A PRACTICAL WIRELESS HANDBOOK

TRANSISTOR RADIO CIRCUITS

FULLY ILLUSTRATED

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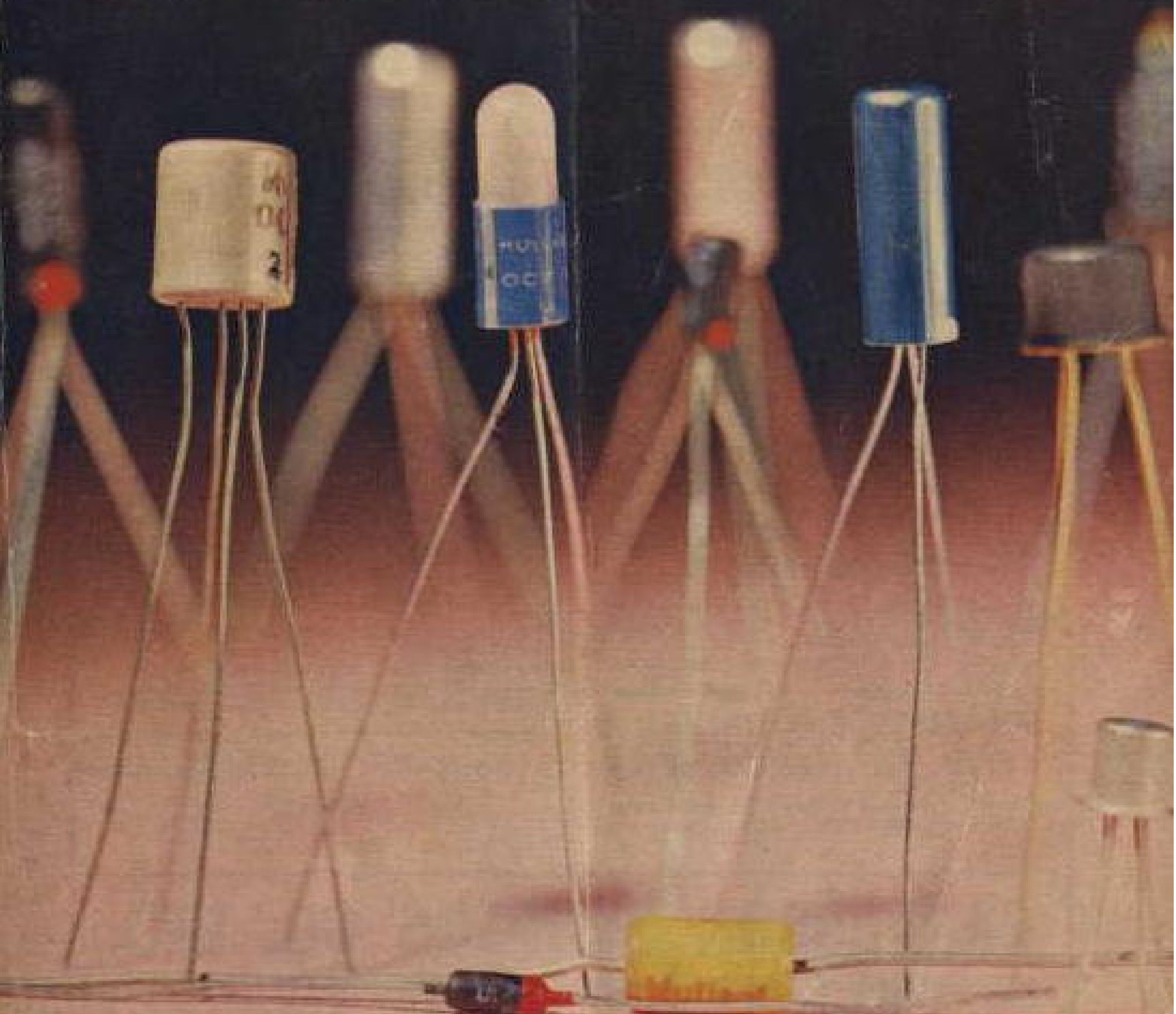

Theory of semi-conductors

Selection of easy-to-build receivers

TRANSISTOR

RADIO CIRCUITS

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A PRACTICAL WIRELESS HANDBOOK

THE TRANSISTOR AS A CIRCUIT DEVICE

There is no reason whatsoever why a transistor circuit should cause confusion. Theoretically, a transistor is considerably less complex than a valve. Indeed, it has only three elements while even the simplest of valves—the triode—has four elements, namely, the anode, grid, cathode and heater. A transistor has no heater, but it has elements (or electrodes) which are much related to the triode valve. It has a base instead of a grid, an emitter instead of a cathode, and a collector instead of an anode. There are also transistors which have four elements, rather like the four essential elements of a tetrode valve, but these are comparatively rare.

We are left, therefore, with the semiconductor equivalent of a triode valve, so, no matter how technical the circuit, it always revolves around a simple three-element device.

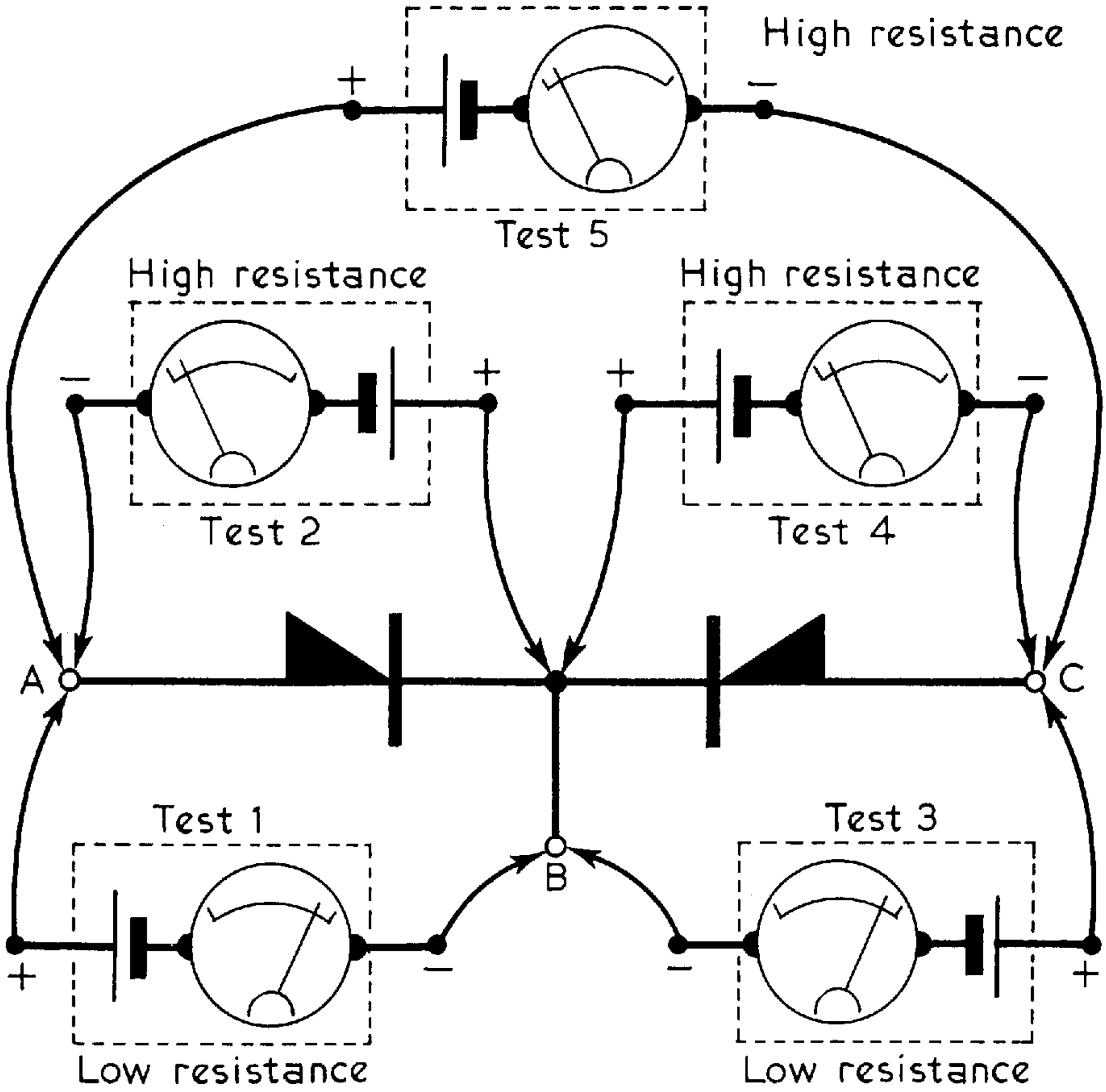


Fig. 1—How a series of ohmmeter tests indicates that a transistor contains two diodes connected in series opposition. (Test 6 is the same as Test 5, but with the ohmmeter leads transposed.)

If we had no previous knowledge of transistors and were given a three-wire device and told that it was a transistor, and we were also handed an ohmmeter and told to find out as much as possible about the transistor by making resistance checks, it would not take us very long to discover that within a transistor exist two diodes, or rectifiers. We would also eventually discover that the diodes are connected in series opposition. If we were to draw a diagram of our findings it would look like Fig. 1.

We know, of course, that an ohmmeter is nothing more than a voltmeter connected in series with a battery, and that when the two terminals are connected together the voltmeter is effectively connected across the battery. Full deflection is given on a dial scaled in 'ohms' by adjusting a variable resistor labelled 'set zero'. Thus, when a resistor is connected across the terminals, the pointer reads something less than full-scale (because of the voltage dropped across the resistor) which is read off the 'ohms' calibration as some definite value.

Polarity of Terminals

The ohmmeter terminals are polarised by the battery (positive and negative), so the ohmmeter therefore provides a source of voltage as well as resistance measurement. This is exactly what is required for examining semiconductors, which are designed to have a low resistance to current passing in the 'forward' direction and a high resistance to current passing in the 'reverse' direction. It should be noted, however, that the 'positive', or red, terminal on some multimeters when set to 'ohms' may not be connected to the positive side of the internal battery. It is as well to check this before becoming involved in resistance checks on semiconductors.

To return to Fig. 1. With the positive terminal of the ohmmeter connected to wire A and the negative terminal to wire B there is a 'low resistance' reading, as shown by Test 1. This indicates that current from the ohmmeter battery is flowing through the diode in the forward direction, and this is indicated by the direction of the 'arrow' on the diode (or rectifier) symbol. Current in this context is the *conventional* flow from positive to negative and *not* electron flow, which is from negative to positive.

Diodes

When the ohmmeter connections are reversed, then we obtain a high resistance reading, as shown by Test 2. This indicates that current from the ohmmeter battery is flowing through the diode in the reverse direction, where it comes up against opposition. Of course, in a perfect diode or rectifier there would be zero resistance to current in the forward direction and infinite resistance to current in the reverse direction, but as no diode is perfect, there will always be a low, but definite

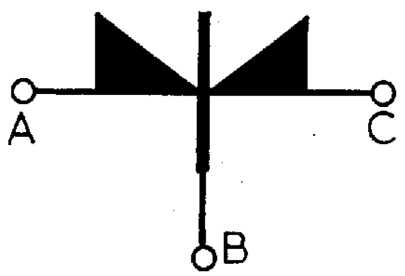


Fig. 2—Although there are two junctions in a transistor, it has one element which is common to both of them (shown at B).

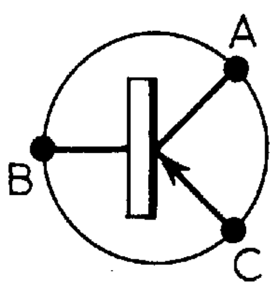


Fig. 3—The conventional transistor symbol using A, B and C, as in Figs. 1 and 2.

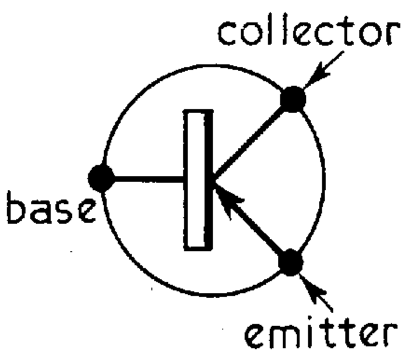


Fig. 4—The conventional symbol with the elements identified.

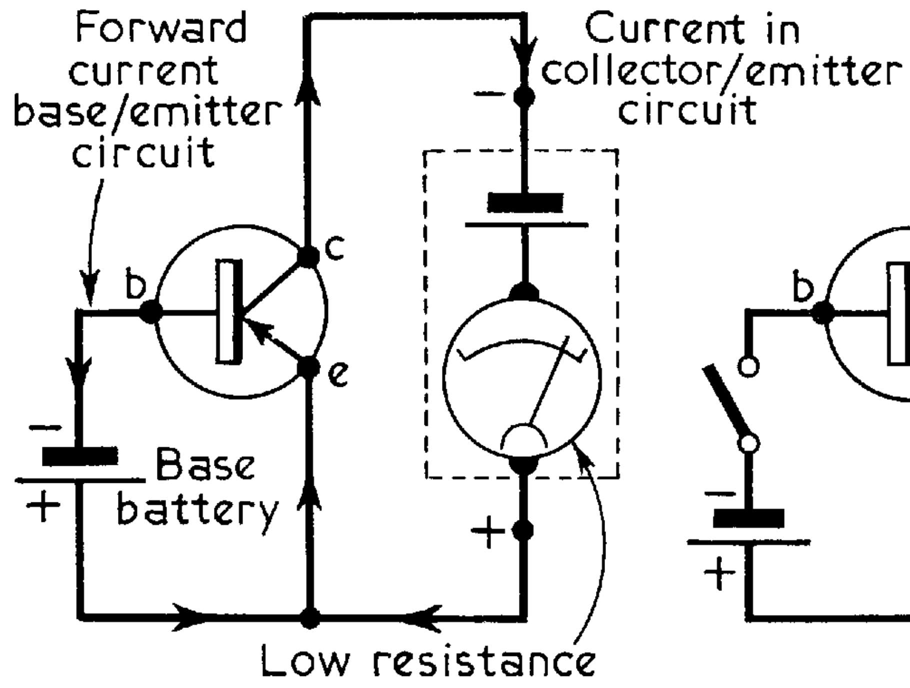


Fig. 5—The action of forward current in the base-emitter circuit gives a reduction in the apparent resistance between the collector and emitter.

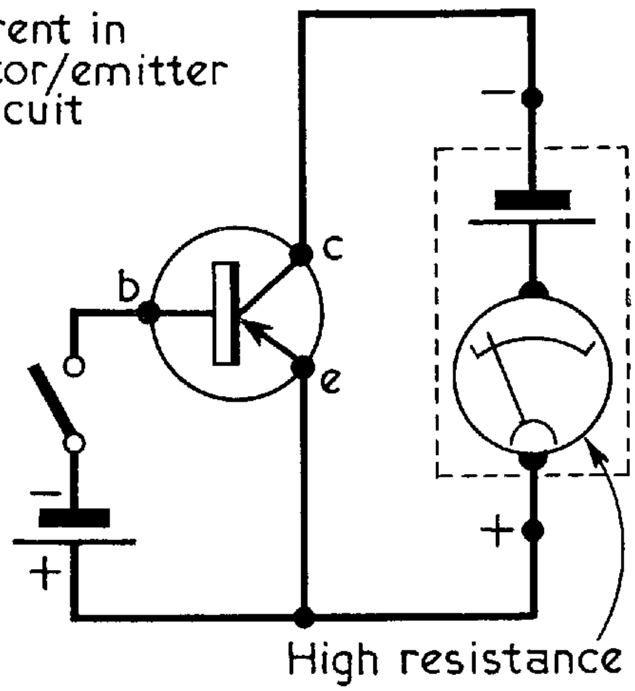


Fig. 6—When the base current in Fig. 5 is switched off, the resistance between the collector and emitter increases. (This was also shown in Test 5 of Fig. 1.)

resistance to forward current and a large, but not infinite, resistance to reverse current, depending on the type of semiconductor. The ratio of reverse to forward resistance can be used as a measure to assess the quality of a semiconductor—as we shall see later.

We discover the other diode section by connecting the ohmmeter between wires B and C, first to give the resistance to forward current (Test 3) and then to give the resistance to the reverse current (Test 4). We see from the forward current tests (Tests 1 and 3) that there is no need to remove the negative ohmmeter connection from wire B, and that forward resistance is given on each diode section simply by changing the ohmmeter positive from wire A to wire C. This in itself reveals that the two diodes must be connected in opposition.

Further proof of this is given, however, by Tests 5 and 6, for whichever way round the ohmmeter is connected across wires A and C there is always a high resistance, indicating that reverse current flows when the battery is connected in both polarities. This could only happen with diodes connected in opposition.

Transistor Make-up

We have so far proved that a transistor contains two diode sections, and it is unlikely whether we would find out much more about a transistor given just a transistor and an ohmmeter. It is possible to find out more with this simple instrument, but assuming that we knew nothing at all about a transistor when we started, additional information would be found more by luck than by technical ability.

Common Electrode

It is true that a transistor has two diode sections connected in opposition, but one ' electrode ' is common to both diodes, and the common electrode is that connected to wire B, as would be expected. We may thus redraw the circuit of Fig. 1 as shown in Fig. 2, which shows clearly the common electrode on wire B.

The conventional symbol for the transistor is shown in Fig. 3. Here the common element is at B and the two ' outside ' elements at A and C. One of the ' outside ' elements is given an arrow-head simply to distinguish it from the other one. To be symbolically accurate, of course, each outside element should be given an arrow-head to conform with the build-up from the symbol in Fig. 2, but, since each ' diode junction ' has a different function, it is essential to be able to differentiate one from the other, and the use of a single arrow-head permits this.

Transistor Elements

We must now abandon our earlier A B C identification and instead use the correct terms for the transistor elements. We have done this in Fig. 4, which reveals that the common element is called the ' base ', the element with the arrow-head the ' emitter ' and the element without the arrow-head the ' collector '.

Transistor Biasing Arrangements

In practical transistor circuits, the base is biased negatively with respect to the emitter, as shown in Fig. 5. It will be seen, therefore, that the base-emitter diode junction is polarised for forward current. This means that the circuit is now equivalent to a low resistance and, as a consequence, passes a current (from the battery) of a value limited by the base-emitter junction resistance, any resistance in the external circuit and the battery voltage.

Furthermore, the collector is also connected to a negative voltage with respect to the emitter. It will be recalled that our previous ohmmeter tests between the two ' outside ' elements (now called collector and emitter) showed that no matter which way round the voltage source was connected there was always a high resistance between them. However, owing to the *forward* current in the base-emitter circuit, the conditions between the collector and emitter are now severely modified, for instead of there being a high resistance between them, an ohmmeter connected negative to collector and positive to emitter would register a relatively low resistance, as shown in Fig. 5.

Change in Resistance

By keeping the ohmmeter connected and switching off the base-emitter forward current, the ohmmeter would change from a low to a high reading, as shown in Fig. 6. Indeed, the apparent resistance as registered on the ohmmeter would alter depending on the actual base-emitter current. Within limits, the greater the current the smaller the apparent resistance—maximum base voltage gives maximum collector current and zero base voltage gives zero collector current (or nearly so as there is always some leakage in semiconductors).

In a transistor, therefore, a change in collector current is promoted by a change in base current (or voltage, since a voltage change gives a current change in the base circuit). This is rather like a valve, where a change in control grid voltage causes a change in anode current. It is because of this similarity that the base of a transistor is sometimes likened to the grid of a triode valve and the collector to the anode. Similarly, the emitter corresponds to the cathode.

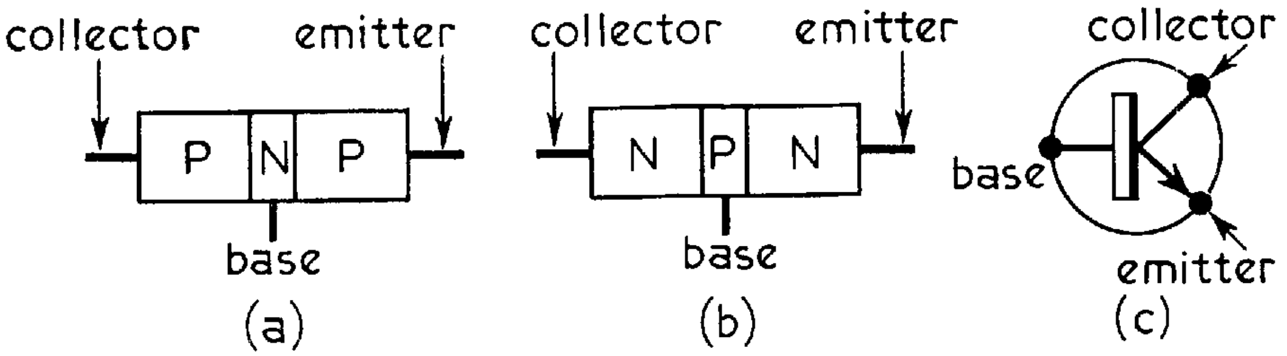


Fig. 7—The basic physical construction of (a) a pnp transistor, and (b) an npn transistor. In (c) is given the symbol for an npn transistor—the emitter arrow points in the opposite direction to the arrow in the symbol for a pnp transistor.

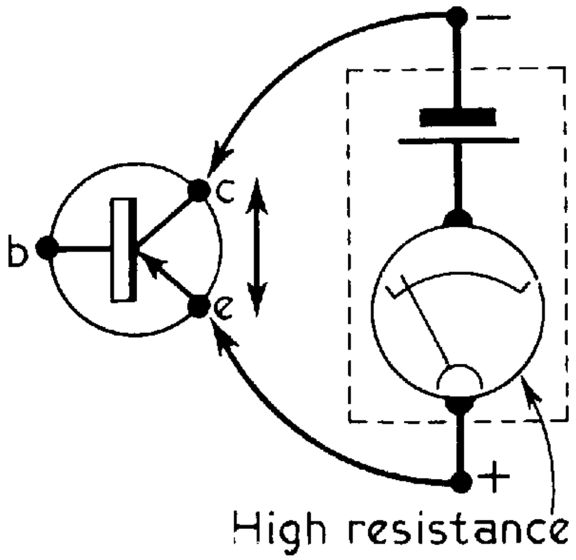


Fig. 8—Transistor leakage test.

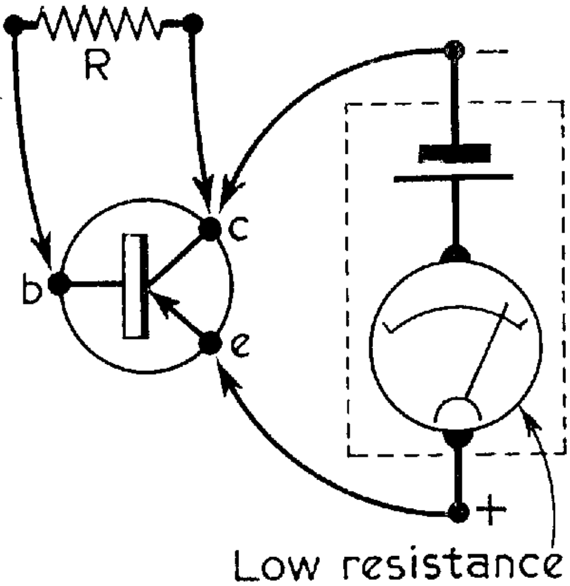


Fig. 9—Using an ohmmeter and a resistor to check effective d.c. gain.

Two Types of Transistor

Transistors are made of two types of semiconducting material; a material which uses 'holes' to give a mobile positive flow called '*p*' (for positive) type, and a material which uses electrons for negative conduction called '*n*' (for negative type). Either a wafer of *n*-type material is sandwiched between two pieces of *p*-type material to make a *pnp* transistor or a wafer of *p*-type material is sandwiched between two pieces of *n*-type material to make an *npn* transistor as shown in Fig. 7.

The majority of transistors used at present in this country are of the *pnp* variety. Transistors of the *npn* variety are used in certain switching applications, though there is reason to believe that they may also be used more extensively in domestic equipment in the future, as they are already used in America.

Transistors of the *npn* type differ basically from *pnp* types by being connected to the supply voltages the other way round, with the base and collector being connected to a positive source with respect to emitter, instead of a negative source, as is required with *pnp* types.

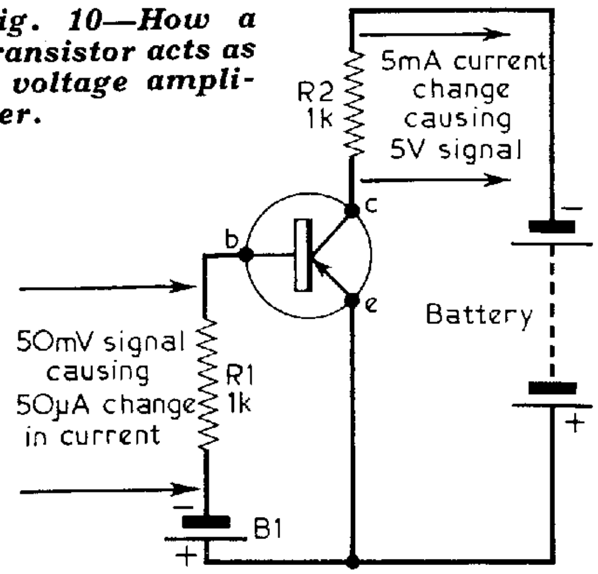
Transistors of the *npn* type are symbolised by the arrow on the emitter pointing away from the base, as shown in Fig. 7c.

A Further Ohmmeter Test

If we reproduce Test 5 of Fig. 1 on a transistor, as shown in Fig. 8, we would again prove that a high resistance exists between collector and emitter whichever way round the meter is connected, though we may find that the resistance is slightly greater when the negative of the meter is connected to the collector than when the positive of the meter is connected to it. However, if we set the arrangement with the negative of the meter to the collector and the positive to the emitter the resistance should be very high.

Now, if we connect a resistor between the collector and base, as shown in Fig. 9, the resistance should fall to a relatively low value, provided the transistor is in good order. Indeed, this represents a very good transistor test since, in effect, the ratio of resistance change corresponds to the d.c. gain of the transistor. The resistor effectively applies a negative bias to the base with respect to the emitter and thus causes conduction to take place between the emitter and collector. For most small transistors a resistor of about 33,000Ω (33kΩ) is suitable, but it is not desirable for this or other transistor resistance measurements to be undertaken if the ohmmeter contains a battery in excess of 1·5V. A higher voltage may result in excessive current through the diode

Fig. 10—How a transistor acts as a voltage amplifier.



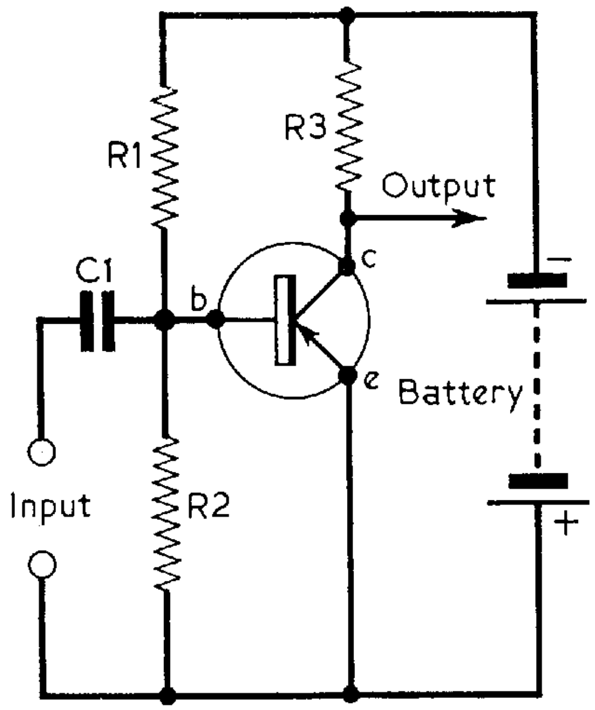


Fig. 11—A circuit in which the base bias battery has been eliminated.

junctions which could cause a breakdown.

Reverse and Forward Resistance

With a good transistor the ratio of reverse to forward resistance should be at least 25:1, but with high quality components the ratio may be as high as 100:1, or even greater.

Low power transistors will in general have a forward resistance about 100Ω and a reverse resistance in excess of 50,000Ω. If both resistances (forward and reverse) are high or infinite, then that particular junction is open-circuit. If there is no difference between forward and reverse resistances, whether the actual values are high or low, the junction is leaky or short circuited. Both junctions, relative to base, should be checked, since if only one is good while the other is either open or shorted, the transistor is useless.

Leakage is checked as was shown in Fig. 8, but it should be noted that temperature has a marked effect on the resistance values obtained, so keep the component away from a soldering iron or bench light while performing resistance tests.

Amplification

With a valve, a small change in control grid voltage produces a change in anode current and this change is reflected as a change in voltage across the high impedance anode load. Because a small change in anode current causes a relatively large change in voltage across the load, compared with that at the grid, a valve provides a means whereby a small voltage at the input is amplified to a larger voltage at the output. In other words, the small change in voltage at the grid gives rise to a larger change in voltage across the anode load.

To be any good, the same thing must happen with a transistor—and it does. This is brought about mainly because the base-emitter junction is biased for forward current and as a consequence has a low resistance which produces a fairly high current from a low voltage. The collector circuit, on the other hand, has a higher resistance, which means that for a given collector current a higher voltage can be applied to the collector through a higher value resistor. This is because the collector circuit cannot be biased for forward conduction. It will be recalled that collector conduction is promoted essentially by the base current.

Current Gain

A transistor would be said to have a current gain of 100 if a change of 5mA were caused in the collector circuit by

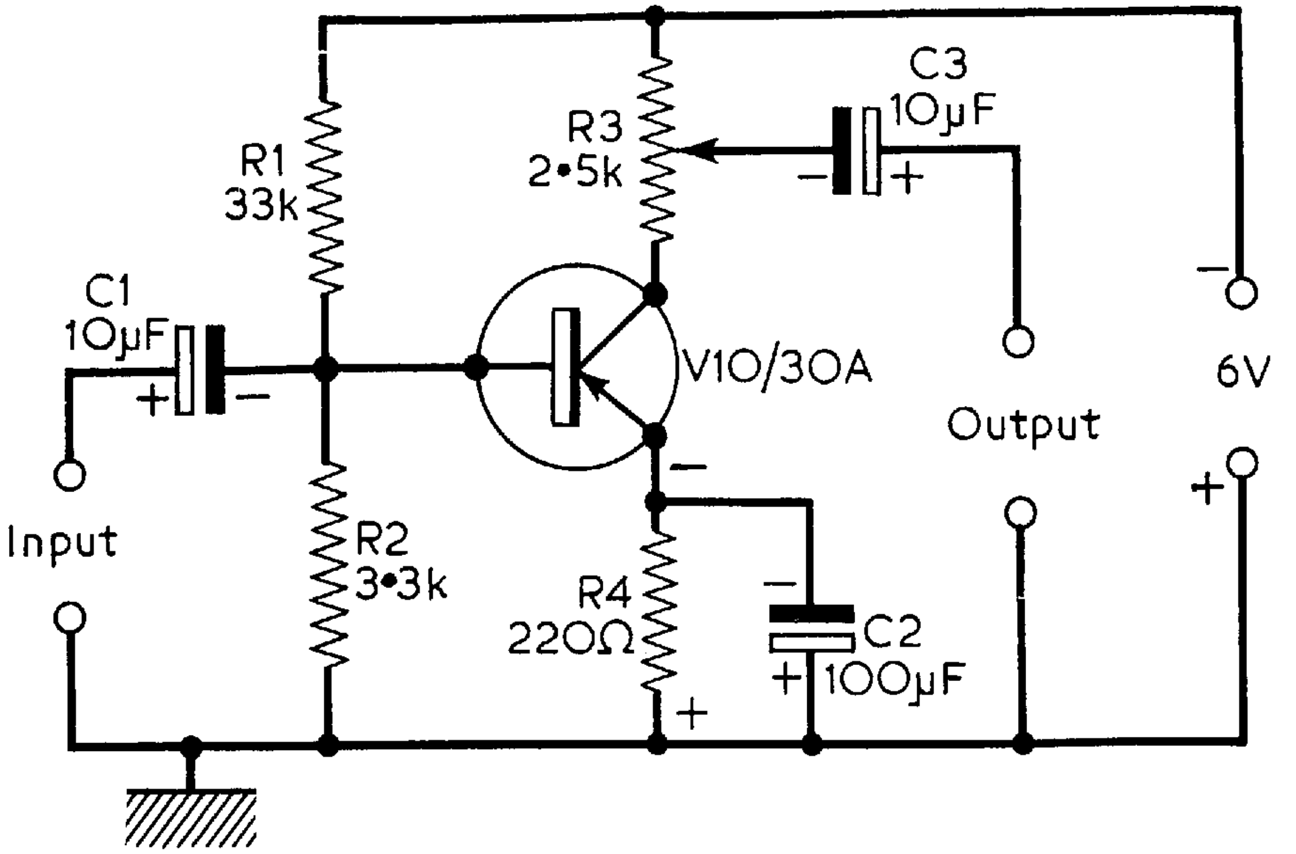


Fig. 12—The circuit of a practical audio amplifier.

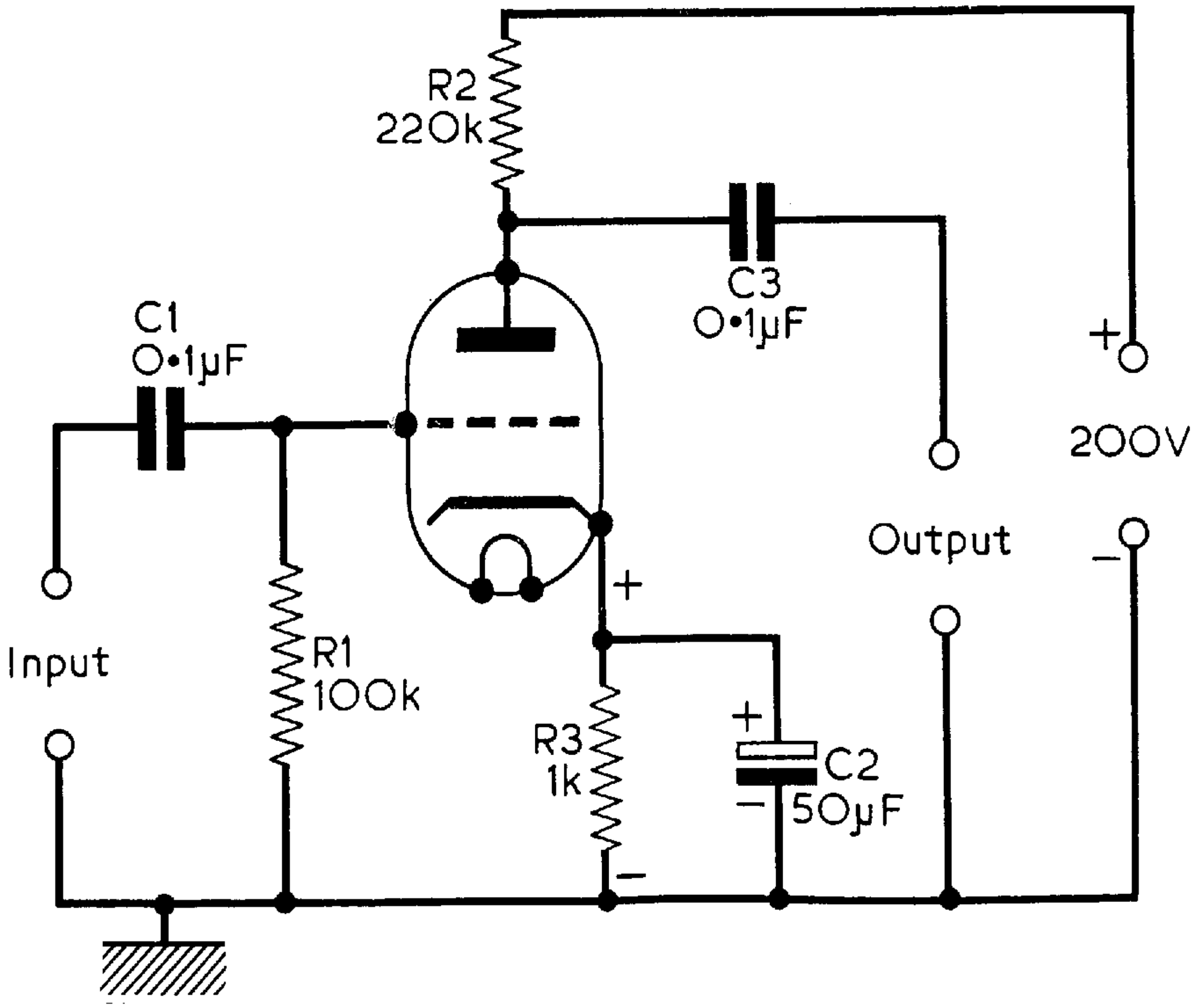


Fig. 13—The valve equivalent of the amplifier of Fig. 12.

a base current increase of 5/100mA, that is 50μA. We can understand how a transistor gives voltage amplification by considering the circuit in Fig. 10. Here, the base is biased to the correct working point by battery B1. Now, suppose an input signal is applied in such a way in relation to R1 that it causes an alteration in base current. If the signal were a pure sine-wave, it would add to the battery voltage on one half cycle and subtract from it on the other half cycle. Let us suppose that the input signal is 50mV peak to peak across 1,000Ω (R1); this would cause a total current change of 50μA in the base circuit (Ohm's law).

If the transistor has a current gain of 100, then there would be a 5mA change in current in the collector resistor R2. If R2 also has a value of 1,000Ω, as shown, a change of 5V peak to peak would occur across it (Ohm's law again). Clearly, then, the transistor has served to step up the 50mV input signal by 100 times to 5V.

If the collector resistor had been 5,000Ω, the same reasoning will show that the output would have been 25V peak to peak. There are, of course, limits to the output voltage that can be obtained, depending on the type of transistor and circuit characteristics, and there are various other factors which alter slightly the simple example above.

The Use of a Common Battery

A transistor requires two voltage sources, one for biasing the base and the other for energising the collector. Fortunately, both sources are negative to emitter with *pnp* transistors (positive to emitter with *npn* types), and for this reason it is possible to eliminate one battery and arrange a potential-divider to tap-down the required bias for the base.

This feature is shown in Fig. 11. Here the battery is connected negative to collector and positive to emitter, as is normal. In addition, a potential-divider comprising R1 and R2 in series is connected across the battery. At the junction of R1 and R2, relative to battery positive, exists a negative voltage of a value governed by the ratio of R1 to R2. The ratio is arranged in relation to the battery voltage and the type of transistor so that the correct base voltage is present at the junction, and the latter is connected to the base as shown.

The input signal is applied to the base through the isolating capacitor C1 to prevent the d.c. conditions from being affected by the input source load. It is also usual to feed the output from the collector through a similar capacitor (or transformer) to subsequent stages.

A Practical Transistor Amplifier

We can now consider a practical amplifier, and a circuit of such a device

Fig. 14—A common-base transistor circuit, which is equivalent to the common-grid valve circuit.

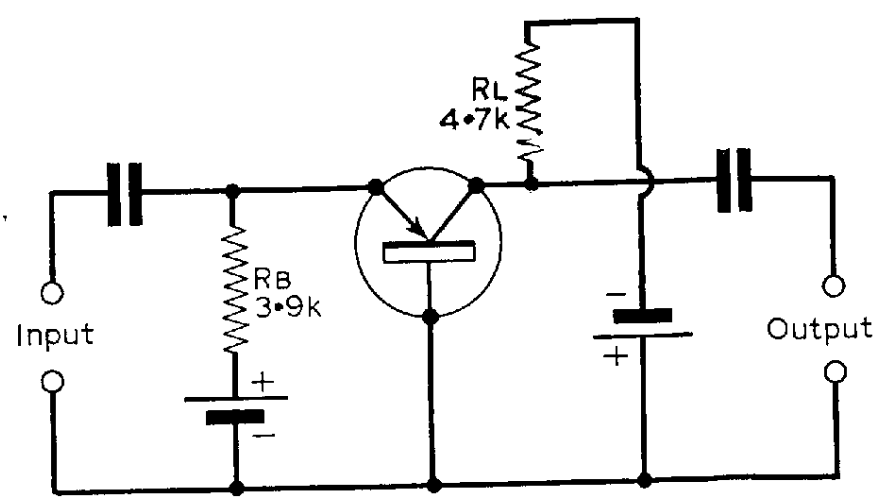
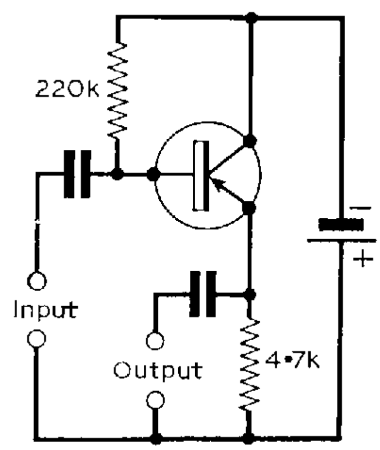


Fig. 15—A common-collector transistor circuit, which is equivalent to the valve cathode-follower.



is given in Fig. 12. This is very little different from the hypothetical arrangement of Fig. 11, for C1 is the input capacitor, R1 and R2 form the base divider, R3 is the collector load and C3 is the output capacitor. In this case, the collector load is a potentiometer which acts as a volume control to feed the required audio output to the following stage. This technique is often adopted in small a.f. amplifiers, where the amplifier is used to strengthen weak signals from a microphone or pick-up so that they will fully drive the main amplifier or control unit.

It will be noted that the input and output capacitors are electrolytic types, which are required owing to the relatively low input and output impedance of a transistor circuit. With valve circuits, a.f. is usually coupled through $0{\cdot}1\mu F$ capacitors, or even lower values. This is possible because of the high grid input and anode output impedance, but if similar values were used for audio coupling in a transistor circuit, there would be a considerable loss of lower frequencies because the reactances of the coupling capacitors would rise to greater values than the effective input and output loads. We must always remember that while a valve works essentially on input voltage, a transistor works on input current.

Thermal Runaway

When a transistor rises in temperature whether because of an increase in the 'ambient' (surrounding) temperature, or because of the current passing through it, its collector current increases. This increase in collector current causes the transistor to become even warmer which results in a further increase in collector current. This state of affairs is likely to continue until the transistor fails, and is called 'thermal runaway'.

It is essential that some method of counteracting this effect is incorporated in transistor circuits, otherwise transistor equipment would be extremely unreliable, to say the least. The resistor R4 in Fig. 12 serves this purpose, and is sometimes called the stabilising resistor. It is wired in series with the emitter and it therefore passes both collector and base current, and across it is developed a voltage that is proportional to the current and resistance values. With *pnp* transistors, the voltage is negative at the emitter with respect to battery positive, as shown on the diagram.

Now, if the collector current were to rise owing to an increase in the temperature of the transistor or from another cause, the negative voltage at the emitter would also rise (because a larger current would be flowing in the resistor). An increase in the negative emitter voltage is exactly the same as a decrease in the negative voltage at the base with respect to the emitter.

Now, the less negative base will result in a fall of collector current (remembering that an increase in collector current is promoted by an increase of negative base bias), so the transistor will cool down and a condition of 'thermal equilibrium' will exist in the circuit.

In some respects, the emitter resistor is rather like the cathode resistor of a valve, and, since it passes collector current, it will have some influence on the base bias. It cannot provide base bias, of course, because it makes the base go positive (or less negative) with respect to the emitter and the base calls for a negative voltage. It thus detracts from the bias provided by the potential-divider, and this must be taken into account when the circuit is designed.

Like an unbypassed cathode resistor, an unbypassed emitter resistor will have developed across it a signal voltage. With a valve this gives rise to negative feedback, but with a transistor it would be likely to cause instability and other disturbing effects, unless the circuit were designed specifically for the resistor being left unbypassed. Usually, however, a large value electrolytic capacitor shunts the resistor (C2 in Fig. 12).

Comparison with Valve Amplifier

At this stage it would be useful to compare a transistor a.f. amplifier with

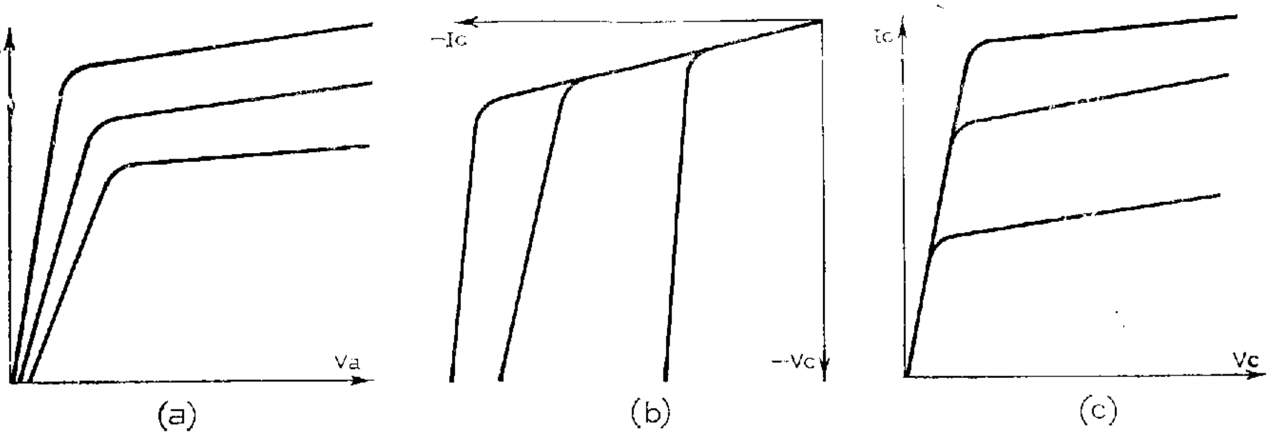


Fig. 16—At (a) is shown typical pentode anode characteristics and at (b) typical transistor collector characteristics. Because the collector of a transistor is negative and the anode of a valve positive, (b) is inverted with respect to (a). This is corrected graphically by turning (b) round, as shown at (c). This clearly reveals that (c) has much in common with (a).

its valve counterpart. Such a circuit is given in Fig. 13. Here, there is a 0·1μF input coupling capacitor C1, and similar value output capacitor C3. R1 is the grid resistor, R2 the anode load resistor and R3 the cathode bias resistor which is bypassed for a.f. by the 50μF electrolytic capacitor C2.

Other Configurations

Aside from the common-emitter configuration shown in Fig. 12, transistors may be operated, for instance, in the common-base mode (equivalent to the earthed-grid, or grounded-grid, valve circuit) where the input signal is applied to the emitter (see Fig. 14). Here the base is connected to signal 'earth' or chassis.

This gives a current gain of less than unity, a low input impedance (compared with a medium input impedance of the earthed-emitter mode) and a relatively high output impedance. This arrangement allows for the maximum operating frequency, which is why it is used in v.h.f. frequency modulated receivers and in television tuners. It is also inherently stable since there is zero phase shift between input and output signals.

The circuit produces a high voltage gain (or power gain) owing to the high ratio of the output to the input impedance. Such a circuit is useful for transformer coupling and for microphone and tape amplifiers and so on, which call for a low input impedance and high output impedance.

Common-Collector

Finally, there is the common-collector mode, which corresponds to the cathode-follower valve circuit (sometimes called the 'emitter-follower'). The basic circuit is given in Fig. 15, where it will be seen that the collector is effectively 'earthed' so far as signal is concerned. The input is applied at the base and the output is taken from the emitter.

This gives a high impedance input and a low impedance output, as does the valve cathode-follower and, likewise, the voltage gain is less than unity. The circuit is ideal as a buffer stage or impedance matching device, where the demand is to feed a low impedance circuit from a high impedance source. It makes an ideal output stage for v.h.f. tuners to feed over a fairly long line to the input of a hi-fi amplifier. Again, the theoretical input-to-output phase shift is zero.

Class A, B and C Operation

Transistor amplifiers may be classified in a similar way to valve amplifiers. That is, when collector current flows continuously throughout the cycle of the applied signal, the amplifier is called 'class A'. Likewise, when the transistor is biased to cut-off so that the collector current changes only through one half-cycle of the applied signal, the amplifier is called ' class B '.

Class B output stages are employed in most domestic portables for two reasons ; one, to provide greater output power and two, as a battery economy device, for it will be appreciated that with class B stages, the battery consumption is related to the sound output. When there is no output (i.e. with the set switched on and with the volume control turned right down) a battery current of only a few milliamps flows, but when the volume control is turned up, a current of 50 or more milliamps may be taken from the battery, depending on the power output of the final stage.

Similarly, transistors may be operated as class AB1, class AB2, class C and so on, just like valves. Large power amplifiers for public address work may use class AB2, since such operation represents a compromise between power output and power consumption (and quality of reproduction). Class C operation may occur in some oscillators and r.f. power amplifiers for small transmitters.

Transistor Curves

The collector characteristics of a transistor are rather like the anode characteristics of a pentode valve. This is illustrated in Fig. 16, where at (a) is shown typical pentode characteristics and at (b) typical transistor characteristics. There is one major difference, of course, and that is of direction. This is because the collector of a *pnp* transistor is negative with respect to emitter, while the anode of a valve is positive with respect to cathode. This can easily be rectified graphically by turning round (b) so that it looks like (c). Now it may be seen that (c) has much in common with (a). The transistor curves are those in the common-emitter mode (equivalent to the common-cathode mode of a valve), which is the most general form adopted in small sets.

Other Factors

The current gain of a transistor in the common-emitter configuration is equal to the ratio of the signal current in the collector to the signal current in the base, and current gain values in excess of 100 are not uncommon these days. Current gain is sometimes denoted by ' beta ', like the amplification factor of a valve is denoted by ' mu ', which is the current gain equivalent, it being equal to the ratio of the signal voltage in the anode to the signal voltage in the grid.

Transistor stages in the common-emitter mode possess a low input impedance which, unfortunately, varies greatly with collector current. For example, at 1mA the input impedance may be around 1kΩ, while at 20mA (collector current) it may drop to as low as 200Ω. The output impedance at the collector itself also decreases with increase of collector current, and may fall from 20kΩ at 1mA to 2kΩ at 20mA, depending on the type of transistor.

TEMPERATURE EFFECTS ON SEMICONDUCTOR OPERATION

Much has been written about the temperature sensitivity of transistors and how excessive temperature, such as the heat from a soldering iron, can ruin them. Also, how the heat from a bench lamp can alter the characteristics of a transistorised circuit and cause rather bewildering voltage and current readings during the course of fault tracing in a transistor receiver. All these things are perfectly true and should be heeded. However, in order to appreciate fully the effects of temperature changes, it is necessary to understand the basic principles of current flow in a semiconductor material.

TRANSISTORS possess what is known as a 'maximum power rating', which applies essentially to the collector junction. This rating, of course, is the product of the collector current and voltage, and is rather like the anode power rating (or anode dissipation) of a valve. With a transistor, however, collector current and voltage are rather critical, and will be dealt with later.

The maximum power rating of the collector (often called maximum collector dissipation) is very much related to the temperature of the junction. Under normal conditions, the collector junction is subjected to a reverse bias and collector current flows only when there is a forward current in the base circuit.

When there is no base current, then there should be only very little collector current, and in fact, the collector current which exists at that time is called 'reverse leakage current'—rather like the reverse current which occurs in an ordinary germanium diode when it is connected for reverse conduction.

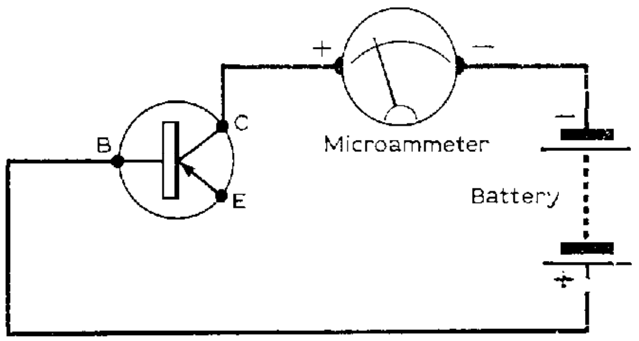


Fig. 1—At normal room temperatures, a small reverse leakage current flows in the base/collector junction when there is zero base/emitter current (see text).

This current is due essentially to 'minority carriers' at the junction (these will be considered in detail later). However, when there is a forward current in the base-emitter junction there occurs a diffusion of 'positive holes' into the collector/base junction, which have the effect of increasing the density of minority carriers and thus cause an increase in collector current. To a point, depending on the type of transistor, the collector current increases with increase in base-emitter current.

Effect of Temperature on Minority Carriers

A perfect transistor junction would be one which passed no reverse current whatever. Unfortunately, the perfect is never possible, and there is an extra shortcoming in a transistor junction in that the reverse current increases with increase in temperature. Thus, if we consider a transistor circuit with zero base-emitter current with a microammeter in the collector circuit, as shown in Fig. 1, at normal room temperature there would be a small reverse leakage current, which would increase considerably with increase of temperature of the transistor.

The maximum junction temperature for most small transistors is of the order of 75° C. At higher temperatures, the efficiency of the transistor falls and, as the temperature is still further increased, the transistor no longer behaves as a semiconductor but turns into an ordinary conductor. This happens because a rise in temperature causes what is termed 'thermal agitation' within the make-up of the germanium crystal. Electrons are freed from their normal orbits and thus contribute to current flow.

What is a Semiconductor?

An ordinary thermionic valve requires a vacuum in which to operate; electrons are emitted by the cathode and are attracted to a positively-charged anode through a vacuum. A control grid is inserted between the cathode and anode to control the flow of electrons and hence the anode current.

A transistor, on the other hand, does not require a vacuum, but works instead in a perfect insulator in which is introduced certain impurities as a means of controlling the flow of current. The perfect insulator used is usually germanium, which is a crystal, and in its perfectly pure state the electrons of each atom are tightly 'bonded' together. This means that there are no free electrons. It will be recalled that a flow of electricity constitutes a movement of free electrons in the conductor. Best conductors are those which have most free electrons, like copper, silver and similar metals, while the best insulators are those with the least free electrons, such as rubber, glass, mica, germanium and so on. The free electrons are caused to move in a conductor by its being subjected to a difference in electrical potential (in volts) between its ends. The free electrons then flow from negative to positive, since electrons are attracted by a positive charge. The idea is illustrated in Fig. 2.

There is no perfect insulator, but pure germanium approaches the ideal. Like all atoms, an atom of pure germanium features a central, positively charged, 'nucleus' surrounded by electrons in orbit—rather like the planetary system, where the nucleus is the sun and the electrons the orbiting planets. The number of electrons in orbit is equal to the positive charge of the nucleus, and the atom has zero overall charge since the negative electrons exactly cancel out the positive charge of the nucleus.

Bonding

Germanium has four orbiting electrons to each atom, and the lattice-like structure of the crystal is achieved because the electrons of one atom share the orbit path of the electrons of an adjacent atom. In this way the atoms are 'bonded' together and there are no free electrons for ordinary conduction. However, controlled conduction is implemented by the introduction of a little impurity into the germanium. Arsenic is such an impurity with five orbiting electrons to each of its atoms. What happens is that an atom of germanium in the crystal lattice is replaced by an atom of arsenic, and only four of the arsenic electrons pair-up with the four electrons of an adjacent germanium atom. This leaves one

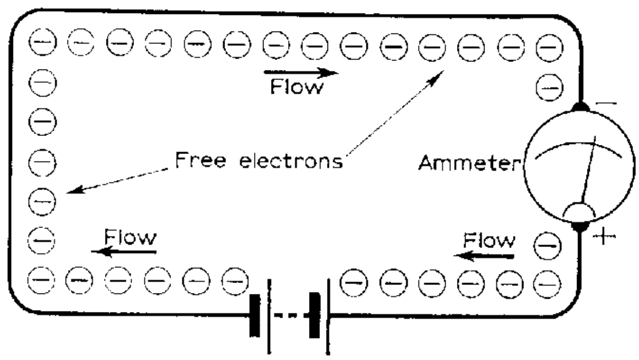
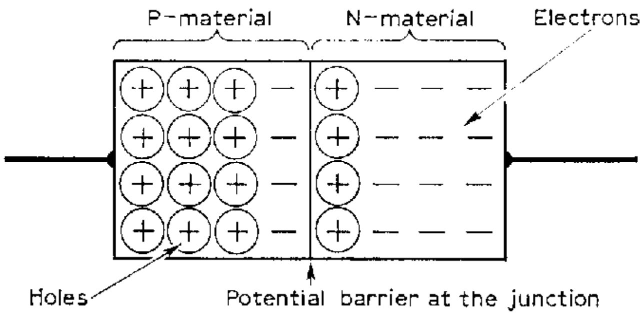


Fig. 2 (above)—Movement of free electrons constitutes a current of electricity.

Fig. 3 (below)—Operation of the crystal diode (see text).



electron per arsenic atom which is not paired and which is free for ordinary conduction.

Conduction is, of course, limited by the number of free electrons so created, and for that reason the material is called a 'semiconductor'. Also, since conduction is by way of electrons which are negative, the semiconductor is called 'n-type'—*n* for *n*egative.

P-type Material

A different type of semiconductor is produced by the introduction of an impurity with only three orbiting electrons, such as indium. The effect here is that the three indium electrons pair with three of the electrons of an adjacent germanium atom, leaving one germanium electron per indium atom without an electron partner.

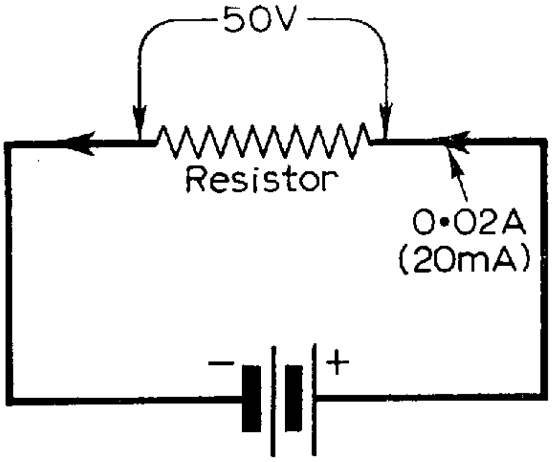
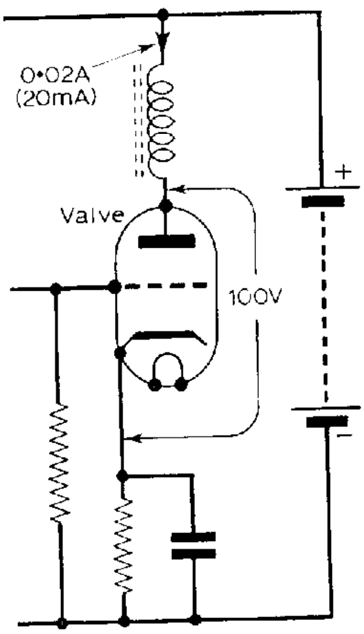


Fig. 4—The power dissipation in a resistor in watts is equal to the voltage multiplied by the current in amperes.

This electron deficiency is called a 'positive hole'; the term 'hole' is used to denote that there is a vacancy for an electron. Such vacancies continue to exist within the crystal, and conduction is said to be by way of a movement of holes. When such a material is subjected to an electric potential a hole is filled by an electron from an adjacent atom. This move leaves a hole behind which itself is filled by an electron from another atom, and so the process continues—a movement of electrons from negative to positive and an apparent movement of holes from positive to negative.

Since the holes move in the opposite direction to electrons they are said to be 'positive' current carriers, and for that reason semiconductor material of such nature is called 'p-type'—*p* for *p*ositive.

It may be said, therefore, that semiconductors possess a conductivity which falls somewhere between that of conductors and insulators, but unlike the latter materials—the conductivity of which decreases with increase in temperature—semiconductors *increase* in conductivity with increase in temperature. This is because some of the orbiting electrons are 'agitated' out of their orbits due to the rise in temperature, and are thus available—rather like free electrons—to contribute to conduction.



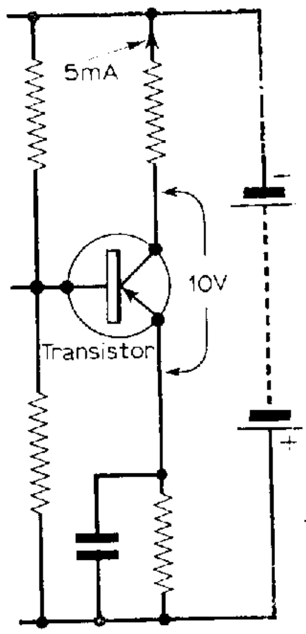


Fig. 5 (left)—A thermionic valve has an anode dissipation value equal to the anode voltage times the anode current.

Fig. 6 (right)—The collector dissipation of a transistor is given by (Ic × Vc).

p-n Junction

When a piece of germanium is processed at one end for *p*-type and at the other end for *n*-type the current carriers in each type of semiconductor diffuse in either direction across the junction. The holes from the *p*-region diffuse into the n-region and the electrons from the n-region diffuse into the p-region. A condition of equilibrium results whereby a 'potential barrier' occurs across the *junction.* This potential is created because the p-material acquires a negative charge due to its loss of holes, while the n-material acquires a positive charge due to its loss of electrons. The effect is shown in Fig. 3.

Now, if a battery is connected across the junction so that the positive side is connected to the p-material and the negative side to the n-material, the current carriers in each material will again start diffusing across the junction. This produces a current flow in the *forward direction,* as would be expected.

However, if the battery connections are reversed, the potential barrier at the junction is reinforced, and in an ideal case there should be no current flow. In practice, though, a small reverse leakage current flows. This is because of the inevitable presence of electrons in the p-material and holes in the n-material. These reversed current carriers are called 'minority carriers', as previously intimated. They increase in density with increase in temperature, and thus cause the reverse leakage current to increase as the junction warms up (see Fig. 1).

The Transistor

The transistor has two junctions. A *pnp* transistor consists of a very thin region of n-material sandwiched between two regions of p-material, while an *npn* transistor consists of a very thin region of p-material sandwiched between two regions of n-material.

The filling of the sandwich is called the base, while the outside pieces are called emitter and collector respectively (basic details were given in the first chapter of this handbook). We thus have two junctions—the emitter-base junction and the collector-base junction.

The former is biased for forward conduction (emitter positive with respect to the base), while the latter is biased for reversed conduction (collector negative with respect to the base).

Collector Dissipation

Dissipation in the context considered is the 'power' that a device can safely withstand. Power is usually rated in watts. Take an ordinary resistive circuit across which is a potential of 50V and through which a current of 0·02A (e.g., 20mA) is flowing (see Fig. 4). The product of the voltage and the current in amperes gives the power dissipation in watts. Thus, in Fig. 4, the power dissipation is 50 times 0·02, which works out at 1W.

An ordinary thermionic valve has an anode dissipation value which is calculated in the same way as with a resistor. In Fig. 5 is shown a simple

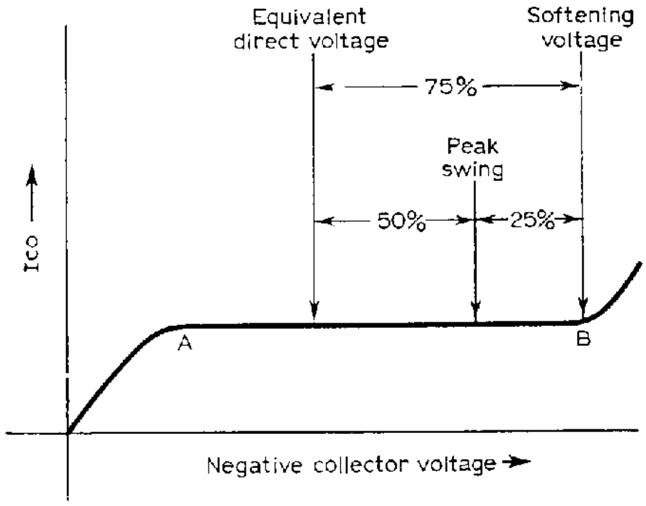


Fig. 7—Curve showing the voltage limits at the collector.

valve circuit with 100V on the anode and, again, 0·02A of current (called anode current). The product of the two works out in this example to 2W.

The maximum dissipation of a resistor is, of course, determined by its physical size and, if wire-wound, the diameter of the resistance wire used coupled with the heat withstanding property of the former on which the wire is wound. Power dissipation produces heat, and in a resistor this is caused by the resistance that the wire or conductor possesses to the flow of electric current.

Anode Heating

In a thermionic valve, the electrons from the cathode are accelerated to a very high speed by the positive anode, and since the electrons have mass, on striking the anode they liberate their kinetic energy and in that way cause the anode to become hot. The maximum anode dissipation of a valve is related to the maximum permissible values of cathode current and anode voltage, and, in turn, these ratings depend upon the size and physical construction of the valve.

From the foregoing, therefore, it will be appreciated that a transistor has a collector dissipation rating. This is usually denoted pc and is given by the product of the maximum collector voltage (Vc max) and the maximum collector current (Ic max). However, with a transistor, there is also another important factor—temperature.

data sheets in terms of °C/mW for small units.

A typical value is 0·33°C/mW. This relates the collector dissipation to the rise of temperature of the junction. It is not really as complicated as it sounds, as a simple example will show.

As we are considering a rise in temperature from the ambient, there are four factors which have to be considered. These are (i) collector dissipation pc, (ii) junction temperature Tj, (iii) ambient temperature Ta and (iv) thermal resistance Rt. These are used in the following equation to permit the calculation of collector dissipation:

$$pc = (Tj - Ta)/Rt.$$

Suppose Tj = 75°C, Ta = 50°C, and Rt = 0·33.

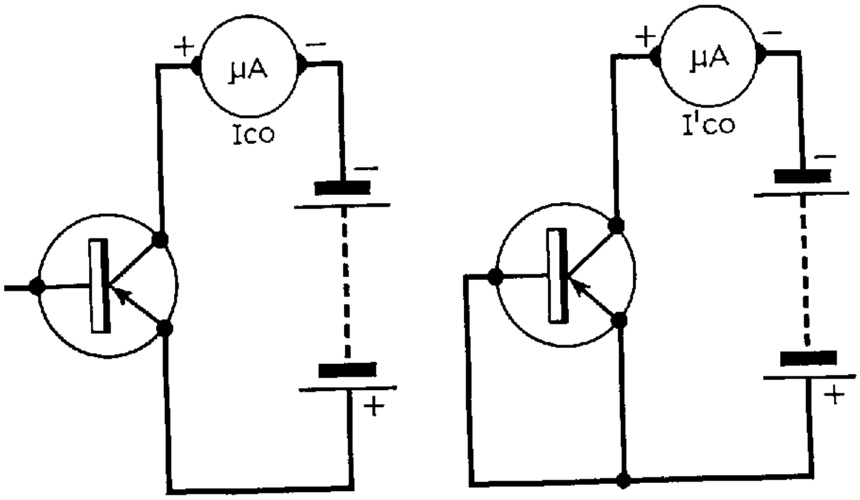


Fig. 8—With the base open-circuit, the collector current present is usually denoted Ico (Fig. 8a—left); and with the base connected to the emitter I'co (Fig. 8b—right).

The maximum junction temperature (which is often the same as the maximum storage temperature) is in the region of 75°C for most germanium transistors. This means that if the temperature of a transistor is allowed to rise above that value it may well cease to work as a transistor and change into an ordinary resistor. The same applies if a transistor is stored for any length of time at a temperature much above 75°C.

Thermal Resistance

It is thus necessary to introduce a temperature factor into the equation dealing with maximum collector dissipation. This factor is called thermal resistance and is given on transistor

Then, pc = (75 − 50)/0·33 which works out to a little under 76mW. This means that a transistor with a thermal resistance rating of 0·33 and a maximum junction temperature of 75°C working in an ambient temperature of 50°C has a permissible collector dissipation of 76mW.

Increased Dissipation

A small transistor would probably not require to operate with a collector dissipation in excess of 76mW, so all is well. However, larger transistors may be called upon to dissipate a power in excess of that allowed by the 'free air' thermal resistance. This is possible by the use of a heat sink which consists of a good conductor of heat on which the transistor is mounted and which drains away the heat produced ; it is not to be confused with a heat shunt which is used primarily for by-passing the heat from a soldering iron away from a transistor during soldering.

In effect, a heat sink keeps the junction temperature below that which would have been reached under free-air conditions for a given collector dissipation. Thus, a transistor with a free-air thermal resistance rating of, say, 0·4°C/mW may well have its rating modified to 0·3°C/mW by the use of a suitable heat sink.

For example, a transistor with a thermal resistance in free air of 0·4°C/mW, that the product of the voltage and current did not exceed that value. This would be satisfied by 10V and 5mA.

The maximum voltage, however, is somewhat related to signal swing at the collector, whereas the maximum current has its limit in terms of permissible collector dissipation. For example, it is possible to operate a transistor at a very low voltage and draw from it relatively high currents.

Maximum Collector Voltage

The converse is not possible (e.g., a very low current and relatively high voltage) as already intimated. Without going into too much theory, we can see

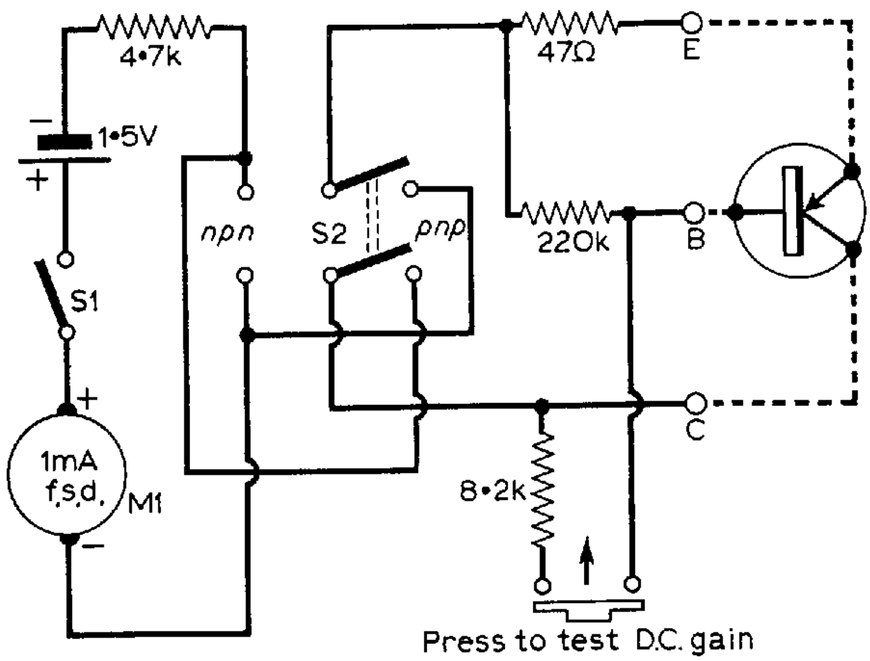


Fig. 9—A circuit of a simple transistor and semi-conductor diode comparator.

with a maximum junction temperature of 75°C and working in an ambient temperature of 50°C would have a collector dissipation of about 62mW. However, by the use of a heat sink (thereby reducing the thermal resistance, say, to 0·3°C/mW) the same transistor could have a collector dissipation of about 83mW—a useful increase.

After finding the permissible collector dissipation, we can then put voltage and current values in the collector circuit, as shown in Fig. 6. Let us suppose that we found that the collector dissipation was 50mW. Then, the circuit elements would have to be arranged so why this is the case by referring to the curve in Fig. 7.

It will be recalled that the base-emitter junction is biased by the power source in the reverse direction (e.g., negative at the collector and positive at the base—see Fig. 6). This, then, gives the curve of Fig. 7 which, for a circuit in the common base mode, is really a representation of the leakage current (Ico).

This leakage current rises to a constant value with increase in negative collector voltage from point 'A' to point 'B'. Point 'B' is sometimes called the 'softening voltage' (rather the same as the turn-over voltage of a semiconductor diode biased for reverse conduction). When point 'B' is reached, Ico starts to rise rapidly. The *peak* voltage swing of the collector is usually limited to a value which is about 25% below the softening voltage, while the *maximum* equivalent direct voltage of the collector is usually considered as being about 75% below the softening voltage, as shown on the curve.

When a transistor is arranged in the common emitter mode, then the factors as described above still apply, but the whole curve is scaled down, since, under this condition, the softening voltage occurs at a value below that for common base operation. The curve then shows leakage current with the base open-circuited, usually denoted I'co (see Fig. 8).

Tester for Comparative Checks

From the foregoing it will be understood that both Ico and I'co increase in value with increase in temperature. Either when a transistor is too warm or in some way defective the value of Ico or I'co rises considerably and in severe cases could result in a reversed conduction approaching the value of forward conduction. It is then that a transistor ceases to operate as such.

The d.c. gain of a transistor is really a measure of the ratio of Ico and collector current when base current is flowing. In Fig. 9 is given a simple circuit which facilitates ratio measurements of this kind on both *npn* and *pnp* transistors. With a transistor connected correctly to the terminals indicated, and with S2 in the appropriate position, a very small reading will be recorded on M1 when S1 is closed. This is effectively the leakage current between emitter and collector with the base open (e.g. Ico). On a good transistor the reading should not exceed 0·1mA (100μA), but should normally be less than this.

This reading will be influenced by the air temperature around the transistor, as already explained, and the temperature sensitivity can vividly be demonstrated simply by bringing the heat from a soldering iron towards the component under test (avoid too much heat !).

Transistors are also light sensitive, which is one of the reasons why they are painted black or sealed in a light-proof container. If there is any leakage of light through the case Ico will change with room illumination.

Indication of D.C. Gain

Now, when the button marked 'press to test d.c. gain' is depressed, the base circuit is closed through the 8·2kΩ resistor which goes back to the battery at the appropriate polarity. The meter reading will then rise up to the region of 0·6mA at least; and it is this *change* in current which gives an indication of the d.c. gain. The greater the change, the greater the gain.

Clearly, then, the tester can be used to select transistors from a bunch and will, at least, allow comparative checks and show whether a unit is serviceable or not. It can also be used to select matched pairs of transistors for push-pull output stages. It is fairly fool-proof as the battery voltage almost prevents burning out transistors.

The circuit can also be used to test semi-conductor diodes. The diode is simply connected between the 'E' and 'C' terminals and the reverse and forward conduction ratio can be assessed by switching S2 from one position to the other. With a good diode, the current change should not be less than about 0·6mA.

SIMPLE M.W. THREE

The basic requirements to be fulfilled by this design were that it should be an easy circuit to construct and set up; it should be cheap, compact and give acceptable results from the local transmitter. It must be emphasised that this is by no means a long-range receiver (this being the province of the superhet circuit) and it is intended only for use in the primary service area of a transmitter.

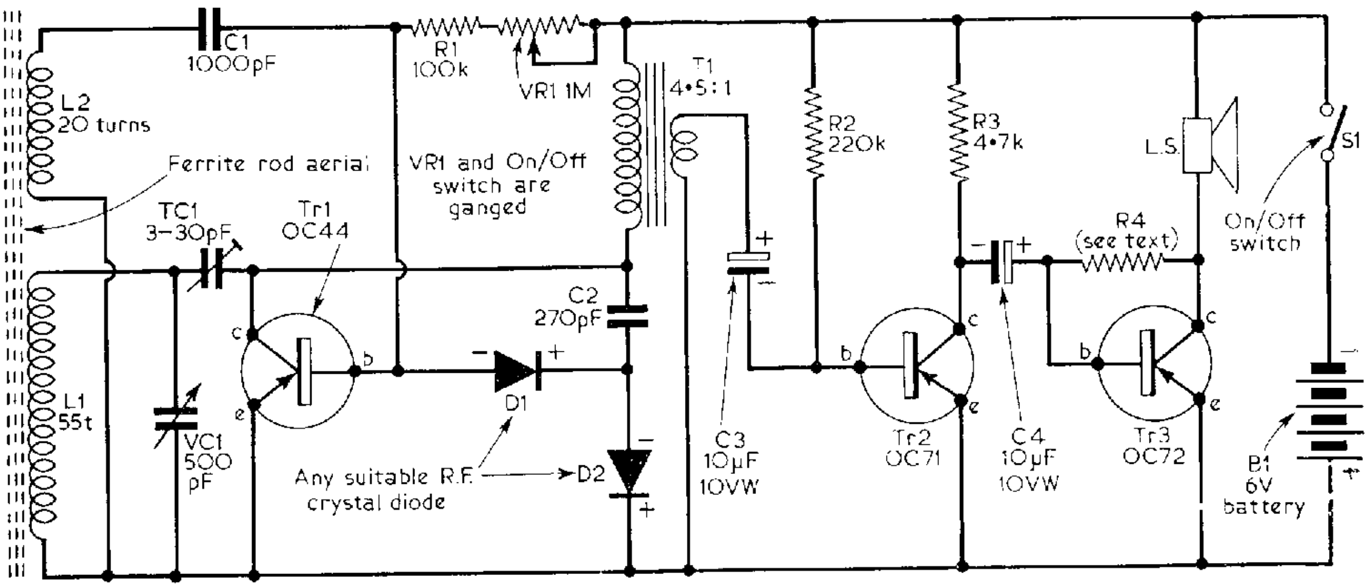


Fig. 1—Circuit diagram of the simple m.w. three.

THE r.f. section of the circuit is somewhat unusual, consisting of an r.f. transistor used as a reflexed r.f./a.f. amplifier with regeneration (reaction). The ferrite aerial is tuned by means of VC1. Regeneration is controlled by TC1, which is pre-set for optimum performance, the final, fine adjustment being controlled by VR1, which varies the bias on the base of Tr1. The r.f. stage feeds a voltage doubler type of detector in the base circuit of Tr1. T1 serves a triple purpose in this circuit; the primary acts as a collector load for Tr1 and also as an r.f. choke. The transformer then acts as a coupling unit for the detected a.f. and passes it on to the audio section (its proper function).

The a.f. section is a simple, very conventional R-C amplifier, the final output of which is delivered directly into a small, relatively high-impedance loudspeaker, obviating the necessity for an output transformer. The bias of the output stage is controlled by R4, which also provides a little feedback. The value of R4 depends on the current drawn by the transistor, which can vary as much as $\pm 50\%$ in transistors of the same manufacture. The value of ' R ' is chosen so that the collector current drawn by Tr2 is as near as possible to 10mA.

The values of the various components used in the circuit—with the exception of R4—are in no way critical, and the circuit should function perfectly well with components the values of which are within $\pm 20\%$ of those shown.

If ' surplus ' types of transistor are used, it is suggested that a ' white spot ' type be used for Tr1, a 'red spot' for Tr2, and a 'green-yellow spot' type for Tr3. If a red spot type is used the bias on the base of Tr2 may require a little adjustment, and this may be found by a trial and error substitution of R2.

Construction

The coil L1 consists of 55 turns of 28s.w.g. enamelled wire close wound on a $\frac{3}{8}$in. diameter ferrite rod. The rod may be of any length, but it is recommended that the minimum length should be 2in. The coil should be insulated from the ferrite rod by first winding on a layer of Sellotape, and then winding the coil on near the end of the rod. L2 consists of 20 turns of the same gauge wire wound over a paper sleeve so that the coil is free to move along the ferrite rod.

The actual physical layout of the components is not at all critical, and any convenient layout may be employed. As the layout will depend upon the size of the cabinet, and this in turn will determine the length of the ferrite rod employed for the aerial coil, no layout details will be given.

Operation

The setting up of the circuit is not very difficult if the following instructions are noted. Having checked the wiring for mistakes, connect the battery as shown, ensuring that the correct polarity is observed. Advance the potentiometer VR1 to about half-way when some sort of sound will be heard from the loudspeaker. With the aid of a milliammeter, adjust the collector current of Tr3 to 10mA by finding a suitable value for R4, either by trial and error, or by making R4 a variable resistor, and adjusting to the right current and then substituting a fixed resistor of equivalent value. The value of the resistor used need only be a near value—there is no real need for great accuracy. L2 should be moved as close as possible to L1 and the beehive trimmer TC1 adjusted until the set starts to oscillate. By varying VC1 it should be possible to tune in the local station. When this has been done the trimmer TC1 should be backed off until oscillation just ceases. By varying the position of L2 with respect to L1 and by suitably adjusting TC1 the position of maximum sensitivity may be found. L2 is then sealed in position with sealing-wax or Sellotape.

It will be found that the sensitivity control VR1 will have an effect on regeneration, and this will be found useful in areas where there are two transmitters—one being a little more powerful than the other.

COMPONENTS LIST

Resistors (all ±10% $\frac{1}{2}$W carbon):
R1 100kΩ   R3 4·7kΩ
R2 220kΩ   R4 (see text)
VR1 1MΩ carbon potentiometer with switch (S1)

Capacitors:
C1 1,000pF ceramic
C2 270pF ceramic
C3 10μF electrolytic 10V
C4 10μF electrolytic 10V
VC1 500pF air-spaced variable
TC1 30pF air-spaced trimmer

Transformer:
T1 Interstage transformer 4·5:1 (Fortiphone 55 or similar)

Transistors:
Tr1 OC44
Tr2 OC71
Tr3 OC72

Diodes:
D1 OA71
D2 OA71

Loudspeaker:
LS Loudspeaker C.M.S. 50 (T.S.L.)

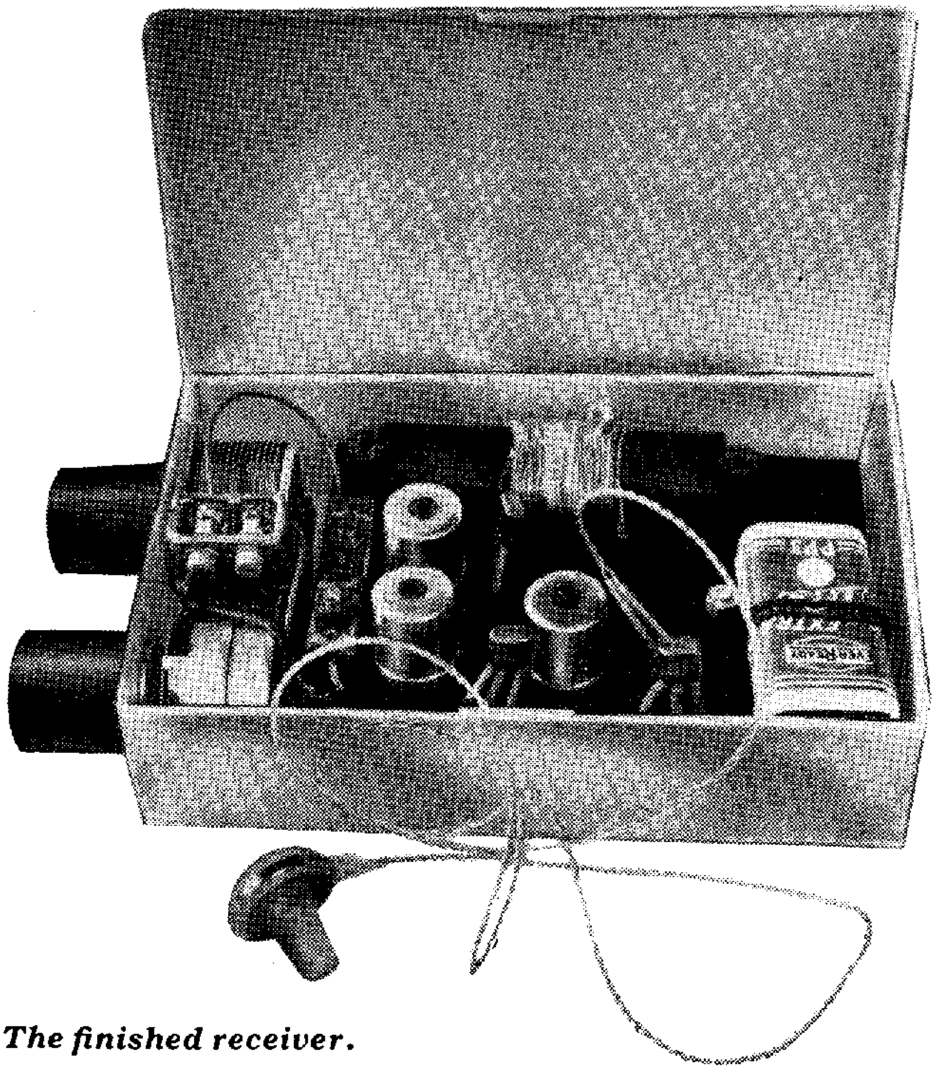
Battery:
B1 6V battery

Miscellaneous:
Ferrite rod, wire for coil, etc.

PERSONAL SUPERHET

Individual listening with earphones, a single earpiece, or a miniature 'personal' phone makes quite sure that others are not disturbed, and this type of reception is often very convenient. The set described here is for this purpose and has the control knobs at one end of the case so that the completed receiver will easily slip into a pocket.

The case holds a 'personal' type of earphone, so that the whole set is self-contained. If a pair of headphones with two earpieces is preferred this is quite in order. A lightweight pair of earphones can give very good results indeed with very good quality reproduction. A single headphone, attached to a length of thin twin flex, could also be used.



The finished receiver.

THE receiver is a superhet and the circuit is shown in Fig. 1. A home-wound ferrite slab aerial tunes medium waves, but a ready made rod or slab aerial would be equally satisfactory. The circuit is simplified and has one i.f. stage, followed by the diode detector and an audio amplifier. A 25kΩ potentiometer, with switch, acts as sensitivity control. The circuit is for use with a 6V to 9V battery and a small 9V battery such as the PP3 will have a long life. Selectivity is very much better with this type of circuit than with the simple type of t.r.f. receiver which is often employed for headphone reception.

The receiver fits in a plastic box approximately 3½in. × 6in. × 1¾in. (outside dimensions). This allows sufficient free space to make construction easy. Holes are drilled at the end of the box to

COMPONENTS LIST

Resistors:
R1 56kΩ
R2 10kΩ
R3 3·9kΩ
R4 56kΩ
R5 680Ω
R6 5·6kΩ
R7 47kΩ
R8 10kΩ
R9 470Ω
VR1 25kΩ carbon potentiometer with s.p. switch (S1)

Capacitors:
C1 0·05µF paper
C2 0·01µF paper
C3 250pF mica or ceramic
C4 0·25µF paper
C5 0·1µF paper
C6 0·01µF paper
C7 2µF electrolytic 6V
C8 30µF electrolytic 6V
C9 50µF electrolytic 9V
VC1 208pF } two-gang variable (Jackson 00)
VC2 176pF }
TC1 50pF trimmer } mounted on VC1/2
TC2 50pF trimmer }

Transistors and Diode:
Tr1 OC44 Tr2 OC45 Tr3 OC71
D1 OA71

Inductors:
L1 Aerial coil (see text)
L2 Oscillator coil (Osmor—red spot)
1FT1 Miniature i.f. transformer 470kc/s (Osmor—white spot)
1FT2 Miniature i.f. transformer 470kc/s (Osmor—blue spot)

Miscellaneous:
Medium or high impedance earpiece or headphones; plastic box ; 9V battery, two knobs

take the tuning capacitor and potentiometer. The capacitor is fixed with short 4B.A. bolts, a washer or two being placed between box and capacitor if necessary. About two washers will also be needed between the potentiometer and box. The spindle is sawn off to match the length of the capacitor spindle. This can most readily be done while holding the *unwanted* end of the spindle in a vice.

Aerial

The ferrite slab is 3in. × $\frac{3}{4}$in. × $\frac{1}{8}$in. and fits in slots filed in two pillars of insulating material, as in Fig. 2. These pillars can be of wood, solid ebonite or similar material, or they may be cut from insulated tubing. Solid pillars will need drilling to take the securing screws. These screws should be short. Metal pillars or any form of metal brackets are not recommended.

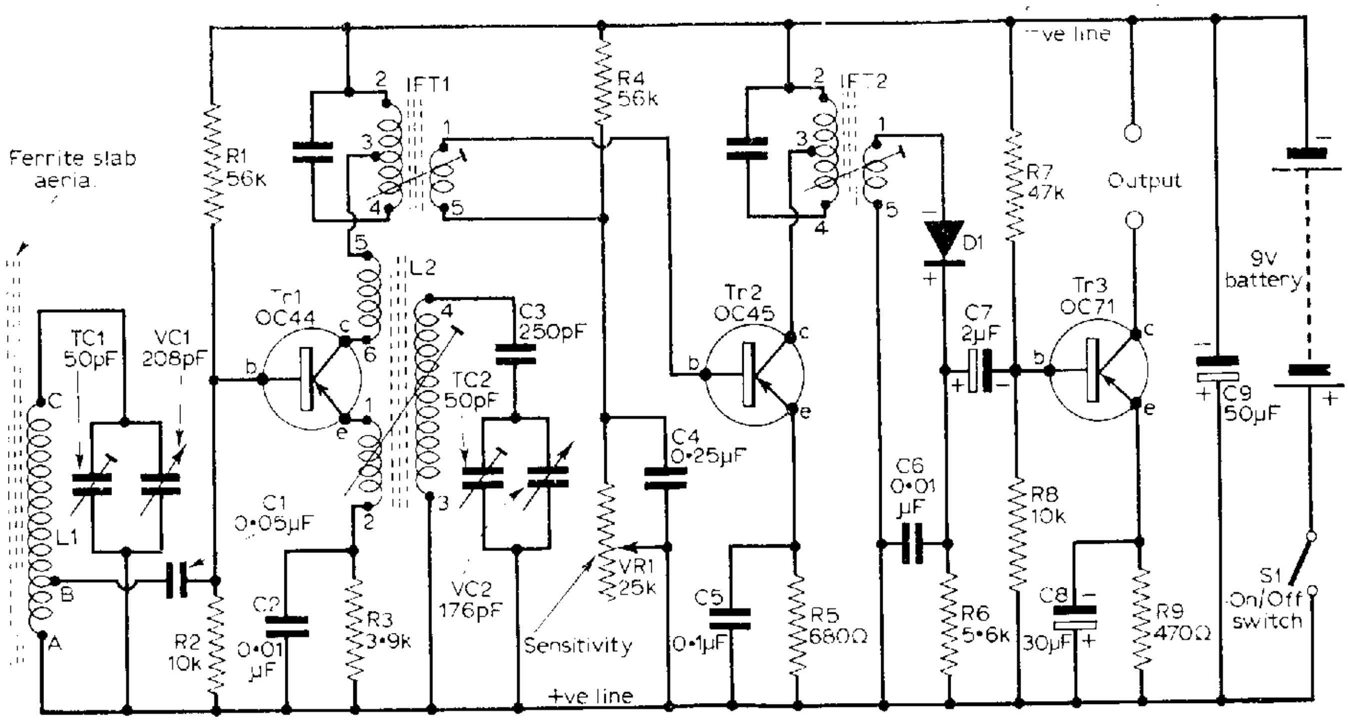


Fig. 1—The circuit of the superhet receiver.

For the winding, 26s.w.g. d.c.c. copper wire can be used and is easy to handle. Beginning at point 'A', twelve turns are wound on in a compact pile. The wire is then bared for a short distance and twisted to form a connecting point for the lead 'B'; then 46 more turns are wound on, forming them into a pile as winding progresses. The whole winding of 58 turns is 1in. long and near the centre of the slab.

Satisfactory alignment is achieved by adjusting the oscillator coil core to suit the inductance of the aerial winding, which is fixed. If the winding is held together with Sellotape it can be moved along the slab, if needed, when first testing the receiver.

If a ready-made aerial is used it may have a separate base coupling winding. If so, connect this winding from the 0·05μF capacitor (C1) to the 'earth' line. The larger winding is wired to the tuning capacitor in the usual way.

Receiver Panel

This is approximately $3\frac{1}{4}$in. × $4\frac{1}{2}$in., so that it fits in the case with a little clearance, and it is cut from $\frac{1}{16}$in. paxolin. It is placed in the case and a 4B.A. clearance hole is drilled through both panel and case in the position shown for the panel-securing nut in Fig. 3. A $\frac{3}{4}$in. 4B.A. bolt with three

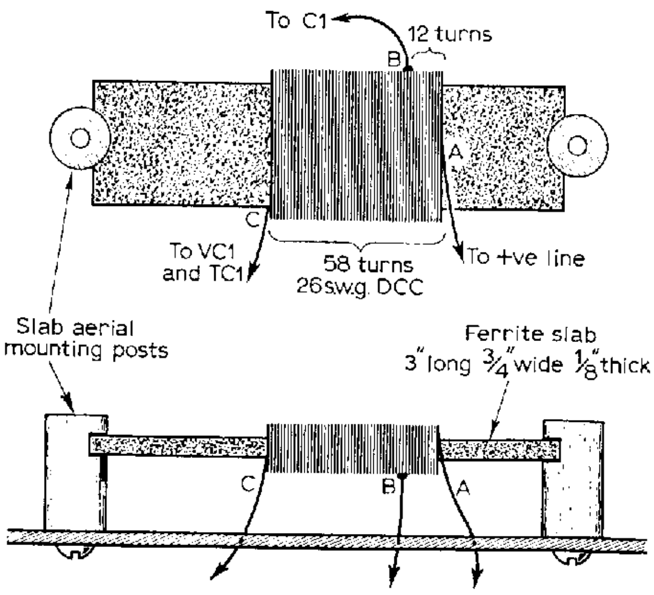


Fig. 2—The aerial winding and mounting details.

nuts will then allow the finished receiver to be held in position.

Fig. 3 shows the layout of parts on the panel.

After the oscillator coil and i.f. transformers have been mounted on to the panel the transistors are soldered into position.

The mixer and i.f. transistors must be of appropriate type, such as an OC44 for mixer and OC45 for the i.f. stage. A wide range of audio transistors will be satisfactory in the a.f. position. The OC71 is suitable and a red/yellow spot transistor was found satisfactory. Pieces of 1mm sleeving are cut about $\frac{3}{8}$in. long and one piece is placed on each transistor lead. This will avoid short-circuits and hold the transistors at a convenient height. The emitter, base and collector leads must, of course, be passed through the correct holes, as shown by 'e', 'b' and 'c' in Figs. 3 and 4.

Wiring Up

Some 26s.w.g. tinned copper wire will be convenient for connections and 1mm sleeving is placed on all leads and the wire ends of components. Fig. 4 shows the underside of the panel (the tuning capacitor and potentiometer are left until last).

The transistor leads are all left reasonably long and the soldered joints should be made quickly. The same care to avoid overheating is also taken with the diode.

Lead 'A' on the aerial is long enough to pass through a small hole to the earth line. Lead 'B' passes through a second hole from the 0·05μF capacitor to the aerial tapping. Lead 'C' passes to the 50pF trimmer TC1, as in Fig. 3, a short lead subsequently passing to the front section of the gang capacitor.

The collector lead of the a.f. transistor emerges through a second hole and one headphone lead is soldered to it, as in Fig. 3. The second headphone lead, through hole 'x' in Fig. 3 is soldered to a lead which is wired to the battery negative side of the circuit. A miniature 2-pin plug and socket could be used but

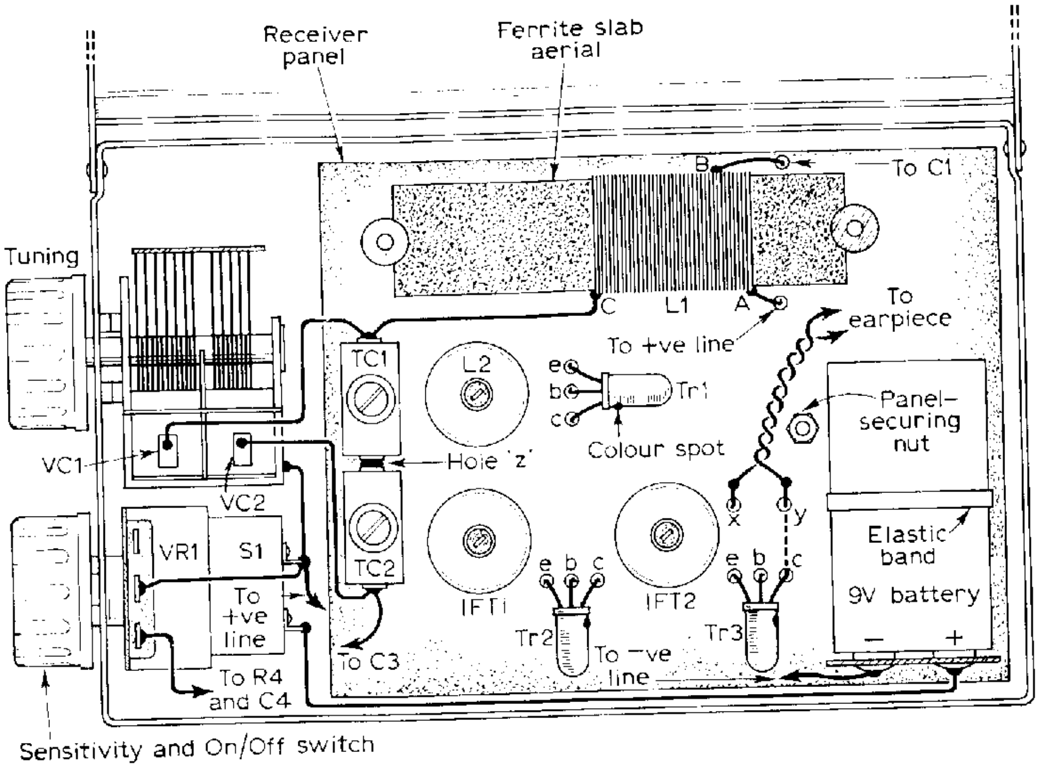


Fig. 3—The controls and panel layout inside the case.

is not really necessary when the earpiece can be accommodated in the case.

When all the wiring in Fig. 4 has been finished the tuning capacitor and potentiometer can be connected. One switch tag is wired to battery positive; the other tag to the earth line, potentiometer slider and the frame of the tuning capacitor. One outer tag of the potentiometer, shown in Fig. 3, is wired to the 0·25μF capacitor at pin 5 of the i.f. transformer. One lead is then taken from each trimmer to the sections of the tuning capacitor, as in Fig. 3.

After wiring has been checked the controls can be secured to the end of the case. Very small knobs are best avoided. The $\frac{3}{4}$in. 4B.A. bolt is then inserted in the hole in the case and a nut is tightened to hold it firmly. A further nut is then run on to leave about $\frac{1}{2}$in. clearance between panel and case. The panel is then dropped into position and held with a third nut.

An elastic band passes through two holes and holds the battery. Clearance holes are drilled for the oscillator coil and i.f. transformer pins, and rough edges are cleaned up as necessary with a small file or a larger drill so that the cans fit flush with the panel. The aerial mounting is shown in Fig. 2. The two 50pF trimmers have their tags soldered together and passed through a hole, this point being wired to the receiver 'earth' line.

Take care to position the oscillator coil correctly or all connections here will be wrong. Note that the first i.f. transformer is coded with a white spot and the second transformer with a blue spot. These items are held in place by bending out the long tags attached to the screening cans. These tags are wired together and to the earth line. It may be found helpful to scratch numbers by the pins on the underside of the panel.

The battery connections can be taken to suitable clips or they may be soldered. A meter may be added in circuit, when first trying the set, to ensure there are no short-circuits or to check the current flowing. This will be in the region of about 3mA to 5mA, depending on the actual battery voltage and transistors.

Alignment

This is similar to that of usual superhet circuits, though there are fewer adjustments. If a signal generator is available set it to 470kc/s, with modulation, and place the output lead near the mixer transistor. The two i.f. transformer cores are then adjusted for

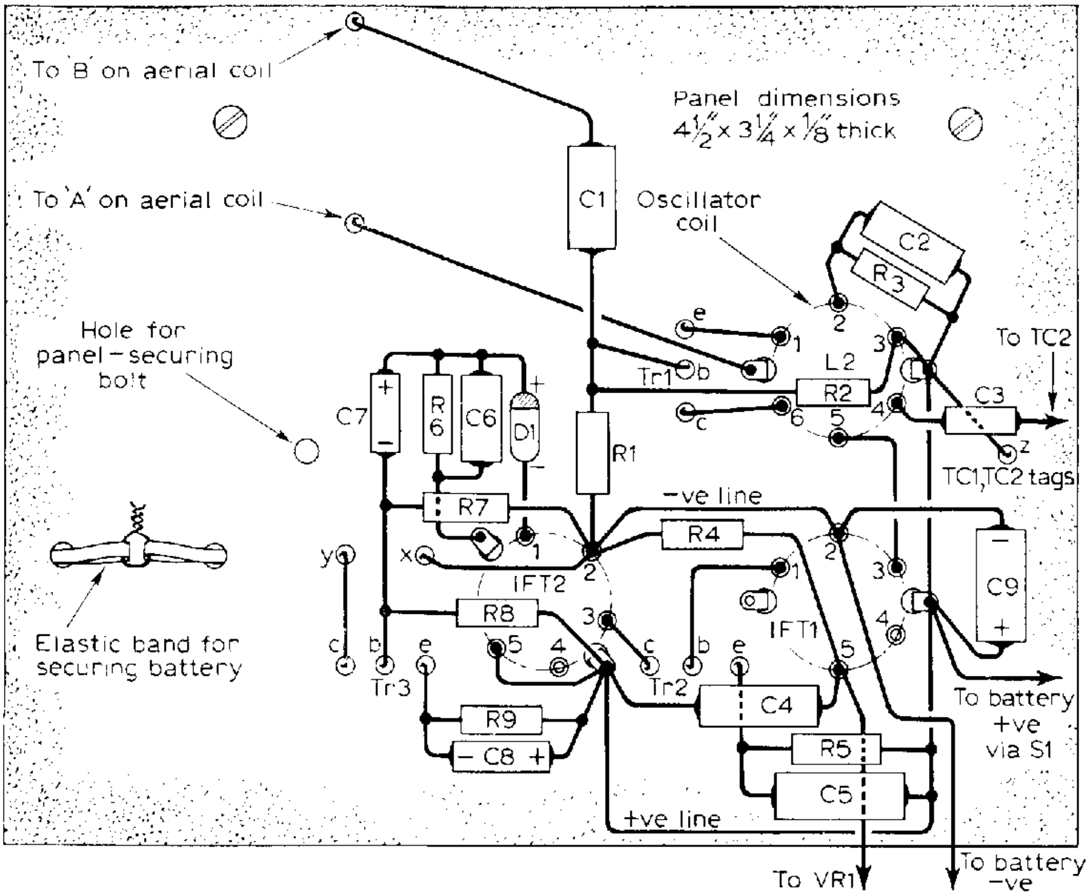


Fig. 4 — The wiring on the rear of the receiver panel.

maximum volume. If a generator is not available, simply adjust the i.f. transformers for best results.

As the sensitivity control is turned up from zero there will be a considerable increase in volume. At some point around the half-way position the i.f. amplifier will commence to oscillate. This is intended, as sensitivity is then very great. The two i.f. cores are finally peaked up for maximum volume, when the sensitivity control is *just* below the oscillation point. This should be carried out while listening to a weak, distant station.

To align the aerial and oscillator circuits, adjust the trimmers at a low wavelength and the oscillator coil core at a high wavelength. It is important that the trimmers have a fairly low minimum capacity. If trimmers with three plates are used it may be necessary to remove the screws and bend up the middle plate slightly to obtain a reasonably low capacity.

With the oscillator trimmer set at nearly minimum capacity a weak station should be tuned in. Adjustment of the aerial trimmer should then bring this station up to maximum volume, and the aerial trimmer should not be either fully screwed down or fully open. If best volume is obtained with the aerial trimmer fully open, screw down the oscillator trimmer slightly, readjust the tuning knob to obtain the station again, then try setting the aerial trimmer.

Alignment at the high wavelength end of the band can be achieved by adjusting the oscillator coil core in conjunction with the tuning capacitor for best volume, or by sliding the aerial winding along the slab, leaving the tuning capacitor untouched. Hand-wound coils vary somewhat in inductance, but moving the winding on the slab will compensate for this.

If sensitivity improves as the oscillator core is unscrewed and it is too far out, this shows that the aerial inductance is too low. Moving the winding nearer the centre of the slab will compensate for this. On the other hand, if the oscillator coil core is too far in, move the aerial winding nearer the end of the slab.

LOCAL STATION PRE-SET TUNER

When used in conjunction with almost any medium or high gain amplifier, this tuner unit will form a very efficient local station radio receiver. There are several advantages of a transistorised circuit over a more conventional valve circuit. In the first place, the use of transistors enables the size of the unit to be reduced; another important point is that the power consumed by the unit is negligible—it is conveniently supplied from batteries—and thus no power connections have to be made to the main amplifier as is usually the case.

In this circuit, the output impedance is high enough to match into most valve circuits. Another feature of the unit is the provision of pre-set switch tuning, which proves to be very satisfactory in practice.

THE tuner uses two transistors together with two germanium diodes. The fact that a radio frequency transistor is capable of functioning equally well at audio frequencies is made use of in this design, the first transistor being 'reflexed' to provide additional gain. The effect is almost that of using three transistors.

The aerial signal is passed via C11 to the coil which is tuned by the pre-set capacitors C1 and C2. Which one of these is used depends upon the station required. An extension of the tuning coil serves as the secondary of a step down transformer, the output of which is taken to the base and emitter of the first transistor. The radio frequency signal is amplified by this component in the normal way, a small portion of it being fed back in the positive sense via the pre-set trimmer C5, which acts as a reaction control. The signal appearing at the collector of the first transistor is demodulated by the two germanium diodes.

The audio output from these is fed back via RFC1 to the base of Tr1 transistor which now acts as an audio amplifier. The amplified audio signal is taken from the collector of the transistor, and fed, via RFC2, to the primary of the interstage transformer

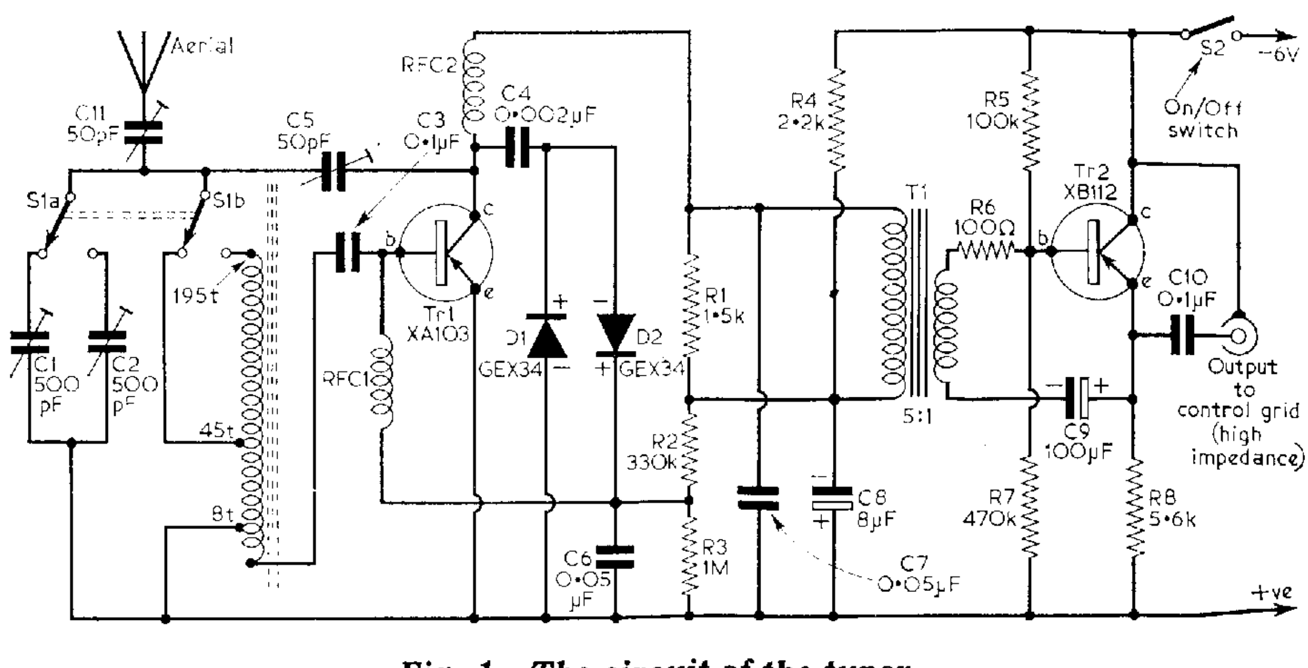


Fig. 1—The circuit of the tuner.

COMPONENTS LIST

Resistors (all ¼W carbon):

R1	1·5kΩ
R2	330kΩ
R3	1MΩ
R4	2·2kΩ
R5	100kΩ
R6	100Ω
R7	470kΩ
R8	5·6kΩ

Capacitors:

C1	500pF	pre-set trimmer
C2	500pF	pre-set trimmer
C3	0·1μF	paper
C4	0·002μF	paper
C5	50pF	pre-set trimmer
C6	0·05μF	paper
C7	0·05μF	paper
C8	8μF	electrolytic 6V
C9	100μF	electrolytic 15V
C10	0·1μF	paper 150V
C11	50pF	pre-set trimmer

Inductors:

RFC1	R.F. choke	10–20mH
RFC2	R.F. choke	10–20mH

Diodes:

D1	GEX34	Germanium diode
D2	GEX34	Germanium diode

Transistors:

Tr1	XA103	r.f. transistor
Tr2	XB112	a.f. transistor

Transformer:

T1 Interstage a.f. transformer, 5:1

Switches:

S1 Rotary switch, d.p.c.o.
S2 Toggle switch, s.p.s.t.

Battery:

6V battery (see text)

Miscellaneous:

Plastic container, polarised socket, coaxial output socket, 8in. length of 5/16in. diameter ferrite rod

T1 (ratio 5:1). The secondary of this transformer feeds the base and emitter of the second audio transistor. This transistor is arranged so that it has a high output impedance, making it suitable for feeding into a valve amplifier having a characteristically high input impedance.

Power Supplies

The tuner requires only 0·7mA or less, at a potential of 6V. This is most easily obtained from a battery. Either a 6V battery designed for transistor work, or one made up from four 1·5V cells connected in series, may be used.

In the prototype, the battery was not housed in the unit, but was connected to it via a polarised socket. The use of such a socket is important to ensure that the battery is always connected with the correct polarity.

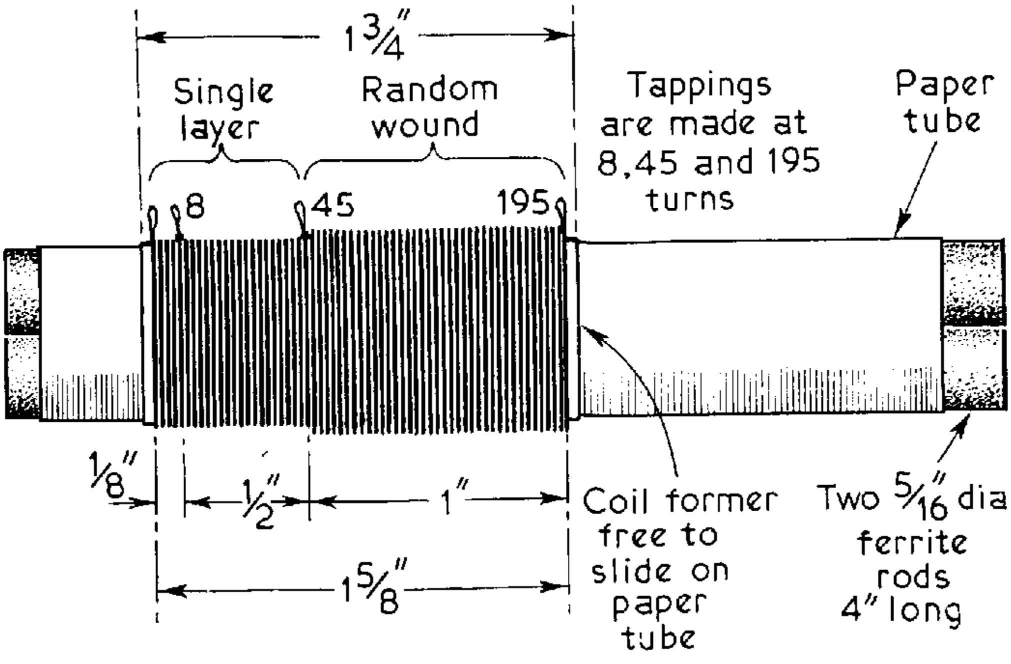


Fig. 2—Details of the tuning coil.

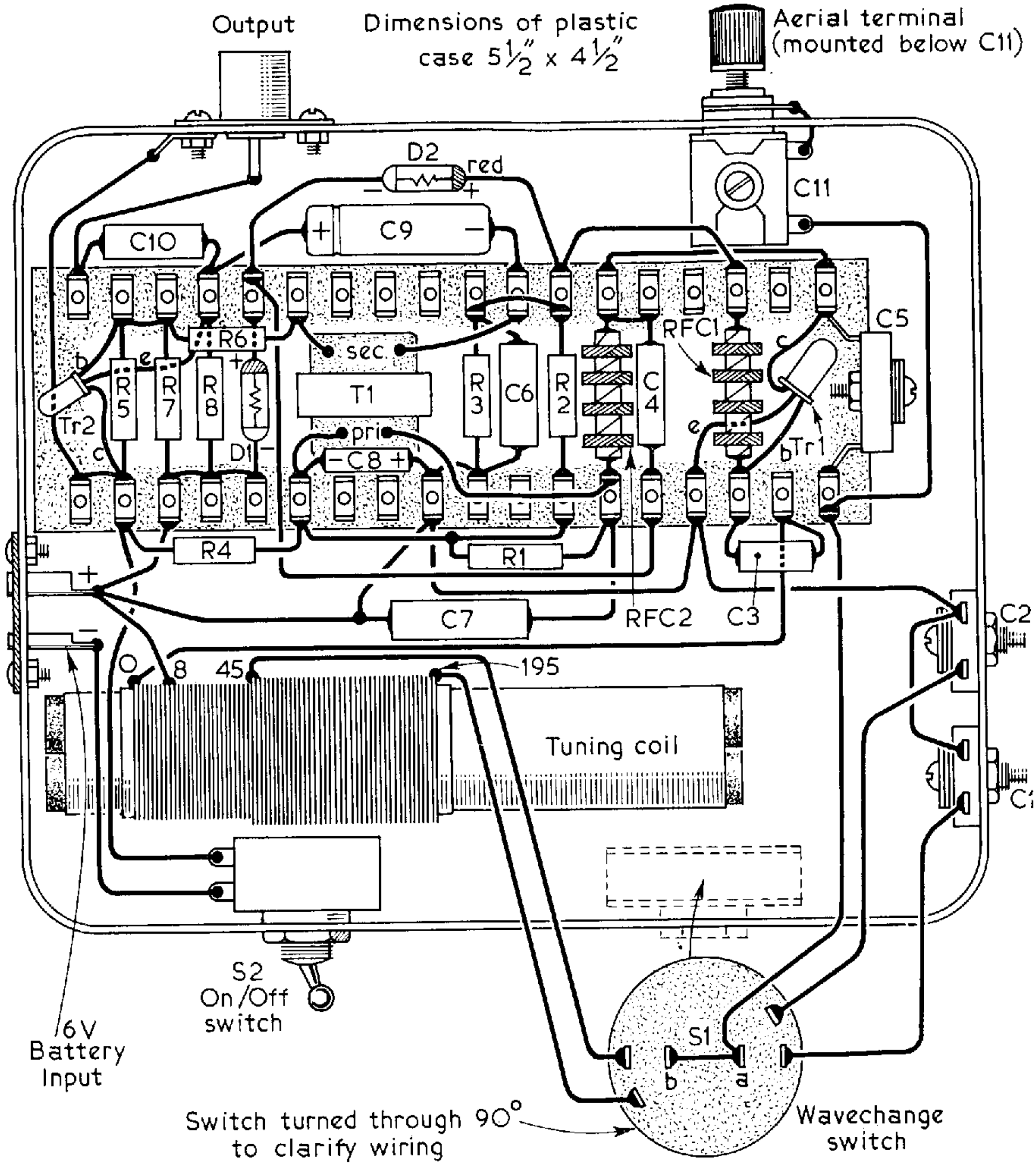


Fig. 3—The under-chassis wiring of the unit.

Construction

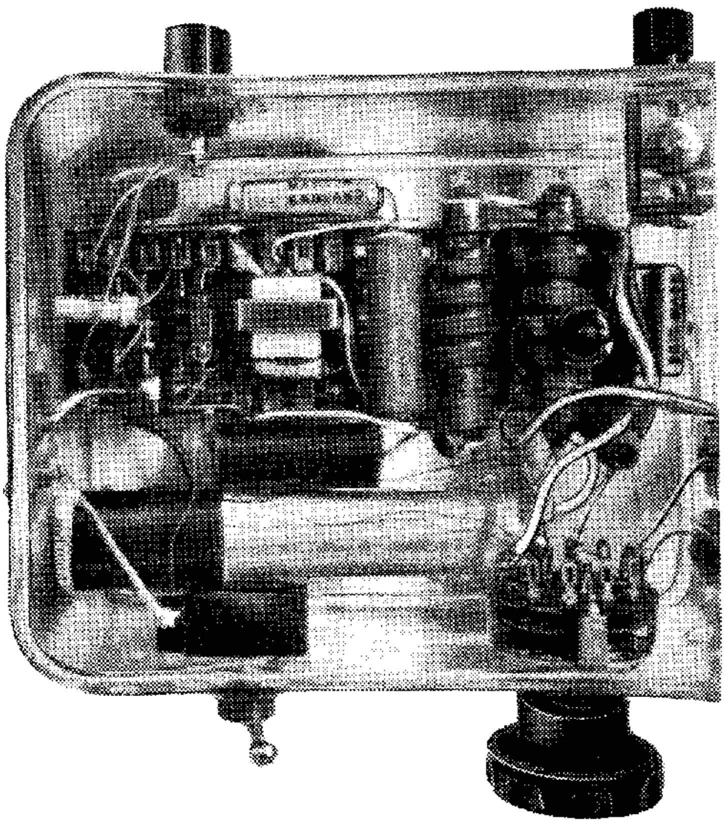
The tuning coil is constructed first. Details of this assembly, together with dimensions, are given in Fig. 2. The core of the coil consists of two 4in. lengths of $\frac{5}{16}$in. diameter ferrite rod side by side. Ferrite rod is usually supplied in 8in. lengths, and thus it will be necessary to cut the rod to secure the correct sizes. This is most easily accomplished by filing a nick in the rod at the point where it is to be cut, and then snapping it in half at that point. Care should be taken in this operation, since, although ferrite materials are extremely hard, they are also very brittle. The wire gauge or the type of insulated copper wire used is not critical. The dimensions given refer to a coil made of 34s.w.g. enamelled wire.

Housing

The whole unit is housed in a plastic box, the size of that used in the prototype being 5½in. × 4½in. A metal box is not suitable, since this would screen the ferrite assembly. The switches and the several sockets are mounted on the walls of the box itself. To enable this to be done, it is necessary to make holes in the plastic. Attempts to drill this type of material, using ordinary twist drills, usually end in failure owing to fracture of the plastic. The plastic is, however, easily pierced using a hot soldering iron or other heated metal tool.

Group Board

An eighteen-way group board is used to mount the main electronics assembly. The miniature transformer T1 is glued to this board. The group board in turn is glued to the plastic box. The wiring is not, in general, particularly critical, though the connections to the tuning coil should be kept as short as possible and care should be taken when soldering the transistor and the diodes—a heat shunt should always be used in soldering components of this kind. Construction is easier if the wiring of the group board is carried out before the component is mounted in the plastic case.



An under-chassis view of the completed tuner.

The output is taken via a coaxial socket, and coaxial or screened cable. The centre connector of the socket should go to C10, and the screen to the negative line. This ensures that the negative line of the feeder is connected to the chassis of the amplifier.

The tuner should on no account be used with an amplifier of the A.C./D.C. variety, which may in some circumstances have a live chassis.

Adjusting the Feeder

The wiring should first be checked thoroughly, and the unit connected to a medium or high gain amplifier. The battery should next be connected, taking great care to see that the polarity is correct. An aerial is then connected to the appropriate terminal. This aerial need only be five or six feet long: indeed, in some areas close to the transmitter, an external aerial may not be necessary, sufficient signal being obtained from the ferrite aerial in the tuner itself.

Capacitor Settings

The pre-set trimmer C5 should first be set to a low capacity, and the aerial trimmer, C11, screwed up fairly tight. The coil is slid to one end of the ferrite rods. The unit is now switched on, and S1 is switched to the medium wave position (i.e. 45 turns of the coil are in circuit). The trimmer corresponding to this position (C1 in Fig. 1) is then adjusted in conjunction with the position of the coil on the ferrite rods, until the local Home Service broadcast is heard at maximum strength. C5 and C11 are then adjusted for best reception. C5 should be adjusted to a position so that the unit is on the point of oscillation. The coil should now be fixed in position on the ferrite rods with glue. S1 is then switched to the Long Wave position and C2 adjusted to receive the Light Programme (1,500m). No further adjustments of C5 or C11 are normally required.

SHORT WAVE REGENERATIVE TWO

Super-regenerative receivers have been well known to amateurs and radio experimenters since the very early days of radio. This type of detector has a very high sensitivity and gain but suffers from one drawback, however, and that is a loud hissing noise. In the two-transistor super-regenerative receiver to be described, this drawback, whilst not eliminated entirely, is reduced to negligible proportions and when the set is tuned to a station the hissing noise is scarcely audible.

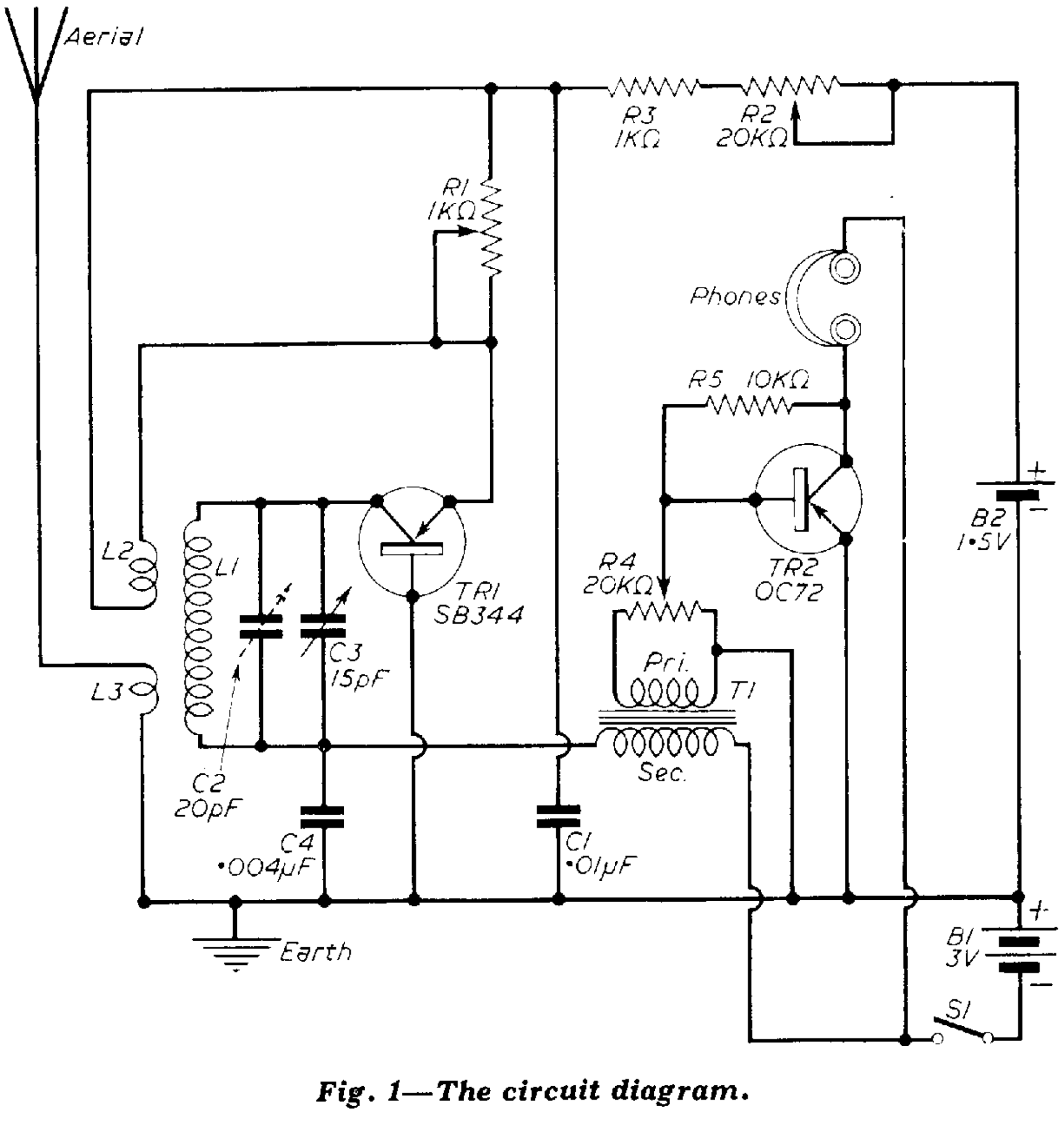


Fig. 1—The circuit diagram.

THE circuit is suitable for all frequencies but, with the super-regenerative detector, operation is most efficient on the higher frequencies. With this in mind, the set has been designed to operate on the 10m amateur band and frequencies adjacent to this band. Two transistors, a type SB344 acting as the detector and a type OC72 as audio amplifier are employed. It is constructed around the front panel of the cabinet and no 'chassis' is necessary. All controls are mounted on the front panel, and the tuning capacitor C3 is rotated by means of a slow motion dial. The bandset capacitor C2 in the original model is of the semi-variable type.

Bandsetting

If required C2 can be of the fully variable type and a further control could be put on the front panel for this capacitor which would give greater coverage. In the original set, however, interest was mainly in the 10m amateur band and therefore C2 was made of the semi-variable type. It was adjusted until the 10m band was heard with C3 approximately half open. This made the amateur band 'spread' over the full travel of C3.

The coils are constructed on formers of ceramic or similar material. The tuned coil, L1, consists of $7\frac{1}{2}$ turns of 20 gauge enamelled wire evenly spaced out over a length of 1in. Coil L2 is three turns of the same wire at the 'hot' end of L1. The aerial winding, L3, is two turns of the same gauge wire wound at the remote or 'cold' end of L1 (see Fig. 4). All the coils should be given a coating of cement after trial to ensure that the turns do not slip. The wire for these coils should be free from kinks. The coil should be provided with mounting brackets as shown and the entire assembly should be quite rigid. If the intending constructor desires to have C2 of the semi-variable type (as in the original) then, C2 can be made part of the coil assembly as shown.

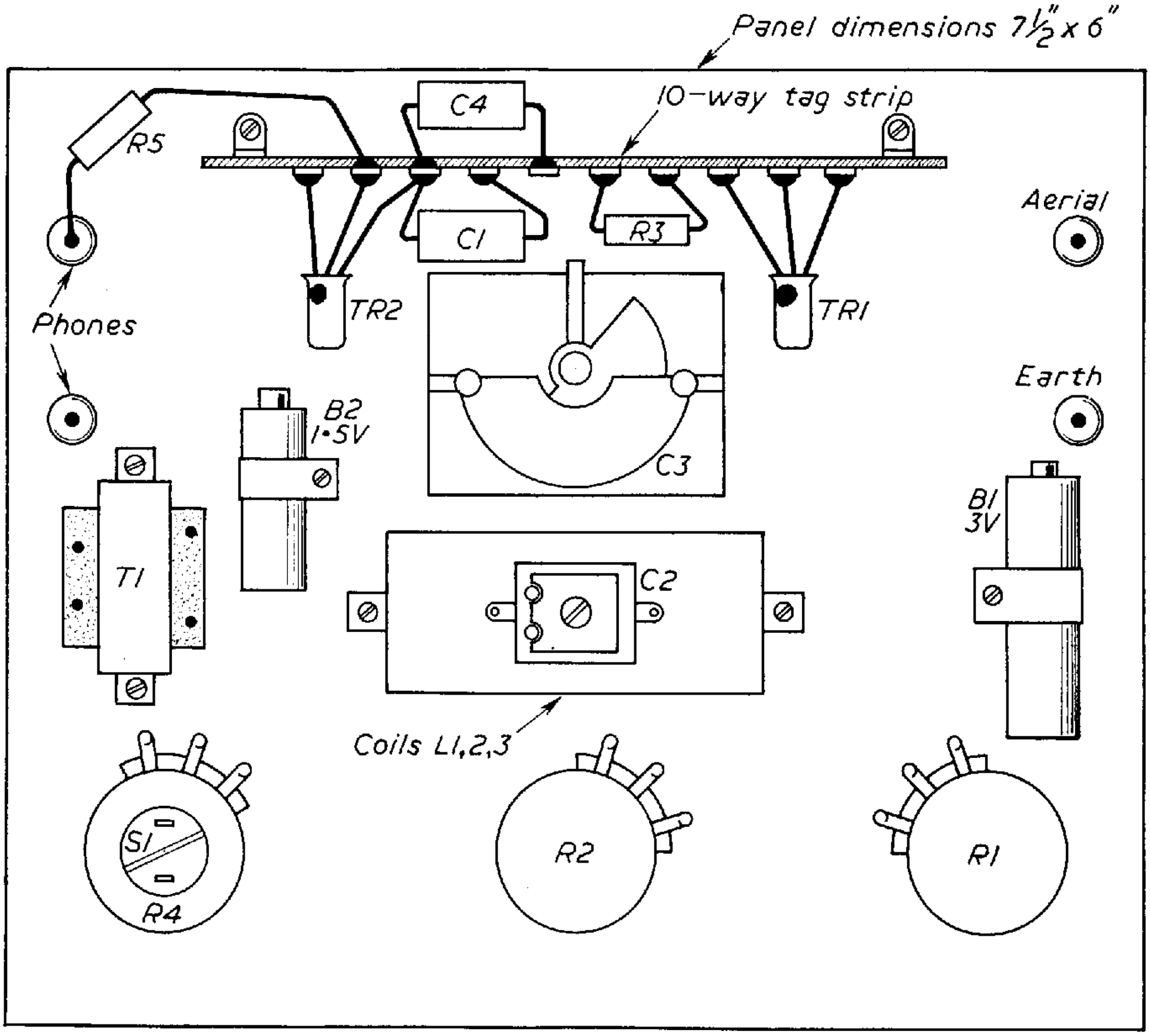


Fig. 2—Layout of the parts.

Coupling Transformer

The interstage transformer T1 is of the ordinary intervalve type connected so that its primary (low resistance winding) is feeding into the base circuit of

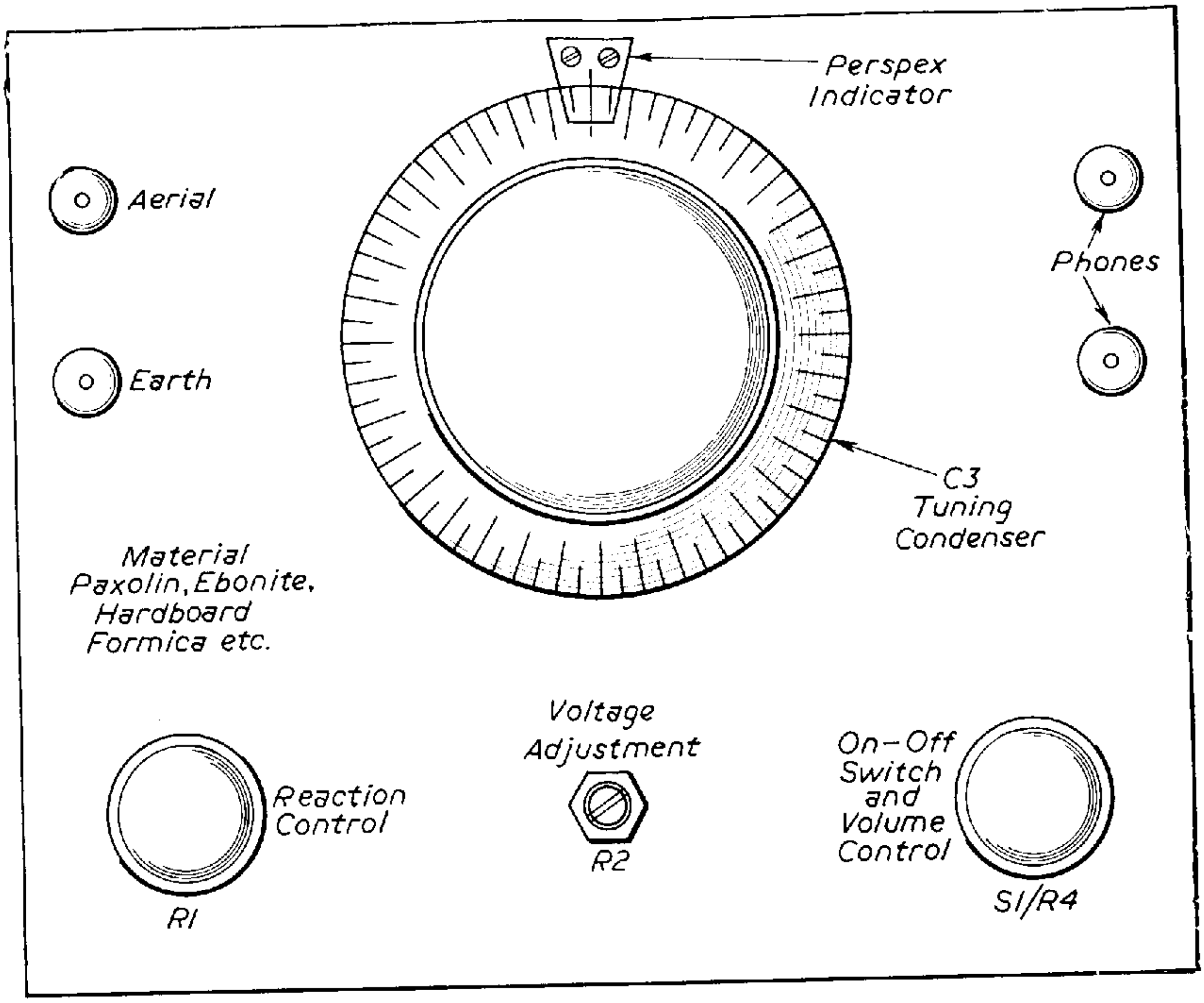


Fig. 3—Front panel.

the OC72. This arrangement gives approximately correct impedance matching.

The sensitivity control is R1, and since it has to be adjusted for practically every station it is best to use a component of the wire-wound type which will give much better wear and service than a carbon type. Capacitor C1, which controls the quench frequency, should be of known good quality with high insulation. The value of C1 is given as 0·01μF. This may have to be altered to suit different sets.

Wiring

Having mounted all the components on the rear of the front panel, wiring may be commenced. The wiring for the coil and inter-connections for the detector stage should be of the heavy, stout type. Loose or wandering connections should be avoided. Each joint should be carefully soldered using a clean, hot iron in conjunction with a

COMPONENTS LIST

Resistors:

R1	1kΩ	wire-wound potentiometer
R2	20kΩ	carbon potentiometer, pre-set type
R3	1kΩ	½W carbon
R4	20kΩ	carbon potentiometer with s.p.s.t. switch (S1)
R5	10kΩ	½W carbon

Capacitors:

C1	0·01μF	paper
C2	20pF	trimmer
C3	15pF	variable tuner
C4	0·004μF	paper

Transformer:

T1 Interstage a.f. transformer

Transistors:

Tr1	SB344
Tr2	OC72

Batteries:

B1	3V	dry battery
B2	1·5V	dry battery (cell)

resin-cored solder. Normal hook-up wire may be used for the audio amplifier section.

The transistors should be wired in last of all, using a heat shunt on each connecting wire when the soldering iron is applied. This will avoid damage to the transistors. The batteries should not be connected until all connections and interwiring has been very carefully checked to avoid the possibility of mistakes. Having made sure that all is in order, the earphones should be connected to the set and the batteries connected with the set switched off.

The set can now be switched on, whereupon a hissing sound will be heard in the 'phones indicating that the detector is operating properly. A short vertical aerial of approximately 15ft, together with a good earth, should be connected to the set. Signals should now be heard. Potentiometer R2 may now be adjusted for maximum gain consistent with good selectivity and low background noise with a station tuned in. Thereafter, R2 will need little, if any, adjustment.

It will be found that R1 also has an effect on signals, and this control should be used and adjusted in conjunction with the tuning control C3, adjusting R1 as each station is tuned to suit personal requirements. The gain control, R4, may be adjusted to give a comfortable level of volume. In the event of no oscillation, or spasmodic operation over the range of C3, the coil L2 may be adjusted closer to L1 and the capacitor C1 altered in value up to a maximum of 0·1μF.

The coil, L3, may also be adjusted for best sensitivity in a similar manner.

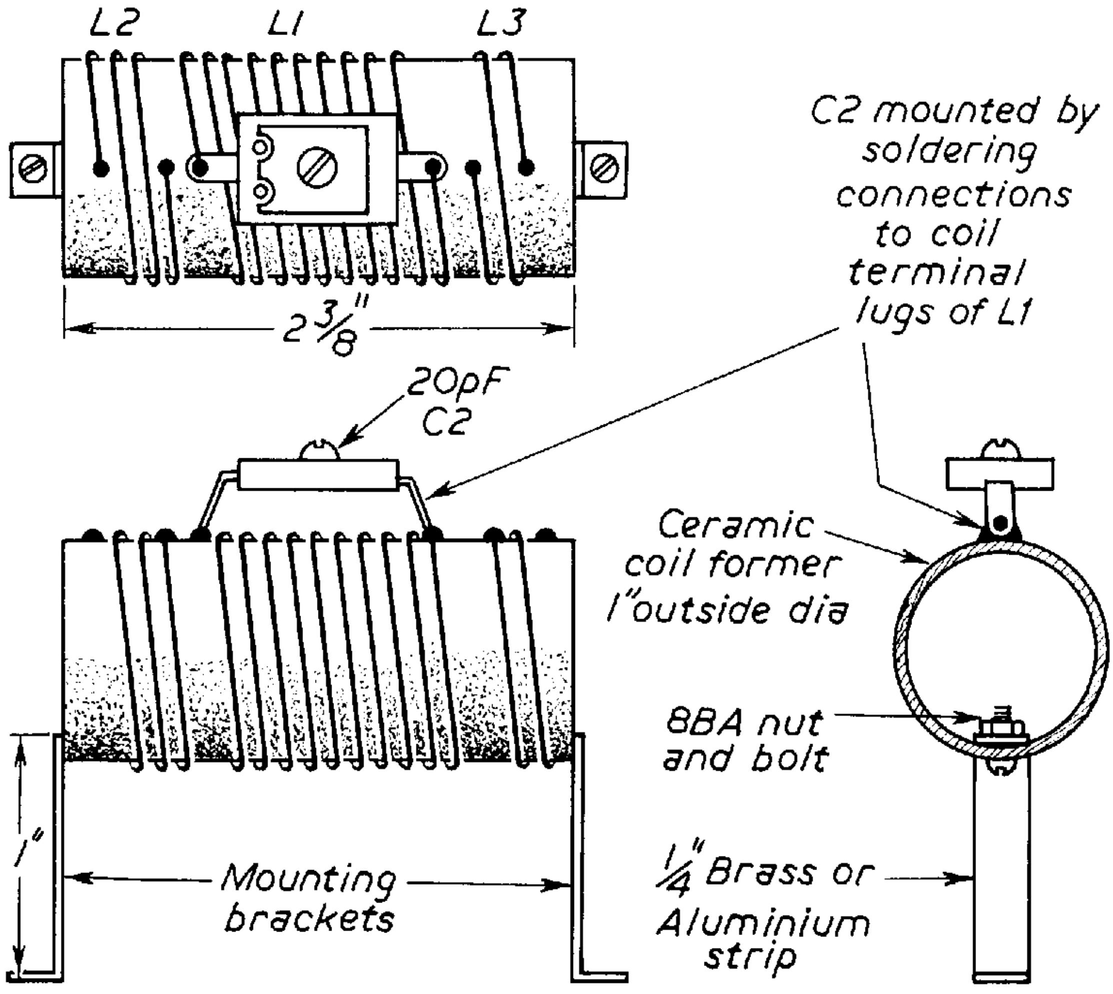


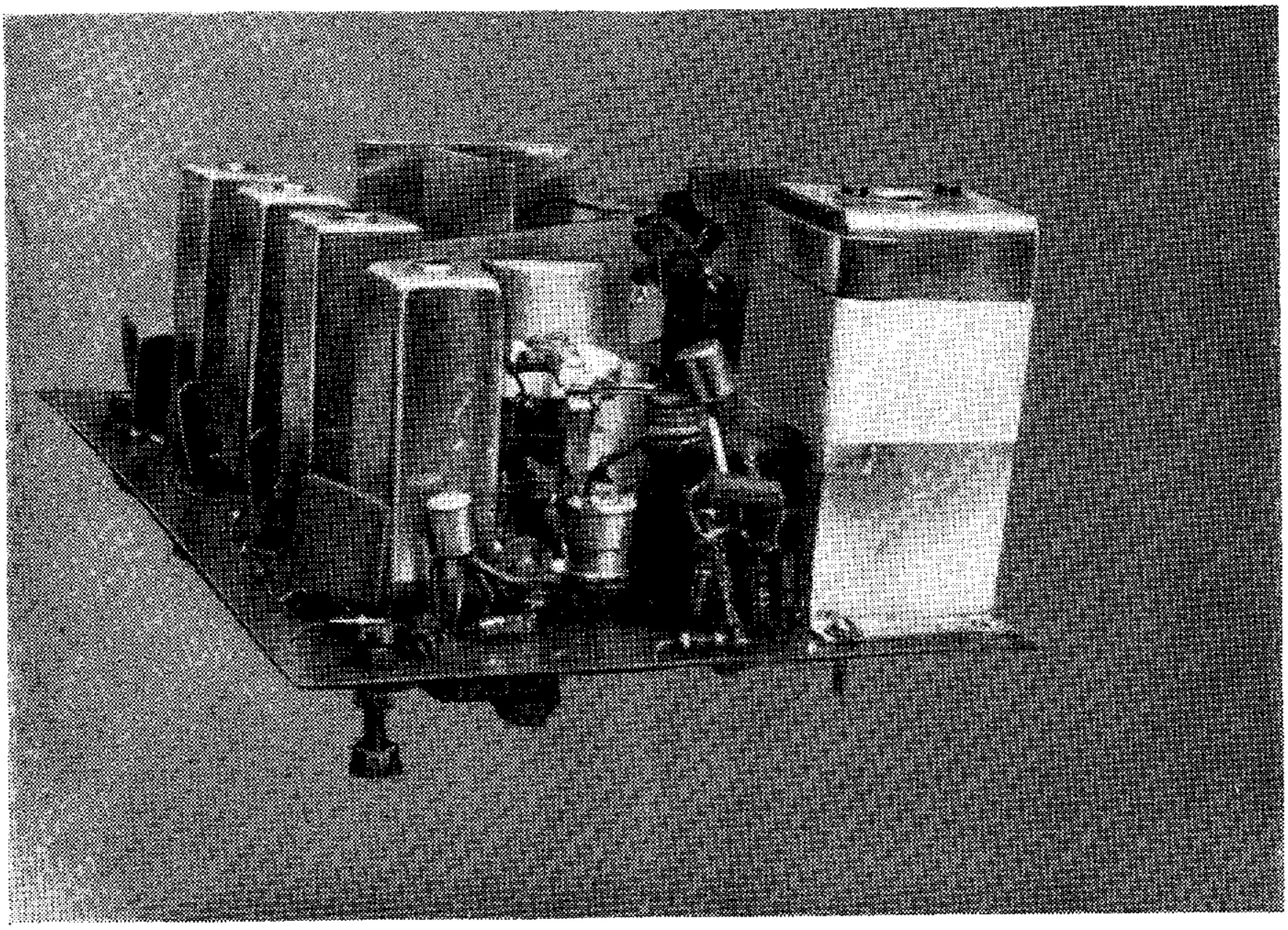
Fig. 4—Coil winding details.

Results

It is, of course, important that one should listen when the 10m band is 'open'. There are times when no signals at all are heard on this band; however, a few hours later signals may be heard very strongly.

V.H.F. SUPERHET

This is a small portable instrument capable of providing good reproduction from the interference-free transmissions on the v.h.f. broadcast band. Printed circuit techniques are employed in the construction and full directions are included for etching the copper-clad board.



OUTPUT of up to 1W is obtained from this receiver, which has a sensitivity of the same order as the usual kind of domestic f.m. mains operated receiver. An aerial signal of 5μV gives a power output of 50mW with the prototype receiver. The normal spread of transistor parameters may cause this to vary appreciably—perhaps from 3 to 20μV—but this will be found quite adequate in practice. Signals of 200mV can be handled, but where such a strong signal is obtainable, a very sketchy aerial can be used, and doubtless will be used, by many constructors. An outside aerial, 20ft high, consisting of a plain dipole, will ensure reception at distances of 100 miles or more from the transmitter.

For reasonable reproduction of bass frequencies, a medium-sized cabinet should be used.

In the prototype receiver, printed circuit construction has been employed. The circuit will be found readily adaptable however for those who wish to use a normal chassis, but the use of copper-clad laminate is recommended for its ease of working and its good electrical properties—no difficulty will be experienced in the etching process.

Figs. 1a and b show the circuit diagram. This, it will be seen, denotes a ‘ line-up ’ of nine transistors ; an r.f. amplifying stage, self-oscillating frequency-changer, three i.f. stages, ratio detector, audio pre-amplifier, driver and push-pull output stages.

The R.F. Stage

The r.f. stage consists of a Mullard OC171, operating in the grounded-base configuration. The real part of the emitter input impedance under the conditions of the circuit, is about 120Ω. The aerial is therefore connected direct to the emitter through the usual coaxial cable of nominal impedance 80Ω. This provides a very reasonable match. If, however, a length of wire is used for portable operation, best results are obtained by plugging a 42in. length into the centre connection of the coaxial input socket. It will be remembered that a single 33in. length will present an impedance of about 40Ω to the emitter, and the extra length is required for a better match.

The input is of course not aperiodic, as might be supposed : the input tuned circuit is in fact the aerial. As long as its Q is about 12 or less, the sensitivity drop at the edges of the v.h.f. band will be less than 6dB. The aerial should therefore ideally consist of a dipole using copper or aluminium tubing of ½in. diameter. However, picture-rail aerial consisting of two 33in. lengths of 14s.w.g. copper wire, has been used and good reception of the 'local' station (56 miles away) obtained.

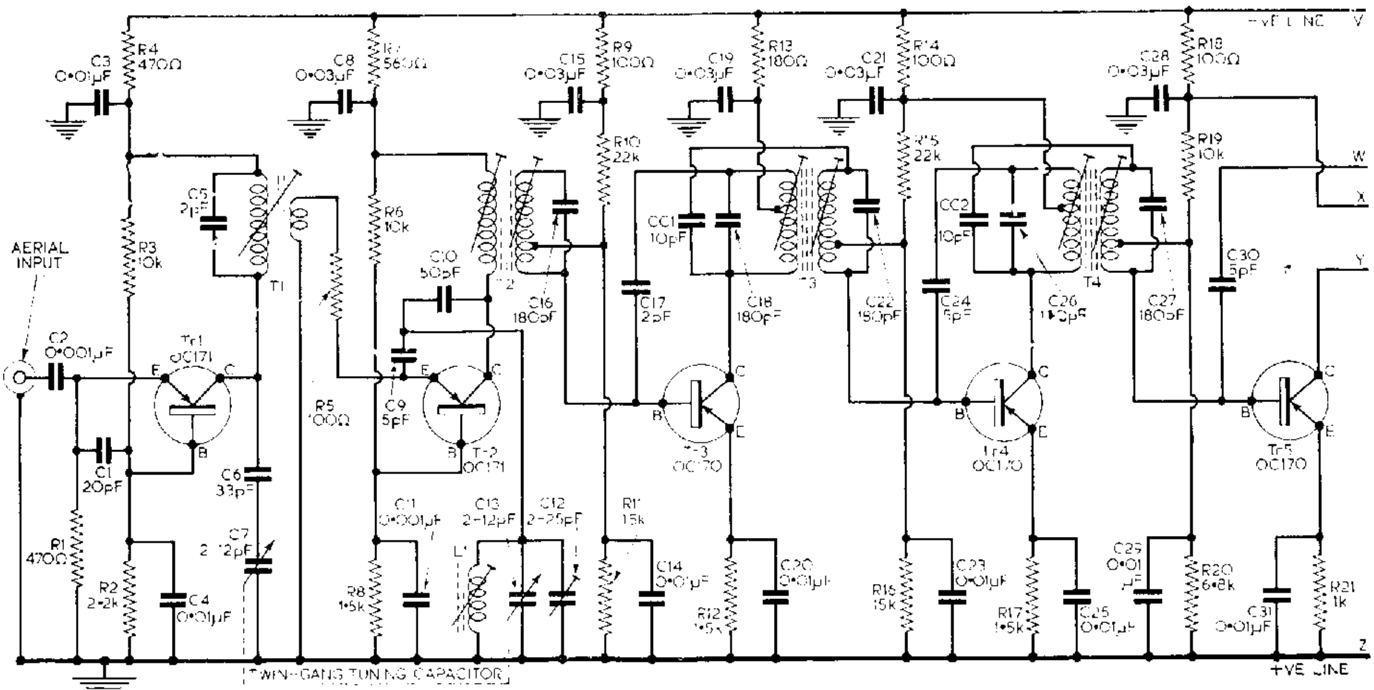
The r.f. OC171 operates at a collector current of about 1·4mA. A higher current gives negligible increase of gain and a noticeable rise in noise-level. A capacitor connected between emitter and base, of value 20pF, may require some comment. The purpose of this is to bring the collector feedback current more into phase with the aerial current, and results in a measure of positive feedback, increasing r.f. gain by 3 to 4dB. It may be possible to increase this capacitor to a value of 25pF, but in the prototype receiver such an increase caused the r.f. stage to oscillate when the collector circuit was tuned to 95Mc/s or higher frequency. By the same token, with certain transistors, it may be necessary to reduce its value to 15pF or even 10pF.

The collector circuit is tuned partly by a fixed capacitance of negative temperature coefficient and partly by a variable capacitor in series with another capacitor of negative temperature coefficient. The collector transformer is so designed that the secondary winding matches the input impedance of the frequency-changer transistor.

The Frequency-Changer

The frequency-changer, another OC171, is also operated in the grounded-base configuration, current from the r.f.

Fig. 1a—The input and i.f. stages of the circuit.



stage being introduced by including the secondary of the inter-stage transformer in the emitter circuit. As this is a self-oscillating frequency-changer, and feed-back from the collector is arranged by capacitive coupling, it is necessary to include a resistor of about 100Ω in the emitter circuit also. This causes some reduction in the signal injected, but the effect is small. The oscillating circuit is tuned partly by a pre-set capacitor, and partly by a variable capacitor ganged with the r.f. inter-stage tuning capacitor. Both are in series with a fixed capacitor of negative temperature coefficient which also does duty as the fixed capacitor of the i.f. transformer in the collector circuit.

The use of negative temperature coefficient capacitors in the r.f. and f.c. circuits is not—as with valve operated equipment—to correct for warming-up drift. In the transistor receiver their function is to correct for changes in ambient temperature, and conditions are much less critical. If the user does not object to retuning as the room temperature changes, silver mica capacitors can be used instead.

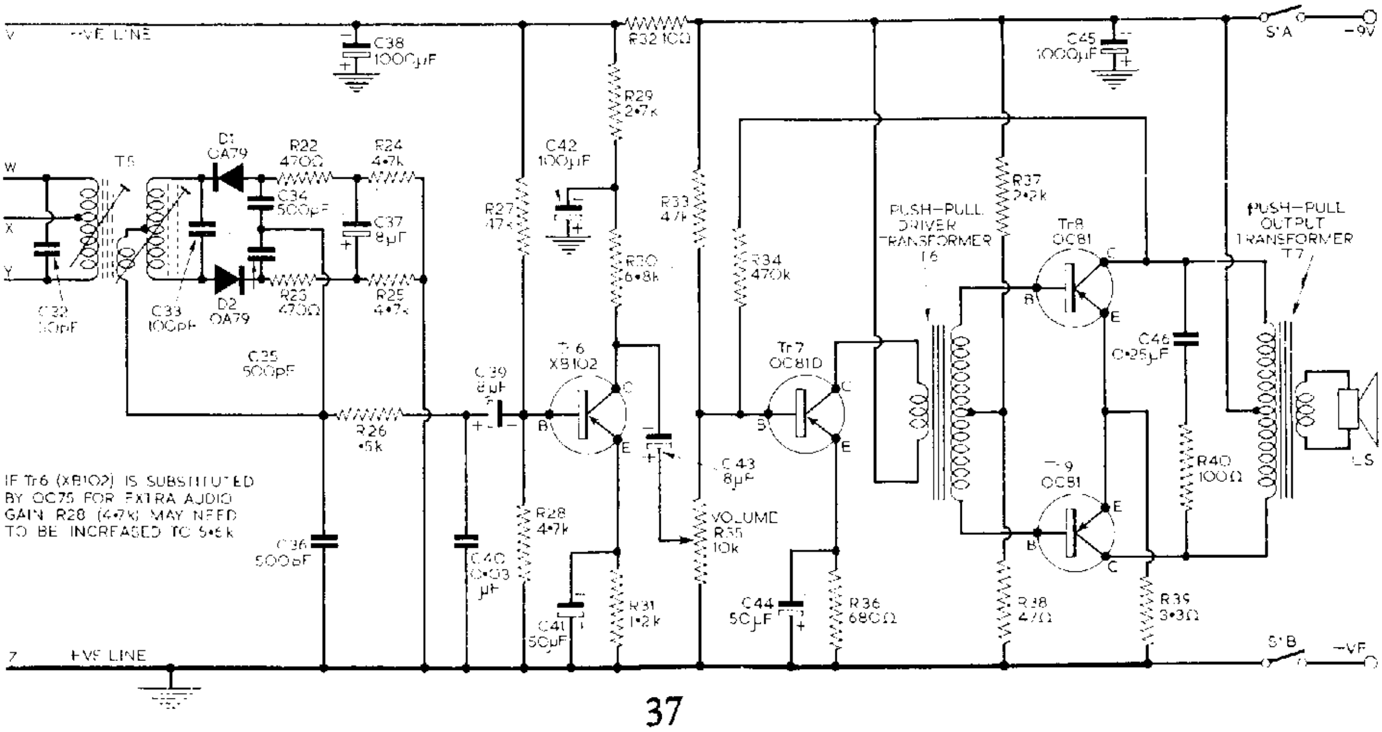
The Intermediate-Frequency Amplifier

It was realised that many constructors would be unwilling to undertake the construction of a receiver in which the setting-up and alignment would require a valve voltmeter or oscilloscope. In this circuit, adjustable coupling has been avoided wherever possible, and the i.f. transformers have been arranged for fixed capacitive coupling between primary and secondary, with non-critical spacing between windings. The only variable coupling is in the collector circuit of the last i.f. stage, where a simple drill enables the precise conditions to be reached, using a meter, or ‘ near-enough ’ conditions by ear.

Mullard transistors, type OC170, are employed in the i.f. stages. Two pairs of coupled circuits are used between the first and second i.f. stages and between the second and third. Coupling is ‘ critical ’, and the dynamic impedance of primary and secondary have been calculated to give the bandwidth needed. For exact bandwidth the transformers should be tuned by 160pF capacitors ; but 180pF capacitors are here specified because the inevitable slight inaccuracies in practical alignment, result in a very slightly ‘ stagger-tuned ’ amplifier, which still has the correct bandwidth.

The last i.f. stage, which drives the ratio detector, requires tighter coupling than critical, and coupling of approximately 1·5 critical is used. The intermediate frequency is 10·7Mc/s nominally, though the constructor may prefer to vary this a little one way or the

Fig. 1b—The detector and audio stages of the circuit.



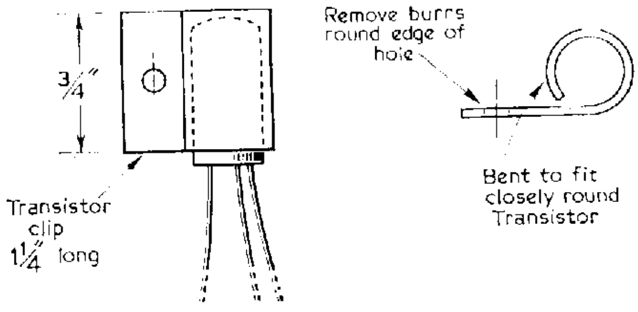


Fig. 2—The construction of the clips for the output transistors—these clips are used to fasten the transistors to their heat sinks (which are described in the text).

other to avoid a powerful local short-wave transmitter.

The Ratio Detector

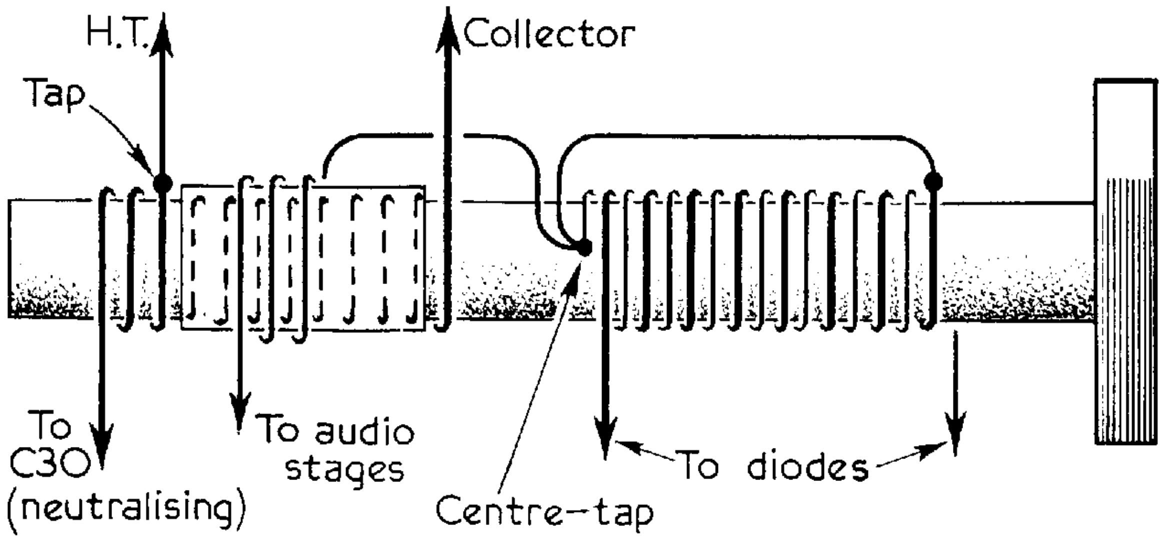
The use of a ratio detector was decided upon because of its simplicity and its ability to deal with small signals effectively. Because of this latter consideration a.g.c. has not been provided and its absence has not been acutely felt. The ratio detector is of conventional design. Diodes supplied in a matched pair (2-OA79) avoid the need for adjustable resistances in series. Amplitude limiting is improved by the stabilisation of only about 90% of the developed voltage, and this is arrived at by the inclusion of small fixed resistors in series with the diodes. The normal de-emphasis (in this case, 45μsec) is provided.

Very thorough decoupling has been found essential in the audio section of the receiver. This is hardly surprising, since approximately 70dB audio gain is obtained. Layout however is not critical. The inevitable increase in battery resistance during discharge causes no instability, and as much as 300Ω has been put in series with the battery without causing trouble.

Neutralisation

As the transistor may be regarded for some purposes as a triode with the grid operated in the positive region, it will be understood that at the intermediate frequency concerned, 10·7Mc/s, neutralisation of the collector-base feedback will be needed. By suitable design of the i.f. transformers, fixed non-critical capacitive neutralisation can be achieved. In fact, this circuit possesses very slight over-neutralisation, and with certain transistors the 5pF neutralising capacitors may need reduction to 3·3pF if i.f. instability is experienced. If desired, the addition of small resistors (about 47Ω) in series with the neutralising capacitors will improve stability and gain. This process, known as unilateralisation, enables wanted and unwanted feedback to cancel each other out exactly in magnitude and phase.

Fig. 3—The discriminator transformer windings (T5 in the circuit). The method of winding the bifilar secondary has been shown by using thick and thin lines to represent the two halves, but, of course, the same gauge of wire is used for both.



However, this is a refinement found not to be necessary in practice—although the purist may prefer to include it in his receiver.

The Audio Amplifier

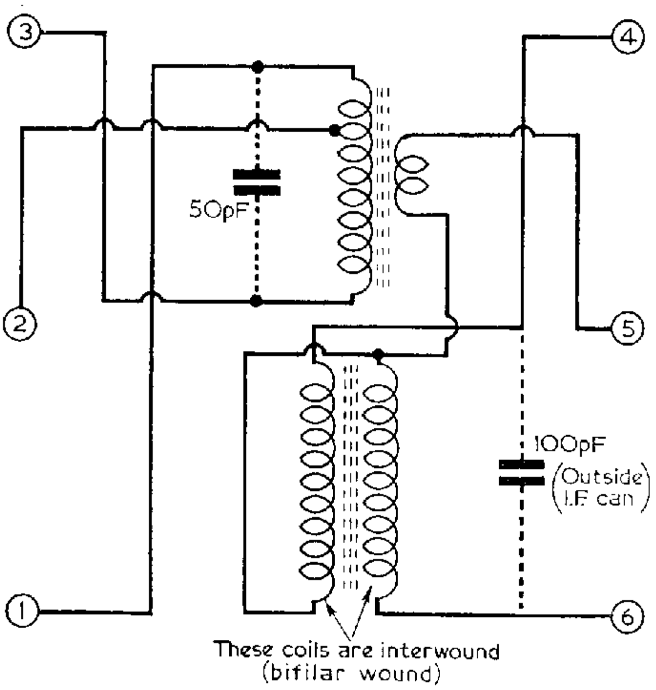
No claim is made that the audio amplifier is original. In fact it is almost identical with the Mullard 1W amplifier, described in *Reference Manual of Transistor Circuits* (first edition, 1960). There seemed to be no point in gilding the lily. However, with the transformers specified, crossover distortion at low signal levels was more noticeable than might be desired, and a slight increase in output quiescent current has been arranged to overcome this.

With the transformers specified, leakage inductance is low enough for quite a large amount of negative feedback to be applied if desired. Here, however, a moderate amount only is used, approximately 6dB.

Overall Gain

Moderate amounts of gain per stage have been designed for, in the interest of stability, except in the r.f. stage where the maximum feasible has been required. The r.f. stage gives about 15dB, the frequency changer 10dB, the i.f. stages 25dB each, and the audio amplifier about 70dB. The total is thus 170dB, from which has to be deducted approximately 8dB per stage (as far as the detector) as transformer insertion loss, and about 20dB for loss in the detector stage. This, with 6dB negative feedback in the audio section, gives a total of approximately 112dB overall gain.

Fig. 4—The connections of the windings of the discriminator transformer—the numbers refer to the coil base connections given in Fig. 6.



COIL WINDING DATA

All formers are Bakelite 0·27in. diameter. Screen cans required for transformers T2, T3, T4 and T5 are $\frac{17}{32}$in. × $\frac{17}{32}$in. × $2\frac{3}{8}$in. All dust cores are VHF (purple-coded) type.

L1 $3\frac{3}{4}$ turns 18s.w.g. bare, spaced 0·3in. outside length. Unscreened; one core required.

T1 Primary—6 turns 18s.w.g. bare, spaced 0·6in. outside length.
Secondary—$1\frac{1}{2}$ turns p.v.c.-covered connecting wire interleaved each side of last (H.T.) end of primary; one core is required.

All the following coils are wound in the same direction. The primary and secondary would thus form a winding of continuous direction but for the interruption at the ' middle '.

T2 Primary—28 turns 28s.w.g. enamelled, close-wound.
Secondary—12 turns 24s.w.g. enamelled, close-wound.
Spacing: $\frac{1}{4}$in. between winding ends.
(*Note:* The secondary is tapped 3 turns from the earth end of the winding; this tapping is the base connection to V3.) Two cores are required.

T3 } T4 } Primary—12 turns 24s.w.g. enamelled, close-wound, tapped 3 turns from ' inner ' end.
Secondary—12 turns 24s.w.g. enamelled, close-wound, tapped 9 turns from ' inner ' end of winding.
Spacing: 0·4in. between ends of winding.
Two cores are required for each transformer.

T5 Primary—28 turns 28s.w.g. enamelled, close-wound, tapped 7 turns from ' outer ' end.
Secondary—8+8 turns 24s.w.g., close-wound, bifilar; Spacing: 0·3in. between ends of winding.
Tertiary—$9\frac{1}{2}$ turns 28s.w.g. enamelled, close-wound, wound over 10 turns of primary nearest the tap. One turn Sellotape as insulation.
Three cores are required.

Power Supplies

A 9V supply is required. The DT9 is a convenient battery, and will last a reasonable time—about a month or six weeks if the receiver is used for about 4 hours daily. The receiver gives good output even when the battery voltage has dropped to 6, and continues to provide a useful signal, at much reduced output quality, down to a battery voltage of 4. The oscillator section continues to operate down to 2·6V with the particular transistor used, though, of course, overall receiver gain at this voltage is negligible.

Heat Sinks

Before fixing, the driver and output transistor heat sinks should be prepared as follows. Three pieces of sheet aluminium 16s.w.g., measuring 3in.× $2\frac{1}{2}$in. are sawn off a flat sheet. Snipping with tin snips causes curvatures which must be avoided. A $\frac{1}{4}$in. flange is turned over on one short side. Then a flat is filed, very lightly, on the middle of the sheet. It is most important to see that this flat is really accurate. An $\frac{1}{8}$in. hole is now drilled in the flat portion and burrs carefully removed. Three pieces of 22s.w.g. aluminium, $\frac{3}{4}$in.× $1\frac{1}{4}$in., are sawn out of a flat sheet and bent round over the shank of a $\frac{5}{32}$in. drill. The final curvature has to be $\frac{3}{16}$in. to accommodate the OC81 transistors, and the natural springiness of soft aluminium sheet, with a very little force, will enable the transistors to be inserted firmly and closed into these cooling clips. Fig. 2 shows the arrangement. The assembly should be inspected against a strong light to ensure that no gaps occur between the transistors and the cooling clip. If

Fig. 5—The mounting lugs of the transformers are cut as shown to enable them to be passed over the fixing bolts (see text).

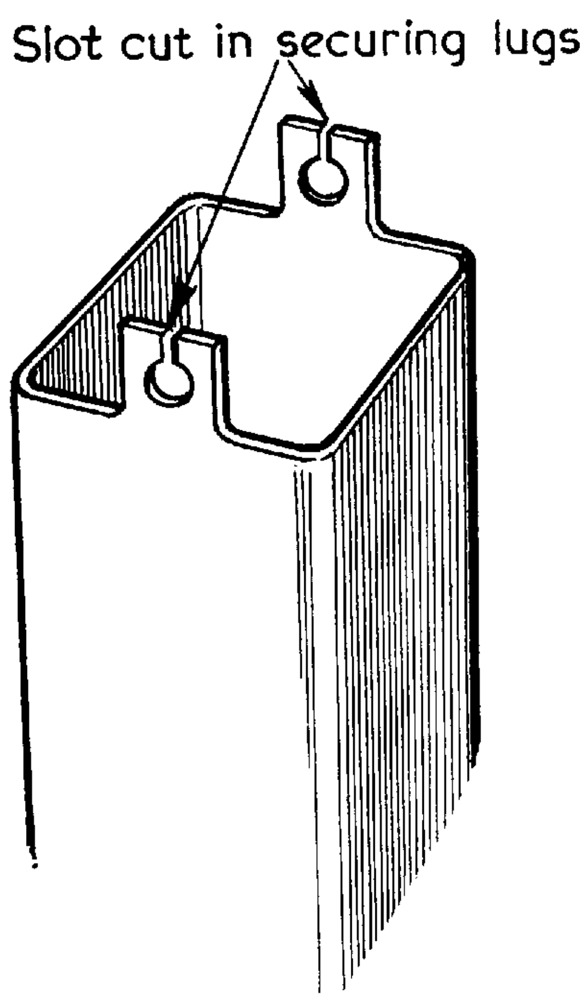
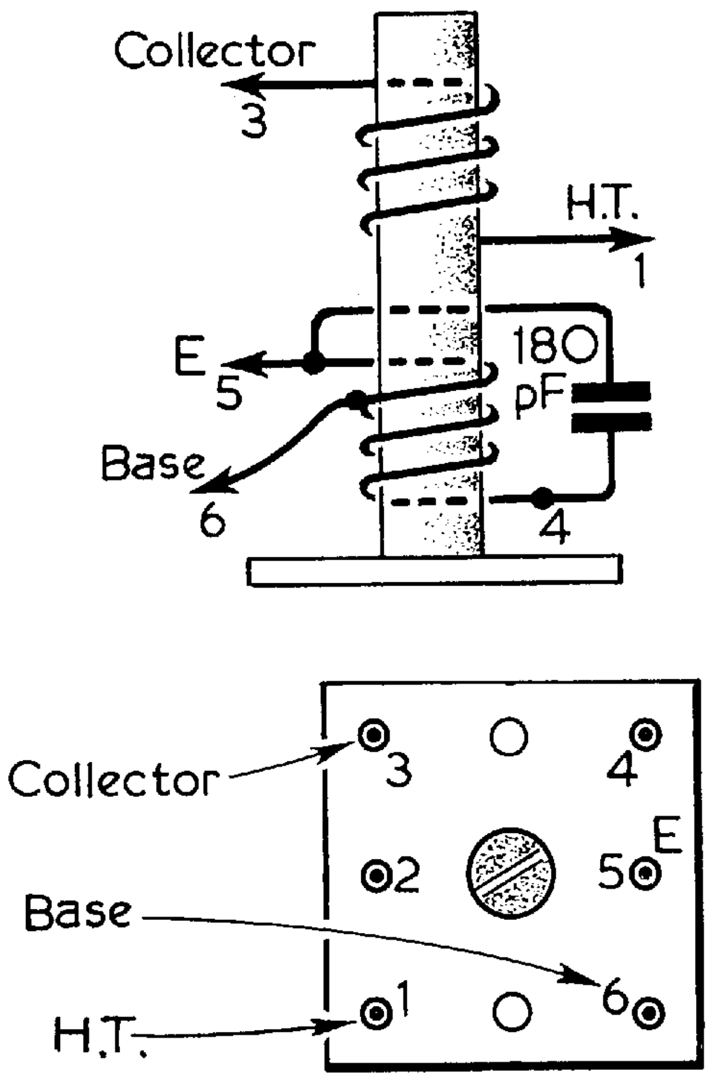


Fig. 6—The i.f. transformer windings and the numbering of the base connections.



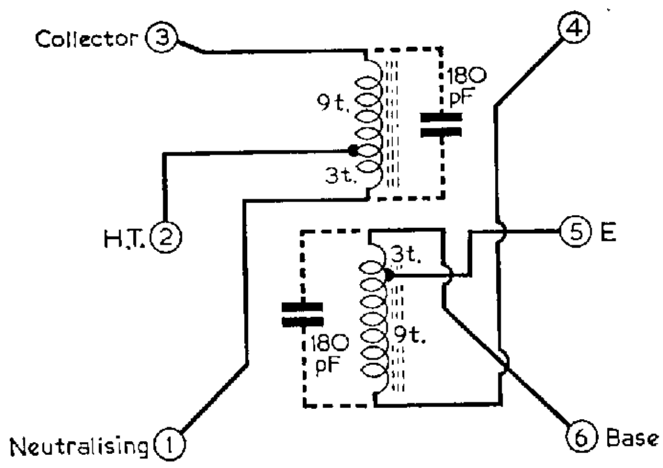


Fig. 7—The connections of the i.f. transformer windings.

small gaps appear, silicone grease—a smear only—may be used to assist dissipation of heat, but gaps should be avoided even if it means making six clips to get three good ones. Before assembly, the tuning capacitor should be inspected. If the bearings carry an appreciable amount of grease it should be wiped away, and if at all slack the bearings should be tightened up. This precaution is mentioned here because in the prototype receiver some considerable trouble was found in obtaining electrical contact of the required effectiveness; the capacitor tuned very noisily through stations. This instability was removed partly by tightening up, partly by soldering to a side pillar of the capacitor an additional phosphor-bronze leaf-spring contact which was arranged to press heavily on the spindle between r.f. and f.c. sections. This spring was connected to chassis through a short length of copper braid. The capacitor had seen previous service, and it is not expected that a new component would cause trouble.

The R.F. and F.C. Stages

(Refer to the data on coil winding given on page 39.)

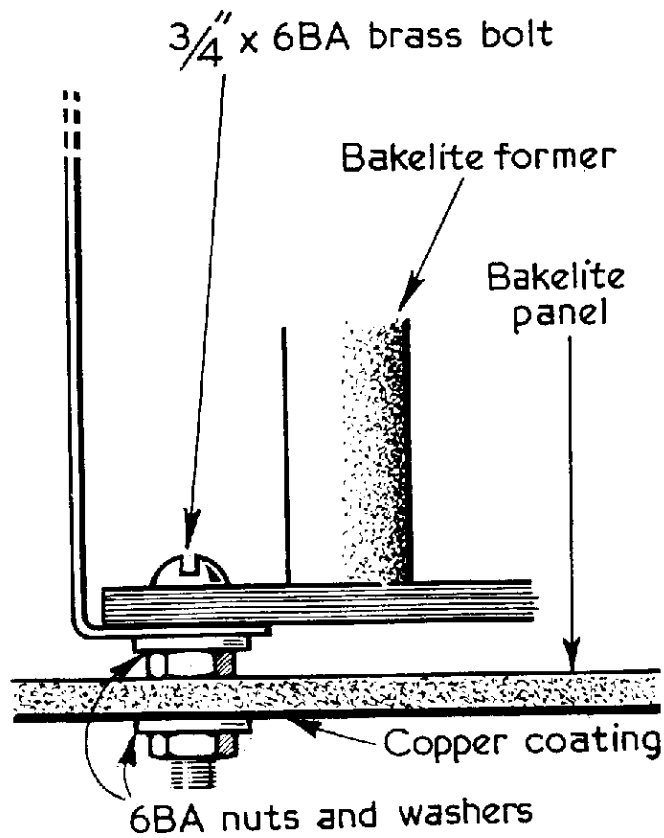
The coils for r.f. collector and oscillator are wound on 0·3in. Bakelite formers, and the direction of winding is immaterial. The wire is 18s.w.g. bare and, preferably silver plated, for the collector and oscillator coils; these coils are first wound on a ¼in. drill shank and then slipped, with some force on to the former. The f.c. emitter winding, of 22s.w.g. copper wire, in thin sleeving (or p.v.c. covered connecting wire) is added between the 'earthy' turns of the r.f. collector winding. The spacing is adjusted to the specified value, and then the whole windings are covered with contact adhesive (clear) and allowed to dry thoroughly. The properties of this adhesive have not been measured but appear to be not markedly inferior to polystyrene cement, and the job is much more reliable than when polystyrene cement is used with thick wire.

The I.F. and Discriminator Transformers

(See Figs. 3, 4, 5, 6 and 7.)

The i.f. transformers could be constructed in the normal way, and for mounting, the lugs of the can slipped through slots in the printed circuit board ready for bolting down. However, cutting neat slots in the laminated board is not a simple matter, and in the prototype the following method of

Fig. 8—The method of spacing the i.f. coils from the chassis—see also Fig. 5.



canning the i.f. transformers was adopted.

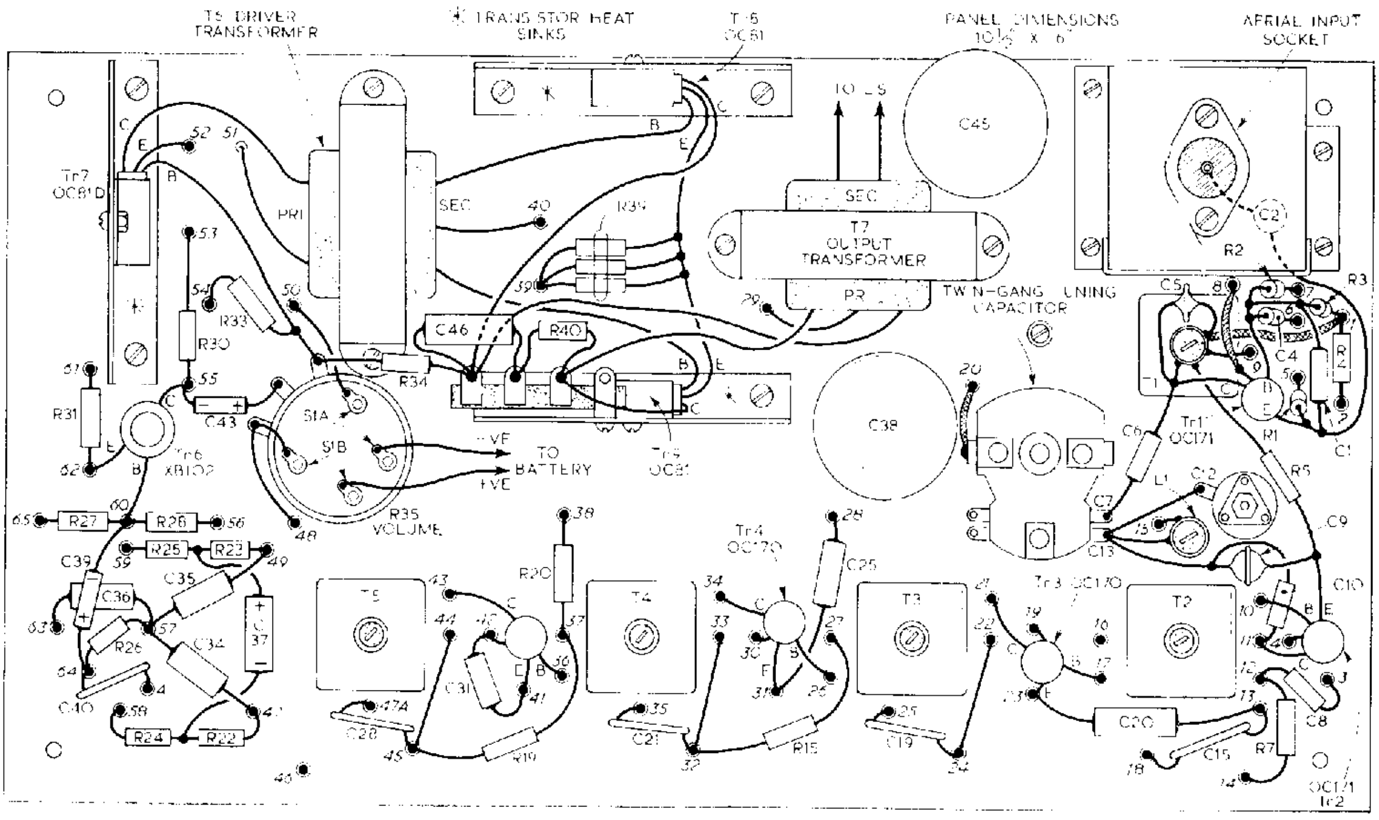
When the transformers have been wound, all cement is thoroughly dry and all exposed metallic surfaces are covered with Sellotape, the $\frac{3}{4}$in. 6B.A. bolts are fixed through the fixing holes, from the 'inside' and are tightened up. The can is then slipped over the assembly. The lugs are then slipped through so that, on bending over, the halves can be worked round the 6B.A. bolts and flattened against the underside of the Bakelite former. A brass washer is placed over the bent over lugs and then a brass nut is screwed down firmly. Nearly $\frac{1}{2}$in. of bolt will stand proud for insertion through holes in the laminated board, and when these in turn are screwed down, with washer and nut, against the copper surface of the printed circuit board a good electrical earth to the can is achieved.

The Printed Circuit

The receiver is based on a piece of laminated copper-clad plastic measuring approximately $10\frac{1}{2}$in. $\times$ 6in. The copper layer serves not only as a source of conductors but as a metal chassis. The prototype receiver was constructed on a sheet of very ordinary laminated board, but for reliability and good electrical properties the board specified is 'Bakelite' grade DH74. This grade is an epoxy glass fibre laminate and is rather expensive; if cost is a major item, 'Bakelite' grade E60 will be found very efficient, and the cost is about a quarter that of the DH74. It is important that the sheet is mechanically stable—the thickness of the board should not be less than $\frac{1}{16}$in.

The first step is to mark out the position of the components, beginning with the large items such as transformers, heat sinks, tuning capacitor and volume control, and following with the i.f. transformers which are contained in four cans. Marking out can be done with a ball pen, very soft pencil or fine brush and white water-colour or drawing ink. Figs. 9 and 11 show the layout suggested, which includes the necessary conductors marked out. Conductors are shown white, while conducting tags, surrounded by an insulating space are marked by a full spot surrounded by a ring. These latter are used for anchoring component wires

Fig. 9—The above-chassis layout and wiring of the receiver.



which need to be insulated from the copper-clad board.

Layout

The i.f. transformers separate the i.f. transistors, and the r.f. and frequency changer stages are mounted to the right of the tuning capacitor ; there is plenty of room in the layout given. The audio stages begin directly below the ratio detector, and continue across the bottom part of the board.

The marking out of all components, down to the last resistor and capacitor, must be carried out before etching is put in hand. When, by comparison between the marked laminate and the theoretical diagram, it is quite certain that full provision has been made, the preparation of the board can begin. First it must be kept in mind that as little copper as possible is removed, and that the ' earth ' part of the copper is electrically continuous. Sufficient space must of course be left for insulation where needed ; the width of conductors should not be less than $\frac{1}{8}$in. and the anchor tags should be of $\frac{3}{16}$in. diameter, surrounded by an $\frac{1}{8}$in. width of insulation where the copper is etched away.

' Resist ' Solution

A ' resist ' material is now made up by dissolving $\frac{1}{2}$oz of shellac in about 4oz of methylated spirit. This will take some while to dissolve, and is conveniently left overnight to complete the process. If some sealing wax is added at the same time, or a little mahogany spirit dye, the resist solution will be found more visible when applied.

A water-colour brush is used to apply the solution which should be reasonably thick or else it may run where not desired. A steady hand is needed, and some practice is essential ; this may well be carried out on a sheet of glass or paxolin. All parts which are to be conducting must be covered, not only on the conductors but the ' chassis '

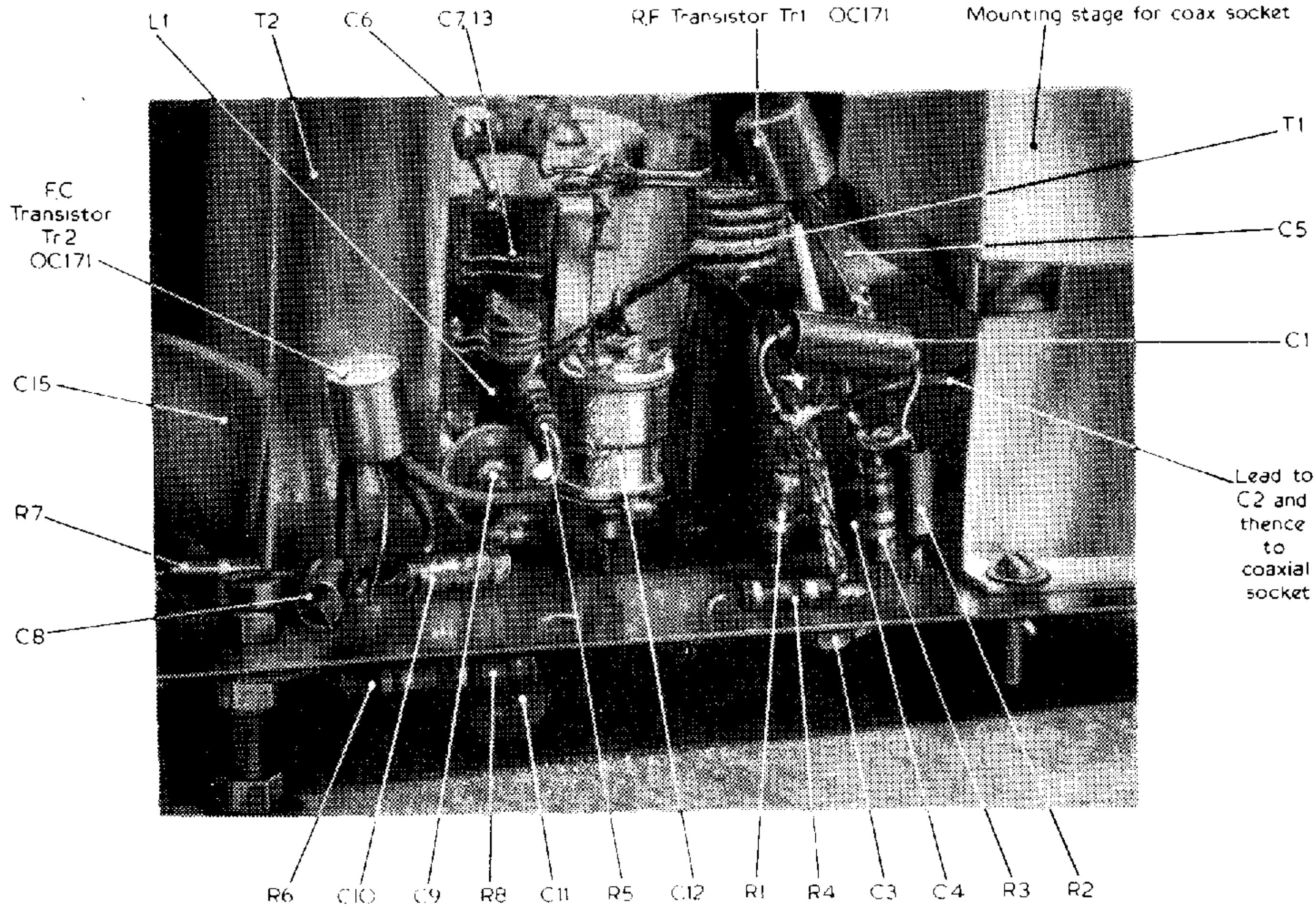


Fig. 10—The layout of the r.f. stage of the receiver—this constitutes the only critical part of the set.

part of the board as well—shown unshaded in Fig. 11. The only parts not covered are those which are to be etched away.

Mistakes can be corrected by a plug of cotton wool damped (not saturated) with methylated spirit ; the plug should be turned frequently so that all traces of the resist are removed from the area concerned. Thorough cleaning is essential and is not easy, so mistakes are best avoided. When it is decided that all is in order, the resist coating is gone over again to thicken it. Finally the prepared board is left overnight to dry.

Etching Solution

A solution of ferric chloride, $FeCl_3$, is made up by dissolving 4oz ferric chloride in 6oz water, adding 1oz concentrated hydrochloric acid HCl (commercial 'spirits of salts' is suitable). This will form a very deep orange clear solution *which is corrosive and must be kept in a well-corked labelled bottle well out of the way of food and out of the reach of children.* For use, the solution is poured into a flat container such as a photographic dish, and the laminated board immersed in it.

Etching will take a little time to accomplish ; about an hour should be allowed but it may take longer, depending on the temperature. When the copper is completely removed, where required, the board should be removed from the solution, washed for a few minutes in running water, and dried with a soft cloth.

The removal of the resist is best effected by soaking the board in methylated spirit for 10–15 minutes, and then rubbing briskly with a plug of cotton wool damped with methylated spirit. Finally, hot water is used with some kitchen scouring powder on a rag ; this will give a bright surface ready for silver-plating if it is now desired to carry out the process. If an electrolytic method is used, only the 'chassis' can be plated, but this is relatively quite effective.

All necessary holes should now be pierced. For holes which carry one wire, a $\frac{1}{32}$in. drill is enough, but where several wires will be anchored at one point, a hole of $\frac{1}{16}$in. diameter will be needed. It is not strictly necessary to

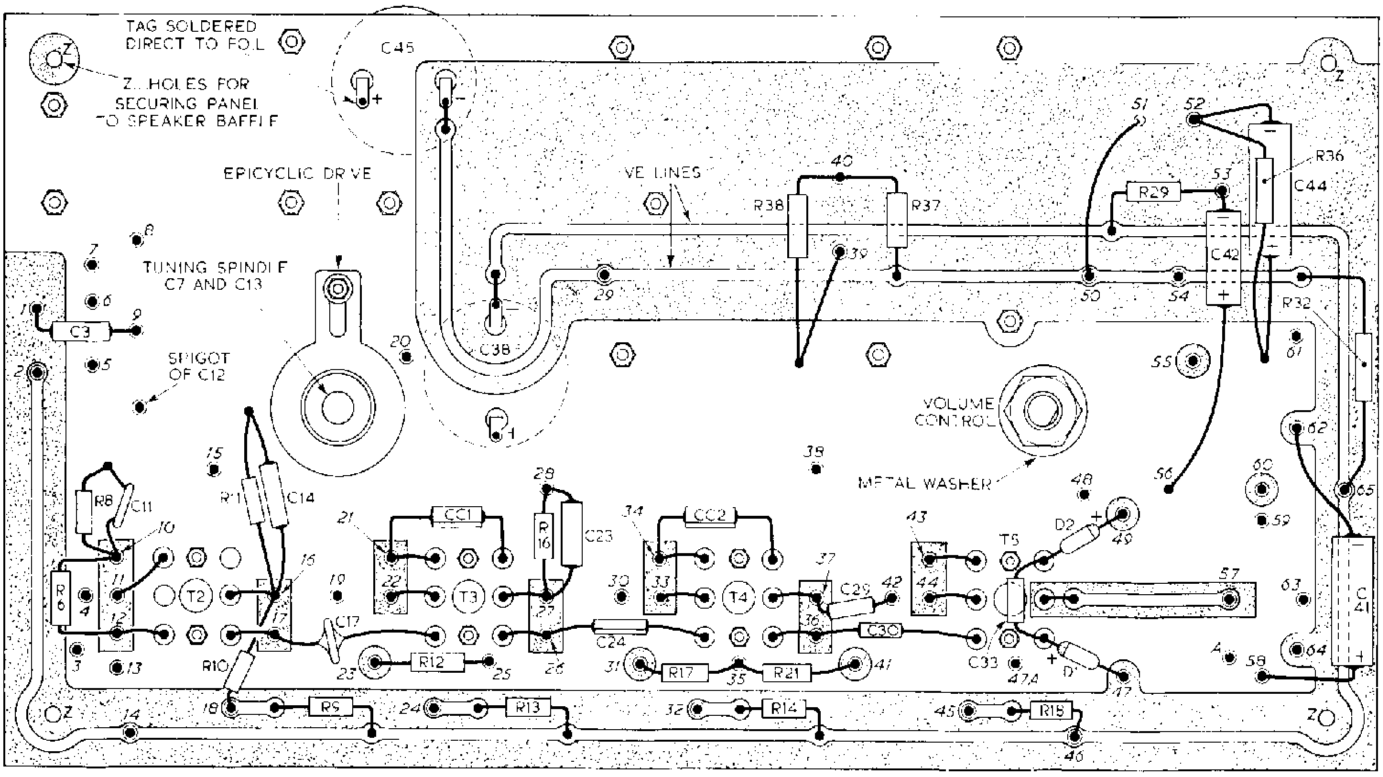


Fig. 11—The under-chassis wiring—this diagram should also be used to mark out the printed wiring before etching ; the copper which remains after etching is shown unshaded.

KEY TO CONNECTIONS
CONNECTIONS THROUGH PANEL ◉ CONNECTIONS DIRECT TO FOIL •
CONNECTIONS SHOWN ◉ ARE ANCHORING POINTS FORMED BY ETCHING AWAY A RING OF COPPER CONNECTIONS TO I.F. TRANSFORMERS ◉

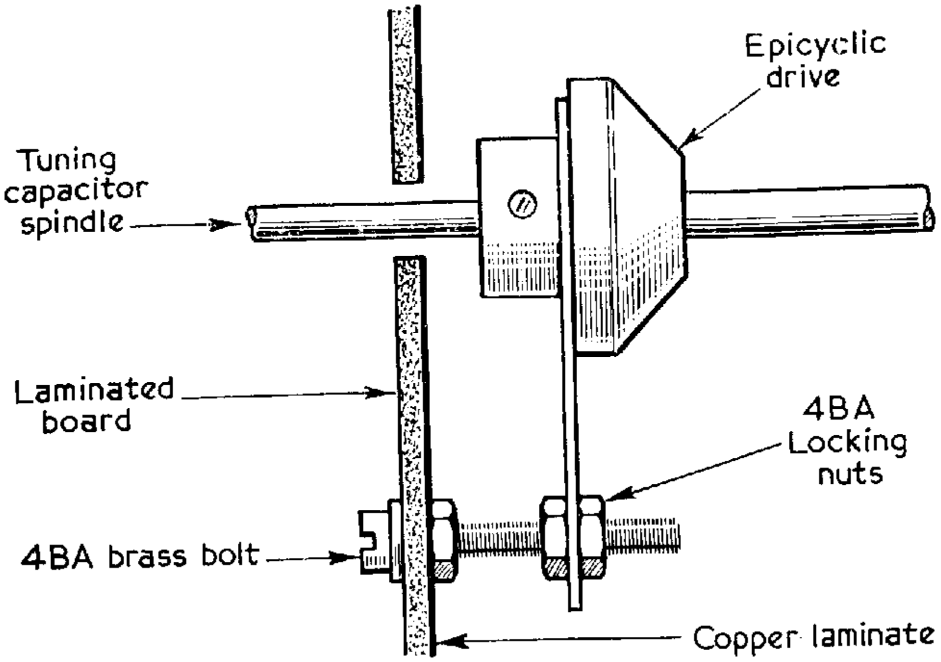


Fig. 12—The mounting of the epicyclic drive for the tuning capacitor.

drill at all points where 'earth' connections have to be made; if a connection is carried through the board a hole will of course be needed.

All the components are now mounted in position, and this is best done direct from the theoretical diagram following the logical layout. When fixing the i.f. transistors, all wires but the 'earth' wire are covered with thin insulating sleeving. The wires are not cut down at all, and this will be found not only convenient for mounting but safe for soldering. Nevertheless a really hot iron should be used, to minimise the time of the soldering operation.

R.F. Stage Layout

In the r.f. stage, it is most important to avoid capacitive coupling between collector and emitter. For this reason, the r.f. stage is a three-dimensional assembly and layout is somewhat critical. Fig. 10, which shows the arrangement of components, should be used as a guide.

The coaxial socket for the aerial is carried on a bracket of bent-up aluminium sheet. Dimensions are given in Fig. 13.

The 'cap' is clipped over the vertical sides of the bracket to shield the aerial connection from the rest of the r.f. assembly, as shown in the photographs.

The Bakelite formers for r.f. and f.c. stages may readily be affixed to the laminated board with the impact adhesive used according to the manufacturers' instructions and remembering that once contact has been made very little further drying can take place. It is therefore essential to ensure that complete drying has taken place before putting the former in contact with the laminated board. After preparing the surface, at least ten minutes should be allowed for drying in a room at 68°F.

The Tuning Capacitor

The specified capacitor is mounted, by two screws, at right angles to the printed circuit board, and is operated by means of an epicyclic drive. The lug of the epicyclic is clamped to the board by means of a 4B.A. brass bolt passed through the board (see Fig. 12).

In the prototype receiver, a circle of Perspex was cut, and a hole drilled in the centre to make a good force fit over a standard knob, to fashion a tuning knob of attractive appearance. A pointer fixed to the epicyclic was arranged to move in front of a scale cut out of paper and stuck to the front of the cabinet.

Mounting of the Loudspeaker

If the loudspeaker is mounted on the same panel of the cabinet as the printed circuit, microphony may be experienced

COMPONENTS LIST

Resistors (all resistors ¼W and 10%, except where otherwise stated):

R1	470Ω	R21	1kΩ
R2	2·2kΩ	R22	470Ω
R3	10kΩ	R23	470Ω
R4	470Ω	R24	4·7kΩ
R5	100Ω	R25	4·7kΩ
R6	10kΩ	R26	1·5kΩ
R7	560Ω	R27	47kΩ
R8	1·5kΩ	R28	4·7kΩ
R9	100Ω	R29	2·7kΩ
R10	22kΩ	R30	6·8kΩ
R11	15kΩ	R31	1·2kΩ
R12	1·5kΩ	R32	10Ω
R13	180Ω	R33	47kΩ
R14	100Ω	R34	470kΩ
R15	22kΩ	R35	(see below)
R16	15kΩ	R36	680Ω
R17	1·5kΩ	R37	2·2kΩ 5%
R18	100Ω	R38	47Ω 5%
R19	10kΩ	R39	3·3Ω(3×10Ω10%)
R20	6·8kΩ	R40	100Ω
R35	10kΩ	potentiometer, log or semi-log, with d.p.d.t. switch	

Capacitors:

C1	20pF	mica or ceramic
C2	0·001µF	ceramic
C3	0·01µF	ceramic
C4	0·01µF	ceramic
C5	2pF	ceramic (N750K)
C6	33pF	mica or ceramic
C7	(see below)	
C8	0·03µF	ceramic
C9	5pF	mica or ceramic
C10	50pF	ceramic (N750K)
C11	0·001µF	ceramic
C12	2–25pF	air trimmer, concentric type
C13	(see below)	
C14	0·01µF	ceramic
C15	0·03µF	ceramic
C16	180pF	silver mica, 5%
C17	2pF	mica or ceramic
C18	180pF	silva mica, 5%
C19	0·03µF	ceramic
C20	0·01µF	ceramic
C21	0·03µF	ceramic
C22	180pF	silver mica, 5%
C23	0·01µF	ceramic
C24	5pF	mica or ceramic
C25	0·01µF	ceramic
C26	180pF	silver mica, 5%
C27	180pF	silver mica, 5%
C28	0·03µF	ceramic
C29	0·01µF	ceramic
C30	5pF	mica or ceramic
C31	0·01µF	ceramic
C32	50pF	mica or ceramic
C33	100pF	mica or ceramic
C34	500pF	mica or ceramic
C35	500pF	mica or ceramic
C36	500pF	mica or ceramic
C37	8µF	electrolytic 6V
C38	1,000µF	electrolytic 9V
C39	8µF	electrolytic 6V
C40	0·03µF	ceramic
C41	50µF	electrolytic 6V
C42	100µF	electrolytic 9V
C43	8µF	electrolytic 6V
C44	50µF	electrolytic 9V
C45	1,000µF	electrolytic 9V
C46	0·25µF	paper or plastic tubular
CC1	10pF	silver mica, 10%
CC2	10pF	silver mica, 10%
C7, C13	12+12pF	twin-gang tuner (Jackson Bros. type C808, 5103)

Transistors:

Tr1	OC171	Tr6	XB102
Tr2	OC171	Tr7	OC81D
Tr3	OC170	Tr8	OC81
Tr4	OC170	Tr9	OC81
Tr5	OC170		

Diodes:

D1 OA79 D2 OA79 (2–OA79 matched pair)

Transformers:

T1–T5	(see Coil Winding Data)
T6	Driver transformer (Gilson WO1806)
T7	Output transformer (Gilson WO929/6V 3Ω)

Loudspeaker:

LS Elliptical 7in.×4in., 3Ω

Battery:

DT9 or equivalent 9V type

at moderate volume levels. To minimise this difficulty the loudspeaker may be mounted on an ellipse of rubber surrounding the hole in the cabinet. Adhesion between loudspeaker and rubber, and rubber and cabinet, can be secured by one of the contact adhesives.

A cut-out will be needed in one of the folds used for fixing the mounting bracket to clear a bolt used for mounting the printed circuit to the loudspeaker baffle (see Fig. 9).

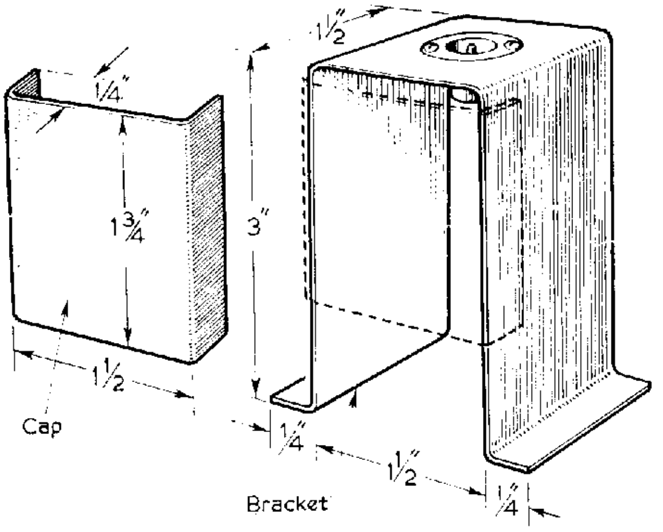


Fig. 13—The mounting bracket for the coaxial socket in the r.f. stage.

Alignment

Alignment is carried out as follows, and a signal generator capable of covering the frequencies of 10·7Mc/s and about 100Mc/s is required. (Amplitude modulation will be needed.)

1. Set the generator to 10·7Mc/s and switch on. Allow ten minutes for warming up. Switch on the internal modulation (A.M.).

2. Switch to ' high ' output and bring an insulated wire from the signal generator close to the base wire of Tr5. Rotate the core of T5 (collector winding) for maximum sound in the loudspeaker. Align the slug of Tr5 base winding in T4 for maximum output.

3. Transfer the wire from the signal generator to near the base wire of Tr4. Align cores of T4 for maximum output. Align the slug of Tr4 base winding in T3 for maximum output.

The alignment of the i.f. stages is now almost complete; the alignment of the discriminator and oscillator circuits will complete the receiver.

4. Switch the signal generator to controlled output. Plug in coaxial lead. Bring it to the board and clip the outer braiding to chassis. Connect coaxial cable core (inner) to the base winding of Tr3 via a 25pF capacitor. Leaving ratio detector core (secondary) alone, re-align for maximum output in the loudspeaker.

5. Transfer the signal generator input to the base of Tr2 (C11). Complete alignment of T2 and T3 as before.

6. Screw in the core of the ratio detector transformer until it overlaps both primary and secondary windings. Adjust the core of the primary for maximum output. Very carefully screw the core of the secondary in towards the primary, keeping adjustment of the primary by slowly withdrawing the primary core. This is a two-handed operation, aimed at varying the coupling between primary and secondary by the adjustment of the coupling core. Continue until maximum output is heard in the loudspeaker. Then, reverse the direction of travel of the coupling core and rotate 1¼ turns, adjusting the primary core to maintain resonance. This gives more-than-critical coupling (about 1·5 critical) with little reduction in sound output; the decrease should be just noticeable, not a pronounced drop off in volume. If 1¼ turns reversed travel causes a considerable drop in sound, less movement of the core is needed; a reduction of 2dB is ideally required and this may be judged by ear to a sufficient degree of accuracy.

7. Insert a third core in the ratio detector secondary winding. Rotate this to see if a minimum output point can be found. If not, use a brass slug instead of a dust core. Rotate the tuning element, whether iron dust or brass, for a minimum output between positions of high output. This point will be quite sharp and will be characterised by a change of ' quality ' of the output tone as the minimum output point is traversed.

8. Set the signal generator to 90Mc/s and connect the coaxial lead to the aerial socket. Set C7, C13 to approximately half setting and C12 to half capacitance. Rotate the core of L1 until a signal is heard; if a signal is heard in two positions of the core, the setting which gives least inductance is correct.

9. Set the signal generator to 86Mc/s. Rotate C7, C13 until the signal is heard. This should occur at nearly maximum capacitance; if not, adjust L1.

10. Set the generator to 100Mc/s. Adjust C12 to hear the signal, and the core of T1 for maximum output.

11. Set to 89Mc/s and locate the signal with tuning capacitor C7, C13. Rotate the core of T1 for maximum output.

12. Reset to 100Mc/s and adjust C12 for maximum output.

13. Repeat the adjustments 11–12 until no further improvement results.

Final Inspection

Finally, a check should be made, using the aerial signal, to ensure that the correct band is being covered. If desired, final adjustments to T1 and C12 can be carried out on the Home and Light programmes. The receiver is very sensitive, so if this is done, one must ensure that the same stations are being received each time tuning is changed. The last adjustment is the ratio detector secondary core; this may need ¼ turn or so one way or the other, using a programme source of signal, to ensure that the minimum-noise tuning point is that giving best audible quality, and that when no modulation is being transmitted, equal noise each side of the tuning-point is obtained. The adjustment is fairly critical; so care will be needed.

For maximum sensitivity, the voltage across C37 should be used to indicate alignment rather than the volume of sound in the speaker. This method of alignment is more accurate and will result in some loss of bandwidth. Voltages measured will be much less than those obtained with a valve-operated receiver; a strong signal at the aerial may only give ½V or so, and weaker signals only 100mV or so, while good reception is obtained when only a very small voltage is measured across C37. The presence of only small voltages should therefore cause no dismay.

PERSONAL T.R.F.

The t.r.f. type of receiver is much easier to construct than a superhet, and does not require any form of trimming or alignment whatsoever. It is thus particularly suitable for use when a straightforward circuit giving reception of local stations only is required. The circuit shown in Fig. 1 has four transistors, and gives very good loudspeaker results, in these circumstances.

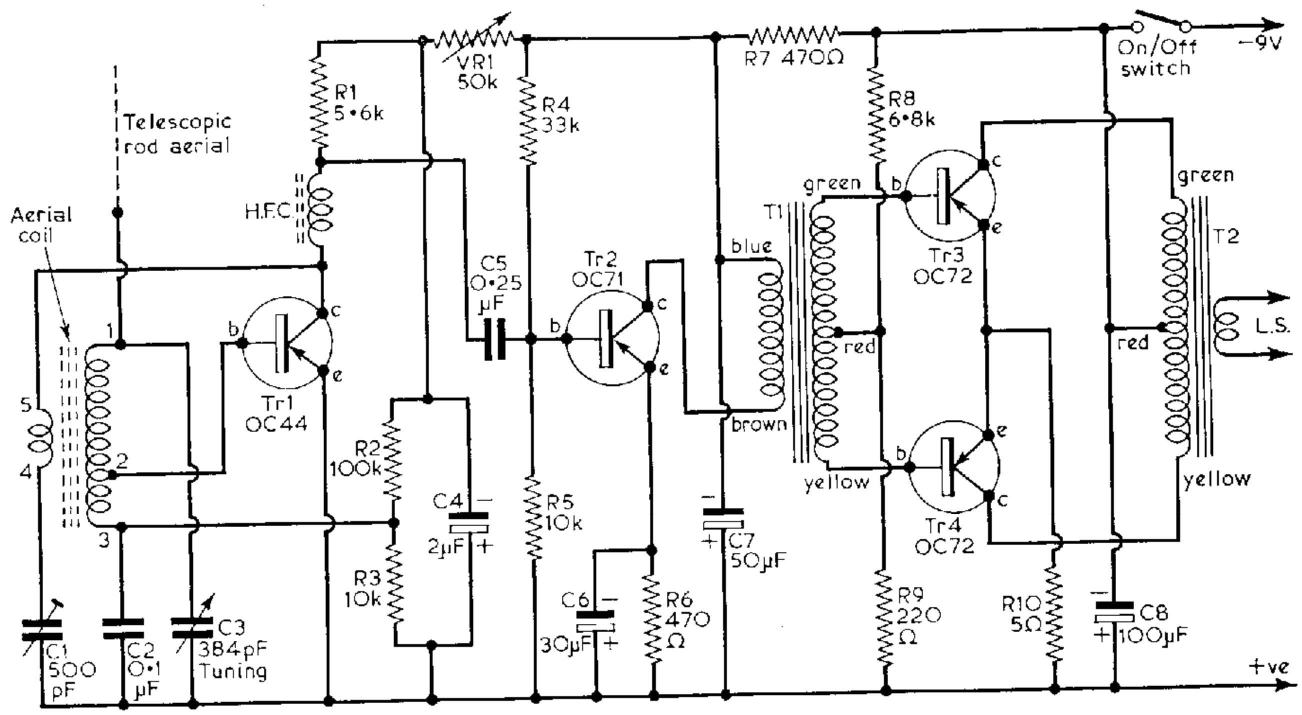


Fig. 1—The circuit of the receiver.

THE first transistor operates as detector, with regeneration, which considerably increases sensitivity. It is followed by a driver and push-pull output stages, with $2\frac{1}{2}$in. loudspeaker. It was found that sufficient volume was often obtained with the ferrite slab internal aerial only. However, to permit more distant reception a telescopic, chrome aerial is incorporated. This is about 6in. long when closed, and extends to about 36in. The receiver is so made that it can stand upright, with the aerial vertical.

When the extended aerial is not in use, the receiver can be placed flat, or upright, and should be turned for maximum signal pick-up in the usual way. If preferred, the extending aerial may be omitted. It is also in order to use a few feet of thin insulated flex for an aerial instead, when the ferrite slab gives insufficient volume. It should generally be possible to obtain sufficient volume without extending the rod, or using an external aerial, except in areas where signal strength is poor.

Ferrite Slab

This is shown in Fig. 2, and is approximately 3in.$\times\frac{3}{4}$in.$\times\frac{1}{8}$in. The larger winding has 52 turns, with tapping 2 made 11 turns from end 3. A space of $\frac{1}{8}$in. is left, and six further turns are wound on in the same direction. Both windings are of 28s.w.g. d.c.c. wire, which is easy to use. The tapping is made by baring the wire, and soldering on a lead. A small piece of insulating material under this joint will prevent any possible shorts to adjacent turns. The ends of the windings can be secured with adhesive, or tape. The windings should not be painted, waxed or covered with adhesive.

A ferrite rod or slab with a ready-made Litz medium wave winding could be used instead. The small additional winding can be of any wire of about 32s.w.g. to 24s.w.g. Enamelled wire should be wound on a layer of paper.

Two mounts are cut from ebonite or similar material, and slotted to take the slab. These mounts are secured to the panel with countersunk screws, which can be self-tapping into holes in the mounts. Adhesive is placed on the slab and mounts, and the slab inserted in the slots.

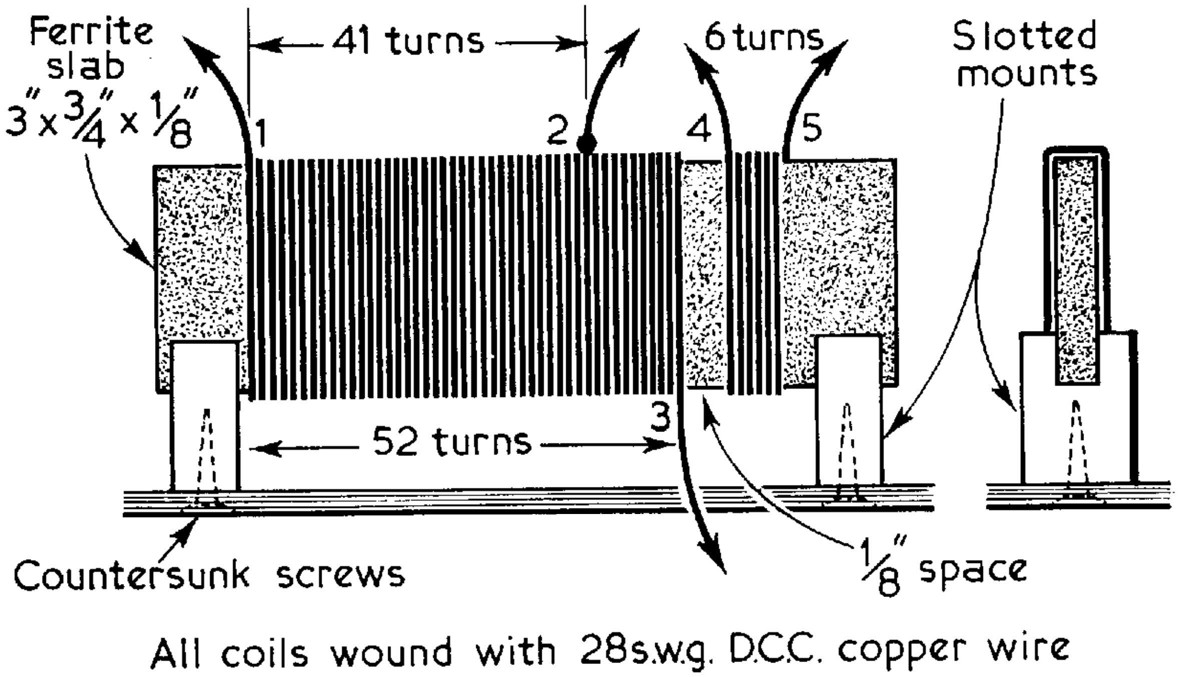


Fig. 2—The construction of the ferrite slab aerial.

Receiver Case

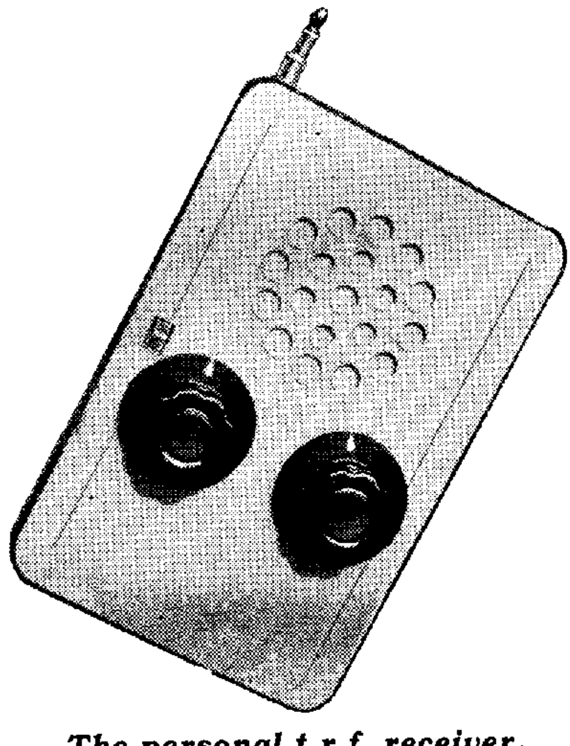
This is easily obtainable and is a popular plastic 'lunch box' approximately $4\frac{1}{2}$in. × $6\frac{3}{4}$in. × $1\frac{5}{8}$in. There is enough free space to make construction easy, and to allow alternative components to be used.

The case is drilled to form a loudspeaker fret, as shown in Fig. 3. Two circles are drawn, one of $\frac{1}{2}$in. radius, and one of 1in. radius. The small circle is divided into six, and the large circle into twelve. This can be done with compasses. Small pilot holes are then drilled, being positioned as accurately as possible. Six holes about $\frac{5}{16}$in. in diameter are then drilled, and thirteen holes about $\frac{3}{8}$in. in diameter.

The case should be supported upon a block of wood while drilling. The drills should be sharp, and only light pressure should be used. Holes about $\frac{3}{8}$in. in diameter are then drilled for the controls, and the slot is made for the switch. This can be done by drilling one or two small holes, and squaring up with a small file.

After removing any fragments, paint the case on the *inside* with the desired colour. A quick-drying enamel or paint will be most suitable.

When the receiver is finished the back is held on by a single screw, near the centre, which enters a threaded bush screwed to the receiver panel. Removing this single screw allows the



The personal t.r.f. receiver.

back to be taken off to change the battery.

Receiver Panel

The receiver is constructed on a paxolin panel $4\frac{1}{2}$in. $\times$ $6\frac{1}{2}$in., and can be tested complete, with loudspeaker, before inserting it in the case. When inserted, it is held in by the nut on the bush of the 50kΩ potentiometer, and by a small bolt near the tuning capacitor spindle hole.

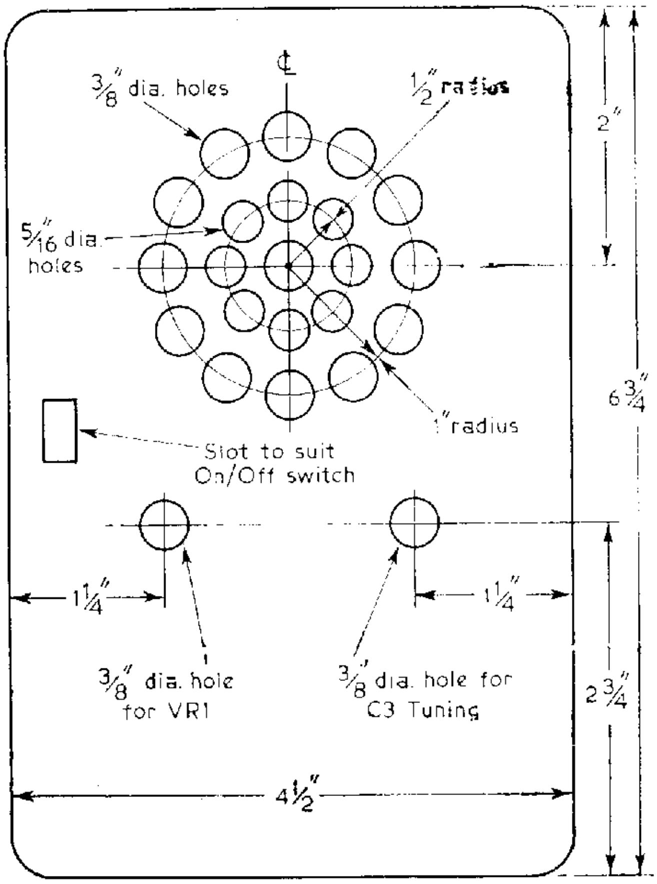


Fig. 3—The drilling details of the case.

Fig. 4 shows the receiver panel inside the case. It is, of course, only inserted when finished and tested.

The tuning capacitor is a two-gang air-spaced miniature type, as this is readily available for transistor receivers. Both sections are in parallel making a total of about 384pF. This capacitor is held to the panel by three short 4B.A. countersunk screws. Subsequently, one screw is removed, and passes through a hole in the case, to hold the receiver, as described. Care is necessary that these screws are not too long, or they will short-circuit the capacitor, or bend its plates. A 500pF solid dielectric type of capacitor may be used instead, with a small reduction in efficiency. If so, the fixing nuts of the 50kΩ potentiometer and 500pF capacitor will secure the receiver in its case.

The loudspeaker is secured with countersunk 6B.A. bolts. Extra nuts, or spacing sleeves, are used with two bolts, so that the 5-tag strip shown in Fig. 4 can be fixed in position.

The detector stage can now be built up complete and tested. Counting the tags from the top (in Fig. 4), connections can be checked as follows: 1, collector, h.f. choke, lead 5; 2, base, lead 2; 3, emitter, 10kΩ (R3), 500pF pre-set capacitor (C1) tuning capacitor frame and battery positive; 4, h.f. choke, 5·6kΩ (R1), 0·25μF capacitor (C5); 5, 0·1μF capacitor (C2), 10kΩ

COMPONENTS LIST

Resistors:

R1	5·6kΩ	R6	470Ω
R2	100kΩ	R7	470Ω
R3	10kΩ	R8	6·8kΩ
R4	33kΩ	R9	220Ω
R5	10kΩ	R10	5Ω

VR1 50kΩ carbon potentiometer

Capacitors:

C1	500pF	trimmer
C2	0·1μF	paper
C3	384pF	variable (miniature two-gang)
C4	2μF	electrolytic 9V
C5	0·25μF	paper
C6	30μF	electrolytic 9V
C7	50μF	electrolytic 9V
C8	100μF	electrolytic 9V

Choke:
HFC miniature h.f. choke

Transistors:

Tr1	OC44	Tr3	OC72
Tr2	OC71	Tr4	OC72

Transformers:
T1 Driver transformer (Osmor PW/DT)
T2 Output transformer (Osmor PW/OT)

Miscellaneous:
On/off switch, $2\frac{1}{2}$in. loudspeaker, whip aerial, case, 9V battery, knobs, etc.

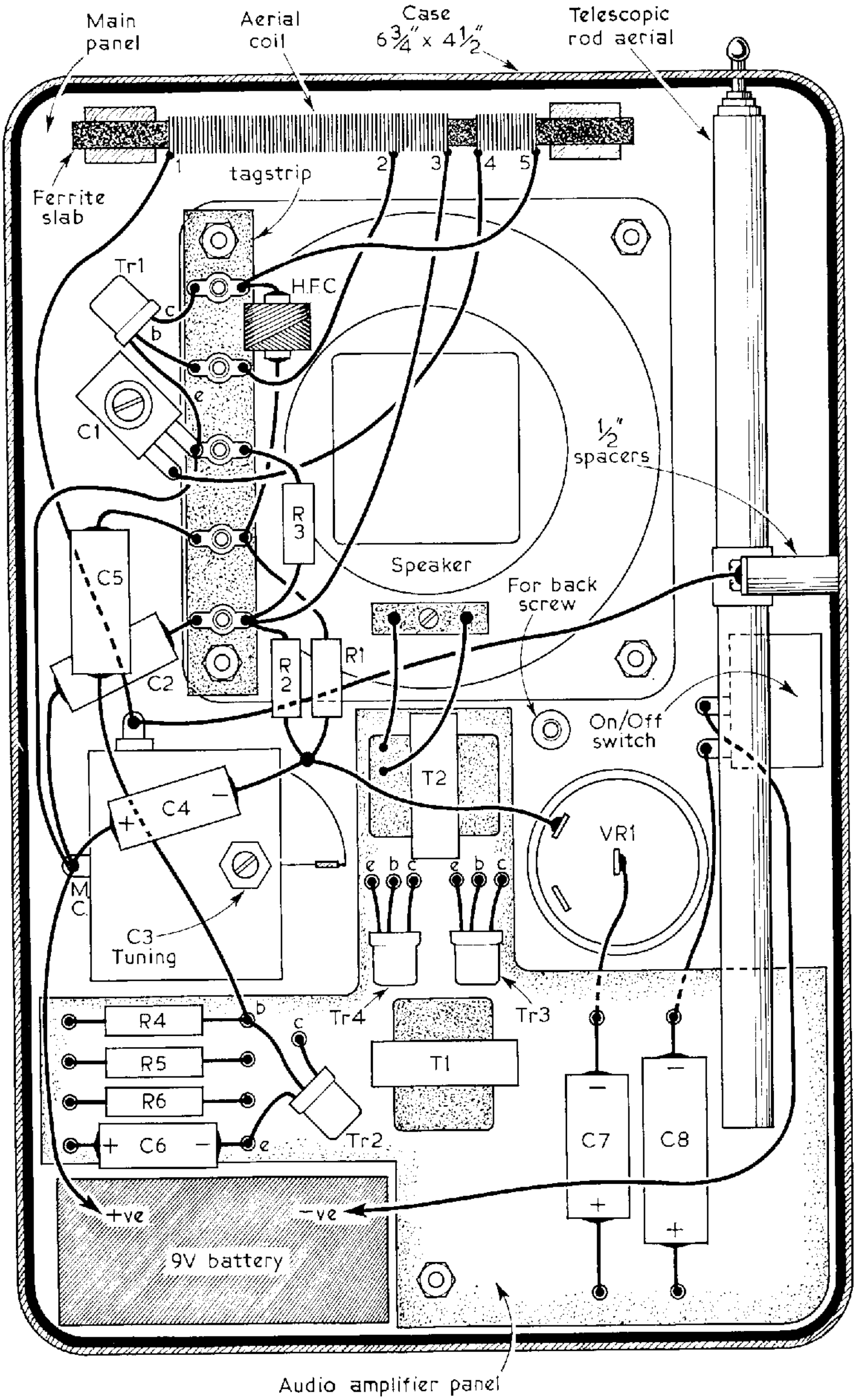


Fig. 4—The internal layout of components.

(R3) and 100kΩ (R2) resistors, lead 3 from ferrite slab.

The 500pF pre-set is held in position by soldering one of its tags directly to tag 3. All the transistor leads can be left long, but should be covered with sleeving. The transistor can be added last, the joints being quickly made, and the iron removed.

Testing

If desired, this part of the receiver can be tested with a pair of headphones. To do this, connect the headphones from the free end of the 0·25μF capacitor (C5), to the tuning capacitor frame, marked M.C. in Fig. 4. Take a lead from the 50kΩ regeneration control to battery negative.

Smooth regeneration, right up to oscillation point, should be obtained with the 50kΩ control. If oscillation cannot be obtained, screw down the 500pF pre-set slightly. If oscillation is too violent, unscrew this capacitor. The correct setting is not very critical, and should allow adequate, yet smooth, regeneration with any battery supply of 4·5V to 9V. If a regeneration winding has been added to an existing slab or rod, it might be necessary to adjust the position of this winding, to secure satisfactory results. If no regeneration at all can be obtained, the winding may have been reversed in error.

Reproduction in the headphones should be free from distortion, and of reasonable volume. When the receiver is adjusted for maximum sensitivity, tuning is sharp, and both controls should be operated carefully together. The regeneration control should never be merely turned fully clockwise (as if it were a volume control) as this will not give satisfactory reception.

Audio Amplifier

This is built as a separate unit. A piece of paxolin is shaped as shown in Fig. 4, so as to clear the tuning capacitor, regeneration control, and leave space for the battery.

Small holes are drilled, and the resistors and other parts are placed with their leads through the holes, as shown in Fig. 4. The reverse side of the audio panel is shown in Fig. 5.

The colour coding of the driver transformer T1, and output transformer T2 applies to the transformers listed. Other driver and output transformers would be equally satisfactory, and the maker's connecting data should be followed. The leads pass straight down through small holes, and are bent over. A little adhesive under the transformers will hold them to the panel, in conjunction with the leads. Leave the two secondary leads of the output transformer free, for connecting to the speaker.

Lead Lengths

All transistor leads can be left quite long, as mentioned, but the soldered joints should still be made quickly. Cover all wires, including the ends of resistors, with sleeving. A few inches of thin flex are used for battery connections terminating with the appropriate positive and negative clips.

When the audio amplifier panel is finished, it is placed in the position shown in Fig. 4. Two short bolts hold it there, with spare nuts so as to obtain about ¼in. space between the audio panel and the receiver panel.

Connections

The leads shown in Fig. 5 can then be connected to their correct points : one lead goes to the switch (battery negative) ; a second lead passes to the 50kΩ regeneration control ; transistor Tr2 base, which is joined to the 33kΩ and 10kΩ resistors (R4 and R5), goes to the 0·25μF capacitor (C5), and, finally, a lead connects the battery positive side of the circuit to M.C., or the frame of the tuning capacitor.

After connecting loudspeaker and battery, the receiver can be tested. Reproduction should be clear and distinct. No further adjustments should be necessary, if the 500pF pre-set has been adjusted as described. If a meter is included in one battery lead, the resting (quiescent) current (no signal) should be around 5mA. This should rise to about 8mA to 15mA on peaks, with average speech or music, according to volume.

Case and Rod

A piece of silk or other thin material about 4in. square is placed over the loudspeaker, and held with adhesive. Fit the threaded bush for the back screw, tightening it securely. The control knobs are removed, together with the nut of the 50kΩ potentiometer, and one screw of the tuning capacitor. The receiver is then inserted in the case, and the nut and screw replaced, and tightened. Pointer knobs of reasonable size will be best for tuning.

The aerial rod has a bracket to take two 6B.A. bolts, with ½in. spacers, or spare nuts, between bracket and case, as shown in Fig. 4. A clearance hole is drilled in the case above the top of the rod. An insulated lead passes from the rod to the fixed plates of the tuning capacitor. A small terminal on the side of the case would do for an external aerial connection instead.

Equivalents

The circuit will work satisfactorily with transistors of similar type, including surplus transistors in proper condition. Tr1 must be an r.f. transistor, or regeneration may not be obtained. Tr2 is an audio amplifier, and other types may need a change in value of R4, R5 or R6. Tr3 and Tr4 are best a matched pair for push-pull output. Some transistors may need values other than 220Ω for R9 and 5Ω for R10, to obtain full gain and distortion-free reproduction.

Miniature H.F. Choke

A miniature h.f. choke can be made by taking a ferrite slug and winding several hundred turns of fine gauge wire upon it.

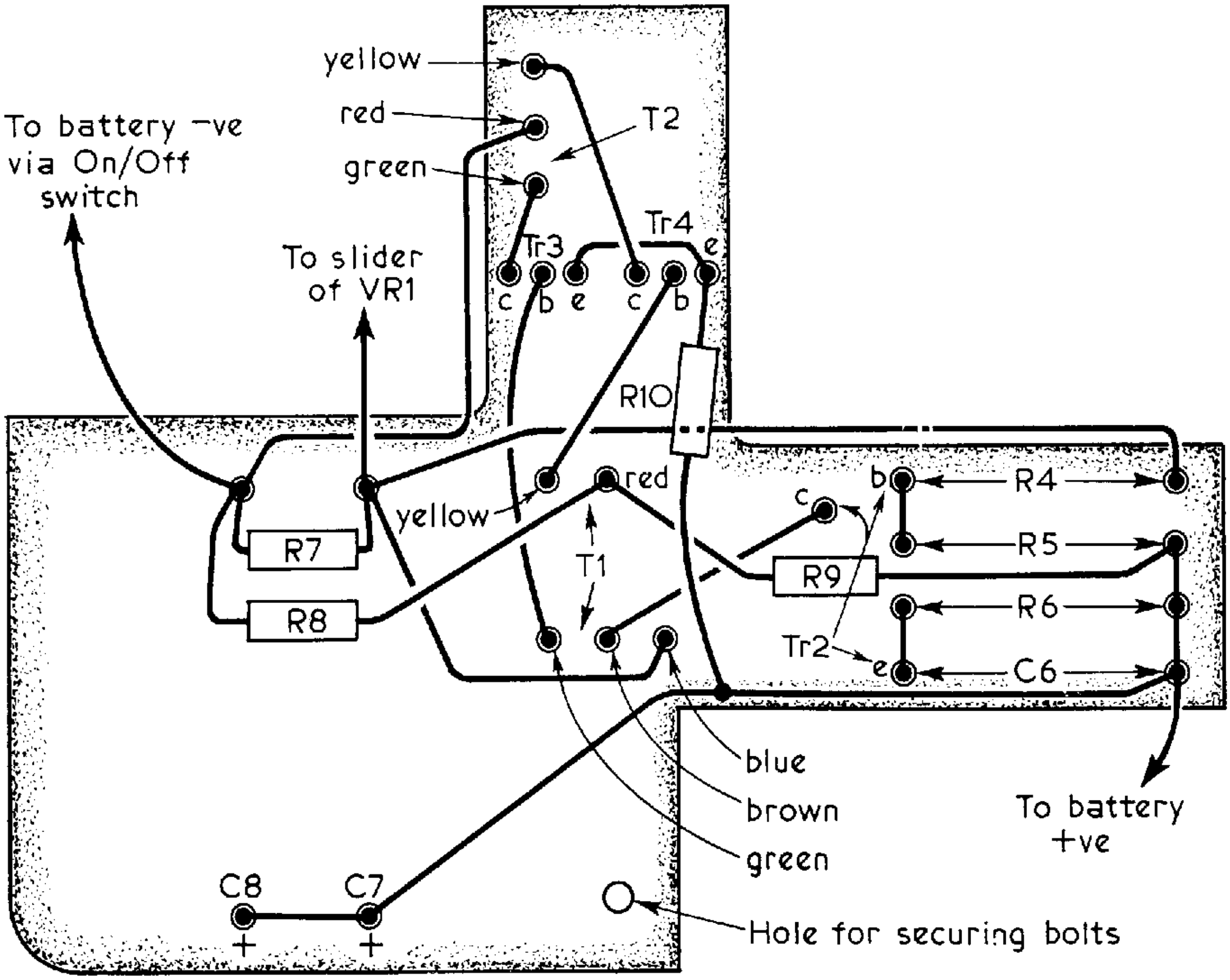
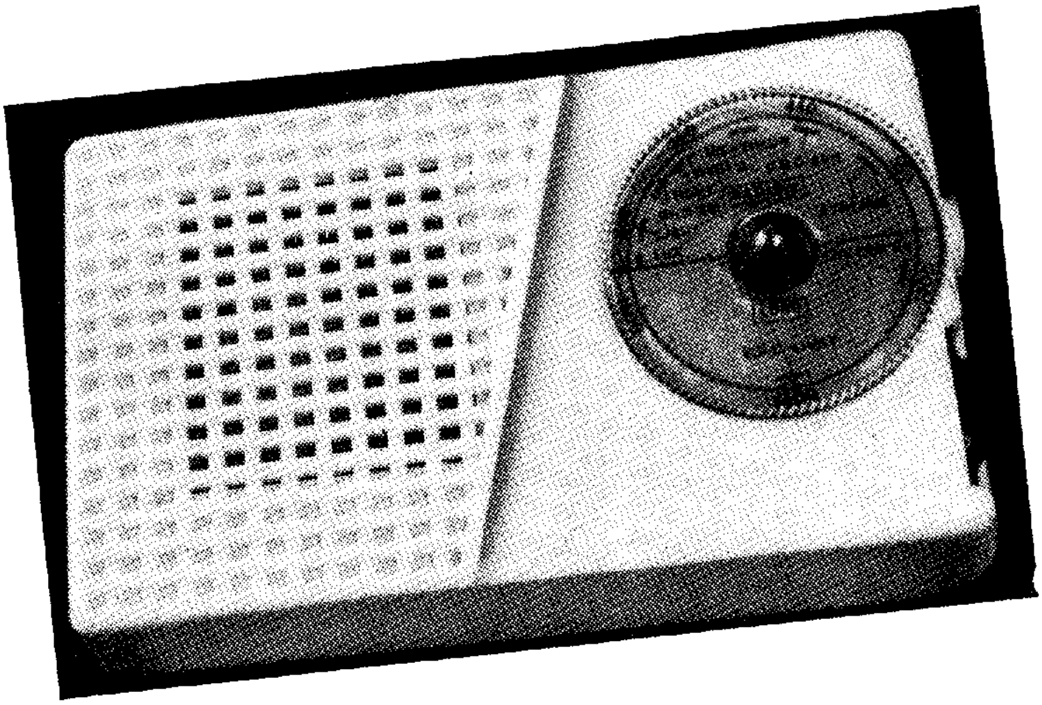


Fig. 5—The reverse side of the audio amplifier panel.

MEDIUM WAVE PORTABLE

This full superhet circuit provides very good sensitivity, and the single-ended push-pull output stage is particularly economical. Current consumption, at low volume, is only about 8mA. At average listening volume, this rises to about 12mA to 14mA or so. The usual small type of 9V battery thus has a long working life.



THE receiver tunes medium waves only, as this simplifies the first stage, but it is possible to add long waves later, without disturbing other parts of the set.

If possible, it is recommended that an OC44 is used for Tr1, with OC45's for Tr2 and Tr3, and an OC71 for Tr4. However, other transistors of similar type were found to work satisfactorily in these stages. For the output stage, a maker's matched pair of OC72 transistors (2×OC72) should be fitted. Resistors R17, R18, R19 and R20 should also be of 5% tolerance, while all others can be of 10% tolerance. Correct working conditions will then be assured, without any need to experiment, or change resistor values.

Paxolin Panel

This should be made first, all important drilling being finished before mounting any parts. The panel is $5\frac{1}{4}$in.×3in.×$\frac{1}{16}$in. thick, this giving a little clearance all round in the specified cabinet. Drill three holes so that the panel can be secured in the case by short 6B.A. bolts. (A piece of thin card can be used as a template, piercing holes in it in the correct positions.)

The gang capacitor fits in a fairly large clearance hole. Check that there is space for the battery, with at least $\frac{1}{8}$in. to spare; then, drill holes for the three short 4B.A. bolts shown in Fig. 3. The pierced card will show exactly where to drill. If the screws project more than the thickness of the capacitor plate, washers are needed under their heads.

Volume Control

Mount the volume control as in Fig. 2. One switch tag projects up through a hole, and the other tags are bent flat. Check that the set will fit in the case, and that the battery can be

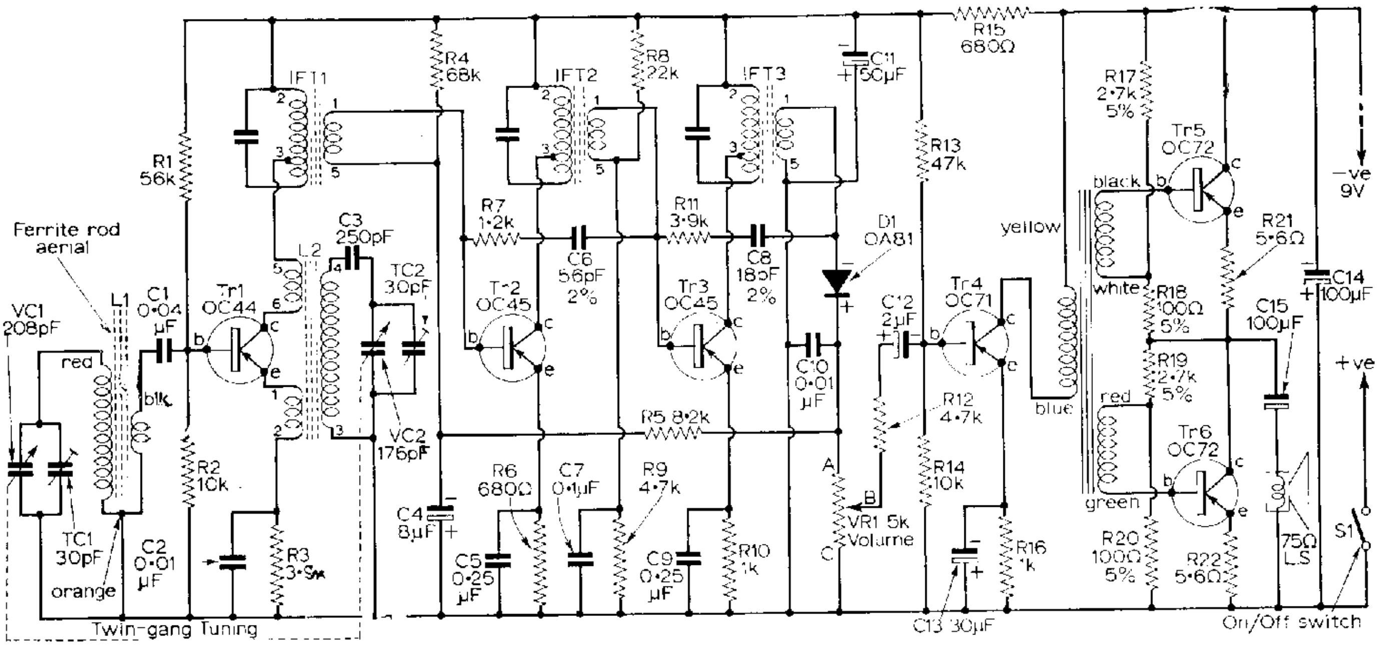


Fig. 1—The circuit diagram.

accommodated. The volume control slot in the case will need widening slightly, with a small file. It may also be necessary to enlarge the tuning capacitor hole.

These parts are then removed, and the holes are drilled for the four screened coils. If the pins are pressed on the thin card template, this will show where to drill. Check that each coil fits easily, then place it on one side. If any holes are not quite correct they can be enlarged with a small round file.

Loudspeaker Mounting

The loudspeaker hole is about ¼in. larger all round than the loudspeaker magnet. It can be made with a washer cutter, a fretsaw or other very small saw, or by drilling holes, and cleaning up with a half-round file. Temporarily position the loudspeaker, mark the two speaker fixing holes (Fig. 3) and drill them.

After drilling holes for the driver transformer, transistor lead holes can be positioned as in Figs. 2 and 3. A short 4B.A. bolt holds the rod mounting.

Clean up all holes, and mount the rod, gang capacitor, loudspeaker, driver transformer and screened coils, and check that the whole can fit readily in the case, with battery. Note that the case tapers slightly towards the back; there should be a little clearance all round.

The loudspeaker is now removed until the set is wired. When finally mounted, it is held by two 6B.A. countersunk bolts, inserted from the front. The bolt near the rod mount has two nuts, one locking the loudspeaker, and the other giving correct clearance between loudspeaker and panel, a third nut then being tightened behind the panel. The remaining loudspeaker mounting hole (Fig. 3) is obscured by the driver transformer. A short countersunk bolt is therefore inserted from behind, and locked with a 6B.A. terminal head. The transformer can then be permanently mounted. Another 6B.A. bolt may then be inserted

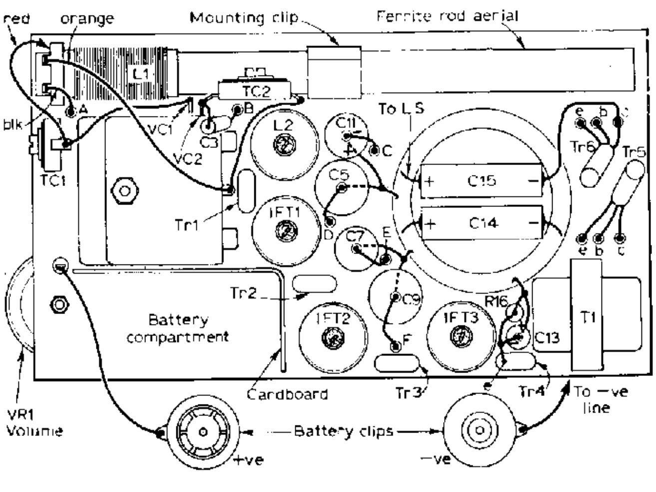
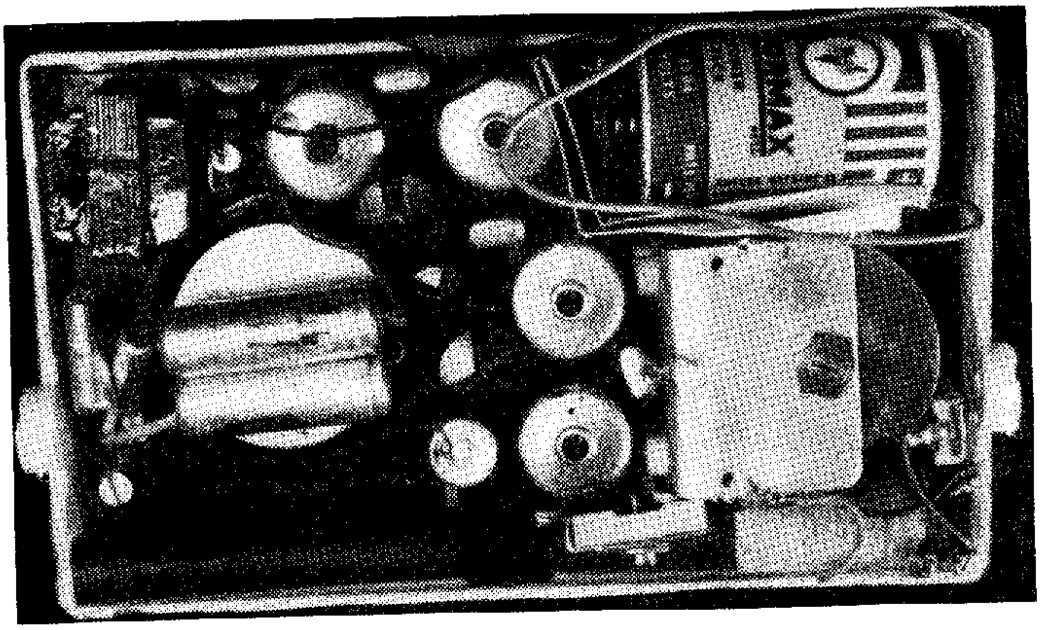


Fig. 2—The layout and wiring diagram of the receiver panel.



The receiver mounted inside its case.

from the front of the loudspeaker, and run into the terminal head, washers or nuts providing spacing.

Construction

All wiring is of 26s.w.g. tinned copper wire, insulated with 1mm sleeving. It will be helpful to use red sleeving throughout the positive side of the circuit, and black sleeving throughout the negative line, with yellow or some other colour for all other leads. Sleeving is also placed over all transistor leads, and the wire ends of all resistors and capacitors. Sleeving on the transistor leads can be of such a length that the tops of the transistors Tr1 to Tr4 come about level with the tops of the screened coils ; Tr5 and Tr6 are bent over as in Fig. 2. Be sure that the transistors are in their correct stages, and that the collector base and emitter leads all emerge as shown by the letters ' c ', ' b ' and ' e ' in Fig. 3.

Control Wiring

Fig. 4 shows the tag side of the volume control.

In Figs. 1, 3 and 4, ' A ' is one end of the element, ' B ' the slider, and ' C ' is the other end of the element and one switch tag. The remaining switch tag passes through the hole in the panel (see Fig. 2). A short piece of thin red flex is soldered on here and fitted with a positive battery clip.

The trimmer TC1 has one tag inserted in a hole, so that it can be soldered to the tag held by the 4B.A. bolt, in Fig. 3. Trimmer TC2 is soldered

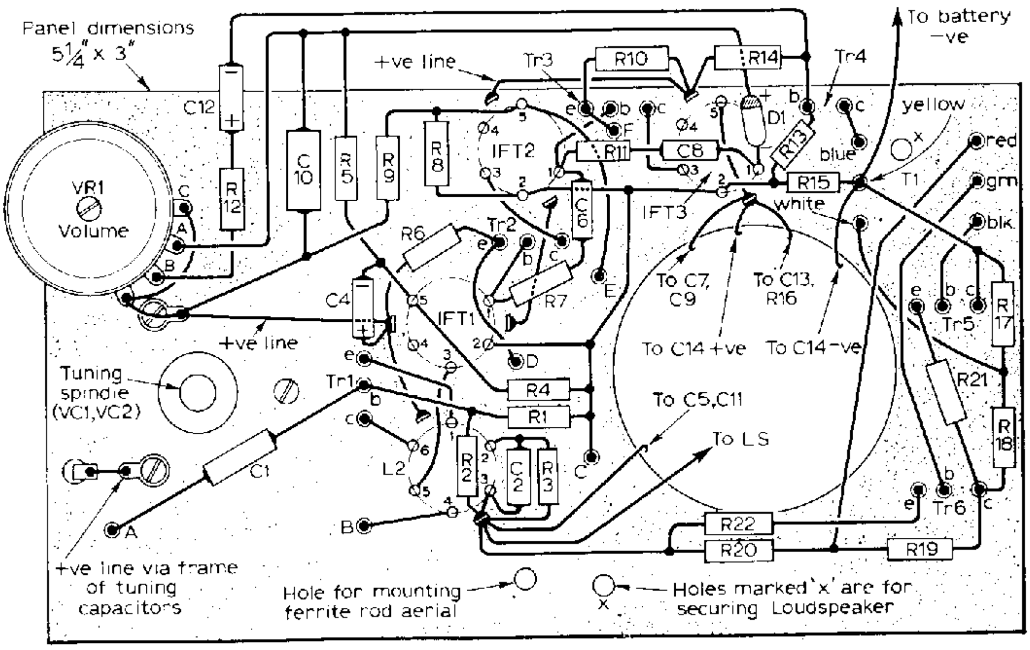


Fig. 3—The wiring on the front of the panel.

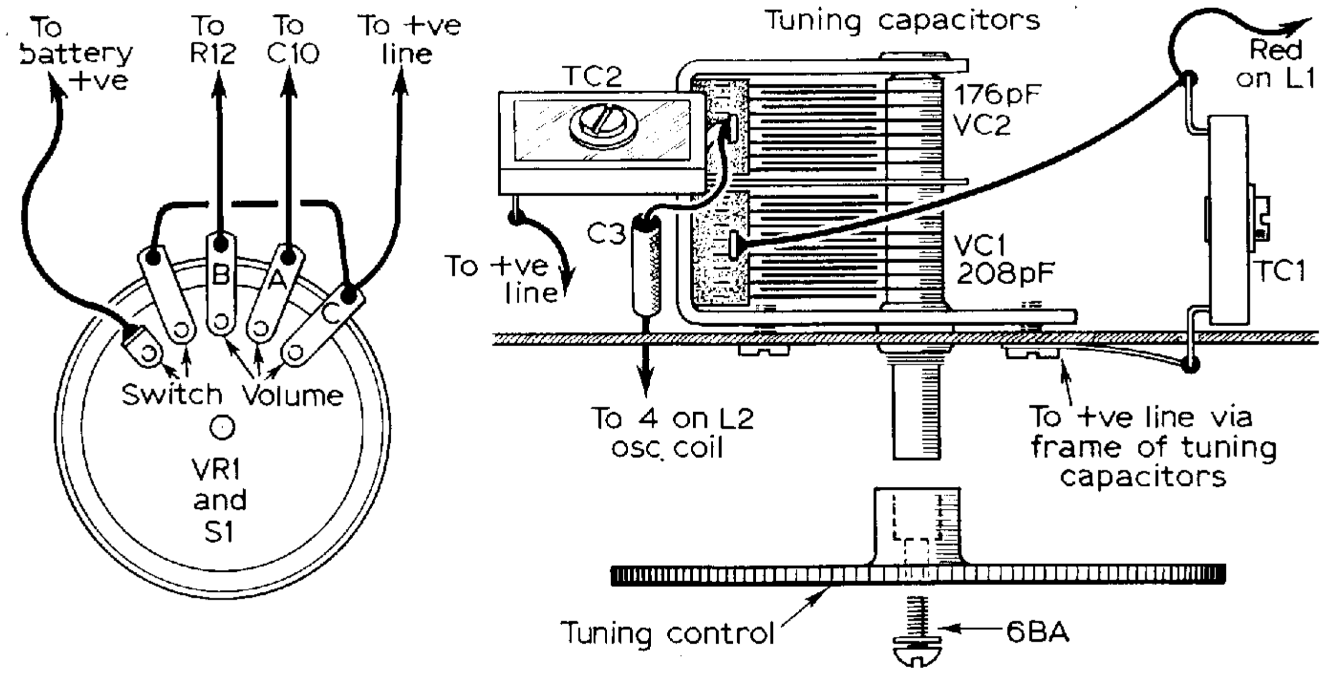


Fig. 4—The details of the volume control and tuning capacitors.

directly to the 176pF tag of the gang capacitor (VC2), a short lead returning to the capacitor frame.

All leads and components are kept close against the panel. Leads and resistors should also be clear of the position which the speaker will occupy. Electrolytic capacitors are wired with the polarity shown in Fig. 3. Other capacitors, and all resistors, may be wired in either way round. The negative end of the diode must go to pin 1 of the third i.f. transformer.

C13 and R16 are wired in parallel. The wire end of R16 passes through a hole, to the earth tag in Fig. 3. The negative lead of C13 goes to the same hole as the emitter of Tr4, to which it is joined.

The negative end of C15 passes into the same hole as the collector of the one OC72, as in Fig. 2, these leads being joined, and also going to R19, R20 and R22 (Fig. 3).

It is best to leave all the transistor leads reasonably long, but prolonged heating with the soldering iron should be avoided.

The larger fixed capacitors are mounted behind the panel, as in Fig. 2; C5, C7, C9 and C11 each have a lead passing directly down through the panel, and all are soldered to the earth line. The top wires of these capacitors are bent over, and pass down through other small holes, as in Fig. 2, so that they can be connected as in Fig. 3.

C14 and C15 must have insulated sleeves, or be covered with insulated material. They are secured side by side with tape, and rest on the loudspeaker magnet. C14 goes from the positive line to the negative line. C15 is wired from collector to loudspeaker, as in Fig. 2.

In Fig. 1, short pieces of thin coloured flex are soldered to the aerial winding tags, for identification. Both 'earth' ends of the windings are joined, for the orange lead. These leads are then connected up as in Fig. 2. That is, orange to tuning capacitor frame, red to T1 and VC1, and black to C1, Fig. 3.

After checking the wiring, solder lengths of thin flex to the 75Ω loudspeaker. One lead goes to an earth point and the other passes back to the positive end of C15. Fix the loudspeaker as described, making sure that its tags do not bear upon leads or parts already fitted. The loudspeaker itself is of insulated material. The spacing between loudspeaker and panel should be so adjusted that the loudspeaker rests on the front of the inside of the cabinet. A pad of material, such as thin soft card, is cut to fit inside the loudspeaker opening, and an aperture is cut to match the loudspeaker cone. This avoids buzzing noises due to vibration between case and loudspeaker frame.

Check that the receiver will fit readily in the case. The unwanted tags of the gang capacitor are bent down, to leave more space for the battery. A piece of cardboard, bent as in Fig. 2, isolates the battery from other parts, and prevents contact between the battery and second i.f. transformer.

Testing and Adjusting

If possible, a meter should be included in one battery lead. This should read about 7mA when the set is switched on. If the meter shows a high current, switch off at once, disconnect the battery, and check the wiring for shorts or errors.

A strip of Paxolin or similar material should now be filed so that it will engage with the coil and transformer cores, to be used as an adjusting tool.

If a signal generator is available, set it for 470kc/s, with modulation, and connect its output to the black lead in Fig. 2, including an isolating capacitor in circuit. Put the receiver volume control at maximum, reducing the generator signal, if volume is too great. The three transformer cores are then adjusted for best results, which will also be the highest reading on the meter included in the battery circuit. All cores should have quite a sharp tuning peak.

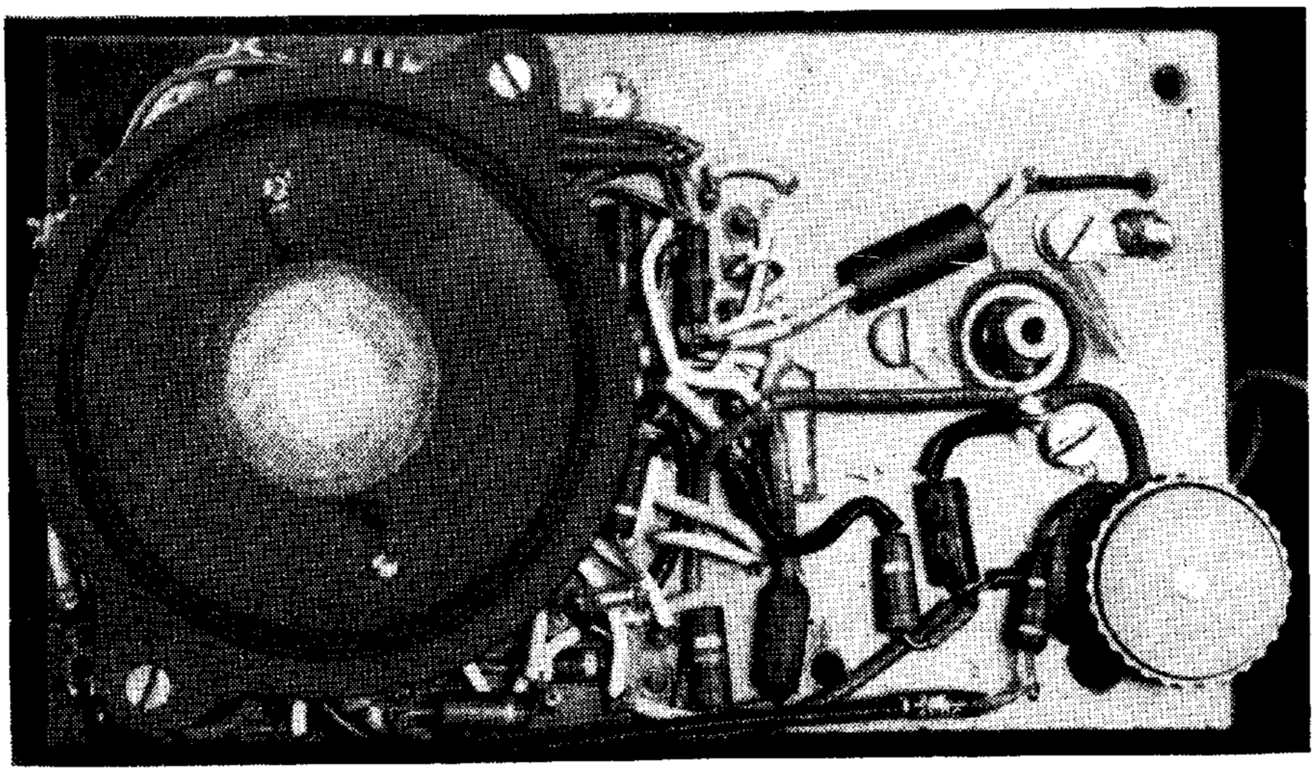
Alignment on Stations

If no generator is available, tune in the local station, adding an external aerial a few feet long, if required. Then adjust the three transformer cores for best volume. They should be in a reasonable position, not screwed right in, or very far out.

Aerial and oscillator stage tuning can then be adjusted. TC1 and TC2 must be capable of reaching a low capacity. To begin, unscrew both trimmers, carefully separating the plates, if necessary. If a signal generator is available, adjust it to 550m, close the gang capacitor, and rotate the oscillator coil core for best results. Then move the aerial winding on the rod, to obtain maximum volume. The generator is then set to 205m, the gang capacitor is opened, and TC1 and TC2 are adjusted for best results.

If coverage is restricted on the low wavelength end of the band, this probably indicates that TC1 and TC2 need opening to a lower capacity. Repeat

The loudspeaker side of the panel, with the wiring complete.



the trimming and inductance adjustments described a number of times, always adjusting the trimmers at a low wavelength, and the aerial and oscillator coil inductances at a high wavelength. Keep the receiver volume control at maximum, but choose weak signals, to keep volume down.

Final adjustment should be at frequencies a little from the extreme ends of the bands, once it has been found that band coverage is satisfactory. It may be difficult to keep volume down to a level where the effect of adjustments can be easily heard, when aligning with broadcast stations. If so, rotate the whole receiver, to make use of the directional properties of the rod, to reduce volume.

During alignment, volume should not be reduced with the receiver volume control, or an exact setting of trimmers and cores will be difficult to find.

Reproduction should be at adequate volume, and of pleasing quality. Should results sound extremely distorted, it is probable that one secondary of the driver transformer has been wrongly wired, in error. If so, reverse leads to one secondary.

The tuning knob should rotate with a little clearance. If not, a washer may be needed under it. The set can be used flat, or standing, with the rod horizontal. Only in rare instances need the receiver be rotated for best signal pick up, as volume should easily be sufficient.

COMPONENTS LIST

Resistors (all 10% unless otherwise indicated):

R1	56kΩ	R12	4·7kΩ
R2	10kΩ	R13	47kΩ
R3	3·9kΩ	R14	10kΩ
R4	68kΩ	R15	680Ω
R5	8·2kΩ	R16	1kΩ
R6	680Ω	R17	2·7kΩ, 5%
R7	1·2kΩ	R18	100Ω, 5%
R8	22kΩ	R19	2·7kΩ, 5%
R9	4·7kΩ	R20	100Ω, 5%
R10	1kΩ	R21	5·6Ω
R11	3·9kΩ	R22	5·6Ω

VR1 5kΩ miniature carbon potentiometer with switch (S1)

Capacitors:

C1	0·04μF	paper
C2	0·01μF	paper
C3	250pF	silver mica
C4	8μF	electrolytic 9V
C5	0·25μF	paper
C6	56pF	2% silver mica
C7	0·1μF	paper
C8	18pF	2% silver mica
C9	0·25μF	paper
C10	0·01μF	paper
C11	50μF	electrolytic 9V
C12	2μF	electrolytic 9V
C13	30μF	electrolytic 9V
C14	100μF	electrolytic 9V
C15	100μF	electrolytic 9V

All the above are miniature types

VC1	208pF	two-gang variable tuner
VC2	176pF	two-gang variable tuner
TC1	30pF trimmer	
TC2	30pF trimmer	

Transistors:

Tr1	OC44	Tr4	OC71
Tr2	OC45	Tr5	OC72 matched pair
Tr3	OC45	Tr6	OC72 matched pair

Inductors:

L1 Ferrite rod (5in.) with M.W. coil
L2 Oscillator coil (Weyrad P50/1AC)

Transformers:

1FT1, 2 I.F. transformers (Weyrad P50/2CC)
1FT3 I.F. transformer (Weyrad P50/3CC)
T1 Driver transformer (Fortiphone L442)

Diode:

D1 OA81 Germanium diode

Loudspeaker:

Loudspeaker 2½in. diameter, 75Ω,

Miscellaneous:

Case 3¼in. × 6½in. × 1⅝in.

SERVICING TRANSISTOR RECEIVERS

The special techniques required when servicing transistor receivers are described, also stage-by-stage test procedures and other valuable hints.

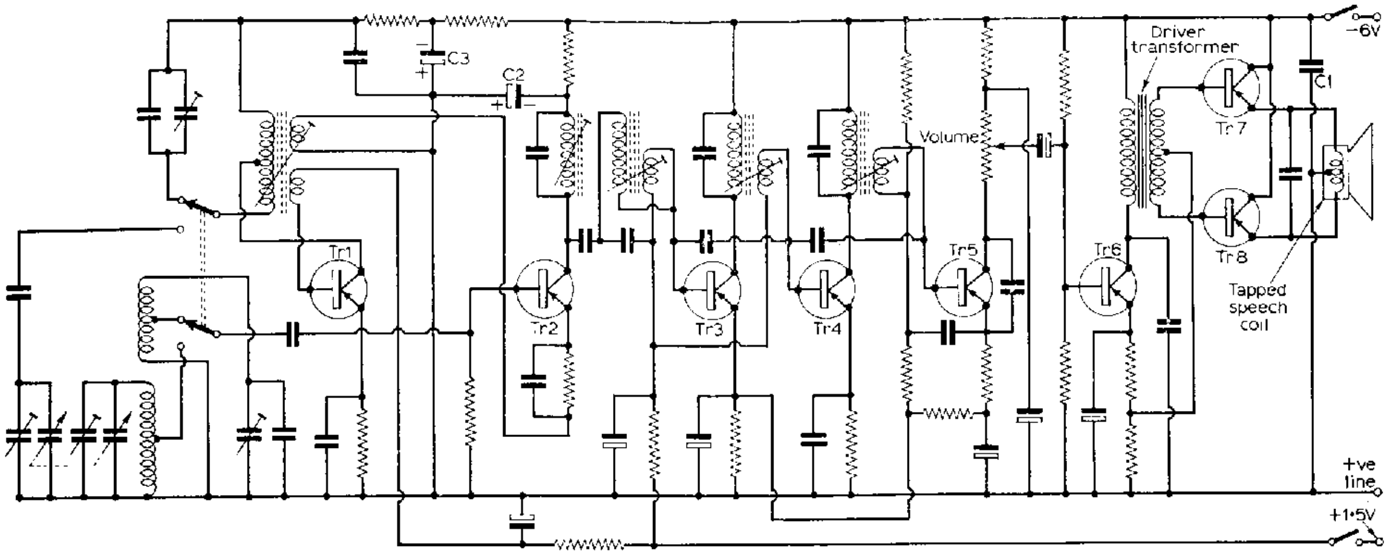


Fig. 1—The circuit diagram of a transistor portable which uses a centre-tapped speech coil coupled direct to the output transistors, Tr7 and Tr8, without a transformer.

BEFORE useful work can be carried out on transistorised equipment, it is necessary to have available a testmeter giving a range of fairly low voltage full-scale deflections. An ideal instrument would be a multimeter with low voltage ranges of 0–1, 0–5, 0–10 and 0–20 and with a sensitivity of 20,000Ω/V. This would require a meter movement which itself had a full-scale sensitivity of at least 50μA.

Sensitivity

A multimeter based on such a movement would also probably give full-scale deflection on the lowest current range at 50 or 100μA. This would be extremely useful for oscillator checking and for other tests in which the circuit current is small. Further full-scale current ranges of 250μA, 1mA, 10mA, 100mA and 1A would be very useful, as also would a range of 'ohms' measurements from about 1Ω to 10MΩ.

Such an instrument would allow almost the whole of any item of transistorised equipment to be analysed from the static (or d.c.) point of view. To secure a reasonable indication of what is wrong—or not wrong—in a transistor stage it is essential to be able to measure small differences in relatively low voltages (and currents). We must also always keep in mind that transistors are current-operated devices—that is, the current is the prominent factor with the relatively low impedances encountered in transistorised circuits compared with the lower currents and higher impedances in valve equipment.

Loading

This impedance difference is also somewhat important when injecting signals from a signal generator and when measuring output on an output meter or a.c. voltmeter. Valve circuits put a negligible load across the termination of a signal generator (owing to their high impedances compared with the low output impedance of most signal generators) and therefore the voltage indicated by the r.f. attenuator on the signal generator may be taken as applied to the circuits.

This may not be so with transistor circuits. Two things could happen here: one is that the low impedance output of the generator could load the transistor input circuits heavily and in certain cases alter the base current distributions sufficiently to put the stages virtually out of action. Secondly, the low impedance of the transistor input circuit could load the generator termination so that the signal actually appearing across the 'loaded' termination was considerably below the value indicated on the attenuator of the signal generator.

Whilst the former condition may be apparent, the latter may simply give a false impression of receiver sensitivity and lead to fault tracing in a fault-free circuit. In some service manuals relating to transistor sets the approximate sensitivity is given in terms of signal voltage applied across a specific value of load resistance. A load value typical in this respect is 500Ω, and an i.f. sensitivity value, for example, may be 5mV for an output of 50mW (audio, of course).

Alternative Method

In some manuals, instead of a definite output power being specified, the voltage across the speech coil of the loudspeaker for 'standard' output may be given. It will be understood that the signal generator must be modulated (usually to a depth of 30% at 400c/s) in order to produce a.f. across the loudspeaker. The reason for a voltage being given instead of a power is because the speech coil impedances differ considerably.

Output Loading

The power output across a load of impedance Z is equal to E^2/Z, where E is the r.m.s. voltage measured on an a.c. voltmeter. With valve sets, Z is usually in the region of 3Ω (at 1,000c/s), while with transistorised sets the speech coil impedance may be 30, 60, 120Ω or some entirely different value, depending upon the design of the output stage. In some cases the speech coil may even be centre-tapped to facilitate connection to a push-pull output stage of a circuit such as that given in Fig. 1 (Tr7 and Tr8). Here there is no output transformer, so the loudspeaker impedance must be of a sufficiently high value to match into the emitter circuits of the two transistors.

An alternative 'transformer-less' push-pull output stage is shown in Fig. 2. This is sometimes called the 'd.c. series' output stage as distinct from the 'd.c. parallel' arrangement shown in Fig. 3. The latter uses a loudspeaker transformer in the normal manner, while the former uses neither a transformer nor centre-tapped speech coil, the push-pull effect being given by the centre tap on the batteries.

It is now fairly clear why it would be difficult for the manufacturers to stipulate a 'standard' output in terms of power in relation to servicing operations on their sets. It is far easier to indicate an a.c. voltage across the speech coil, for then the impedance does not need to be considered after the first computation at the factory.

However, if neither a voltage reference nor impedance value is given, the power output of most class B output stages can be discovered in a very interesting manner. The idea is first to measure the current consumed by the output stages under zero signal conditions, then measure the current when a signal is applied to give the required audio output. The difference in current (in milliamperes) should then be multiplied by three-quarters of the battery voltage and the resulting figure will approximate to the power output in milliwatts.

Let us take an example. Suppose we find that the current increases by 20mA when a signal is applied and that the set is working from an 8V battery. Three-quarters of 8 is 6 and 6 times 20 is 120. Thus, the output power could be taken as 120mW. This is not highly accurate, of course, but it is sufficiently

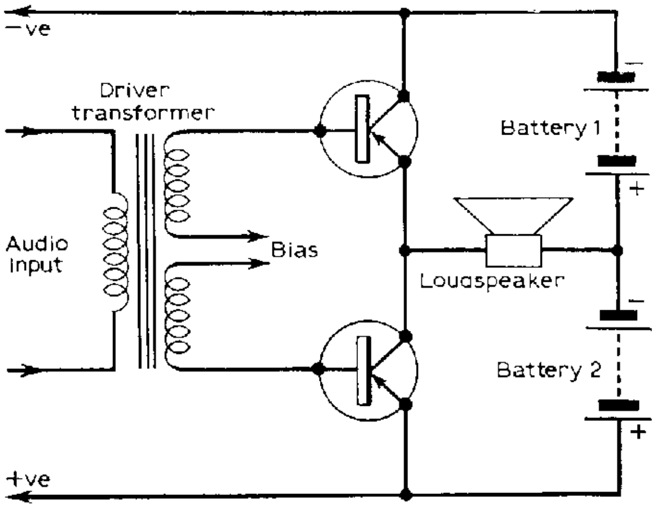


Fig. 2—An alternative transformer-less output stage using a tap on the battery system instead of on the speech coil. This is sometimes called a 'd.c. series' output stage.

accurate for most servicing activities provided (a) that the output stage is of the true class B type and of d.c. parallel mode and (b) that the signal applied is a pure sine wave.

Generator Input Loading

The sensitivity of a receiver (or section of a receiver) is usually given in terms of signal required to produce a 'standard' output when the signal is modulated to a depth of 30% at 400c/s. This is easy to check with valve equipment where one can be fairly sure that the voltage given on the attenuator of the signal generator and r.f. output controls is being applied to the set or circuits under test.

With transistorised equipment the generator may have to be 'loaded' by, say, 500Ω to feed into the base circuit of a transistor stage. There is no difficulty in securing such a loading, since if the signal generator is normally loaded at, say, 70Ω then it is necessary simply to include a series resistor of 430Ω to increase the impedance to 500Ω, as shown in Fig. 4, but now what happens to the output voltage?

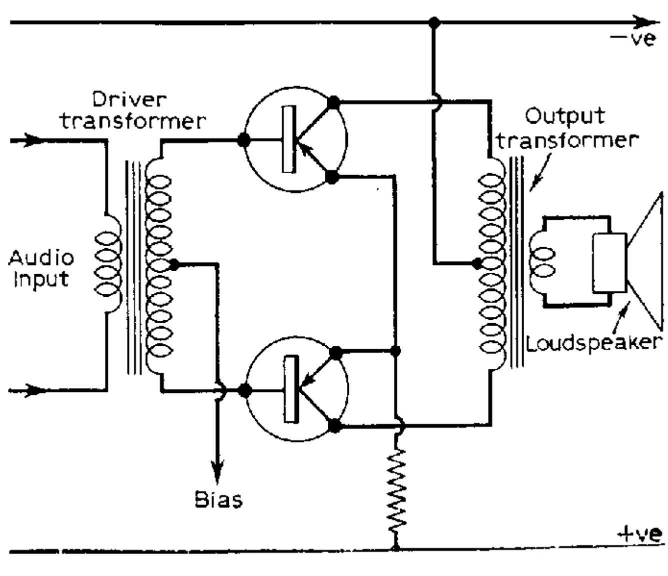
Let us suppose that the generator produces the voltage indicated on the attenuator across 70Ω within the instrument (e.g. without an external 70Ω load resistor). The signal voltage is thus being applied across the 430Ω resistor and the 500Ω load in series, and the load (i.e. the input circuits of the set) will receive only approximately half the voltage indicated on r.f. controls of the generator. On the other hand, if the generator requires an external 70Ω load to give the signal voltage outputs indicated on the r.f. controls, then by running the generator without a load the voltage across the two series resistive elements will be twice that indicated, and the signal across the 500Ω load will be approximately equal to that indicated on the r.f. controls.

There is another very important point and that is the signal output lead of the signal generator must be isolated from the transistor circuits by two capacitors (one in each conductor). If such isolation is not adopted there is a strong possibility that d.c. continuity through the attenuator and r.f. controls of the generator will disturb the base current of the stage to which the generator is connected.

General Tests

Experience has shown that there are two major causes of trouble in transistorised sets, these being poor insulation in interstage coupling electrolytics and alteration in value of the base potential-divider resistors. Transistors sometimes fail when they are fairly new, but once they have been in operation

Fig. 3—The more conventional output stage, using a loudspeaker transformer. This is a 'd.c. parallel' arrangement, as distinct from the series circuit of Fig. 2.



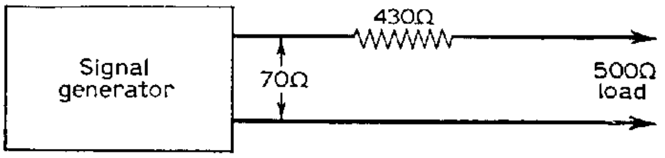


Fig. 4—How the output of a signal generator may be 'padded' to give a higher impedance. Care must be taken when using this arrangement, however, since some of the signal voltage is lost across the series resistor—see text.

for some time they rarely give trouble unless, of course, they are damaged or overloaded by incorrect servicing techniques.

A good idea of the operation of the various stages can be gleaned simply by measuring the voltages across the emitter resistors and comparing them with the voltages given in the manual or service sheet. The voltage is normally fairly low here, usually around one volt or below, hence the reason for a low-reading voltmeter.

Very low or zero voltage across an emitter resistor should lead to a check of the base bias and collector voltage, and if these are normal then one can be fairly certain that the associated transistor is faulty—probably open-circuited. A reading which is higher than normal should, again, lead to a check of the base bias, for excessive base current could cause the symptom. And this may be promoted either by a leak in a coupling electrolytic (in an a.f. stage, for example) or by an alteration in value of one of the base resistors.

Specific Tests

Signal tracing is practised extensively in servicing transistorised equipment and can quickly lead to the stage which is at fault. There are two methods, one by using the loudspeaker as the 'signal detector' and the other by using an r.f. probe and a.f. amplifier. In the latter the signal (modulated) is applied to the input of the set, and the detector probe used to extract the signal at various points in the circuit towards the loudspeaker. The detected signal is then applied to an a.f. amplifier and separate loudspeaker. By moving the probe along the circuit the point at which the signal fails to pass can quickly be discovered.

The other method requires the actual signal (from a signal generator) to be moved from point to point in the set, starting at a.f. in the output stage, until a point is reached where the signal fails to pass through the stages under test. As an example, suppose that an a.f. signal could be heard in the loudspeaker when applied to the base of Tr6 in Fig. 1, and yet could not be heard when applied to the base of Tr5. As Tr5 is the detector stage (dealing also with a.f.) it would follow that the trouble lies either in Tr5 itself or in an associated component.

Similarly, if an i.f. signal could be passed through the set from the base of Tr4 but not from the base of Tr3, then the trouble would lie in Tr3 stage or associated components. If an i.f. signal could be passed through the set from Tr1 base circuit, and yet the set is completely dead to aerial signals, the trouble would almost certainly lie in the oscillator section of Tr1. Tr1 itself could be defective, but the most likely cause would be either in the oscillator coil or associated components or in the base or emitter components.

Distortion in the output should first lead to a check of the battery voltage and, if it is normal, to a check of the two push-pull output transistors. Motor-boating is also invariably caused by a worn battery, but the trouble may be aggravated by a low value or open-circuit h.t. by-pass capacitor such as C1 in Fig. 1.

Impaired battery life should also lead to a check of C1, for this could be slightly leaky without detracting too much from the efficiency of decoupling. Other h.t. decoupling capacitors such as C2 and C3 in the circuit should also be checked.

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