

# TRANSISTOR SUPERHET RECEIVERS

by

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# **TRANSISTOR SUPERHET RECEIVERS**

**(Transistor Receivers Book 2)**

***By Clive Sinclair***

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## CHAPTER ONE

**THE TRANSISTOR SUPERHET**

Of all the many types of receivers that have been designed the superhet, invented by Armstrong in 1918, is almost the only type in common commercial use today. This applies as much to transistors as it does to valves. There are several excellent reasons for this unique state of affairs. First of all, the well designed superhet has better sensitivity and selectivity than any other type, furthermore the quality is also first class. Secondly, however many stages of pre-demodulation amplification may be used, only two variably tuned stages are necessary. The disadvantages are mainly difficulty of alignment and fairly high cost.

One of the disadvantages of the T.R.F. type of receiver is the dependance of its gain upon frequency. The superhet attempts to overcome this by changing the frequency of the incoming signal to a certain fixed value and then amplifying this intermediate frequency with fixed tuned circuits.

**HOW THE SUPERHET WORKS**

The incoming modulated R.F. signal is selected by means of a normal parallel tuned circuit. It is then combined with another, usually higher, frequency generated inside the receiver. The combination of these two radio frequencies contains one frequency modulated with a frequency equal to the sum of the original frequencies and another equal to the difference between them. These are demodulated giving the sum and the difference of the original signals.

The I.F. amplifier is tuned to the difference frequency and consists of one or more fixed tuned stages of R.F. amplification. As the input to the I.F. amplifier must always be of the same frequency (usually between 450 and 470 kc/s) the oscillator has to be varied in step with the first tuned circuit. If the receiver is designed to tune from 800 kc/s to 1.5 mc/s then the oscillator frequency must range from 800 + 450 kc/s to 1.5 mc/s + 450 kc/s that is from 1.25 mc/s to 1.95 mc/s and, if the required signal has a frequency of  $x$  mc/s the oscillator frequency must always be  $x + 0.45$  mc/s.

The block diagram of a transistor superhet is shown in fig. 1. Basically it is the same as

the valve superhet. The differences that do exist are entirely from the design point of view, the mode of operation of each circuit section remaining the same.

Before the complete circuit diagrams shown later in the book can be understood, the advantages and disadvantages of all the different types of circuits must be fully appreciated. This chapter, therefore, splits up the superhet into its various units and discusses each one as a separate circuit. At the end of the book there is a section describing the transistor itself and those who have had no previous experience might like to read this first.

**THE R.F. AMPLIFIER**

An R.F. amplifier is sometimes used before the frequency changer to increase the sensitivity of the receiver and to reduce the effective background noise. Either the common emitter or common base configuration may be used though the latter is very uncommon as it gives less gain. Sometimes the R.F. amplifier is used to improve the selectivity and thus reduce the image frequency response, but this may also be achieved by use of another I.F. stage.

To prevent the transistor from being overloaded by too strong a signal, A.G.C. is usually applied to the base. The A.G.C., which is taken from the detector, varies the base bias in accordance with the signal strength thus controlling the gain of the amplifier.

A typical example of the r.f. amplifier is shown in fig. 1. The output is fed to the converter stage and the tuning condensers must be coupled to the oscillator making a three gang condenser necessary.

The signal is picked up by a ferrite rod or aerial. As the transistor has a low input impedance this must be tapped down or a secondary used to couple the signal to the base. The turns ratio of this R.F. transformer should be about five to one.

The base bias is supplied by the potentiometer R1, R2 which is designed so that the emitter current is about 500 microamps. C1 bypasses the R.F. and has a value of about 0.1 mfd. R3 is inserted in the emitter lead to feed back out

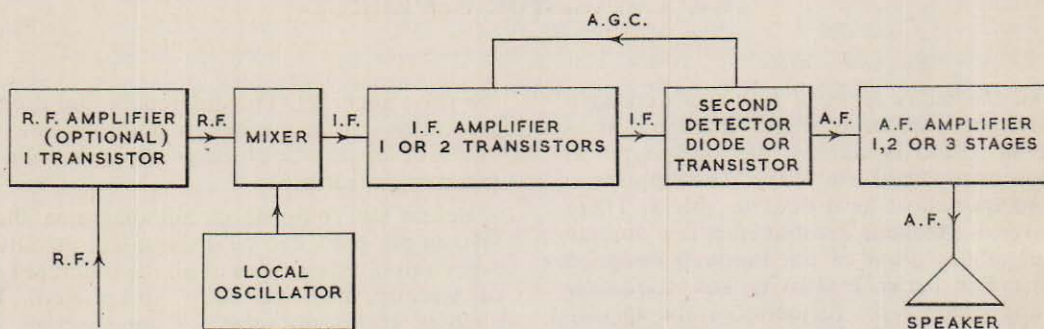


Fig. 1 Block Diagram of the Transistor Superhet

of phase d.c. to the input so as to d.c. stabilise the transistor. It is bypassed by C2, about 0.1 mfd. again, to prevent negative feedback at signal frequencies.

To prevent oscillation due to the internal resistive and capacitive feed back inside the transistor, neutralisation is often used. This is achieved by feeding back a portion of the output signal comparable but of opposite phase to that of the transistor via C3 and R4. The value of the components varies from transistor to transistor and frequently C3 is in the form of a trimmer so that adjustment may be made when a transistor is replaced

The output is coupled to the next stage via an R.F. transformer with a turns ratio of about 5 to 1. This is necessary if the maximum gain is to be obtained as the output impedance of a transistor is about 20 times the input impedance. Furthermore, taking the output from the collector directly into a low impedance source would load down the tuned circuit and reduce the selectivity.

A well designed R.F. stage of this type should give a power gain of about 20 db. Higher gains than this may be obtained with transistors which

combine a very high beta with a cut-off frequency of 15 mc/s or more such as the OC44. With the Mullard OC44 gains of up to 25 db are possible in the R.F. stage.

The use of a normal R.F. amplifier has one or two disadvantages. It adds to the cost of a receiver both from the point of view of extra component cost and increased alignment difficulty. The main disadvantage however, as far as the small receiver is concerned, is that a three gang tuning condenser must be used which is rather a bulky component. For these reasons the R.F. amplifier is mainly confined to car radios where extra sensitivity is essential.

Fig. 2 shows another type of R.F. amplifier which does not need a three gang condenser. The output from the amplifier is not tuned but is resistance-capacity coupled to the converter. This type of circuit is fairly economical as no R.F. transformer is required. It does not, however, improve the selectivity and its gain is only about 15 db at the most. This is sufficient gain to noticeably improve the sensitivity. The gain of the amplifier varies fairly considerably with frequency but this may be compensated for by inserting a series peaking coil between the collector and the converter.

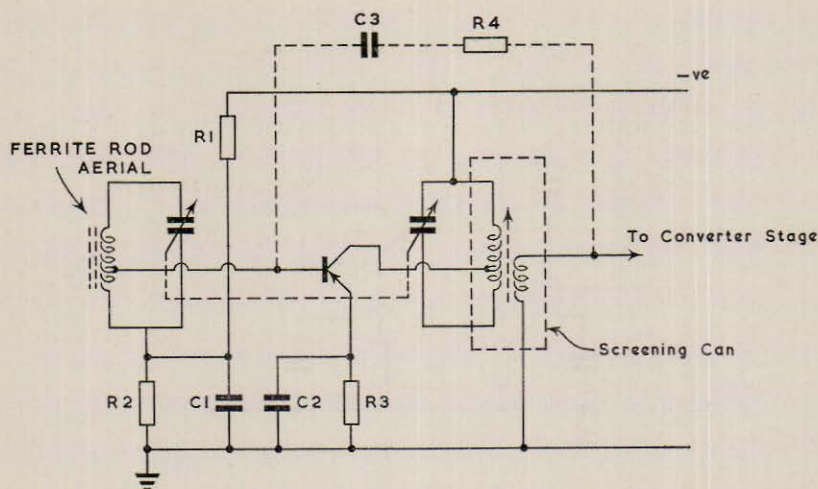


Fig. 2 Tuned R.F. or Preselector Stage

Receivers for certain applications do not require the sensitivity and selectivity provided by two stages of I.F. amplification and the untuned R.F. stage combined with a single stage of I.F. amplification may find a use here. This would save the expense of one I.F. transformer and, also, a small amount of space. If the R.F. amplifier is reflexed to provide A.F. gain, the saving is even greater. This question of reflexing will be discussed more fully in the I.F. amplifier section where it finds its most important application.

### THE FREQUENCY CHANGER

There are two main types of frequency changer or converter. There is the type that uses two transistors, one as a mixer and the other as a local oscillator, and there is the type that combines these two functions and uses only a single transistor in an autodyne circuit.

Fig. 4 shows a typical converter using a separate oscillator and mixer. The oscillator is of the Hartley type using a tapped coil and separate secondary. The collector is tapped about one third of the way down the coil in

order to decrease the effect of collector capacitances and to improve the impedance matching, stability and tracking properties. Almost any form of sinusoidal oscillator may be used so long as it is capable of producing sufficient power to overcome the losses due to damping by the mixer.

The output from the oscillator is coupled to the mixer via C1 and the secondary of the oscillator coil. The signal frequency is simultaneously applied to the base from the secondary of the ferrite rod aerial. The oscillator may also be fed to the emitter but this incurs a heavier loss of power. The two signals are mixed in the base-emitter diode and the sum and difference frequencies appear, amplified, at the collector. The difference frequency is selected by the tuned circuit and coupled to the I.F. amplifier by means of the secondary winding which may also be tuned.

The injection voltage to the base of the mixer depends upon the setting of the tuning control and varies between 0.01 and 0.03 volts. The collector current varies between 250  $\mu$ a. and 1 ma.



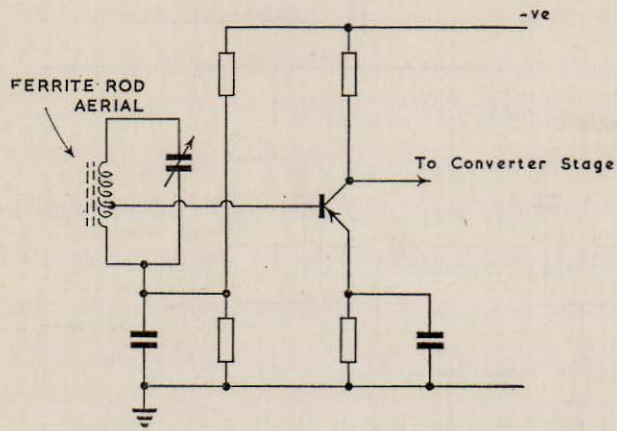


Fig. 3 Basic Circuit for an untuned R.F. Stage

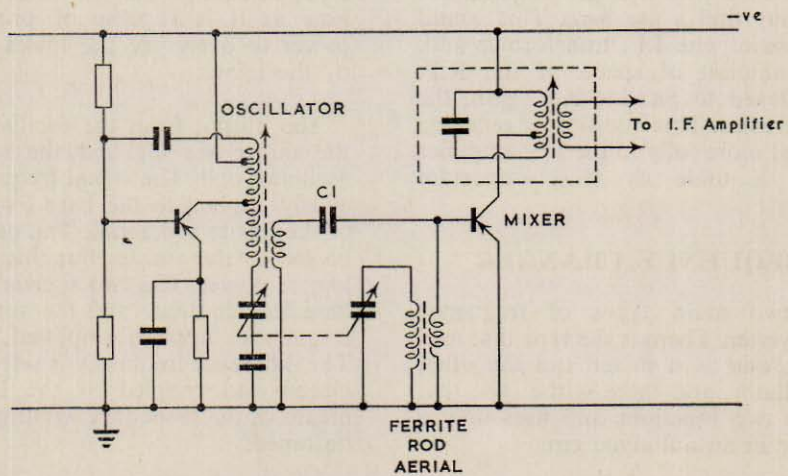


Fig. 4 Typical Frequency Changer using separate Oscillator and Mixer

The conversion gain achieved with this circuit should be between 15 and 20 db with high gain—high frequency transistors.

The type of circuit just described is uneconomical in that it uses two transistors. Furthermore the frequency stability is inferior to that of the autodyne and the gain is no better. The various types of autodyne converter are shown in figs. 5, 6, 7 and 8. Disregarding fig. 8 which will be dealt with later, they perform three separate functions. They generate the local oscillation, mix the two frequencies and act as I.F. amplifiers.

Consider fig. 5. The oscillator operates as follows: There is always a movement of electrons in the base. When the receiver is turned on, this movement, known as noise, is amplified and appears in the collector winding of the oscillator coil, L2. A similar signal is induced in L3 and sets up oscillations at the resonant frequency of the tuned circuit. This signal is fed to the emitter via C1. If L2 and L3 are wound so that there is no overall phase change the signals will again appear at the collector and the oscillation will be maintained. L3 is, in effect, an auto transformer which ensures a proper match between the high impedance tuned circuit and the relatively low impedance of the emitter circuit. In fig. 6 the same result is

achieved by means of a third winding on the same former. Thus the required local oscillation is generated by the transistor operating in the common base mode. As the signals are fed from the tuned circuit to the emitter this type of converter is known as the emitter injected autodyne.

The required signal frequency is selected by the tuned circuit formed by the ferrite rod aerial and C2. The winding of the aerial is tapped to match the low impedance input of the transistor. Alternatively a secondary with a small number of turns may be wound onto the aerial as in fig. 6.

At low current levels the amplification of the transistor is not linear so that detection or mixer action takes place in the base-emitter junction. The frequencies that result from this mixer action are amplified and appear at the collector. These frequencies will be:

- (1) The local oscillator frequency.
- (2) The signal frequency.
- (3) The sum of these two.
- (4) The difference between them.

The primary of the I.F. transformer L4 is tuned by C3 to the difference between the two frequencies. As C4 is mechanically coupled to C2, this difference is constant, usually about 455 kc/s.

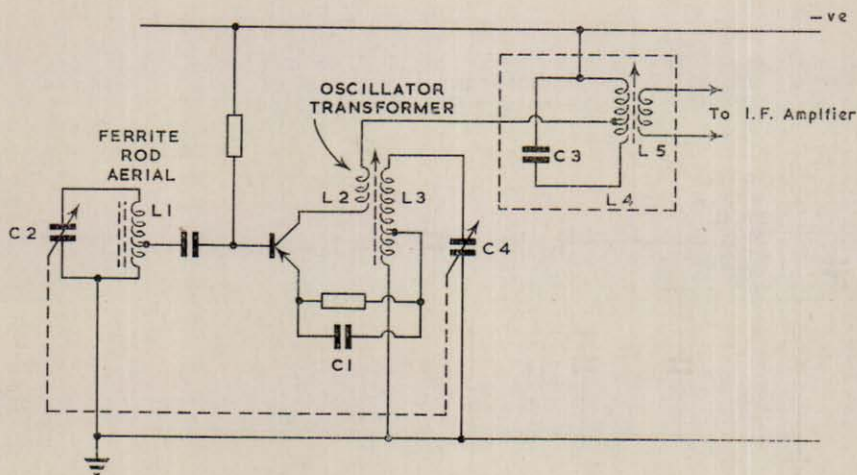


Fig. 5 A commonly used type of Autodyne Converter with Emitter Injection

In fig. 7 two more variations of the autodyne are shown. These are what is known as the base injected autodyne because the local oscillator signal is fed to the base rather than to the emitter. In this type of circuit the transistor operates as a common emitter unit both as a mixer and as an oscillator, otherwise the operation is exactly the same as in figs. 6 and 7. From the performance point of view there is little to choose between the two types but the base injected variety requires a transistor having a rather high cut-off frequency. This is because any transistor will oscillate at a much higher frequency in the common base mode than it will in the common emitter mode. The mixer action, however, requires a fairly high frequency transistor so the overall difference is only slight. In Great Britain emitter injection appears to be almost universal whilst the Japanese receivers mainly use base injection. Both types are used in the United States.

Fig. 8 shows a rather unusual but nevertheless practical type of circuit. The transistor operates as a converter in the normal way giving the usual conversion gain of about 20 db. The output is then amplified by the I.F. stages and demodulated. The audio output is then fed back to the base of the converter transistor which

provides about 20 db. of audio amplification. R1 provides the audio load. C2 has to be a high value electrolytic to prevent degeneration at audio frequencies. C1 and C3 must be carefully selected so as to bypass most of the R.F. without offering a low impedance of the A.F. signal. Typical values for these components are 0.01 mfd.

Although the reflex converter has not so far been used in a commercial receiver, it is a rather attractive possibility and may find a place for itself in the pocket type of receiver where component economy is important both to reduce the size and the cost.

### THE I.F. AMPLIFIER

The output from the converter is fed to an I.F. amplifier which may consist of 1, 2 or 3 stages. The choice depends upon the sensitivity and selectivity required by the designer. The majority of receivers use two I.F. stages with single tuned I.F. transformers but a well designed receiver with only a single I.F. stage is capable of very fair performance.

Either the grounded emitter or the grounded base configuration may be used. Although the former gives higher gain and is far more popular it usually requires neutralisation while the grounded base type does not.

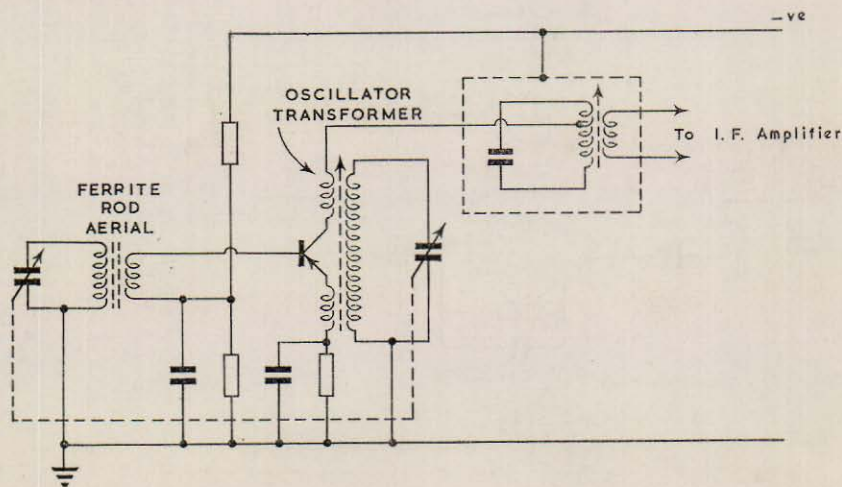


Fig. 6 An alternative type of Emitter Injected Autodyne Converter

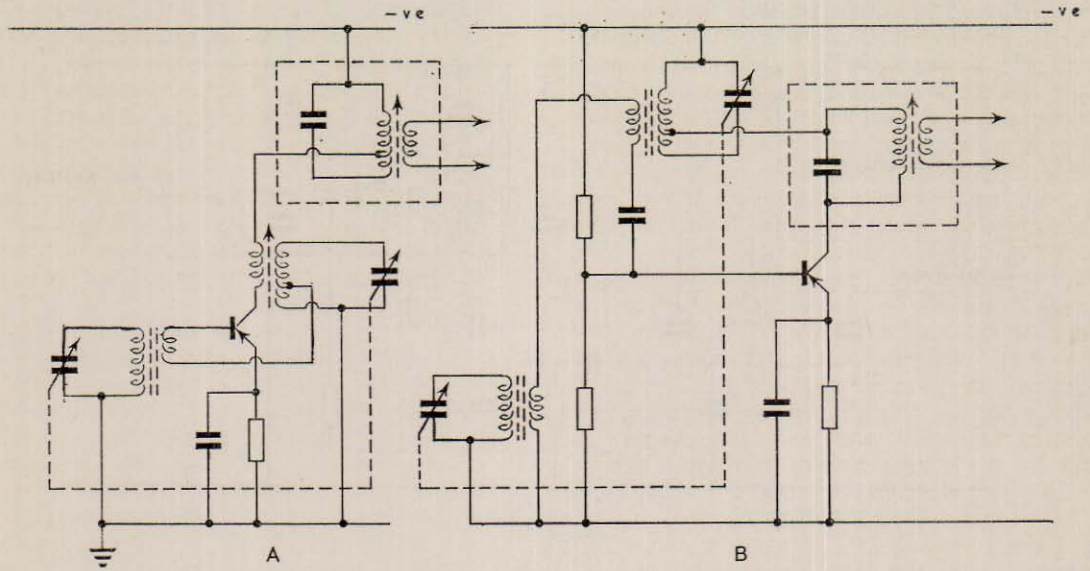


Fig. 7 Two forms of the Base Injected Autodyne Converter

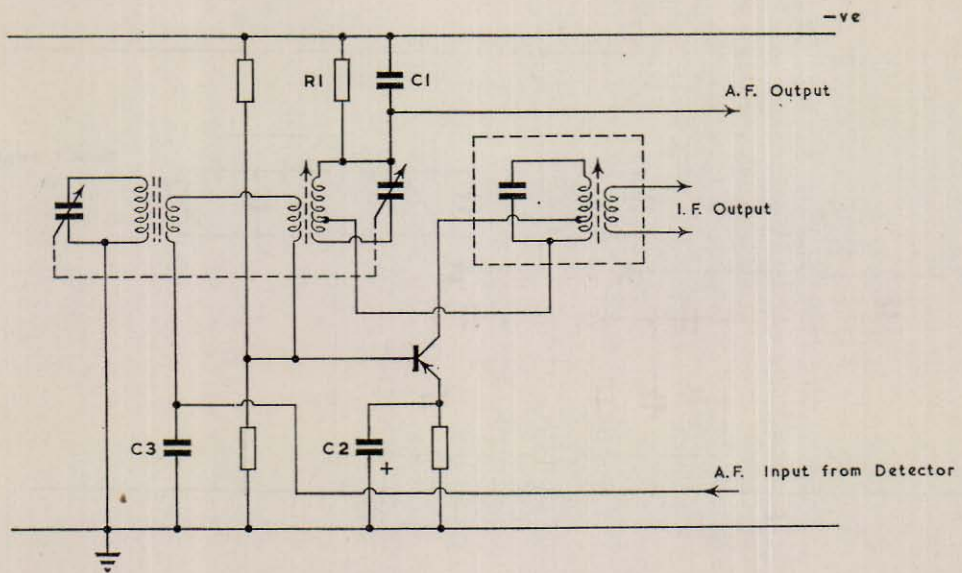


Fig 8 Base Injected Autodyne Converter reflexed to provide A.F. Gain

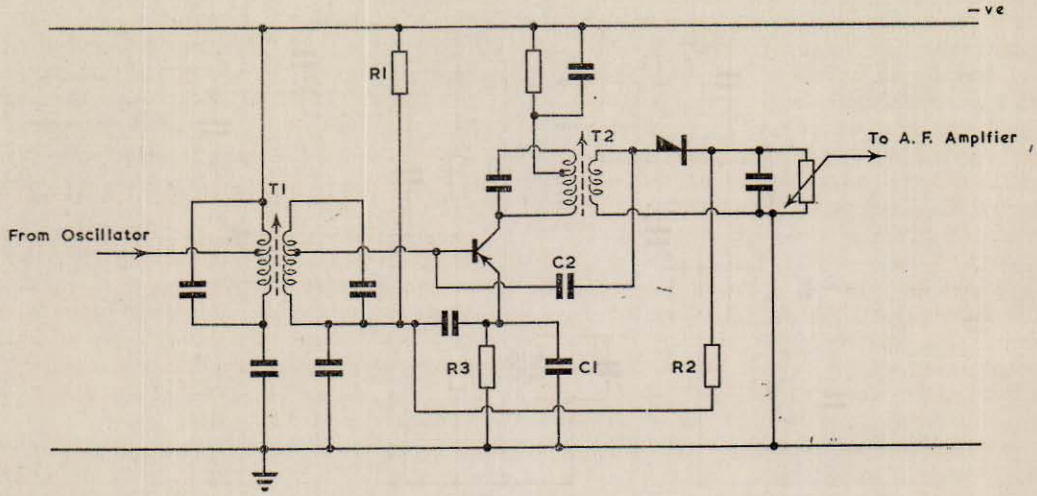


Fig. 9 Single Stage neutralized I.F. Amplifier with double-tuned I.F. Transformer

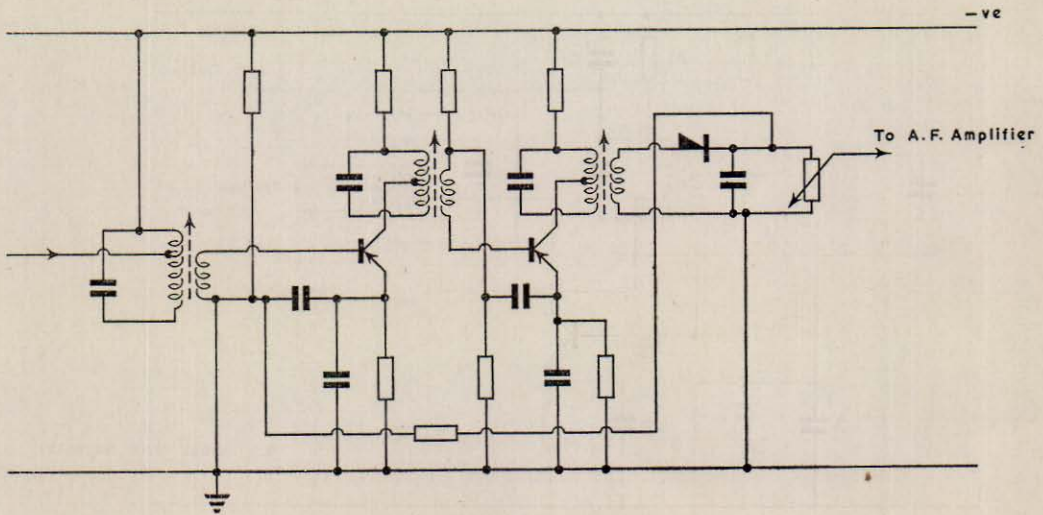


Fig. 10 Two Stage I.F. Amplifier with single tuned I.F. Transformers

Fig. 9 shows a typical single stage grounded emitter amplifier. The output from the converter is selected by a double tuned I.F. transformer T1. Double tuning is used to improve the adjacent channel rejection and is usually unnecessary with two stage amplifiers. The transformer has to be carefully designed so as to match the output impedance from one stage to the far lower input impedance of the next stage. A fairly small mismatch may result in a considerable loss of gain. The collector is usually connected to a tapping on the primary to reduce the effect of changing the transistor for another of the same type.

The collector current is normally stabilised by the potential divider R1, R2 and the resistance in the emitter lead R3. To prevent overloading by strong signals, however, A.G.C. is applied from the detector. The variation in the voltage from the detector controls the base bias which, on strong signals, reduces the collector current of the stage. When two stages of I.F. amplification are used A.G.C. is applied to the first stage only which has a collector current of about 0.5 ma. The second stage has its collector current controlled at about 1 ma. so that it is always providing maximum gain.

I.F. amplifiers require stabilisation with most types of transistor now in use. This is achieved

in the same way as in the R.F. amplifier. As the internal resistive feed back of the transistor is very small it is usually ignored, the external negative feed back being entirely capacitive as provided by C2 in fig. 9.

Fig. 11 shows the basic form of a common base I.F. amplifier. Although the power gain per stage is lower the noise level is also reduced and the maximum frequency of operation is much higher for any given type of transistor.

#### THE REFLEX I.F.-A.F. AMPLIFIER

The reflex amplifier was devised and used in the early days of valve receivers when the saving of the price of a valve was very considerable. With transistors, the reflex circuit is much less troublesome because the amount of feed back required to produce oscillation is far greater and so there is little likelihood of this finding its way back with the A.F. signal.

The circuit most usually used is shown in fig. 12. The A.F. output from the detector is fed back through R2 and C1 to the base of the transistor. It has to pass through the secondary of the I.F. transformer but, as this consists of only a few turns, it offers a negligible impedance to the A.F. signal. The audio output is developed across T1 which is bypassed at radio frequencies by C2. The collector current should

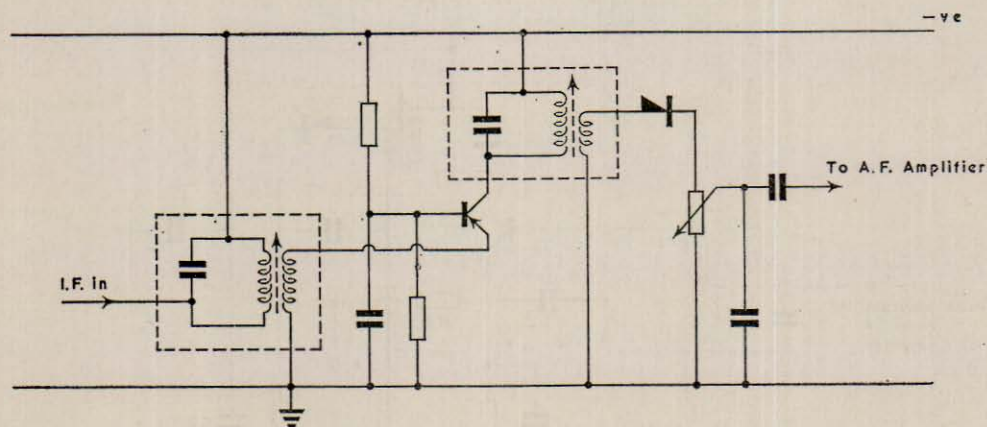


Fig.11 A typical form of Common Base I.F. Amplifier

be about 1 ma. If only one stage of I.F. amplification is used then C1 will probably be in parallel with R2 so that the diode is D.C. coupled to the transistor and thus provides A.G.C. The disadvantage with this is that the A.F. gain varies with the R.F. gain.

The power gain of a normal I.F. stage is about 35 db. and the gain of a reflex stage is between 30 and 32 db. for I.F. and about 25 to 30 db. for the A.F. If transformers are used to match the output from the detector to the base and from the collector to the output stage the A.F. gain may be increased to nearly 40 db.

From this it may be seen that the reflex amplifier saves power, space and expense. It is considerably more difficult to design, however once an operating circuit has been designed no real problems arise in reproducing it.

### USING A TRANSISTOR FOR DETECTION

The majority of transistor superhets use a germanium diode for detection and automatic gain control. This type of circuit was illustrated by the I.F. amplifier diagrams. If an N.P.N. transistor is used in the I.F. stages then the diode should be reversed.

Although the diode performs the function very well and is economical, a transistor may

also be used with several advantages.

Fig. 13 shows a class B power detector which not only demodulates the signal but also supplies a power gain of about 10 db. Because of this gain, which is effective at d.c. as well as A.F., the provision of a sufficiently high level of A.G.C. is simplified.

The output from the detector consists of the A.F. signal, a certain amount of residual I.F. signal, and a d.c. potential. The latter is selected by R2, C2 and fed back to the first I.F. stage to provide A.G.C. Most of the audio output is developed across R1 which is a potentiometer used as the volume control of the receiver. The required amount of audio is taken from this potentiometer to the audio amplifier.

A Surface Barrier transistor such as those made by Semiconductors Ltd., performs very well indeed as a detector providing a power gain of up to 20 db. from as little as 3 volts power supply. The reasons for the superiority of the surface barrier transistor in this type of circuit will be discussed in the section devoted to components.

The way in which a transistor operates as a detector is very simple. The base bias is controlled so that the transistor operates near the point of collector cut-off. In this condition the transistor operates in a nonlinear portion of the

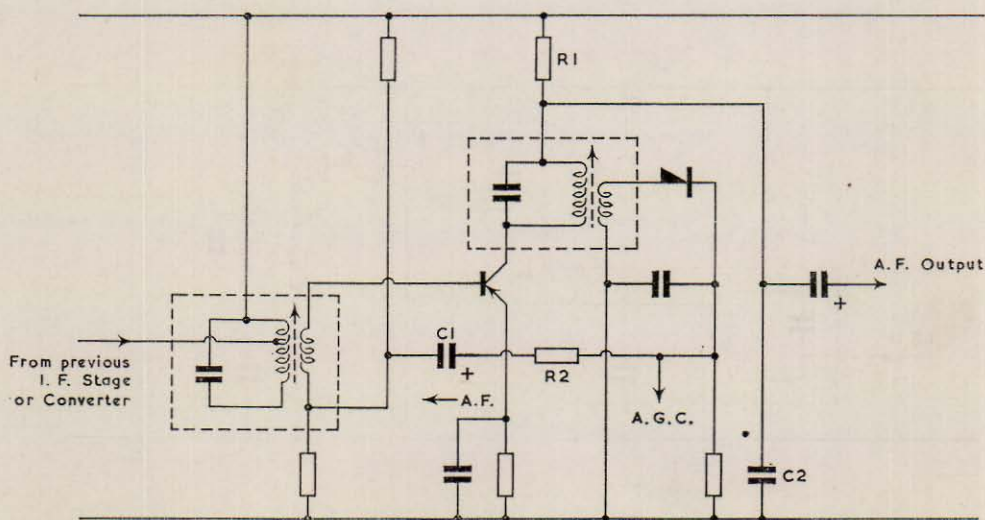


Fig. 12 Common Emitter Reflex I.F.-A.F. Amplifier

transfer curve so that detection takes place in the emitter diode. When there is no signal applied to the base the output of the transistor has a very high resistance and the collector is almost at the potential of the negative side of the battery. When a signal is applied, however, the output resistance drops and lowers the collector voltage. It is this change in voltage that is used to provide the A.G.C.

When only one stage of I.F. amplification is used the detector is sometimes made regenerative so that it provides some I.F. gain. In this case the collector current should be slightly higher to increase the I.F. gain of the transistor even though this means a slight reduction in detection efficiency. Regeneration is usually applied by means of a feedback loop. Circuit diagrams of the many different types of regenerative detector are given in "Practical Transistor Receivers Book I" published by the publishers of this book.

**THE A.F. AMPLIFIER**

All the units so far described may be used in any broadcast band superhet irrespective of the application. The audio amplifier however, must be chosen carefully to suit the type of receiver required. It is no use putting a 15 mw. output stage in a car radio.

When designing an audio section the following considerations are most likely to govern the choice of circuit. Firstly it must be decided what level of output power is required, this may be any value from 1 mw. for a wrist or small pocket receiver feeding an earpiece, to 5 or even 10 watts for a powerful car radio. Having decided what kind of output is required the power gain needed to amplify the small output from the detector must be determined and this dictates the number of stages. Consideration must also be given to the amount of distortion that can be tolerated. Finally there is the very important point of power consumption. Most of the drain on the battery is due to the driver and output stages, the R.F. section consuming a total of only about 2½ ma. It is important to realise that the circuit which uses the fewest transistors is not necessarily the most economical from the power point of view.

Fig. 14 illustrates an extremely popular form of audio section. The input is taken from the receiver volume control which acts as a load to the detector. The signal is fed to the driver transistor which is a high gain common emitter amplifier. The load for TR1 is the primary of T1 the phase splitting transformer. The secondary of T1 is centre tapped and feeds into the

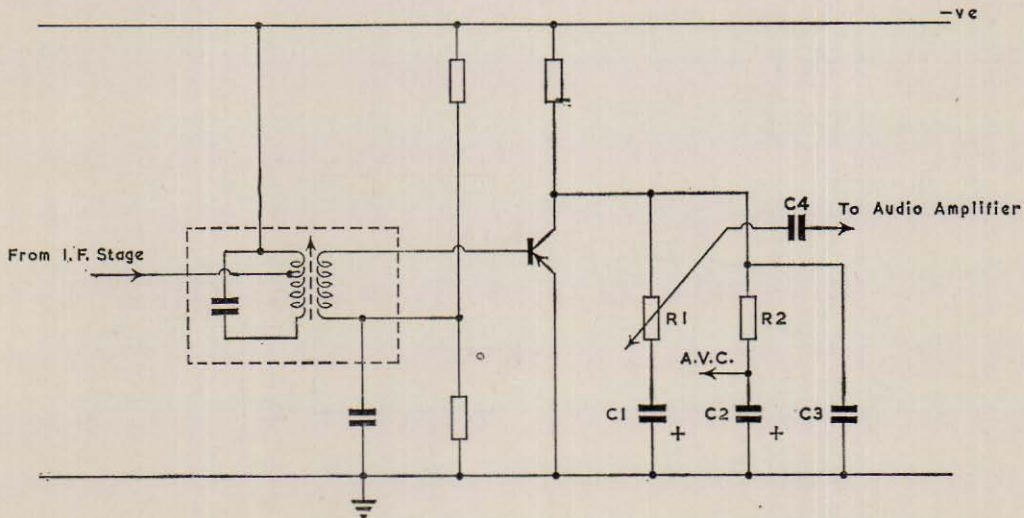


Fig.13 Typical Class B Power Detector



symmetrical output stage consisting of TR2 and TR3. These two transistors form a common emitter, Class B, push-pull amplifier. The reason for using the far more expensive Class B type of output, even in many pocket receivers, is the superior battery economy. The maximum efficiency of a Class B stage is nearly 80% compared with less than 50% for a Class A output stage. With no signal applied to a Class A stage the biasing is such that the dissipation is twice the amount of power that amplifier is capable of delivering to the load. With a Class B type, however, there is hardly any dissipation in the absence of a signal. Another advantage of this type is that it is capable of 5 times the output power that a Class A stage, using the same type of transistor, can deliver. Finally as the power consumption is directly proportional to the input signal instead of inversely proportional the actual difference in efficiency is far better than the maximum theoretical efficiency figures would seem to indicate. For example, if we assume that the average output level on speech or music is 25% of the peak output, then the Class B type will be about 5 times as efficient as the Class A. On the other hand the Class A type provides greater gain with transformer coupling and is

more economical on components. In the case of a car radio, where battery economy is relatively unimportant, the Class A type, using a power transistor is usually used. It is also used when the required output is only a few milliwatts as in this case the consumption will be so low anyway that the added cost of the Class B would be unjustifiable.

In the circuit shown the transistors are used in the common emitter mode. Although this form of connection incurs greater distortion than the common collector type it is almost invariably used because of the increased gain. Unless the two transistors have fairly similar characteristics, distortion can arise. For this reason, transistors designed for output stages, such as the OC72, are often sold in matched pairs. If one pair breaks down it is often necessary to replace them both, but in many cases the effects of a mismatch are minimised by the application of about 10 db. of negative feedback.

The primary of the output transformer is centre tapped and, as the power supply for the two transistors travels through this in opposite directions, there is no resultant d.c. in the trans-

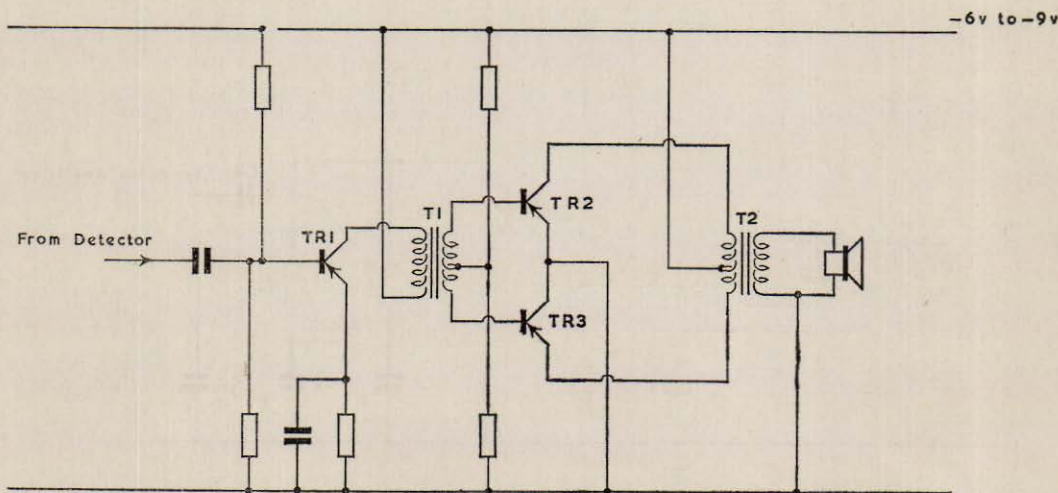


Fig. 14 A Typical Audio section using a Class B push-pull Output Stage

former winding. This means that the size of the transformer may be small compared with a Class A output transformer handling a similar amount of A.F. power. T2 may be, and often is, replaced by a centre tapped loudspeaker of suitable impedance. As there is no standing d.c. the cone will not be permanently displaced.

Fig. 15 shows another type of amplifier with a Class B output stage. In this case, however, the output is single ended so that no centre tapped transformer or loudspeaker is required. Using a centre tapped speaker in the symmetrical type described above results in a halving of the acoustical efficiency, or, alternatively, the loss inevitable in the use of a transformer is incurred. This means that the single ended type is about twice as efficient from the point of view of acoustical power delivered for a given power consumption. As the two transistors are in series across the power supply, each transistor operates from only half the total voltage. However, for the same acoustical output and using the same total battery voltage, the single ended circuit still uses only slightly more than half the power used by the symmetrical circuit. For this reason the fig. 15 type of circuit is the most suitable for the very small pocket types of receiver now being made.

The impedance of the speaker usually lies between 40 and 80 ohms. Two forms of connection are possible. If there is no objection to the use of two batteries then the type designated by the letter A may be used, but if for some reason only a single battery is used then the speaker must be connected in series with a high value electrolytic capacitor, C1, which should have a value of at least 100 mfd. if it is to offer a high impedance to the lower frequencies. A small amount of negative feed back is applied via R1 to reduce the distortion.

The turns ratio of the interstage transformer will depend upon the transistors used and the output power. Both the primary and the two secondaries should have as low resistances as is possible with an inductance of about 5 henries.

Fig. 16 shows an interesting form of push-pull amplifier which requires neither an interstage transformer nor an output transformer. It makes use of the fact that an N.P.N. transistor requires a positive bias for the collector and the base whereas a P.N.P. transistor uses negative biases. This makes possible the design of complementary symmetrical circuits such as this one. The advantages of this circuit over those shown in figs. 14 and 15, are obviously economy of space and expense. The gain is less than the other

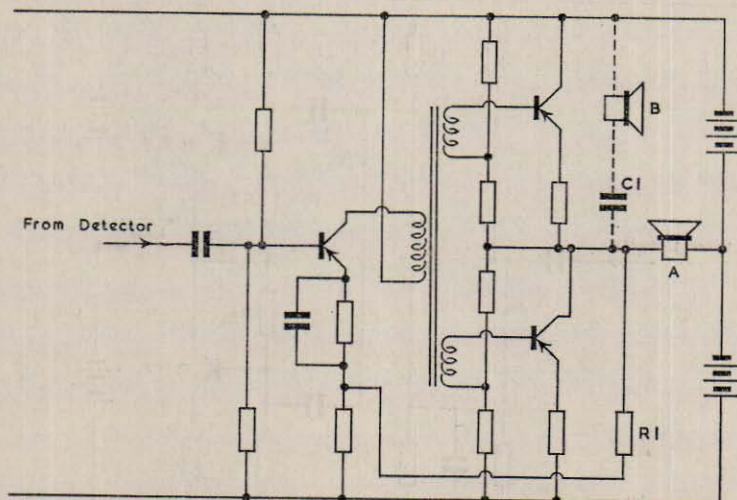


Fig. 15 Audio Section with single ended push-pull Output



	Class A	Class B push-pull
Available power gain	36 db	25 db
Maximum power output	2.5 watts	10 watts
Distortion at max. power output	3.5%	5%
Initial cost	x	nearly 2x

This table shows that the gain of the Class A stage is 11 db higher and the distortion is lower. The cost is only about half that of the Class B stage.

Now let us consider two similar receivers. The only difference between them being in the audio sections, the frequency changers, I.F. amplifiers and detectors are identical. We are not too worried about output, 2.5 watts will suit us just as well as 10 watts, after all, we are unlikely to need more than about 100 mw. output power most of the time. The output from the detectors is the same and we must provide sufficient gain before the output stages to drive them to their maximum output level when necessary. But the output level of the Class B stage is 6 db higher than that of the Class A stage so the rest of the audio section in the receiver using this type of output must supply

(36 - 25) + 6 db more power gain. That is another 17 db. This extra gain must either be provided by an additional stage of resistance-capacity coupled audio amplification or a transformer coupled stage must be used where an R-C stage would normally be sufficient. Whichever method is used, the final cost of the output stage of a receiver using Class B output will be more than twice that of the Class A type. For this reason the Class A output stage is sometimes used by manufacturers wishing to produce a cheap and compact receiver.

The amount of output power that may be obtained from a transistor is dependent upon the heat that can be dissipated. The question of suitable heat shunts will be discussed later but it is obvious that there is no room in an average portable receiver for more than a very small shunt. In a car radio, however, the output transistor may be fixed to a large metal heat shunt away from the rest of the receiver. In practice the transistor is frequently attached to the loudspeaker mounting. As a car has a large accumulator, which can supply several amps when necessary, the question of obtaining maximum power efficiency does not arise. Thus a Class A output stage, with a single high power transistor is frequently used.

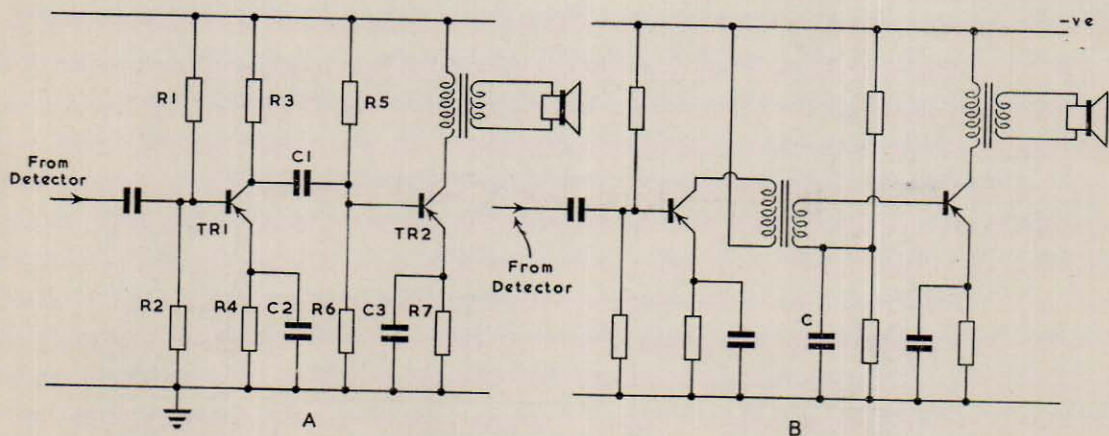


Fig. 17 Two common forms of single ended Output Audio Stages

Two types of audio amplifier with Class A output stages are shown in fig. 17. Type A uses resistance capacity coupling between the driver and the output stage and type B uses transformer coupling. R-C coupling gives better fidelity but considerably less gain. When high outputs are required transformer coupling is invariably used because R5 and R6 would have to have very low values to supply sufficient current to the base and they are effectively in parallel with the transistor input causing a considerable loss of power. The secondary of the interstage transformer in fig. 17B will have a very low impedance with high power transistors so the coupling capacitor C must have a very high value. Values of 500 muf. are not uncommon. Sometimes, when a heat shunt is required it is desirable to be able to connect the collector directly to the receiver chassis. In this case the rest of the receiver must be isolated from the chassis. Alternatively the negative side of the battery may be connected to the chassis and the output load connected in the emitter. The collector will then be at H.T. negative and may be connected to chassis via the outer case of the transistor which is usually in contact with collector in high power transistors. Sometimes the transistor casing is isolated from the chassis by a material which offers a high resistance to

electric current but a relatively low resistance to the conduction of heat. This system makes the previous precautions unnecessary.

Three, rather than two, stages of post detector amplification are often needed to provide sufficient gain. In this case a third transistor stage similar to the driver will normally be used. There is another very attractive possibility however. This is shown in fig. 18. Direct coupling is used between each stage. R2 provides the base current for TR3 and the collector current for TR2 whilst R1 provides the base current for TR2 and the collector current for TR1. Once the current in the output stage has been decided upon the current required by the base is known to be very nearly beta times the collector current where beta is the current gain of the transistor. Thus R1 and R2 are easily calculated if one remembers that the collector current of TR2 will be equal to the base current of TR3. Because direct coupling enables the transistors to amplify D.C. as well as A.C., the three transistors act as a single transistor having a beta equal to the products of the betas of TR1, TR2 and TR3 and leakage current equal to the leakage current of TR1. This means that the circuit may be stabilised as a single unit with a resultant saving of components. A considerable amount of d.c. feed back must be

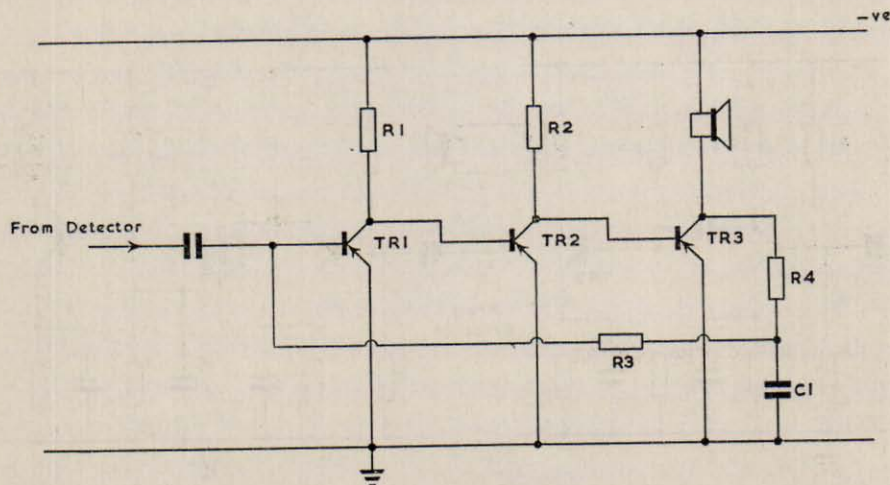


Fig. 18 Basic Three Stage Audio Section using Direct Coupling. High performance is obtained with few components

applied because of the very high beta (64,000 or more). In this case it has been provided by taking the base bias for TR1 from the collector of TR3 via R3 and R4 which should have a total value of about 10k ohms. To prevent these resistances from feeding back at audio frequencies a large value electrolytic, C1, grounds the A.F. feed back before it can reach TR1. Apart from the advantage of economy of components the circuit has excellent base frequency response due to the direct coupling. If the detector is also direct coupled to TR1 then the output from TR3 may be used to apply A.G.C. to the I.F. amplifier taken, perhaps, from the junction of R3, R4 and C1.

Fig. 19 shows another type of direct coupled amplifier that is sometimes met. TR1 is a common collector stage directly coupled to a common emitter stage, TR2. As TR1 is a common collector amplifier it has a high input impedance which matches the high output impedance of a transistor detector. TR1 and R1 form a potentiometer to supply the base bias to TR2. The voltage dropped across TR1 will vary with the input signal and thus vary the bias supplied to TR2.

A similar circuit in appearance is shown in fig 20. In this case, however, the driver tran-

sistor is an N.P.N. type and operates as a common emitter amplifier. The gain of fig. 20 is therefore comparable with the fig. 17A type of circuit, without the latter's expense. In some foreign receivers, the last I.F. stage is reflexed, and an N.P.N. transistor is used so that the I.F. transistor may be directly coupled to the output stage.

The number of transistors used in a superhet will vary from 3 or 4, for a cheap pocket portable, to 8 or more for a car radio. Some American car radios use as many as 13.

The examples of circuits that have been shown by no means exhaust all the possibilities. For example, it should be possible to reflex the I.F. stages so that they act as a Class A push-pull output stage. As better and more varied transistors become available, new types of circuit will certainly be developed and used. Various types of tetrode transistors show promise at high frequencies and these may form the basis for F.M. receivers within the next few years.

### THE COMPONENTS

R.F. Coils: The development of the ferrite rod aerial has greatly simplified the problem of

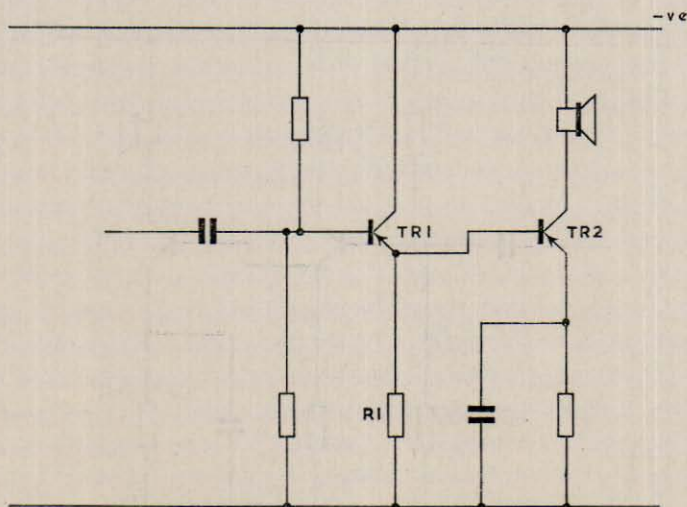


Fig.19 Two Stage direct-coupled A.F. Section

signal pick up in small portables. The signal supplied by a ferrite aerial depends upon the length and diameter of the rod. For this reason the rod should be as long as the size of the case will allow. Increasing the diameter will increase the Q of the tuned circuit so as large a diameter as possible should be used. Separate windings are made for the long and medium wavebands and these should be separated to avoid damping of one by the other. When the receiver is switched to the medium waveband the long-wave coil is usually shorted to prevent it from resonating at a frequency within the medium waveband by means of its own capacity. The inductance of the winding will depend on its position along the rod, maximum inductance being obtained when the coil is exactly in the centre. This property is used by winding the coil on a sleeve which can slide freely along the rod so that the inductance may be varied when trimming the receiver. When the correct position is found, the coil is anchored by a blob of wax or glue.

**Audio Transformers:** These differ from those used in valve circuits only in that their resistances must be much lower owing to the low impedances involved, and their impedances need not be so high. Interstage transformers must

match an output impedance of about 20 k ohms to an input impedance of about 1 k ohm thus their turns ratio must be about  $\sqrt{20} : 1$  or about 4.5 : 1. The turns ratio of the output will depend upon the speaker used.

**Resistors:** Most of the resistors in a transistor superhet never have to dissipate more than a few milliwatts so that the question of power rating need not be considered. Although resistors are now made with ratings as low as 1/30 of a watt, the type most generally used is the standard  $\frac{1}{4}$  watt size as this is, at present, the most economical. The variable resistance used as the volume control is frequently of the rim control or hearing aid type usually incorporating a single pole switch. This type is used in preference to the spindle control type because of its smaller size, lighter weight and the ease with which it may be attached to a printed circuit board.

**Capacitors:** Because of the low input and output impedances of the transistor compared with those of the valve, the value of the capacitors must, in general, be higher if they are not to impede the signal more than a small amount. The coupling and de-coupling capacitors in the audio section usually have a value

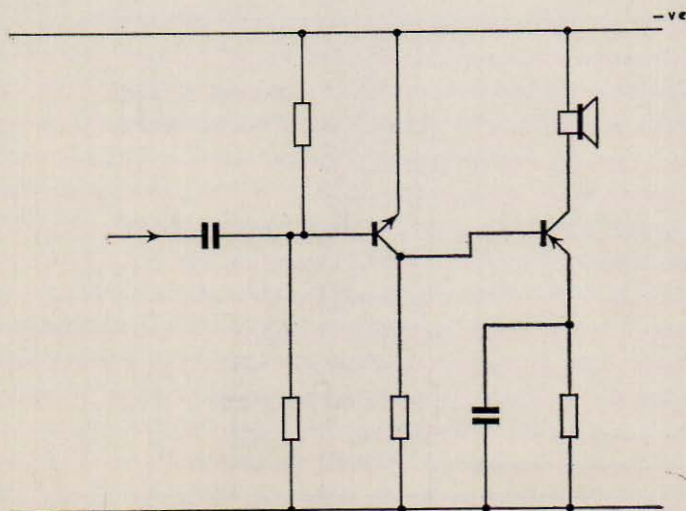


Fig. 20 Two Stage A.F. Section using P. N. P. & N. P. N. Transistors

of about 8 mfd. and the battery de-coupling capacitor may be as high as 200 mfd. Nevertheless the physical size of these components need not be large as they are required to operate only at very low voltages. Tuning capacitors are usually of the two gang type with an aerial tuning section of about 200 pf. Although most tuning capacitors use an air dielectric a new type has recently appeared with polythene dielectric. Because of the high dielectric strength of polythene, these capacitors are extremely small, usually about one inch square by  $\frac{1}{4}$  of an inch deep.

*Printed Circuits:* Almost every transistor receiver now manufactured uses printed wiring. It is not hard to see the reasons for this. Once designed and proved to be reliable, a receiver may be mass produced without any fear of instability arising through misplacement of components, no wiring errors are possible and the finished article is neat, logical and, above all, compact. Cossor Radio & Television Ltd. have published a leaflet describing the servicing of printed circuits and I would like to thank them for their permission to quote from this leaflet.

## COSSOR

### *The Servicing of Printed Circuits*

**INTRODUCTION.** Among the many advantages to be gained from the use of the printed circuit, not the least is the ease of servicing. Many of the problems encountered in the heavy chassis, long leads, and lack of uniformity of wired equipment have gone, and in their place is convenience, and order. It remains however, for method to be adjusted to the new technique, and the recommendations which follow are intended to help the student or engineer who is meeting the printed circuit for the first time.

Fundamentally, a printed board is a pattern of copper foil bonded to an insulator base into which holes have been punched for the insertion of components and/or leads. The foil provides the circuit connections and, frequently, some of the circuit components. Additional patterns of foil which might appear to have no function are included to ensure equal distribution of heat during the manufacturing dip-soldering process.

The essential aim in servicing printed circuitry is to examine and repair the assembly with least disturbance to the printed board. This may be accomplished most effectually by using the

methods explained below:

**EQUIPMENT.** The tools and materials necessary are:

1. A soldering iron with a 3/16th inch chisel type bit of not more, preferably less, than 60 watts rating. A miniature instrument iron of 25 watts rating would be most suitable.
  2. Diagonal wire cutters.
  3. Pointed-nosed pliers.
  4. Small and medium screwdrivers.
  5. Tweezers.
  6. Small gauge 60 tin/40 lead resin-cored solder.
  7. Appropriate measuring instruments.
- The following additional items may usefully be added to the list:
8. Magnifying glass.
  9. Soft wire brush.

**CIRCUIT TRACING.** The layout diagram in a service manual is commonly made from the same original as the printed circuit, making it easy to collate one with the other and interpret any service instructions which may be given. In the diagram, moreover, the components will often have been superimposed on to the printed circuitry to give the effect of a view of both sides of the panel at once. It is possible to obtain the same effect in practice by holding the board, which is translucent, against a strong light, or, more conveniently, by placing a lamp behind or under the board, when the other side will show through.

**Note:** Where both sides of a board contain components and/or both sides have been printed, the printed or foil side means the side opposite to the component being considered, or conversely.

**TESTING.** In general, measurements are made more easily from the insulated side of the board by applying the instrument probe or clip directly to the leads of a component. If measurements have to be made on the conductor side care must be taken not to damage the foil.

**REMOVING COMPONENTS.** Most components may be removed in either of the two following ways:

- (i) By cutting the leads or tags of a component, then heating the joint and pulling through the lead from the component side.
- (ii) By cutting the leads or tags of a component, then heating the joint and pulling through the lead from the foil side.

In (i) the leads may best be gripped with pliers, in (ii) tweezers will generally be found more suitable.



It is often unnecessary to cut the leads of small components such as half-watt resistors. Pulling the components gently but firmly away from the board with the hand as each joint in turn is heated will usually free it.

Care must be taken not to apply too much heat to the board. A clean, fully-heated soldering iron with a small diameter bit may be applied for long enough to remove a simple joint or make a new one. Overlong application will cause overheating of the board and the foil will rise.

The solder on difficult joints should be removed in stages until the lead or tag is free enough to be withdrawn. This may be done either by taking off the solder a little at a time with the soldering iron, or by repeatedly heating the joint and flicking off the melted solder with a soft wire brush. The first method is preferable as it precludes the likelihood of flicking solder in unintended directions.

Treatment of individual components is given below:

*Resistors.* Small resistors may be removed as already described, larger ones, especially power resistors with heavy, closely-aligned, multiple tags are differently dealt with. The simplest method is to cut all the tags on the component side of the board, then to heat and remove each tag separately.

*Thermistors.* Proceed as with resistors.

*Transistors, Germanium Diodes, and other semiconductors.* Proceed as with resistors, but if the component is to be used again, prevent damage to it by using a heat shunt (see "Precautions").

*Capacitors.* Those of the small ceramic, silvered mica, moulded mica, and midget electrolytic variety may be removed in the same way as resistors. The removal of the larger mica, paper, and electrolytic types will be dictated by the style of mounting and should be evident from inspection.

Electrolytics of the upright mounting type may be easily removed by heating each tag in turn and then pushing the tag inwards, into its slot and away from the foil, when the solder is fluid. Other than printed circuit electrolytics in this mounting may be removed similarly to I.F. transformers.

*I.F. Transformers.* The component should first be examined to determine its style of mounting. Some transformers possess a can which is separately clipped into the board, while with others the can and transformer must be

taken off the board together. The four or more connections of the I.F. transformer itself are usually best freed by heating each tag in turn, then canting the transformer away from the tag as the solder melts.

*Coils, Chokes.* These may be removed similarly to I.F. transformers or resistors, according to which they resemble. The corresponding remarks will then apply.

*Valveholders.* If sufficient tag is showing between component and board the tags may first be cut, releasing the valveholder, and then removed separately. It may sometimes be found easier or necessary to break the valveholder.

Note: Where a component is soldered to foil on both sides of a board, it will usually be found that the heating of one side will also melt the solder on the other, so that the lead or tag may be withdrawn at one go.

*Replacing Components.* Usually, the style of removing a component will determine the way of replacement. Treatment of individual components is therefore unnecessary.

The new leads should be bent or crimped in such a way as to make a firm mechanical contact with the surface of the foil. Leads and tags should be cleaned and, where necessary, tinned prior to jointing so that the solder will run easily and shorten the time necessary for the application of heat.

#### *Precautions:*

1. Do not apply too much heat to the board. Only an iron whose bit is thoroughly clean should be used, and only when fully heated.
2. Remove difficult connections in stages. When necessary, a simple heat shunt may be provided by gripping the leads with the pointed-nosed pliers, or by holding the pliers firmly against the lead and adjacent foil.
3. Use only sufficient solder to ensure a sound joint. Excessive solder increases the possibility of heat damage and the creation of short-circuits between neighbouring conductors.
4. Clean the board on completion of a repair. The soft wire brush may be used to remove small globules of solder still adhering to the board. The entire side should be brushed gently but thoroughly.
5. Avoid subjecting the board to excessive mechanical pressure or strain. This must be borne in mind when removing and replacing boards and their components, or if carrying out any structural modifications.

## CHAPTER TWO

## TRANSISTOR SUPERHET KITS

One of the finest ways of gaining experience with transistor superhets is, of course, to build one. There is an excellent range of kits now available on the British market, ranging from pocket receivers, such as the Mini-7, to completely transistorised car radios, some of these make use of printed circuit boards which not only simplify construction but also give the finished product a professional appearance. My thanks are due to Henry's Radio Limited, Repanco Limited, Weymouth Radio Manufacturing Company Limited, and the Teletron Company Limited, each of whom kindly gave me permission to include their circuits and data in this chapter.

**HENRY'S RADIO TRANSISTOR '8'**

The circuit diagram of the Transistor '8' is shown in figure 21. As the name implies eight transistors are used which is two more than the usual six transistor commercial receiver. TR1 is an emitter injected antodyne converter of normal design. The I.F. amplifier is rather less orthodox using as it does, three stages of common base amplification resulting in extremely good selectivity, sensitivity and adjacent channel separation. As the transistors are operated in the common base mode no neutralisation is necessary and the high sensitivity makes the receiver ideal for use as a car radio. A diode, D1, is used for demodulation and is coupled to the A.F. amplifier via VR1, which acts as volume control, C16 and R.F.C.1. preventing any residual R.F. from reaching TR5. The A.F. amplifier uses two common emitter stages before the output stage which is of the symmetrical push-pull type and feeds into a centre tapped speaker. The high gain of the A.F. section is useful if you wish to use it to amplify the output from a record player. In the circuits shown A.G.C. has not been incorporated. It may, however, be added as follows: Change C11 to an 8 microfarad electrolytic and then connect a diode and a 4.7K ohm resistor in series with pin 3 of I.F.T.4 and the base of TR3.

The receiver uses a 7" x 4" elliptical speaker which is sufficient to fill even the largest room with sound of very reasonable quality. A

pleasant looking rexine covered case is supplied with the kit.

**THE REPANCO MINI-7**

The Mini-7 receiver is called a pocket radio by the manufacturers but, although it is extremely small by normal standards, you would need a somewhat accommodating pocket to keep it in. I think the term personal portable might be more appropriate.

This circuit also uses common base amplifiers for the I.F. stages but only two transistors are used. A.G.C. is applied to the base of T2 by R8. The only thing unusual about the audio section is the use of direct coupling between T4 and T5 which saves two resistors. The push-pull output stage delivers a maximum of about 100mw to the speaker which is more than sufficient for a set of this size.

*Assembly Instructions*

1. Use an instrument type soldering iron.
2. Use only specified components.
3. Follow the instructions exactly.
4. Check every step very carefully before attempting the next.

*Stage 1*

1. Cut the spindle of R9 (10K pot: with S.P. switch) to 5/32".
2. Remove the first locknut from R9 and run the other further on to the threaded bush of R9. Fit R9 to the 17/S group board through hole D, with the spindle on the TOP side as shown in the Stage One diagram. Adjust the two locknuts so that the body of the pot: is 1" below the group board, turn the body of the pot: round so that the three solder tags are pointing inwards (see the Stage Two diagram), and tighten the lock nuts.
3. Cut the spindle of the Jackson Bros. type '00' gang to 5/16".
4. Solder 4" of GREEN P.V.C. connecting wire to the right hand tag of C1 (front section of '00' gang) and leave free. Solder 4" of RED P.V.C. connecting wire to the right hand tag of C2 (rear section of '00' gang) and leave free. To determine the right hand tag hold the gang, vanes uppermost, and view from the rear.

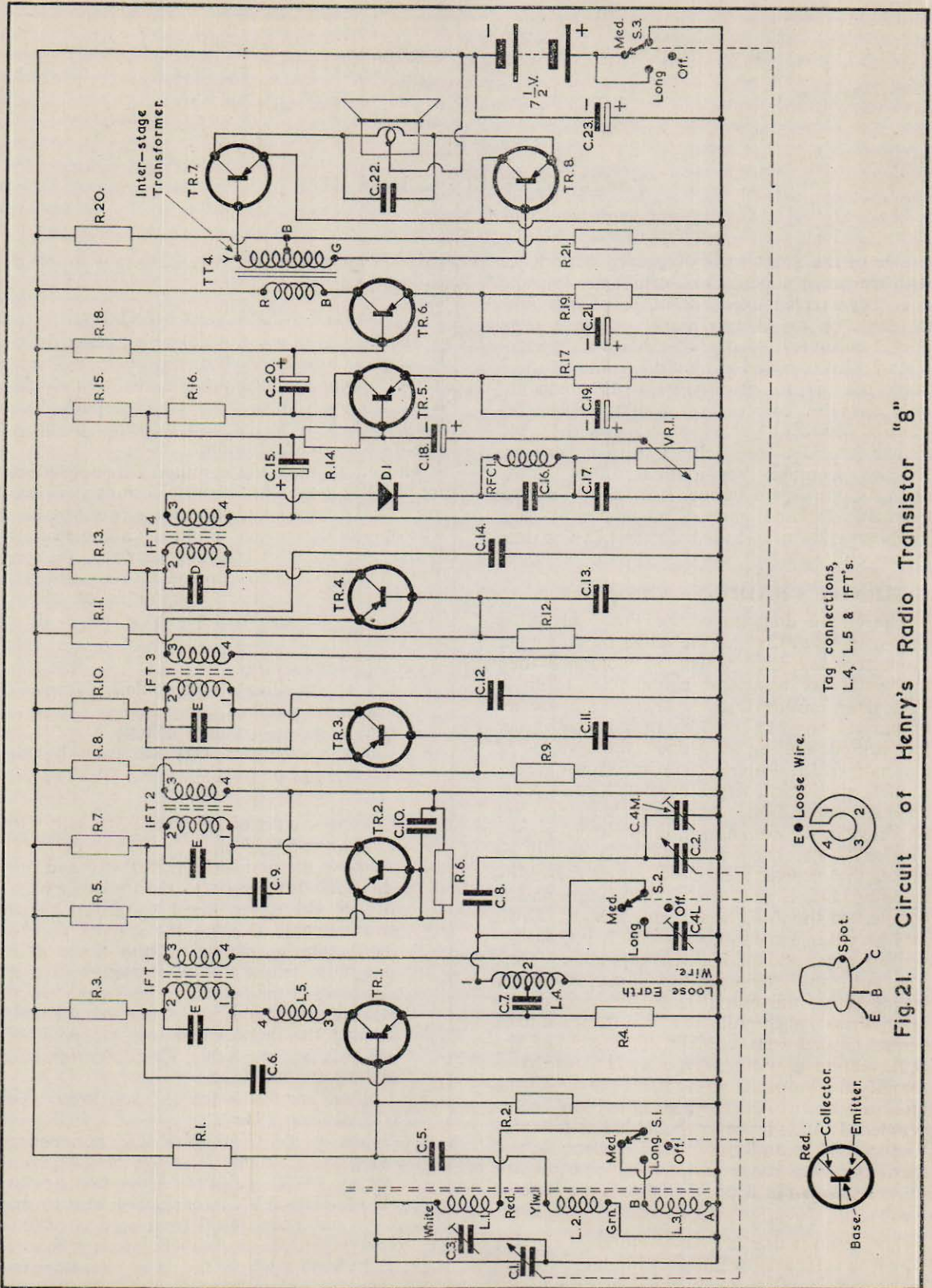


Fig. 21. Circuit of Henry's Radio Transistor "8"



5. Fit the gang to the 17/S group board, spindle on TOP through hole O, and secure with 3 4BA x  $\frac{1}{8}$ " bolts, through holes N, Q and P, with 4BA solder tags at N and Q. Fully close the gang and file a flat 1/16" deep parallel to the edge of the group board as shown. Push the four solder tags of the gang in towards the body of the gang so that they do not protrude.
6. Fit the 4 speaker stand off pillars on TOP of the 17/S group board, using 4BA x  $\frac{1}{8}$ " countersunk bolts through holes A, B and L and a 4BA x  $\frac{1}{4}$ " bolt at G. Fit a 4BA solder tag both sides of the board at B, i.e. under the pillar on top and under the bolt underneath the board.
7. Fit the 3rd IFT coil (XT7) at C, so that the can is on the underneath side and the connecting pins are on the TOP side, in the position shown and secure by bending over the tags on the can.
8. Fit the 2nd IFT coil (XT6) at F, ensure the pins are in the position shown, bend over the solder tags on the can to secure.
9. Fit the 1st IFT coil (XT6) at M, checking the pins are as shown and secure as before. Make sure the solder tags of the '00' gang do not touch the can of the IFT.
10. Fit the oscillator coil (X08) at K, check the pins are in the correct position before securing.
11. Insert a 6BA bolt through hole T, head on the underneath side of the group board, follow with a 6BA washer on the top side, then the wavechange switch lever (position as shown), another 6BA washer, a 6BA solder tag and a 6BA nut, tighten until the switch lever has a nice firm action over eyelets Nos. 18 and 19 and then a 6BA locknut on the bolt and tighten.

In the following instructions it is essential that all wiring and components are kept as close to the group board as possible.

12. Using tinned copper put in the earth line as follows:
  - (a) Join the solder tags of the IFT cans, nearest to the speaker slot, together. Solder this wire to eyelet No. 5 and also to eyelet No. 13.
  - (b) Connect the solder tag on IFT2 to the solder tag on the can of the X08 coil.
  - (c) Connect the solder tag under the pillar at B to eyelet No. 4. Join eyelet No. 4 to the earth line as shown.
  - (d) Connect pin 5 of XT7 to the solder tag on the can of XT7.

(e) Connect pin 5 of XT6 (2nd IFT) to the solder tag on the can of XT6.

(f) Connect pin 5 of XT6 (1st IFT) to the solder tag on the can of XT6.

(g) Connect pin 2 of X08 to the solder tag on the can of X08.

(h) Connect the solder tag under the bolt at N to the tag on the can of the 2nd IFT as shown. Connect this point to eyelet No. 11.

(i) Join the solder tag at T to the solder tag at Q.

Using P.V.C. covered connecting wire proceed:

13. Connect eyelet No. 3 to eyelet No. 8.
14. Connect eyelet No. 1 to pin 3 of XT7.
15. Connect pin 1 of XT7 to eyelet No. 7.
16. Connect R6 (220K) from pin 3 of XT7 to eyelet No. 6.
17. Join pin 3 of XT7 to eyelet No. 9.
18. Connect R20 (3.3K ohms) from pin 3 of 2nd IFT (XT6) to eyelet No. 9.
19. Connect R3 (82K) from pin 3 of XT6 (2nd IFT) to eyelet No. 14.
20. Connect R2 (10K) from eyelet No. 12 to the solder tag on the can of the 2nd IFT.
21. Connect 4" of connecting wire to eyelet No. 16 and push the free end through hole R.
22. Connect pin 2 of XT6 (1st IFT) to pin 5 of X08.
23. Connect R1 (330K) from pin 3 of XT6 (1st IFT) to eyelet No. 17.
24. Connect R19 (270 ohms) from pin 3 of 1st IFT (XT6) to eyelet No. 9.
25. Connect C15 (250pf) from pin 4 of X08 to eyelet No. 18.
26. Connect C13 (0.01mfd) from pin 3 of 1st IFT (XT6) to the tag on the coil can.
27. Connect C14 (0.01mfd) from pin 3 of 2nd IFT (XT6) to the tag on the coil can.
28. Connect D2 (OA81) from pin 4 of 2nd IFT (XT6) to pin 2 of the 1st IFT (XT6), with the positive end of the diode to the 2nd IFT.
29. Fit T1, collector (spot) to pin 1 of X08, base (Centre wire) to eyelet No. 17, emitter to eyelet No. 12.
30. Join pin 3 of X08 to eyelet No. 15.
31. Fit T2, collector (spot) to pin 2 of XT6 (2nd IFT), base (centre wire) to eyelet No. 14 emitter to pin 1 of XT6 (1st IFT).
32. Fit T3, collector (spot) to pin 2 of XT7, base (centre wire) to eyelet No. 6, emitter to pin 1 of XT6 (2nd IFT).

*Stage 2*

1. Take the twin block of trimmers (TC1 and TC2) and cut off one of the mounting lugs flush with the body of the block; so that the '60' marking are on the inside when fitted. Mount the trimmer block on the 17/S group board under the bolt at G, fitting 2 4BA washers between the board and the mounting strip of the trimmer block, also fit a 4BA solder tag under the same bolt.
2. Join the inside tags of TC1 and TC2 to the solder tag at G.
3. Fit C5 (300pf) from the outside tag of TC2, thread the free end through hole J and solder to pin 4 of X08.
4. Cut the RED from C2 to length and solder to the outside tag of TC2.
5. Cut the GREEN lead from C1 to length and solder to the outside tag of TC1 (the Stage 2 diagram shows these two leads side by side for clarity, in order to prevent the GREEN lead fouling lay it on the top of the RED lead).
6. Connect the solder tag at B to contact W of S1 (switch on the back of R9).
7. Join contact W of S1 to tag Z of R9.
8. Fit R8 (3.3K) from eyelet 14 to tag X on R9.
9. Connect D1 (crystal diode) from eyelet No. 7 to tag X of R9, with the positive (red) end to tag X.
10. Connect C8 (0.01mfd) between tags X and Z of R9.
11. Connect C9 (8mfd electrolytic), solder the negative end to eyelet No. 10, hold perpendicular to the group board and then solder the positive end to tag Y of R9. Open and close the ganged tuning capacitor and make sure the vanes clear the components fitted.
12. Mount TT9 (Repanco miniature interstage transformer), turning so that the colours are as shown in the diagram and then bending the clips under the group board to secure.
13. Cut the BLACK fly lead of TT9 to length, push back the insulation, and solder to eyelet No. 2.
14. Connect the RED tag of TT9 to eyelet No. 1.
15. Fit R16 (330 ohms), solder one end to eyelet No. 1, and leave perpendicular to the group board (see Stage 3 diagram A).
16. Fit R17 (6.8K), solder one end to eyelet No. 2 and leave perp. to the board.
17. Twist the free ends of R16 and R17 together and solder.
18. Take R18 (120 ohms), sleeve one wire end and solder to eyelet No. 2, leaving the other end free.
19. Take C12 (100mfd electrolytic), sleeve the negative wire end and solder to eyelet No. 1, leaving the positive end free.
20. Mount TT10 (Repanco miniature push-pull output transformer), turn so that the colours are as shown and bend the clips under the group board to secure.
21. Solder 1½" of PVC connecting wire to the positive battery socket and connect the free end to contact V of S1.

*Drawing A*

1. Cut the BLACK fly lead from TT10 to length, push back the insulation and solder to the junction of R16 and R17.
2. Solder the positive wire end of C11 (8mfd electrolytic) to eyelet No. 4, place the capacitor at the side of the TT9 transformer as shown and leave perpendicular to the group board.
3. Solder one wire end of R15 (1K) to eyelet No. 4, place by the side of C11 and leave perp. to the group board (take care the wire end of R15 does not foul the can of C11).
4. Twist the free ends of C11 and R15 together and solder (the components should not stand more than 1" off the group board).
5. Connect one wire of C6 (0.1mfd) to eyelet No. 6 and leave perp. to the group board.
6. Connect one wire end of R7 (47K) to eyelet No. 6.
7. Join the free ends of C6 and R7 together and solder to eyelet No. 5, leaving the two components perp. to the group board, max. height 1".
8. Connect the negative wire end of C7 (8mfd electrolytic) to eyelet No. 14 and leave perpendicular.
9. Connect one wire end of R5 (417K) to eyelet No. 14.
10. Twist the free ends of C7 and R5 together and solder to eyelet No. 13, max. height 1".
11. Connect one wire end of C4 (0.01mfd.) to eyelet No. 12 and leave perpendicular.
12. Connect one wire end of R4 (56 ohms, see note) to eyelet No. 15 and leave perp. to group board.
13. Twist the free ends of C4 and R4 together and solder.
14. Connect one wire end of C3 (0.01mfd) to eyelet No. 17 and leave perpendicular.
15. Bend over the free end of C3 and solder to eyelet No. 16.

*Drawing B*

16. Connect the positive end of C10 (8mfd electrolytic) to eyelet No. 11 and leave perp.
17. Connect one wire end of R12 (1K) to eyelet No. 11 and leave perpendicular.
18. Twist the free ends of C10 and R12 together and solder.
19. Connect one wire end of R10 (10K) to eyelet No. 11 and leave perpendicular.
20. Bend over the free end of R10 and solder to eyelet No. 10.
21. Connect one wire end of R11 (47K) to eyelet No. 10 and leave perpendicular.
22. Bend over the free end of R11 and solder to eyelet No. 9.
23. Connect one wire end of R14 (3.3K) to eyelet No. 9 and leave perpendicular.
24. Bend over the free end of R14 and solder to eyelet No. 8.
25. Connect one wire end of R13 (10K) to eyelet No. 8, hold perpendicular and solder the other wire end to contact W on S1.
26. Solder approximately 1" of PVC connecting wire to the solder tag on C1 and leave free.

NOTE. R4 is given as 56 ohms in the components list as an average value. The function of this resistor is to regulate the amplitude of the oscillations of the local oscillator and may vary with each RF transistor. With some transistors it has to be shorted out completely and with others the value may be as high as 270 ohms. The optimum value will give maximum output without spurious oscillations.

*Stage 4*

1. Solder approximately 2" of PVC connect-wire to the negative battery plug and connect the other end to the junction of R16 and R17.
2. Fit the ROLA C25 speaker to the 4 stand-off pillars with 4BA x  $\frac{1}{8}$ " countersunk screws. Ensure that the speaker connecting tags are towards the edge of the group board as shown in the Stage 4 diagram.
3. Connect tag T of the speaker to the solder tag at G.
4. Connect the free end (positive) of C12 (fitted in Stage 2) to tag T of the speaker. (To avoid confusion C12 is not shown again in Stage 4).
5. Connect the free end of R18 (fitted in Stage 2) to tag T of the speaker.
6. Connect the BROWN tag of TT10 to tag T of the speaker.
7. Connect the MAUVE tag of TT10 to tag U of the speaker.

8. Fit T6, connect the emitter to the BROWN tag of TT10, collector (spot) to the RED tag of TT10, and the base (centre wire) to the YELLOW tag of TT9.
9. Fit T7, connect the emitter to the BROWN tag of TT10, collector (spot) to the BLUE tag of TT10 and the base (centre wire) to the GREEN tag of TT9.
10. Fit T5, emitter to the junction of R15 and C11, collector (spot) to the BLUE tag of TT9, and the base (centre wire) to eyelet No. 3.
11. Fit T4, collector (spot) to eyelet No. 8, base (centre wire) to eyelet No. 10, and the emitter to the junction of R12 and C10.
12. Fit the FS3 aerial (this is mounted vertical to the group board, in the diagram it is shown at an angle in order to show the connections). Remove the rubber grommets, slide the FS3 coil (MW) to the left hand end of the slab and the XL1 coil (LW) on to the right hand end of the slab with the earth tag of XL1 nearest to the FS3 coil. Connect the BLUE fly lead of XL1 to the BLUE eyelet of FS3 and the BLACK marker of XL1 to the BLACK eyelet of FS3. Connect the wire from C1 (fitted in stage 3B) to the RED eyelet of FS3. Connect the wire through hole R (fitted in Stage 2) to the GREEN eyelet of FS3. Connect the BLACK eyelet of FS3 to eyelet No. 19. Connect the earth tag of XL1 to contact W of S1.
13. Press the positive battery stud on the positive of the battery, and the negative stud on the negative of the battery.

The receiver is now ready for switching on and aligning.

*Alignment Instructions*

Remove the positive end of D2 from pin 4 of 2nd IFT (XT6). With a signal generator set to 465 kc/s connect the leads to pin 1 of the 2nd IFT and the earth line, tune the core of XT7 for maximum output. Connect the generator to pin 1 of the 1st IFT and tune the 2nd IFT for maximum output. Connect the generator leads to eyelet No. 12 and the earth line and tune the 1st IFT for maximum output. Now make the final adjustment of the three IFT's for maximum output. Reconnect D2 to pin 4 of the 2nd IFT.

Switch to MW. Set the generator to 665 kc/s and turn the dial to 450 metres, adjust the core of X08 for maximum output.

Set the generator to 1.2 mc/s, tune to 250 metres, adjust TC2 for maximum output. Reset

the generator to 665 kc/s, tune to 450 metres and readjust the core of X08 for maximum output. Reset the generator to 1.2 mc/s, tune to 250 metres, readjust TC1 for maximum output. Repeat until no further adjustment is necessary.

Switch to LW. Set the generator to 200 kc/s, tune until the signal is heard and slide the XL1 coil along the slab for maximum output.

### THE REPANCO MAJOR-7

The circuit of the Major-7 resembles fairly closely that of the Minor-7 shown in Fig. 23.

The coupling between T4 and T5 is the more usual resistance-capacity type and the battery voltage is 7.5 instead of 9. The speaker is a 7" x 4" elliptical type and the size of the case is comparable to the small valve portable type of receiver. The tuning is variable and covers both the medium and long waves.

At first sight it may seem that as the circuit of the Major-7 and Minor-7 are so similar there can be little difference in the performance. However, the larger case size of the former makes possible a far larger ferrite rod aerial which results in increased sensitivity.

Lack of space prevents me from including step by step instructions for all the kits described here but these are available from the suppliers.

Repanco have also designed a receiver similar to the Major-7 but using preset tuning. This is called the Transeven and has 3 M.W. preset stations and 1 on the LW.

### THE REPANCO TRANSISTOR CAR RADIO

The circuit shown in Fig. 24 is that of a 7 transistor car radio. As car radios have to operate even in areas of extremely low signal strength they require greater sensitivity than a normal portable; this is obtained in this circuit by the use of an R.F. amplifier before the frequency changer. As the signal strength will vary considerably whilst the car is in operation a strong A.G.C. must be applied to prevent large variations in volume. As the noise level inside a car is so much greater than normal, more output is required from the speaker. To provide this a Mullard OC16 power transistor is used in the output stage as a Class A amplifier giving an output of about 2 watts. This circuit may be used in cars having either a 12 or a 6 volt power supply but the component values will differ.

When a twelve volt supply is used an OC71 is able to supply sufficient power to drive the OC16, but with only 6V this must be replaced by OC72 which can handle the greater collector current now required.

### SIEMENS-EDISWAN SR2/2

Although the receiver to be described here and the one that follows it are not actually supplied in kit form, they have been designed in such a way as to make it simple for the home constructor to build them. As they are designed by the firms who actually make the transistors they are naturally excellent circuits and well worth building. I would like to thank Siemens-Ediswan Limited, for their permission to publish the circuit and information given here.

The receiver uses 6 transistors and a germanium diode. Tuning is continuously variable from 530-1620 kc/s with preset tuning of the light programme on 200 Kc/s. An 8" x  $\frac{3}{8}$ " ferrite rod aerial is used with the two coils 4" apart and symmetrically placed on either side of the centre. The frequency changer is an XA102 operating with a collector current of about 600 micro.A. The mixer is coupled to the I.F. amplifier via a bandpass, double tuned I.F. transformer. The 1st I.F. stage has a collector to emitter voltage of 5 and a no signal collector current of 0.5 ma. The 2nd I.F. transistor again has a collector-emitter voltage of 5 but the collector current is 3 ma. The XB103 acts not only as the audio driver but also as a source of amplifier A.G.C. for the first I.F. stage. The push-pull output stage uses two XC101's each with a quiescent collector current of 2 ma. 4db of negative feedback is applied from the secondary of the output transformer to the emitter of the driver. The maximum power delivered to the primary of the output transformer is 220 milliwatts.

A stage by stage gain analysis of the receiver is shown in Fig. 28. The average sensitivity with 5mw reference output, is about 90  $\mu$ V/M.

### MULLARD PORTABLE SUPERHET

This circuit and the allied information is published by permission of Mullards Application Laboratory who were responsible for the design.

The circuit shown is actually that of a miniaturised version of the original design, the overall dimensions being  $6\frac{1}{2}$ " x  $4\frac{1}{2}$ " x  $1\frac{1}{2}$ ".

The variably tuned circuits give a frequency coverage of 550 to 1600 Kc/s in the M.W. band and 150-250 Kc/s in the long wave band.

The receiver has an output power of 100 mw. however, if an output of, say, 30 mw. is considered sufficient the push-pull output stage may be replaced by a single transistor operating as a Class A amplifier. A further transistor may be saved by reflexing the second I.F. stage thus making a separate driver stage unnecessary.



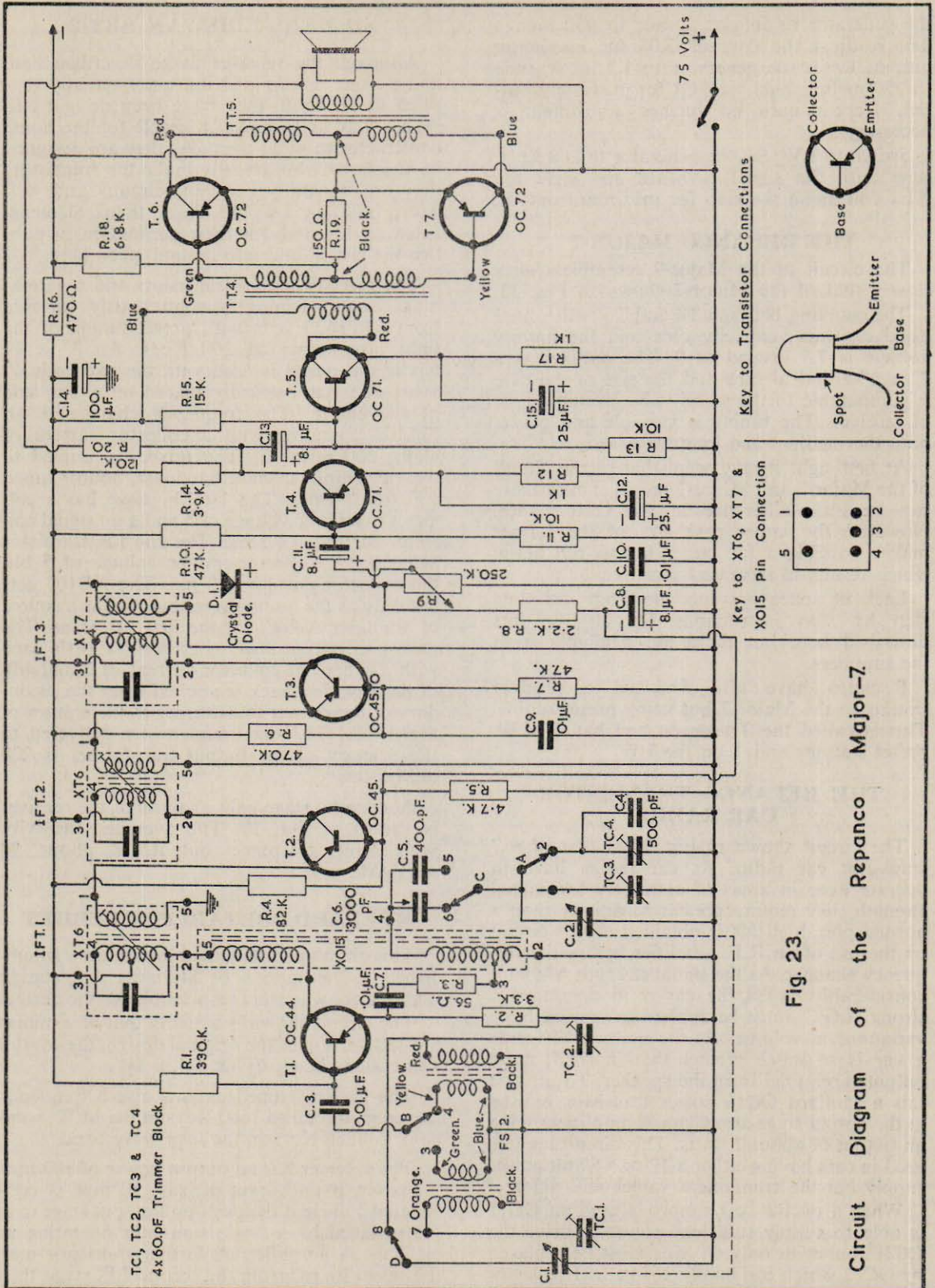


Fig. 23.

Circuit Diagram of the Repanco Major-7

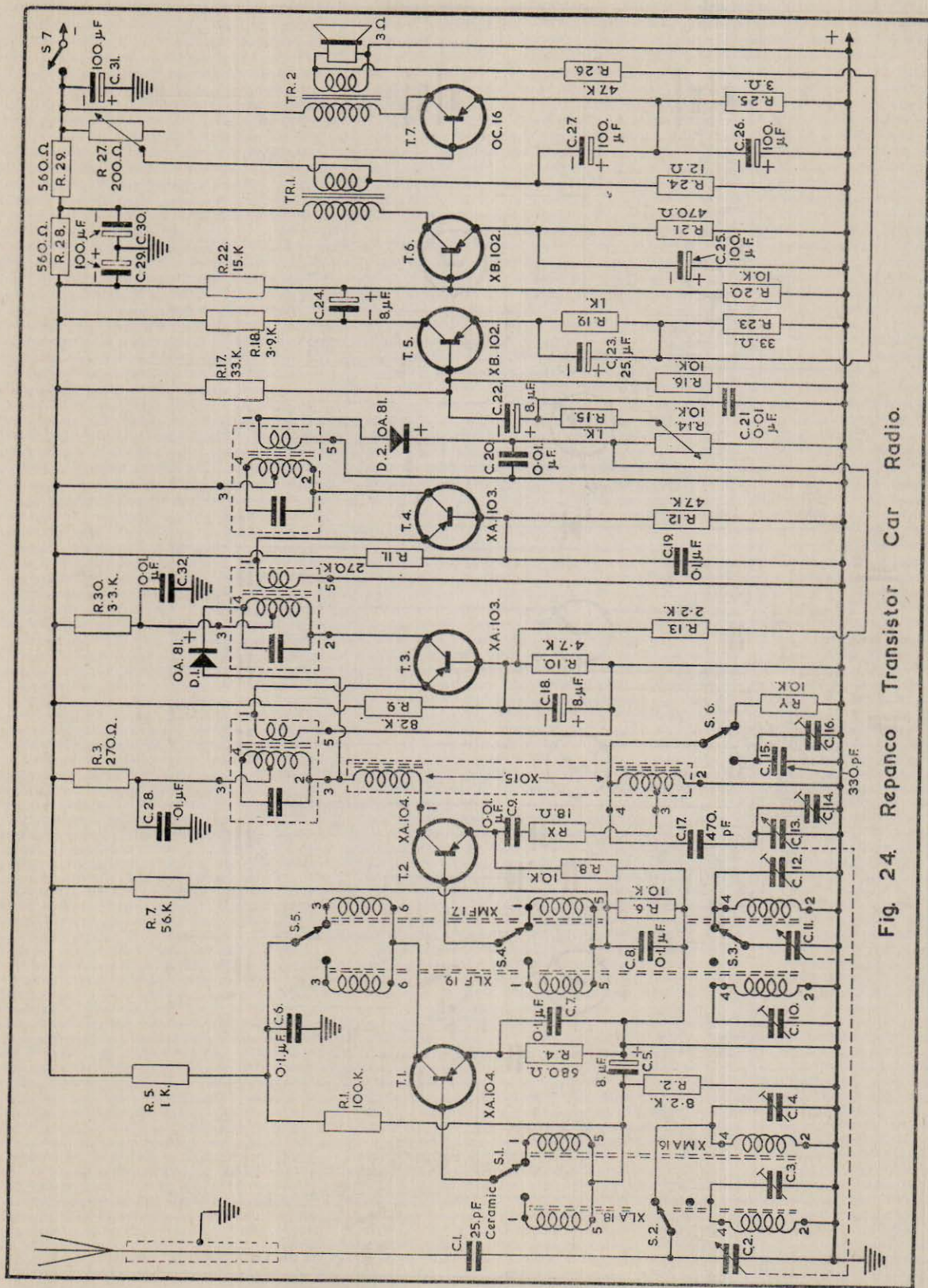


Fig. 24. Repanco Transistor Car Radio.

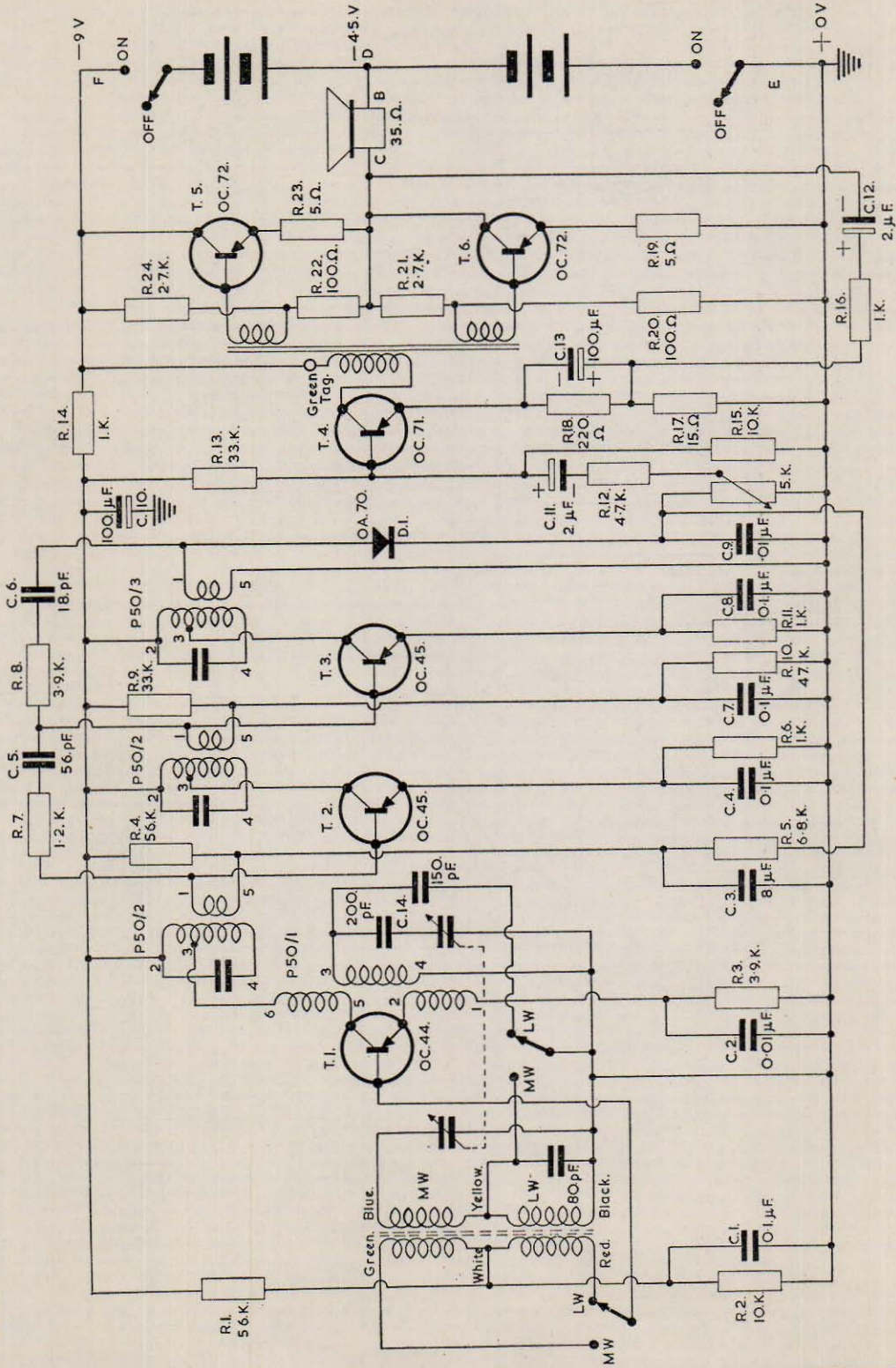


Fig. 25.  
Circuit Diagram for Weyrad Transistor Receiver.

The details of the main components used in this receiver are as follows:

Aerial:

Mullard Ferroxcube rod, type FX1057.

M.W. Transformer.

Primary:

88 turns of 19/0.0028 bunched conductors wound in a single layer.

Secondary:

12 turns of 19/0.0028 bunched conductors wound at the low end of the primary, nearest to the centre of rod.

L.W. Transformer.

Primary:

240 turns of 3/0.0024 bunched conductors wave-wound in three sections.

Secondary:

45 turns of 3/0.0024 bunched conductors wound as fourth-pie section, nearest centre of rod.

The total length of the four L.W. windings (including three spaces of 3/32" each) is 1".

Tuning Capacitor.

Aerial section: 115pF. swing.

Oscillator section: 115pF. swing.

Wingrove and Rogers, types C78-22 or C78-02 (with slow-motion drive). Either type to include an inter-section screen.

Oscillator Coil.

Inductance: 313 uH.

Windings:

Main = 100 turns.

Collector = 13 turns.

Emitter = 2 turns.

Qo:

105 at 1Mc/s with tuning capacitance of 70pF

Wireless Telephone Company type

CP124924/10.

Driver Transformer.

Turns-ratio: 7:(1+1).

Primary inductance: 5H at 1.5mA d.c.

Primary resistance: Less than 750 ohms.

Secondary resistance:

Less than 100 ohms per winding.

Fortiphone type L442.

Loudspeaker.

Speech Coil impedance: 75 ohms.

Plessey 3" x 3".

Battery.

Voltage: 9V.

Ever Ready, Batrymax, Type PP4.

Note. The type numbers given above refer to components used in the prototype receivers. Their inclusion here should not be taken to imply either that the list is exhaustive or that these specific components are available generally.

## THE WEYMOUTH 6 TRANSISTOR RECEIVER

Fig. 25 is the circuit of a receiver designed by the Weymouth Radio Manufacturing Co., for use with their coils. This circuit is very similar to those used by many radio manufacturers being a 6 transistor set with two common emitter I.F. stages and a single ended push-pull output stage using a split battery.

Both capacitive and resistive feedback is used to stabilise the I.F. stages but this introduces no problems in construction as the feedback components are all fixed. A.G.C. is applied to the first I.F. stage via R5.

## THE TELETRON TRANSIDYNE

One of the most carefully designed kits on the market is the Teletron "Transidyne". It uses a printed circuit and is supplied complete with an attractive plastic case the size of which is 6 $\frac{1}{4}$ " x 3 $\frac{3}{4}$ " x 1 $\frac{3}{4}$ ".

The receiver covers the long and medium wave bands but in the long wave position the set is designed so as to receive only the light programme on 1500 metres, only the oscillator frequency being variable. TR1 is the usual emitter injection autodyne type of converter. TR2 and TR3 form the I.F. amplifier and both of them are used in the common emitter mode. The I.F. output from TR3 is rectified by D1. The output from D1 consists of two parts, a d.c. component and the A.F. signal. The former is used to apply A.G.C. to TR2 and the latter is fed back to TR3 which then acts as an A.F. amplifier. The A.F. output from TR3 is coupled to the audio amplifier via the primary of I.F.T.3 which prevents any I.F. signal from reaching TR4 but offers only a very low impedance to the A.F. signal. Apart from the reflex action of TR3 the audio amplifier is perfectly normal and uses a symmetrical push-pull output stage.

The sensitivity and selectivity of the receiver is quite adequate for receiving continental stations on the medium wave band which says quite a lot for so small a receiver. The assembly instructions given below are those supplied by The Teletron Company in their booklet on this set.

1. *I.F. Transformers and oscillator coil.* First to be mounted are the I.F. transformers and oscillator coil, the reference mark in the base is intended to show the correct orientation of each component, and a screwdriver may be used to guide the pins into position. A pencil mark on the side of the can assists in this operation. The tags on top of the cans must be earthed to the nearest point marked "E" (fig. 2). 15-amp fuse wire is ideal for this purpose and may also be used in other positions

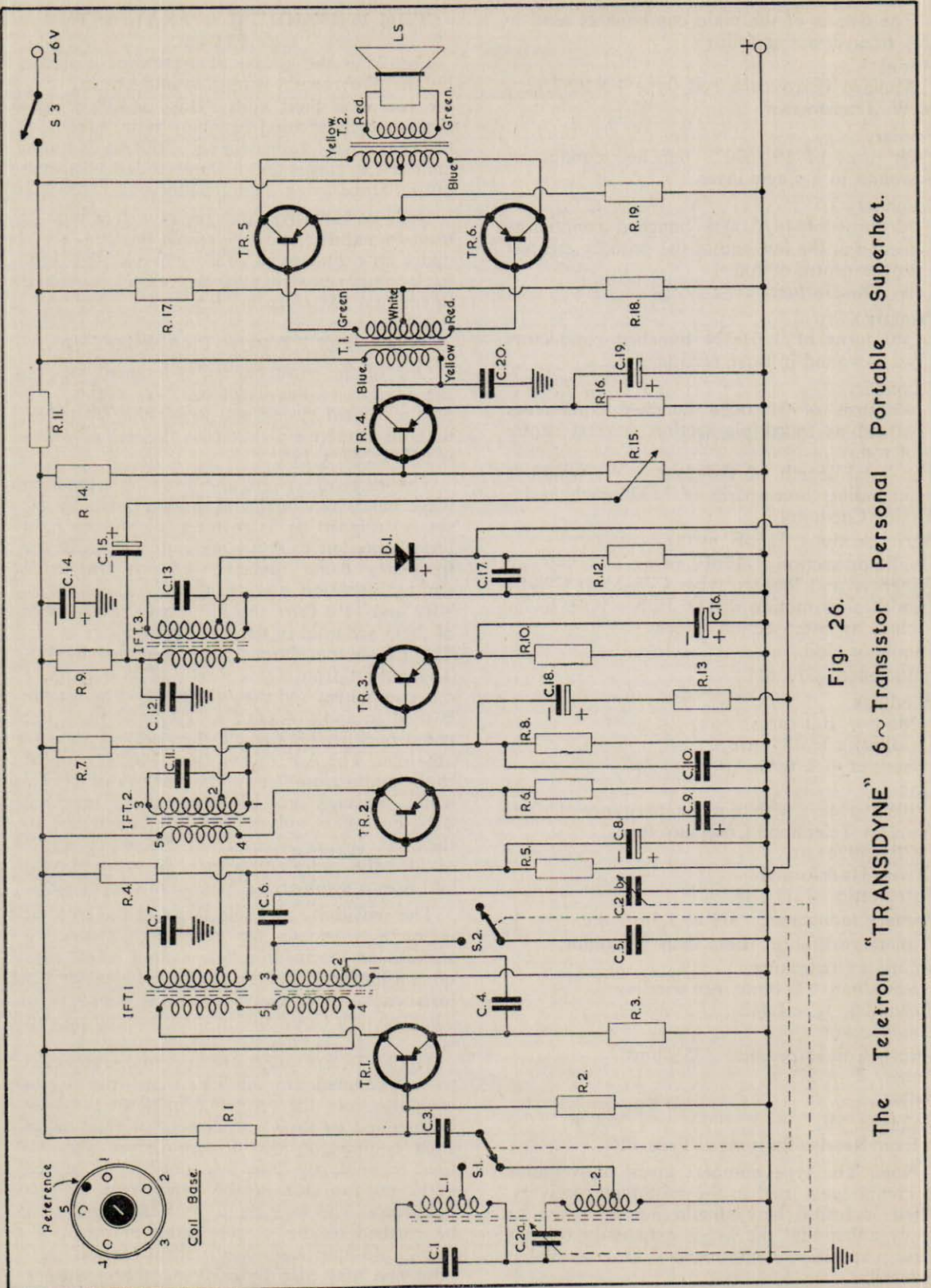


Fig. 26. The Teletron "TRANSIDYNE" 6-Transistor Personal Portable Superhet.

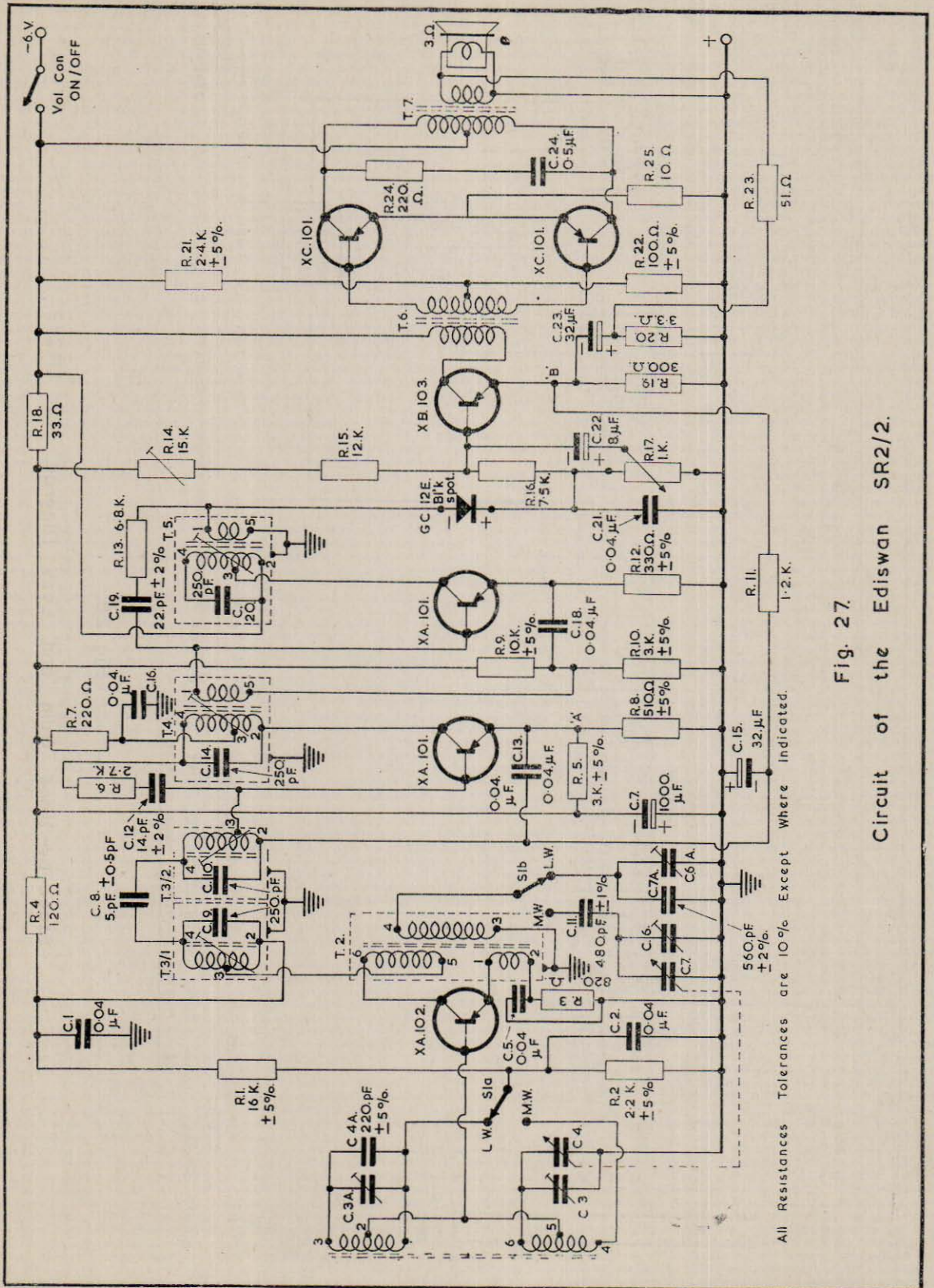


Fig. 27. Circuit of the Ediswan SR2/2.

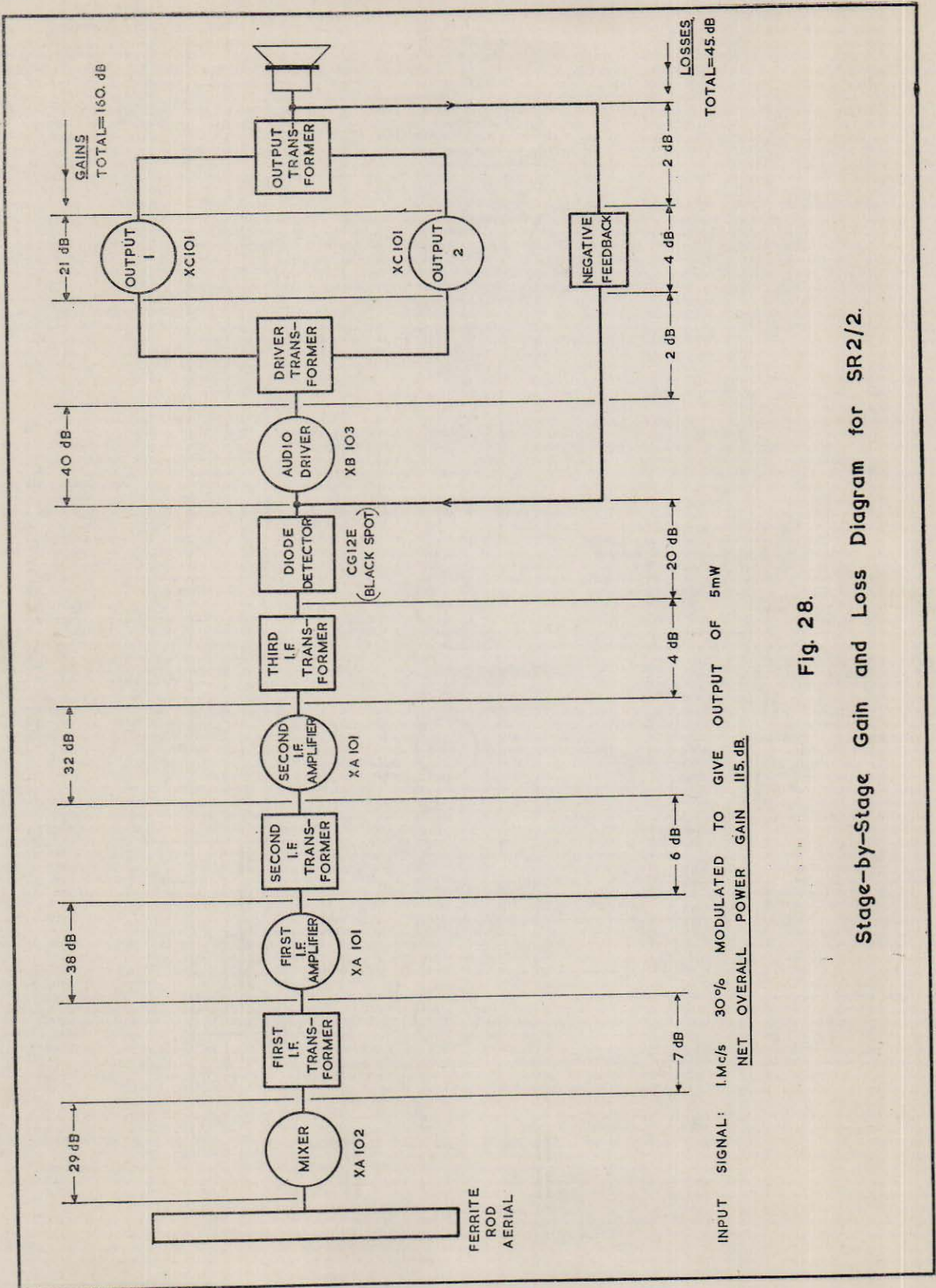


Fig. 28.

Stage-by-Stage Gain and Loss Diagram for SR2/2.

insulated with 1 mm. sleeving. Heavy wire should be avoided as it may damage, by strain, small components. Due to the shrinkage of material, the I.F. transformers and oscillator coil mounting holes may require to be reamed out with a 1/16" drill to permit an easy fit.

2. *Loudspeaker and ferrite rod bracket.* The 2½" loudspeaker is next fitted in position through the chassis, its flange being on the printed circuit side, with four 6BA counter-sunk screws and nuts together with a 6BA solder tag and the ferrite rod mounting bracket as shown in fig. 2.

3. *Tuning condenser.* Next is mounted the "00" gang, but the spindle must first be cut down to 3/16" long. Only two 4BA x ¾" counter-sunk screws are used here—the throd hole nearest to the wave-change switch is used for retaining the chassis within the cabinet.

4. *Output Transformers, wavechange switch, and volume control.* Then follows the volume control (R15) secured with an 8BA x ½" counter-sunk screw and the nut and the wave-change switch, secured by two 8BA x ½" counter-sunk screws and nuts. The output transformers are positioned as shown in fig. 2, and secured by inserting the lugs through their respective holes in the printed circuit panel and bending over. Fig. 2 shows the correct terminations for the coloured lead-out wires, which should be wound in the form of a spring around a piece of 18-gauge wire. The ends can then be cleaned and stretched to their terminating points.

5. *Resistors and condensers.* Resistors and condensers should next be soldered into position, omitting R.6 at this stage. The value of this resistor is discussed under "Alignment and Biasing". Care must be taken to observe correct polarity of electrolytic condensers and where the metal cans of these are liable to be in contact with other components they should be insulated with two layers of sellotape. C.6 is connected between the rear (smaller) section of the tuning condenser and the printed panel (fig. 2). C.14 is mounted with its negative end to the printed panel, the positive end being insulated with sleeving and soldered where shown. Wiring links are also fitted at this stage (fig. 2).

When soldering components to the printed circuit the lead-out wires should be pushed through their respective holes, the ends cut off, a little NON-CORROSIVE flux applied and soldered neatly, with, preferably, a 25-watt iron. Surplus flux may afterwards be removed with a little methylated spirit. All components must be securely soldered to the printed wiring. Large "blobs" of solder formed with a cold or untinned iron will NOT suffice.

6. *Transistors.* Transistor lead-out wires should be insulated with 1 mm. sleeving and **SHOULD NOT BE CUT SHORT**, a heat shunt being used when soldering. Transistors may be pushed into any advantageous position. TR5 and 6 collector currents should be within .1 ma. difference for correct matching but within .5 ma. is acceptable.

7. *Ferrite Rod Aerial.* When mounting the ferrite rod aerial the grommets may require to be moved along the rod. The medium wave layer winding is nearest to the gang. Connections for the L.W. winding are shown in fig. 2. Yellow to C1; White to S1; Green to earth (6BA solder tag on speaker).

8. *Battery.* Two No. 8 batteries are inserted into the paxolin tube provided, the brass cap of one against the zinc case of the other. The brass cap is the POSITIVE end and must be in contact with the clip NEAREST TO THE TUNING CONDENSER. Constructors are warned that reversal of the batteries will destroy transistors.

9. *Biasing.* The nominal value for R6 is 1k; but due to variations in transistor gain, this value may vary between 500 ohms and 2.2K. Therefore, a variable resistor of approximately 10K should be temporarily fitted in place of R6 during alignment and adjusted to maintain stability.

10. *Alignment.* Where a signal generator is available, this should be set to 470 K/cs., and the output connected via a .1 condenser to the base of TR3, adjusting L6 screw core for maximum output. Then connect the TR2 base and adjust L5 screw core. Finally connect to TR1 base and adjust L4 screw core. The generator output should be decreased as each additional tuned circuit is brought into use. Repeat above until no further improvement is obtained.

A suitable trimming tool may be formed from a plastic knitting needle. All cores must be rotated slowly.

The signal generator may next be coupled to the M.W. ferrite winding by forming a single turn loop of insulated wire around the ferrite rod. Set generator to 600 K/cs. Set tuning condenser near to maximum capacity. Adjust M.W. ferrite winding in conjunction with L3 screw core for maximum output.

Switch to L.W. and adjust L.W. ferrite winding only in conjunction with tuning condenser.

Repeat alignment procedure until no further improvement can be obtained.

The value of R6 may now be determined from the setting of the 10K variable resistor and a suitable fixed resistor fitted.





In some cases it may be necessary to fit a 10pf condenser across the aerial section of the gang.

**SUMMARY OF POSSIBLE FAULTS**

1. Receiver "Dead": Faulty battery connection. Badly soldered joint(s). Faulty or damaged transistor(s).
2. Distorted Reproduction: Reduce value of R16. TR5/TR6 incorrectly matched.
3. Low Gain: Reduce value of R5. TR2/TR3 faulty.
4. Receiver Unstable: Increase value of R5. Ageing batteries. C14/C17 open circuit.
5. Receiver Unstable at high frequency end of M.W. band: Increase value of R3.
6. I.F. Section working—no signals: Check wave change switch.
7. L.W. Instability: Fit a .01 condenser from the volume control moving arm to earth (fit 8BA solder tag on top of R15 and connect .01 from here to 6BA tag on speaker).

**COMPONENTS LIST**

\* Supplied with I.F. trans.

R1	47K
R2	3.3K
R3	1K
R4	47K
R5	4.7K
R6	1K (see text)
R7	4.7K
R8	4.7K
R9	560 ohms
R10	1K
R11	220 ohms
R12	4.7K
R13	8.2K
R14	22K
R15	5K vol. and S3 switch
R16	220 ohms
R17	3.3K 5% tolerance
R18	120 ohms 5% tolerance
R19	10 ohms

All resistors 1/8 watt. 10% tolerance.

C1	100pf 10%
C2	"J.B.00" gang
C3	.01 Hunts W99 150V
C4	.01 Hunts W99 150V
C5	200pf 5%

C6	300pf 5%
C7	*500pf 5%
C8	25mfd T.C.C. CE67AE
C9	4mfd T.C.C. CE68A
C10	.01 Hunts W99 150V
C11	*500pf 5%
C12	.01 Hunts W99 150V
C13	500pf 5%
C14	25mfd T.C.C. CE67AE
C15	4mfd T.C.C. CE68A
C16	25mfd T.C.C. CE67AE
C17	.04 Hunts W99 150V
C18	4mfd T.C.C. CE68A
C19	25mfd T.C.C. CE67AE
C20	.01 Hunts W99 150V

TR1	Red/Yellow spot	} or equivalents
TR2	Red Yellow spot	
TR3	Red/Yellow spot	
TR4	Green/Yellow spot	
TR5	Green/Yellow spot	
TR6	Green/Yellow spot	
TX1	GEX34	
TT1	Ardente D131	
TT2	Ardente D132	
	Loudspeaker Celestion C25 2½"	
	S1/S2 Wavechange Switch	

L1	Teletron FML22
L2	Teletron FML22
L3	Teletron FT04
L4	Teletron FT4E
L5	Teletron FT4E
L6	Teletron FT4D
	Printed circuit panel
	Cabinet
	Dial
	2—No. 8 batteries
	Ferrite rod mounting bracket

**TABLE OF VOLTAGES & CURRENTS**

	Ve	Vb	Vc	Ic (ma)
TR1	0.4	0.2	4.4	0.11
TR2	0.5	0.4	4.4	0.3
TR3	2.0	1.5	3.0	2.2
TR4	0.7	0.5	4.3	3.1
TR5/6	0.04	0.2	5.2	2.0

each

Measured on 10v range. Model 7 Avo. Gang at maximum capacity. H.T. no signal current. 12 ma. approx.

## CHAPTER THREE

## BRITISH RECEIVERS

Almost all the radio manufacturers in Great Britain now produce one or more transistor receivers. The circuits and servicing information in this chapter were supplied by the following firms: Ace Radio, Berec, Cossor, Ever-Ready, R.G.D., Pam, Perdio, Pye, and Websters, all of whom I would like to thank for their kind co-operation.

The majority of receivers so far produced use six transistors that is, a frequency changer, two I.F. transistors, a driver and two transistors in a push-pull output stage. There are also, however, a few 4, 5 and 7 transistor receivers.

## THE ACE COURIER

Fig. 30 shows the circuit diagram of this six transistor receiver which is of the hand held portable type. Provision is made for connecting an external aerial and power supply so that the receiver may be used as a car radio. Choice of either the internal or external power supply is made by means of a built-in switch.

The specified battery is either an Exide DT1 or an Ever-Ready PP1. The speaker is a 7" x 4" type of 10,000 lines and the power output is a  $\frac{1}{2}$  watt. The overall size is 10" x 7" x 3 $\frac{1}{2}$ ", with a weight of 4 $\frac{1}{2}$  lbs., including the battery.

## THE WEBSTER "POCKET PRINCESS"

The "Pocket Princess" measures 5 $\frac{3}{4}$ " x 3 $\frac{1}{2}$ " x 1 $\frac{1}{2}$ " and weighs 14 $\frac{1}{2}$  ozs.

The frequency changer is a self oscillating mixer. The signal input from the ferrite aerial is taken to the transistor base.

The oscillator circuit is initially biased into Class A operation but as the oscillation increases, rectification of the oscillator voltage at the emitter causes a negative D.C. voltage to be developed across the emitter resistor which tends to drive the transistor into Class B operation thus stabilising the oscillator amplitude.

For the I.F. amplifier two transistors are used in unilateralised common emitter stages.

The gain of each OC45 is 38.3db. Taking into account the losses incurred in the I.F. trans-

formers the overall gain of the 1st and 2nd I.F. stages are 31.2db and 34db respectively.

The audio amplifier consists of an OC71 driving two OC72's in a symmetrical output stage.

## THE PERDIO RECEIVERS

Perdio Limited manufacture a large range of miniature transistor receivers in which they specialise. They were in fact, the first firm in this country to manufacture anything approaching a pocket sized transistor receiver.

The circuit of the PR5 is shown in fig. 31. The original design used only 5 transistors, one of them being reflexed but this was later changed to six transistors without any reflexing. The operating voltages of the transistors are given below, measurements were made with a model 8 Avometer using the 10V range.

Transistor	Emitter Voltage	Base Voltage	Collector Voltage
TR1 OC44	1.1	1.1	7.0
TR2 OC45	0.45	0.6	7.0
TR3 OC45	1.0	1.15	7.0
TR4 OC71	1.2	1.35	8.1
TR5 OC72	4.5	4.68	9.0
TR6 OC72	0	0.18	4.5

## Five Transistor Model

Transistor	Emitter Voltage	Base Voltage	Collector Voltage
TR1 OC44	1.3	1.2	8.1
TR2 OC45	0.5	0.6	8.1
TR3 OC45	1.0	1.15	8.2
TR4 OC72	4.0	4.1	9.0
TR5 OC72	0	0.17	4.0

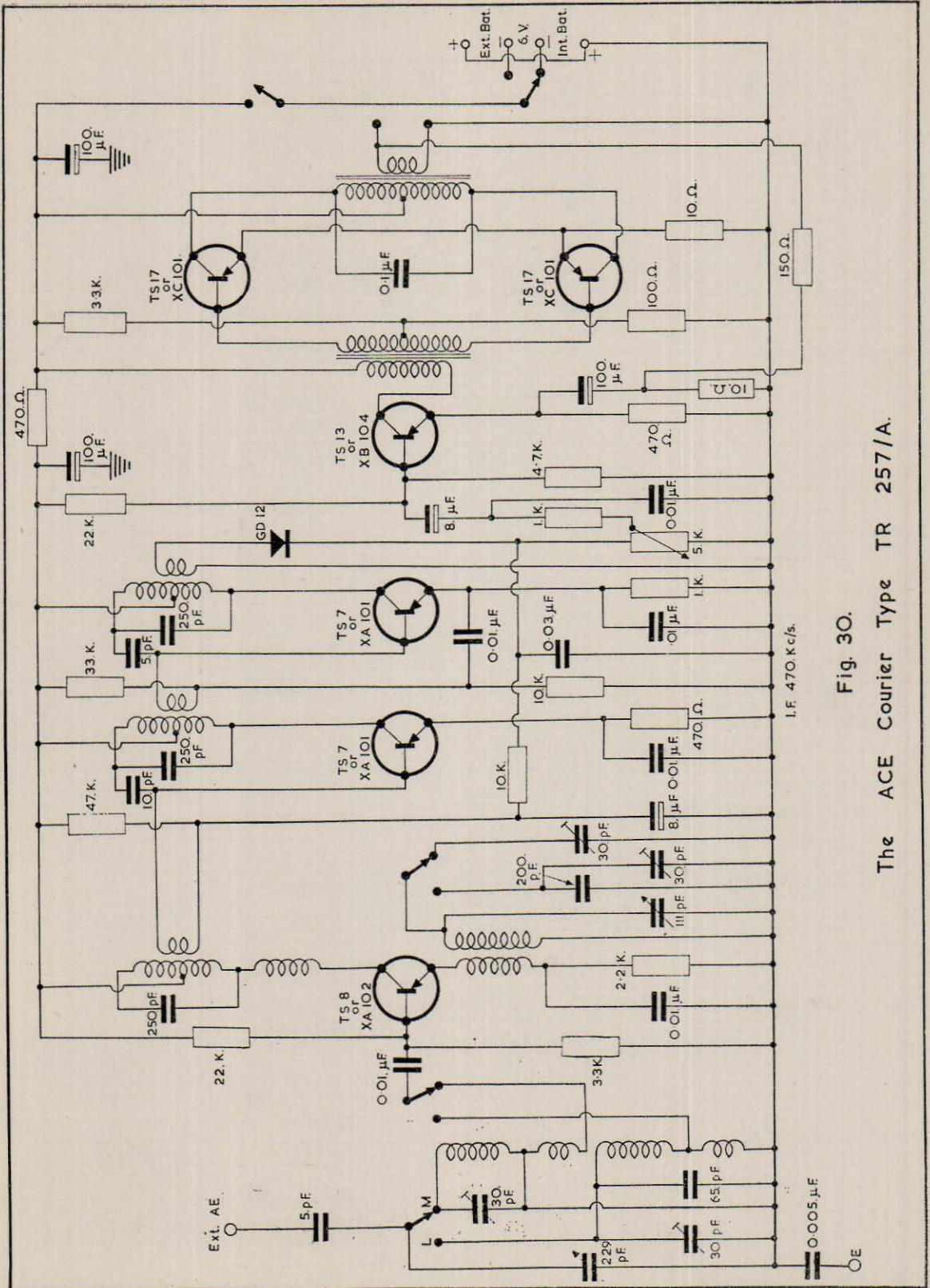
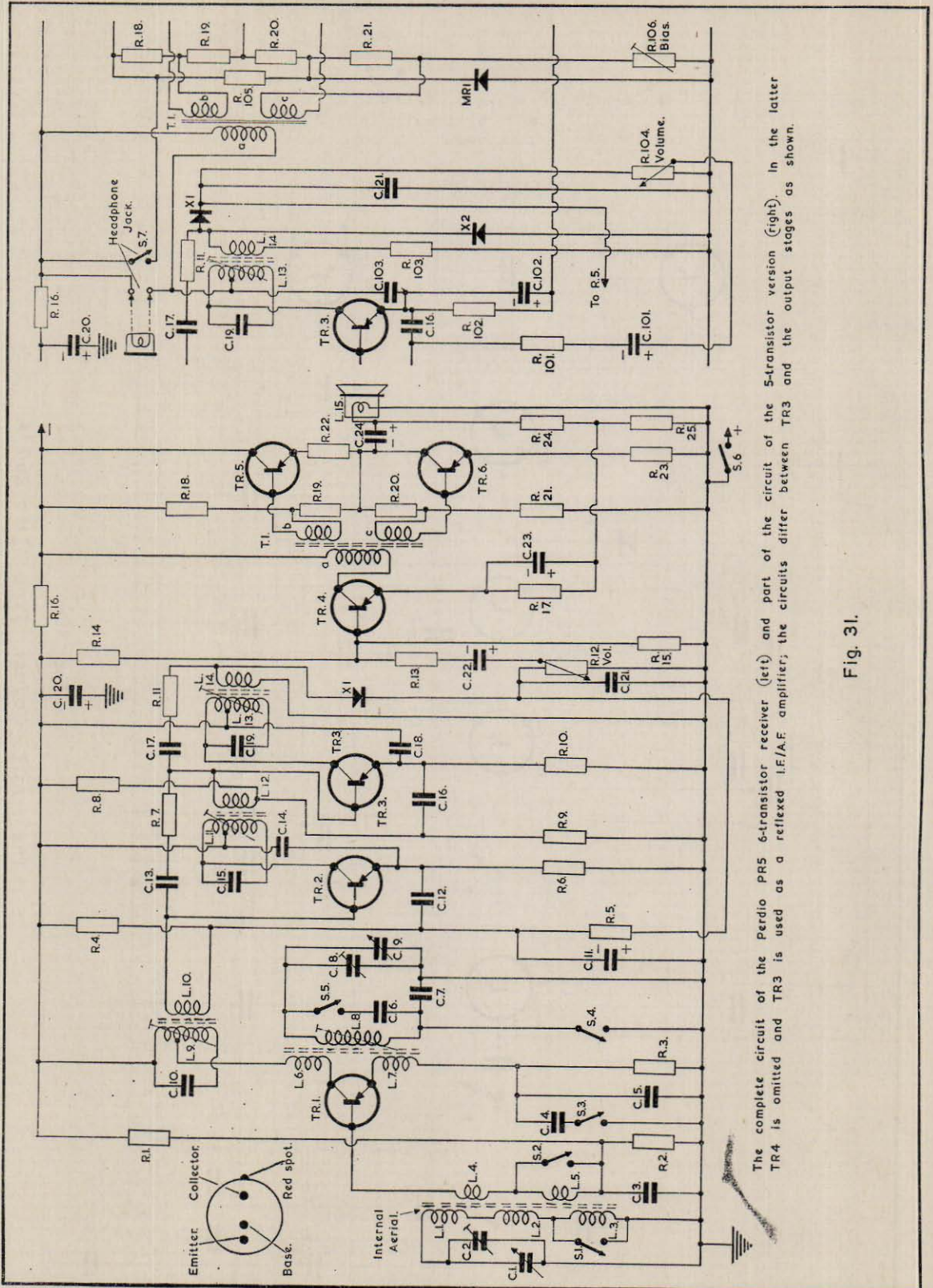


Fig. 30.  
The ACE Courier Type TR 257/A.



The complete circuit of the Perdio PR5 6-transistor receiver (left) and part of the circuit of the 5-transistor version (right). In the latter TR4 is omitted and TR3 is used as a reflexed I.F./A.F. amplifier; the circuits differ between TR3 and the output stages as shown.

Fig. 31.

Components List

Resistors

R1	56K	C2
R2	10K	C2
R3	3.9K	C2
R4	68K	B1
R5	8.2K	B1
R6	680 ohms	B1
R7	1.2K <sup>1</sup>	B1
R8	22K	B2
R9	4.7K	B2
R10	1K	B2
R11	3.9K	B2
R12	5K	B2
R13	5.6K	B2
R14	33K	B2
R15	10K	B2
R16	680 ohms	B2
R17	470 ohms	B2
R18	2.7K <sup>1</sup>	A1
R19	100 ohms <sup>1</sup>	A2
R20	2.7K <sup>1</sup>	E4
R21	100 ohms <sup>1</sup>	E4
R22	5 ohms	A1
R23	5 ohms	B2
R24	1K	B1
R25	15 ohms	B2
R101	3.3K	—
R102	470 ohms	—
R103	100 ohms	—
R104	5K	—
R105	2.2K	—
R106	1K	—

Capacitors

C1	—	C1
C2	—	C1
C3	0.04uf	C2
C4	0.04uf	C2
C5	0.01uf	C2
C6	188pF <sup>2</sup>	C2
C7	250pF <sup>2</sup>	C2
C8	—	C1
C9	—	C1
C10	250pF	C2
C11	10uf	C1
C12	0.04uf	B1
C13	56pF <sup>2</sup>	B1
C14	0.04uf	B2
C15	250pF	B2
C16	0.04uf	B2
C17	.18uf <sup>2</sup>	B2
C18	0.04uf	B2
C19	250pF	B2
C20	50uF	B2
C21	0.04uF	B2
C22	10uF	B2
C23	32uF	B2
C24	100uF	A1

C101	10uF	—
C102	32uF	—
C103	0.01uF	—

Coils

L1	0.4	C1
L2	0.4	B1
L3	12.3	A1
L4	0.1	B1
L5	0.4	A1
L6	0.4	C2
L7	0.1	C2
L8	2.8	C2
L9	4.0	C2
L10	0.2	C2
L11	4.0	B2
L12	0.2	B2
L13	3.4	B2
L14	0.4	B2
L15	30.0	—

Other Components

a	375	
T1	b 43	A2
	c 60	
MR1	C2HMB1 <sup>3</sup>	—
X1	0A70	B2
X2	0A70	—
S1-S6	—	C2

The PR4, shown in fig. 32 uses some rather unusual circuitry. The first transistor, G1, acts as a self oscillating mixer in the usual way and is coupled to G2 via a single tuned I.F. transformer. The I.F. amplifier consists of only a single stage, G2, and is reflexed to provide A.F. gain. Both the D.C. and A.F. components of the output from D1 are fed back to the base of G2 so that A.G.C. is achieved.

The A.F. output from G2 is R-C coupled to the audio amplifier which consists of G3 directly coupled to the Class A output transistor G4.

The output power is in the region of 30mw and despite the use of only a single I.F. stage sensitivity and selectivity are quite adequate. A degree of component economy has been achieved by both the reflex system and the use of direct coupling in the audio section.

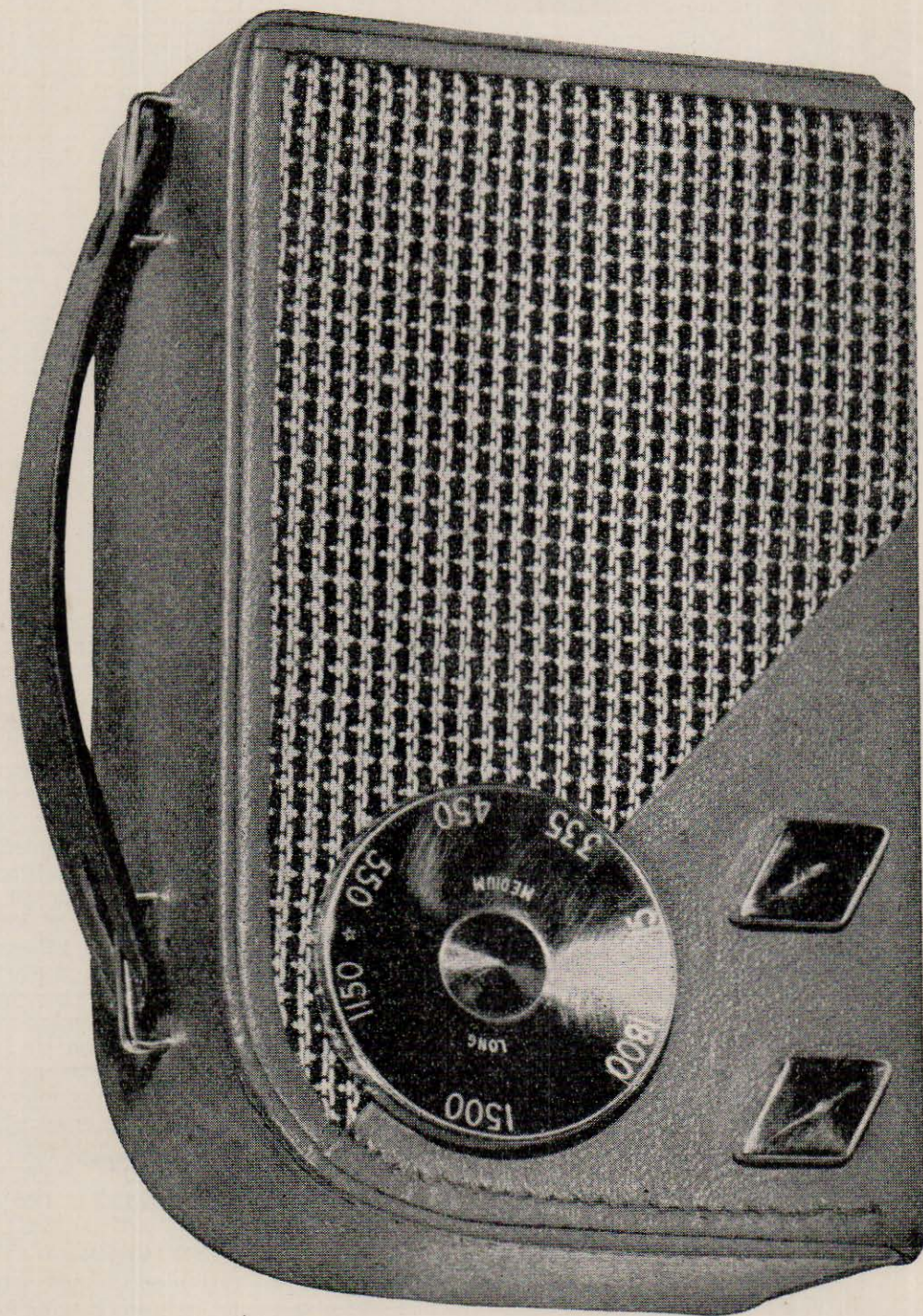
The voltages on the bases, emitters and collectors of the four transistors are as follows:

	Emitter	Base	Collector
G1.	1.0	1.0	6.8 V.
G2.	2.4 (min)	1.7	5.8 V.
G3.	0	0.15	1.65 V.
G4.	1.45	1.65	8.1 V.

COSSOR RECEIVERS

Cossor Radio and Television Limited, manufacture several transistor receivers ranging from the personal sized "Traveller's Friend" to a 6 transistor portable radiogram.

The "Traveller's Friend" is a four transistor superhet with two I.F. stages, the second I.F.



PERDIO PR5 6 Stage Transistor Radio

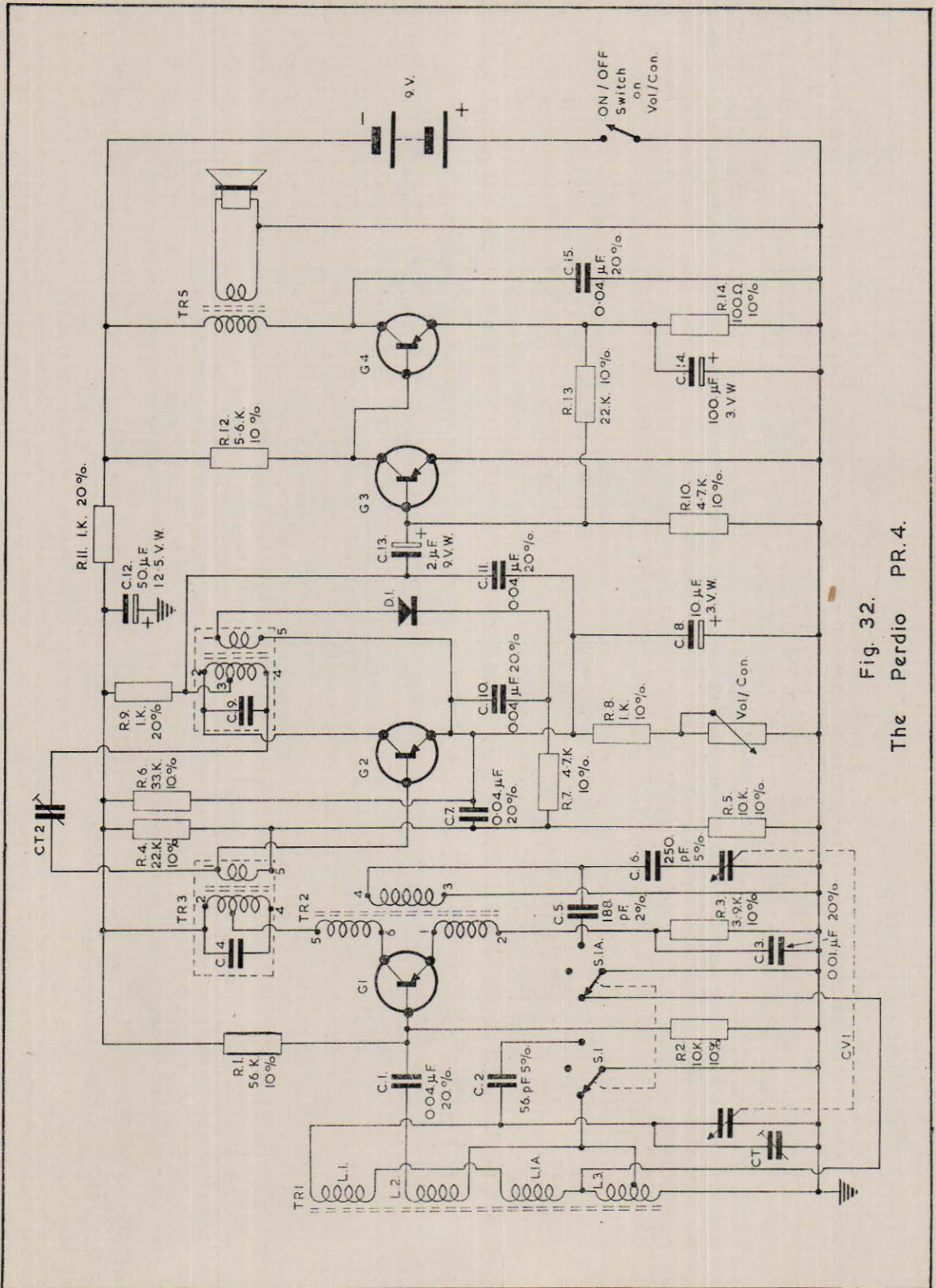


Fig. 32. The Perdio PR.4.



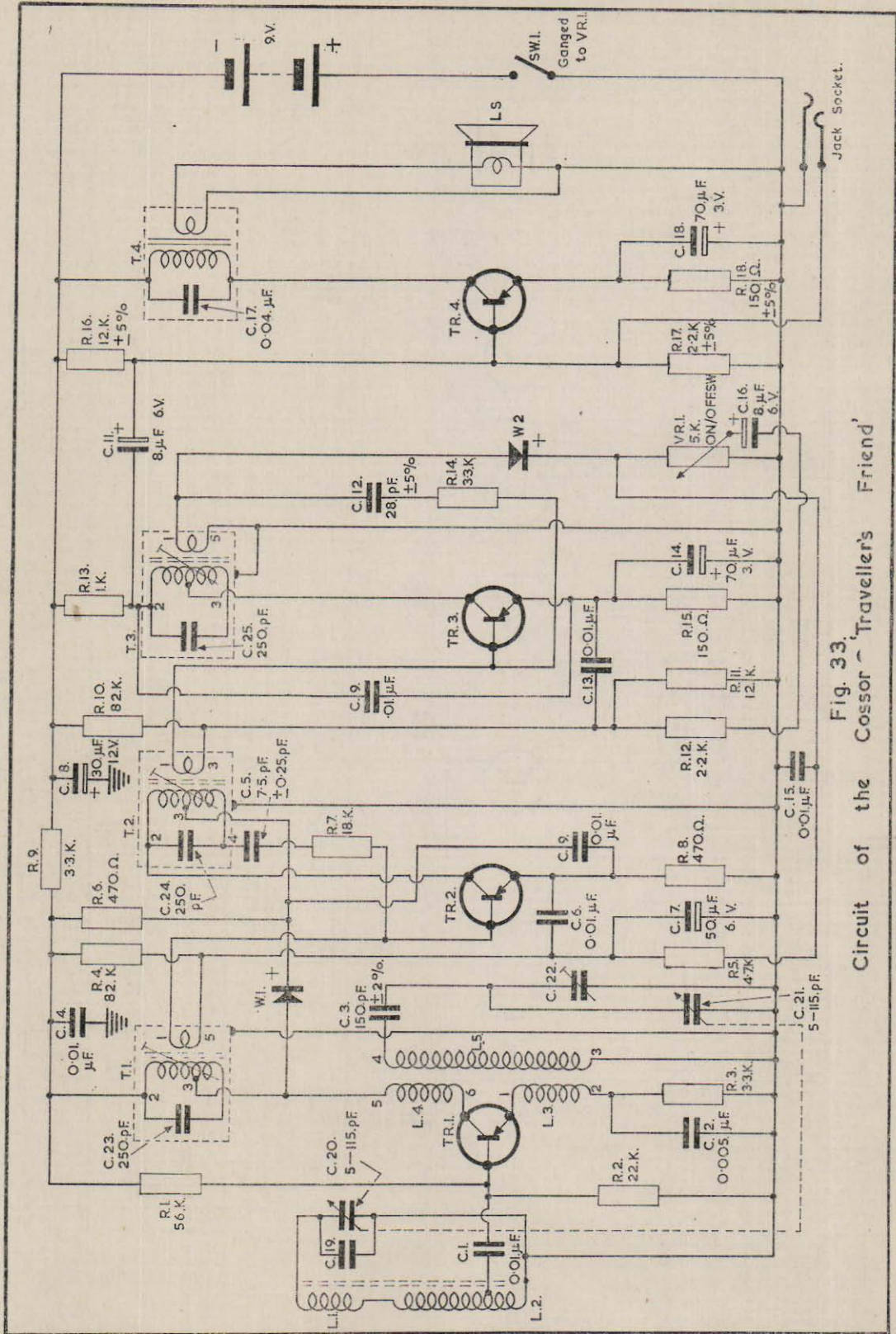


Fig. 33. Circuit of the Corsor 'Travellers Friend'

stage being reflexed to act as the audio driver. A single transistor Class A output stage is used to drive the 2 $\frac{1}{4}$ " loudspeaker, the output power being 30 mw. The size of the case is 6" x 3 $\frac{7}{8}$ " x 1 $\frac{3}{4}$ " and the weight is 17 ozs. A.G.C. is applied to TR2 from the D.C. component from the demodulator diode. W1 is backed off by the battery supply until a strong enough signal is applied to force into the conductive state where it reduces the gain of the receiver by shunting T1 and reducing its effective Q.

An earpiece socket is included as an integral part of the receiver. When the earpiece is plugged in it shunts R17 and cuts off the output stage thereby considerably reducing the power consumption. The alignment instructions are given below.



COSSOR MODEL 581

*Apparatus required*

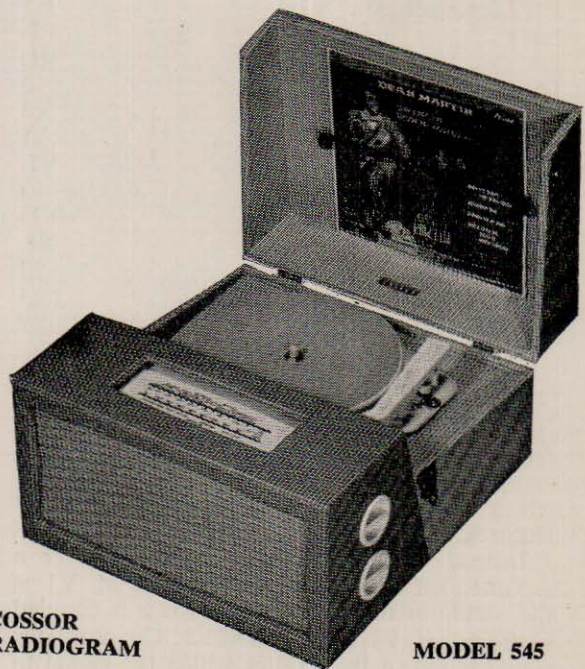
Output meter with impedance of 10 ohms OR A.C. voltmeter across L.S. (reading of output meter should not be allowed to exceed 10mW, or of voltmeter 275mV). Signal generator with 400 c/s modulated output and low output impedance.

*I.F. Alignment*

1. Set gang to maximum.
2. Set Volume Control to maximum.
3. Connect signal generator, tuned to 470 Kc/s and modulated, via an 0.1 mfd. capacitor between TR1 base and earth.
4. Adjust core of T3 for maximum response.
5. Adjust core of T2 for maximum response.
6. Adjust core of T1 for maximum response.
7. Repeat 4, 5 and 6.
8. Seal cores with wax.

*R.F. Alignment*

1. Carefully screw in aerial trimmer (C19) on gang until it is just tight. (Note that tightening this trimmer too much will cause damage to the component).
2. Rotate tuning control to gang maximum.
3. Set signal generator to 545 Kc/s and place output lead near aerial rod (alternatively output may be connected to junction of aerial tap and C1 via a 2pf capacitor).
4. Adjust core of L5 (oscillator coil) for maximum response.
5. Rotate tuning control to gang minimum. NOTE: This is electrical minimum and is 5° away from the mechanical minimum.
6. Reset signal generator to 1580 Kc/s.
7. Adjust oscillator trimmer (C22) on gang for maximum response.
8. Repeat 2 to 7 as necessary (always finishing with 7).
9. Set signal generator to 575 Kc/s.
10. Tune set to this frequency and adjust position of aerial coil trimmer on ferro-dyne rod for maximum response.
11. Set signal generator to 1450 Kc/s.
12. Tune set to this frequency and adjust the aerial trimmer (C19) on gang for maximum response.
13. Repeat 5, 6 and 7.



COSSOR RADIOGRAM

MODEL 545

14. Repeat 9 to 12 until no further improvement is made (if possible final adjustments should be made with an output meter and signal adjusted to give a reading of 5mW).

15. Seal gang trimmers, oscillator coil core and aerial coil trimmer with wax.

#### Voltage and Current Tables

The figures given below are typical readings which will be obtained using a model 8 Avometer.

Battery Voltage	8.9V	(10V range)
Total Current	10.5mA	(100mA range)
TR1 Ic	0.35mA	(1mA range)
TR1 Ve	1.35V	(2.5V range)
TR1 Vb	1.075V	(2.5V range)
TR2 Ic	0.35mA	(1mA range)
TR2 Ve	0.2V	(2.5V range)
TR2 Vb	0.3V	(2.5V range)
TR2 Ic	2.8mA	(10mA range)
TR3 Ve	0.45V	(2.5V range)
TR3 Vb	0.575V	(2.5V range)
TR3 Ic	6.55mA	(10mA range)
TR4 Ve	1.1V	(2.5V range)
TR4 Vb	1.2V	(2.5V range)
Junction of R6 C9	5.5V	(10V range)

All the above measurements are with no signal. Slight deviation from these figures can be ignored since they will be due to normal tolerances.

#### Approximate D.C. Resistance

#### Values of Inductors and Transformers

Circuit No.	Ohms
L1, L2 (in series)	1.5
L3	VL
L4	VL
L5	3
T1, T2 Primary (overall)	4
Primary (2-3)	1
Secondary	VL
T3 Primary (overall)	3
Primary (2-3)	0.75
Secondary	VL
T4 Primary	22
Secondary	1.25
Loudspeaker	9

VL = Very low ( 0.5 ohms)

#### PAM RECEIVERS

Pam manufacture a wide range of transistor receivers most of which employ more or less standard circuitry. Their Model 710, however, which is shown in fig. 34 has several unusual features which make it very interesting.

Instead of the usual antodyne converter a separate oscillator and mixer are used. V1 is the oscillator the output from which is coupled to the mixer, V2, by means of L3. The oscillator signal is fed to the emitter whilst the signal to be received is fed to the base. Two stages of common emitter I.F. amplification are used. These operate at unusual current levels, the emitter currents of V3 and V4 being 0.22ma. and 0.5ma. respectively. V6 is biased so as to

operate in a nonlinear portion of its curve so that detection of the I.F. signal takes place in its base emitter circuit. The amplified audio signal is fed to V6 and this is used to drive the output stage. V7 and V8 form a common collector Class B push-pull amplifier. Although this type of output stage gives considerably lower gain than the common emitter type the quality is superior, furthermore, the low output impedance makes it simple to direct couple into a centre tapped speaker.

#### PYE

Fig. 36 shows the Pye Model 150BQ. This is only one of a fairly large range of transistor receivers made by Pye, but lack of space prevents me from showing more.

The 150BQ is a five transistor superhet of conventional design built into a very attractive leather case which is almost small enough to fit in a pocket.

The voltages and currents at which the transistors operate with no signal input are as follows:

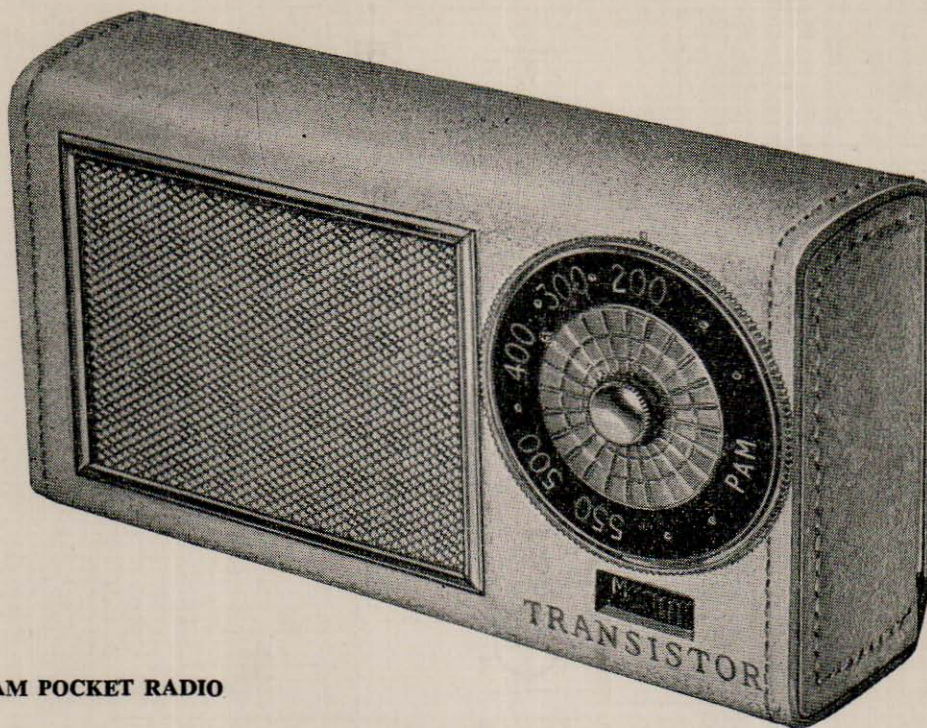
Code	Function	EC	1C	Eb	Ee
V1	Freq. changer	3.15	0.6ma	0.65	0.6
V2	1st I.F. Amp.	5.2	1.3ma	0.8	0.63
V3	2nd I.F. Amp.	5.2	0.81ma	0.58	0.38
V4	A.F. Amp.	5.6	1.0ma	1.2	1.05
V5	Output	5.6	15.0ma	1.3	1.1

#### Components List

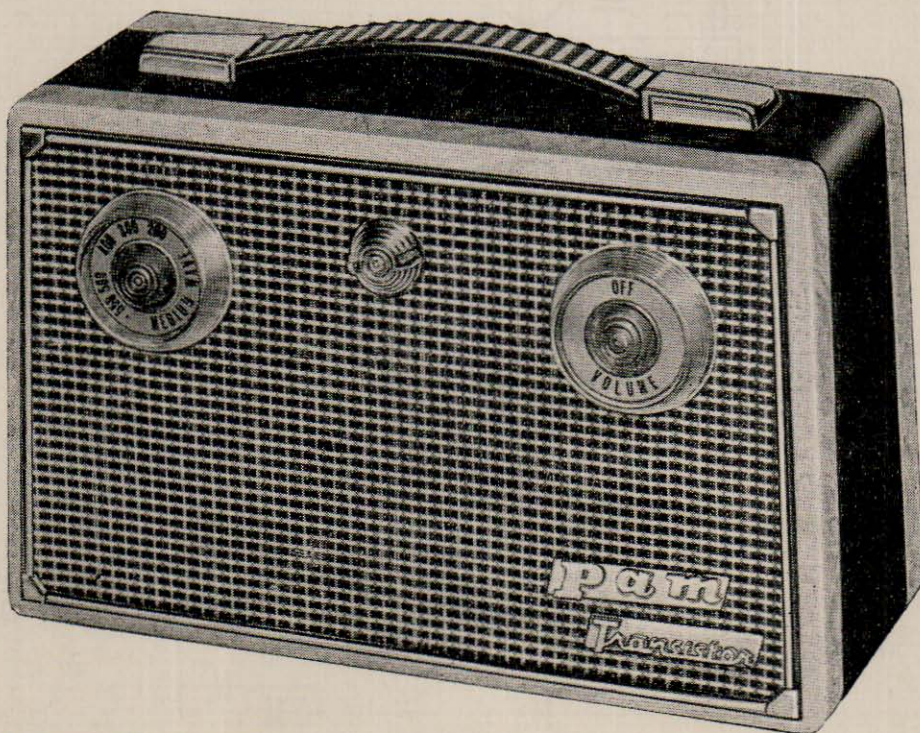
C1	115pF
C2	0.03uF
C3*	2.15pF
C4	6800pF
C5	0.03uF
C6	140pF
C7	115pF
C8*	2.15pF
C9	176pF
C10†	250pF
C11	0.008uF
C12	Selected between 100 and 160pF
C13	0.03uF
C14†	250pF
C15	8uF
C16	0.03uF
C17	0.03uF
C18†	250pF
C19	0.03uF
C20	Selected between 39 and 62pF
C21	16uF
C22	0.03uF
C23	3uF
C24	1uF
C25	0.01uF
C26	8uF
C27	0.01uF

\* Part of Gang capacitor.

† Integral part of I.F. transformer.



PAM POCKET RADIO



PAM PORTABLE MODEL TB.20

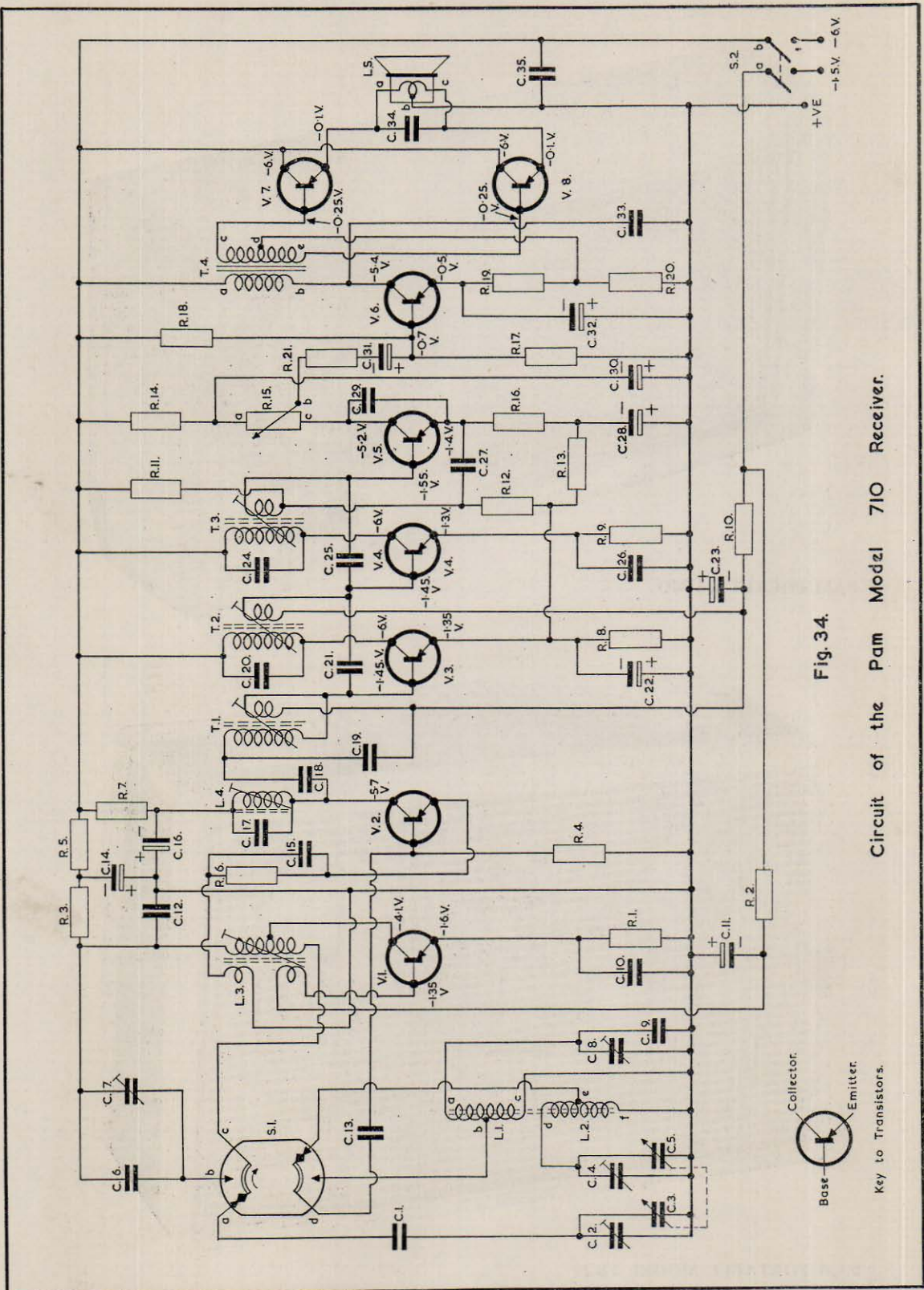
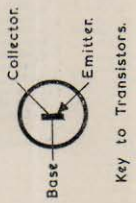
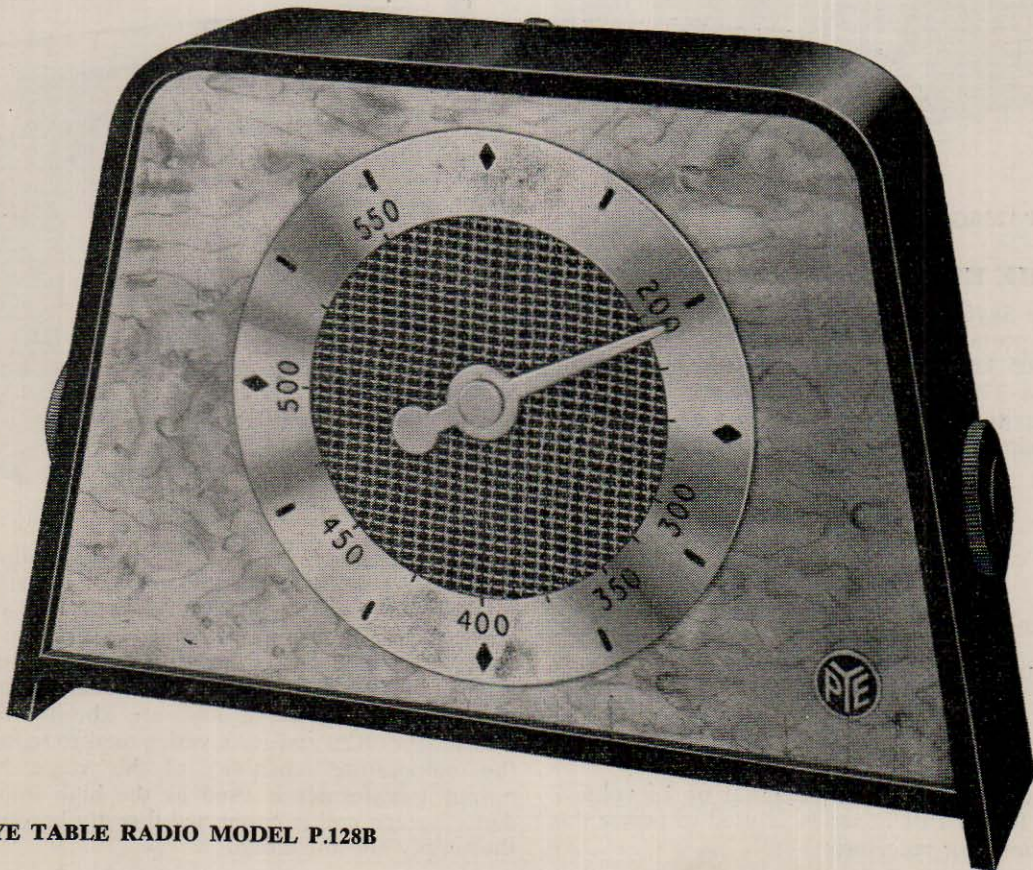


Fig. 34. Circuit of the Pam Model 710 Receiver.





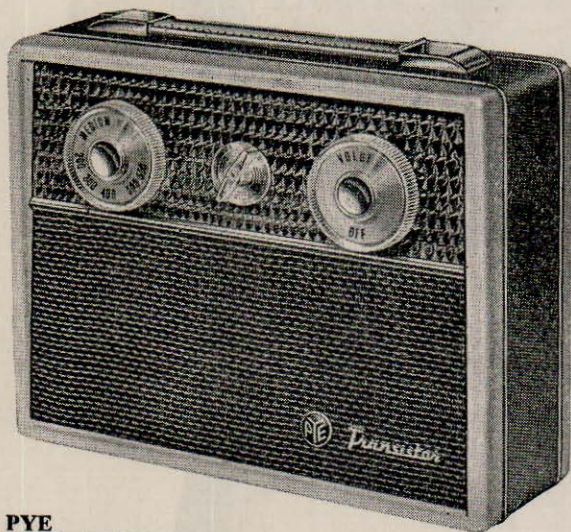
**PYE MODEL P160BQ**



**PYE TABLE RADIO MODEL P.128B**

*Resistors*

R1	33K	R14	6.8K
R2	10K	R15	220 ohms
R3	3.3K	R16	1K
R4	330 ohms	R17	3.3K
R5	1K	R18	1K
R6	470 ohms	R19	680 ohms
R7	10K		
R8	10K		
R9	1.5K		
R10	82K		
R11	470 ohms		
R12	5K volume control		
R13	22K		



**PYE  
MODEL P.123BQ**

**THE EVER READY SKYLEADER**

The Skyleader, fig. 36, is a six transistor full sized portable. The frequency coverage is 540 to 1605 kc/s on the medium wave band and 160 to 270 kc/s on the long wave band. The sensitivity is 150uv/m for an output of 50mW, the voltage on the transistors are as follows:

		Vc	Vb	Ve
VT1	0C44	7.2	1.08	0.95
VT2	0C45	7.2	0.77	0.60
VT3	0C45	7.16	1.19	1.025
VT4	0C71	7.87	1.40	1.23
VT5 & 6	0C72's	—	0.17	0.03

Measurements were made with a valve volt meter.

**THE R.G.D. B56**

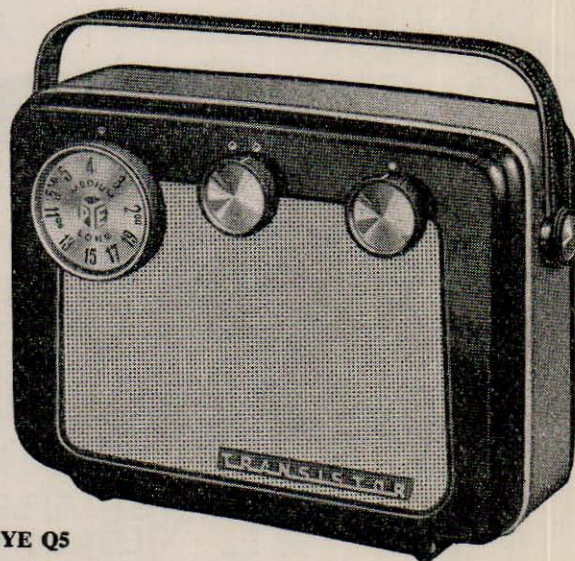
The unusually high potential of 12 volts, 2 Ever Ready PP1 in series, is used to power this six transistor receiver.

L.W. coil L1, and M.W. coil L2, are mounted at opposite ends of a Ferrite rod to form the internal aerial. Tuning on M.W. is provided by C21, and on L.W. by the fixed condenser, C1.

Signals are applied from the low impedance secondary windings on the Ferrite aerial to the Transistor TR1 which works as a mixer oscillator. The emitter of TR1 is connected to a low impedance winding on the oscillator transformer L3 which is tuned by C23 on M.W., and pre-set by C4 and C25 for L.W.

TR2 operates as an earthed emitter I.F. amplifier working into the second I.F. transformer L6, L7 which has a tuned primary and a low impedance secondary. Signals are passed from this winding to TR3 which operates as the second I.F. amplifier, the signal being tuned by L8, and coupled by L9 to the crystal diode detector CDI.

Neutralising is by C9, R9, for TR2, and by C13, R13 for TR3.



**PYE Q5**

The driver stage, TR4, has a primary winding of a step-down transformer connected to its collector, while the secondary windings are connected to TR5 and TR6 which operate as a common committer Class B output stage. Resistors R22 and R27 are the base biasing resistors for this stage and are shunted by Thermistors R20 and R23, which tend to reduce the temperature sensitivity of this stage. No output transformer is used as the high impedance speech coil is connected directly between the supply and the circuit.

TRANSISTOR SUPERHET RECEIVERS

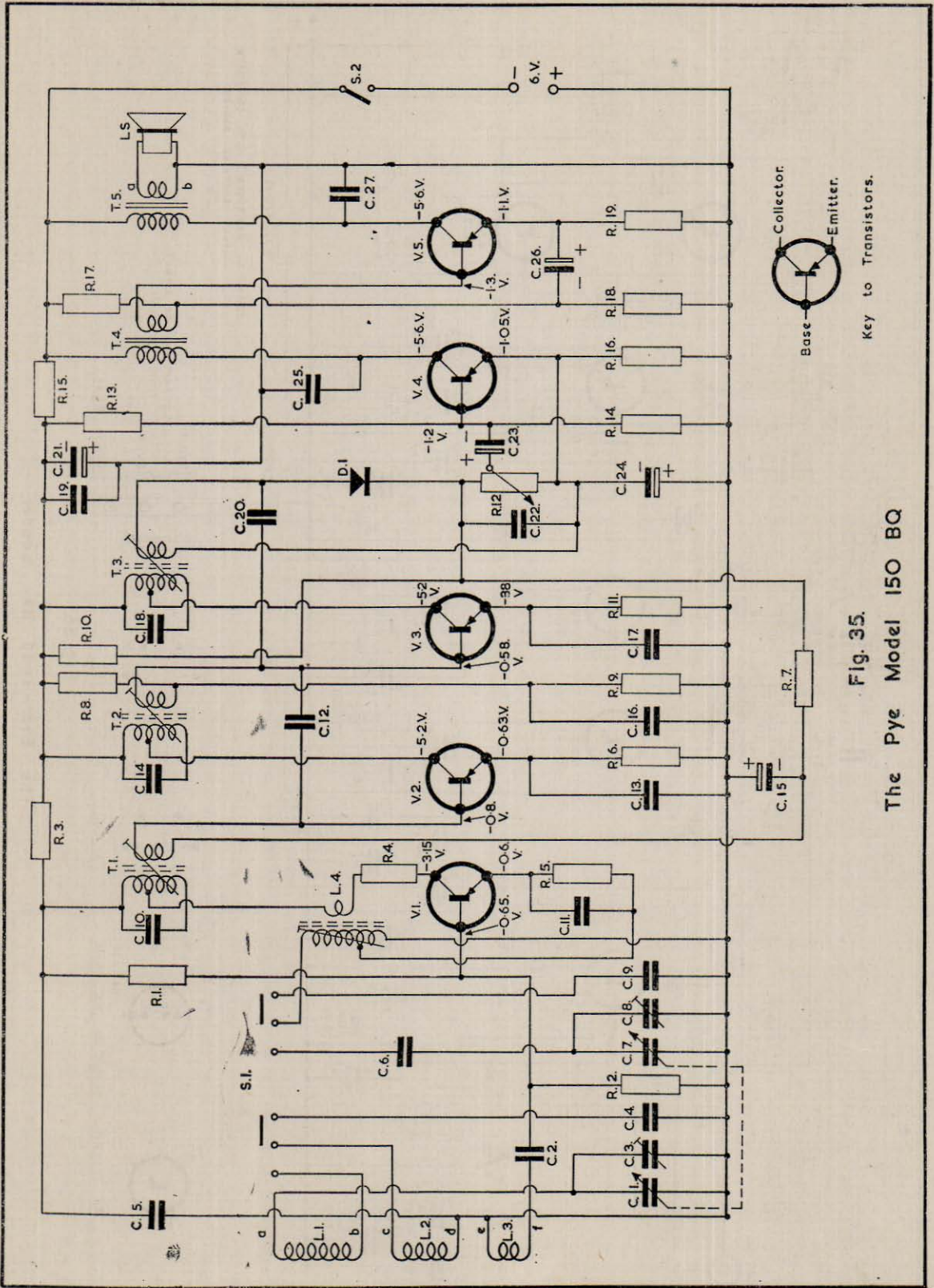
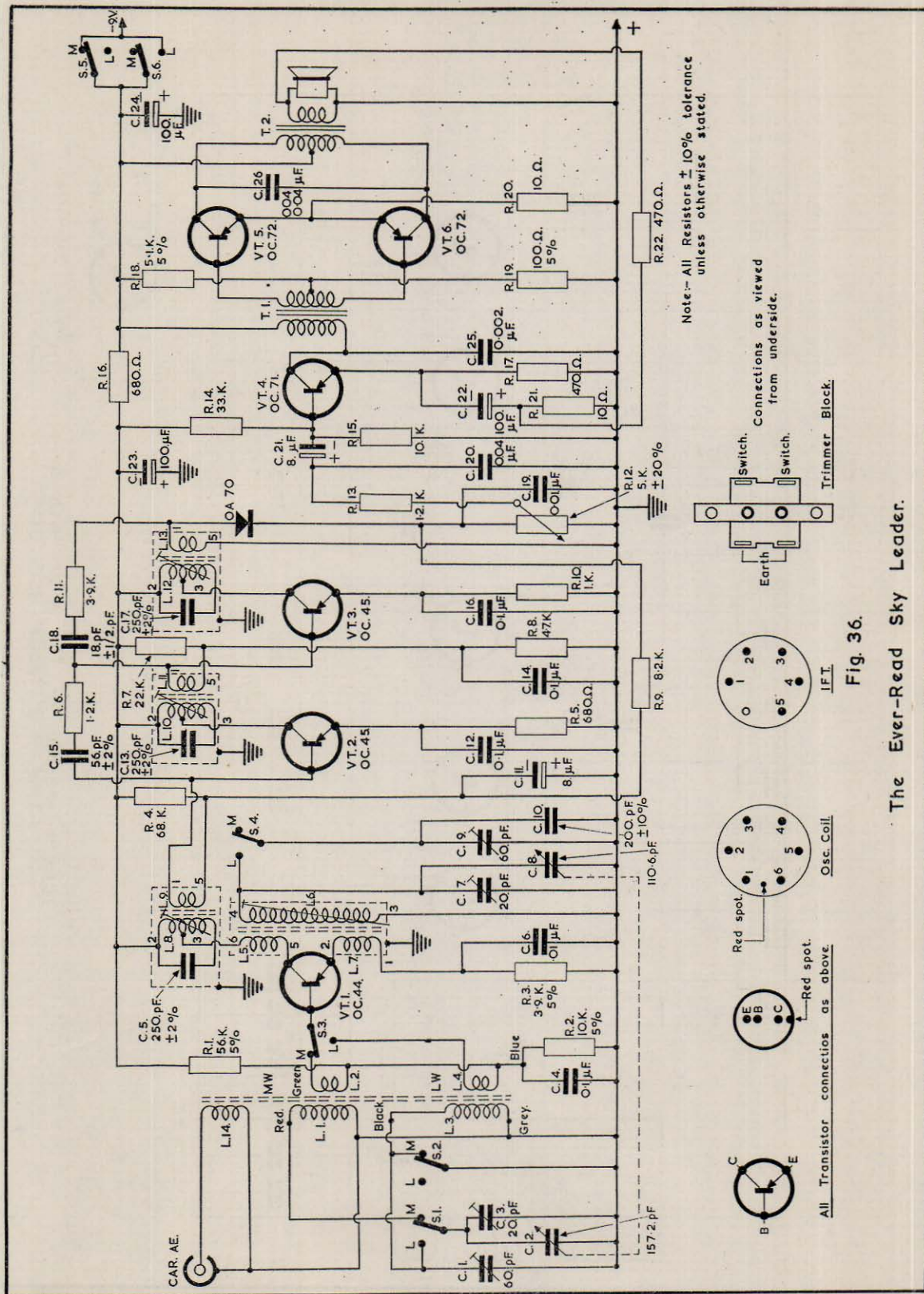
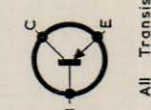
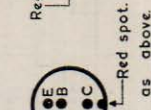
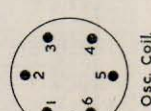
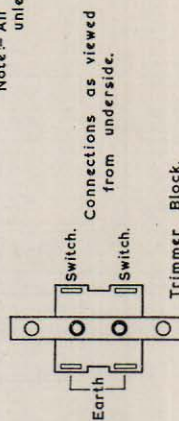


Fig. 35. The Pye Model 150 BQ





Note: All Resistors ± 10% tolerance unless otherwise stated.



All Transistor connections as above.

Fig. 36.

The Ever-Read Sky Leader.

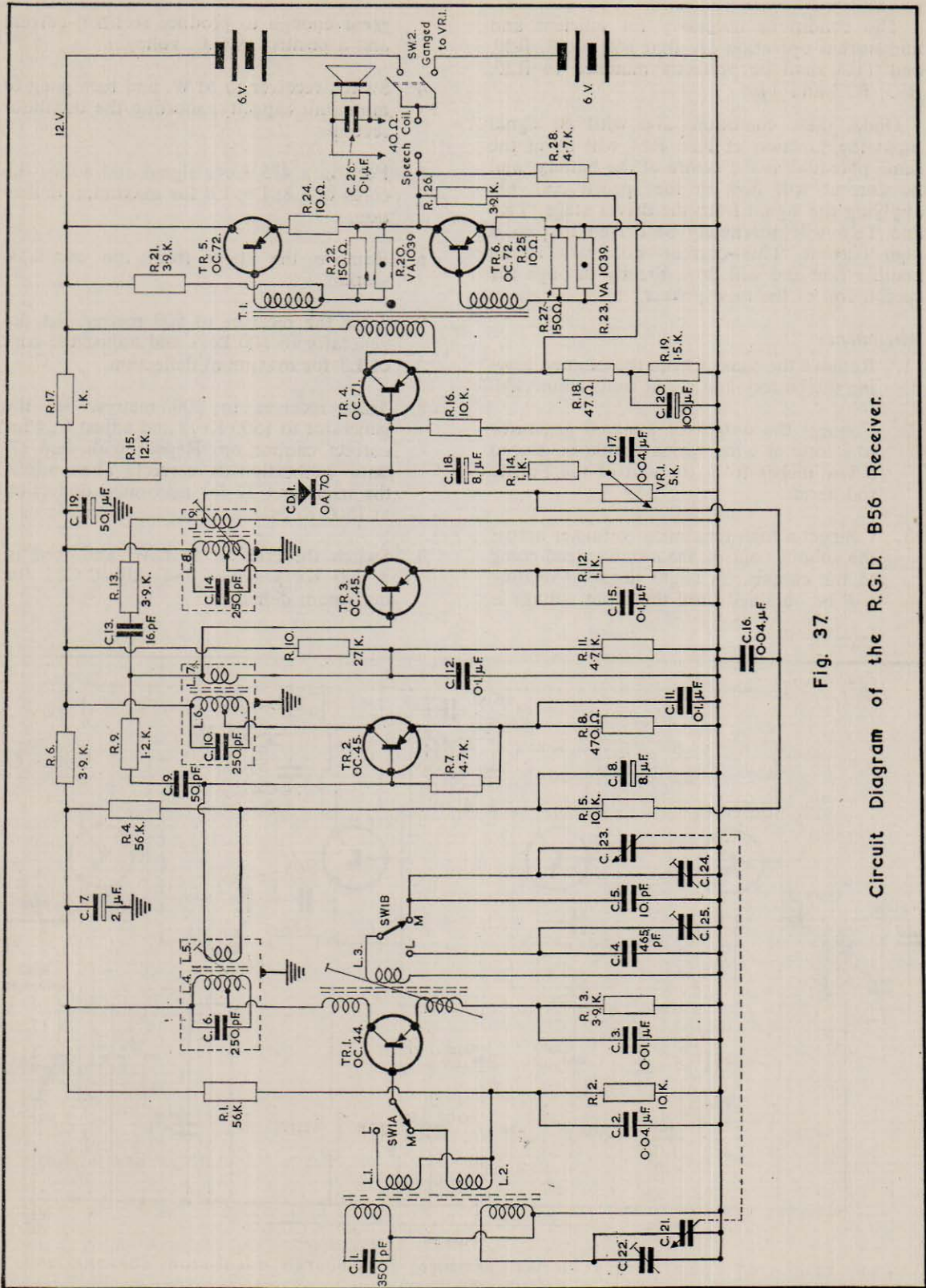


Fig. 37

Circuit Diagram of the R.G.D. B56 Receiver.



## CHAPTER FOUR

## AMERICAN RECEIVERS

All the varieties of circuits described in the previous chapter may also be found in American receivers in a slightly different form. In addition, however, there are a large number of rather more unorthodox receivers which either take advantage of the peculiar properties of some of the more recent types of transistors, for example, the low power and voltage requirements of the surface barrier type, or endeavour to obtain the required results with fewer components.

One rather interesting trend in America which has not, so far, been followed in Great Britain or on the Continent is the production and popularity of earpiece only receivers. These sets are similar in design to the more conventional receivers equipped with both loudspeaker and earpiece socket but they omit the output stage. The maximum output power is usually in the order of 1mw which is quite sufficient to be painful when driving an earpiece. The little sets have several advantages which may be enumerated as follows:

1. Lower initial cost (no speaker or output stage).
2. Smaller size and weight.
3. Greater battery life for a given size of battery.

## CIRCUITS DESIGNED BY TRANSISTOR MANUFACTURERS

As one might expect the American transistor manufacturers have contributed a great deal to the design and development of transistor superhets. A large number of the designs employ a reflexed I.F./A.F. amplifier. Those readers who are familiar with the reflex thermionic valve receivers that used to sell in America may have their doubts as to the advisability of this when they remember the resulting distortion and high playthrough that these receivers possessed. These faults, however do not occur in a correctly designed transistor reflex circuit as there is no filament feedback problem. The overall gain obtainable in these receivers when the I.F./A.F. stage is R.C. coupled to a Class A

output stage is of the order of 60 db. which is usually more than adequate. As N.P.N. R.F. transistors are readily available in the U.S.A. it is possible to save several components by directly coupling the I.F./A.F. stage to the output stage.

As this eliminates the losses made in the R.C. coupling components it also results in a slight increase of gain.

The circuits shown in figs. 38, 39 and 40, are designed around transistors made by the Industro Transistor Corporation. The transistors for use in these circuits are as follows:

	High Gain	Med. Gain
Converter-Oscillator	2N486	2N485
1st I.F. Amplifier	2N483	2N482
2nd I.F. Amplifier	2N483	2N482
Audio driver	2N362	2N363
Push-Pull output	2N359/360	2N361
Single-Ended Output	2N362	2N363
Separate Oscillator	2N481	—

Diode 1N60, 1N64, 1N69, 1N295

As may be seen, two types are listed for each transistor function. One for high gain and one for medium gain. For example, the 2N483 has a gain of 35db. at 455 Kc/s compared with 31db. for the 2N482. The conversion gains of the 2N486 and the 2N285 are 30 and 26db. respectively.

The decision as to whether a high gain or a medium gain set of transistors is to be used will depend upon the type of receiver required. A large receiver using six transistors with highly efficient coils and transformers will not require anything better than the medium gain transistors. A very small pocket set, however, using only a single I.F. stage and relatively inefficient aerial coil and transformers could use to advantage the added sensitivity of the high gain transistors.

The first two sets use the familiar emitter injected antodyne converter, the third uses a separate oscillator and mixer. All three employ two I.F. stages with neutralisation by means of both condensers and resistors.

It is rather interesting to note that the circuit of fig. 38 has a performance at least as good as that of the familiar four valve portable which uses a pentagrid frequency changer and a single I.F. stage.

A combination of N.P.N. and P.N.P. transistors are used in the receiver shown in fig. 41, which uses transistors made by the General Transistor Corporation. As transformer coupling is used between the third and fourth stages, sufficient gain is obtained without reflexing the I.F. amplifier.

As only a single I.F. stage is used, sensitivity is rather low, this means that the receiver must be used with a reasonable size of aerial coil if it is to operate in areas of low signal strength.

Although so simple, this receiver is quite adequate in areas of reasonable signal strength. It may, however, be further simplified without noticeable loss of performance by reflexing the I.F. stage to perform the duties of the driver thus saving the cost of one transistor and its associated components. In areas of strong signal strength the transformer coupling may be replaced by direct coupling between the N.P.N. I.F./A.F. stage and the output stage. This will mean a loss of about 12db in gain but will improve the quality of reproduction.

## AMERICAN MANUFACTURERS RECEIVERS

Fig. 42 shows the circuit diagram of the Regency Model TR-1 which was probably the first transistor receiver to be put on the market anywhere in the world. It was first put on the market around Christmas, 1954, and, surprisingly enough, differs very little from present day designs. The battery voltage,  $22\frac{1}{2}$ , is somewhat higher than usual and the primary of the I.F. transformers are not tapped but these are the only major differences between this set and comparable receivers of today.

The transistors used were N.P.N. types made by Texas Instruments of Dallas. The frequency changer used was a T1223. The I.F. stages used were T1222's, and the audio output stage used was a T1210. The overall size of the receiver was 3" x 5" x  $1\frac{1}{4}$ ". To obtain maximum gain from the I.F. stages, an I.F. of 262 Kc/s was used instead of the far more usual 455 Kc/s. The gain of a transistor declines rapidly beyond a certain point making the use of a low I.F. rather attractive, furthermore stabilisation is simpler at this frequency.

The Class A output stage provides an output of about 12mw. at the primary of the transformer resulting in about 6mw. being fed to

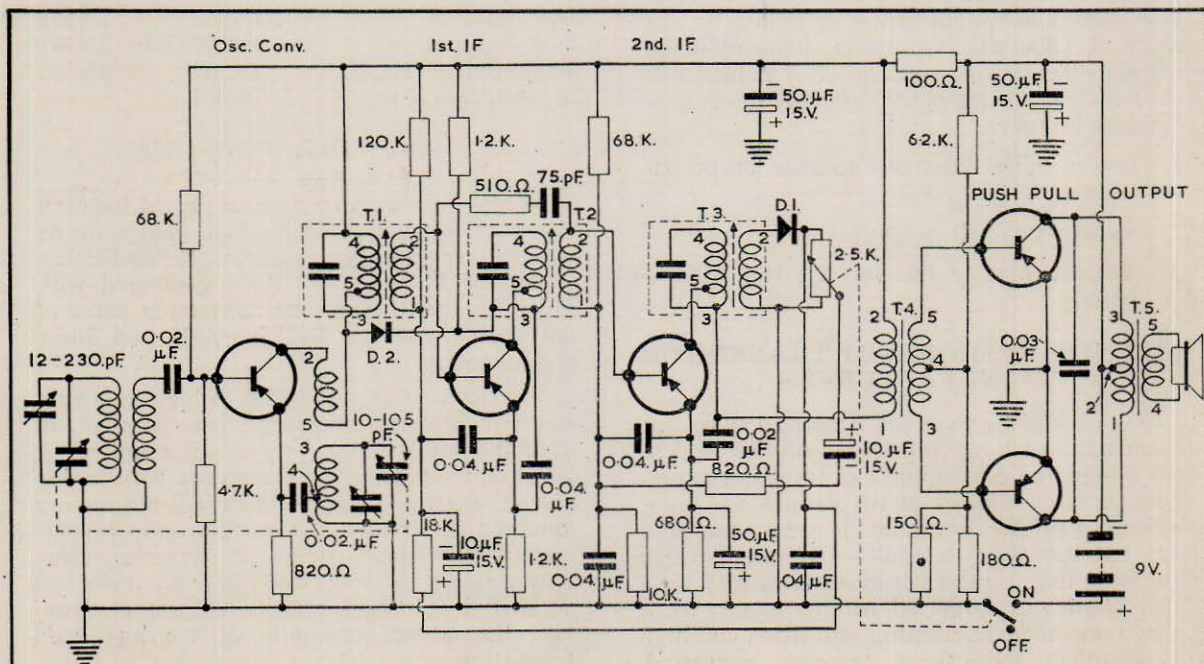


FIG. 39.

FIVE TRANSISTOR RADIO REFLEX CIRCUIT DESIGNED BY INDUSTRO TRANSISTOR CORPORATION.

the speaker. This may appear to be rather low but with an efficient loudspeaker it is sufficient for personal listening which is all the receiver is designed for. Many modern pocket receivers are designed to give a peak output in the region of 100mw. which has several disadvantages. Surprisingly enough increasing the available output power from 12 to 100mw. means using two extra transistors. When 100mw. is required a push-pull output stage must be used to keep the current consumption within reasonable limits. But a Class B push-pull stage has about 7db less gain than a Class A stage using the same type of transistor. Furthermore the difference between 12mw. and 100mw. is more or less 10db. Thus an extra 17db gain must be added to the receiver somehow. The only way in which this can be done is by using another stage of R.C. coupled audio amplification.

Fig. 43 illustrates the Raytheon FM-101A which was one of the first transistor receivers to use the now more or less standard I.F. of 455 Kc/s.

The frequency changer uses a separate oscillator and mixer, V1 being the local oscillator and V2 being the mixer. V2 has no bias on either the emitter or the base so that it operates in the most nonlinear portion of its

curve thus providing a very efficient mixing action.

The two I.F. stages are perfectly normal and require neutralising capacitors of 30pfs. The output from the second I.F. amplifier is transformer coupled to V5 which is a class detector and which also provides an amplified A.G.C. voltage for V3 and V4. Thus gain control is applied to both the first and the second I.F. stages rather than only to the first which is more usual. To ensure that adequate control is maintained even under the most extreme conditions, V3 operates from only half the total battery voltage, that is 3 volts.

The output from the detector is developed across a 25K ohm potentiometer which acts as the volume control. The audio amplifier consists of two stages, a driver, V6, and the push-pull output stage. This latter stage uses two CK722's in push-pull providing a maximum output power of about 100mw.

A five transistor superhet having several unusual features is the Motorola 56T1 shown in fig. 44. 4 N.P.N. transistors are used in the R.F. and detector stages with a P.N.P. transistor as the audio output stage. V1 is a conventional emitter injection, antodyne converter which is

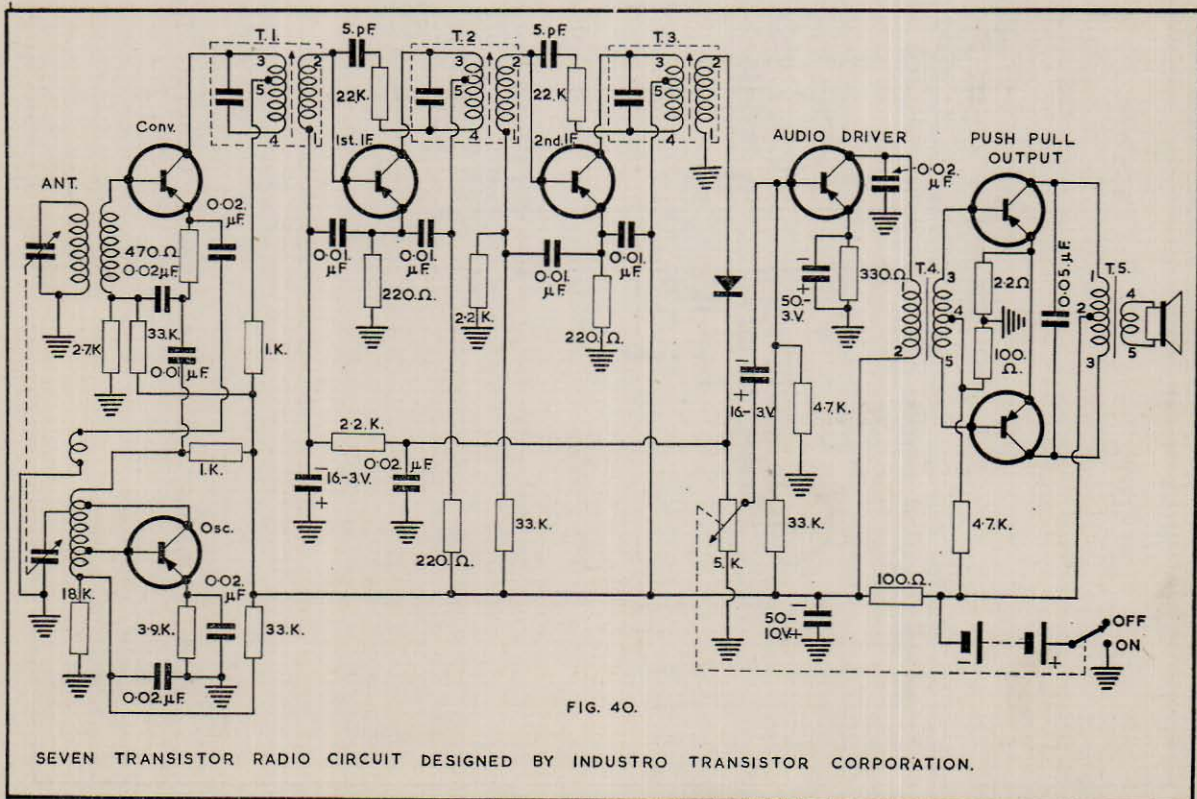


FIG. 40.

SEVEN TRANSISTOR RADIO CIRCUIT DESIGNED BY INDUSTRO TRANSISTOR CORPORATION.

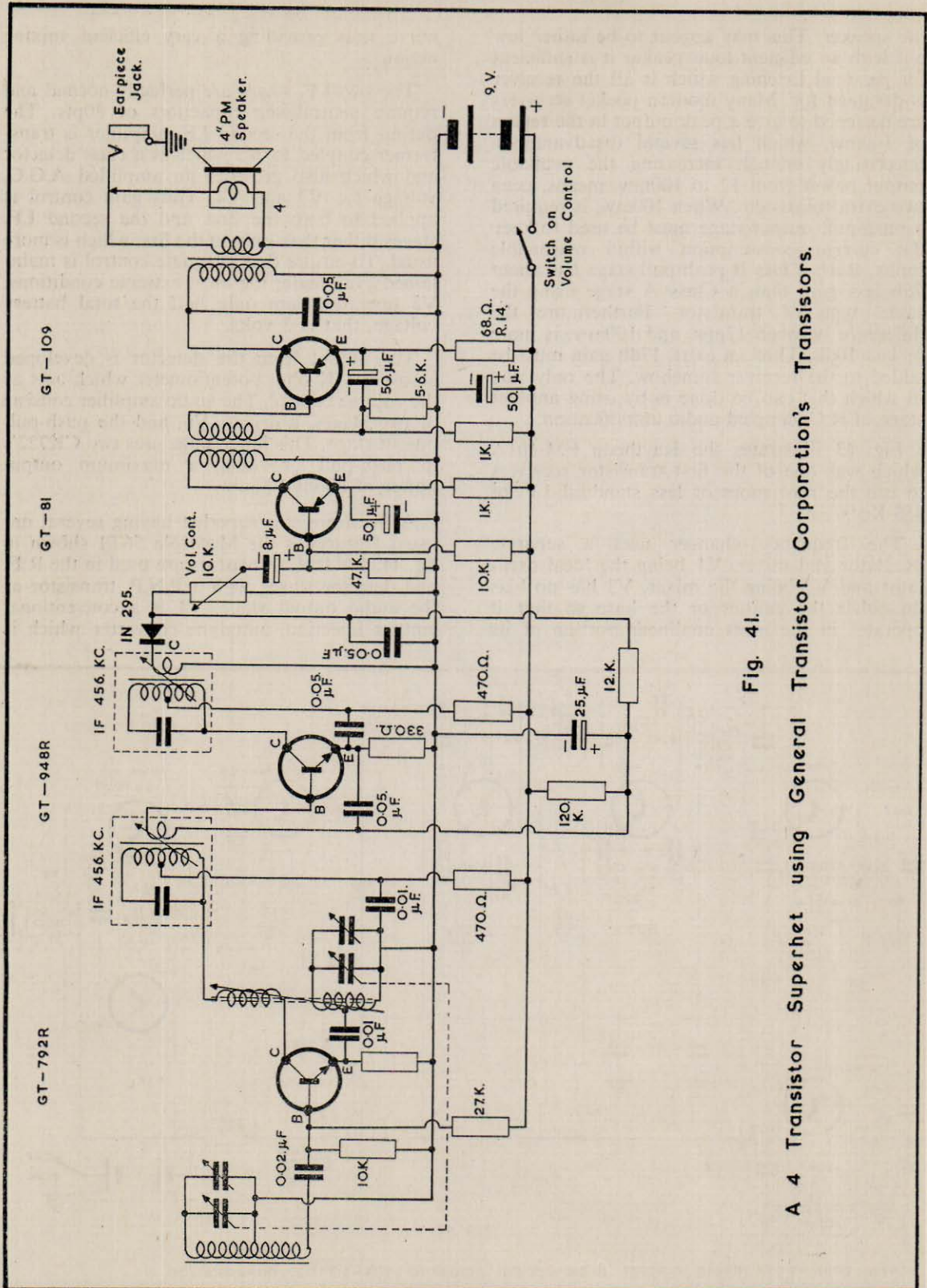


Fig. 41.

A 4 Transistor Superhet using General Transistor Corporation's Transistors.





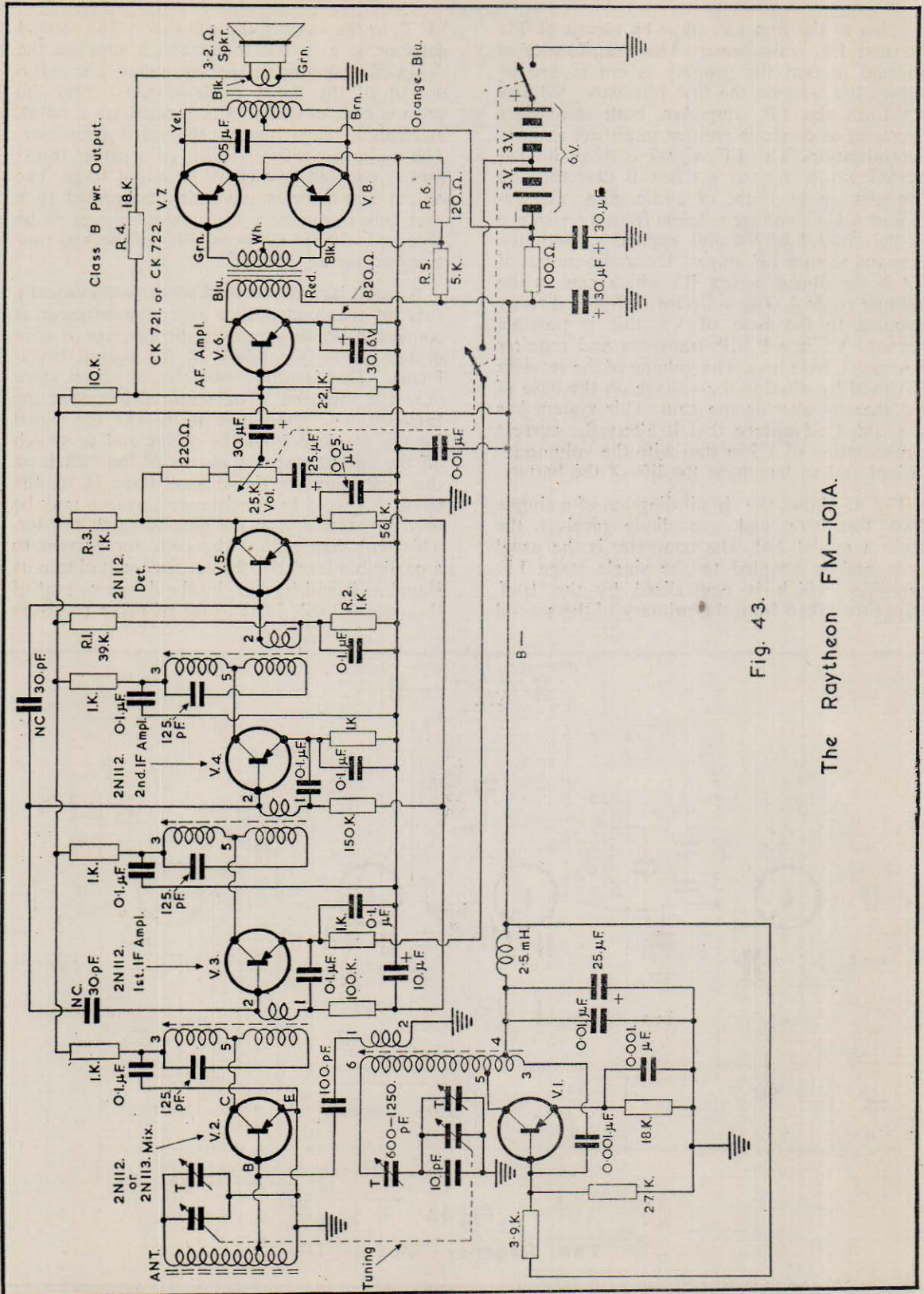


Fig. 43.

The Raytheon FM-101A.



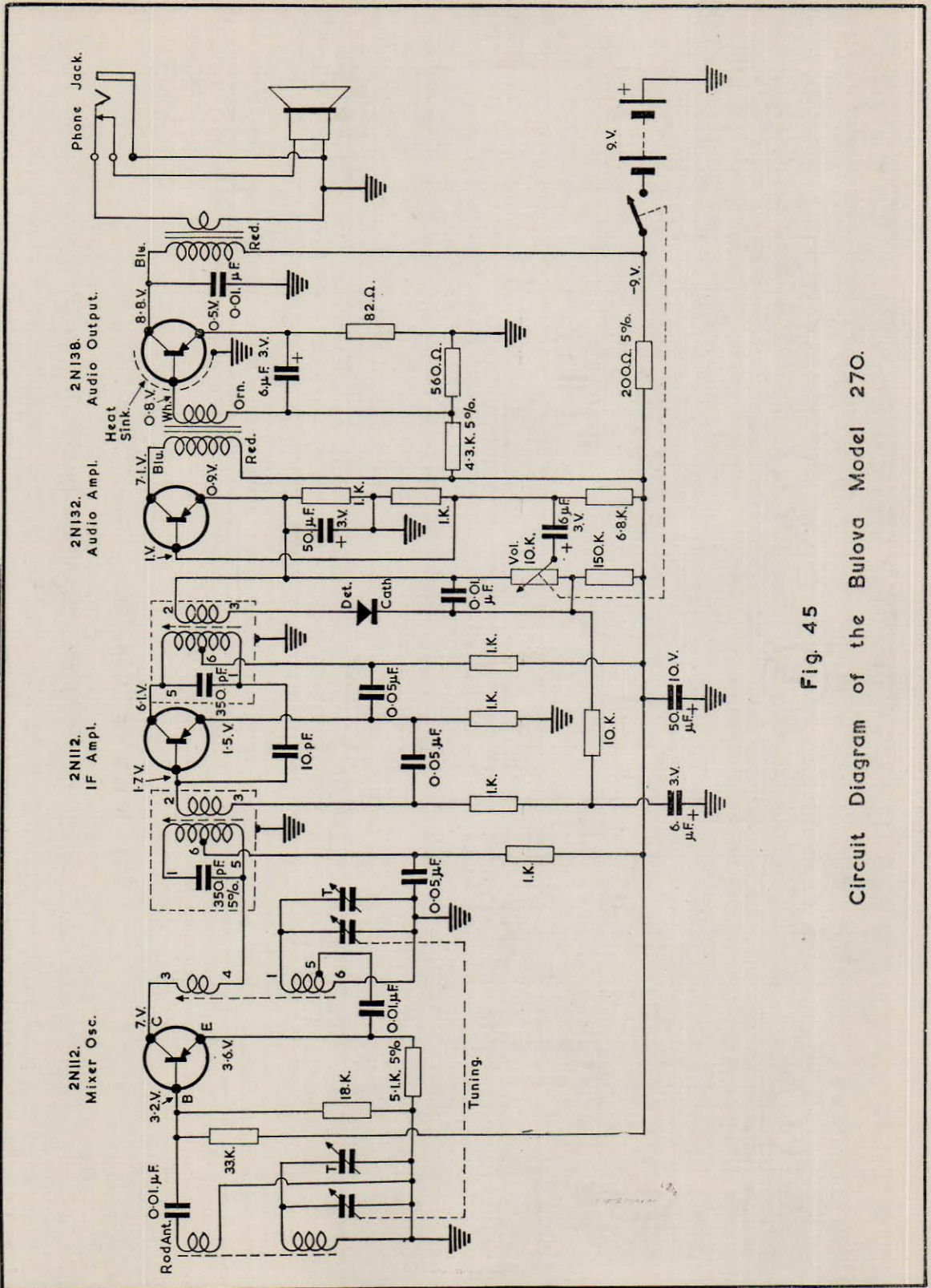


Fig. 45  
Circuit Diagram of the Bulova Model 270.

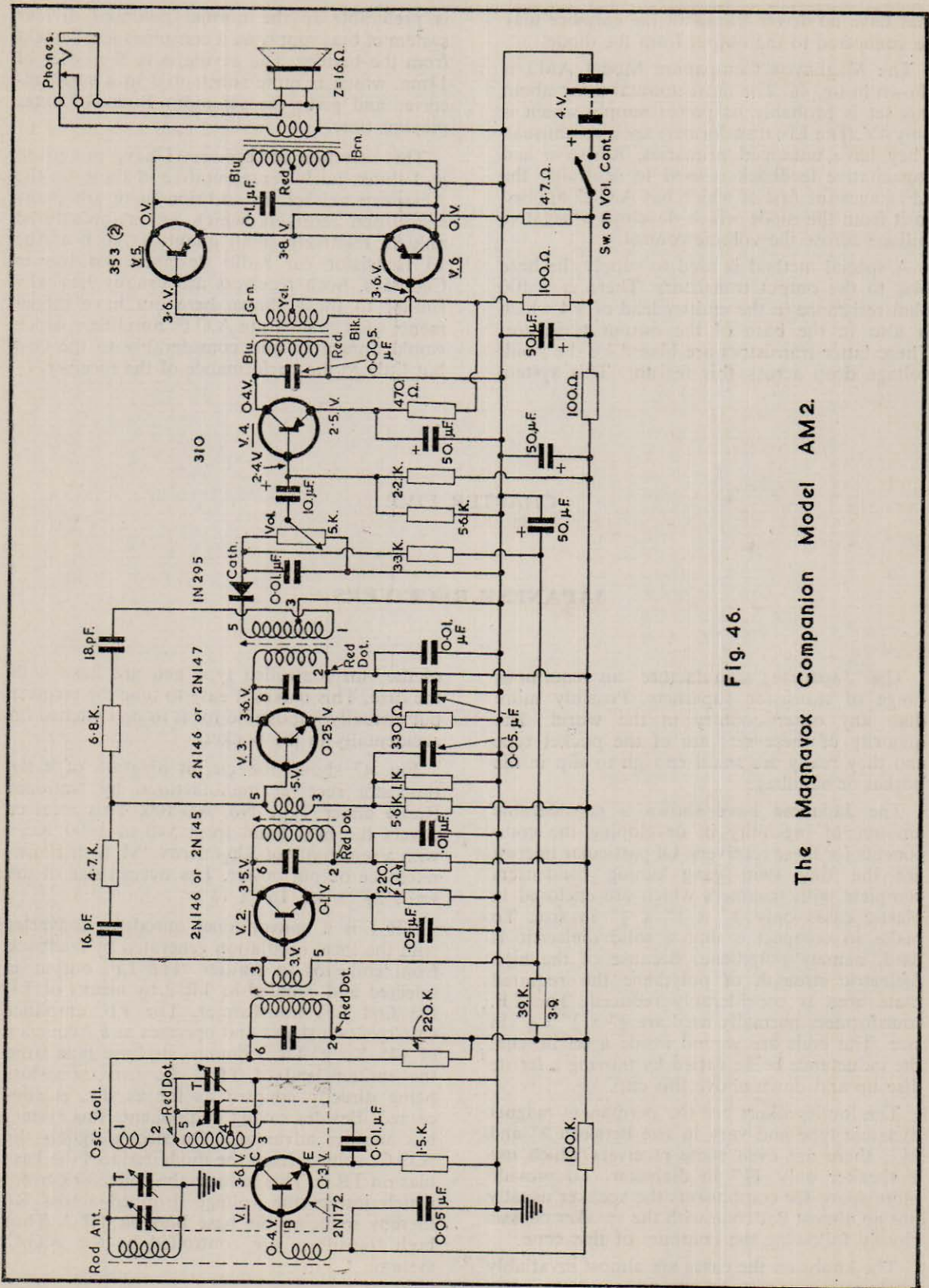


Fig. 46.

The Magnavox Companion Model AM2.

that have no driver transistor the earpiece may be connected to the output from the diode.

The Magnavox Companion Model AM2 is shown in fig. 46. The most unusual thing about this set is probably its power supply which is only 4V. The I.F. transformers are also unusual. They have untapped primaries. Resistive and capacitive feedback is used to neutralise the I.F. stages the first of which has A.G.C. applied to it from the diode which develops a negative voltage across the volume control.

A special method is used to supply the base bias to the output transistors. There is a 100 ohm resistance in the emitter lead of V4 which is also in the base of the output transistor. These latter transistors are biased by the small voltage drop across this resistor. This system

is preferable to the normal potential divider system of bias supply as it consumes less current from the battery. The saving is in the order of 1½ma. which is quite substantial in a small receiver and gives the set many hours of extra playing time.

This selection of receivers I have just given is, I think, fairly representative of those on the American market. In addition there are many specialised receivers which are manufactured only in relatively small quantities such as the 13 transistor car radio designed for use in Cadillacs. Such receivers are usually basically similar to those shown here but have refinements such as separate A.G.C. amplifiers which would appear to add considerably to the cost but little to the performance of the receiver.

## CHAPTER FIVE

### JAPANESE RECEIVERS

The Japanese manufacture an enormous range of transistor superhets. Possibly more than any other country in the world. The majority of these sets are of the pocket type and they really are small enough to slip in the pocket or handbag.

The Japanese have shown a considerable amount of ingenuity in developing the components for these receivers. Of particular interest are the tiny twin gang tuning condensers complete with trimmers which are enclosed in plastic cases only 1" x 1" x ⅜" in size. To make so compact a unit a solid dielectric is used, namely polythene. Because of the high dielectric strength of polythene the required plate area is considerably reduced. The I.F. transformers normally used are ⅜" x ⅜" x ½" in size. The coils are wound inside a ferrite cup, the inductance being varied by moving a ferrite disc up and down above this cup.

The loudspeakers are the permanent magnet dynamic type and vary in size between 2" and 2½"; there are even some receivers which use a speaker only 1½" in diameter. To provide more space for components the speaker usually has an almost flat cone with the speaker chassis closely following the contours of this cone.

The knobs on the cases are almost invariably

of the rim controlled type and are flush with the case. This makes it easy to tune the receiver but virtually impossible for it to be switched on accidentally in the pocket.

Fig. 47 shows the circuit diagram of a six transistor receiver manufactured by National Radio under Type No. AB-100. This receiver covers the mw. band from 540 to 1600 Kc/s with a sensitivity of 300 microv./M. with 10mw. reference output power. The overall size of the set is 2⅞" x 4.3/16" x 1⅛".

TR-1 is a conventional autodyne converter with the local oscillation generated by feedback from collector to emitter. The I.F. output is selected and coupled to TR-2 by means of T1, the first I.F. transformer. The I.F. amplifier employs two stages and operates at a frequency of 445 Kc/s. TR-3 obtains its base bias from the emitter lead of TR-2 the two transistors being directly coupled as far as d.c. is concerned. Besides saving components this system has another advantage. On strong signals the A.G.C. voltage from the diode reduces the base bias on TR-2. This reduces the collector current which lowers the voltage dropped across R6 thereby reducing the base bias on TR-3. Thus both transistors are controlled by the A.G.C. system.

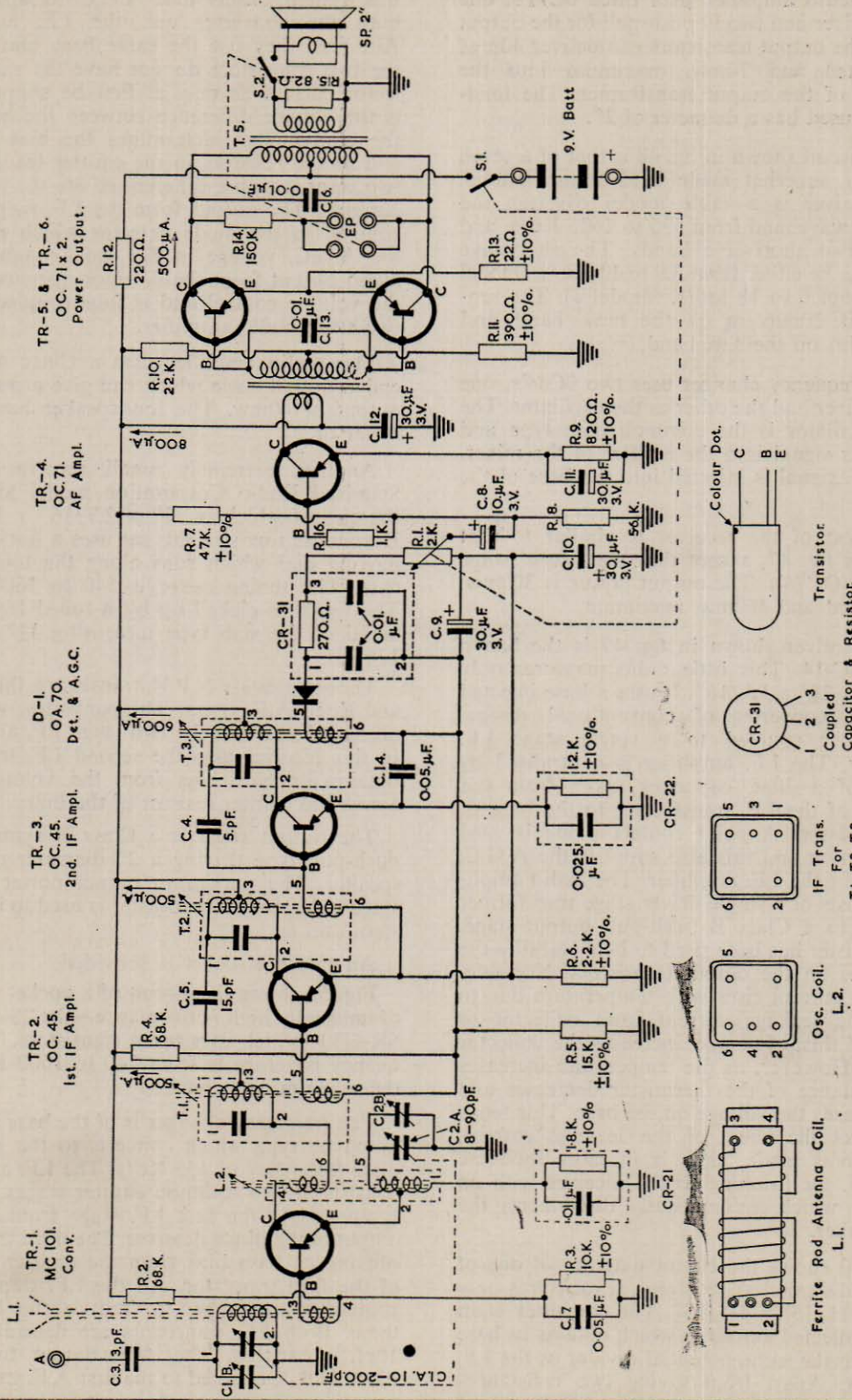


Fig. 47. The National Radio Model AB-100.

- Ferrite Rod Antenna Coil, L.1.
- Osc. Coil, L.2.
- IF Trans. For T1, T2, T3.
- CR-31 Coupled Capacitor & Resistor.
- CR-22 IF Trans. For T1, T2, T3.
- CR-31 Coupled Capacitor & Resistor.
- Transistor Colour Dot.

The audio amplifier uses three OC71's, one as the driver and two in push-pull for the output stage. The output transistors can deliver 40mw. undistorted and 70mw. maximum into the primary of the output transformer. The loudspeaker used has a diameter of 2".

The circuit shown in fig. 48 is that of a seven transistor superhet made by National Radio. The receiver is a table model covering the medium waveband from 535 to 1605 Kc/s. and one of two shortwave bands. The shortwave band may be either from 3.9 to 12 mc/s. (model M) or from 6 to 18 mc/s. (model J). The sensitivity is 20mv/m on the m.w. band and 50 mv/m on the s.w. band.

The frequency changer uses two OC44's, one as the mixer and the other as the oscillator. The local oscillator is the common base type and injects its signal into the emitter of the mixer. The R.F. signal is injected into the base of the mixer.

The rest of the receiver is similar to that shown in fig. 47, except that the output stage uses two OC76's. The output power is 300mw. undistorted and 450mw. maximum.

The receiver shown in fig. 49 is the Sanyo Model SC-14. This little radio measures only 4.5/16" x 2 $\frac{5}{8}$ " x 1.5/16". It uses a base injected autodyne converter of conventional design, transformer coupled to a single stage I.F. amplifier. The I.F. amplifier is neutralised by means of a 30pf. capacitor taken from the primary of the I.F. transformer to the base of the transistor. A point contact diode is used for detection and this also supplies the A.G.C. voltage for the I.F. amplifier. The audio amplifier consists of a single driver stage transformer coupled to a Class B push-pull output stage. A thermister has been used to help stabilise the base bias on the output transistors. Normally the base current rises with temperature due to increasing leakage current from collector to base and this, of course, increases the collector current. However, as the temperature increases the resistance of the thermistor decreases and so decreases the voltage on the base. This tends to correct the effect of the leakage current. Provision is made, as it is in most Japanese receivers, for listening to the receiver with an earpiece which automatically disconnects the 2 $\frac{1}{4}$ " speaker.

Fig. 50 shows the circuit diagram of one of the world's smallest receivers. It measures only 2 $\frac{1}{2}$ " x 3.11/16" x 1.1/16". The converter is an emitter injected autodyne which obtains its base bias from the same potential divider as the I.F. amplifier. Apart from saving two resistances

this system means that A.G.C. is applied to both the converter and the I.F. amplifier. Although they use the same base bias supply the two transistors do not have the same collector current as may at first be supposed. It is the voltage difference between the base and the emitter that determines the bias current and as the resistors in the emitter leads of the two transistors are different so are the collector currents. The output from the I.F. amplifier is coupled to the diode detector which provides the A.G.C. voltage in the usual manner. The audio output from the detector appears across the volume control and is thus coupled to the two stage audio amplifier.

The audio amplifier uses a Class A single ended output stage which can give a maximum output of 40mw. The loudspeaker has a diameter of 2".

Another extremely small receiver is the Standard Radio Corporation model SR-F211, the size of which is 3 $\frac{7}{8}$ " x 2.7/16" x 1.1/16". Despite its tiny size this set uses a horizontally moving dial which runs along the top of the case. The tuning range is 540 to 1600 Kc/s. The signal is picked up by a tuned ferrite rod aerial of the slab type measuring 1 $\frac{3}{4}$ " x  $\frac{1}{2}$ " x 1/6".

The set uses six N.P.N. transistors, three R.F. and three A.F. types. The converter, which is normal, feeds into the two stage I.F. amplifier. In this receiver also the second I.F. transistor obtains its base bias from the voltage drop across the emitter resistor of the first.

The output stage is a Class B symmetrical push-pull type driving a 2" diameter dynamic speaker. The maximum output power of this stage is 100mw. A thermister is used to improve stabilisation.

An earpiece socket is provided.

Fig. 52 shows the circuit of a pocket receiver of unusually high performance—the "Standard" SR-G204 which uses seven transistors. The frequency coverage is from 540 to 1600 Kc/s on the medium wave band.

The frequency changer is of the base injected autodyne type which converts to the intermediate frequency of 455 Kc/s. The I.F. amplifier consists of two common emitter stages. A.G.C. is applied to the first I.F. stage from the d.c. output of the diode detector. The third transistor obtains its base bias from the emitter resistor of the fifth transistor. All the I.F. transformer primaries are tapped to reduce the load on them. Both I.F. transistors are neutralised by 10pf. capacitors. The A.F. output from the diode is R-C coupled to the first A.F. transistor.

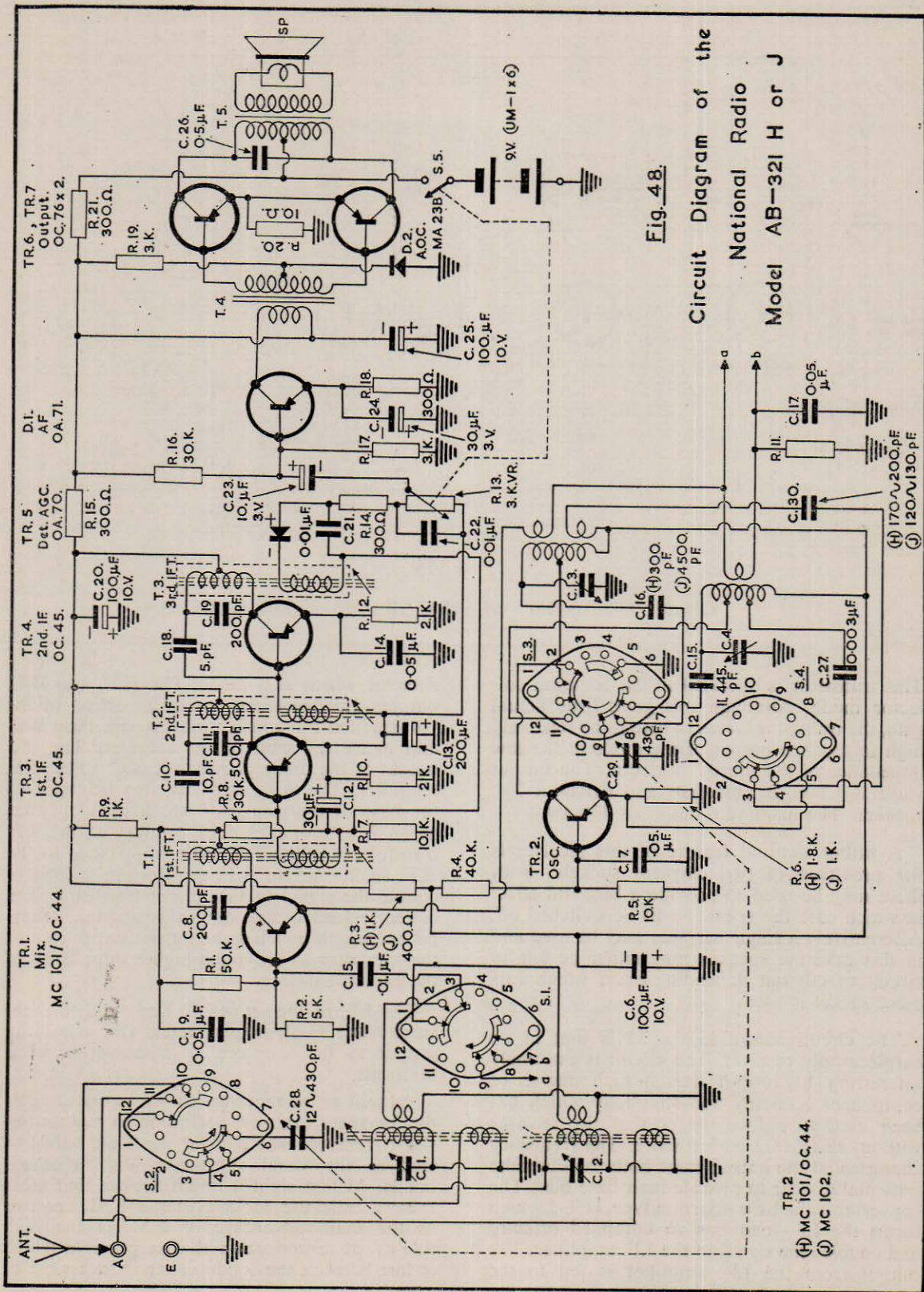


Fig. 48.

Circuit Diagram of the  
National Radio  
Model AB-321 H or J

TR.2  
(H) MC 101/OC 44.  
(C) MC 102.



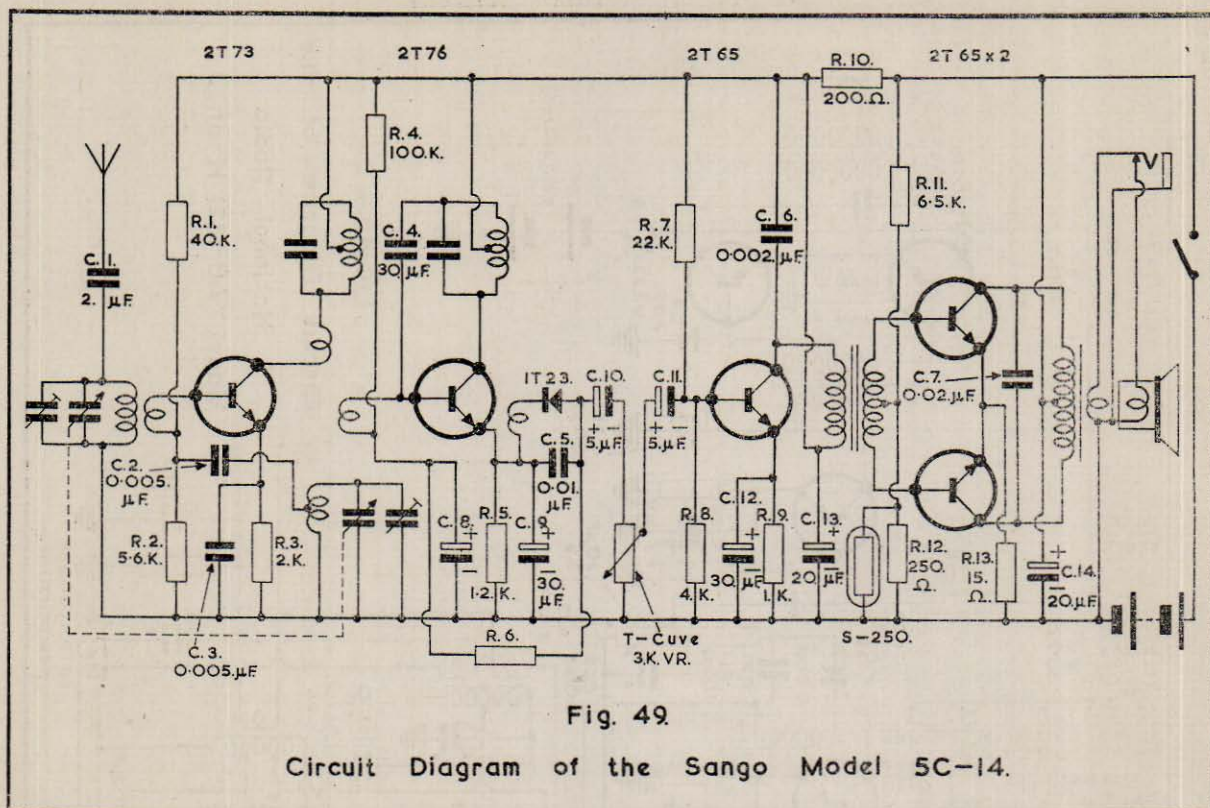


Fig. 49.

## Circuit Diagram of the Sango Model 5C-14.

This transistor is operated in the common collector mode. Although this gives little actual gain, the transistor serves to match the relatively high impedance output of the diode to the low impedance of the fourth transistor. The output stage is Class B push-pull and drives a  $2\frac{1}{2}$ " speaker. The maximum output is 150mw.

A rather unusual feature of this receiver is the provision of two earpiece sockets. Both these may be used to provide a binaural effect in which case the speaker will be switched off. Alternatively a single earpiece may be used and in this case the speaker may either be left in circuit or cut out depending upon which earpiece socket is used.

The circuit shown in fig. 53 is that of an earpiece only receiver. The circuit is extremely interesting because it uses a high degree of component economy and simplicity which has been used to reduce the cost of the receiver without sacrificing performance. The frequency changer and the output stage both use the same potential divider to provide their base bias. The converter is the base injection type, IFT-1 which forms the I.F. load has an untapped primary and couples the signal to the I.F. amplifier. The output from the I.F. amplifier is fed to the

detector which is a diode. The A.F. and D.C. outputs are developed across a portion of the volume control which controls the base bias and hence the gain of the receiver. The d.c. output of the diode provides A.G.C. to the I.F. amplifier. The A.F. signal is also fed back to the base of the transistor which then operates as an A.F. amplifier. The primary of the I.F. transformer offers very little impedance to the A.F. signal and an A.F. transformer is used to couple the signal to the output transistor. The collector lead of the output is an auto transformer which matches the output impedance of the transistor to the much higher impedance of the crystal earpiece.

The I.F. of the set is 260 Kc/s and the sensitivity is 1 millivolt per meter. The maximum output to the earpiece is in the order of a milliwatt.

As well as the receivers shown in this chapter the Japanese are now beginning to make transistor receivers which cover the F.M. bands as well as the usual shortwave and broadcast bands. At first sight it might appear that there is very little use for a portable F.M. receiver as the main advantage of F.M. is the high fidelity of reproduction that is possible which is lost because the loudspeaker is incapable of







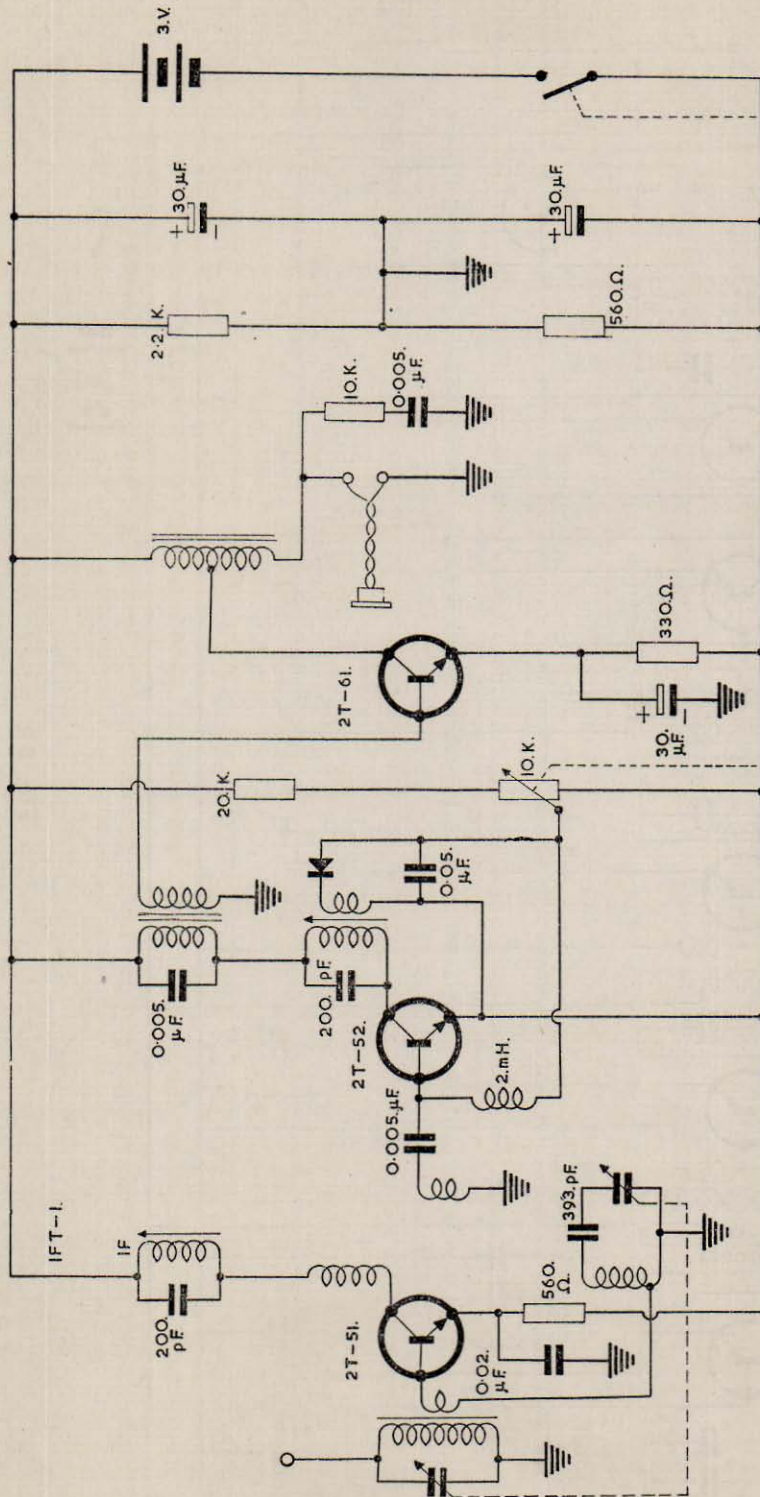


Fig. 53.

Ear-piece only Pocket Superhet.

reproducing the entire audio spectrum. However, there is another important factor. In many areas it is sometimes virtually impossible to receive programmes on the broadcast band due to interference from powerful but unwanted stations on adjacent channels. Because of the more or less line of sight range of F.M. transmitters this problem is solved by the use of an F.M. receiver. At the moment the mass production of transistor F.M. receivers is being held up by the high cost of suitable transistors, although such transistors are readily available. However, prices are likely to drop in the fairly near future and transistorised F.M. radios will then probably become commonplace.

Another development, which is perhaps even more interesting, is the transistorised completely portable television receiver. Although the problems are considerable these have now been overcome and once again the only thing preventing production is the high cost of the transistors themselves. This topic falls somewhat outside the range of this book, however, I hope

to devote one of the books in this series entirely to this subject in the near future.

While I am on the subject of future developments, it might be interesting to consider the next advances to be made in the field of the ordinary broadcast band portables. The main possibility here is the further reduction in case size. Although the pocket radios now being made are very small they are still too bulky to be carried in the pocket without a considerable bulge. Slimmer receivers, perhaps  $\frac{3}{4}$ " thick, will certainly appear in the near future. Further reductions in size are held up only by the development of smaller speakers which are capable of reasonable performance. I have heard one Japanese set which used a speaker only  $1\frac{1}{2}$ " in diameter and yet gave a very good performance. This little speaker had a cone area of about 2.4". A rectangular speaker could, therefore, be made with a similar performance which measured only 2" x 1.2". Such a speaker would make possible the construction of radios almost small enough to be worn on the wrist.

## CHAPTER SIX

### FRENCH AND GERMAN RECEIVERS

The receivers manufactured by the French have tended to follow a fixed pattern rather more than in other countries. Their receivers almost invariably use six or seven transistors and there has been little attempt at component economy. They do, however, make their sets in a wide range of sizes though nothing so small as the Japanese receivers have yet been produced.

The German circuits have more variety and several receivers have been produced which endeavour to obtain a high performance with fewer than usual transistors. A good example of this is one of the Grundig receivers illustrated in fig. 54. This set uses five transistors. Two R.F. and three A.F. types. The signal is selected by a tuned ferrite rod aerial and taken to the frequency changer from a tapping on the coil. The converter is an 0C44 which uses emitter injection in the normal way. The I.F. output is coupled to a single 0C45 I.F. amplifier by

means of a most unusual I.F. transformer. This transformer has three windings, instead of the more usual two, all of which are tuned. Each of the windings has the same inductance and two of them are tapped to match the impedances of the transistors. By using this transformer selectivity equivalent to that of a two transistor I.F. strip is obtained.

A crystal diode, type 0A70, is used as the second detector and as the A.G.C. voltage source. This drives a two stage audio amplifier of conventional design. The driver is an 0C71 transformer coupled to a symmetrical, Class B, push-pull output stage.

Fig. 55 shows another Grundig circuit which is very similar to the last one. Two I.F. stages are used, however, and a second diode shunts one of the I.F. transformers. With a strong signal sufficient voltage is applied to this diode to cause it to conduct thereby shunting the coil.







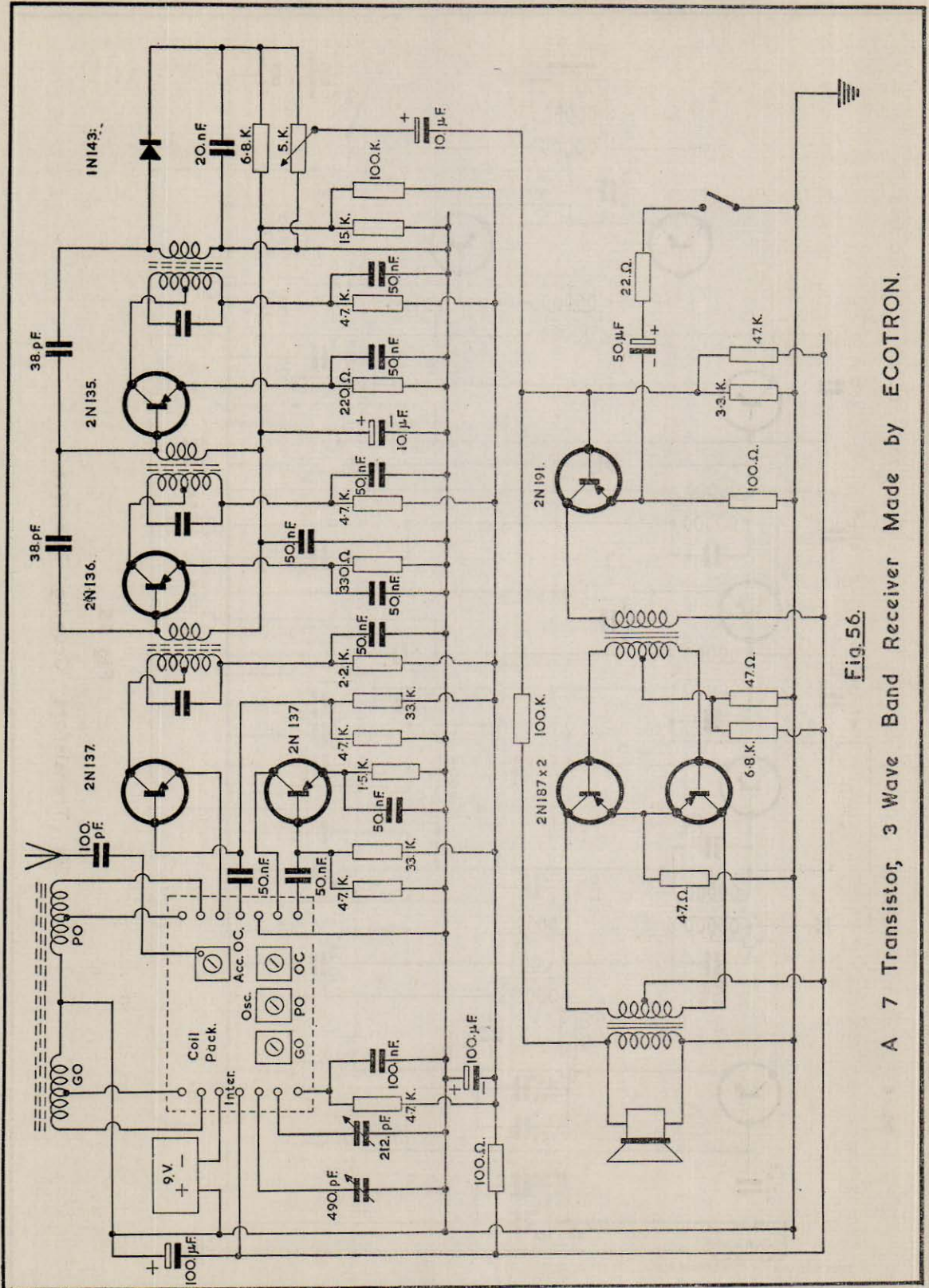


Fig. 56.  
A 7 Transistor, 3 Wave Band Receiver Made by ECOTRON.

This reduces gain and so the diode acts as an auxiliary A.G.C. system augmenting the A.G.C. provided by the second detector. A.G.C. is applied only to the first I.F. stage, the second stage being operated at maximum gain all the time.

A temperature dependant resistor is used to stabilise the push-pull output stage which consumes 2.5 ma. with no signal input.

Grundig also make a seven transistor receiver the circuit of which is similar to the last. A further stage of audio amplification is used and the battery voltage is reduced to 4.5.

The vast majority of French receivers cover both the medium and long wave bands. Many sets also receive one or more of the short wave band, such a receiver is shown in fig. 56. This set uses seven transistors, 4 R.F. types and 3 A.F. types, and a crystal diode.

The frequency changer has a separate oscillator and mixer. The oscillator is the common emitter type and feeds into the emitter of the mixer. The signal is picked up and tuned by a ferrite rod aerial for the medium and long wave bands and by an external aerial on the shortwave band for which an internal tuned R.F. transformer is used. The R.F. signal is fed to the base of the mixer.

The I.F. output from the mixer is selected by a conventional I.F. transformer which couples

it to the first I.F. stage. The I.F. amplifier uses two stages both as common emitter amplifiers. The base biases for these stages are taken from the same potential divider. The voltage is varied by the d.c. output from the diode so that A.G.C. is applied to both stages. The second stage, however, is operated at a higher current level than the first so that the variation in gain of this stage is only slight and near the optimum value even with strong signals.

The output from the second detector is R.C. coupled to a two stage A.F. amplifier. The common emitter driver stage has an unbypassed resistor in its emitter which provides negative feedback and increases the input impedance and the quality of reproduction. It also reduces the gain, however, and so a 50 microfarad condenser in series with a 22 ohm resistor may be switched in parallel with the emitter resistor. The effect of this is to reduce the A.F. feedback without affecting the D.C. feedback so that the gain is increased.

The driver is transformer coupled to the output stage which uses two 2N187 transistors in a Class B symmetrical push-pull circuit transformer coupled to the loudspeaker. A small amount of negative feedback is applied to the base of the driver from the secondary of the output transformer. This improves the quality but reduces the gain by about 6 db.

## CHAPTER SEVEN

### TRANSISTORS USED IN SUPERHETS

A vast range of transistors suitable for use in superhet circuits are now available. No two types of transistors are the same although two different manufacturers may make transistors so similar as to be readily interchangeable.

Most transistors are manufactured with a specific purpose in mind although they may be used for a wide variety of functions. The Mullard OC44 for example is designed as a frequency changer, mixer or R.F. amplifier, but it could be used as an I.F. or even an A.F. amplifier. The OC45 on the other hand is an I.F. amplifier. It would work as a frequency changer but would have a performance inferior to the OC44.

As the transistors of one manufacturer can differ so much from those of another it is always desirable to replace a bad transistor by another

of the same type. Sometimes this is impossible due to the required type being unavailable. In this case, a near equivalent must be used and this may be chosen from the list given further on in this chapter.

In reading about and dealing with transistors you will meet many terms which have been coined for use with semiconductors. A list of these, together with their meaning, is given below. However, because of the rapid developments in this field new words and phrases are appearing all the time so that you may come across quite a few words that are not included here.

*Alloy junction:* A junction produced by alloying a metal such as indium to the semiconductor such as germanium or silicon. In the case of indium N type germanium is used, the

indium producing a P type impurity and acting as the collector or the emitter.

*Alloy transistor:* A very common type of transistor made by the above mentioned technique.

*Alpha:* The current gain of a transistor operated as a common base amplifier. In a junction transistor the value of alpha is always slightly less than one, but in the more or less obsolete point contact type is usually greater than one. When alpha is known the common emitter current gain may be calculated as it is

equal to  $\frac{a}{1-a}$  where alpha = a.

*Alpha-cutoff frequency:* A measure of the high frequency performance of a transistor defined as the frequency at which the current gain of a transistor operated in the common base mode is reduced to 0.707 of its gain at 1 Kc/s. That is a reduction in gain of 3db.

*Base:* One of the electrodes of a transistor, corresponding roughly to the grid of a thermionic valve.

*Base bias:* The voltage applied to the base of a transistor.

*Base current:* The current flowing through the base.

*Beta:* The current gain of a transistor operated in the common emitter mode. If the beta value is known and the value of alpha is required it may be determined as alpha =  $B/(1+B)$  where Beta = B.

*Beta-cutoff frequency:* The frequency at which the current gain of a transistor operated in the common emitter mode is reduced by 3db from its value at 1 Kc/s. Beta cutoff frequency is approximately equal to the alpha cutoff frequency divided by beta.

*Carriers:* The electrons or holes which carry a current through a semiconductor. A flow of electrons carries current from negative to positive and a flow of holes carries a current from positive to negative.

*Collector:* One of the electrodes of a transistor corresponding roughly to the anode of a thermionic valve.

*Collector bias:* The voltage applied to the collector of a transistor.

*Collector cutoff current:* The current that flows in the collector when the emitter current is zero.

*Collector efficiency:* The percentage of the power from the supply that is delivered to the load.

*Common Base:* An amplifier is said to be operated in the common base mode when the base is common to the input and output circuits.

In this condition the transistor has the following characteristics: Low input impedance, high output impedance, maximum operating frequency, small collector leakage current  $I_c(0)$ , zero phase shift between the input and the output and a current gain of less than one.

*Common Collector:* An amplifier operates in this mode when the collector is common to the input and output circuits. In this condition the transistor has the following characteristics: High current gain, approximately equal to beta, high input impedance, low output impedance, frequency cutoff varying with source impedance and zero phase shift between the input and output.

*Common Emitter:* An amplifier operates in this mode when the emitter is common to the input and output circuits. In this configuration the transistor displays the following characteristics: High current gain, medium input and output impedances, maximum power gain, maximum operating frequency much lower than for common base and 180° phase shift between input and output.

*Complimentary symmetry:* A symmetrical circuit making use of the complimentary properties of P.N.P. and N.P.N. transistors. For example, transformerless push-pull stages, oscillators and switching circuits.

*Coupling:* The method of conveying the signal from one stage to the next. This may be resistance-capacity, inductance-capacity, transformer or direct coupling.

*Current gain:* Ratio of output to input current.

*Depletion layer transistor:* A transistor such as the spacistor that relies directly on the motion of carriers through the area near the barrier that has no current carriers when reversely biased.

*Derating:* The adjustment that has to be made to a transistor parameter to compensate for operation under a condition other than that at which the rating is specified. For example the collector dissipation permissible reduces with the ambient temperature.

*Diffused-junction transistor:* A transistor in which the collector and emitter are formed by diffusion of an impurity into the semiconductor.

*Diode:* A two electrode semiconductor.

*Double-base diode:* A type of transistor which is similar to a diode in that it has only one junction. It has, however, two base connections, one either end of a semiconductor rod, and may be used in oscillator and switching circuits.

*Double-base junction transistor:* A tetrode transistor with two separate connections to the

base the main purpose of which is to increase the maximum operating frequency. Certain types have also been made for use as high efficiency mixers, the two signals being injected into different base contacts.

**Electro-forming:** A process used to produce a P-N junction in point contact diodes and transistors. It involves passing a large current through the contact for a short time.

**Emitter:** One of the electrodes of a transistor similar in function to the cathode in a thermionic valve.

**Emitter follower:** A common collector amplifier so called because of its similarity in behaviour to the cathode follower used in thermionic valve practice.

**Feed-back capacitance:** The interelectrode capacitance of a transistor which causes feedback from the output to the input.

**Feed-back resistance:** The internal resistance of a transistor which causes feedback from the output to the input.

**Forward bias:** The application of a voltage to a P-N junction in such a direction as to cause a large current to flow. Reversing the voltage would result in reverse bias in which case only a very small current would flow.

**Frequency cutoff:** The frequency at which the current gain of a transistor is 0.707 times the gain measured at 1 Kc/s. That is a reduction of 3db.

**Germanium:** The 32nd element in the periodic table the properties of which make it the most widely used semiconductor in the manufacture of transistors. Because of its low melting point it is relatively easy to handle but for the same reason a transistor made with germanium cannot operate at high temperatures. The germanium used in semiconductor devices has to have an impurity content no greater than one part in a thousand million.

**Grounded Base:** This term is synonymous with common base.

**Grounded collector:** Synonymous with common collector.

**Grounded Emitter:** Synonymous with common emitter.

**Grown Junction Transistors:** Transistor that is formed by the addition of impurities to the semiconductor during the formation of the crystal.

**H-Parameters:** Parameters that combine both conductive and resistive parameters. The H stands for Hybrid.

**Heatsink:** A piece of material having a high thermal conductivity which is used in the case

of a transistor to dissipate the heat generated by the transistor thereby increasing permissible collector dissipation. The heatsink may also be used when soldering a transistor to conduct heat from the electrode leads to prevent the heat of the soldering iron reaching the junction.

**Hole:** A current carrier with a positive charge.

**Impurity:** A metallic element which is added in minute quantities to a semiconductor to give it either a surplus or a shortage of electrons.

**Intrinsic semiconductor:** Any semiconductor that has neither a shortage nor an excess of electrons.

**Junction diode:** A diode which rectifies, demodulates, or mixes by means of a P-N junction rather than a point contact.

**Junction transistor:** A transistor that has two junctions that is between the emitter and base and the collector and base. This type is the most commonly used.

**Madt.:** A commonly used abbreviation for Micro-alloy diffused base transistor.

**Micro-alloy transistor:** A transistor in which the emitter and collector electrodes are formed by alloying a thin film of impurity to the semiconductor. Behaviour of this type of transistor is similar to that of the surface barrier type.

**N-Type:** A semiconductor containing donor impurity.

**N.P.N.:** A transistor with N-type collector, P-type base, and N-type emitter.

**Peak Inverse Voltage:** Maximum voltage that may be applied in the reverse direction to a diode or transistor before causing breakdown.

**Photo diode:** A junction diode which is designed to respond to variations in incident light. The reverse current alters in step with the illumination. All junction diodes display this property but some types are made solely for use as photo diodes.

**Photo transistor:** A device which takes advantage of the light sensitive properties of a semiconductor and at the same time provides amplification. Photo transistors have a partially or wholly translucent casing to enable the light to reach the emitter junction which is the most sensitive point.

**P-N junction:** A junction between P-type and N-type semiconductors.

**P-N-P transistor:** A junction transistor with P-type collector, N-type base and P-type emitter.

**Point contact diode:** A diode formed by the contact of a sharp piece of wire and a semiconductor.

*Point contact transistor:* A transistor with two wire contacts very close together on a semiconductor.

*Power transistor:* Any transistor designed to handle more than about one watt of power. In this type of transistor the collector is normally in good thermal contact with the case which is then bolted to a heat shunt to increase permissible collector dissipation.

*P-Type:* A semiconductor containing an acceptor impurity.

*Rate grown transistor:* A transistor in which the junctions are formed by varying the rate of growth in the semiconductor crystal.

*Reverse bias:* A semiconductor junction is said to be reversely biased when the voltage is applied in such a direction as to allow only a low current to flow.

*Selenium:* A semiconductor used for some types of diode.

*Semiconductor:* A material that has properties in between those of an insulator and conductor.

*Silicon:* The 14th element in the periodic table used in making diodes and transistors. It is more difficult to use than germanium because of its high melting point but for the same reason a transistor made from silicon will operate satisfactorily at fairly high temperatures.

*Stability:* This term is used in the case of transistors to specify the ability of a transistor in a given circuit to remain at or near the d.c. operating point for which the circuit was designed.

*Stabilisation:* Control of the d.c. operating point of a transistor.

*Surface barrier:* The barrier formed at the surface of the semiconductor by trapped carriers.

*Surface barrier transistor:* The type of transistor that uses surface barriers instead of junctions. It has properties which make it especially useful at high frequencies and in the circuits where a very low power consumption is required. The surface barrier transistor will in fact oscillate with only about 1/10th of the power required to maintain oscillation for a junction transistor.

*Symmetrical transistor:* A junction transistor in which the emitter and collector electrodes are identical. This type of transistor was designed for switching circuits mainly in computers.

*Tandem pair:* Two transistors in a single envelope with the emitter of one transistor internally connected to the next.

*Tetrode transistor:* Any transistor having four electrodes.

*Thermal run-away:* As the collector current increases with temperature due to increased leakage to the base, the situation could arise whereby the transistor increases its own temperature to such an extent that the semiconductor is melted or destroyed. This is known as thermal run-away.

*Transistor:* A type of valve using a semiconductor and having more than two electrodes.

*Uni-junction transistor:* A term synonymous with double base diode.

*Zener break-down:* When a large reverse voltage is applied to a semiconductor a point is reached when a large current starts to flow. This is the zener break-down point.

## TRANSISTOR SPECIFICATIONS

Because of the very wide range of transistor types it is frequently difficult to find the characteristics of a certain transistor used in a receiver without writing to the manufacturer. This may be difficult and may take a considerable amount of time when the receiver is a foreign one which, in these days of ever increasing trade, it frequently is.

For this reason I have compiled a list of transistors together with their more useful characteristics. It is by no means a complete catalogue of the world's transistors but it does,

I believe, cover most of the types found in receivers.

Because it is frequently difficult to obtain a transistor one requires, I have also compiled an equivalent list. This is an international list which links the transistors of Great Britain, America, and the continent.

Although one transistor may be listed as a close equivalent to another this does not mean that they are interchangeable in every case. It merely means that their characteristics are similar.

### EQUIVALENTS LIST OF BRITISH, EUROPEAN AND AMERICAN SEMICONDUCTORS

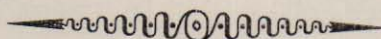
Types without brackets are direct equivalents.

Types shown in brackets have comparable characteristics, and can be used in the majority of circuits with very minor component value changes.

Type	Equivalent Type	Type	Equivalent Type	Type	Equivalent Type
1N34	(OA85); (1N478)	1N192	(OA87); (1N490)	2N104	(OC71)
1N34A	(OA85); (1N478)	1N198	(OA95); (1N618)	2N105	(OC65); (OC66)
1N38	(OA85); (1N478)	1N270	(OA5)	2N106	(OC71)
1N38A/B	(OA85); (1N478)	1N277	(OA5)	2N109	(OC72); (2N281)
1N43	(OA85); (1N478)	1N295	(OA70)	2N113	(OC45)
1N44	(OA85); (1N478)	1N476	OA81 ; 1N476	2N114	(OC44)
1N45	(OA85); (1N478)	1N478	OA85 ; 1N478	2N115	OC16 ; 2N115
1N46	(OA85); (1N478)	1N480	OA86 ; 1N480	2N116	(OC65); (OC66)
1N47	(OA85); (1N478)	1N490	OA87 ; 1N490	2N123	(OC76)
1N48	(OA85); (1N478)	1N541	OA79 ; 1N541	2N130	(OC65); (OC66)
1N50	(OA85); (1N478)	1N542	2-OA79; 1N542	2N131	(OC65); (OC66)
1N51	(OA85); (1N478)	1N616	OA73 ; 1N616	2N132	(OC65); (OC66)
1N52	(OA85); (1N478)	1N617	OA91 ; 1N617	2N133	(OC65); (OC66)
1N54	(OA85); (1N478)	1N618	OA95 ; 1N618	2N135	(OC45)
1N54A	(OA85); (1N478)	2N27	(OC71)	2N136	(OC45)
1N57	(OA85); (1N478)	2N28	(OC71)	2N137	(OC44)
1N58	(OA85); (1N478)	2N34	(OC72)	2N138	(OC72)
1N58A	(OA85); (1N478)	2N34A	(OC72)	2N138A	(OC72)
1N60	(OA70); (1N87)	2N36	(OC72)	2N139	(OC45)
1N61	(OA85); (1N478)	2N37	(OC72)	2N140	(OC44)
1N62	(OA85); (1N478)	2N38/A	(OC72)	2N145	(OC45)
1N63	(OA85); (1N478)	2N41	(OC65) ; (OC66)	2N146	(OC45)
1N64	(OA70); (1N87A)	2N43	(OC72)	2N147	(OC45)
1N65	(OA81); (1N476)	2N43A	(OC71)	2N155	(OC16)
1N66	(OA85); (1N478)	2N44	(OC72)	2N156	(OC16)
1N67/A	(OA95); (1N618)	2N44A	(OC72)	2N158	(OC16)
1N68	(OA85); (1N478)	2N45	(OC72)	2N166	(OC45)
1N68A	(OA95); (1N618)	2N46	(OC65); (OC66)	2N167	(OC76)
1N69	(OA85); (1N478)	2N47	(OC65); (OC66)	2N168	(OC45)
1N70	(OA85); (1N478)	2N48	(OC65); (OC66)	2N168A	(OC44)
1N75	(OA85); (1N478)	2N49	(OC65); (OC66)	2N169	(OC45)
1N81	(OA85); (1N478)	2N54	(OC72)	2N169A	(OC45)
1N86	(OA85); (1N478)	2N55	(OC72)	2N170	(OC45)
1N87/A	OA70 ; 1N87A	2N56	(OC72)	2N172	(OC44)
1N88	(OA81); (1N476)	2N62	(OC72)	2N173	(OC16)
1N89	(OA85); (OA95)	2N63	(OC72)	2N175	(OC65); (OC66)
1N90	(OA95); (1N618)	2N64	(OC72)	2N176	(OC16)
1N95	(OA85); (OA95)	2N65	(OC72)	2N180	(OC72)
1N99	(OA85); (OA95)	2N76	(OC71)	2N182	(OC76)
1N111	(OA85); (1N478)	2N77	(OC71); (OC66)	2N183	(OC76)
1N112	(OA85); (1N478)	2N78	(OC45)	2N184	(OC76)
1N113	(OA81); (1N476)	2N79	(OC71)	2N185	(OC72)
1N114	(OA81); (1N476)	2N85	(OC72)	2N186	(OC72)
1N115	(OA81); (1N476)	2N86	(OC72)	2N187	(OC72)
1N116	(OA85); (1N478)	2N87	(OC72)	2N188	(OC72)
1N117	(OA85); (OA95)	2N88	(OC65); (OC66)	2N189	(OC72)
1N126	(OA95); (1N618)	2N89	(OC65); (OC66)	2N190	(OC72)
1N127	(OA95); (1N618)	2N90	(OC65); (OC66)	2N191	(OC72)
1N128	(OA95); (1N618)	2N94	(OC45)	2N192	(OC72)
1N135	(OA85); (1N478)	2N94A	(OC45)	2N194	(OC44)
1N191	(OA86); (1N480)	2N96	(OC71)	2N195	(OC72)

Type	Equivalent Type	Type	Equivalent Type	Type	Equivalent Type
2N196	(OC72)	2N326	(OC16)	1340	(OC72)
2N197	(OC72)	2N352	(OC16)	1350	(OC72)
2N198	(OC72)	2N353	(OC16)	1360	(OC72)
2N199	(OC72)	2N378	(OC16)	1390	(OC45)
2N200	(OC71)	2N380	(OC16)	1400	(OC45)
2N204	(OC71)	2N386	(OC16)	1410	(OC45)
2N205	(OC71)	2N394	(OC76)	A01	(OC45)
2N206	(OC71)	2N395	(OC76)	CG1-E	(OA81); (1N476)
2N207	(OC65); (OC66)	2N396	(OC76)	CG4-E	(OA81); (1N476)
2N207A	(OC65); (OC66)	2N397	(OC76)	CG12-E	(OA73); (OA90)
2N207B	(OC65); (OC66)	2N402	(OC71); (OC72)	CK705	(OA85); (1N478)
2N215	(OC71)	2N403	(OC72)	CK707	(OA85); (1N478)
2N217	(OC72)	2N404	(OC76)	CK708	(OA85); (1N478)
2N218	(OC45)	2N405	(OC71)	CK13A	(OA85); (1N478)
2N219	(OC44)	2N406	(OC71)	CK721	(OC71)
2N220	(OC65); (OC66)	2N407	(OC72)	CK722	(OC71)
2N231	(OC45)	2N408	(OC72)	CK725	(OC71)
2N232	(OC45)	2N409	(OC45)	CK727	(OC71)
2N233	(OC45)	2N410	(OC45)	CK751	(OC72); (2N281)
2N233A	(OC45)	2N411	(OC44)	CK759	(OC45)
2N234	(OC16)	2N412	(OC44)	CK760	(OC45)
2N234A	(OC16)	2N413	(OC45)	CK761	(OC45)
2N235	(OC16)	2N413A	(OC45)	CK762	(OC44)
2N235A	(OC16)	2N414	(OC45)	CK766	(OC44)
2N236A	(OC16)	2N414A	(OC45)	CK766A	(OC44)
2N237	(OC65); (OC66)	2N425	(OC76)	CV425	(OA81); (1N476)
2N238	(OC72)	2N426	(OC76)	CV442	OA73 ; 1N616
2N241	(OC72)	2N427	(OC76)	CV488	(OA81); (1N6)47
2N241A	(OC72)	2N428	(OC76)	CV1353	(OA81 ; 1N476
2N242	(OC16)	2-OA72	2-OA72	CV2389	(OC71)
2N252	(OC44)	2-OA79	2-OA79; 1N542	CV2400	(OC71)
2N253	(OC45)	2-OC16	2-OC16	CV3934	(OA85); (1N478)
2N254	(OC45)	2-OC30	2-OC30	CV5105	OC45
2N265	(OC72)	2-OC72	2-OC72; 2N282	DP6	(OA8); (1N478)
2N268	(OC16)	8D	(OC45)	DP6C	(OA85); (1N478)
2N269	(OC76)	8E	(OC45)	DR126	(OC65); (OC66)
2N270	(OC72)	8F	(OC45)	DR128	(OC65); (OC66)
2N279	OC70 ; 2N279	206	(OC71); (OC66)	DS60	(OA85); (1N478)
2N280	OC71 ; 2N280	207	(OC71); (OC66)	DS61	(OA85); (1N478)
2N281	OC72 ; 2N281	208	(OC71); (OC66)	DS61A	(OA85); (1N478)
2N282	2-OC72; 2N282	222	(OC45)	DS62	(OA85); (1N478)
2N283	OC71 ; 2N280	223	(OC44)	DS604	(OA81); (1N476)
2N284	OC76 ; 2N284	225	(OC45)	DS611	(OA81); (1N476)
2N284A	OC77 ; 2N284A	228	(OC44)	DS621	(OA81); (1N476)
2N292	(OC45)	300	(OC72)	G26	(OA85); (3/1N478)
2N293	(OC45)	301	(OC72)	GD1E	(OA85); (1N478)
2N296	(OC16)	302	(OC72)	GD1Q	(OA85); (1N478)
2N297	(OC16)	310	(OC72)	GD2E	(OA85); (1N478)
2N301	(OC16)	350	(OC72)	GD2Q	(OA85); (1N478)
2N301A	(OC16)	352	(OC72)	GD3	(OA70); (OA73)
2N302	(OC76)	353	(OC72)	GD3E	(OA85); (1N478)
2N303	(OC76)	830	(OC44)	GD4E	(OA85); (1N478)
2N307	(OC16)	1032	(OC72)	GD5	(OA79)
2N311	(OC76)	1033	(OC72)	GD6	(OA70)
2N315	(OC76)	1034	(OC72)	GD8	(OA81); (OA85)
2N316	(OC76)	1035	(OC72)	GEX34	(OA90)
2N317	(OC76)	1036	(OC72)	GEX35	(OA73)
2N322	(OC72)	1320	(OC72)	GEX44	(OA81)
2N325	(OC16)	1330	(OC72)	GEX45/1	(OA85); (1N478)

Type	Equivalent Type	Type	Equivalent Type	Type	Equivalent Type
GEX45/2	(OA85); (1N478)	OA5	OA5	OC45	OC45
GFT20	(OC72)	OA7	OA7	OC57	OC57
GFT26	(OC16)	OA9	OA9	OC58	OC58
GFT44	(OC45)	OA31	OA31	OC59	OC59
GSD5/2	(OA90)	OA47	OA47	OC65	OC65
GT14	(OC72)	OA50	OA81 ; OA85	OC66	OC66
GT14H	(OC65); (OC66)	OA51	OA81 ; OA85	OC70	OC70 ; 2N279
GT20	(OC72)	OA52	OA81 ; OA85	OC71	OC71 ; 2N280
GT20H	(OC65); (OC66)	OA53	OA81 ; OA85	OC72	OC72 ; 2N281
GT38	(OC71); (OC66)	OA54	OA81 ; OA85	OC73	OC71
GT81	(OC72)	OA55	OA81 ; OA85	OC75	OC75
GT81H	(OC65); (OC66)	OA56	OA81 ; OA85	OC76	OC76 ; 2N284
GT109	(OC72)	OA57	OA81 ; OA85	OC77	OC77
GT122	(OC76)	OA58	OA81 ; OA85	OC170	OC170
GT222	(OC71)	OA60	OA70	OC601	(OC70); (2N279)
GT759	(OC45)	OA61	OA81	OC602	(OC71)
GT760	(OC45)	OA70	OA70 ; 1N87 ;	OC604	(OC72); (2N281)
GT761	(OC45)		(OA90)	OC624	(OC65); (OC66)
GT762	(OC44)	OA71	OA81	OCP70	OC71
HA1	(OC71); (OC66)	OA72	OA72	ORP30	ORP30
HA2	(OC71); (OC66)	OA73	OA73 ; 1N616	ORP90	ORP90
HA3	(OC71); (OC66)	OA74	OA81 ; OA85	RL31	(OA81); (1N476)
HA8	(OC65); (OC66)	OA79	OA79 ; 1N541	RL32	(OA81); (1N476)
HA9	(OC65); (OC66)	OA81	OA81 ; 1N476	RL41	(OA70); (1N87A)
HA10	(OC65); (OC66)	OA85	OA85 ; 1N478	RL43	(OA81); (1N476)
HD2053	(OA85); (1N478)	OA86	OA86 ; 1N480	RL44	(OA81); (1N476)
HD2057	(OA85); (1N478)	OA87	OA87 ; 1N490	RL143	(OA81); (1N476)
HD2060	(OA85); (1N478)	OA90	OA90	RL231	(2-OA79)
HD2063	(OA85); (1N478)	OA91	OA91 ; 1N617	RL232/B	(2-OA79)
HS3	(OC76)	OA95	OA95 ; 1N618	T34A	(OC65); (OC66)
HS4	(OC76)	OA150	(OA81); (OA85)	T34B	(OC65); (OC66)
J1	(OC72)	OA159	(OA73)	T34C	(OC65); (OC66)
J2	(OC72)	OA160	(OA70); (1N87)	T34D	(OC72); (2N281)
J3	(OC72)	OA161	(OA85); (1N478)	T34E	(OC72); (2N281)
JP1	(OC72)	OA172	(OA72)	T34F	(OC72); (2N281)
M550A	(OA85); (1N478)	OA200	OA200	T1040	(OC16)
M550B	(OA85); (1N478)	OA201	OA201	T1041	(2-OC16)
M3100	(OA85); (1N478)	OA202	OA202	TS161	(2-OC72)
MN24	(OC16)	OA210	OA210	TS162	(OC71)
MN25	(OC16)	OA211	OA211	TS163	(OC71)
MN26	(OC16)	OA214	OA214	TS165	(OC72); (2N281)
NU34	(OA85); (1N478)	OAP12	OAP12	TS166	(OC70); (OC65)
NU38	(OA85); (1N478)	OC16	OC16 ; 2N115	TS620	(OC65); (OC66)
NU58	(OA85); (1N478)	OC30	OC30	TS621	(OC65); (OC66)
NU58	(OA85); (1N478)	OC44	OC44	Z113	(OC72)





## BRITISH TRANSISTORS

<i>Number Type</i>	<i>VC Max. (volts)</i>	<i>Ic Max. (ma)</i>	<i>PC Max</i>	<i>Beta</i>	<i>Alpha cut-off Frequency</i>	<i>Application and Comments</i>
<b>Associated Transistors Ltd.</b>						
AP9 (P.N.P.)	30	50	50 mw.	75	700 Kc/s	Class A audio amplifier. Power gain 41db.
<b>B.T.H.</b>						
GT31 (P.N.P.)	15	—	125 mw.	20	800 Kc/s	A.F. amplifier noise figure 12db.
GT32 (P.N.P.)	15	—	125 mw.	40	900 Kc/s	A.F. amplifier noise figure 12db.
GT33 (P.N.P.)	15	—	125 mw.	50	1.0 mc/s.	A.F. amplifier noise figure 12db.
GT41 (P.N.P.)	15	—	100 mw.	30	4 mc/s.	I.F. amplifier min. f. alpha 3 mc/s.
GT42 (P.N.P.)	15	—	100 mw.	60	6 mc/s.	I.F. amplifier min. f. alpha 5 mc/s.
GT43 (P.N.P.)	15	—	100 mw.	100	mc/s.	I.F. amplifier min. f. alpha 7 mc/s.
<b>G.E.C.</b>						
GET102 (P.N.P.)	30	1 amp.	200 mw.	60-160	1.5 mc/s.	High gain A.F. transistor. A.F. amplifier for Class B push-pull (800 mw.).
GET103 (P.N.P.)	30	1 amp.	200 mw.	30-80	1 mc/s.	A.F. amplifier.
GET104 (P.N.P.)	30	1 amp.	200 mw.	30-80	1 mc/s.	A.F. amplifier.
GET113 (P.N.P.)	15	1 amp.	200 mw.	60-160	1.5 mc/s.	High gain A.F. amplifier.
GET114 (P.N.P.)	15	1 amp.	200 mw.	30-80	1 mc/s.	A.F. amp. for Class B push-pull (800 mw.).
GET871 (P.N.P.)	15	125	55 mw.	20 (min)	3 mc/s (min)	Low gain R.F. amplifier. R.F. amplifier (medium gain)
GET872 (P.N.P.)	12	125	55 mw.	30 (min)	7 mc/s (min)	I.F. amplifier 35db gain @ 465 Kc/s.
GET873 (P.N.P.)	12	10	55 mw.	20 (min)	3 mc/s (min)	Frequency changer Con- version gain 20db.
GET874 (P.N.P.)	12	10	55 mw.	30 (min)	7 mc/s (min)	
<b>Mullard Ltd.</b>						
OC16 (P.N.P.)	16	1.5 amps.	8.3 watts	45dc	200 Kc/s.	Power output used in car radio available in matched pairs as 2-OC16.
OC19 (P.N.P.)	16	1.5 amps.	8.3 watts	45dc	200 Kc/s.	A.F. power amplifier for use as output stage in car radio (2.0W).
OC27 (P.N.P.)	16	3.5 amps.	12.5 watts	75dc	—	High gain A.F. amplifier for car radio.
OC44 (P.N.P.)	10	5	70 mw.	100	15 mc/s.	Frequency changer conver- sion gain 27db.
OC45 (P.N.P.)	10	5	70 mw.	50	6 mc/s.	I.F. amplifier with 30 db gain @ 470 Kc/s.
OC70 (P.N.P.)	20	10	125 mw.	30	500 Kc/s.	Low noise, low gain audio amplifier.
OC71 (P.N.P.)	20	10	125 mw.	47	600 Kc/s.	Medium gain audio ampli- fier.
OC72 (P.N.P.)	16	125	125 mw.	50	—	Audio output amp. power output = 38 mw.
2-OC72 (P.N.P.)	matched pair of OC72 for class B push-pull use power output = 390 mw.					

<i>Number Type</i>	<i>VC Max. (volts)</i>	<i>lc Max. (ma)</i>	<i>PC Max.</i>	<i>Beta</i>	<i>Alpha cut-off Frequency</i>	<i>Application and Comments</i>
OC75 (P.N.P.)	20	10	125 mw.	90	900 Kc/s.	High gain A.F. amplifier.
OC170 (P.N.P.)	20	10	100 mw.	80	70 mc/s.	Short wave converter, mixer, oscillator, and F.M. I.F. amplifier.
<b>Newmarket Transistors Ltd.</b>						
V10/15A (P.N.P.)	10	30	200 mw.	20	600 Kc/s.	A.F. amplifier 29db gain when R-C coupled.
V10/30A (P.N.P.)	10	30	200 mw.	40	700 Kc/s.	Class A amp. to 100 mw.
V10/50A (P.N.P.)	10	30	200 mw.	75	1.2 mc/s.	Class B to 500 mw.
V15/20R (P.N.P.)	15	12	25 mw.	25	30 mc/s.	High gain A.F. amp. 33db R-C coupled.
V6/2 R (P.N.P.)	6	30	75 mw.	25	3 mc/s.	R.F. Transistor for use in all-wave portables and as I.F. amp. in F.M. receivers.
V6/4R (P.N.P.)	6	30	75 mw.	50	5.5 mc/s.	I.F. amp. gain at 470 Kc/s = 30 db.
V6/8R (P.N.P.)	6	30	75 mw.	80	10 mc/s.	Frequency changer conversion gain = 27 db.
<b>Siemens Edison Swan Ltd.</b>						
XA101 (P.N.P.)	16	—	60 mw.	35	5 mc/s.	Frequency changer M.W. conversion gain = 29.5 db.
XA102 (P.N.P.)	16	—	60 mw.	60	8 mc/s.	A.F. amp. suitable for use as driver.
XB102 (P.N.P.)	16	—	90 mw.	30	—	A.F. amp. suitable for use as driver.
XB103 (P.N.P.)	16	—	90 mw.	66	—	A.F. amp. suitable for use as driver.
XB104 (P.N.P.)	16	—	60 mw.	30	—	A.F. amp. suitable for use as driver.
XC101 (P.N.P.)	16	—	100 mw.	66	—	Class B push-pull stages (220 mw.).
* { XA104 (P.N.P.)	12	—	—	18 min.	4 mc/s.	Frequency changer and R.F. amp.
* { XA103 (P.N.P.)	12	—	—	15 min.	2 mc/s.	I.F. amplifier.
* { XB102 (P.N.P.)	16	—	—	18-47	—	A.F. amp. driver or output stages.
*The three transistors above have been tested by "Bernard's" and recommended to home constructors who will find their prices very reasonable.						
<b>Standard Telephones and Cables Ltd.</b>						
TS7 (P.N.P.)	12	—	70 mw.	35	4 mc/s.	R.F./I.F. amp. gain at 470 Kc/s of 28 db.
TS8 (P.N.P.)	6	—	70 mw.	65	8.5 mc/s.	R.F. amplifier frequency changer.
TS13 (P.N.P.)	20	—	70 mw.	52	600 Kc/s.	High gain audio amplifier.
TS14 (P.N.P.)	20	—	70 mw.	32	500 Kc/s.	Medium gain audio amplifier.
TS17 (P.N.P.)	18	—	130 mw.	70	—	Push-pull class B audio amplifiers.
TK20B (P.N.P.)	12	—	200 mw.	43	6.3 mc/s.	Symmetrical R.F./I.F. amplifier.
TK25B (P.N.P.)	6	—	200 mw.	63	11 mc/s.	Symmetrical R.F./I.F. amplifier.

## AMERICAN TRANSISTORS

<i>Number Type</i>	<i>VC Max. (volts)</i>	<i>Ic Max. (ma)</i>	<i>PC Max.</i>	<i>Beta</i>	<i>Alpha cut-off Frequency</i>	<i>Applications and Comments</i>
2N34 (P.N.P.)	25	8	50 mw.	40	600 Kc/s.	A.F. amplifier.
2N35 (P.N.P.)	25	8	50 mw.	40	800 Kc/s.	A.F. amplifier.
2N36 (P.N.P.)	20	8	—	45	—	A.F. amplifier.
2N37 (P.N.P.)	20	8	—	30	—	A.F. amplifier.
2N38 (P.N.P.)	20	8	—	15	—	A.F. amplifier.
2N38A (P.N.P.)	20	8	—	18	—	A.F. amplifier.
2N41 (P.N.P.)	25	15	—	40	—	A.F. amplifier.
2N44 (P.N.P.)	30	50	150 mw.	33	1 mc/s.	A.F. driver or output amplifier.
2N46 (P.N.P.)	25	15	—	40	—	Audio amplifier.
2N47 (P.N.P.)	35	20	50 mw.	39	—	Audio amplifier.
2N48 (P.N.P.)	35	20	50 mw.	39	—	Small signal audio amplifier.
2N49 (P.N.P.)	35	20	50 mw.	39	—	Small signal audio amplifier.
2N63 (P.N.P.)	22	10	100 mw.	22	600 Kc/s.	Small signal audio amplifier.
2N64 (P.N.P.)	15	10	100 mw.	45	800 Kc/s.	Small signal audio amplifier.
2N65 (P.N.P.)	12	10	100 mw.	90	1.2 mc/s.	High gain audio amplifier.
2N68 (P.N.P.)	25	1½ amps.	2 watts	40	400 Kc/s.	Power output amp. for car radio.
2N76 (P.N.P.)	20	10	50 mw.	20	1 mc/s.	Low gain audio amplifier.
2N77 (P.N.P.)	25	15	35 mw.	55	700 Kc/s.	High gain audio amplifier.
2N78 (P.N.P.)	15	20	65 mw.	58	4 mc/s.	R.F. amplifier.
2N79 (P.N.P.)	30	50	35 mw.	46	700 Kc/s.	Small signal audio amplifier.
2N80 (P.N.P.)	28	8	50 mw.	80	—	High gain audio amplifier.
2N81 (P.N.P.)	20	15	50 mw.	30	—	Medium gain audio amplifier.
2N82 (P.N.P.)	20	15	35 mw.	30	—	Small signal audio amplifier.
2N94 (N.P.N.)	30	10	50 mw.	30	3.5 mc/s.	I.F. amplifier (medium gain).
2N94A (N.P.N.)	30	10	50 mw.	30	6 mc/s.	High gain I.F. amplifier.
2NA5 (N.P.N.)	25	1½ amps.	4 watts	40	400 Kc/s.	Power output stages, i.e. car radio.
2N101 (P.N.P.)	25	1½ amps.	1 watt	—	—	Power output amplifier.
2N102 (N.P.N.)	25	1½ amps.	1 watt	—	—	Power output amplifier.

<i>Number Type</i>	<i>VC Max. (volts)</i>	<i>Ic Max. (ma)</i>	<i>PC Max.</i>	<i>Beta</i>	<i>Alpha cut-off Frequency</i>	<i>Application and Comments</i>
2N104 (P.N.P.)	30	50	150 mw.	40	700 Kc/s.	Class A low power output and A.F. stages.
2N105 (P.N.P.)	25	15	50 mw.	55	750 Kc/s.	Small signal A.F. amplifier.
2N106 (P.N.P.)	6	10	—	45	800 Kc/s.	Small signal A.F. amplifier.
2N107 (P.N.P.)	12	10	50 mw.	20	1 mc/s.	Small signal A.F. amplifier.
2N108 (P.N.P.)	20	15	50 mw.	—	—	A.F. output stages.
2N109 (P.N.P.)	12	35	50 mw.	70	—	A.F. output stages.
2N111 (P.N.P.)	6	5	30 mw.	40	3 mc/s.	Oscillator in Frequency changers.
2N111A (P.N.P.)	6	5	30 mw.	40	3 mc/s.	Oscillator in frequency changers.
2N112 (P.N.P.)	6	5	30 mw.	40	5 mc/s.	R.F. or I.F. amplifier Medium gain.
2N113 (P.N.P.)	6	5	30 mw.	45	10 mc/s.	Medium gain R.F. amplifier.
2N114 (P.N.P.)	6	5	30 mw.	65	20 mc/s.	High gain R.F. amplifier (38 db).
2N128 (S.b.)	10	5	30 mw.	28	65 mc/s.	Surface barrier transistor. R.F. amplifier.
2N129 (S.B.)	10	5	30 mw.	20	60 mc/s.	R.F. amplifier frequency changer or oscillator.
2N130 (P.N.P.)	22	10	100 mw.	22	800 Kc/s.	A.F. amplifier low gain.
2N131 (P.N.P.)	15	10	100 mw.	45	800 Kc/s.	A.F. amplifier medium gain.
2N132 (P.N.P.)	12	10	100 mw.	90	1 mc/s.	High gain audio amplifier.
2N133 (P.N.P.)	15	10	100 mw.	25	800 Kc/s.	A.F. amplifier.
2N135 (P.N.P.)	20	50	100 mw.	20	4.5 mc/s.	I.F. amplifier.
2N136 (P.N.P.)	20	50	100 mw.	40	6.5 mc/s.	R.F. amplifier.
2N137 (P.N.P.)	10	50	100 mw.	60	10 mc/s.	R.F. amplifier.
2N138 (P.N.P.)	12	20	50 mw.	140	—	A.F. output stages.
2N138A (P.N.P.)	30	100	50 mw.	40	—	A.F. output stages.
2N139 (P.N.P.)	16	15	80 mw.	48	7 mc/s.	Medium gain I.F. amplifier.
2N140 (P.N.P.)	16	15	80 mw.	75	10 mc/s.	Frequency changer.
2N141 (P.N.P.)	30	800	1.5 watts	40	400 Kc/s.	Power output stages (4 watts push-pull).
2N142 (N.P.N.)	30	800	1.5 watts	40	400 Kc/s.	Power output stages (4 watts push-pull).
2N143 (P.N.P.)	30	800	1.5 watts	40	400 Kc/s.	Power output stages (4 watts push-pull).
2N144 (N.P.N.)	30	800	1.5 watts	40	400 Kc/s.	Power output stages (4 watts push-pull).
2N145 (N.P.N.)	20	5	65 mw.	—	—	I.F. amplifier low gain.

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2N146 (N.P.N.)	20	5	65 mw.	—	—	Medium gain I.F. amplifier.
2N147 (N.P.N.)	20	5	65 mw.	—	—	High gain I.F. amplifier.
2N148 (N.P.N.)	16	5	65 mw.	—	—	Low gain I.F. amplifier.
2N148A (N.P.N.)	32	5	65 mw.	—	—	Low gain I.F. amplifier.
2N149 (N.P.N.)	16	5	65 mw.	—	—	Medium gain I.F. amplifier.
2N149A (N.P.N.)	32	5	65 mw.	—	—	Medium gain I.F. amplifier.
2N150 (N.P.N.)	16	5	65 mw.	—	—	High gain I.F. amplifier.
2N150A (N.P.N.)	32	5	65 mw.	—	—	High gain I.F. amplifier.
2N155 (P.N.P.)	30	3 amps.	1.5 watts	45	150 Kc/s.	Power output stages 7.5 w. max. in push-pull.
2N156 (P.N.P.)	30	3 amps.	1.5 watts	45	180 Kc/s.	Power output stages 7.5 w. max. in push-pull.
2N158 (P.N.P.)	60	3 amps.	1.5 watts	41	180 Kc/s.	Power output in stages 7.5 w. max. in push-pull.
2N164A (N.P.N.)	15	20	65 mw.	40	8 mc/s.	Oscillator in frequency changers.
2N165 (N.P.N.)	15	20	65 mw.	72	5 mc/s.	I.F. amplifier.
2N166 (N.P.N.)	6	20	25 mw.	32	5 mc/s.	Low gain I.F. amplifier.
2N168 (N.P.N.)	15	20	55 mw.	20	6 mc/s.	R.F. amplifier.
2N168A (N.P.N.)	15	20	65 mw.	40	8 mc/s.	R.F. amplifier or oscillator.
2N169 (N.P.N.)	15	20	50 mw.	40	4 mc/s.	Class B detector.
2N169A (N.P.N.)	25	20	55 mw.	30	5 mc/s.	Detector or reflex I.F.-A.F. amplifier.
2N170 (N.P.N.)	6	20	25 mw.	20	4 mc/s.	R.F. or I.F. amplifier.
2N172 (N.P.N.)	16	5	65 mw.	—	—	I.F. amplifier or frequency changer.
2N173 (P.N.P.)	60	7 amps.	40 watts	100	600 Kc/s.	Power output stages in car radio, etc.
2N174 (P.N.P.)	80	7 amps.	40 watts	45	200 Kc/s.	Power output stages in car radio, etc.
2N175 (P.N.P.)	10	2	20 mw.	65	800 Kc/s.	Small signal audio amplifier.
2N176 (P.N.P.)	12	600	5 watts	—	—	Power output stages (3 watts class A).
2N178 (P.N.P.)	12	600	10 watts	30	—	Power output stages (3 watts class A).
2N179 (P.N.P.)	20	60	1 watt	—	—	Power output stages (300 mw class A).
2N180 (P.N.P.)	30	25	150 mw.	60	700 Kc/s.	A.F. output stages 300 mw class B push-pull.
2N181 (P.N.P.)	30	38	250 mw.	60	700 Kc/s.	A.F. output stage 110 mw. Class A.
2N182 (N.P.N.)	25	10	100 mw.	25	3.5 mc/s.	I.F. amplifiers 34 db gain at 455 kc/s.

<i>Number Type</i>	<i>VC Max. (volts)</i>	<i>Ic Max. (ma)</i>	<i>PC Max.</i>	<i>Beta</i>	<i>Alpha cut-off Frequency</i>	<i>Application and Comments</i>
2N183 (N.P.N.)	25	10	100 mw.	40	7.5 mc/s.	I.F. amplifier or oscillator.
2N185 (P.N.P.)	20	150	150 mw.	55	—	Push-pull A.F. output (250 mw).
2N186 (P.N.P.)	25	200	100 mw.	24	800 Kc/s.	Push-pull A.F. output 300 mw. 28 db gain.
2N186A (P.N.P.)	25	200	200 mw.	24	800 Kc/s.	Push-pull A.F. output 750 mw. 30 db gain
2N187 (P.N.P.)	25	200	100 mw.	36	1 mc/s.	Push-pull A.F. output 300 mw. 30 db gain.
2N187A (P.N.P.)	25	200	200 mw.	36	1 mc/s.	Push-pull A.F. output 750 mw. 30 db gain.
2N188 (P.N.P.)	25	200	100 mw.	54	1.2 mc/s.	Push-pull A.F. output 300 mw. 32 db.
2N188A (P.N.P.)	25	200	200 mw.	54	1.2 mc/s.	Push-pull A.F. output 750 mw. 32 db.
2N189 (P.N.P.)	25	50	75 mw.	24	800 Kc/s.	Small signal audio amplifier. 37 db gain.
2N190 (P.N.P.)	25	50	75 mw.	36	1 mc/s.	Small signal audio amplifier. 39 db gain.
2N191 (P.N.P.)	25	50	75 mw.	54	1.2 mc/s.	Small signal audio amplifier. 41 db gain.
2N192 (P.N.P.)	25	50	75 mw.	75	1.5 mc/s.	Small signal audio amplifier. 43 db gain.
2N193 (N.P.N.)	15	50	50 mw.	6	3 mc/s.	Local oscillator.
2N194 (N.P.N.)	15	50	50 mw.	7.5	3.5 mc/s.	Local oscillator.
2N206 (P.N.P.)	30	50	75 mw.	47	800 Kc/s.	High gain small signal A.F. amplifier.
2N207 (P.N.P.)	12	20	50 mw.	100	2 mc/s.	High gain small signal A.F. amplifier.
2N207A (P.N.P.)	12	20	50 mw.	100	2 mc/s.	High gain small signal A.F. amplifier.
2N207B (P.N.P.)	12	20	50 mw.	100	2 mc/s.	High gain small signal A.F. amplifier.
2N211 (N.P.N.)	10	50	50 mw.	30	3.5 mc/s.	Local oscillator.
2N212 (N.P.N.)	10	50	50 mw.	15	6 mc/s.	Local oscillator.
2N213 (N.P.N.)	25	100	50 mw.	150	—	High gain A.F. amplifier.
2N214 (N.P.N.)	25	75	125 mw.	70	800 Kc/s.	Low gain A.F. amplifier.
2N215 (P.N.P.)	30	50	50 mw.	44	700 Kc/s.	Small signal A.F. amplifier.
2N216 (N.P.N.)	15	50	50 mw.	15	3 mc/s.	Low gain I.F. amplifier. 26 db.
2N217 (P.N.P.)	25	70	50 mw.	70	—	Small signal A.F. amplifier.
2N218 (P.N.P.)	16	15	35 mw.	48	4.7 mc/s.	I.F. amplifier 30 db gain.
2N219 (P.N.P.)	16	15	80 mw.	75	10 mc/s.	Frequency changer.
2N220 (P.N.P.)	10	2	20 mw.	65	800 Kc/s.	High gain 43 db small signal A.F. amplifier.
2N223 (P.N.P.)	18	150	100 mw.	95	600 Kc/s.	Small signal A.F. amplifier. 37 db.

<i>Number Type</i>	<i>VC Max. (volts)</i>	<i>Ic Max. (ma)</i>	<i>PC Max.</i>	<i>Beta</i>	<i>Alpha cut-off Frequency</i>	<i>Application and Comments</i>
2N224 (P.N.P.)	25	150	150 mw.	75	500 Kc/s.	Push-pull A.F. output stages. 300 mw.
2N225 (P.N.P.)	25	150	150 mw.	75	500 Kc/s.	Push-pull A.F. output stages. 300 mw.
2N226 (P.N.P.)	25	150	100 mw.	55	400 Kc/s.	Push-pull A.F. output stages. 300 mw.
2N227 (P.N.P.)	25	150	100 mw.	55	400 Kc/s.	Push-pull A.F. output stages. 300 mw.
2N228 (N.P.N.)	25	—	50 mw.	70	800 Kc/s.	Push-pull A.F. output stages. 100 mw.
2N229 (N.P.N.)	12	40	50 mw.	25	1.6 mc/s.	Small signal A.F. stage.
2N230 (P.N.P.)	30	2 amps.	15 watts	83	1 mc/s.	High power audio output stages.
2N233 (N.P.N.)	10	50	50 mw.	4.5	—	A.F. amplifier.
2N234 (P.N.P.)	30	3 amps.	25 watts	—	—	Power output stages.
2N34A (P.N.P.)	30	3 amps.	25 watts	—	—	Power output stages.
2N241 (P.N.P.)	25	100	100 mw.	73	1.3 mc/s.	A.F. output stages 35 db gain at 1 Kc/s.
2N241A (P.N.P.)	25	200	200 mw.	73	1.3 mc/s.	A.F. output stages 35 db gain at 1 Kc/s.
2N242 (P.N.P.)	45	2 amps.	—	40	200 Kc/s.	Power output stages 2.5 watts in Class A.
2N247 (P.N.P.)	35	10	35 mw.	60	30 mc/s.	R.F. amplifier 37 db gain at 1.5 mc/s.
2N249 (P.N.P.)	25	200	350 mw.	45	—	A.F. output stages 50 mw Class A.
2N253 (N.P.N.)	12	5	65 mw.	—	—	I.F. amplifier 30 db gain.
2N254 (N.P.N.)	20	5	65 mw.	—	—	I.F. amplifier 34 db gain.
2N255 (P.N.P.)	15	3 amps.	1.5 watts	40	200 Kc/s.	Power output stages 1 watt Class A.
2N256 (P.N.P.)	30	3 amps.	1.5 watts	40	200 Kc/s.	Power output stages 2 watts Class A.
2N265 (P.N.P.)	25	5 oma	75 mw.	110	1.5 mc/s.	High gain A.F. amplifier 45 db.
2N267 (P.N.P.)	25	5 oma	75 mw.	110	1.5 mc/s.	High gain A.F. amplifier 45 db.
2N270 (P.N.P.)	25	150	150 mw.	70	—	500 mw. push-pull output stages.
2N274 (P.N.P.)	40	10	35 mw.	60	30 mc/s.	High gain R.F. amplifier.
2N291 (P.N.P.)	25	200	180 mw.	45	—	A.F. amplifier 33 db gain.
2N292 (N.P.N.)	15	20	65 mw.	25	6 mc/s.	I.F. amplifier max. gain 35 db.
2N293 (N.P.N.)	15	20	65 mw.	25	7 mc/s.	R.F. amplifier and converter.
2N306 (N.P.N.)	12	—	50 mw.	30	750 Kc/s.	Small signal audio amplifier.
2N307 (P.N.P.)	35	1 amp.	—	25	200 Kc/s.	Output stages.
2N307A (P.N.P.)	35	2 amps.	17 watts.	20	100 Kc/s.	Power output stages.

<i>Number Type</i>	<i>VC Max. (volts)</i>	<i>lc Max. (ma)</i>	<i>PC Max.</i>	<i>Beta</i>	<i>Alpha cut-off Frequency</i>	<i>Application and Comments</i>
2N308 (P.N.P.)	20	5	30 mw.	—	—	I.F. amplifier 41 db gain.
2N310 (P.N.P.)	30	5	30 mw.	—	—	Reflex I.F./A.F. amplifier.
2N319 (P.N.P.)	20	200	240 mw.	33	2 mc/s.	A.F. output stages 30 db gain.
2N320 (P.N.P.)	20	200	240 mw.	48	2.5 mc/s.	A.F. output stages 32 db gain.
2N321 (P.N.P.)	20	200	240 mw.	48	3 mc/s.	A.F. output stages 35 db gain.
2N322 (P.N.P.)	16	100	140 mw.	70	2 mc/s.	High gain A.F. amplifier. 39 db.
2N323 (P.N.P.)	16	100	140 mw.	90	2.5 mc/s.	High gain A.F. amplifier. 41 db.
2N324 (P.N.P.)	16	100	140 mw.	80	3 mc/s.	High gain A.F. amplifier. 43 db.
2N325 (P.N.P.)	35	2 amps.	12 watts	40	200 Kc/s.	High power transistor.
2N328 (P.N.P.)	35	100	335 mw.	24	350 Kc/s.	Medium gain A.F. transistor. 34 db.
2N329 (P.N.P.)	30	100	335 mw.	50	500 Kc/s.	Medium gain A.F. transistor. 36 db.
2N330 (P.N.P.)	45	50	335 mw.	30	250 Kc/s.	Low gain A.F. amplifier. 34 db.
2N331 (P.N.P.)	30	10	200 mw.	48	700 Kc/s.	High gain, A.F. amplifier. 44.5 db.
2N344 (P.N.P.)	5	5	20 mw.	22	50 mc/s.	R.F. amp. surface barrier type.
2N345 (N.P.N.)	5	5	20 mw.	15	75 mc/s.	R.F. amp. surface barrier type.
2N346 (P.N.P.)	5	5	20 mw.	60	50 mc/s.	R.F. amp. surface barrier type.
2N381 (P.N.P.)	25	200	200 mw.	50	1.2 mc/s.	Push-pull output stages. 25 db gain.
2N382 (P.N.P.)	25	200	200 mw.	75	1.5 mc/s.	Push-pull output stages. 33 db gain.
2N383 (P.N.P.)	25	200	200 mw.	100	1.8 mc/s.	Push-pull output stages. 31 db.
2N384 (P.N.P.)	30	10	120 mw.	65	100 mc/s.	V.H.F. amp. 10.7 mc/s. I.F. amplifier.
2N386 (P.N.P.)	60	3 amps.	12.5 watts	100	700 Kc/s.	High power amp. suitable car radio.
2N387 (P.N.P.)	80	3 amps.	12.5 watts	100	600 Kc/s.	High power amp. suitable car radio.
2N402 (P.N.P.)	20	150	180 mw.	24	600 Kc/s.	A.F. amplifier 37 db gain.
2N403 (P.N.P.)	20	200	180 mw.	32	850 Kc/s.	Audio output stages 32 db Class A.
2N405 (P.N.P.)	18	35	150 mw.	35	650 Kc/s.	High gain audio amplifier. 43 db.
2N406 (P.N.P.)	18	35	150 mw.	35	650 Kc/s.	43 db.
2N407 (P.N.P.)	18	70	150 mw.	65	—	High gain audio amplifier. Push-pull output stages. 160 mw.
2N408 (P.N.P.)	18	70	150 mw.	65	—	Push-pull output stages. 160 mw.
2N409 (P.N.P.)	12	15	80 mw.	45	7 mc/s.	I.F. amplifier 39 db gain.



<i>Number Type</i>	<i>VC Max. (volts)</i>	<i>Ic Max. (ma)</i>	<i>PC Max.</i>	<i>Beta</i>	<i>Alpha cut-off Frequency</i>	<i>Application and Comments</i>
2N410 (P.N.P.)	13	15	80 mw.	45	7 mc/s.	I.F. amplifier 39 db gain.
2N411 (P.N.P.)	13	15	80 mw.	75	10 mc/s.	R.F. amplifier or converter.
2N412 (P.N.P.)	13	145	80 mw.	75	10 mc/s.	R.F. amplifier or converter.
2N413 (P.N.P.)	18	200	150 mw.	30	2.5 mc/s.	Low gain R.F. amplifier.
2N413A (P.N.P.)	15	200	150 mw.	30	2.5 mc/s.	I.F. amplifier 33 db.
2N414 (P.N.P.)	15	200	150 mw.	60	7 mc/s.	Low gain R.F. amplifier.
2N414A (P.N.P.)	15	200	150 mw.	60	7 mc/s.	I.F. amplifier 35 db gain.
2N415 (P.N.P.)	10	200	150 mw.	80	10 mc/s.	R.F. or I.F. amplifier.
2N415A (P.N.P.)	10	200	150 mw.	80	10 mc/s.	I.F. amplifier. 30 db gain.
2N416 (P.N.P.)	12	200	150 mw.	80	10 mc/s.	R.F. amplifier. 20 db gain.
2N417 (P.N.P.)	10	200	150 mw.	140	20 mc/s.	High gain R.F. amplifier.
2N422 (P.N.P.)	20	100	150 mw.	50	800 Kc/s.	High gain audio amp. 38 db. Audio amplifier suitable for output stages.
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