22 TESTED CIRCUITS USING MICRO ALLOY TRANSISTORS

by

Clive Sinclair

All circuits have been tested by a panel of amateur constructors.

Complete parts lists and full constructional details.

26 comprehensive theoretical diagrams.

Practical hints and tips on construction.

Super sensitive receivers, transmitters, and amplifiers fully described.

Comprehensive servicing data included.

Fault finding and practical hints and tips for the constructor.

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

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CHAPTER ONE

An Introduction to the M.A.T

Since the initial invention of the point contact transitor some twelve years ago engineers have continually striven to develop new types with improved performance. The original point contact transistors were very noisy, rather delicate and it was very difficult to produce consistently good quality types. When the alloy junction transistor was invented, therefore, they rapidly became obsolete. Alloy junction transistors, such as the OC71 and OC44, make excellent A.F. amplifiers with comparatively low noise figures and R.F. types may be used at frequencies of up to about 5Mc/s. Even at medium wave band frequencies of around 1Mc/s, however, their gain is comparatively low because even the best of them provide a common emitter current of only about 10 times at these frequencies.

To overcome the limitations of the conventional alloy transistor the alloy diffused type was developed, examples of this type being the OC170 and OC171. In these the resistivity of the base region, instead of being constant, varies steadily from the emitter to the collector. This results in the charge carriers being accelerated across the base thus reducing the transit time and increasing the cut-off frequency. Alloy diffused transistors make excellent, high gain R.F. amplifiers at M.W. frequencies and they will operate up to 100Mc/s or more. However, they have very high saturation voltages which means that a comparatively high collector voltage must be used and their current gain drops rapidly as the collector current is reduced making them unsuitable for operation at low collector current levels. They also make poor A.F. amplifiers and are thus difficult to use in reflex circuits unless the designer takes numerous precautions.

We may now sum up the last two types. The alloy junction transistor makes an excellent A.F. transistor down to fairly low levels of collector current and voltage but is a poor R.F. amplifier by comparison. The alloy diffused type is an excellent R.F. transistor which can operate right up to V.H.F. frequencies but is not very good as an A.F. amplifier or at low collector currents and voltages. A transistor was required, therefore, which combined and extended the advantages of both types just mentioned without any of the disadvantages. An early attempt to achieve this resulted in the surface barrier transistor or SBT. The SBT was made by electrochemically etching away the base prior to plating on the collector and emitter electrodes. This resulted in an extremely narrow base width and, hence, a very high cut-off frequency. SBT's operated perfectly at both audio and radio frequencies and they could also operate at very low power levels. Unfortunately, however, their common emitter current gain was always very low and they were limited to collector currents of 5mA and collector voltages of 5 volts. These disadvantages precluded their widespread application although they were very useful for some purposes such as in radio control receivers or in radio receivers designed to operate from low voltage batteries.

Finally the micro alloy transistor, or MAT, was developed. These are made by a technique similar to that invented for SBT's but developed considerably to overcome all the disadvantages of the latter. MAT's have extremely high levels of current gain, as high as 200 in many cases, and they can also operate at collector currents of up to 50mA and collector voltages up to about 12 volts. Their cutoff frequencies are as high or higher than those of alloy diffused transistors and yet they make better A.F. amplifiers than alloy junction types. Furthermore they will operate at much lower levels of collector current and voltage. The two tables below compare typical MAT's with the best alloy junction and alloy diffused types on the market.

Table I.—Comparison between MAT and best A.F. transistor hitherto available.

	Vce(sat.)	Beta	Ic(max.)
MAT	0.05V	75—250	50mA
Alloy junction	0.15V	20—90	50mA

From this it will be seen that the micro alloy transistor will operate down to one third the collector voltage Vce(sat.) of the best alloy junction type available and will provide over three times the current gain. This means that the power gain is about ten times as high because power gain is proportional to the square of the current gain.

Table II.—Comparison between MAT and the best R.F. transistor hitherto available.

	Vce(sat.)	Cut-off frequency	Beta	Ic(max.)
MAT	0.05V	120M/cs	75—250	50mA
Alloy diffused transistor	1.3V	70M/cs	15—150	10mA

Here the superiority of the MAT at low collector voltages is even more spectacular (and this is very important when high efficiency is required as it is in transmitter output stages). The cut off frequency of the MAT is slightly higher and the current gain is considerably higher. Furthermore, the variation in current gain is very much less so that the constructor is guaranteed a high gain transistor in every purchase he makes. The maximum collector current for the MAT is 5 times higher and this again is very important in the output stages of transmitters.

Neither of these tables illustrates the advantages of MAT's at very low power levels and these should not be forgotten because of their importance in very small receivers, radio control equipment, hearing aids, etc. An example may be useful therefore: An MAT operating from a 1.3 volt supply with a collector current of 0.1mA (100 microamps) will give as much or more gain than the best alloy junction transistor operating from a 12 volt supply with a collector current of 3mA. Thus the power consumption of a small signal A.F. or R.F. amplifier may be reduced to one fortieth of that normally required.

MAT Specifications.

Up to now we have talked of MAT's in general rather than of specific types. In fact, four types are available and two of these, the MAT100 and the MAT101, are specified for very low power operation. That is to say, whilst they are similar to the other two types their parameters are measured and guaranteed at very low power levels. The other two types are the MAT120 and MAT121. These are measured and specified at normal power levels, but of course, they will also operate down to the very low power levels just as the MAT100 and MAT101 will operate up to 50mA.

The technical specifications for these transistors, are, then, as follows:—

Absolute Maximum Ratings (all types).

Storage temperature	- 65° to + 85°C.
Junction temperature	85°C.
Collector voltage	- 9V (up to - 12V if required)
Collector current	- 50mA
Power dissipation at 25°C	50mW
Lead temperature	230°C ± 5°C for five seconds.

Electrical Characteristics.

Low Power Types	MAT100	MAT101
A.F. current gain (Beta) at Vce = 1.5 volts, Ic = 0.5mA		
Min.	25	75
Typical	50	100
Max.	75	250
Alpha cut-off frequency at Vce = 1.5V, Ic = 0.5mA	60Mc/s	60Mc/s
Vce Sat. (Minimum Collector voltage) at Ic = 1mA	0.04V max.	0.04V max.
Retail price	7/9d.	8/6d.

Ordinary Power Types	MAT120	MAT121
A.F. current gain (Beta) at Vce = 6V, Ic = 4mA		
Min.	25	75
Typical	50	150
Max.	75	250
Alpha cut-off frequency at Vce = 6V, Ic = 4mA	120Mc/s	120Mc/s
Vce Sat. (Minimum Collector voltage) at Ic = 6mA	0.05V	0.05V
Retail price	7/9d.	8/6d.

It will have been noticed from the above tables that the MAT100 and MAT120 retail at 7/9d. and the MAT101 and MAT121 at 8/6d. At these prices they are very much cheaper than alloy diffused transistors and they are even cheaper than standard R.F. alloy junction types. This is possible because MAT's are produced not by hand but by fully automatic machines which not only make them in great quantity but control the necessary operations to a very fine degree. There are, therefore, far fewer rejects with the automatic process and the transistors sold differ from one another far less. This simplifies circuit design and ensures that all circuits constructed with MAT's give optimum performance.

Good quality A.F. alloy junction transistors can be bought for less than MAT's and it may, at first, be thought that MAT's would have little application in A.F. circuitry except where very low power operation is required. In fact this is certainly not the case and it can easily be shown that considerable savings are made by using MAT's in A.F. amplifiers. The gain of a conventional alloy junction transistor used as a standard small signal, R—C coupled, A.F. amplifier is about 20dB (100 times). An MAT120 will give a gain of 34dB (2,500 times) in the same circuit and the MAT121 will give the amazing figure of 40dB (10,000 times). Similar gains will be achieved with the MAT100 and the MAT101. Now the significance of these figures is obvious: Two MAT120's can replace three alloy junction transistors and besides the saving of a transistor, it's associated components will not be needed. There will also be a considerable reduction in noise level and an improvement in quality. With MAT121's the saving is even more striking because one of these can replace two alloy diffused types. The number of components required to achieve a given gain is, therefore, halved with an enormous saving in cost.

Encapsulation and lead connections.

The MAT is physically a small transitor, being a lot smaller, for example, than the OC71, and it has a metal encapsulation or can. Both the can and the leads are gold plated to make the appearance attractive, to prevent corrosion and to make the leads easy to solder. The cans are cylindrical being about ⅜" long by 1/5" diameter with a small flange one third of the way up from the lead end. The gold plating on the can being bright, aids dissipation of heat by radiation.

As mentioned above, the leads being gold plated, are very easy to solder and the iron need

only be applied to them for a very short time. MAT's are no more prone to damage by heat than any other type but reasonable precautions should be taken and soldering time kept to a minimum. It is always worthwhile using transistor sockets whenever possible because it facilitates the removal of the transistors from a circuit when that circuit is no longer required.

The physical dimensions and lead connections for MAT's are shown in Fig. 1. As shown by the diagram MAT's are PNP transistors as are the vast majority of alloy junction and diffused types. The collector, therefore, should always be negative with respect to the emitter.

CHAPTER TWO

Circuitry Techniques with Micro Alloy Transistors.

Lest the heading to this chapter be misleading, let it be said immediately that MAT's can be used, without any component changes, in virtually any circuit designed to use ordinary A.F., R.F. or V.H.F. transistors. In many cases, in fact, it is possible to substitute MAT's, reduce the collector voltage to half the specified value or even less and yet still obtain improved performance.

The Micro Alloy transistor, however, has many advantages over conventional types as has already been explained. These make it possible to design circuits using them which otherwise would not be feasible. In reflex and regenerative receivers, for example, they are particularly useful and they also make possible certain types of direct-coupled amplifier which would otherwise be unsatisfactory. In push-pull circuits they provide much higher efficiency than is usual and the same applies to transmitter circuits. Their high gain is useful in hearing aid circuits and in R.C. oscillators as well as in receivers and amplifiers.

Amplifier Circuits.

The main advantages of MAT's in A.F. circuits are as follows: —

1. Extremely high gain.
2. Very high efficiency in output circuits.
3. Ability to provide high gain at very low levels of collector current and voltage. This makes it easy to design very low noise hi-fi preamplifiers.
4. Completely linear frequency response throughout the A.F. range; again essential in hi-fi circuitry.
5. Ability to operate perfectly with the collector-base junction forward biassed. This is important in direct coupled amplifiers.

Of these advantages No. 1 is obvious but the others may need a little explanation. The high efficiency in output circuits arises because the voltage swing of any output transistor is restricted by the knee or saturation voltage and, as we have already seen, this is much lower in an MAT than in any other type. At the time of writing, matched pairs of MAT's for use in push-pull circuits are not available but the constructor can select such pairs for himself if necessary.

The prime requirement of a microphone preamplifier is that it should provide high gain with the minimum possible amount of noise generation. The noise generated by any transistor may be kept to a minimum by using low values of collector current and voltage because the smaller the power dissipated in the transistor the lower the noise level. Unfortunately, with normal transistors a low value of collector current immediately results in very low gain and this technique cannot be taken very far. MAT's, however, will give very high gains at collector currents of only 50 microAmps and with only a fraction of a volt on the collector. Thus low noise and high gain can be achieved at the same time.

The advantage mentioned in point No. 4 is an extremely important one in hi-fi equipment design. Conventional alloy transistors drop in gain as the frequency increases through the audio band. The drop is not very large, possibly as little as 3dB in the best types, but in a multistage amplifier it is quite large enough to degrade the performance to well below hi-fi standards. With MAT's there is no drop at all until the frequency reaches several Mc/s thus the problem is completely overcome.

In power amplifiers, and MAT's may be used in push-pull circuits with outputs up to 250mW., another advantage occurs. With MAT's the

common emitter current gain remains remarkably constant over the entire current range normally used. That is to say the variation in current gain is negligible from 0.5mA to 50mA. This small variation also means that a much lower level of quiescent forward bias than usual may be used; another contribution to increased efficiency.

The last advantage in the list may seem a little curious at first but it is a very useful fact when direct coupled circuits are used. The type of circuit shown in fig. 2 demonstrates this. It has been used extensively in hearing aids but is normally rather limited in frequency response because of the very low voltage on the collectors. The collector voltage may, in some cases be lower than the base voltage causing the output impedance of the transistor to drop sharply thereby shunting the next stage and reducing the gain of the amplifier considerably. This has always been something of an annoyance because the circuit is so delightfully economical and it would be nice to be able to use it in radio receivers and high quality amplifiers. With MAT's this now becomes possible. These transistors still give maximum gain at the collector voltages involved and the output impedances remain high even when the collector voltage is below the base voltage. This type of amplifier may now be used with outputs in the 25mW region.

To summarise the application of MAT's in A.F. amplifiers, they may be used with collector currents between 0.02mA (20 micro Amps) and 50mA and at collector voltages as low as 0.04 volts. The frequency response is perfectly linear and the gain is constant with current. The narrow beta spread with any type is also useful as it enables the gain and performance to be predicted accurately.

Oscillator Circuits.

MAT's may be used in tuned oscillators in precisely the same way that alloy junction and alloy diffused types are employed. The maximum frequency of oscillation attainable will be in the region of 130Mc/s with the transistor used in the common base mode and with a collector current of about 4mA. With a collector current of 0.5mA the maximum practical frequency of oscillation will be around 65Mc/s. MAT's thus extend the frequency range obtainable quite considerably.

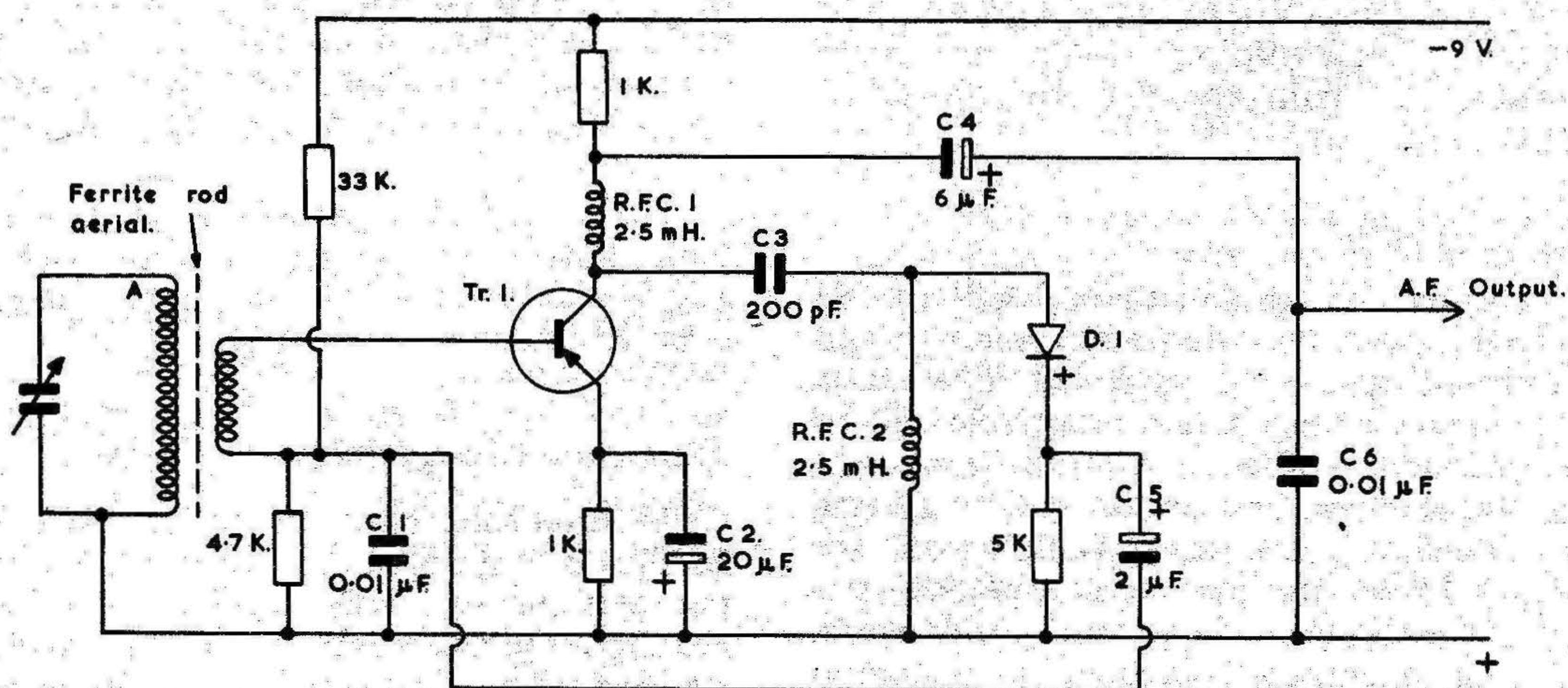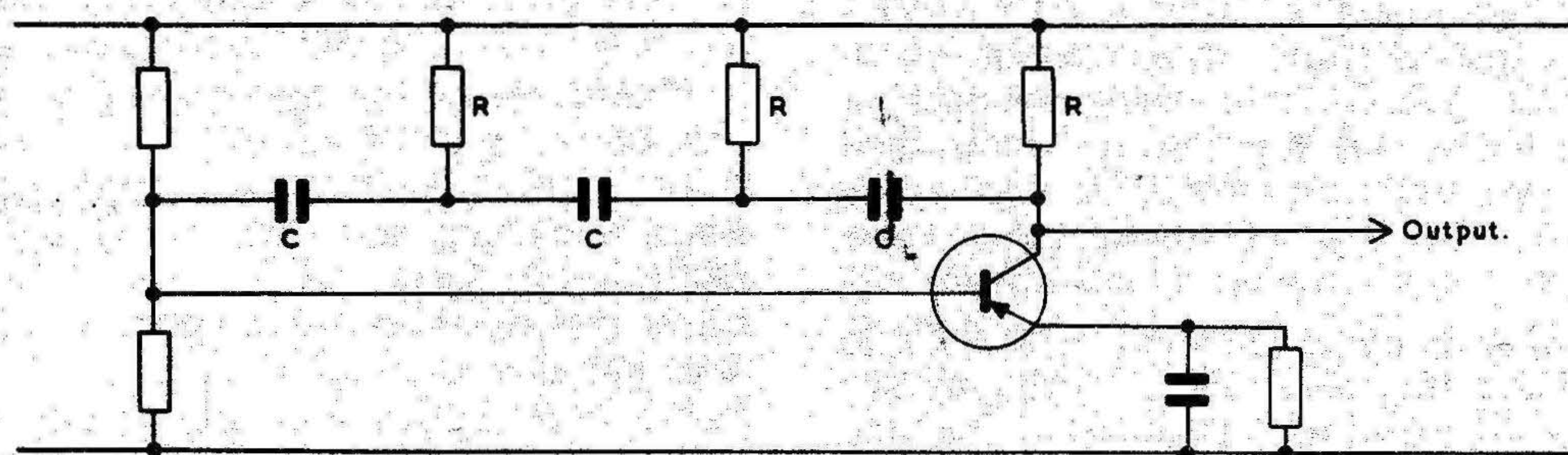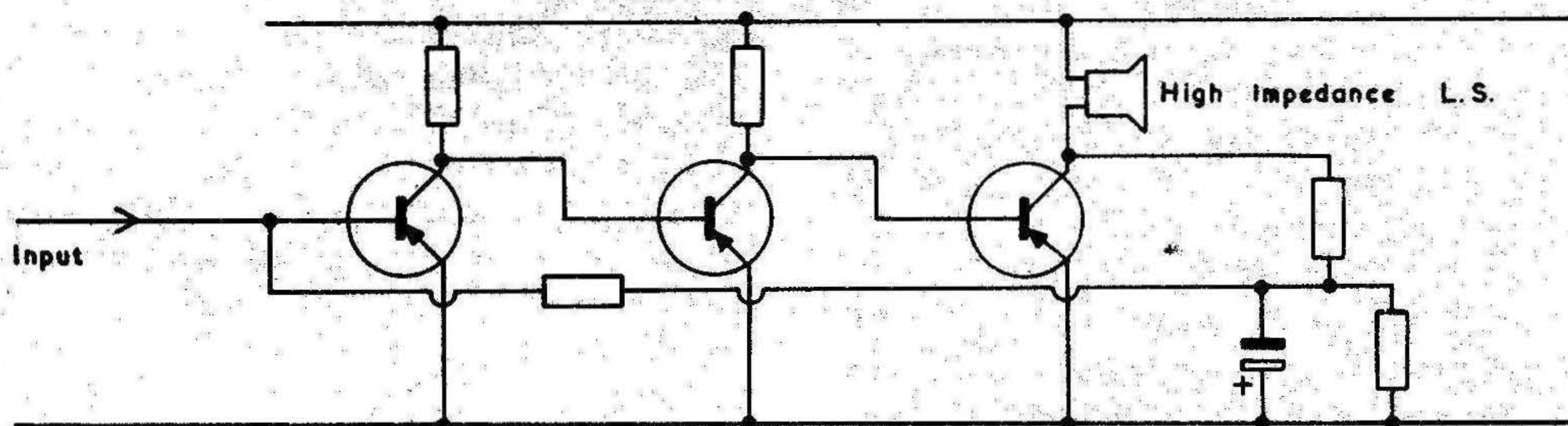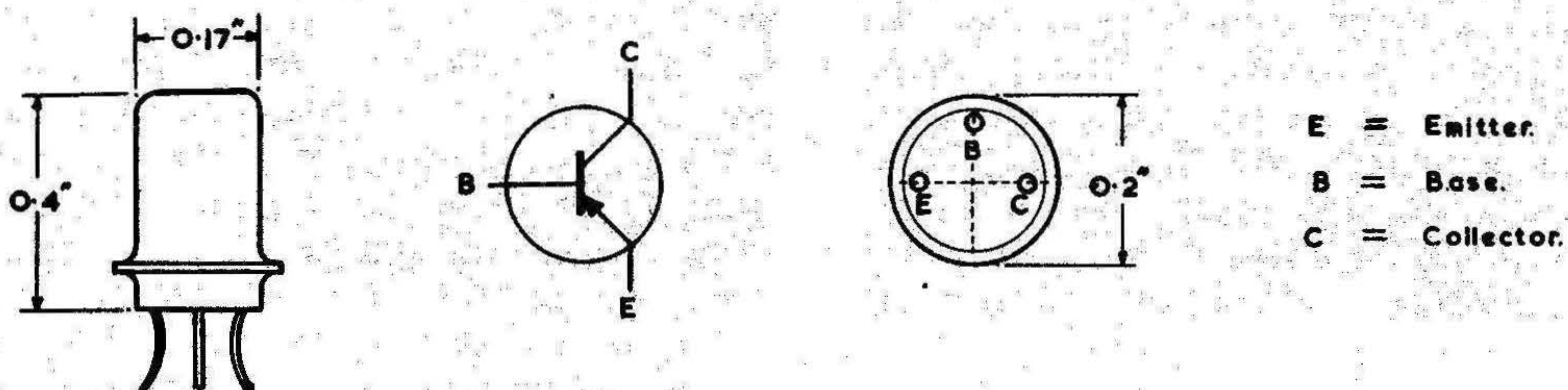In phase shift or R—C' oscillators MAT's have two important advantages. Single transistor phase shift oscillators, of the type shown in Fig. 3, employ a three section ladder network to produce a phase change of 180° at a specific frequency. Since the network, comprising the three resistors marked R and the three capacitors marked C, is connected between the collector and the emitter of the transistor, which also introduces a 180° shift, the circuit oscillates at a frequency determined by the values of R and C. Unfortunately, however, this delightfully simple circuit has, in the past, been difficult to construct consistently because the phase shift network introduces a considerable current loss which makes it essential to use a transistor with a Beta of at least 60. Now, whilst many transistors on the market have Beta ranges which include this value, only a fairly small percentage of any given type will exceed 60 and anyone wishing to build an oscillator of this type has had to buy several transistors and test them to find one that is suitable. With the MAT101 and the MAT121 however, this is quite unnecessary as every one of these bought has a minimum Beta of 75 which is more than sufficient.

The formula for the frequency of oscillation of the type of circuit shown in Fig. 3 is $f = \frac{1}{2} \pi \, CR \sqrt[4]{6}$. This only applies, however, when the phase shift introduced by the transistor is precisely 180°. With alloy junction transistors this is only true when the frequency does not exceed a few kc/s. So for this reason, and because the value of Beta drops rapidly as the frequency is increased phase shift oscillators using a single transistor, have formerly been limited to low A.F. frequencies. With MAT's however, phase shift and Beta remain constant up to at least 1Mc/s so that oscillators operating at, or above, this frequency become possible.

Every MAT101 or MAT121 bought will, then, operate perfectly in a phase shift circuit and will extend the frequency range possible by over 10 times.

Frequency Changers.

In broadcast band frequency changers the MAT100 and MAT101 are ideal. The choice between the two will depend upon the gain required, the latter type giving the greater gain. They may be used in precisely the same type of circuit used with alloy diffused and alloy junction transistors and will give extremely high conversion gain, but they also make it possible

Fig. I. Physical dimensions and Pin connections of MAT's.

E = Emitter.
B = Base.
C = Collector.

Fig. 2. Example of direct coupled A.F. amplifier.

High impedance L.S.

Input

Fig. 3. Basic Circuit of a phase-shift Oscillator.

Output.

R   R   R

C   C

Fig. 4. Example of reflex amplifier in common use.

−9 V.

Ferrite rod aerial.

A.F. Output.

1 K.

33 K.

R.F.C. 1
2·5 mH.

C 4
6 μF.

C 3
200 pF.

Tr. I.

D. 1

R.F.C. 2
2·5 mH.

C 6
0·01 μF.

4·7 K.

C 1
0·01 μF.

1 K.

C 2.
20 μF.

5 K.

C 5
2 μF.

+

to design superhets operating from only 3 or even 1.5 volt batteries with correspondingly low values of collector current. This facility is extremely useful in the design of subminiature receivers because high capacity Mallory mercury cells can then be used with a considerable saving in space. No special circuitry techniques are required and in fact it is often possible to use a superhet circuit designed for 6 or 9 volt operation and to replace the transistors with micro alloy types and reduce the battery voltage to 3 volts without any loss in sensitivity.

In V.H.F. converters the MAT121 should be used and requires precisely the same type of circuity as alloy diffused types. In conversion gain and noise level the performance of the two types will be much the same except that the current gain of the MAT121 is consistently higher and, of course, it costs very much less.

R.F. and I.F. Amplifiers.

I.F. amplifiers operating in the range up to 470kc/s (i.e. that used in broadcast band sets) MAT's offer the advantage of very much higher gain than that obtained from the alloy junction types normally used. Furthermore, with MAT's absolutely no neutralisation is required.

A large saving can be made in the number of components used in a standard superhet because an MAT frequency changer with a single MAT I.F. amplifier will give as good a performance as a standard circuit using 2 I.F. stages. This saves one transistor and the associated components. Either the MAT100 or the MAT101 may be used, the latter giving higher gain.

For 10.7Mc/s I.F. amplifiers, as used in F.M./V.H.F. receivers, the MAT120 is ideal. The MAT121 may also be employed if very high gain is needed.

The MAT121 will operate as an R.F. amplifier up to, or above, 100Mc/s and should be used in the common base mode above about 70Mc/s or so. When the transistor is used as an R.F. amplifier in the output of a transmitter, of either the radio control or broadcast type, the high collector current rating and very low saturation voltage of the MAT121 proves very useful. A single micro-alloy transistor can give an output of up to 150mW in a class B output circuit whilst the alloy diffused transistors available are limited to about 30mW by the low collector current limits and voltage restrictions.

Completely transistorised radio control trans-

mitters can readily be built with outputs in the region of 300mW. Even higher outputs are possible, if necessary, as four transistors may be used in the output in a parallel, push-pull arrangement. For maximum dissipation heat sinks may be used on the transistors.

To summarise the advantages of MAT's in R.F. and I.F. amplifiers; they save space, power, components and money, they reduce noise and dissipation and lead to increased efficiency.

Reflex Amplifiers.

The basic principle of the reflex amplifier is well known by now because of its widespread use in low cost Japanese receivers and in many kits made in this country. Manufacturers in Britain have been rather hesitant about employing this technique, presumably because the transistor manufacturers have failed to issue circuitry information on it and the producers have not felt inclined to do the development work themselves. This is regrettable, however, since a reflex amplifier does save a transistor and, although a little more difficult to design, does not necessarily introduce any noticeable distortion.

Basically, a reflex amplifier operates at two widely different frequencies at the same time. The same transistor may be used to amplify at R.F. and A.F. or, in the case of a superhet, at I.F. and A.F. Since the former example is more common we will concentrate on it and all the information given will also apply to I.F./A.F. amplifiers.

The type of reflex R.F./A.F. amplifier which is most frequently used today is shown in Fig. 4. The R.F. signal required is selected by the tuned circuit comprising the tuning capacitor and the ferrite rod aerial. It is then amplified by Tr_1 and passed to the diode for detection. Chokes RFC_1 and RFC_2 prevent the R.F. signal from going to earth. The A.F. output from the diode is developed across the 5k ohm resistor and fed back to Tr_1 via C_5.

C_1 removes any residual R.F. signal and the A.F. signal is amplified by the transistor. The A.F. output passes readily through RFC_1 but is blocked by C_3—it thus appears across the 1k ohm collector load resistor. Some care must be taken in the choice of component values over and above that normally required. For example, C_1 must be large enough to remove virtually all the R.F. signal but not so large that it removes a significant amount of the A.F. signal. RFC_1

must allow the A.F. signal to pass freely but must block the R.F. signal and C_3 must pass the R.F. signal and block the A.F. signal. The values shown have been found, both in theory and practice, to be optimum. If C_1 is reduced, R.F. gain will be lost and if C_3 is increased A.F. gain will be lost.

Regeneration, that is positive feedback, is often employed to increase the R.F. gain and the selectivity. This may be achieved in several ways. RFC_1 may be placed near the aerial coil in such a way that the mutual inductance between the two coils augments the signal or a feedback trimmer may be connected between the collector of Tr_1 and point A on the aerial coil. Unless the degree of regeneration is to be readjusted each time a station is tuned in, however, which is most inconvenient, the degree of regeneration can only be slight to avoid the set oscillating on any part of the band. This means that the sensitivity is limited with this type of circuit. What is required is a circuit in which the degree of regeneraton is automatically self adjusting. A further improvement could be achieved by putting a slight forward bias on the diode so that it operates over a more non-linear part of its curve and thus provides better detection efficiency. This point may need a little further explanation; no diode is a perfect rectifier and, whilst at large signal levels it may act very much like one, at very low signal levels, such as those we are dealing with, the imperfections are important. At these very low signal levels the forward conduction of the diode is very little greater than the reverse conduction and detection efficiency is low. If the diode is permanently slightly forward biassed it moves in and out of the high conduction region as the signal changes polarity and the efficiency is much improved.

A circuit which achieves these two objectives, controlled regeneration and improved detection, is shown in Fig. 5. It is very similar to Fig. 4 but D_1 replaces RFC_2 and D_2 is directly coupled to the transistor. Because of these changes the base-emitter voltage of Tr_1 also appears across the two diodes thus providing the necessary forward bias. The output from D_2 consists of a signal which is positive with respect to the bias level and, since D_2 is connected to the base of Tr_1 via the secondary of the aerial coil, this positive signal reduces the base bias, and hence the collector current and gain of the transistor. Now if sufficient regeneration is applied just to cancel out the losses in the tuned circuit the circuit would normally oscillate vigorously but any oscillation will be rectified by the diodes and the output from these will reduce the collector current sufficiently to reduce the oscillations to a very low level. Thus, in the absence of a signal the level of oscillation is automatically limited. When a signal appears, it is amplified strongly because the regenerative amplifier provides very high gain, and the detected output reduces the collector current still further so that, unless the signal is very weak, the transistor ceases to oscillate and the signal is amplified without noticeable distortion.

The stronger the signal is, the greater will be the drop in collector current and the lower the gain will become thus there is a high degree of A.G.C. With low strength signals the transistor will operate near the point of regeneration and provide very high gain.

This circuit is, therefore, a great improvement on the last one. It is by no means the ultimate in reflex design because simplicity has been aimed at but it does give a surprisingly good performance. The collector current of TR_1 depends upon the characteristics of the diodes used. This makes it necessary to adjust R_1 for the value required, usually about 1mA.

Now that the types of circuit used in reflex amplifiers have been considered we can turn our attention to the transistor. This is required to amplify at R.F. and A.F. and should give a good performance at both frequencies. As we have seen, alloy junction transistors make good A.F. amplifiers but even the best of them give comparatively low gain at R.F. Alloy diffuse transistors on the other hand give high R.F. gain, as long as the voltage and current levels are high enough, but their A.F. performance is poor, the noise level being very high. Micro alloy transistors are, therefore, the obvious choice. They provide very high gain at both A.F. and R.F. (or A.F. and I.F. as the case may be) and they may be used with virtually any value of collector current and voltage. The obvious types for reflex circuits are the MAT101 and the MAT121 because their high gain properties are used twice and the overall gain of the reflex circuit, using these types, is incredibly high.

Detectors and Regenerative Detectors.

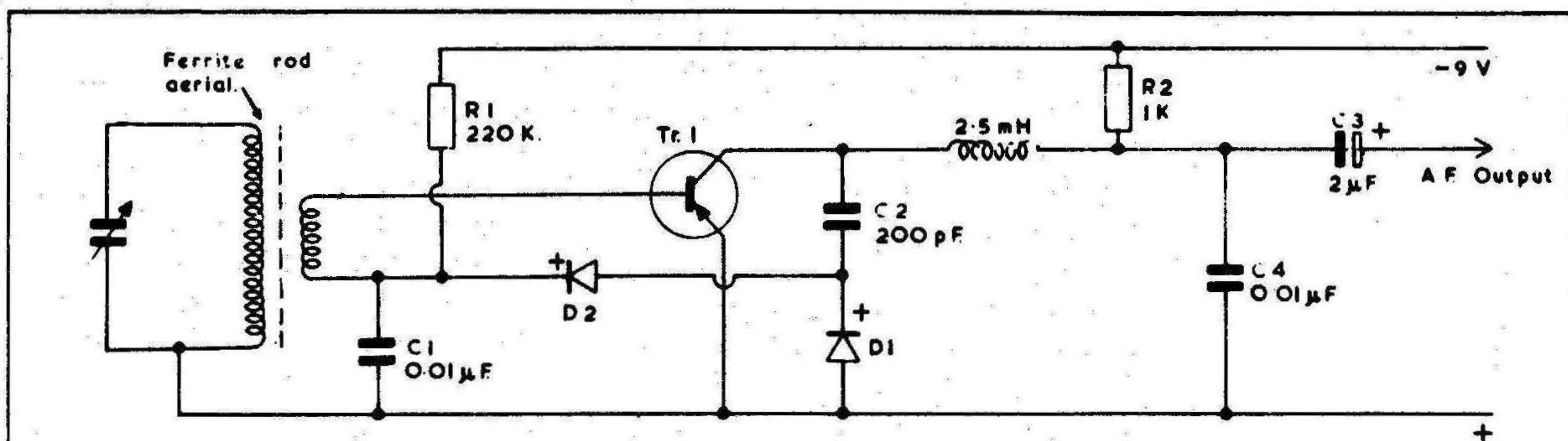The majority of commercial and amateur built receivers use germanium point contact
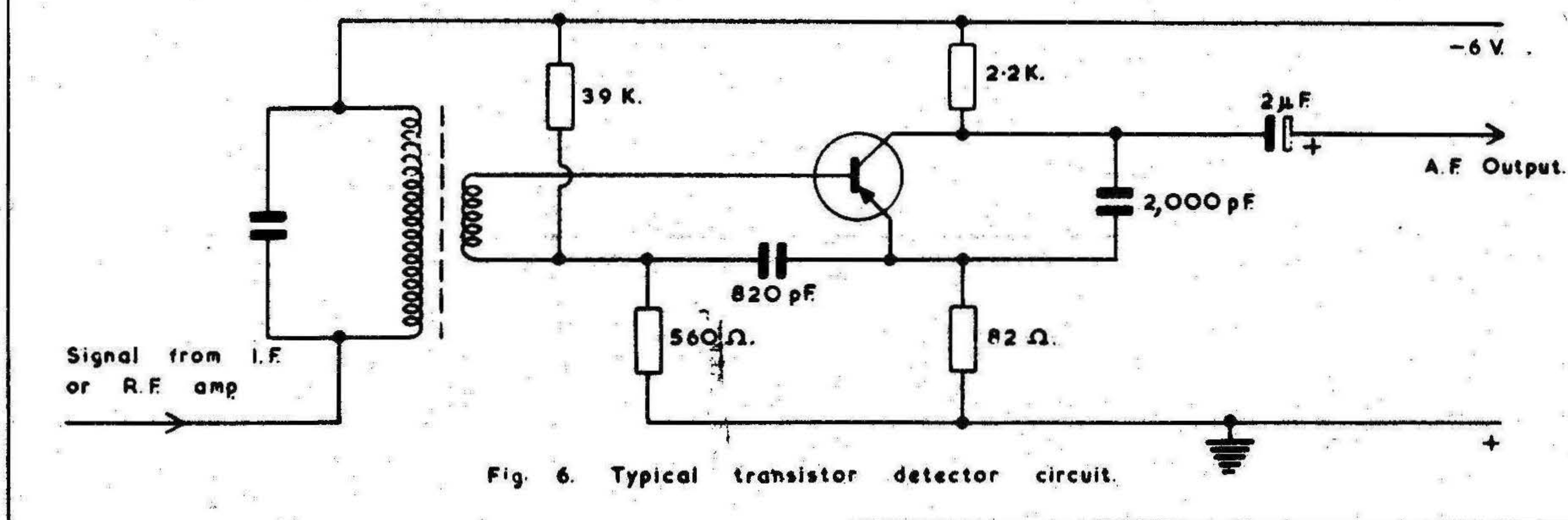
Fig. 5. Improved reflex circuit.

Fig. 6. Typical transistor detector circuit.

diodes as detectors. This function they perform with reasonable efficiency as long as the signal level is high enough. If the signal strength is low, however, the crystal diode becomes very inefficient. That is to say, the A.F. output is very much smaller than the R.F. input power. This is the reason why crystal sets are effective only when used with good aerials.

A transistor may be used as a straight detector instead of a diode and, despite the added expense, this is often worthwhile because the transistor provides gain as well as detection. The efficiency at low levels is also superior to that of a diode.

A typical circuit using a transistor is shown in Fig. 6. The transistor is an R.F. alloy junction type biassed to a collector current of between 100 and 200 microAmps. Detection occurs because the transistor amplifies a negative signal more than it amplifies a positive one. A negative signal causes an increase in collector current and thus current gain which rises with current at low levels. A positive signal reduces

the collector current and thus receives less gain. Furthermore, the circuit is so designed that the input impedance of the transistor is always higher than the impedance of the coupling winding feeding it. Since the input impedance rises with a decrease in collector current and drops for an increase, there is actually less power fed to the transistor on positive signals than there is on negative ones.

This type of circuit is used, then, after one or more stages of R.F. amplification in a T.R.F. receiver or after a frequency changer and I.F. amplifier in a superhet. However, the detector can be made to provide R.F. amplification itself by use of regeneration. This involves feeding back the R.F. output from the transistor, to the input in such a way as to increase the input signal instead of removing it by the 2,000pf capacitor.

This type of circuit is known as a regenerative detector and it is interesting because not only is R.F. gain obtained but the detection efficiency is improved enormously at very low

levels. This makes it possible to feed the regenerative detector directly from a ferrite rod aerial without any preceding stage of R.F. amplification. The output from the detector is fed directly to an A.F. amplifier.

In the past transistor regenerative detectors have not been used a lot because the transistors available were not as well suited to the purpose as was desired. The reasons for this may be seen if we examine the functions the single transistor has to perform. These are as follows:—

1. It must detect the signal efficiently which means that a collector current of 100 microAmps or less must be used.
2. It must provide A.F. gain.
3. The R.F. gain must be high.

Thus to obtain reasonable detection efficiency at low levels the collector current must be low. But at 100 microAmps collector current even the best R.F. types of alloy junction transistor have very low cut off frequencies thus either R.F. gain or detection efficiency must be sacrificed. With alloy diffused transistors both R.F. and A.F. gain falls off badly at these very low collector current levels.

With micro alloy transistors, however, both the cut off frequency and the current gain are extremely high still at 100 microAmps and so all three functions listed above are performed very well.

Since MAT's make such excellent regenerative detectors this form of circuit may well be reconsidered by the designers of simple receivers, particularly since many components can be saved in this way.

Most regenerative detectors designed in the past have suffered from poor regeneration control. To achieve the maximum sensitivity the transistor must operate near its point of oscillation and the regeneration control should bring the transistor near to the point of oscillation smoothly. In the past this type of detector has tended to burst into howls before the point of maximum gain was reached. This was due to the fact that de-coupling capacitors were employed for d.c. stabilisation and coupling purposes. This was a mistake because the regenerative detector is a non-linear circuit and the average collector current level changes with the signal strength. The capacitors tended to charge up and alter the biassing conditions in such a way as to push the transistor into oscillation. Usually a form of relaxation oscillation occurred.

These faults have been overcome in the circuit shown in Fig. 7. This uses no decoupling capacitors in the d.c. part of the circuit. The only capacitors used, C_2 and C_3, cannot affect the working conditions of the transistor. R_1 and R_2 put a voltage of 0.22V on the base of the transistor. With an MAT this gives a collector current of about 100 microAmps. Since the input impedance of the transistor is about 10K ohms at this current level the fact that the R_2 is not decoupled will cause no loss of gain whatsoever.

Regeneration is applied by means of L_3 which consists of 3 or 4 turns of wire on the opposite end of the ferrite rod aerial to L_2. L_3 is slid up and down the rod to find the most sensitive point without regeneration occurring on any part of the band. It is then fixed in position and should not need further adjustment. For maximum sensitivity the degree of regeneration is normally altered each time a station is tuned in but with this circuit sufficient sensitivity may be obtained with fixed regeneration.

Either the MAT100 or the MAT101 may be used in this circuit but it is well worthwhile using the latter because of its higher gain.

The circuit may be used equally well with any battery voltage if suitable component changes are made. Component values for several voltages are given in the table below:—

Battery Voltage	R_1	R_2	R_3
1.3V	4.9K	1K	2.2K
3V	12K	1K	5K
4.5V	20K	1K	5K
6V	25K	1K	10K
9V	39K	1K	33K

It is well worthwhile considering the transistor detector, particularly the regenerative type, as a replacement for the germanium diode in T.R.F. and superhet receivers. An MAT regenerative detector in a superhet can save the use of an I.F. or an A.F. stage. The circuit of Fig. 7 could be used with the last I.F. transformer replacing the aerial coil. Feedback would be by means of a trimming capacitor of about 10pf.

Most of the basic applications in which transistors can be used have now been covered. It is hoped that these examples have shown how micro-alloy transistors can be used to advantage in virtually every case and that their employment invariably saves money and components.
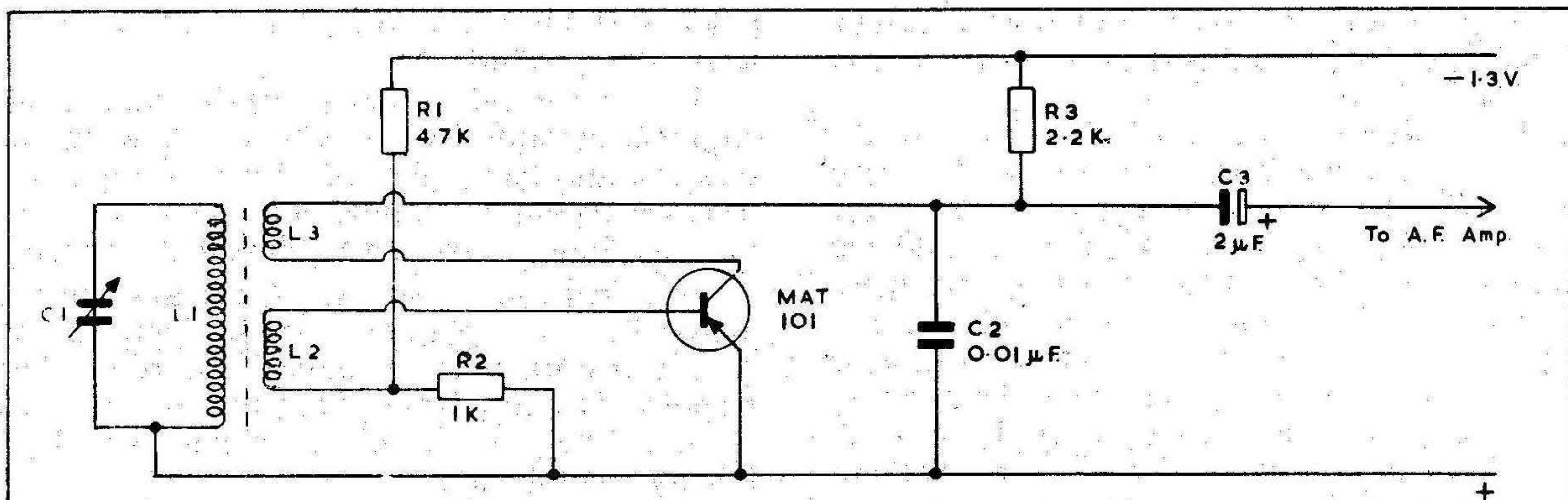
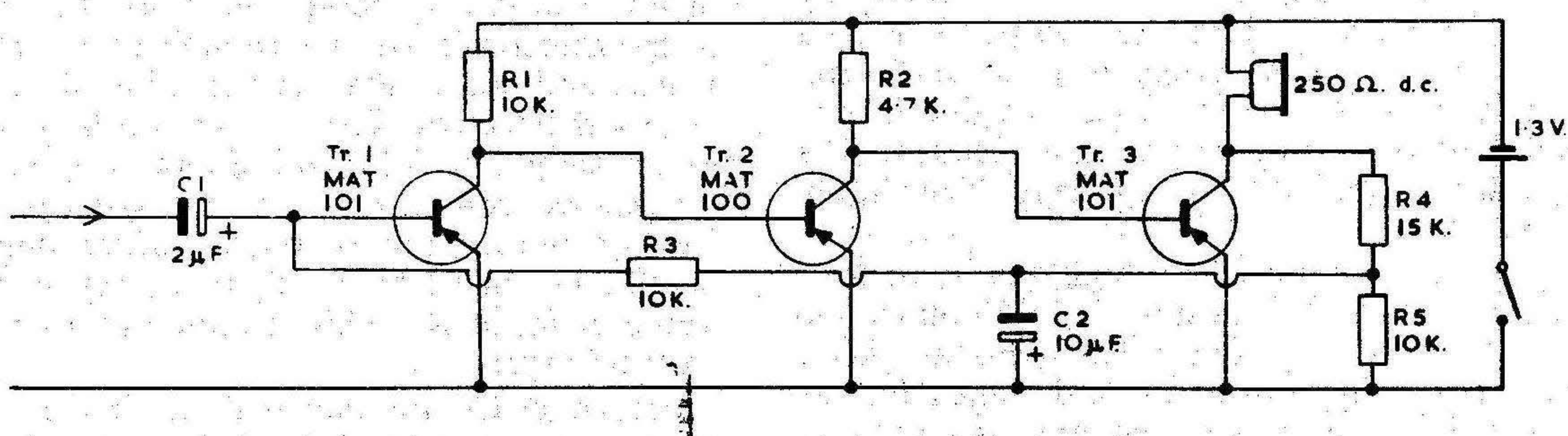Fig. 7. High performance regenerative detector circuit.

Fig. 8. High-stability 1 mW. direct-coupled amplifier.

CHAPTER THREE

Practical MAT Circuits.

No special precautions are required in the use of micro-alloy transistors over and above those of conventional types. They may, in fact, be used directly in any circuit designed for alloy-junction or alloy diffused transistors and will almost invariably give an improvement in performance. However, as we have seen, better results still can often be achieved by designing circuits specifically for micro-alloy transistors. In this chapter 18 new circuits are given all of which were designed around MAT's and which achieve performance levels hitherto impossible without the use of extra transistors.

1mW Direct-Coupled A.F. Amplifier.

In hearing aids and very small radio sets a high gain amplifier is required capable of operating from a low battery voltage. For reasons of economy, size and efficiency, the number of components, the battery voltage and the current drain should all be as low as possible. These requirements are fulfilled admirably in this circuit, Fig. 8. The battery voltage is only 1.3v and the total consumption a mere 2mA. Yet the power gain is at least 90dB (1,000 million times) and the number of components used is very much below average. To achieve a similar gain from conventional transistors at least 4 transistors in an R—C coupled circuit or 3 transistors in a transformer-coupled circuit would be required. In either case the cost and size would be very much greater than those of the circuit of Fig. 8.

Effective direct-coupling of the type shown in Fig. 8 is possible with MAT's because the minimum collector-emitter voltage for high gain is well below the base-emitter voltage. This is not true of ordinary alloy-junction transistors and, whilst these could be used in such a circuit, the current gain of each stage would be very

low and the inter-stage coupling efficiency would be poor because of the low transistor output impedances. Alloy-diffused transistors would not work at all.

The collector currents of Tr_1, Tr_2 and Tr_3 are 0.1, 0.2 and 1.8mA respectively. The very low levels of collector current in Tr_1 and Tr_2 result in very high overall efficiency and yet cause no loss of gain because of the types used. Despite the incredible simplicity of the circuit the working point of each transistor is thoroughly stabilised against wide temperature changes. This is achieved by overall d.c. feedback from the collector of Tr_3 to the base of Tr_1. The degree of feedback is made very high by dividing the voltage on the collector of Tr_3 by R_4 and R_5 thus enabling a low value to be used for R_3. C_2 prevents degeneration at audio frequencies and may be increased in value if very good low frequency response is needed. The value shown should be adequate for most applications however.

The earpiece must be a high quality hearing aid type with a d.c. resistance of 250 ohms and an impedance of about 1.000 ohms at 1kc/s. The low cost type of earpiece designed for use with radio receivers is not suitable as it requires an input power of about 10mW for a reasonable output.

The battery must be a mercury cell because a low internal resistance is required. The Mallory type RM675 is extremely small and ideal for this purpose. The battery life should then be at least 75 hours.

This amplifier is ideal for use in a high gain hearing aid. In this case R_3 should be replaced by a hearing aid magnetic microphone and C_1 should be removed from the circuit. R_1 should be a volume control with a resistance of 10k ohms (a 5K ohms type may be used if necessary) with the wiper taken to ground via a 5 microfarad electrolytic in a similar arrangement to that shown in Fig. 9.

The gain of the amplifier could be increased slightly by the use of an MAT101 for Tr_2 but there is really no point in this change under most circumstances.

Very High Gain 35mW Amplifier.

The principles used in the last circuit may be applied to higher power, higher voltage circuits with equally good results. A typical example is shown in Fig. 9. This amplifier has an output power of 35mW and requires no output transformer. Since the full 35mW is fed into the

70 ohm loudspeaker the actual acoustical output is very high and more than sufficient for a large living room.

The power gain is about 80dB making the amplifier suitable for use with very low output pickups and microphones. When a high impedance crystal or ceramic microphone or pickup is used the polarity of C_1 should be reversed.

The frequency response of the amplifier is extremely good mainly because there is no A.F. transformer to introduce distortion. The response is linear from 50c/s to 30kc/s which suggests the use of this amplifier with high fidelity headphones.

Like the last amplifier described the stability of this unit is very good. The collector currents of the transistors are determined by the resistor values and not by the current gains of the transistors themselves. The voltage on the collector of Tr_3 should be 2.3V with a new battery. Slight deviations from this value will not cause any loss of output power but a larger deviation should be cured by a slight alteration to the value of R_5 or R_6. This is unlikely to be necessary however.

R_4 and C_2 are included in this circuit to prevent positive feedback being caused by the internal resistance of the battery. They were unnecessary in the last circuit because a mercury cell was used but with this amplifier an ordinary zinc-carbon battery is a better choice. C_2 may be omitted, however, if the value of C_3 is increased to 50 microfarads. In this case R_4 may also become unnecessary but it should still be included as it prevents any chance of feedback at the maximum volume setting.

Three Very Low Noise Pre-amplifiers.

Very low noise operation in a transistor amplifier can be achieved by using low levels of collector current and voltage. Unfortunately, this usually results in very low gain and a compromise between gain and noise level has to be made. With the MAT101, however, the high gain characteristics are maintained down to very low levels of collector current and voltage. In the case of the three pre-amplifiers shown in Fig. 10, the collector current is 0.1mA and the collector emitter voltage is only a fraction of a volt. In each case, however, the gain is high.

The three pre-amplifiers should, between them, serve virtually every pre-amplifier requirement. Type (a) has an input impedance of 100 ohms. Type (b) of 5k ohms and Type (c) of
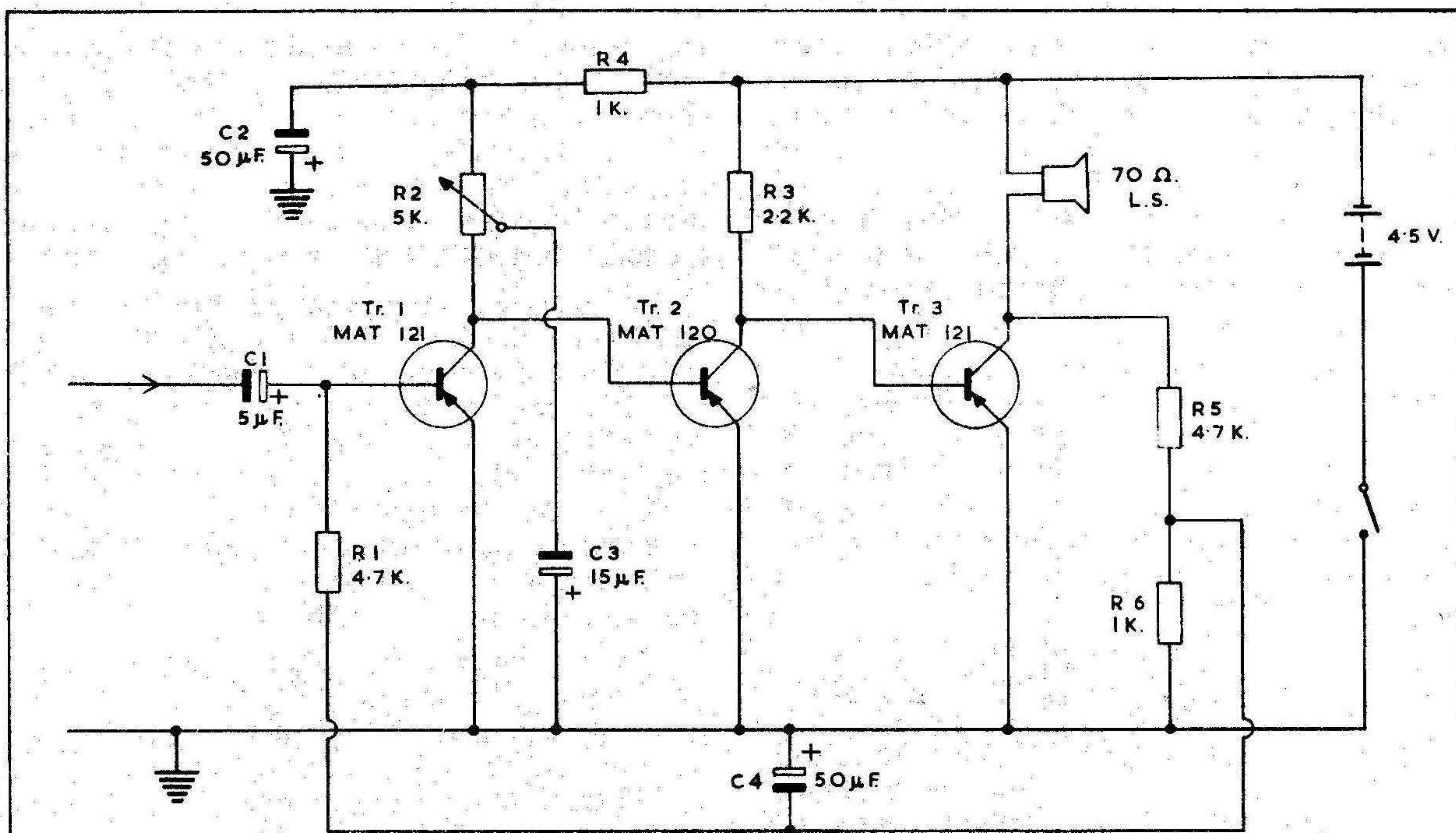
Fig. 9. Very high gain 35 mW. amplifier.

(a) Low Impedance.
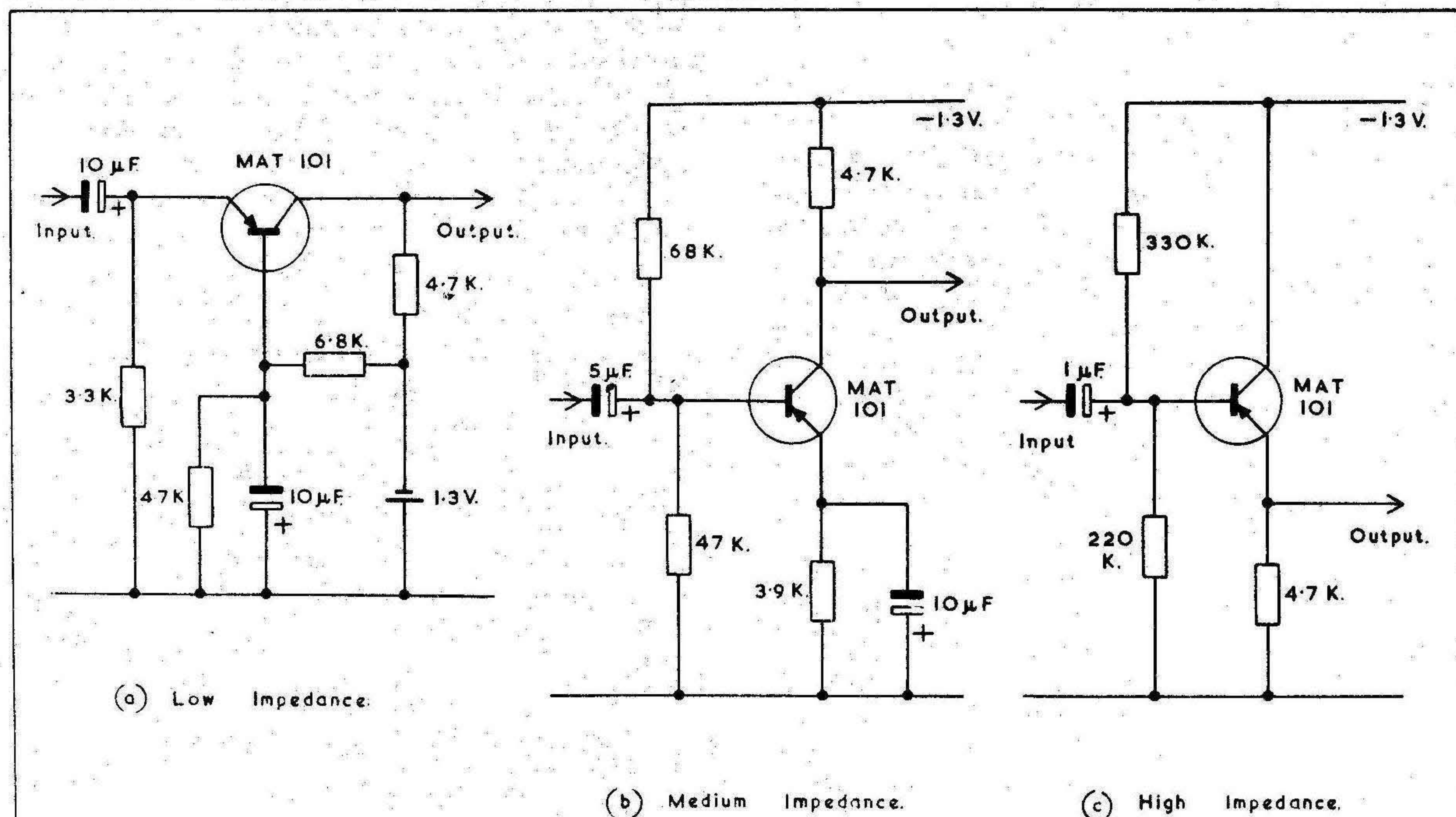
(b) Medium Impedance.

(c) High Impedance.

Fig. 10. Three very low noise preamplifiers.

200k ohms. These different impedance levels are achieved by operating the transistors in the common base, common emitter and common collector modes respectively. Types (a) and (c) have power gains of 17dB and Type (b) has a gain of 30dB. To achieve similar levels of gain and noise with conventional alloy transistors would require at least two transistors in each case.

The output impedance of each pre-amplifier is the same; namely 4.7K ohms. This makes them suitable for feeding directly into either a valve or a transistor power amplifier. Their frequency response will be at least as good as and probably better than the amplifiers they drive. The response in each case is typically 20 to 40,000 c/s ± 1dB.

The most obvious power supply for each unit is a mercury cell but a small zinc-carbon cell could be used with equally good results. The total consumption of type (a) is 0.2mA and Type (b) and (c) consume 0.12mA each. Thus, even with the shirt button size RM312 mercury cell, the battery life will be in excess of 200 hours.

An MAT100 may be used in place of the MAT101 in Types (a) and (c) without significant loss of gain but for Type (b) the MAT101 is preferable.

Single Transistor Phase Shift Oscillator.

In Chapter 2 it was mentioned that an RC oscillator using a single transistor could be made so long as the value of Beta, the common emitter current gain of the transistor, was greater than 60. The MAT101 and MAT121 are unique amongst available types in that they invariably fulfil this requirement. All MAT101's and MAT121's have gains of over 75 and even at 0.1mA collector current Beta will always be greater than 60. Thus phase-shift oscillators can be constructed without any selection of transistors.

The circuit of a 1kc/s phase-shift oscillator is shown in Fig. 11, resistors R_2, R_3 and R_4 and capacitors C_1, C_2 and C_3 form a three section ladder network which produces a phase-shift of 180° at a frequency determined by the formula

$$f = \frac{1}{2 \pi CR \sqrt{6}}.$$

Since the transistor also produces a phase-shift of 180° the circuit oscillates. In practice the frequency of oscillation is slightly higher than indicated by the formula because of the input and output impedances of

the transistor. This has been taken into account in the design of this circuit but since the effect cannot be determined accurately the frequency will not be precisely 1kc/s. However, this will not matter in most applications since it is usually the sine wave output that is required and the exact output frequency is not significant.

The distortion of the output from this oscillator will depend upon the amplitude of the signal so some means of controlling the amplitude is necessary. In this case the amplitude is controlled by varying the degree of negative feedback produced by the unbypassed portion of R_6 in the emitter circuit. If the output is observed on an oscilloscope R_6 may be adjusted until maximum amplitude, within the limits of tolerable distortion is produced.

Other frequencies may be obtained simply by changing the values of C_1, C_2 and C_3. With these all equal to 0.001 microfarads the frequency will be about 10kc/s. Values of 100pf and 0.1mfd will produce frequencies of about 100kc/s and 100c/s respectively.

Two Reflex Receivers.

The design of reflex receivers has already been discussed and it was pointed out that direct coupling of the diode to the transistor results in improved sensitivity because of the automatic control provided by regeneration. The two receivers shown in Figs. 12 and 13 embody this improvement and, despite their simplicity, provide a level of performance which is quite remarkable.

Considering the receiver of Fig. 12 first, this is unusual in that the total consumption is only ½mA and that it is designed for use with a low cost crystal earpiece. Crystal earpieces have impedances of about 50k ohms at 1kc/s and, whilst they are extremely sensitive, this makes them unsuitable for most designs of earpiece receiver. In this case, however, the collector current of the output transistor is only ¼mA which enables an unusually high value of collector resistor to be used. The quality obtained from a crystal earpiece is not as good as that provided by a hearing aid type of magnetic earpiece but in a high voltage circuit of this sort the sensitivity is actually quite a bit higher. The quality may be improved by connecting a capacitor in parallel with the earpiece. The best value must be determined by trial and error but something in the region of 1,000pf should be suitable.
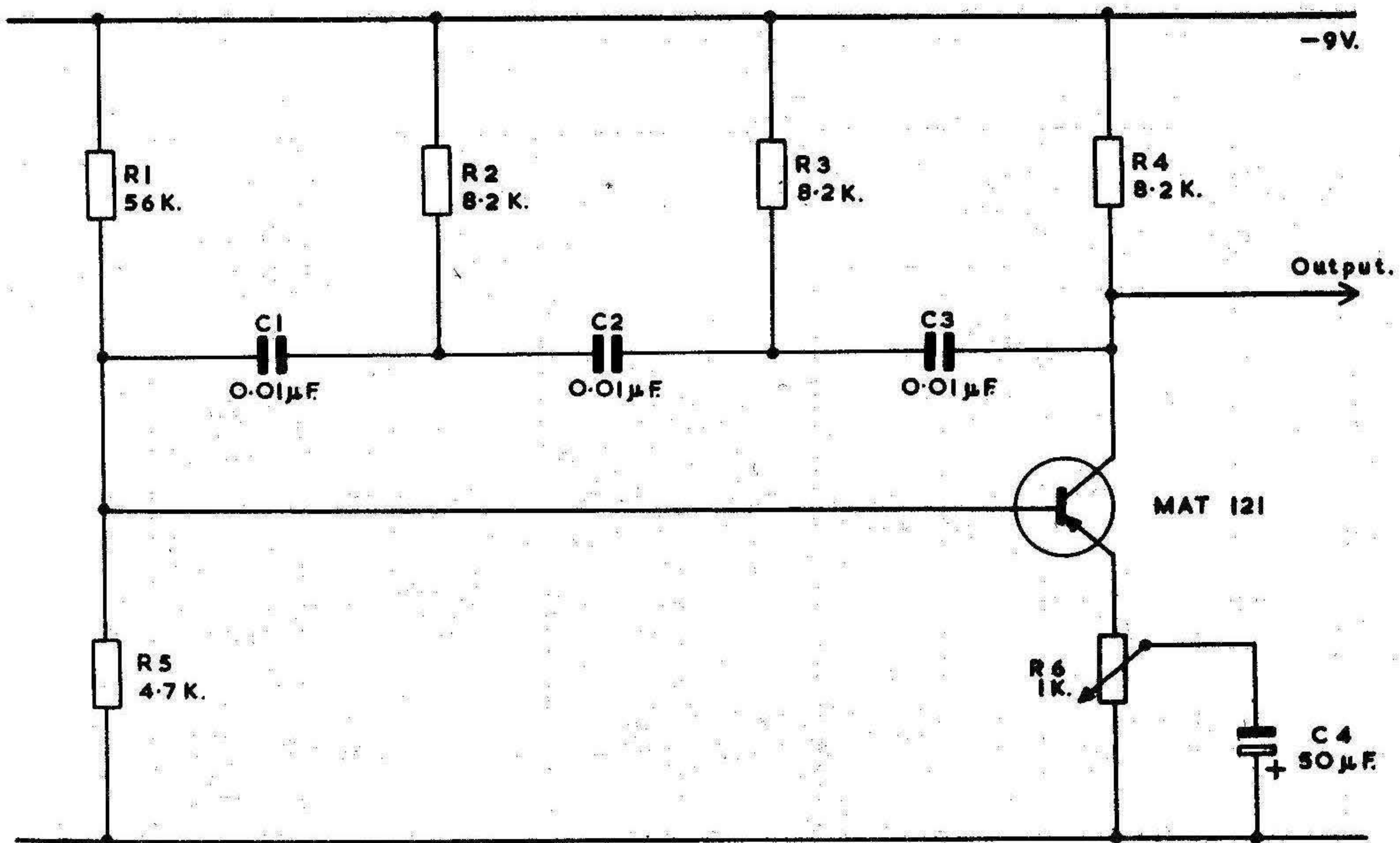
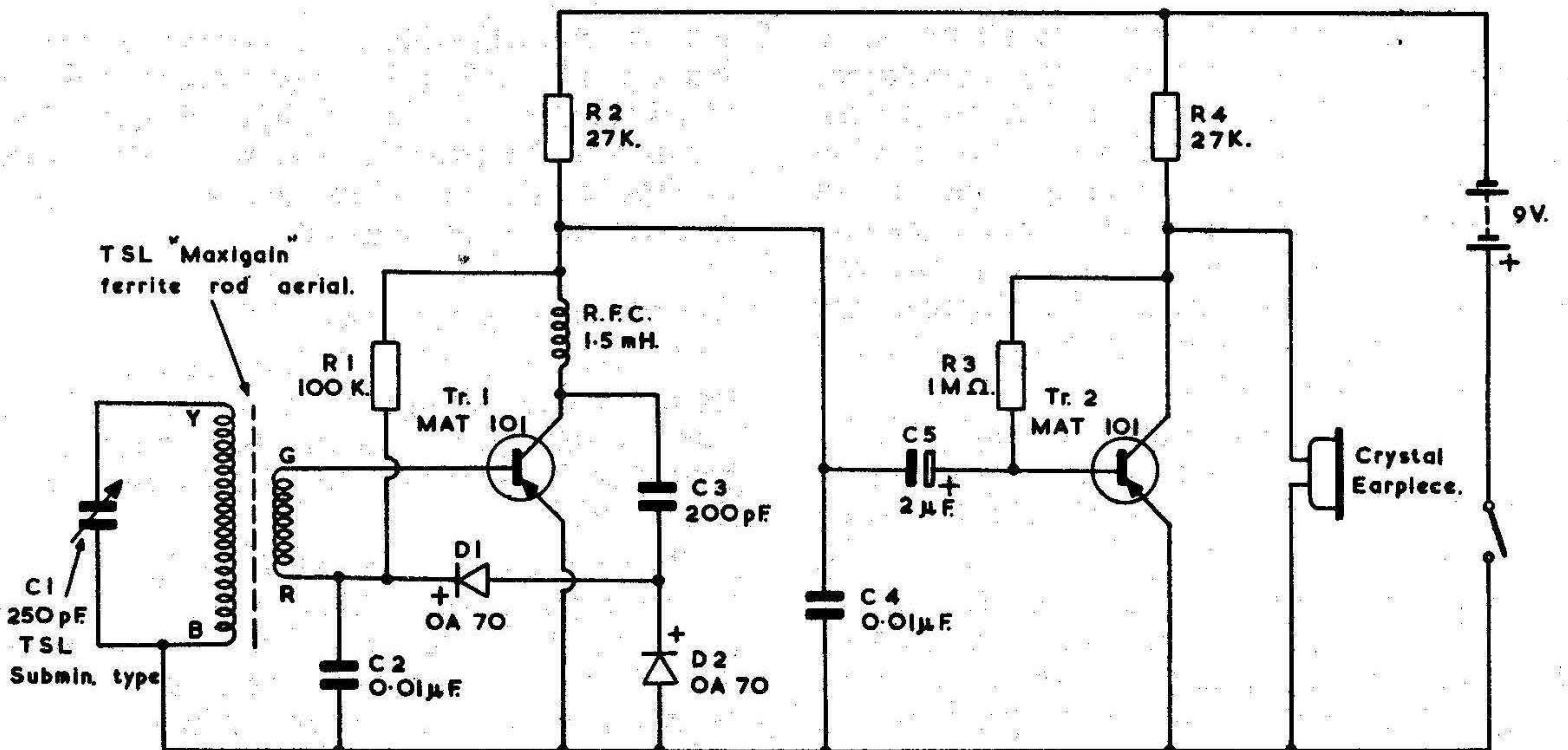Fig. 11. 1 Kc/s. phase—shift oscillator.
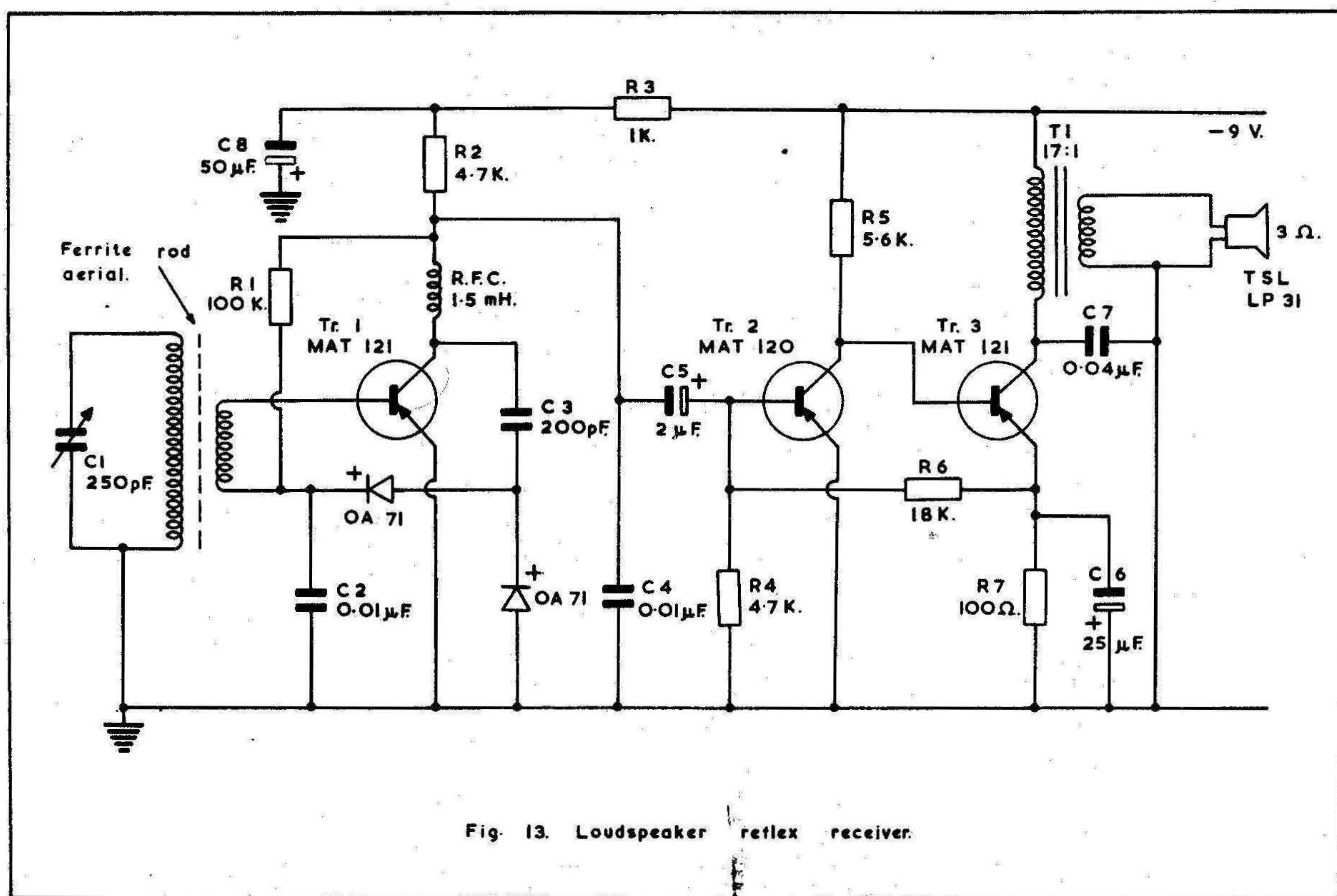

Fig. 12. Sensitive low cost reflex receiver.

Fig. 13. Loudspeaker reflex receiver.

No means of providing regeneration is shown in the diagram but this may be obtained by positioning the R.F. choke near the ferrite rod aerial and rotating it for maximum sensitivity. Alternatively a trimming capacitor of about 30pf may be connected between the collector of Tr_1 and point Y on the ferrite rod aerial. If regeneration cannot be obtained the connections to the secondary of the aerial coil should be changed over.

The value of R_1 may require alteration under some circumstances. The collector current of Tr_1 should be 0.25mA and R_1 should be chosen to provide this.

The battery used will depend on the size of the set. For very small sets an Everready PP5 will be the best choice and will give a very long life because of the minute consumption of the receiver.

The receiver shown in Fig. 13 uses the same principles as the last set but it is designed for loudspeaker operation. Higher collector currents are used and the total consumption is increased to about 6mA. Any loudspeaker with

a voice coil impedance of 3 ohms may be used but the TSL LP31 is a good choice for a very small set. Any medium or long wave ferrite rod aerial will be suitable and the same methods of regeneration as were suggested for the last receiver are recommended.

Regenerative Receivers.

Figs 14 and 15 show two regenerative detector receivers designed for the broadcast band. The design principles involved have already been discussed so only the details need be considered here.

The receiver of Fig. 14 is designed for earpiece operation and a high impedance magnetic type must be chosen; the higher the impedance the better. L_3 consists of 1 or 2 turns of enamelled copper wire wound on a paper former and able to slide up and down the ferrite rod on which the aerial is wound. The aerial may be any commercial type.

Fig. 15 is designed to obtain high performance from a single Mallory mercury cell such as the RM675. A three stage directly coupled
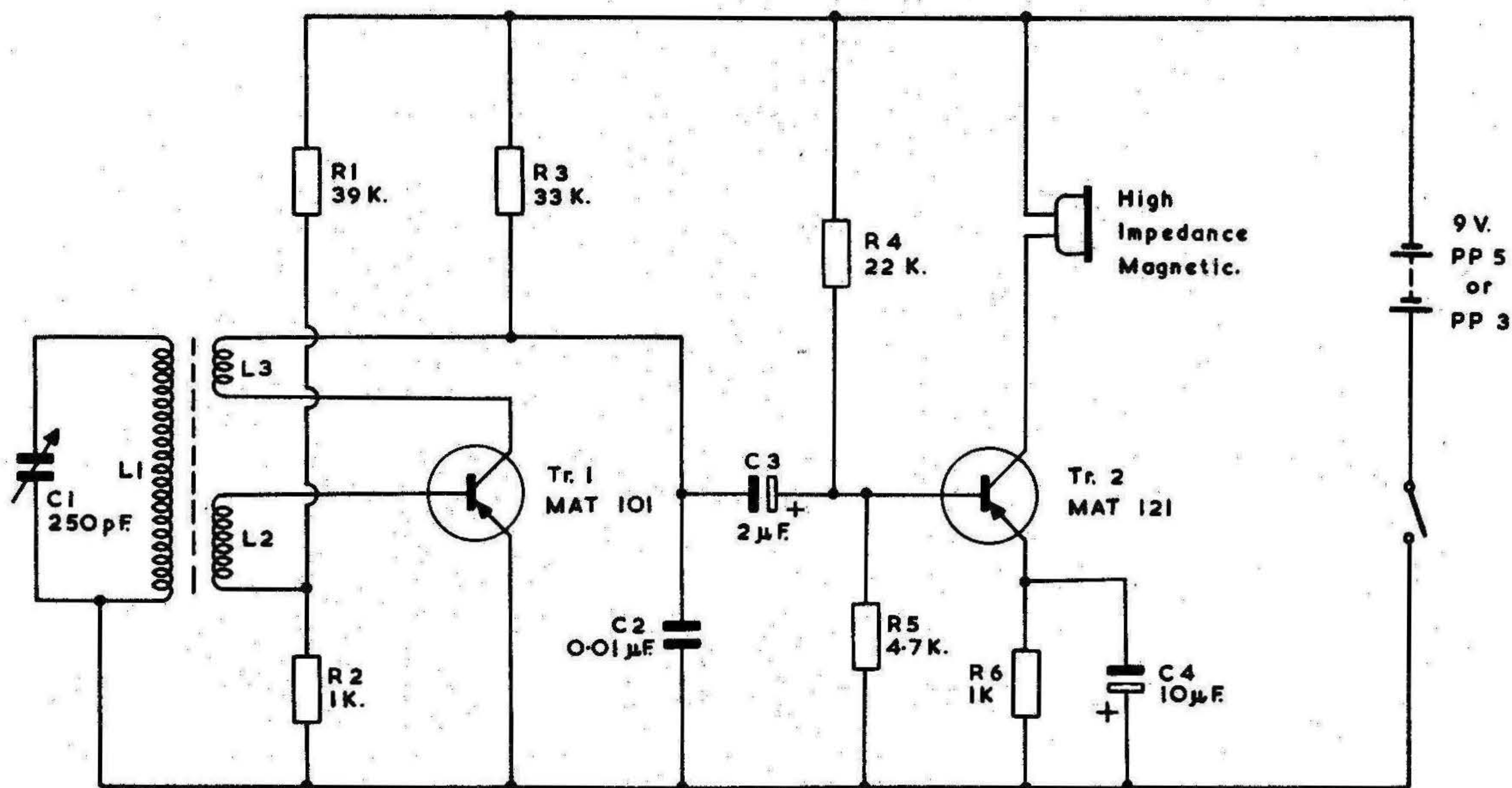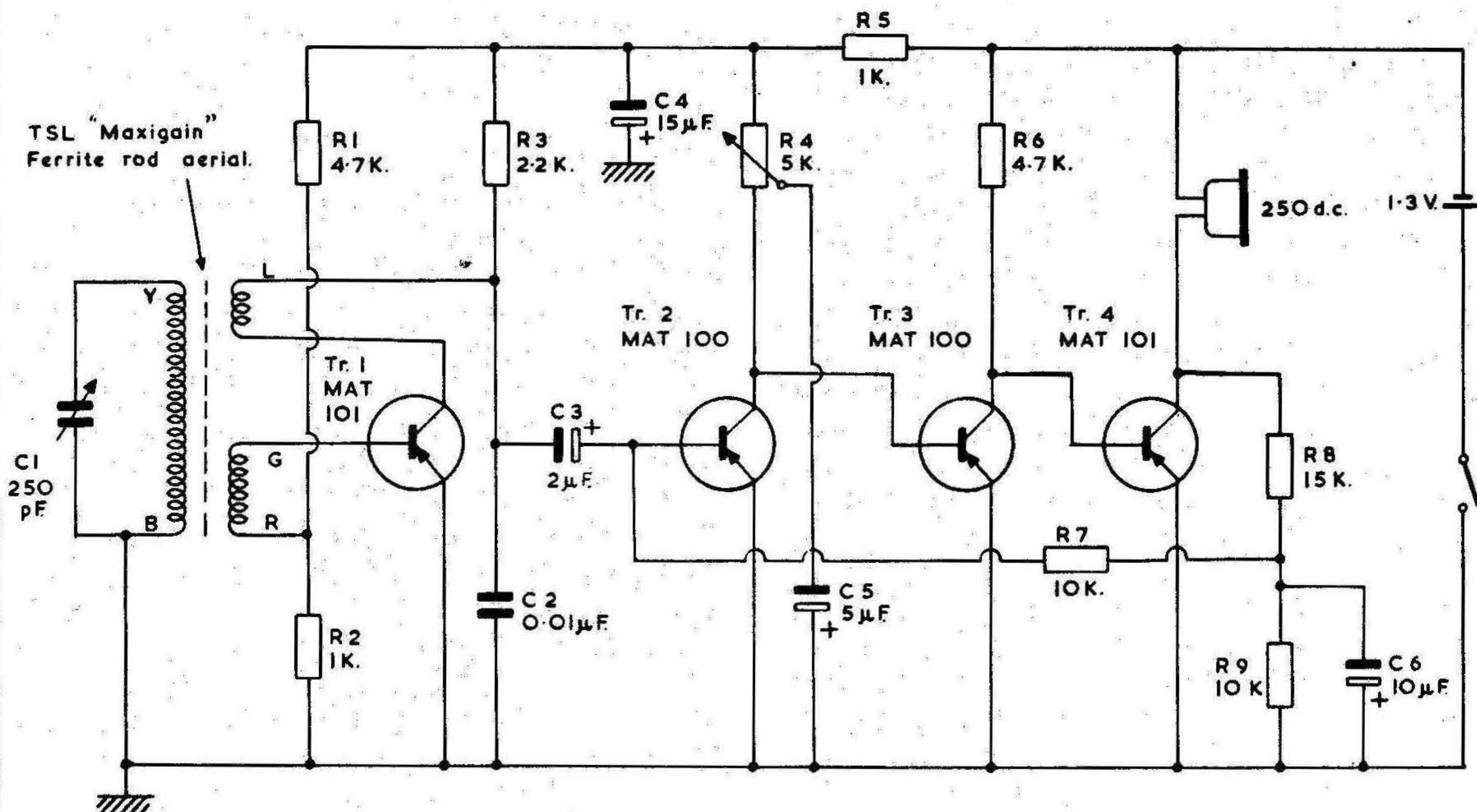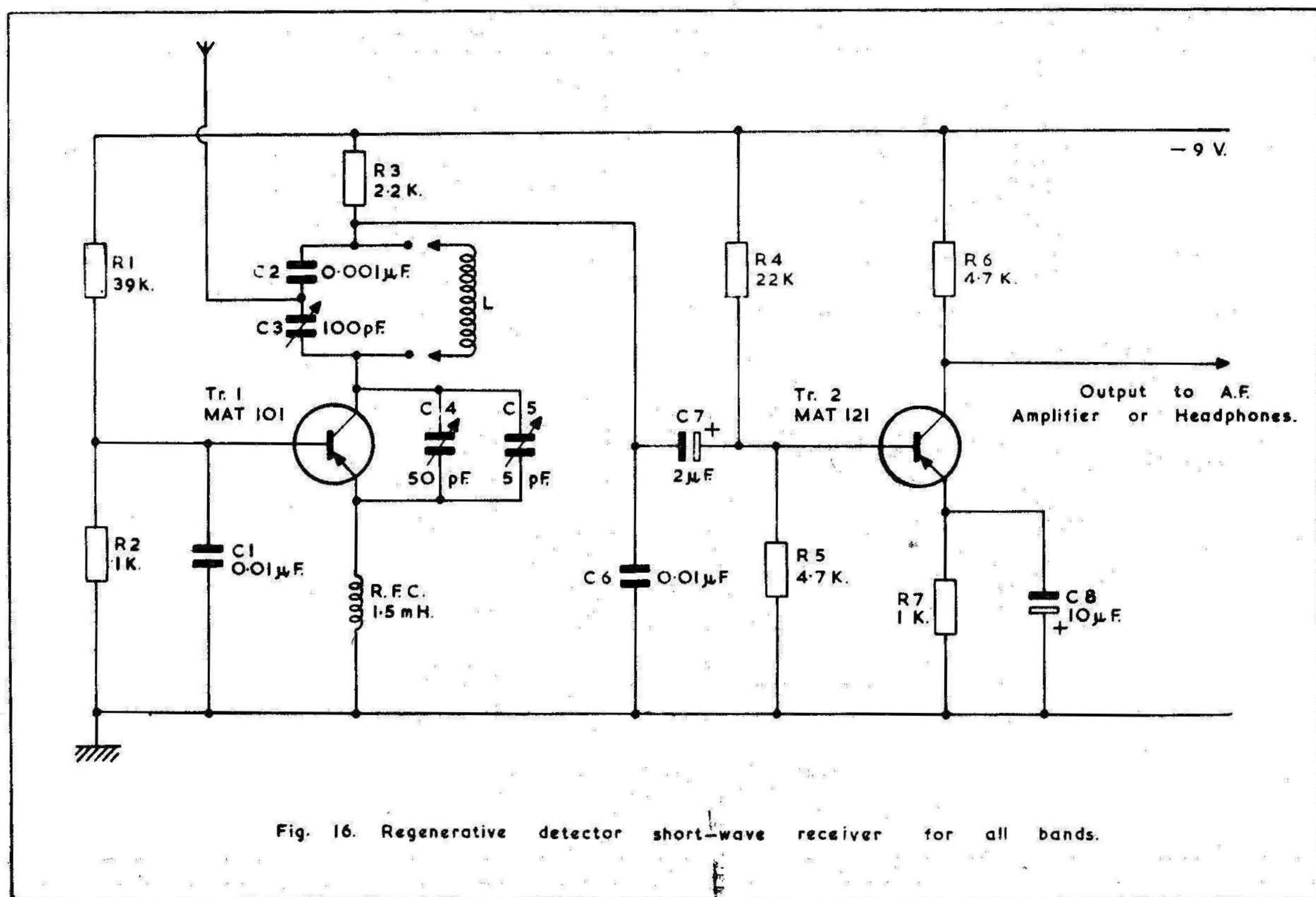
Fig. 14. Two Transistor regenerative receiver.

Fig. 15. High performance, very low voltage, regenerative receiver.

Fig. 16. Regenerative detector short—wave receiver for all bands.

amplifier follows the detector and gives enough gain for reception of even very weak signals. The regeneration loop L is the same as in Fig. 14 and should slide up and down the rod beyond the Y end of the aerial winding. Once the best position has been found it may be sealed.

Regenerative detectors are excellent for use in multi-waveband short wave receivers. To simplify coil changing, however, it is desirable that the coil should consist of only a single winding without any taps. This is possible if the common base mode of operation is chosen and this has the additional advantage of extending the maximum frequency of operation to beyond 100Mc/s. Thus, simply by plugging indifferent coils, any frequency from 100kc/s to 100Mc/s may be tuned. The coils used may be any proprietary types or may be home wound. Regeneration is controlled by C_4 and C_5 and the latter being used for the final precise adjustment. At very high frequencies, beyond about 30Mc/s, only C_5 will be required.

The output from Tr_2 will not be very large and an amplifier must be used for loudspeaker operation. A high impedance pair of headphones may be connected in place of R_6 and

the volume should be sufficient for all but the weakest signals.

Shortwave Transmitter.

Simple shortwave band transmitters using transistors often employ modulation of the oscillator to reduce the number of components required. Audio modulation is achieved by this means but frequency modulation also occurs so that the signal received is distorted. For high quality transmission an R.F. amplifier should be used after the oscillator and the modulation should be applied after this.

A circuit of this type is shown in Fig. 17. Tr_2 is the oscillator which drives a class B output stage using Tr_3. Tr_1 is an A.F. amplifier which applies modulation to the base of Tr_3.

L_1 and L_2 are identical coils with turns ratios of about 6 : 1 selected for the band required. C_4 and C_5 may be 100pf trimmers or they may be fixed if the coils are slug tuned. For top band operation L_1 and L_2 may be transistor I.F. transformers with their fixed capacitors removed. Slug tuning can then be used and C_4 and C_5 may be 100pf fixed.

See text for values of C4 and C5.

Fig. 17. Short—wave Transmitter.

Fig. 18. Synchronous detector F.M. tuner.
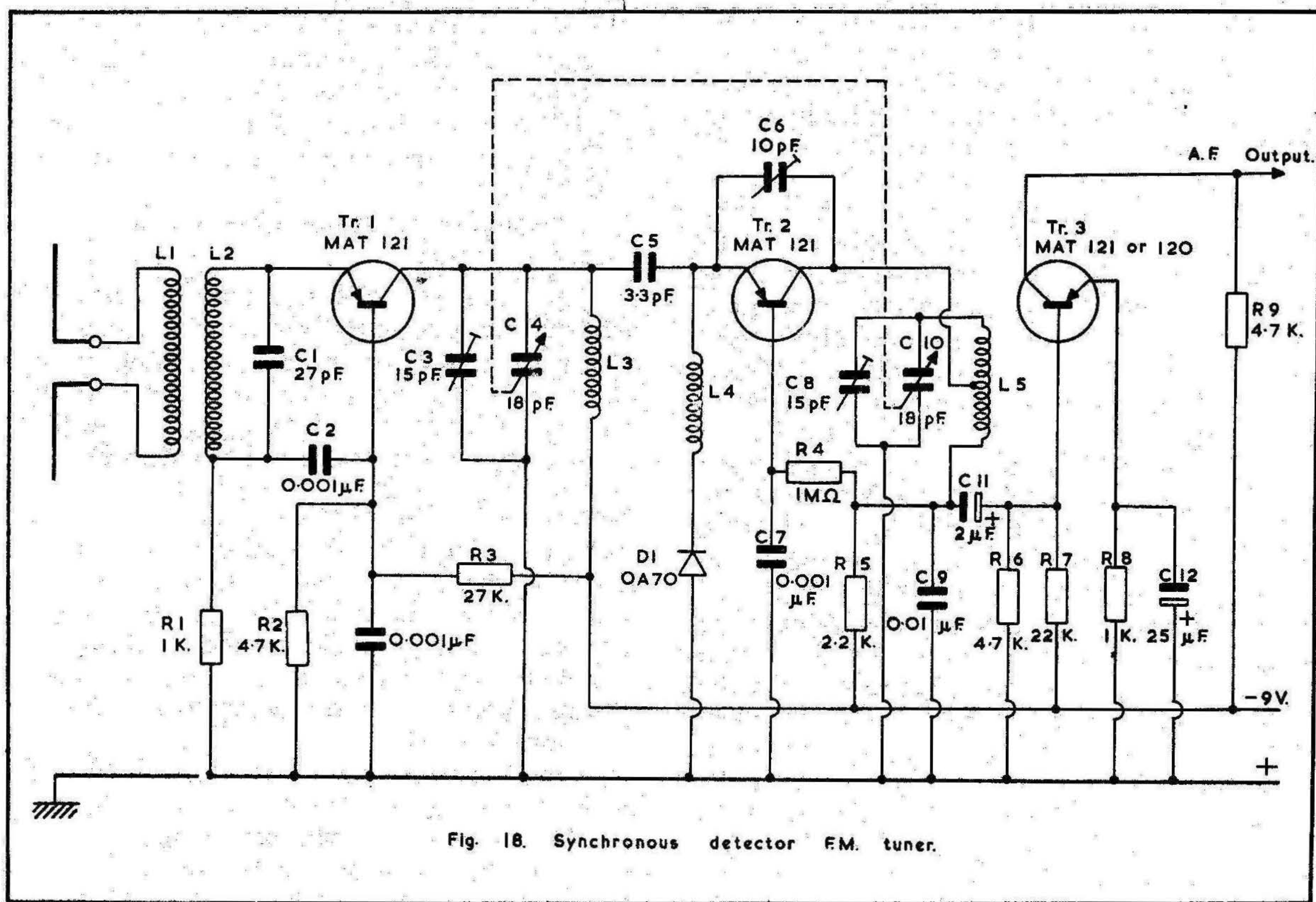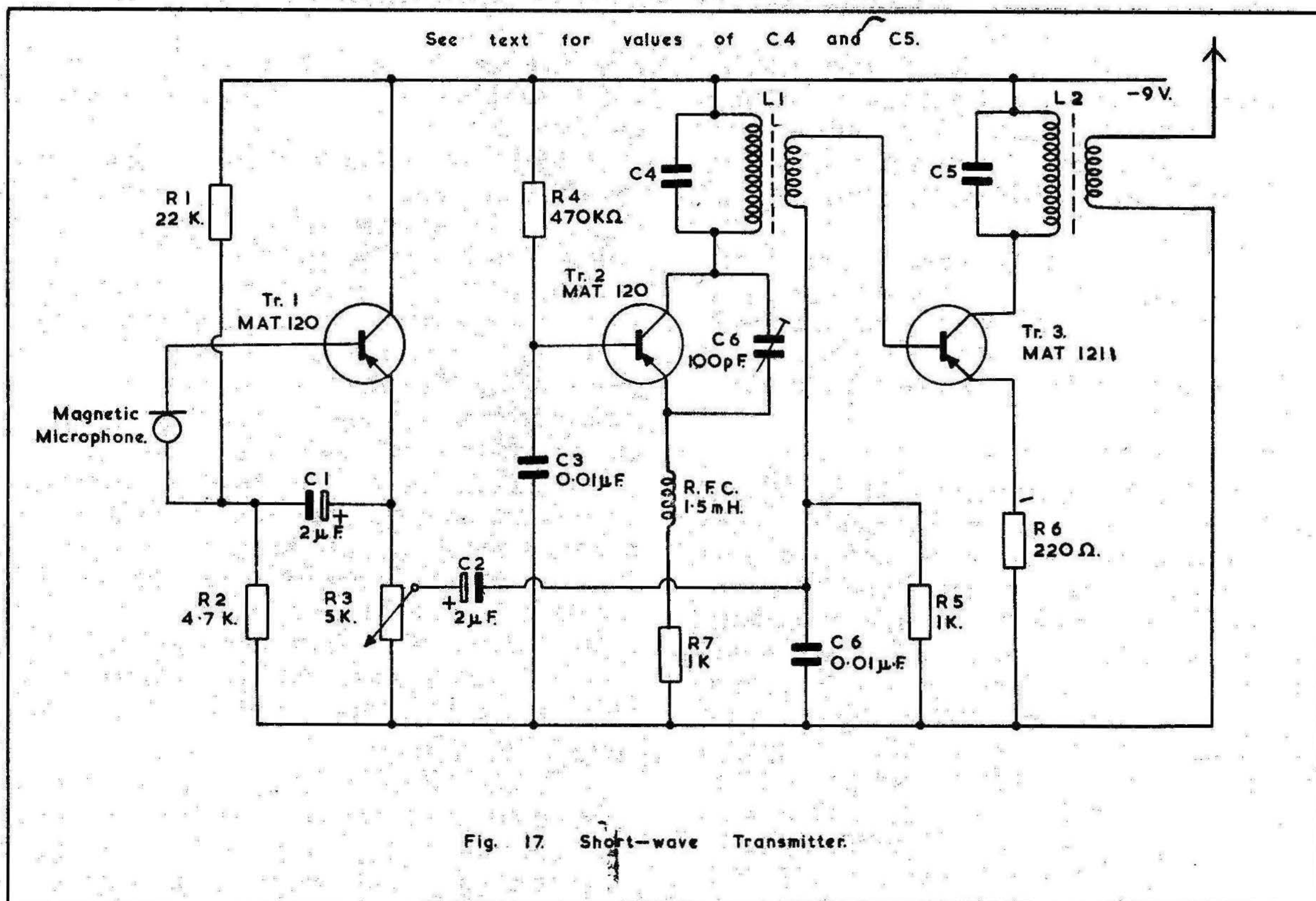
C_6 controls the amplitude of oscillation in Tr_2. It should be adjusted to the minimum position consistent with reasonable output. R_3 controls the modulation and should be adjusted to provide maximum modulation short of distortion.

The microphone should have an impedance of between 500 ohms and 5k ohms. The very small types designed for hearing aids are ideal. In some cases the addition of a 1,000pF. capacitor from the emitter of Tr_2 to ground may improve performance.

Synchronous Detector F.M. Tuner.

Conventional transistorised F.M. tuners employ 5 V.H.F. transistors, two matched diodes and 20 or more coil windings as well as a large number of resistors and capacitors. They are also rather difficult to align. In order to achieve simplicity superregenerative circuits are sometimes used and several designs have been published. These, however, suffer from several faults: they are difficult to adjust properly, are extremely susceptible to hand capacitance effects and they radiate strongly over a wide band causing interference. The first fault, difficulty of adjustment, arises because self-quenching circuits are normally used and the performance of these is hard to predict. Separately quenched circuits use more components but are considerably better in this respect. Nevertheless all superregeneratives designed to date have been rather unsatisfactory.

This circuit, Fig. 18, has been designed to overcome these difficulties. Although it uses only two transistors (Tr_3 is simply an A.F. amplifier) and relatively few associated components it achieves high sensitivity with good quality, does not radiate interference and is very much less prone to hand capacitance effects. Tr_1 is a broadband R.F. amplifier primarily intended to isolate the detector circuit from the aerial. It is operated in the common base mode and provides about 10dB of gain. Tr_2 forms the main part of the tuner. This transistor oscillates, again in the common base mode, at the signal frequency. C_6 is adjusted so that the amplitude of oscillations is well below the maximum of which the oscillator is capable. As the signal frequency deviates abouts its centre position the oscillator follows it as it tends to lock in on it. As the degree of deviation increases, however, the oscillator amplitude is reduced because the impedance of the tuned circuit formed by L_5 and C_{10} is reduced. Thus the amplitude of oscillation is proportional to the modulation amplitude. Now there is a diode in the emitter of Tr_2,

this rectifies the oscillation and produces an A.F. output which finally appears across R_5 and is amplified by Tr_3.

Adjustment of the synchronous detector, as the oscillator circuit is known, is very simple. C_6 is varied for maximum sensitivity on a strong signal. Too high a setting for C_6 will result in clipping of large signals and too low a setting will reduce the sensitivity. The value of C_7, shown in the diagram as 1,000pf, may affect the performance. In some cases a larger value will give greater output and values up to as high as 10 microfarads may be tried.

C_3 and C_8 are used to align the two tuned circuits and to adjust the tuning range so that it covers the whole of the F.M. band. C_4 and C_{10} are the two halves of a twin-ganged 18pf tuning capacitor. The value is not critical and anything from 10 to 20pf may be used instead.

All the coils are wound on $\frac{1}{4}''$ formers but only L_1 and L_2 should have a dust iron slug.

Aerial Transformer:

    Primary (L_1)—5 turns of 32 gauge enamelled copper wire wound between secondary.

    Secondary (L_2)—4 turns of 20 gauge enamelled copper wire wound with 2mm. spacing between turns.

    R.F. Collector Coil (L_3)—3 turns of 20 gauge enamelled copper wire wound with 1mm. space between turns.

    Oscillator Emitter Coil (L_4)—40 turns of 32 gauge enamelled copper wire close wound.

    Oscillator Collector Coil (L_5)—As L_3 but centre tapped.

The slug in coils L_1 and L_2 should be adjusted for best sensitivity over the band.

The output from Tr_3 may be used to drive either a valve or a transistorised amplifier. Alternatively a pair of high impedance headphones may be connected in place of R_9.

F.M./V.H.F. Transmitter.

For high quality transmission over a short distance the V.H.F. band is ideal. With the simple transmitter shown in Fig. 19 a range of 100 yards can be achieved and the quality is excellent. Direct modulation of the oscillator is possible because it is frequency modulation that is required.

Tr_1 is operated as an oscillator in the common base mode with feedback being applied via C_7. Tr_1 also acts as a common emitter A.F. amplifier to the microphone output. Tr_2 operates as an untuned common base R.F. amplifier and

Fig. 19. FM. / V.H.F. Transmitter.

Fig. 20. Sub—miniature Radio—control receiver with 1/2 mile range.
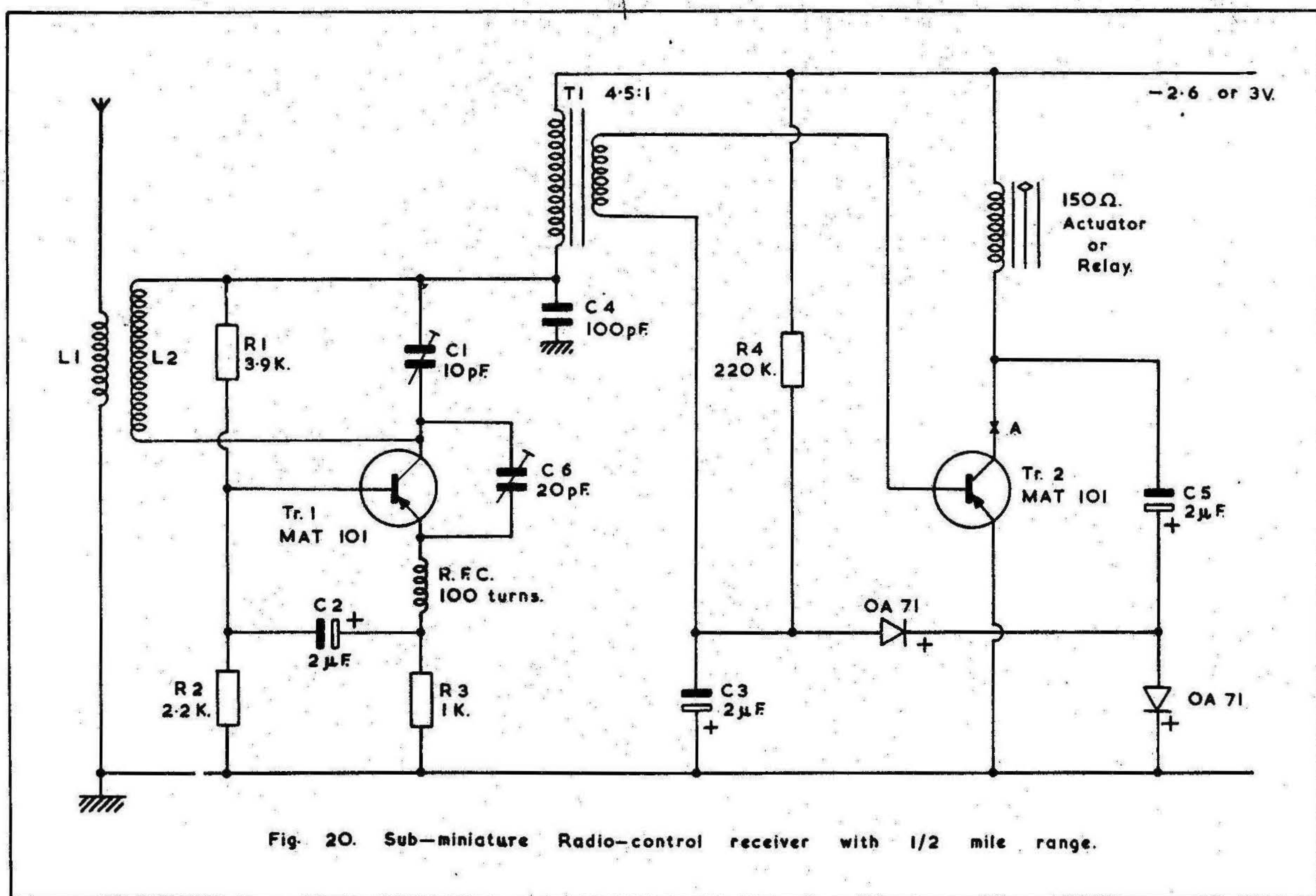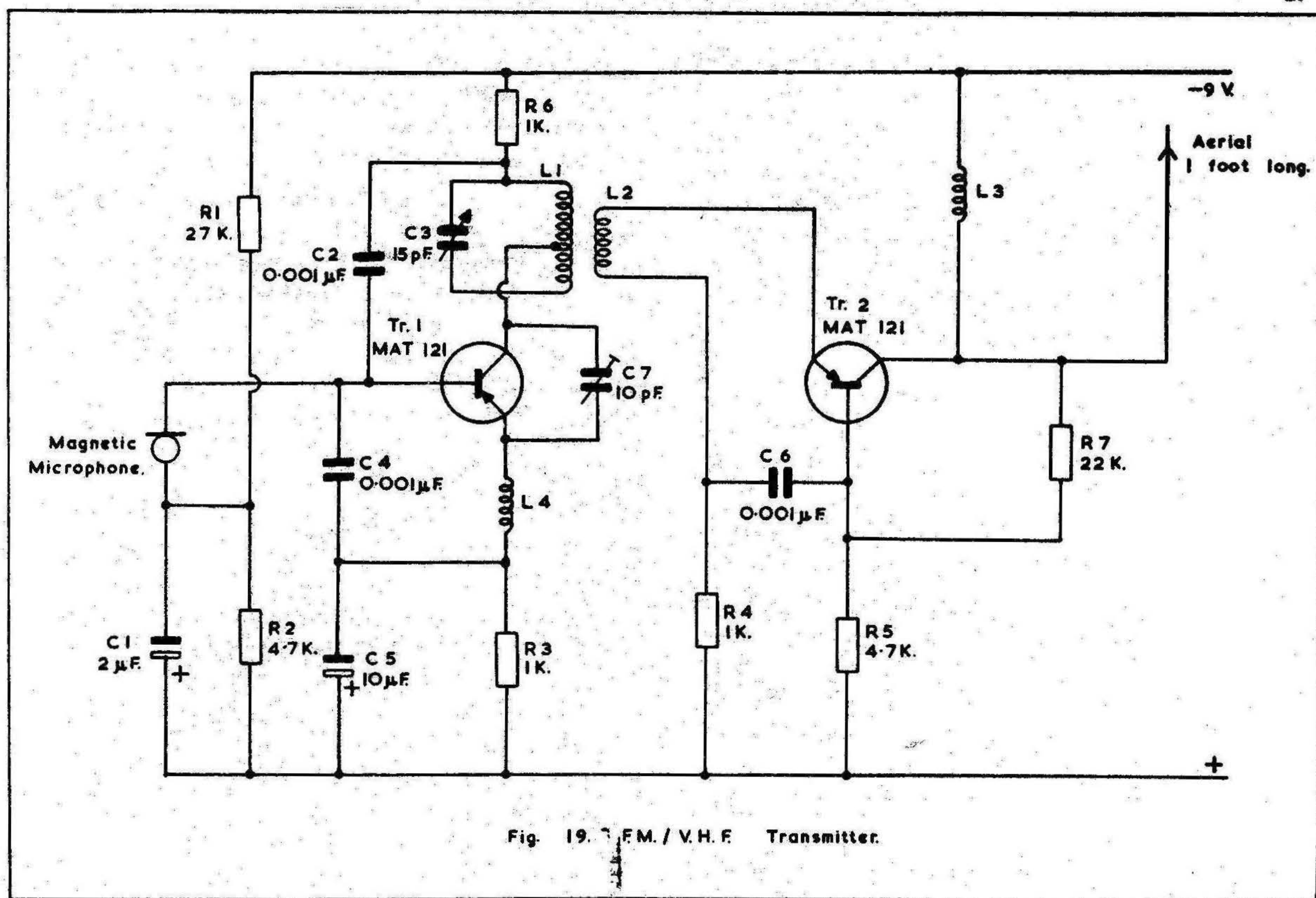
serves to isolate the oscillator from the aerial and thus avoid hand capacity effects.

All the coils are wound on $\frac{1}{4}''$ formers as in the last circuit. Once the coils have been wound the former may be removed as the coils will have sufficient rigidity to support themselves.

Oscillator Coils:

Primary (L_1)—5 turns of 24 gauge enamelled copper wire spaced 1mm. apart and centre tapped.

Secondary (L_2)—2 turns of 24 gauge enamelled copper wire close wound.

R.F. Choke (L_4)—30 turns of 32 gauge enamelled copper wire close wound.

Aerial Coil (L_3)—10 turns of 24 gauge enamelled copper wire close wound.

The adjustment of C_7 is not critical and in most cases it can be replaced by a 5pf fixed capacitor.

The aerial may be a 1' length rod or, if only a very short range is required, the radiation from L_3 will be sufficient. In the latter case, spacing the turns of L_3 may improve the range.

Sub-miniature Radio Control Receiver with $\frac{1}{2}$-mile range.

For radio control use the micro-alloy transistor is far and away the best type ever put on the market. In receivers its ability to provide a very high gain at 27Mc/s with low levels of collector current and voltage is unique and enables a considerable reduction to be made in the size and weight of a receiver. In transmitters the maximum current rating of 50mA, five times that of alloy diffused types, increases the maximum possible output power, and hence the range, very considerably.

Fig. 20 shows the circuit diagram of a surprisingly simple receiver which has a quiescent consumption of only about $1\frac{1}{2}$mA from a 2.6 or 3 volt battery.

The design is based on an original one by Capt. Plessier of France published in "Transistor Circuits for Radio Controlled Models" by Howard Boys. The original receiver used an A01 surface barrier transistor for Tr_1 and a 2N217 for Tr_2. The transistors had to be selected for high gain and the range was rather limited. Substituting MAT101's for Tr_1 and Tr_2 removes the need for selection, reduces the number of components required and extends the range considerably. Furthermore, in this circuit, the battery voltage and the total current

consumption have both been halved. The original circuit was remarkable for the performance it gave with so few components but the new one is even more amazing.

The receiver is designed for use with modulated signal in the 27Mc/s band. Tr_1 is a super-regenerative detector and provides an output at the modulation frequency which is fed to Tr_2 via a 4.5 : 1 step down transformer. Tr_2 amplifies the modulation frequency which is then fed to the diodes for rectification. The d.c. component of the output from the diodes is used to forward bias Tr_2 and thus increase the collector current considerably. Since the collector current flows through the actuator it is operated whenever a modulated signal of sufficient amplitude is received.

The current in the output stage rises from about 1mA to 15mA on reception of a signal and this is sufficient to operate an actuator directly making a relay unnecessary.

When the receiver has been built a pair of headphones should be connected into the circuit at point A and C_6 adjusted until a rushing noise is heard. C_6 may be replaced by a fixed capacitor, a suitable value being found by trial and error.

L_2 should consist of 15 turns of enamelled 24 gauge copper wire on a $\frac{1}{4}''$ former. L_1 should be 5 turns of the same wire wound beside L_2. Both coils should be close wound.

Superhet Receivers using MAT's.

Most commercial superhet receivers, as well as the majority of kits, use two I.F. stages after the frequency changer. With the advent of the alloy diffused transistor it became possible to eliminate one of the I.F. stages and yet still obtain the usual degree of sensitivity. The same applies with micro-alloy transistors with the added advantage that collector currents and voltages can be reduced considerably without loss of gain should this be necessary.

Fig 21 shows the circuit diagram of a fairly conventional 3-transistor superhet designed to feed a high impedance magnetic earpiece. Using an Everready PP5 for the battery this set can be built into a case little larger than a matchbox because the tuning capacitor specified is only $\frac{5}{8}''$ square and the aerial is only $1\frac{1}{2}''$ long.

Tr_1 is the autodyne converter, Tr_2 the I.F. amplifier and Tr_3 the A.F. amplifier. A.G.C. is taken from the detector to the base of Tr_2 and
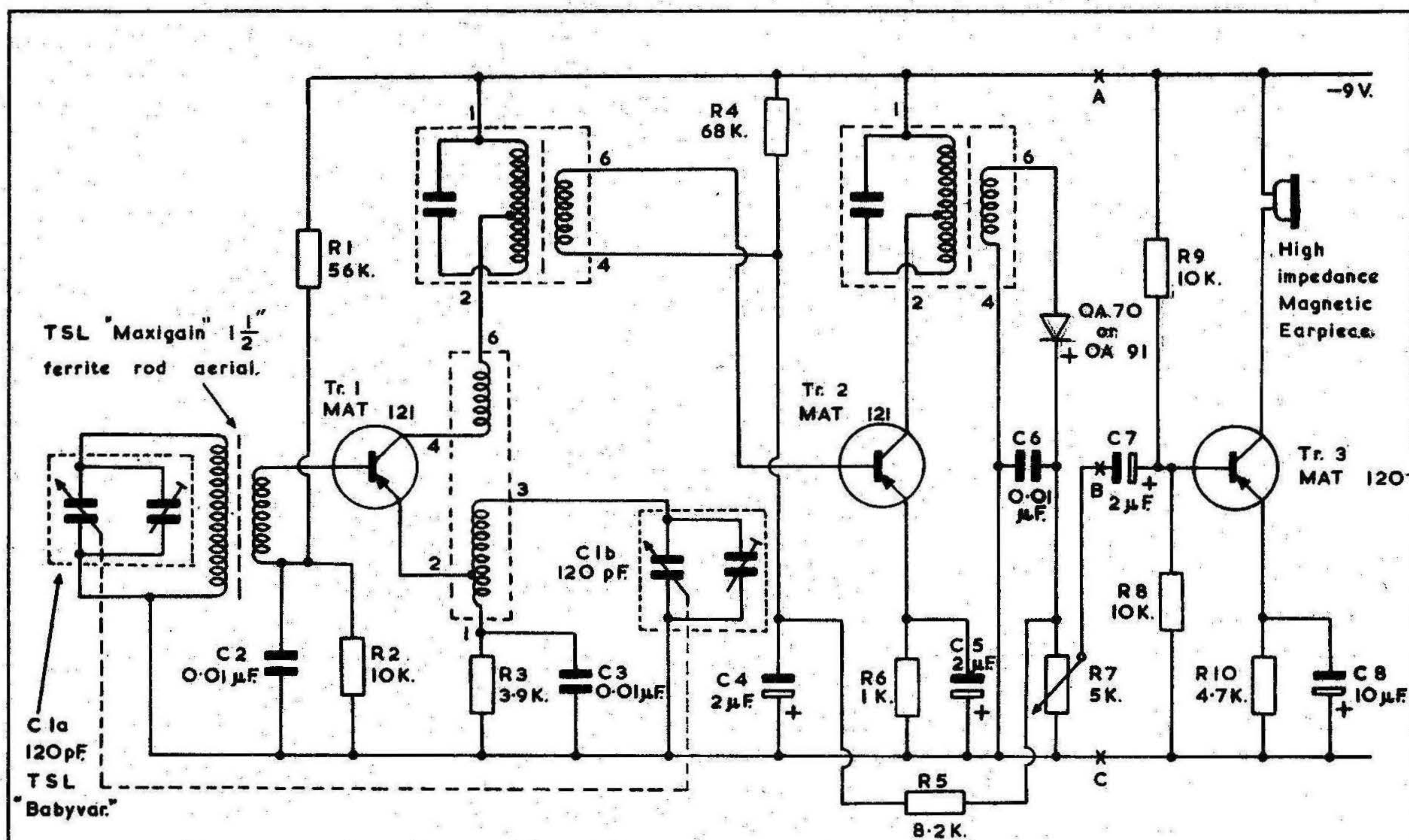
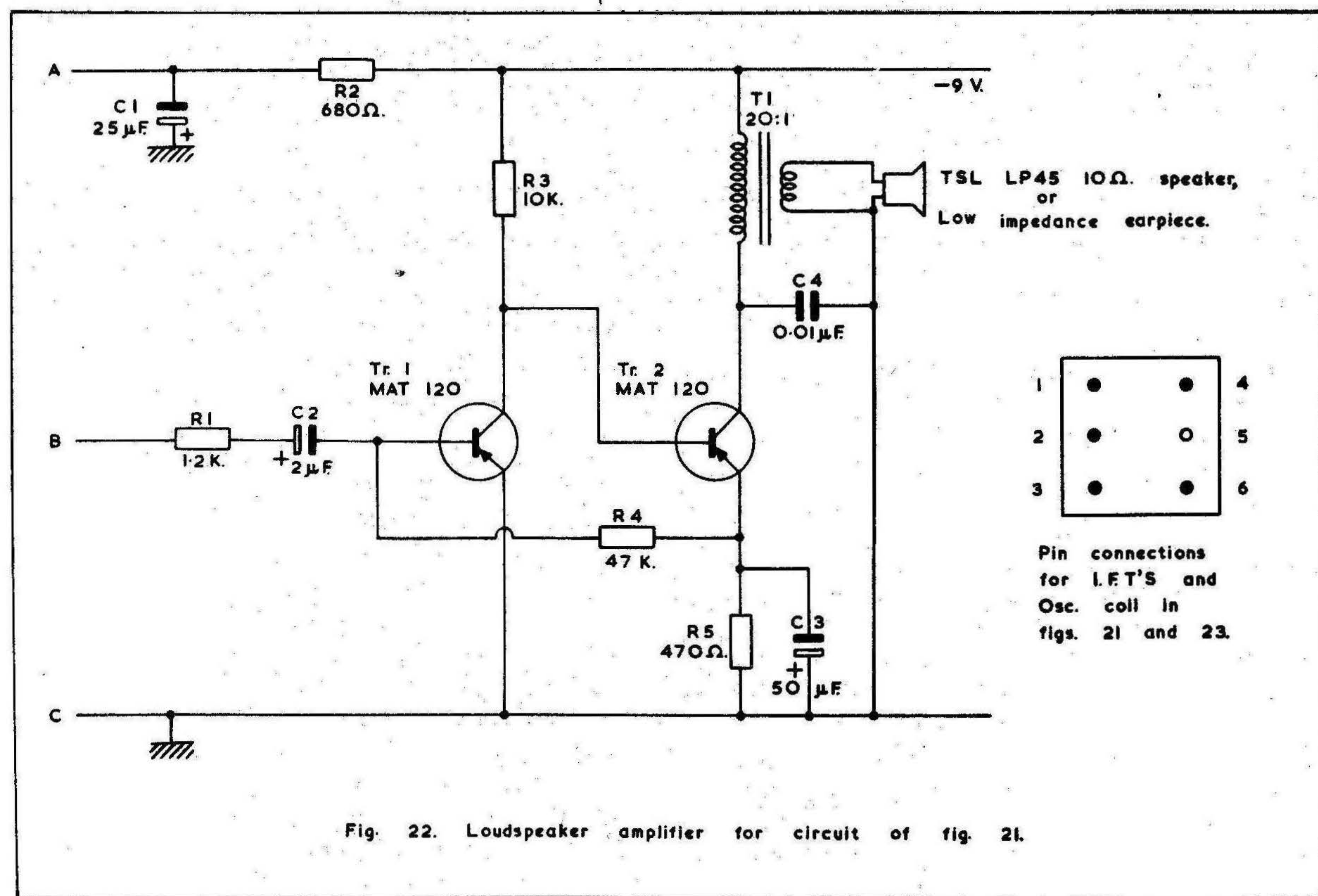Fig. 21. High sensitivity 3—Transistor pocket superhet.

Fig. 22. Loudspeaker amplifier for circuit of fig. 21.

Fig. 23. Subminiature 3—transistor superhet with speaker.

a volume control is incorporated. The total consumption is about 3mA. Alignment follows the normal procedure and the trimmers shown connected in parallel with the tuning capacitor are incorporated in the TSL—"Babyvar".

Tr_3 may be replaced by the two stage amplifier shown in Fig. 22. Connections are made at points A, B and C. With this amplifier, either an LP45F—TSL 1¾" loudspeaker—or a low impedance magnetic earpiece may be used.

Combining the circuits of Figs. 21 and 22 results in a four transistor loudspeaker superhet but similar results can be achieved with only 3 transistors if the I.F. stage is reflexed to double as an A.F. amplifier. Such a circuit is shown in Fig. 23. The sensitivity of this receiver is much the same as that of a conventional 6-transistor superhet and despite the fact that the output power is low the volume is good because of the high sensitivity of the loudspeaker specified.

TECHNICAL SUPPLIERS LIMITED now have available a vast range of components for the home constructor. For the last ten years this Company has specialised in supplying sub-miniature parts for all circuits shown in Bernards comprehensive range of practical radio and electronic handbooks.

TECHNICAL SUPPLIERS can also supply parts for all circuits and designs shown in practically every radio magazine published in this country. Listed herewith are brief details of some of the most popular items available. It is only possible to show very brief details of the enormous range of components, and our very comprehensive range of prefabricated units for the home constructor and radio experimenter. We have available many leaflets complete with circuit data, etc., which we can supply on demand, which give full technical details, layouts, etc., of our complete range. A nominal charge of 1s. 3d. is made for this range of data sheets, and upon receipt of Postal Order for this amount we will supply by return, post paid.

TSL - LORENZ SUBMINIATURE LOUDSPEAKERS

CIRCULAR MODELS

The application of transistors to small radio receiver design brings with it the need for other equally small parts. This has been successfully achieved in all respects save one, that of the loudspeaker. It became quickly apparent that those which simply duplicated the electro-mechanical features of standard types on a small scale prevented transistor outputs from being used to full advantage. To overcome this, it became necessary to design exceedingly small loudspeakers specially with "transistor characteristics", and those presented here will be found to conform ideally with the requirements involved.

TYPE LP70

A circular unit of extra high sensitivity, functioning well from only a quarter of the power required to obtain comparable results from larger units, yet it will comfortably handle up to 500 milliwatts loading without signs of distress. Its amazing wide response ensures quality reproduction from the very smallest of sets, making it at least possible to compare pocket-size performance with that of top-ranking commercial portables, however powered. Model LP.70 is recommended particularly for high-quality output portable sets.

Technical Details

Overall diameter—2¾" x 1 1/16" depth.

Response—120-14,500 c/s.

Loading—4 milliwatts to 500 milliwatts.

Impedance—10 ohms.

Price: 24s. 4d. inc. Purchase Tax.

TSL TYPE CMS50

2" diameter x ⅝" overall depth. Response 200 c/s to 12 Kc/s. D.C. resistance 280 ohms. Impedance at 800 c/s—750 ohms. Designed to be connected directly to Class A output. Sensitivity is superior to any speaker under 4" diameter, apart from models LP70 and LP31.

Price: 17s. 1d. inc. Purchase Tax.

ELLIPTICAL MODELS

TYPE LP31

Of similar functional characteristics to Model LP.70, the fantastically small dimensions of this elliptical speaker with an overall face size of only 4" x 1½" makes even greater achievements in small set design possible. Using a battery-powered 45 r.p.m. turntable, a portable gramophone or radiogram can be built only two inches in depth. High efficiency pocket receivers 4¾" x 3" x 1¼" become practical propositions, with outputs of ½ watt using class B drive. Yet this speaker will convert as little as 4 milliwatts into a loud, clearly audible signal. Specially made cone suspended with watchmaker's precision ensures extra sensitivity and the wide range response essential to obtain high-fidelity performance within the restricted dimensions of transistor portables. Such is their ruggedness and quality that these loudspeakers may also be used to advantage in larger size instruments.

Technical Details

Size—4" x 1½" x 1" deep.

Response—120-14,000 c/s.

Loading—4-500 milliwatts.

Impedance—3 ohms.

Price: 23s. 5d. inc. Purchase Tax.

TYPE 125 ULTRA HI-FI 125 mW AUDIO AMPLIFIER

TSL type 125 is an economical, miniature (2" x 1" x 1") transformer-less two-stage 125 mW AF amplifier. It uses matched npn/pnp/audio transistors in complementary symmetry circuits to achieve low distortion, high sensitivity, and low standby battery current. It is designed to use a standard 9V battery. The transistors are AF types specially developed for this type of application.

Designed as a general purpose amplifier, it can be used in intercom sets and in ultra portable record players fed direct from a medium impedance pick-up or from a high impedance through a matching transformer. It is supplied to a tight overall performance specification, guaranteed 100%. Selective assembly takes up all the component tolerances and gives a narrow overall amplified performance spread unobtainable by other means.

TECHNICAL DETAILS

This direct-coupled complementary symmetry transistor amplifier is assembled on a standard printed circuit board using conventional components in a high packaging density, space saving being achieved also by the absence of transformers. Standard-spaced end connections are designed for plug-in use with sockets while holes in the printed circuit permit direct soldering of flying lead connections. The board also has two holes for mounting fixing. A high transistor content combined with the reliability of standard field proved components ensures maximum reliability.

All units meet the following overall specification limits for 9V battery voltage:—

Maximum output power	125 mW
Maximum total distortion at 50mW	6%
Minimum sensitivity (1 Kc/s, 600 ohm source impedance, 50 mW out)	50 mV
Maximum standby (no-signal) battery current	4 mA

Detailed specifications are set out below:—

PERFORMANCE SPECIFICATION

CIRCUIT	Three-transistor, two-stage, 125 mW, 9V, medium gain AF amplifier (pnp Class A driver direct coupled to a pnp-npn complementary symmetry Class B single-ended push-pull output.
SUPPLY VOLTAGE	9V nominal (operates at reduced performance down to 4V).
OUTPUT LOAD	Optimum speaker or load impedance 40 ohms (25 to 60 ohms may be used without significant performance deterioration).
OUTPUT POWER	(a) Absolute maximum ... ... 125 mW.
	(b) Maximum (for 6% total distortion) ... ... 50 mW.
CURRENT CONSUMPTION	(a) Quiescent (no signal) (i) typical ... ... 4 mA.
	(ii) max. ... ... 5 mA.
	(b) At 125 mW ... ... 27 mA typ.
POWER GAIN	Typical (measured at normal 9V supply voltage at 50 mW output on to 40 ohm load with 1 Kc/s input for 600 ohm signal source) ... ... 45 db.
SENSITIVITY	For 50 mW out (measured as above under power gain) better than 50 mV rms input.
FREQUENCY RESPONSE	Typical (for 50 mW out and 3 dB down) ... ... 100 c/s to 25 Kc/s.
DISTORTION	Total distortion for 50 mW out typical 2%
	max. 6%
INPUT IMPEDANCE	Typical ... ... 1.5 K ohm.
TEMPERATURE	Normal operating ambient temp. ... ... 45°C. max. (112°F.)
DIMENSIONS	Approximate: length 2", width 1", height 1".
CONNECTIONS	Four, comprising:
	(a) Signal input—internally capacitor isolated (normally connected to slider of 5 K volume control).
	(b) Common earth and positive of d.c. supply.
	(c) Output to speaker (internally d.c. connected to driver transistor collector via resistors).
	(d) Negative of d.c. supply and speaker.
WEIGHT	½ oz. (approx.)
FINISH	Matt cellulose spraked except connector terminations.
GUARANTEE	12 months against all manufacturing faults.

Price 45/-

(Packed in dustproof plastic case)

LP45F. TECHNICAL SPECIFICATIONS

Overall diameter	...	... 1⅜".
Depth	... ...	... ⅜".
Voice coil impedance		... Standard low impedance.
Magnet material	... ...	Ferrite.
Flux density	... ...	... 9,500 gauss.
Frequency response	...	120-14,000 c/s.
Loading	... ...	... 1 mW to 300 mW.

The LP45F represents a remarkable development in the field of small speakers and provides the home constructor with a complete new dimension in which to work. The sensitivity is so high that a clearly audible output can be obtained with an input of only 1 mW. At the same time the assembly is sufficiently flexible to permit an input power of 300 mW. At this level the output from the speaker, in a suitable case, is comparable with that obtained from a 4 or 5 inch speaker.

The speaker is ideal for use in tiny pocket radios of the regenerative, reflex or superhet type and if incorporated in such a set will vastly increase its performance. It is, in fact, recommended by Clive Sinclair, author of "Practical Transistor Receivers" and numerous other books on transistors.

TSL, in offering the LP45F. to the home constructor, guarantees that it is superior to any other speaker of this type.

Price: 24s. 4d. inc. Purchase Tax.

For some time now TSL have been well ahead of their competitors in making available subminiature components. Their lead is now strengthened by the introduction of a complete range of really tiny components for use in subminiature superhets. The range comprises the following products:—

TSL "Babyvar" twin gang tuning capacitor—17s. 6d. each. This is the smallest tuning capacitor made anywhere in the world. Each section has a maximum capacity of 120 pf. and is padded by a 5 pf. trimmer. The overall size is only 3/5" x 3/5" x ½".

Technical Specification

Maximum capacity for each section	120 pF.
Minimum capacity for each section	less than 4 pF.
Rotation angle	180°
Capacity variation of the trimmers	0—5 pF.
Insulating voltage	50 volts D.C.
Maximum operating temperature	60° C.
Size	⅝" x ⅝" x 29/64"

SUB-MINIATURE FERRITE ROD AERIAL

This unit has an overall size of only 1¼" x ¼" x ⅛" yet by using a new type of ferrite of very high gain and first grade Litz wire a sensitivity has been achieved which is as good as a normal 6" ferrite rod aerial. Thus, by using this rod, a pocket set can be made having the same sensitivity as a full size table radio. This aerial is ideal for use in any pocket or portable superhet, T.R.F. regen. or reflex circuit. Since the inductance is adjustable, it may be used with any tuning capacitor from 150 pf. to 500 pf. in value.

Size: 1¼" x ¼" x ⅛".
Turns ratio and current gain: 10 to 1.
Inductance range (varied by sliding coil along rod): 200-440 uH.
Q-Factor: Better than 240.
Colour code: Primary—yellow and blue.
            Secondary—red and green.
Retail price: 3s. 6d.

SUB-MINIATURE SINGLE GANG TUNING CAPACITORS

Two types are now available. They are identical except that type A has a value of 250 pf. and type B a value of 365 pf. They are totally enclosed in plastic cases to keep out dust, and although the smallest of their type in the world. the performance of these tuning capacitors is second to none.

Size: ¼" x ¼" x ⅛". (Smaller than an ordinary postage stamp.)
Capacity: Type A—250 pf., price 7s. 6d. retail.
          Type B—365 pf., price 12s. 6d. retail.

HIGH IMPEDANCE CRYSTAL EARPIECE WITH JACK PLUG AND SOCKET

The performance of any receiver can be enhanced by use with one of these earpieces, the quality and sensitivity of which are vastly better than ordinary headphones. Because of their very small size and low weight they are convenient to carry and sufficiently comfortable to be worn for long periods. The earpiece lead is connected to a sub-miniature jack plug and a matching socket, with built in switch, is included in the price.
Retail price: 10s. 6d.

MINIATURE PLASTIC CASES

One of the main difficulties involved in building subminiature receivers is the difficulty of obtaining a suitable and attractive case. We have now remedied this situation by making available a clear plastic box. This may be painted inside, in any colour or colours, to produce a durable and attractive finish. Holes may easily be drilled as required and the case will accommodate our new ferrite rod aerial and sub-miniature tuning capacitors. Many circuits built with our components will fit completely into this case.

Size: 2¼" x 1½" x ¾"
Retail price: 1s.

TSL "Microtran" I.F. transformers and oscillator coil—25s. per set. This set comprises the usual 3 I.F. transformers and 1 oscillator coil. Each coil is enclosed in a minute metal can only ¼" square by under ½" tall. Despite their small size each I.F.T. has its 200 pf. capacitor built in. The oscillator coil is specifically designed for the "Babyvar".

TSL "Maxigain" ferrite rod aerial—3s. 6d. each. This is a new ferrite rod aerial with an overall length of only 1½" and a maximum diameter of ⅜" including the coil. It is wound to match the "Babyvar" tuning capacitor. The sensitivity of the aerial is such that even in areas of very low signal strength it will pick up more than enough signal for superhet circuits.

TSL A.F. transformers. Two types are available: a driver transformer with a centre tapped secondary and a turns ratio of 4½ : 1 and an output transformer with a centre tapped primary and a turns ratio of 20 : 1. These transformers may be used in either class B push-pull or class A amplifier circuits with outputs of up to 200 mW.

BERNARD'S RADIO BOOKS