should be replaced and the set tested with the new unit.

If the fault in the set still persists the next step is to determine in which part of the circuit it occurs. Starting with the output stage, work back towards the converter. An A.C. valve voltmeter should be connected across the speaker terminals of the set (an output meter may be used if available) and each time the signal generator or injector is used it should be adjusted for an output power of around 50mW. With a 3-ohm speaker this will mean a voltage of 0.4V RMS. For any other speaker impedance the output voltage may be calculated from the formula $V=\sqrt{PZ}$ where P is the output power and Z is the speaker impedance. With sets having output powers of 100mW or less a reference output level of 5 to 10mW should be used.

With the voltmeter in position a signal may be applied to each stage in turn until the one that is not functioning is found. The points shown in Figs. 7, 8 and 9 by a, b, c, d, e and f are convenient for the tests required. Points e and f will require an A.F. signal of 400 or 1,000 c/s approximately of the amplitude shown in the previous section. That is 100mV for point f, 3mV for point e. Whether or not the output signal is distorted may be determined by listening to the speaker or by displaying a trace of the output on an oscilloscope, should one be available.

The signals injected at points b, c and d should be at the intermediate frequency of the receiver modulated to about 30 per cent. by a 400 or 1,000 c/s signal. The amplitudes required at points b, c and d should be of the order of 100mV, 2.5mV and 50mV respectively.

If the receiver still functions correctly by the time point b is reached the autodyne converter must be at fault, since this is the only remaining stage. Lack of oscillator amplitude or signal may be the trouble, and this can be measured by connecting an A.C. valve voltmeter between the emitter and earth. The voltmeter must be able to measure up to 2 mc/s and an R.F. probe may be necessary. The magnitude of the oscillation should be 50 to 500mV right across the band. These measurements must be made in the absence of a signal.

Amateurs who do not possess the equipment required for the above tests may nevertheless be able to isolate the trouble by learning to use a simple signal injector such as the one described in the chapter on service equipment. The signal injector should be applied to each stage in turn, as above, and the result listened to in each case. If this procedure is performed several times on radios that are working perfectly the operator will soon know what sort of results he may expect at each stage and will be able to tell, from the sound coming from the speaker, precisely which stage is at fault. Although this method is not quantitative it is entirely satisfactory once the necessary experience and ability are obtained. It may even appeal to the service engineer, since it is certainly a faster method if not quite such an accurate one.

Another means of localising a fault using only inexpensive equipment exists. This uses a high gain A.F. amplifier or signal tracer together with an R.F. probe. An A.F. amplifier must have a high input impedance so as not to load the circuit being tested. Using the signal tracer, the procedure is reversed from that used in the two methods outlined above. The R.F. probe is first connected to point a and the tuning capacitor rotated. Faint signals should be heard. In some cases, where the signal strength in the area is low or if the gain of the amplifier is insufficient, no signal will be heard. The R.F. probe may now be connected to points b, c and d in turn, the same procedure of tuning across the band being employed. If the fault does not show up in the R.F. section, points e and f should be tested, this time without the R.F. probe. If no fault shows up when point f is reached, the fault must lie in the output stage.

This method of testing for the fault is simple to perform but, like the last one, it requires a certain amount of acquired skill for satisfactory results.

In addition to the methods of fault-finding mentioned above, the service engineer can gain a great deal of preliminary information from the nature of the fault itself and this will enable him to reduce the possible parts of the circuit in which the trouble is occurring. Most of the symptoms that can occur are listed below with the possible causes.

Faults may occur with causes other than those listed below, but they are very unusual.

Fault: Radio operates intermittently or not at all.

Causes: Jack plug socket switch not closing properly (VERY COMMON).
Dirty volume control or switch contacts.
Dust between the vanes of the tuning capacitor.
Dry or broken solder joints.
Broken components.

Fault: Dies slowly after being switched on or goes off tune.

Causes: Weak battery or bad battery contacts
Leaky battery decoupling capacitor.

Fault: Heterodyne oscillations and squeals on all stations.

Causes: Weak battery.
Set misaligned.
Broken ferrite rod or ferrite slug in coil.
C5 faulty (Fig. 8).
I.F. neutralising capacitor broken.

Fault: Large change in volume as radio is tuned from one station to another or rotated slightly.

Causes: Faulty A.G.C. system.
Fault in first I.F. stage.
D1 broken (Fig. 8).

Fault: Low sensitivity at one end of the band.

Causes: Misalignment of receiver.
Weak battery.
Faulty converter transistor.

Fault: Low A.F. output.

Causes: Weak battery.
Speaker cone off centre, or loose.
Faulty capacitor in A.F. section.
Faulty Tr4 (Fig. 9), particularly if signal undistorted.
Faulty output transistor.

Fault: Distorted A.F. output on all stations.

Causes: Weak battery.
Cross-over distortion in output stage due to change in value of a resistor.
Faulty A.F. transistor.
Loose or broken loudspeaker.
Pieces of dirt or case touching speaker cone.
Faulty decoupling capacitor in the A.F. stages.
Fault in A.G.C. system.
Faulty A.F. transistor.

Fault: Short battery life.

Causes: Broken or dirty on-off switch.
Shorted or leaky battery decoupling capacitor.
Broken transistor.
Owner of radio expects battery to last too long. This is often the case with miniature sets, some of which have ridiculously short battery lives.

Having used one or other of the fault-finding procedures and considered the fault, the stage in which the trouble occurs and something of its nature should be known.

The faulty component or components may now be found by making suitable measurements. As far as the transistors are concerned, the collector currents that should be found have already been given. The base-emitter voltage should be roughly between 100 and 200 millivolts, and a large deviation from this should lead one to suspect the biasing components or the transistor. The emitter current should always be very slightly less than the collector current, but it should never be measured directly by sticking a milliammeter in the emitter circuit, since this will tend to raise the current being measured. The best method is to measure the voltage drop across the emitter resistor and to calculate the current by Ohms law. If there is no emitter resistor used, as is the case in some directly coupled circuits, the milliammeter may be connected in the emitter lead without any significant effect on the conditions. The fact that a transistor has all the correct operating currents is not a definite indication that it is functioning properly. Should the transistor still be suspect the only thing to do is to replace it in the set with another known to be effective. If this fails to cure the fault, other components must be suspected.

The lists below give likely causes of faults in each of the stages and should help in tracing the trouble. Component values refer to Figs. 8 and 9.

Converter Stage

The collector current of the transistor should be between ¼ and 1½mA.

Fault: No signal at all.

Causes: C1, C2, C3 or C4 shorted.
Faulty transistor.
R1, R2 or R3 changed in value or broken.
Broken winding on oscillator coil or I.F. transformer.
Broken winding on aerial coil.

Fault: Noise on all stations.

Causes: Broken or damaged tuning capacitor.
Faulty transistor.

Fault: Heterodyne whistles when tuning.

Causes: Broken ferrite rod.
Aerial coil loose.
Oscillator coil misaligned.
First I.F. transformer misaligned.

Fault: One station over entire band.

Causes: Oscillator circuit not working.

Oscillator section of tuning capacitor not turning.
C2 open circuited or disconnected.

Fault : No output at high frequency end of the tuning range.
Causes : Faulty transistor.
Aerial circuit misaligned.
Tuning capacitor plates warped or shorting.
I.F. transformer or oscillator coil misaligned.

Fault : No output at low frequency end of the tuning range.
Causes : Tuning capacitor plates warped or shorting.
Oscillator coil misaligned
I.F. transformer misaligned.

Fault : Poor sensitivity at one end of the band.
Causes : Faulty transistor.
Broken aerial rod.
Misalignment of aerial circuit, oscillator coil or I.F. transformer.

First I.F. Stage

The collector current of the transistor should be between ¼ and 1mA in the absence of a signal.

Fault : No output.
Causes : Faulty transistor.
Open or shorted winding on I.F. transformer.
C5 or C6 leaky or shorted.
C7 shorted.
R5, R6 or R8 broken or changed considerably in value.

Fault : Weak signal.
Causes : As above plus—
Misalignment of I.F. transformer.

Fault : Noisy output.
Cause : Faulty transistor.

Fault : Output distorted on strong signals.
Causes : R8 changed in value.
Low A.G.C. from detector.
C5 leaky.
R5 or R6 changed in value or broken.
Faulty transistor.

Fault : Oscillation on some or all stations.
Causes : With certain I.F. frequencies a set may oscillate on one or more stations without being faulty because the signal heterodynes with the oscillator frequency. The only way to cure this is to change the I.F. frequency slightly.
C5 open circuit.
Change in value of neutralising capacitor or resistor.

Second I.F. Amplifier

Collector current of transistor normally lies between ¼ and 1½mA. Faults and causes as with first I.F. transformer, except that no faults will be caused by the A.G.C. system.

Diode Detector

Fault : No signal.
Causes : Faulty diode.
C11 shorted.
Volume control open circuited or shorted.
I.F. transformer winding broken.

Fault : Weak signal.
Causes : C11 faulty.
Faulty diode.
I.F. transformer misaligned.

Fault : Diode not providing any A.G.C. voltage to Tr2.
Causes : Faulty diode.
C11 very leaky or shorted.
R8 broken.
V.R. shorted.

Fault : Distorted output.
Causes : C11 faulty.
C5 faulty.
Faulty diode.

A.F. Driver Stage

Collector current will normally lie between 1 and 5mA, but high current levels may be used in high-powered table or portable radios.

Fault : No output signal.
Causes : Faulty transistor.
Winding of driver transformer open circuit (T2).
C12 open circuited.

Fault : Low output signal.
Causes : C14 open or shorted.
R11, R12 or R13 changed in value.
C12 faulty.
Faulty transistor.

Fault : Motor-boat oscillations.
Cause : C13 open circuit.

Fault : Distortion.
Causes : C14 shorted.
Faulty transistor.
R11, R12 or R13 changed in value.

A.F. Output Stage

The quiescent collector current levels of the transistors will normally be between 1 and 5mA.

Fault : No output.
Causes : Speaker coil open or short circuited.
Faulty transistor.
Winding of output transformer open circuited.
C15 shorted.

Fault : Output distorted (very common fault in this stage).
Causes : Cone of speaker misaligned or hitting something such as case of radio. This is particularly likely with radios which use metal speaker grilles.
Shorted turns in transformer windings.

R15, R16, R17 or R18 changed in value
Faulty transistor.

Fault : Motor-boat oscillations.
Causes : C15 open circuit.
R14 shorted or changed in value considerably.

One rare but elusive fault which has not been mentioned above is the oscillation due to a microphonic tuning capacitor. This only occurs with air dielectric types and is caused by the vibrations from the speaker vibrating the capacitor plates, causing the set to move on and off tune very rapidly. Positive feedback then occurs at one frequency and oscillation starts. This fault may be curable by remounting the tuning capacitor on rubber feet, but it is usually necessary to replace it.

When a set has been repaired it is normally necessary to realign it, particularly since misalignment may have been part of the trouble in the first place. The sensitivity of the set is very dependent upon careful alignment, so the technique required should be mastered. The equipment required is a signal generator covering up to 2 mc/s or so, and an A.C. valve voltmeter or output power meter.

The signal generator should be connected to a radiating loop which may consist of a few turns of wire about a foot in diameter. Alternatively a ferrite rod aerial may be used. The A.C. valve voltmeter or the power output meter should be connected to the loudspeaker terminals and will be required for keeping the set at an output level of 50mW or 5 to 10mW in the case of a very small receiver. The receiver should be placed from one to two feet from the radiating loop in the position of maximum pick up.

To align the set the following steps should be taken :

1. Turn the volume control of the set to maximum volume.
2. Turn the tuning capacitor to the high frequency end of the dial (blades fully open).
3. Set the signal generator to the I.F. frequency of the receiver. If there is less than the reference output power from the receiver (50mW or 5 to 10mW), move the set nearer to the radiating loop until this level is reached. If there is more reduce the output from the signal generator.
4. Turn the slug of each I.F. transformer in turn for maximum output, working from the last I.F.T. back to the first. Where double-tuned I.F.T.s are used, tune the secondary first. Keep the output power constant all the time by reducing the output power from the signal generator as required.
5. Now tune all the I.F. transformers again, this time working from first to last. The alignment of the I.F. strip is now complete.
6. Set the signal generator to a frequency of 1,630 Kc/s, keeping the tuning capacitor tuned to the high frequency end of the band. Now adjust the trimming capacitor of the oscillator coil for maximum output at this point.
7. Turn the capacitor to the minimum frequency position (plates fully meshed) and tune the signal generator for maximum output from the set, which should occur between 530 and 540 Kc/s.

If the low frequency end is not between about 520 and 540 Kc/s the set is badly misaligned and the oscillator coil slug must be adjusted to obtain a bottom frequency of 530 Kc/s. This will make it necessary to repeat operation 6 and 7 again, repeating this performance until proper coverage is obtained.

8. Tune the signal generator to 1,400 Kc/s and adjust the tuning capacitor for maximum output from the receiver. Now peak the aerial trimmer for maximum volume.
9. Tune the signal generator and the set to 600 Kc/s and see if the sensitivity is as good as it was at 1,400 Kc/s. If it is not, adjust the slug of the oscillator coil, adjusting the tuning capacitor backwards and forwards slightly to keep the two in alignment whilst the best position is found. The alignment of the receiver is now complete. Other methods of alignment exist, for example the A.G.C. voltage may be monitored instead of the output. They all achieve the same result, however, and the method just given is probably the simplest and certainly the one most generally applicable.

Alternative Types of Circuitry

The radio circuit that has just been described is typical of most of the sets on the market, but many sets do not use special circuitry. The alignment details given, of course, apply to all sets.

In some receivers the functions of oscillator and mixer are performed by separate transistors. There is no advantage in this as far as I know, but it means that the manufacturer can call his set "seven-transistor" or "eight-transistor" as the case may be. So far as servicing is concerned, this makes no difference, but it should be remembered that the quiescent collector current of the mixer transistor may be very low indeed, possibly only a few tens of microamperes.

Quite a few sets use only a single transistor in the output stage. This usually operates as a normal Class A amplifier and the faults it is liable to are the same as those of the driver stage.

Three-Transistor Superhets

The circuit of a typical three-transistor superhet is shown in Fig. 10. This type of set is quite popular with Japanese manufacturers, but European producers have so far not turned out any three-transistor units. Probably because of the rather low sensitivity and the limited output power. With alloy-diffused transistors, however, which are just becoming available, the sensitivity could be made as good as that of a six-transistor unit and by using a form of sliding bias in the output stage the output power could be reasonable without exorbitant battery drain.

Tr1 acts as a normal autodyne converter and drives the single I.F. stage formed by Tr2. As well as acting as an I.F. amplifier, Tr2 is the driver stage, the audio signal being returned from the diode as well as the A.G.C. signal. Tr2 is transformer coupled to the output stage which is a normal Class A amplifier.

The transistors used in this type of receiver are usually high gain types because of the limited number of stages. Tr2 in particular should have as high a gain as possible, because it is used twice.

Four-transistor superhets may be similar to this circuit but have an additional I.F. or A.F. stage. The interstage A.F. transformer may be omitted because of the extra gain.

Two-Transistor Reflex Receiver

The circuit in Fig. 11 is typical of the two-transistor reflex radio. This type of set is very popular with the Japanese, and some British, European and American manufacturers have also made them.

Tr1 acts as a reflex R.F./A.F. amplifier and is coupled to the diode by means of an untuned R.F. transformer. Tr2 is a normal output stage. Both transistors should be very high gain types and even then the sensitivity is limited. To achieve maximum gain, regeneration is normally applied to the R.F. stage, either by means of a trimming capicitor or by controlled coupling between the R.F. transformer and the aerial coil.

These little reflex sets are reliable because there are few components to fail. They are also very useful as cheap local station receivers. They suffer, however, from one or two faults. Quite often the regeneration control alters slightly and this causes distortion, oscillation or loss of gain. Since they rarely have much A.G.C., if any, they are liable to distort on strong stations, and the only cure for this is to rotate the set slightly so that it picks up less signal. The sensitivity tends to drop very rapidly as the battery voltage falls because of reduced regeneration.

Alignment of these receivers merely involves adjusting the regeneration level, so that maximum gain is obtained all over the band without oscillation occurring at any frequency or at any setting of the volume control. In some sets two methods of regeneration are employed : one inductive and the other capacitative. This makes it possible to adjust the regeneration so that the set is just on the verge of oscillation over a large part of the band.

CHAPTER 4

TRANSISTORISED TEST EQUIPMENT

The average amateur will not wish to spend more than is absolutely essential on test equipment, and he can save himself a great deal by building his own. This has the additional advantage of giving him an insight as to how the instrument works. Service engineers may also like to build some of the equipment they use, particularly since some of the most useful items described here—for example, the signal injector —are not available on the market as ready-made units.

Very little need be said about these instruments, since their application has already been discussed.

Fig. 12. 800 c/s Phase-Shift Oscillator

This unit, designed by Mullard Limited, may be used to inject a signal into the audio stages of a radio to determine the quality of reproduction. The output is a good sine wave, the amplitude of which can be adjusted by varying RV6 This will also affect the frequency slightly. An OC75 must be used rather than an OC71 to overcome the losses in the feedback network.

The frequency of oscillation is given by $f = \frac{1}{2}\pi CR\sqrt{6}$, where C is the value of C1, C2 and C3 and R is the value of R3, R4 and R5. In practice the frequency is raised from this value by the input and output impedances of the transistor.

Too high a setting of RV6 will result in distortion.

This oscillator may also be used as an oscillator for a signal generator.

Fig. 13. Signal Injector

This signal injector produces an output at a frequency of about 2 Kc/s. The output is very rich in harmonics, however, which extend up to at least 2 mc/s. This means that the unit may be used for every stage of a broadcast band radio. The components used are all available in very small sizes so that the whole circuit may be built into a small plastic tube with a metal pointer as the probe. A crocodile clip may be used to couple the ground of the injector to that of the radio set, although this contact may not be necessary when feeding the first stages of the set.

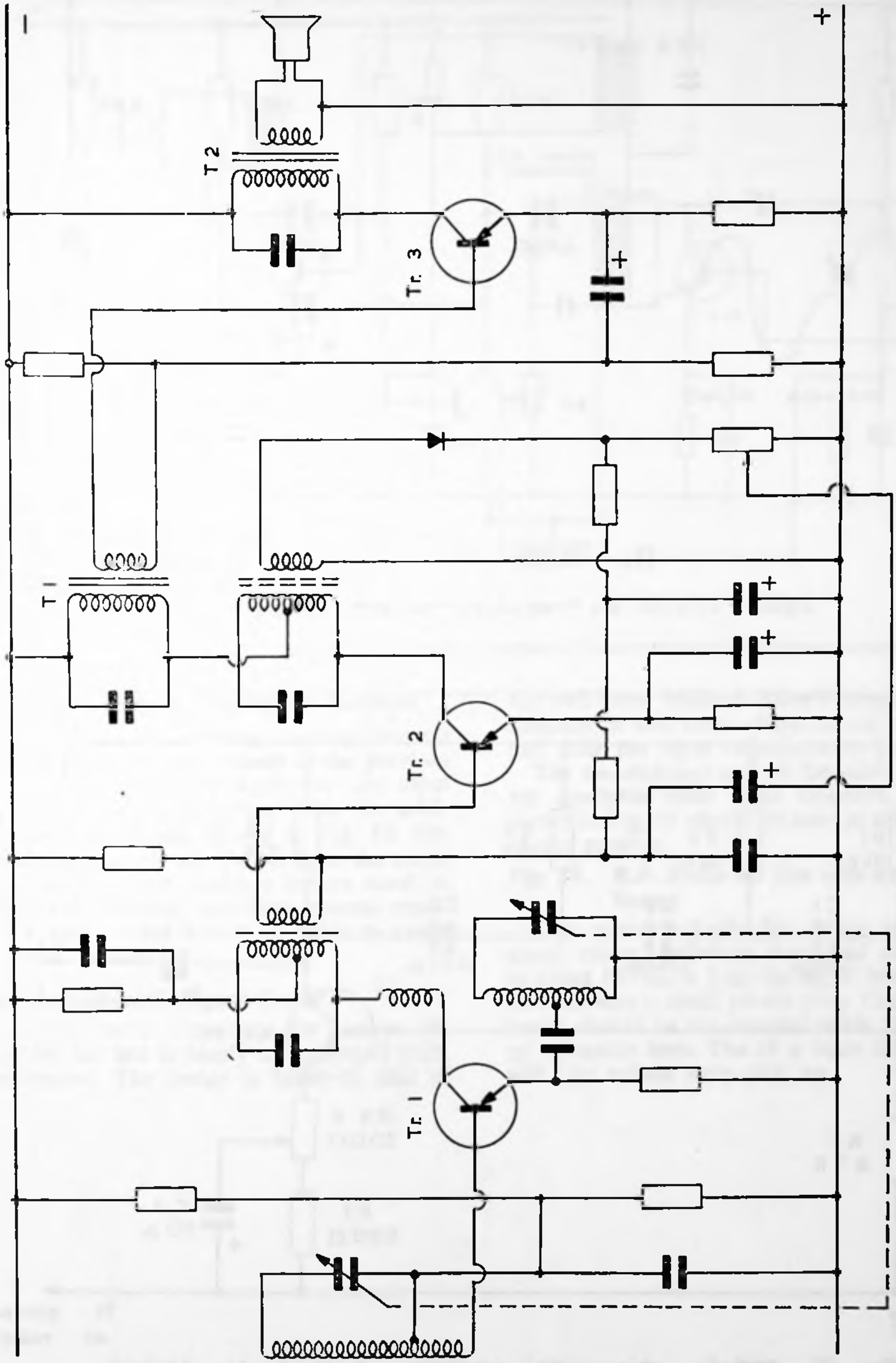


Fig. 10. Typical three transistor superhet circuit.

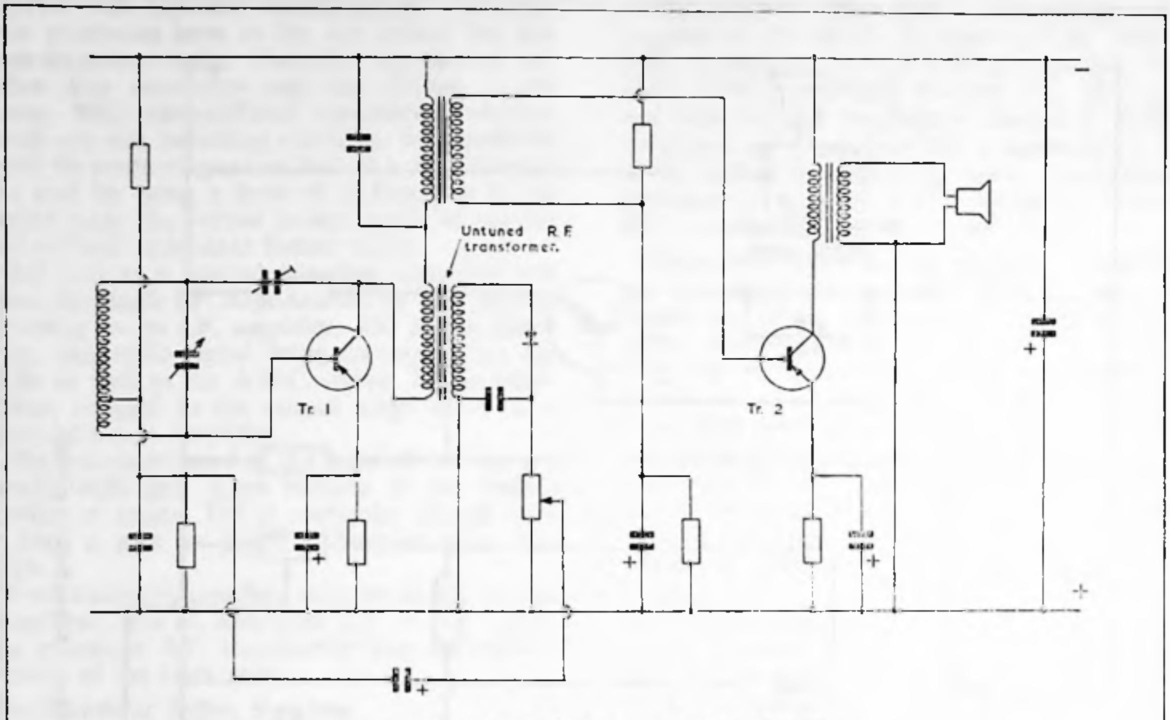


Fig. 11. Typical 2-transistor reflex receiver.

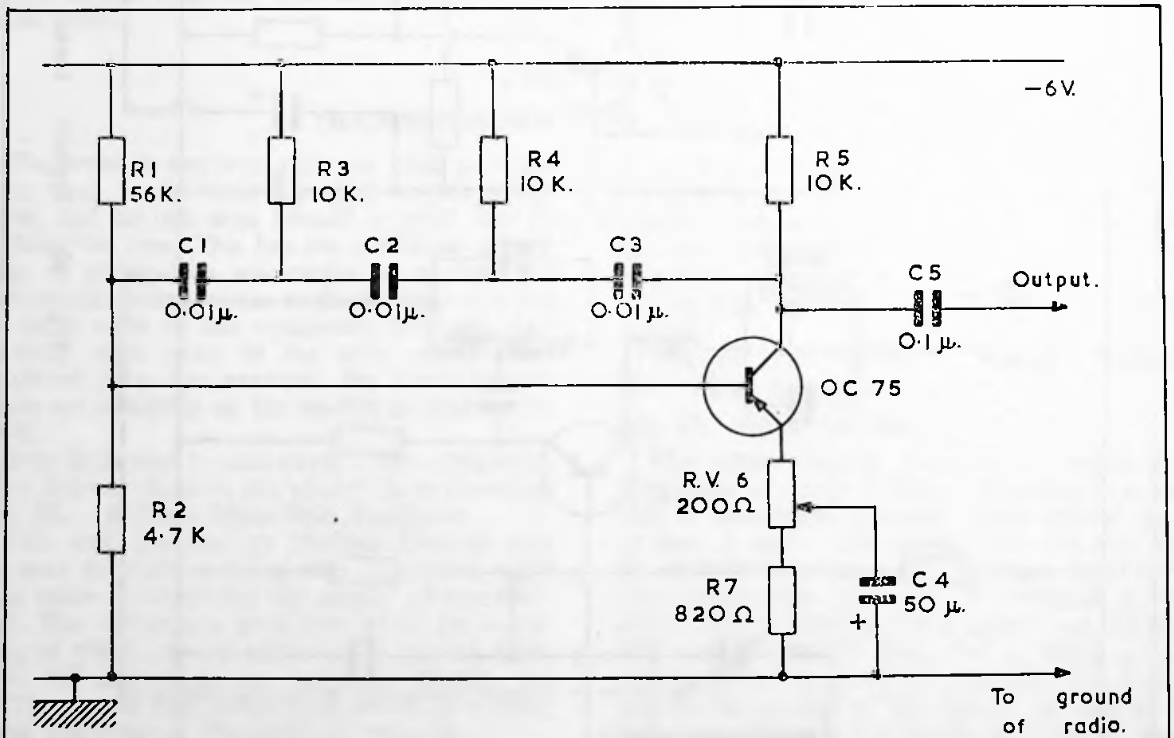


Fig. 12. 800c/s. phase-shift oscillator designed by Mullard.

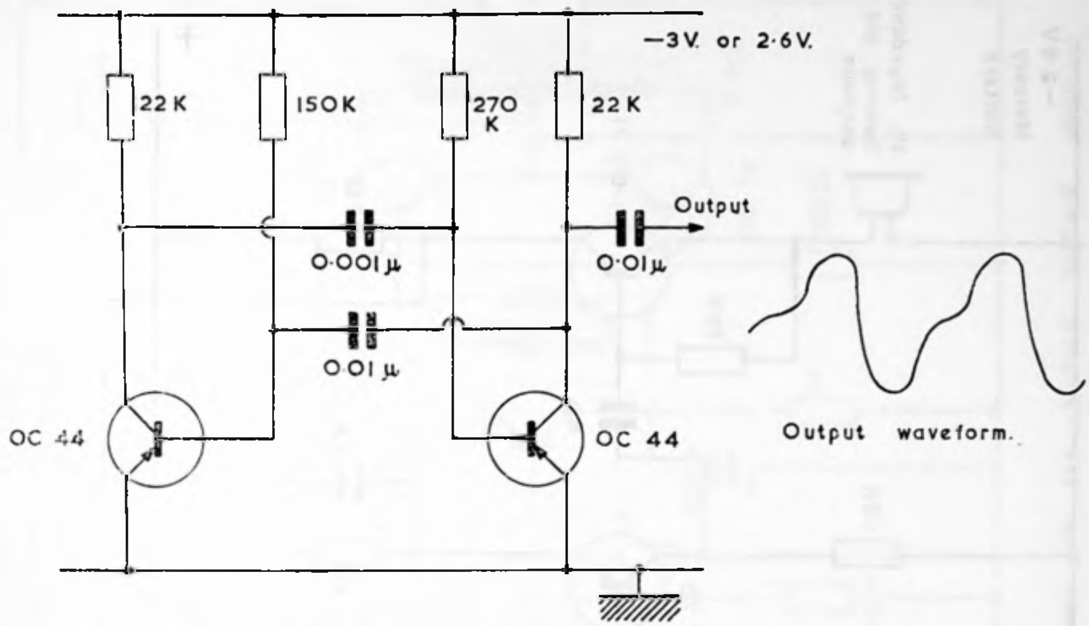


Fig. 13. Signal injector suitable for entire radio.

Fig. 14. Signal Tracer Feeding an Earpiece

This circuit fulfils completely the requirements for an A.F. signal tracer outlined in the previous chapter. The gain is very high and the input impedance is nearly ¼ megohm. With the addition of the R.F. probe shown in Fig. 16, this tracer may be used to test the set from the aerial circuit to the diode. A mercury battery must be used since the comparatively high internal resistance of a zinc-carbon battery is liable to cause "motor-boat" oscillation.

Fig. 15. Loudspeaker Signal Tracer

This unit is more convenient for use on the bench whilst the last is handy as a piece of portable equipment. The design is based on that of the well-know Mullard 200mW amplifier with the addition of two extra stages to increase the gain and raise the input impedance to ½ megohm.

The transformers and all the other components are available from most suppliers. The probe shown in Fig. 16 should be used in the R.F. stages of the receiver.

Fig. 16. R.F. Probe for Use with an A.F. Signal Tracer

This probe extends the range of any A.F. signal tracer, including those just described, up to about 100 mc/s. Like the signal injector, it may be built into a small plastic tube. Coupling to the tracer should be via co-axial cable to avoid pick up of mains hum. Use of a meta tube (earthed) will also reduce stray pick up.

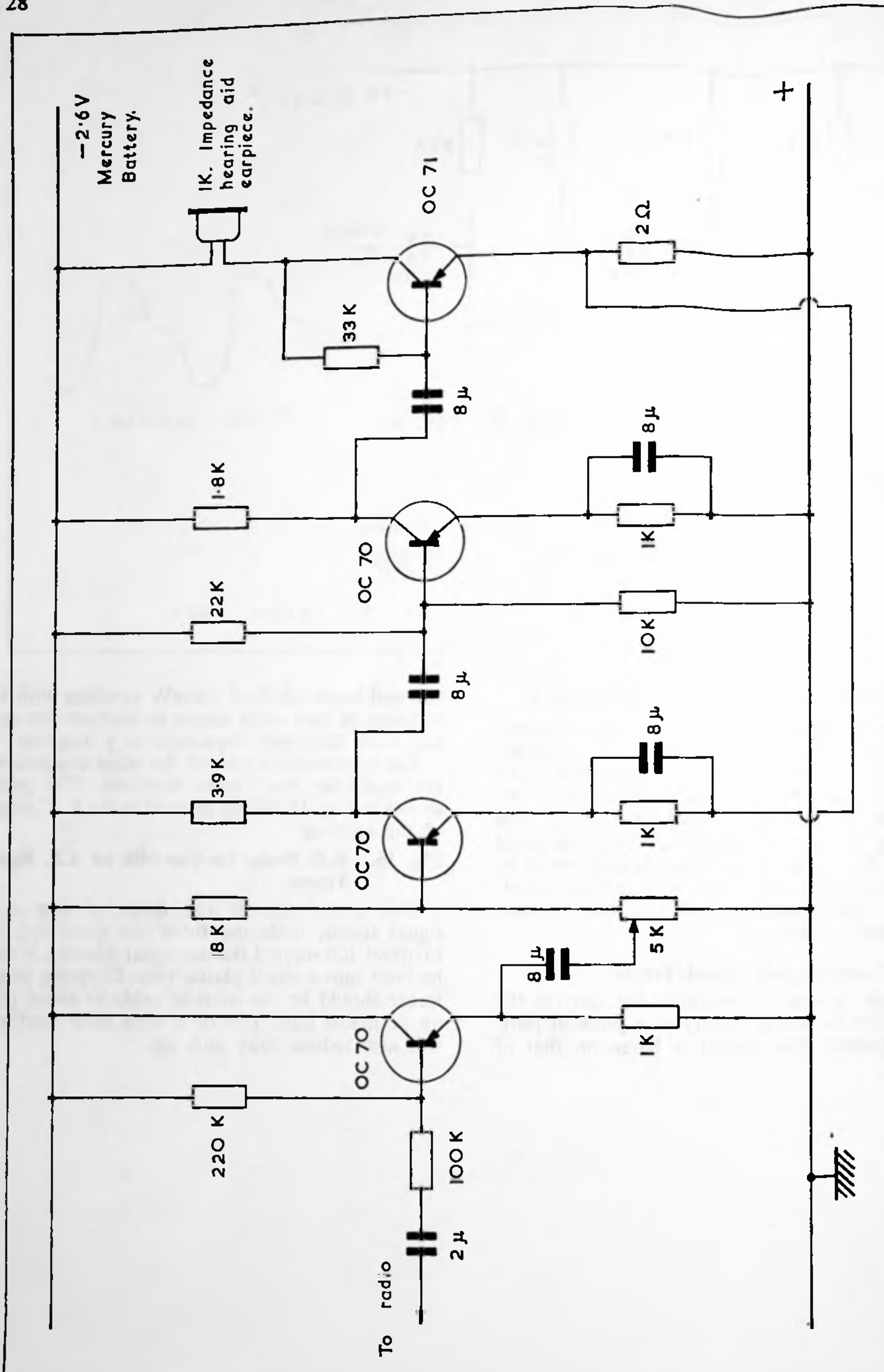


Fig. 14. Signal tracer feeding an earpiece.

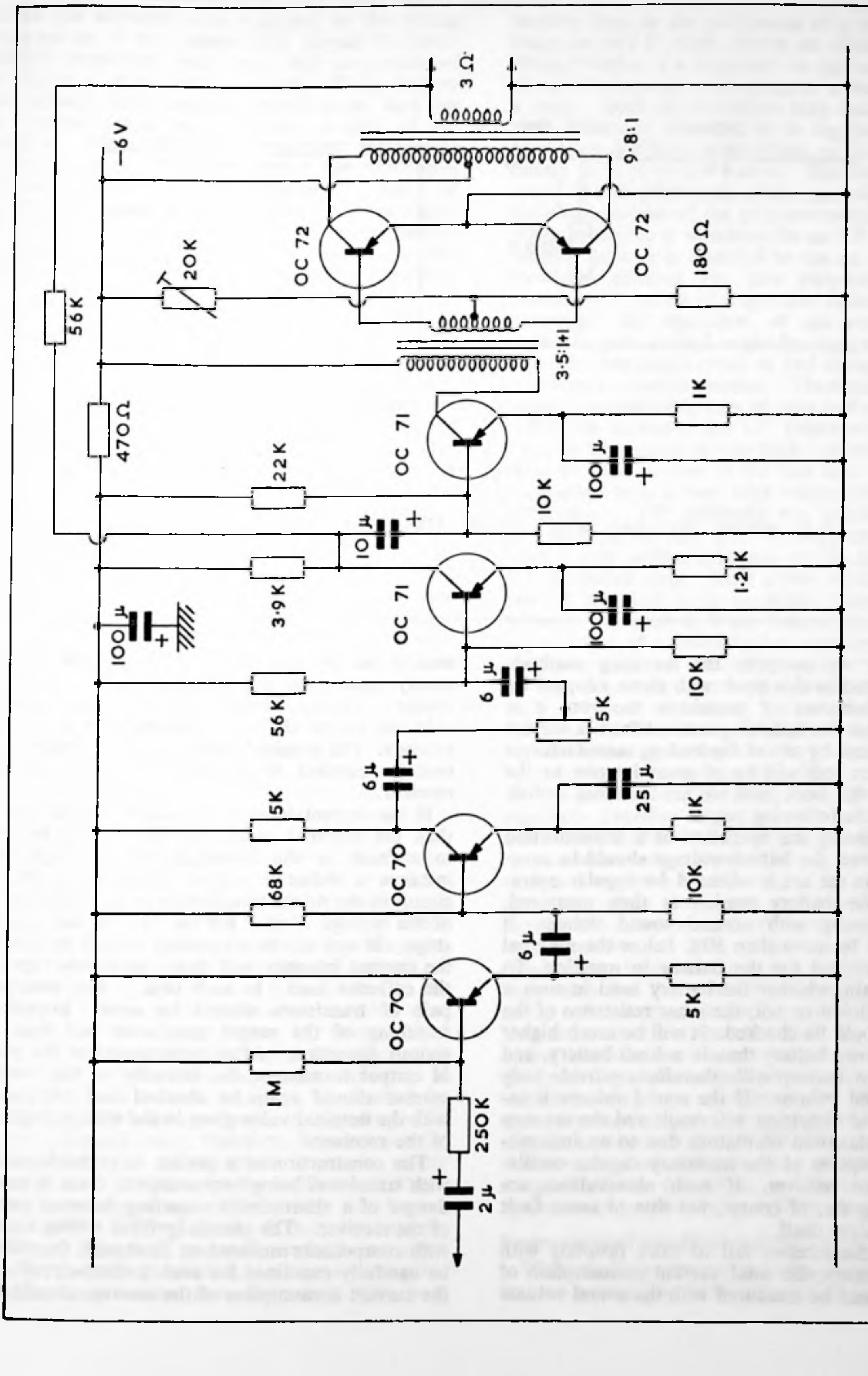


Fig. 15. High gain loudspeaker signal tracer based on the Mullard 200 mW amplifier.

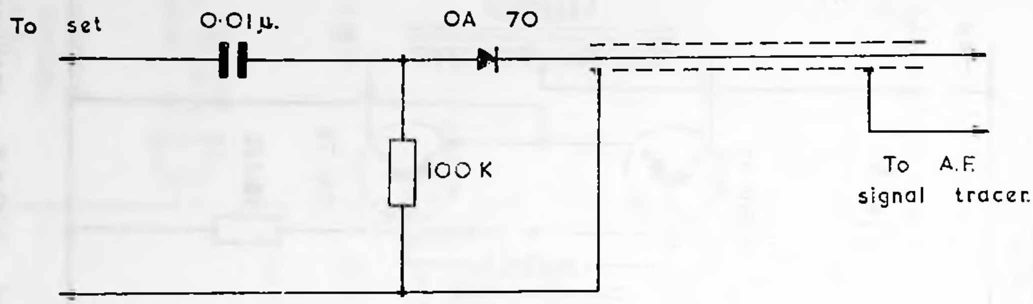


Fig. 16.

R.F. probe for use with signal tracers of figs. 14 and 15.

In order to compare the servicing methods recommended in this book with those adopted by the manufacturers of transistor receivers it is believed that the following extract from a service bulletin issued by one of the leading manufacturers of transistor sets will be of great interest to the readers of this book, and we are therefore including this in the following pages.

Before testing the operation of a transistorised radio receiver, the battery voltage should be measured, while the set is adjusted for regular operation. If the battery tension is then measured, while receiving with normal sound volume, it should not be more than 50% below the nominal voltage specified for the battery in question. To make certain, whether the battery used in such a set is run down or not, the inner resistance of the battery should be checked. It will be much higher in a run-down battery than in a fresh battery, and a run-down battery will, therefore, provide only a low sound volume. If the sound volume is increased, bad distortion will result and the set may produce relaxation oscillation due to an intermittent interruption of the necessary regular oscillation of the receiver. If such observations are made, they are, of course, not due to some fault in the receiver itself.

Should the receiver fail to work properly with a fresh battery, the total current consumption of the set should be measured with the sound volume control set at minimum. In this condition the steady current of the transistor receiver should amount to about 20 milliamps in a regular portable set or to about 5 milliamps. in a pocket receiver. The nominal intensity of the steady current is specified in the wiring diagram of the receiver.

If the current intensity should be much higher than the nominal value, this will mostly be due to a fault in the push-pull output stage, for instance a defective output transistor, a short-circuit in the driver transformer or an interruption of the voltage divider for the base of the output stage. If one of the transistors should be faulty, the current intensity will drop, when interrupting the collector lead. In such case, a new matched pair of transistors should be used. Imperfect matching of the output transistors will lead to serious distortion. After replacement of the pair of output transistors, the intensity of the steady current should again be checked and compared with the nominal value given in the wiring diagram of the receiver.

The construction of a pocket or portable radio with transistors being very compact, there is some danger of a short-circuit occurring between parts of the receiver. The chassis (printed wiring board with components mounted on it) should, therefore, be carefully examined for such a short-circuit. If the current consumption of the receiver should be below the nominal value specified in the wiring diagram or if the current flow should be interrupted completely, look for a bad connection of a lead or a loose battery contact. If the battery has already been renewed several times, look for a possible defect in the battery holder of the receiver. When testing the receiver in regular operation, the operating voltages of the consecutive stages of the set should be measured by means of a voltmeter with a very high internal resistance (impedance). All stages should have the proper current consumption, which condition is checked by measuring the emitter resistance. A difference of up to about 20% as compared with the nominal value, specified in the wiring diagram, will be admissible. In rather rare cases, the emitter resistor may be defective, even if you are getting a correct measurement. If this should happen, the usual procedure will not lead to satisfactory results, but the transistor current should, instead, be measured directly in the collector circuit. If making the measurement in the emitter circuit, a considerable error may result due to the inner resistance of the measuring instrument. Especially, when measuring the steady current of the output stage, the measurement should take place in the collector circuit.

A wrong tension at the base of the transistor will mostly be due to an interruption in the voltage divider of the base. A further possible cause may be a short circuit between the coils of the base and collector circuits, if I.F. amplifier stages with single-circuit coupling are used. If, even in case of proper voltage and current measurements no reception should be possible, the mixer stage of the receiver should be tested for regular operation. A break of one of the very thin wire ends of the coils of the R.F. input and oscillator circuits may be the possible cause of the failure. If a self-oscillating mixer is used in the receiver, a direct connection between the R.F. input circuit and the oscillator circuit exists through the transistor, and an interruption of the R.F. input coil may cause a failure of the oscillator. Such a failure may also be due to detuning of the input R.F. circuit or the oscillator circuit or to a poor contact in the switching keyboard or push-button switches used in some of the larger types of transistorised receivers. Contrary to the experience made with valve-equipped receivers, the proper oscillation of a transistorised receiver can not be checked by means of a D.C. measurement. A high-frequency valve voltmeter must, therefore, be used for the testing and the measurement must be made directly at the emitter or at the oscillator coil itself. The alternating voltage at the emitter may have a value of 50 to 200 millivolts. A fault not happening very often and, generally, only in an older type of transistorised radio, where a capacitive reaction may occur more frequently than in a modern type, is the production of a sudden oscillation in an I.F. stage, due to an alteration in the characteristics of a transistor, in the neutralization of an I.F. stage or to detuning of a circuit in such a stage. Such an oscillation may lead to a complete failure of the radio or to the production of relaxation oscillations, whistling, or the like, when tuning in a powerful station. The cause will be found in a displacement of the operating point on the characteristic of the gain-controlled I.F. stage. When replacing a transistor in an I.F. stage with variable gain, it is essential to use an appropriate transistor selected for this purpose, normally marked with points of a specified colour, because, otherwise, the operation of the receiver with regard to gain control might be changed considerably and this might result in bad distortion, when receiving a powerful station. There might further occur a considerable loss of gain in the amplifier.

For the testing of the I.F. stages with variable gain, an instrument of very high internal resistance must be used in view of the fact that such stages themselves have a very high resistance, so that a difference of 100 millivolts for example in the measurement of the D.C. voltage may already have a very serious influence on the operation of the controlled stage. Even a low cross current in one of the electrolytic condensers may cause a failure of the control. When measuring the operating voltages of a transistorised receiver fed from the power line, it is essential to connect the chassis of the measuring instruments used for the test, such as signal generators, valve voltmeters and the like, with the receiver chassis, before measuring the operating voltages of the individual stages by touching their test points with the test probe of the instrument. The base of a transistor is especially sensitive to current or voltage pulses due to a possible bad grounding of the chassis. A procedure often used when servicing valve-equipped receivers, i.e. listening to the hum or click occurring, when touching a grid terminal or the like, should never be used, when testing transistorised receivers, as this might lead to wrong conclusions inasmuch as you might get the impression that the sensitivity of a stage is higher at the collector than at the base of the transistor. You must always remember that the input and output impedances of a transistor stage are different from those of a stage using a valve. The base impedance may have a value of only 100 to 1,000 ohms, for example, while that of the collector may amount to about 50,000 to 500,000 ohms. It is, therefore, recommended to use a test generator or a signal follower (searching probe) for testing the operation of consecutive amplifier stages.

Replacement of transistors and other component parts

When replacing transistors, always make certain that all connections to the measuring instruments, to the ground, the power supply, etc., are disconnected, before unsoldering or soldering a joint on a receiver chassis (printed wiring board). The transistor should never be heated, so that soldering and unsoldering should be effected as quickly as possible. It is of still greater importance, to prevent the production of voltage and current pulses, as transistors and diodes are most sensitive to such pulses, which might occur, when using a defective soldering iron, for example. After replacement of transistors in the I.F. amplifier part of the receiver, the alignment of the circuits in this part should be checked and, if necessary, realigned carefully.

For the replacement of a transistor on a printed wiring board, the connection leads of the transistor should be cut about 3 mm. above the surface of the board, and the new transistor should be soldered to the wire stubs remaining on the board. The same procedure should be used, when replacing other component parts, such as capacitors or resistors. It will then, in most cases, not be necessary to remove the printed wiring board from the receiver. This is a great advantage, as the removal of the board is, generally, quite a complicated performance. Another important reason for the use of the recommended procedure is the prevention of damage done to the protective coating of the metal foil on the soldered side of the printed wiring board, which is applied in order to prevent oxidation of the foil.

An exception to the above rule must be made, when replacing an I.F. band-pass filter (I.F. transformer), due to the fact that it is practically impossible to disconnect all terminals of such a unit at the same time without doing damage to the unit or to the printed wiring board. It is recommended, to place the board in a vertical position, so that it can be turned in such a manner that the molten solder will flow off the terminal over the conductor on the printed wiring board. In this way, the terminal may be disconnected and the pin may be separated from the corresponding conductor by moving it cautiously to and fro. In this manner, the several terminals of the unit may be unsoldered and set free one after the other.

When replacing a capacitor or resistor, the connection wires of the defective unit should be cut immediately at the body of the unit and the remaining leads are bent upward. The connection wires of the replacement unit are then cut to an appropriate length and bent to form small loops. These loops are then pushed over the wire stubs remaining on the board and soldered to them. If, in a special case, soldering immediately on the metal foil should be unavoidable, the soldered joint made with the utmost care, should afterwards be coated with a protective lacquer consisting of rosin C dissolved in alcohol, so as to prevent a subsequent corrosion of the joint. When making repairs on a printed wiring board, be careful to avoid sputtering solder on the metal coating. Use the very best grades of solder for repairs of this kind. Never use soldering flux.

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