No. 176

40p

TRANSISTOR AUDIO AMPLIFIER MANUAL

by

Clive Sinclair

32 practical transistor amplifier circuits.

Complete parts list and full constructional details.

Amplifiers ranging from 50 micro-watts up to 75 watts output.

33 layout and constructional diagrams.

Comprehensive servicing data.

Practical hints and tips on construction.

Amplifiers for hearing aids, pocket radio sets, tape recorders, record players, table radios, etc.

Choice of amplifiers for specific requirement.

High fidelity amplifier design.

Servicing and fault finding, etc.

BERNARD'S RADIO MANUALS

TRANSISTOR AUDIO AMPLIFIER MANUAL

by

CLIVE SINCLAIR

BERNARDS (PUBLISHERS) LTD.

THE GRAMPIANS
WESTERN GATE
LONDON W.6

FIRST PUBLISHED FEBRUARY, 1962

Reprinted July, 1963.

Reprinted November, 1964.

Reprinted August, 1966.

Reprinted January, 1969.

Reprinted July, 1970.

Reprinted May, 1972.

ACKNOWLEDGEMENT

We must express our grateful thanks to G.E.C. Limited, Mullard Limited, Newmarket, Limited, and the University of Cincinnati for their kind co-operation in supplying us with information without which this book would not have been possible.

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

Printed by V. Cooper & Partners Ltd., Flitcroft Street, W.C.2,
for Bernards (Publishers) Ltd., The Grampians, Western Gate, London, W.6.

CONTENTS

LIST OF ILLUSTRATIONS

INTRODUCTION

In Book 1 of "Practical Transistor Audio Amplifiers" I dealt with the basic principles involved in transistor A.F. amplifier design and the practical examples given were mainly limited to single stages. In this second book the situation is reversed and all the space is devoted to practical amplifier circuits employing all the principles and ideas already described. Most of the circuits may be built as they stand but in a few cases the transistors required are not yet available. These last mentioned circuits have been included, however, for the sake of completeness and so that the book will not be out of date for a long while to come.

Because the range of amplifier sizes used is very wide, from a few hundred microwatts to many watts, the book has been divided into sections classified according to the power of the amplifiers described. The sections cover amplifiers of from 0 - 10 mW, 10 - 100 mW, 100 mW - 1 W and 1-75 W. Amplifiers that could fall into either of two sections are included in the latter. For example, a 100 mW amplifier would appear in the 100 mW to 1 W section and not in the previous one.

Since this book leads on from the last one, the technical details given there are not repeated here except where an unusual application of a circuit is described or where the circuit itself is unusual. Most of the text is devoted to performance specifications of the amplifiers and their component values.

I have included as many amplifiers as space would allow but there has had to be quite a lot of selection. Because most readers will be mainly concerned with the medium and low power amplifiers these have been given more space than those in the high power section which are of the public address size.

TSL-Ducati Capacitors

These capacitors are specially designed for use in transistor amplifiers. They have very long life and very low leakage characteristics which remain stable after years of use. Furthermore because of their extremely low price, the cost of any equipment mentioned in this book is brought down to an economical figure.

Also recommended are the TSL transistor holders, miniature loudspeakers, and all other items in the subminiature and miniature range of components.

SPECIAL NOTE—*Polarity of input capacitor.*

The polarity of the input capacitor on any amplifier in this book will depend on the nature of the signal source. With a magnetic microphone the negative side of the electrolytic should go to the transistor but when a transistor tuner unit is providing the signal the base side of the capacitor should normally be positive.

CHAPTER 1

Amplifiers with outputs of up to 10 mW.

The first transistor amplifiers were, of course, in the very low power range and it is in this field that the transistor has scored its greatest victory because valves, at these powers, are hopelessly inefficient. Even the subminiature hearing aid valves were comparative gluttons for power.

With output powers of less than 10 mW it is not normally possible to obtain satisfactory performance on a loudspeaker although, with a large and sensitive type the output can be surprising. Amplifiers in this range will be used mainly with earpieces therefore and are useful in hearing aids and tiny earpiece radio sets. The quality of reproduction obtained from a good earpiece driven by a carefully designed amplifier can be quite remarkably good and certainly very much better than that obtained from a small loudspeaker. When the linkage between the diaphragm of the earpiece and the ear drum is air tight the bass response can be excellent and the power requirements of the earpiece are extremely low. The high sensitivity type of earpiece used with hearing aids requires a peak input of only 1 mW for a good listening level and the lower sensitivity types used with radios require up to about 10 mW depending on the design.

Amplifiers for hearing aids and small radios have to operate from extremely small batteries. If the battery of such a unit is to have a reasonable life the design must be efficient and the earpiece must match the output impedance. It is also important that the amplifier chosen for a particular application be no more than what is required as regards output power because the output stage is normally class A and if the amplifier is designed for a larger output than is required there will be an unnecessary drain on the battery.

Fig. 1. 500 Microwatt output amplifier

When an earpiece of the type used in hearing aids is employed a really satisfactory sound level can be obtained with an A.F. drive power of only a few hundred microwatts. This amplifier provides an output of $\frac{1}{2}$ mW which is more than sufficient for people with normal hearing and is even enough for many deaf people.

The overall power gain of the amplifier is about 50 dB or 100,000 times. This makes it quite suitable as the A.F. section of a small radio or for the output stage of a hearing aid.

When the amplifier is powered by a mercury cell such as the RM625, R1 and C1 may be omitted since no unwanted feedback will occur. The life of this cell in the circuit will be over 100 hours despite its small size.

The total current consumption is $2\frac{1}{2}$ mA, the current in the output stage being 2 mA with a fresh battery.

The stabilisation in the first stage is by means of a feedback resistor. Although this results in some A.C. feedback, the loss of gain is very slight. The output stage is not stabilised at all but the ratio of the collector current to the leakage current is large and any change in the latter will have little effect.

The earpiece should have an impedance of 600 ohms and a D.C. resistance of between 200 and 250 ohms. The Fortiphone type T earpiece is suitable.

Components

Resistors—270 ohms, 100K ohms, 3.3K ohms, 47K ohms all 1/10th watt.
Capacitors—2 microfarad, 3 v.w. x 2. 10 microfarad 3 v.w. (TSL).
Transistors—Mullard OC57 and OC58 hearing aid types.
Volume Control— 50K ohms log or semi-log.
Earpiece—600 to 650 ohms impedance. 200 to 250 ohms D.C. (TSL).
Battery—1.3 volt mercury cell or 1.5 volt zinc carbon cell.

Fig. 2. Direct Coupled $\frac{1}{2}$ milliwatt Amplifier

As was shown in Book 1, a considerable saving in components can be achieved by the use of direct coupling between the transistors. Although this amplifier has one more stage than the last it uses one less resistor and one less capacitor. The power gain is about 75 dB.

The currents of the various stages should be about 1/3 mA for Tr1 and Tr2 and about 2 mA for T3. Because the gains of transistors vary, it is necessary to adjust the 30K ohm preset. resistor (which may also be 50 or 100K), f[illegible]he correct current in the output stage. Once [illegible] correct value for R has been found it may be replaced by a fixed resistor of the same value.

The operation of the circuit depends upon the fact that with these types of transistor high gain can be obtained at very low levels of collector voltage. The collector voltages of Tr1 and Tr2 are in fact the same as the base voltages of Tr2 and Tr3. This would normally mean that Tr1 and Tr2 where operated below their knee voltages but by employing very low collector current levels in the first two stages this is avoided.

The battery must be a mercury cell since the higher internal resistance of a zinc-carbon cell is likely to cause motor-boat oscillation.

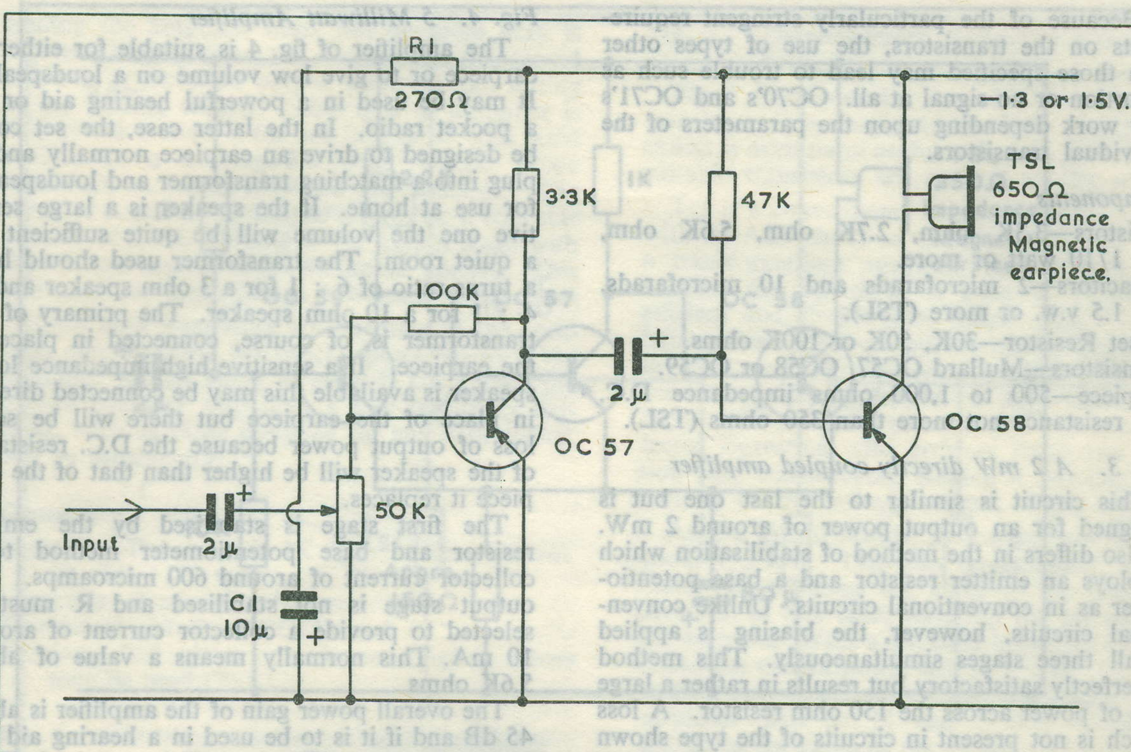

Fig. 1. 500µW. output amplifier.

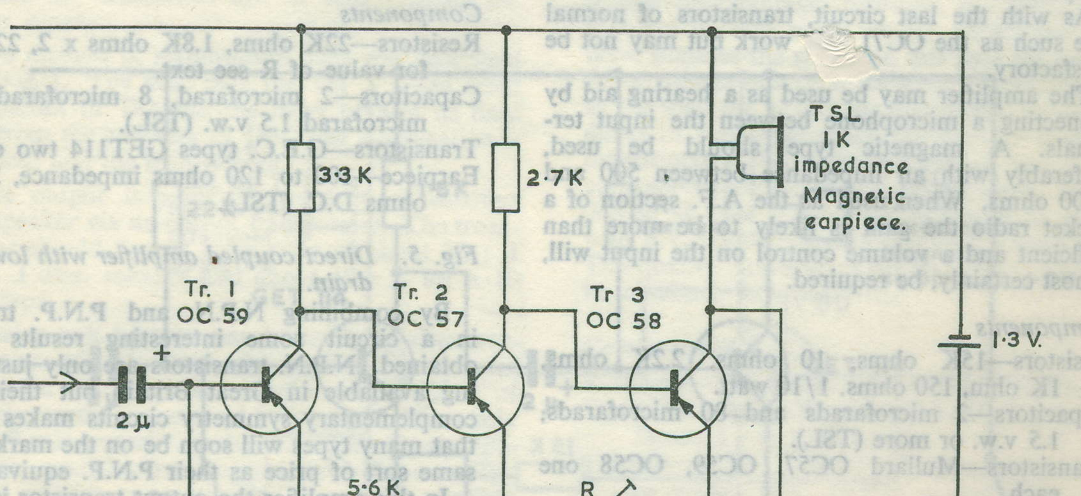

Fig. 2. Direct coupled 1/2mW. amplifier.

Because of the particularly stringent requirements on the transistors, the use of types other than those specified may lead to trouble such as distortion or no signal at all. OC70's and OC71's may work depending upon the parameters of the individual transistors.

Components

Resistors—3.3K ohm, 2.7K ohm, 5.6K ohm, 1/10 watt or more.
Capacitors—2 microfarads and 10 microfarads. 1.5 v.w. or more (TSL).
Preset Resistor—30K, 50K or 100K ohms.
Transistors—Mullard OC57, OC58 or OC59.
Earpiece—500 to 1,000 ohms impedance D.C. resistance not more than 350 ohms (TSL).

Fig. 3. A 2 mW directly coupled amplifier

This circuit is similar to the last one but is designed for an output power of around 2 mW. It also differs in the method of stabilisation which employs an emitter resistor and a base potentiometer as in conventional circuits. Unlike conventional circuits, however, the biasing is applied to all three stages simultaneously. This method is perfectly satisfactory but results in rather a large loss of power across the 150 ohm resistor. A loss which is not present in circuits of the type shown in fig. 2. It also necessitates the use of a large value electrolytic capacitor, in this case 80 microfarads, which tends to be a rather bulky component.

As with the last circuit, transistors of normal type such as the OC71 may work but may not be satisfactory.

The amplifier may be used as a hearing aid by connecting a microphone between the input terminals. A magnetic type should be used, preferably with an impedance between 500 and 1,000 ohms. When used as the A.F. section of a pocket radio the gain is likely to be more than sufficient and a volume control on the input will, almost certainly, be required.

Components

Resistors—15K ohms, 10 ohms, 2.2K ohms, 1K ohm, 150 ohms. 1/10 watt.
Capacitors—2 microfarads and 80 microfarads, 1.5 v.w. or more (TSL).
Transistors—Mullard OC57, OC59, OC58 one each.
Earpiece—About 250 ohms impedance, 55 ohms D.C. (TSL).
Battery—1.3v. Mallory mercury cell such as RM625.

Mercury cells are available normally from chemists as they are used in hearing aids. One of the tiniest types, the RM400, is hardly larger than an aspirin tablet and yet it will give a life of 20 hours in this circuit and of about 40 hours in the previous one.

Fig. 4. 5 Milliwatt Amplifier

The amplifier of fig. 4 is suitable for either an earpiece or to give low volume on a loudspeaker. It may be used in a powerful hearing aid or for a pocket radio. In the latter case, the set could be designed to drive an earpiece normally and to plug into a matching transformer and loudspeaker for use at home. If the speaker is a large sensitive one the volume will be quite sufficient for a quiet room. The transformer used should have a turns ratio of 6 : 1 for a 3 ohm speaker and of 4 : 1 for a 10 ohm speaker. The primary of the transformer is, of course, connected in place of the earpiece. If a sensitive high impedance loudspeaker is available this may be connected directly in place of the earpiece but there will be some loss of output power because the D.C. resistance of the speaker will be higher than that of the earpiece it replaces.

The first stage is stabilised by the emitter resistor and base potentiometer method to a collector current of around 600 microamps. The output stage is not stabilised and R must be selected to provide a collector current of around 10 mA. This normally means a value of about 5.6K ohms.

The overall power gain of the amplifier is about 45 dB and if it is to be used in a hearing aid two stages of pre-amplification will be required. For a radio set or gramophone, [illegible]er, it should have sufficient gain as it stands for normal use.

Components

Resistors—22K ohms, 1.8K ohms x 2, 220 ohms, for value of R see text.
Capacitors—2 microfarad, 8 microfarad and 2 microfarad 1.5 v.w. (TSL).
Transistors—G.E.C. types GET114 two off.
Earpiece—100 to 120 ohms impedance, 30 to 50 ohms D.C. (TSL).

Fig. 5. Direct coupled amplifier with low battery drain.

By combining N.P.N. and P.N.P. transistors in a circuit some interesting results can be obtained. N.P.N. transistors are only just becoming available in Great Britain but their use in complementary symmetry circuits makes it likely that many types will soon be on the market at the same sort of price as their P.N.P. equivalents.

In this amplifier the output transistor is directly coupled to the driver with the volume control acting as the load for the former. When the setting of the volume control is reduced the base bias of Tr2 is reduced by a proportionate amount and this causes the collector current to drop. Thus, when the volume required is less than the maximum of which the amplifier is capable, the collector current of Tr2 is below its maximum value and the drain on the battery is reduced. The only disadvantage with this system is that the signal

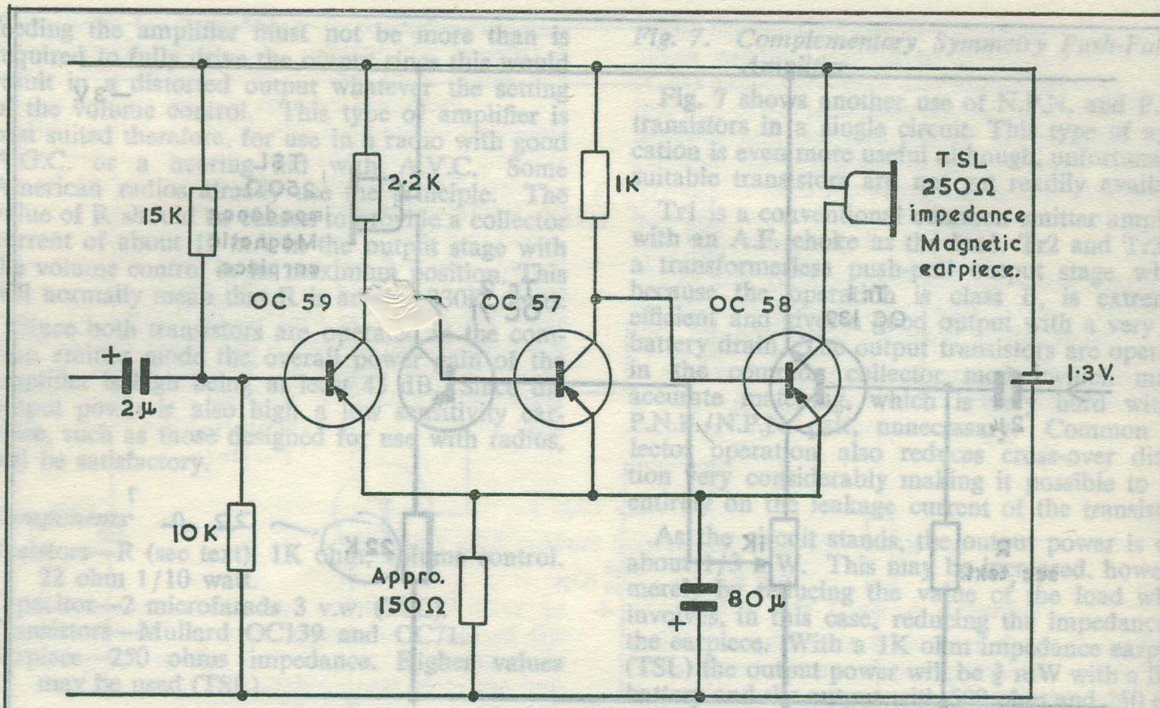

Fig. 3. A 2 mW. directly coupled amplifier.

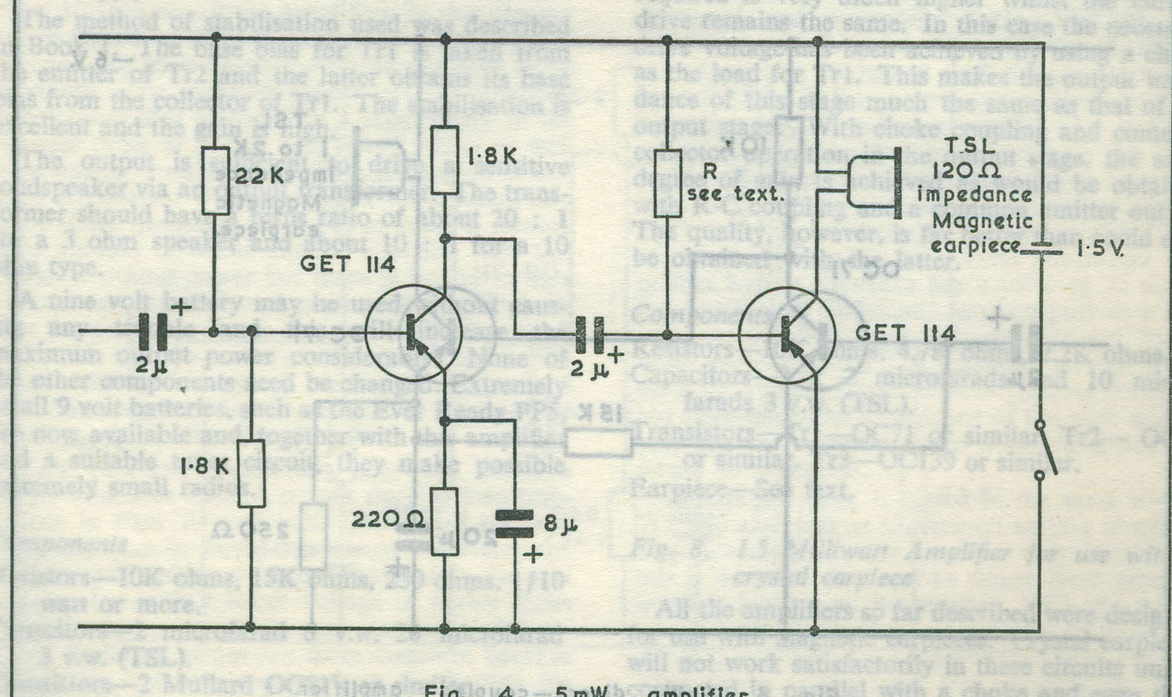

Fig. 4. 5 mW. amplifier.

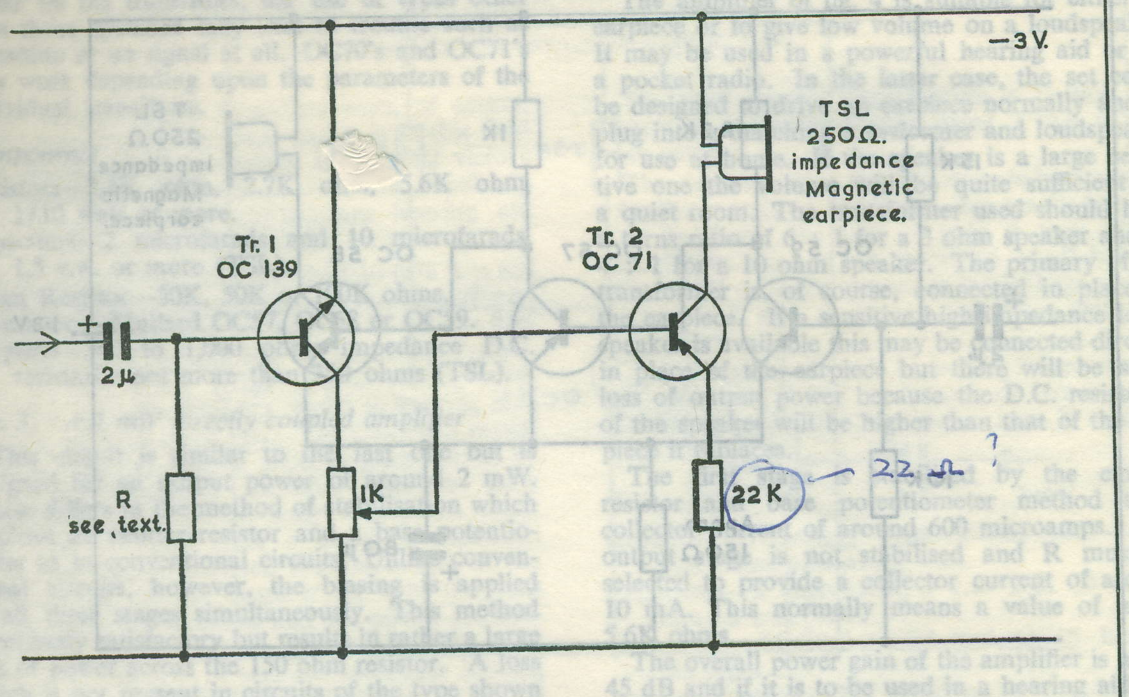

Fig. 5. Direct coupled amplifier with low battery drain.

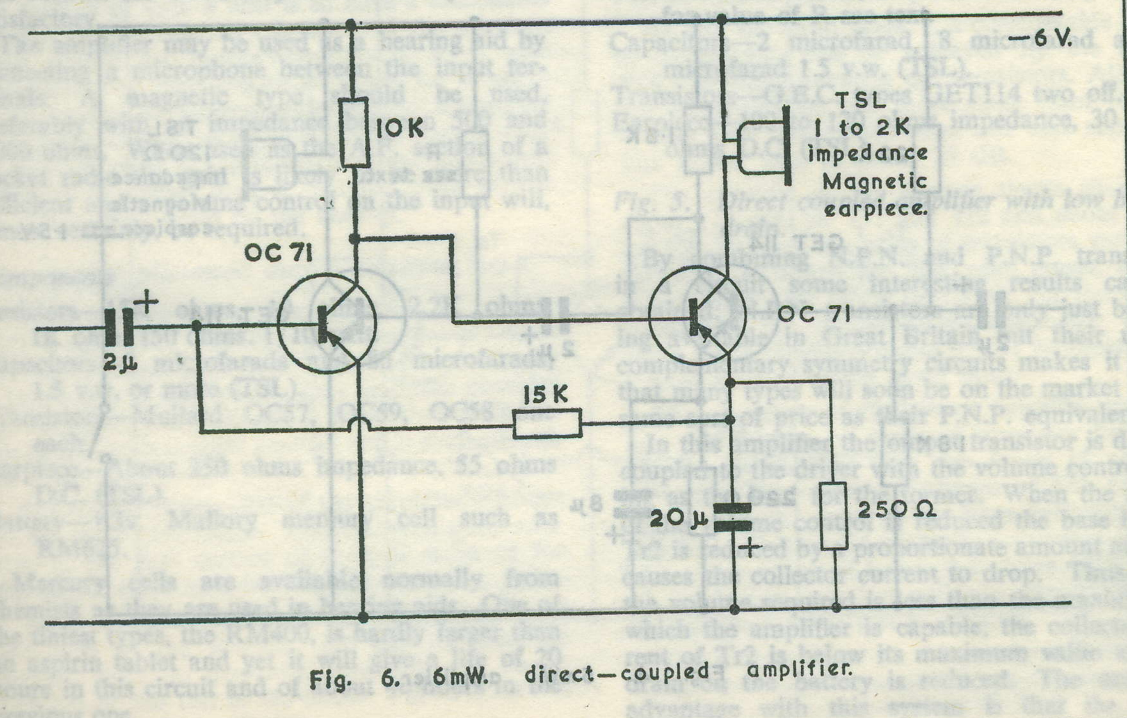

Fig. 6. 6mW. direct—coupled amplifier.

feeding the amplifier must not be more than is required to fully drive the output since this would result in a distorted output whatever the setting of the volume control. This type of amplifier is best suited therefore, for use in a radio with good A.G.C. or a hearing aid with A.V.C. Some American radios already use the principle. The value of R should be chosen to provide a collector current of about 10 mA in the output stage with the volume control in its maximum position. This will normally mean that R is around 330K ohms.

Since both transistors are operated in the common emitter mode the overall power gain of the amplifier is high being at least 45 dB. Since the output power is also high a low sensitivity earpiece, such as those designed for use with radios, will be satisfactory.

Components

Resistors—R (see text), 1K ohm, volume control. 22 ohm 1/10 watt.
Capacitor—2 microfarads 3 v.w. (TSL).
Transistors—Mullard OC139 and OC71.
Earpiece—250 ohms impedance. Higher values may be used (TSL).

Fig. 6. 6 Milliwatt direct — coupled amplifier

Where a rather higher battery voltage than we have been considering is available this type of circuit is useful. The higher voltage is necessary because the transistors are in series across the power supply.

The method of stabilisation used was described in Book 1. The base bias for Tr1 is taken from the emitter of Tr2 and the latter obtains its base bias from the collector of Tr1. The stabilisation is excellent and the gain is high.

The output is sufficient to drive a sensitive loudspeaker via an output transformer. The transformer should have a turns ratio of about 20 : 1 for a 3 ohm speaker and about 10 : 1 for a 10 ohm type.

A nine volt battery may be used without causing any trouble and this will increase the maximum output power considerably. None of the other components need be changed. Extremely small 9 volt batteries, such as the Ever Ready PP5, are now available and, together with this amplifier and a suitable tuner circuit, they make possible extremely small radios.

Components

Resistors—10K ohms, 15K ohms, 250 ohms. 1/10 watt or more.
Capacitors—2 microfarad 6 v.w. 20 microfarad 3 v.w. (TSL).
Transistors—2 Mullard OC71's or similar.
Earpiece—1 - 2K ohms impedance. Low sensitivity type may be used (TSL).

Fig. 7. Complementary Symmetry Push-Pull Amplifier

Fig. 7 shows another use of N.P.N. and P.N.P. transistors in a single circuit. This type of application is even more useful although, unfortunately, suitable transistors are not yet readily available.

Tr1 is a conventional common emitter amplifier with an A.F. choke as the load. Tr2 and Tr3 for a transformerless push-pull output stage which, because the operation is class B, is extremely efficient and gives a good output with a very low battery drain. The output transistors are operated in the common collector mode which makes accurate matching, which is very hard with a P.N.P./N.P.N. pair, unnecessary. Common collector operation also reduces cross-over distortion very considerably making it possible to rely entirely on the leakage current of the transistors.

As the circuit stands, the output power is only about 1/3 mW. This may be increased, however, merely by reducing the value of the load which involves, in this case, reducing the impedance of the earpiece. With a 1K ohm impedance earpiece (TSL) the output power will be ¾ mW with a fresh battery and the output with 500 ohm and 250 ohm earpieces will be 1½ and 3 mW respectively. Reducing the value of the earpiece will reduce the gain slightly.

The advantages of common collector operation for the output stages have been mentioned. There is one disadvantage, however, the drive voltage required is very much higher whilst the current drive remains the same. In this case the necessary drive voltage has been achieved by using a choke as the load for Tr1. This makes the output impedance of this stage much the same as that of the output stage. With choke coupling and common collector operation in the output stage, the same degree of gain is achieved as would be obtained with R-C coupling and a common emitter output. The quality, however, is far better than could ever be obtained with the latter.

Components

Resistors—10K ohms, 4.7K ohms, 2.2K ohms.
Capacitors—2 x 2 microfarads and 10 microfarads 3 v.w. (TSL).
Transistors—Tr1—OC71 or similar. Tr2— OC71 or similar. Tr3—OC139 or similar.
Earpiece—See text.

Fig. 8. 1.5 Milliwatt Amplifier for use with a crystal earpiece

All the amplifiers so far described were designed for use with magnetic earpieces. Crystal earpieces will not work satisfactorily in these circuits unless connected in parallel with a choke and even then the results may not be good. These earpieces are, however, extremely cheap and yet very sensitive

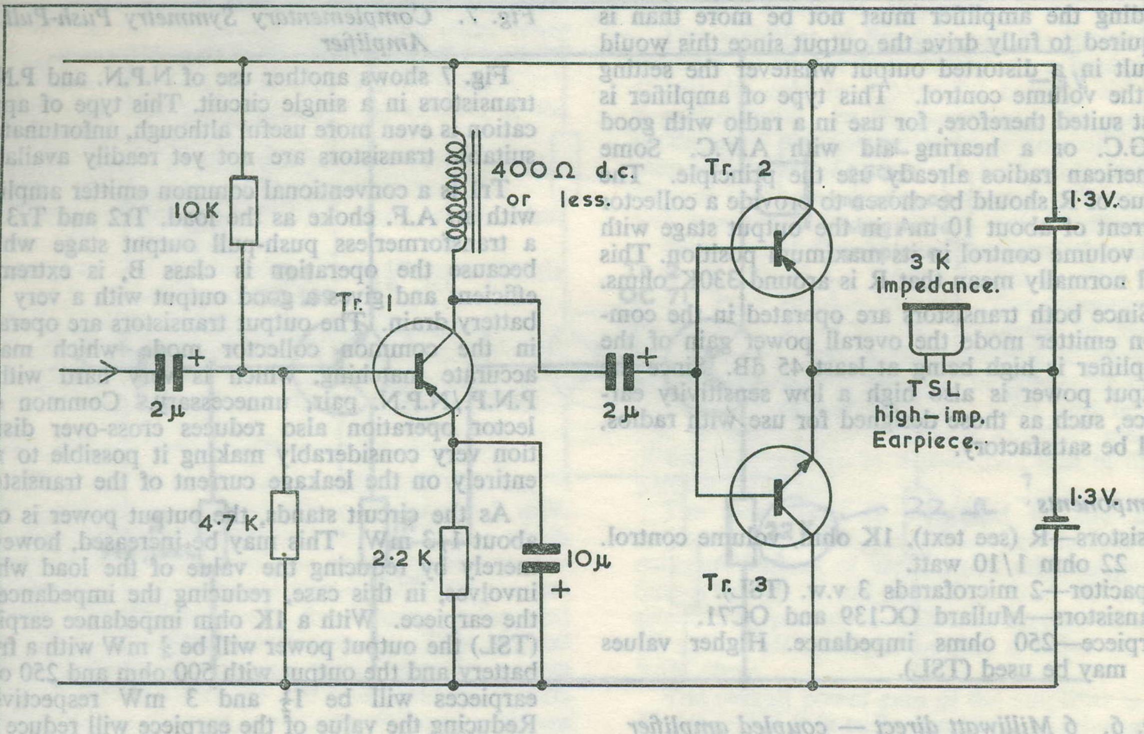

Fig. 7. Complementary symmetry Push-Pull amplifier.

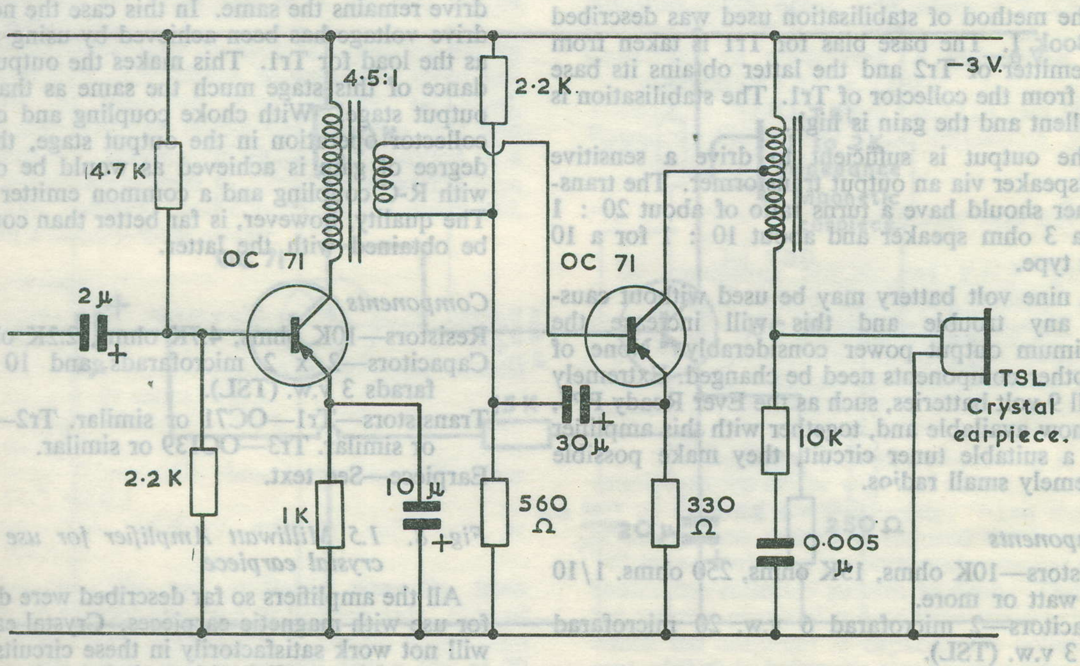

Fig. 8. 1½ mW. amplifier for use with a crystal earpiece.

The reason for their failure to work in a conventional circuit is two fold. Firstly, the impedance of this type is normally around 150K ohms and secondly, they do not conduct electricity.

This circuit is specifically designed to overcome these difficulties and to make the best possible use of the earpiece. The first stage is a conventional common emitter amplifier stabilised by means of an emitter resistor and a base bias potentiometer and transformer coupled to the output stage. The output stage is biased in the same way. The output impedance of the second stage is about 20K ohms and a step up tapped choke is used to match this to the higher impedance of the earpiece. An ordinary interstage transformer with a turns ratio of about 4.5 : 1 may be used as the choke. One end of the primary (high impedance winding) should be connected to the end of the secondary (low impedance winding). The free end of the secondary should then go to battery negative and the free end of the primary to the earpiece, the join going to the collector. The connection between the secondary and primary of the transformer must be the right way round but the best way can easily be found by trial and error.

The 10K ohm resistor and the 0.005 microfarad in parallel with the earpiece provide correction for the non-linear response of the latter.

Although the maximum output of the amplifier is only 1½ mW this is quite sufficient to drive the earpiece to full volume.

CHAPTER 2

Amplifiers with outputs between 10 and 100 mW

All requirements for an amplifier to drive an earpiece should be met by one or other of the circuits given in the last chapter. In some cases the amplifier may be suitable apart from the battery voltage used or the amount of gain provided. The former may be changed to suit requirements if the principles outlined in Book 1 are followed. The latter problem may be overcome by removal or addition of a stage of preamplification as the case requires.

No earpiece requires a driving power of more than 10 mW so all the amplifiers in this chapter are designed to drive a loudspeaker although, of course, they may be used with an earpiece as an auxiliary. The range of output powers discussed here covers that provided in a great many of the cheaper types of pocket and " toy " radios as well as a smaller number of portable gramophones and tape recorders. With a sensitive loudspeaker and a carefully designed enclosure or case, a reasonable amount of sound can be obtained with this order of output power but there is bound to be a certain amount of distortion on peak (clipping) unless the average volume is very low. With a small radio this will not matter much because the quality is not very good anyway making these sets best suited to speech or light background music where clipping will not be objectionable.

Low powered pocket sets may use either a single transistor class A output stage or two transistors in class B push-pull. The latter are not very common in this power range and, since the circuits used are identical to those given in the next chapter but with a lower voltage or higher turns ratios in the transformers, none are included here. Class A output stages are more common because at this level of consumption from the battery the greater efficiency of the class B output is less significant than the economy of the class A output.

Fig. 9. 20 mW Class A Amplifier

This amplifier is typical of those to be found in a great many cheap portables, particularly those of Japanese origin. A great many of these sold under the title of " Boys' Radio " or " Toy Radio " to satisfy the requirements of the Japanese government, are two transistor reflex receivers in which the output stage will be similar to fig. 9 and the first transistor will be both a regenerative R.F. amplifier and an audio driver.

The circuit of the amplifier is completely conventional and extremely stable. Virtually any small signal A.F. transistors may be used without any significant change in performance other than overall gain. Tr1 is a common emitter amplifier operating with a collector current of 1 mA this level being chosen for maximum gain the drive requirements of the output stage being extremely small. Biasing is by means of an emitter resistor and a base potentiometer which provide quite adequate stability for all normal conditions. The emitter bypass capacitor has a value of 32 microfarads which is sufficiently large to provide a bass response which is more than good enough for all radio requirements. The collector resistor could be made slightly larger without clipping occurring but since the input impedance of the next stage is very low any increase in gain achieved in this way would be negligible.

The output stage is biased in the same way as Tr2 and also acts as a common emitter amplifier. The quiescent collector current is only 11 mA and this is no more than can be drawn from even the smallest battery on the market. With the output power available the loudspeaker should be as sensitive as possible. Even a very small type can give good results at this level. For example, the TSL-Lorenz LP45F which has an overall diameter of only 1¾", works very well indeed. With a 10 ohms

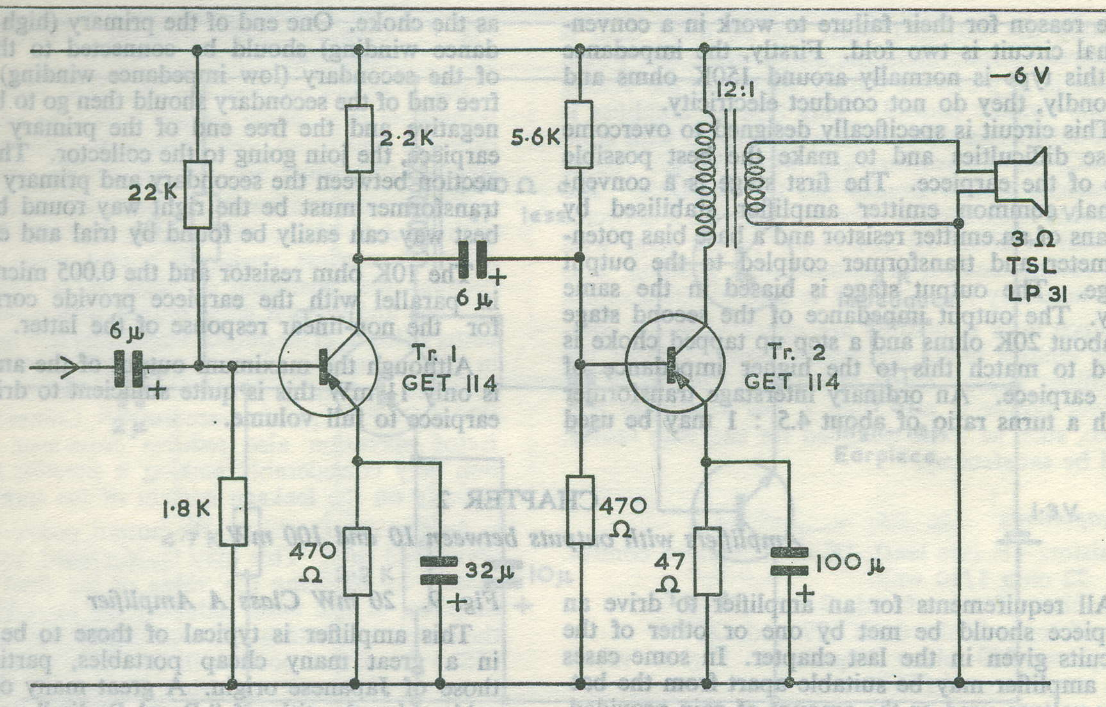

Fig. 9. 20 mW. class-A amplifier.

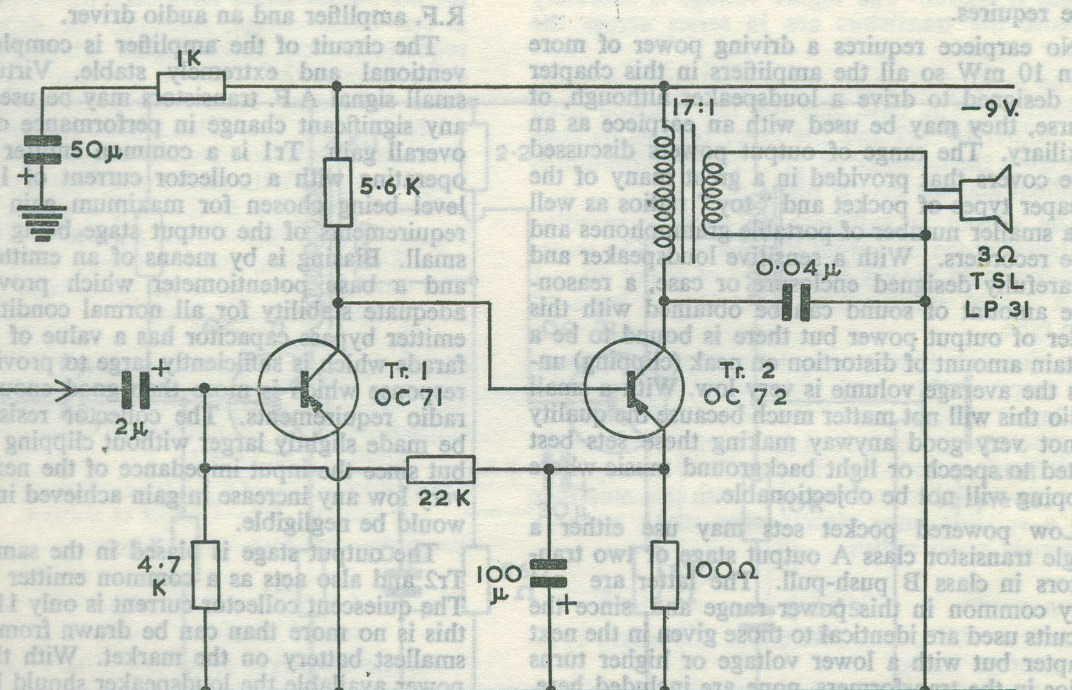

Fig. 10. Direct coupled 30 mW. amplifier.

speaker the turns ratio of the output transformer should be about 6.5 : 1.

Fig. 10. Direct Coupled 30 mW Amplifier

By using direct coupling techniques an amplifier of comparable performance to that of fig. 9 but using far fewer components can be built. Ignoring the battery decoupling components which were not included in the last circuit, fig. 10 only uses 4 resistors and 2 essential capacitors compared with the 7 resistors and 4 capacitors used in fig. 9. This is useful not only because it saves expense but also because the amount of space available is normally very limited in miniature radios, tape recorders and gramophones.

The circuit of fig. 10 was designed by Perdio and used by them in one of their first radios. The thermal stability is good and quite wide tolerances in the components may be accepted without loss of performance. The only disadvantage with this type of circuit is that the collector voltage of Tr1 is about the same as the emitter voltage of Tr2. Here there has to be a compromise because the emitter voltage of Tr2 should be as low as possible to avoid loss of power and this makes the collector-emitter voltage of Tr1 lower than is desirable. In practice, any loss of power gain resulting from this compromise is made up for by the fact that there is less loss in the coupling between the transistors than there is in conventional circuits.

The 0.04 microfarad capacitor compensates for the fact that small output transformers and small loudspeakers are more efficient at the high frequencies than they are at the low frequencies. If a large transformer and speaker are used this component may be omitted or its value may be reduced.

Components

Transistors—Tr1—OC71. Tr2—OC72.

Resistors—1K ohm, 5.6K ohm, 4.7K ohm, 22K ohm, 100 ohm.

Transformer— 17 : 1 turns ratio for 3 ohm speaker. 9 : 1 for 10 ohm speaker.

Capacitors—50 microfarad electrolytic. 100 microfarad electrolytic. (TSL) 0.04 microfarad paper or ceramic.

Fig. 11. Conventional 50 mW Amplifier

If the maximum output of the amplifier shown in fig. 9 is increased the gain is reduced and the input requirements for full output are still further degraded. To achieve comparable input sensitivity with 50 mW output it is necessary to use transformer coupling between the driver and output stages. The amplifier shown in fig. 11 was designed by Newmarket and does this.

The input sensitivity of the amplifier for an output of 50 mW is 20 mV. Since the input impedance is 1K ohm this makes the overall power gain just over 50 dB or 100,000 times. This is more than adequate for use with an ordinary superhet front end.

The collector currents of Tr1 and Tr2 are 0.5 and 20 mA respectively. The total battery drain is 22 mA which is still well within the scope of batteries using cells as small as those used in slim penlight torches. The consumption would not have to be a great deal higher, however, to make the use of a small battery unsatisfactory. This is why small pocket sets with output powers above about 50 mW almost invariably use push-pull output circuits. An additional reason is that in a class A circuit there is a continuous flow of direct current through the primary of the output transformer which degrades the performance and makes a larger transformer than is used with a push-pull circuit necessary. With current levels much above 25 mA the transformer will be too large for a really tiny pocket set.

Components

Resistors—R1—1.8K, R2—5.6K, R3—470 ohms, R4—1K, R5—3.3K, R6—4.7K, R7—47 ohms.

Capacitors—C1—10 mfd, C2—100 mfd, C3—10 mfd, C4—10 mfd (TSL).

T1—Turns ratio 3 : 1, primary inductance equal to or greater than 4H, maximum primary resistance 500 ohms.

T2—Turns ratio 10 : 1, primary inductance equal to or greater than 1H, maximum primary resistance 20 ohms.

Fig. 12. Simple 60 mW Gramophone Amplifier

The more sensitive type of crystal pick-up provides sufficient output to drive a well designed single stage amplifier to full volume. Such an amplifier, designed by Mullards, is shown in fig. 12.

For the sake of simplicity and economy the design is based on the half supply voltage principle described in Book 1. At normal room temperature the collector voltage of Tr is half the battery voltage. Any increase in collector current due to a rise in temperature will cause a reduction in the collector voltage and a corresponding reduction in the power dissipation in the transistor. Thermal runaway is, therefore impossible. Changes in collector current are also kept to a minimum by taking the base bias from the collector so that any increase or decrease in the collector current is partially cancelled out by an opposite movement of the base current. The technique does not result in negative feedback at signal frequencies because any A.F. returned via R2 is grounded by the 100 microfarad capacitor.

The input transformer matches the high output impedance of the crystal pick-up to the relatively extremely low impedance of the transistor. The

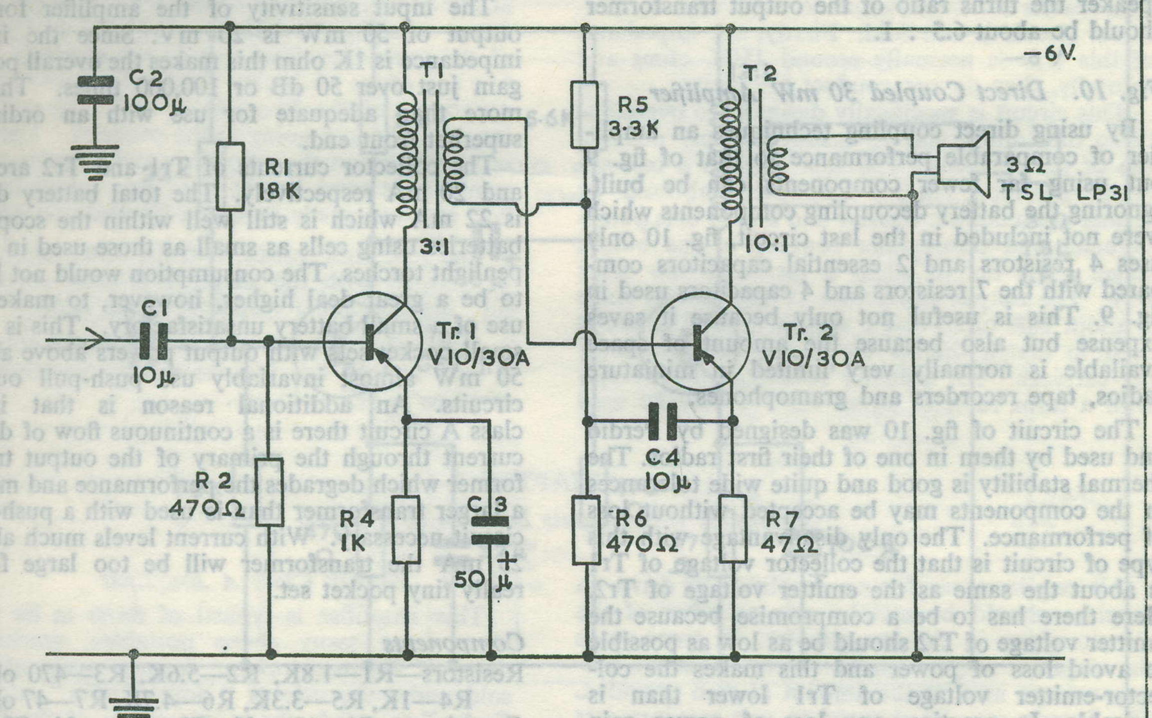

Fig. 11. Conventional 50 mW. amplifier. (Newmarket.)

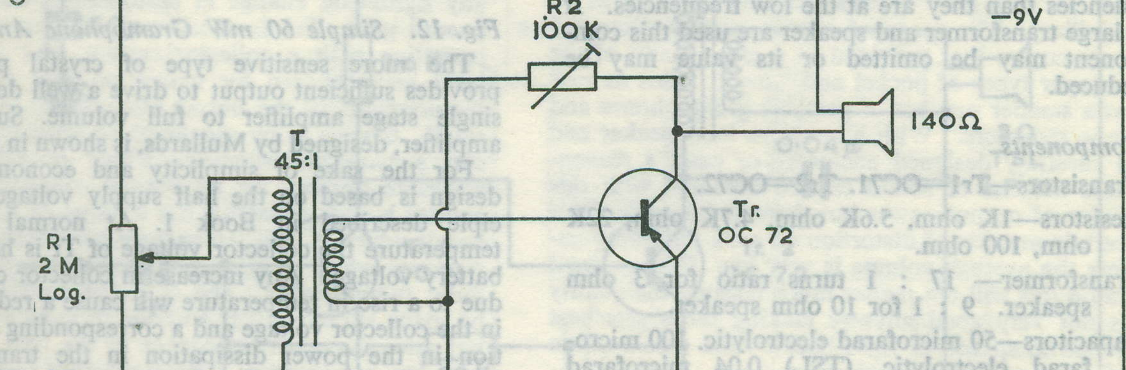

Fig. 12. Simple 60 mW. gramophone amplifier by Mullard.

turns ratio is 45 : 1 and the primary inductance should be at least 250H and preferably about twice this.

The maximum efficiency of the amplifier is only 25% because half the power is dissipated in the loudspeaker's D.C. resistance. As the temperature rises the maximum efficiency and power output both drop but with a really sensitive loudspeaker the sound level should remain quite sufficient. The collector voltage should be adjusted, at 25°C, to 4.5 volts by altering R2.

Fig. 13. Simple 90 mW Amplifier

This amplifier is similar to the last but has a higher output power and a driver stage making it suitable for use in a radio set. As it stands the circuit is quite adequate for use in a table or large portable radio. It is not really suitable for a pocket or personal receiver because the drain on the battery would be too high and the direct current passing through the cone of a small speaker would degrade the performance too much.

Both transistors use a feedback resistor for their base bias to save components. This results in some A.F. feedback which improves the quality but reduces the gain. This reduction in gain is not as high as it might be, however, the higher input impedance which it causes also improves the coupling efficiency.

The stability of the first stage is not as high as it would be with conventional stabilising circuitry but it is sufficient for practical purposes. Any change in collector current that may occur will not affect the gain materially.

Fig. 14. Direct Coupled 75 mW Amplifier

The combination of an N.P.N. and a P.N.P. transistor make possible an interesting type of circuit that is both economical and well stabilised. In this circuit of fig. 14 Tr1 is a common emitter amplifier stabilised in conventional fashion. The base of Tr2 is directly connected to the collector of Tr1 thereby saving two resistors and one capacitor. In effect, R4, Tr1 and R3 form the base bias potentiometer for Tr2. The advantage of this system over that of fig. 10 which employs 2 P.N.P. transistors in a rather similar circuit, is that no limitation is imposed upon the collector emitter voltage of the first transistor.

The OC139 is rather an expensive transistor but it may be replaced by any cheaper N.P.N. type when these become available.

CHAPTER 3

Amplifiers with Outputs between 100 mW and 1 Watt

The power range covered in this chapter is that most commonly used in pocket and portable radios, gramophones and tape recorders. The smaller 6 transistor sets normally have outputs in the range 100 to 250 mW. Partly to keep battery life within reasonable limits and partly because any higher level would either overload the speaker or cause severe distortion. The larger sets, however, nowadays tend to use 500 mW to 1 Watt not because this level is required, since the listening level normally used is 10 to 20 mW, but to avoid distortion of high peaks.

Fig. 15. 200 mW sliding bias amplifier

Except in a car radio which can be driven from an extremely large battery, class A output stages are too wasteful of power for radios in the range we are now considering. They are, however, very much more economical than class B push-pull circuits which normally require two transistors and at least one transformer. Philips of Eindhoven have developed a circuit which combines some of the advantages of both systems. It cost no more than a class A circuit and is a lot more efficient. Although not quite as efficient as a class B circuit it is still quite acceptable.

The circuit is shown in fig. 15 and, as may be seen from the diagram, no transformers are used and only a single output transistor is required. A small part of the output is developed across R7. It is rectified by the diode, an OA51, and the output from this contributes to the bias of Tr2. Since Tr2 is directly coupled to Tr3 and change in the bias of Tr2 will alter the bias of Tr3. The circuit is so arranged that an increase in the signal handled by Tr3 results in a reduction of the base bias of Tr2 and this increases the base bias of Tr3. This type of circuit is known as "sliding bias" because the bias of the last stage is automatically adjusted to suit the level of the signal.

In this particular circuit the collector current of the output stage ranges from a mean level of 35 mA to a maximum mean of 100 mA. If the sliding bias was not included the mean collector current would be 100 mA however small the signal. In practice, this technique doubles the efficiency of the amplifier because the 100 mA level is only reached on occasional peaks.

The amplifier requires a certain amount of initial adjustment. In the absence of any signal the collector current of the output stage should be adjusted to a value of 35 mA by varying VR1. A strong signal should then be fed through the amplifier to fully load the amplifier and VR2 should be adjusted for a collector current of 100 mA.

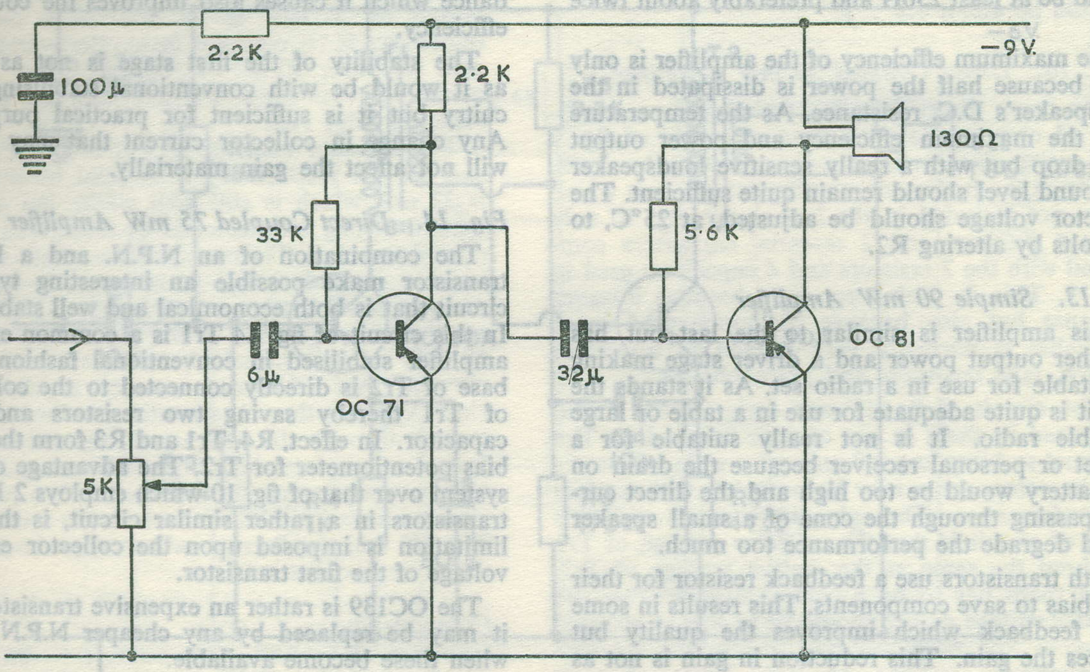

Fig. 13. Simple 90mW. amplifier.

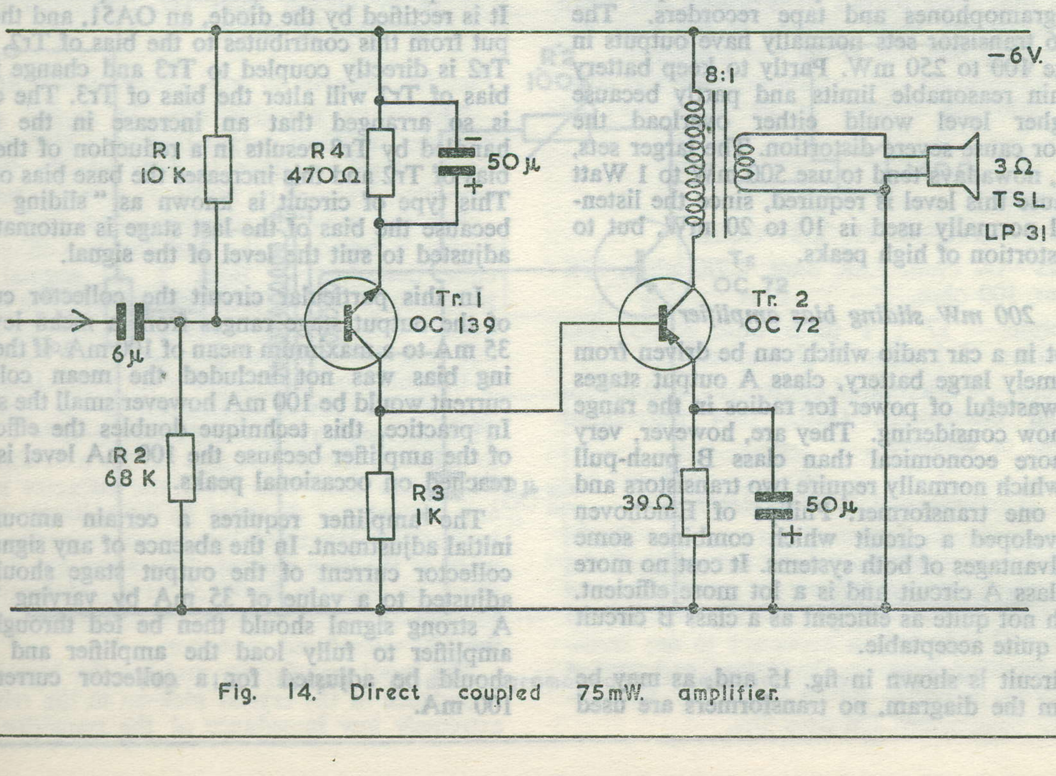

Fig. 14. Direct coupled 75mW. amplifier.

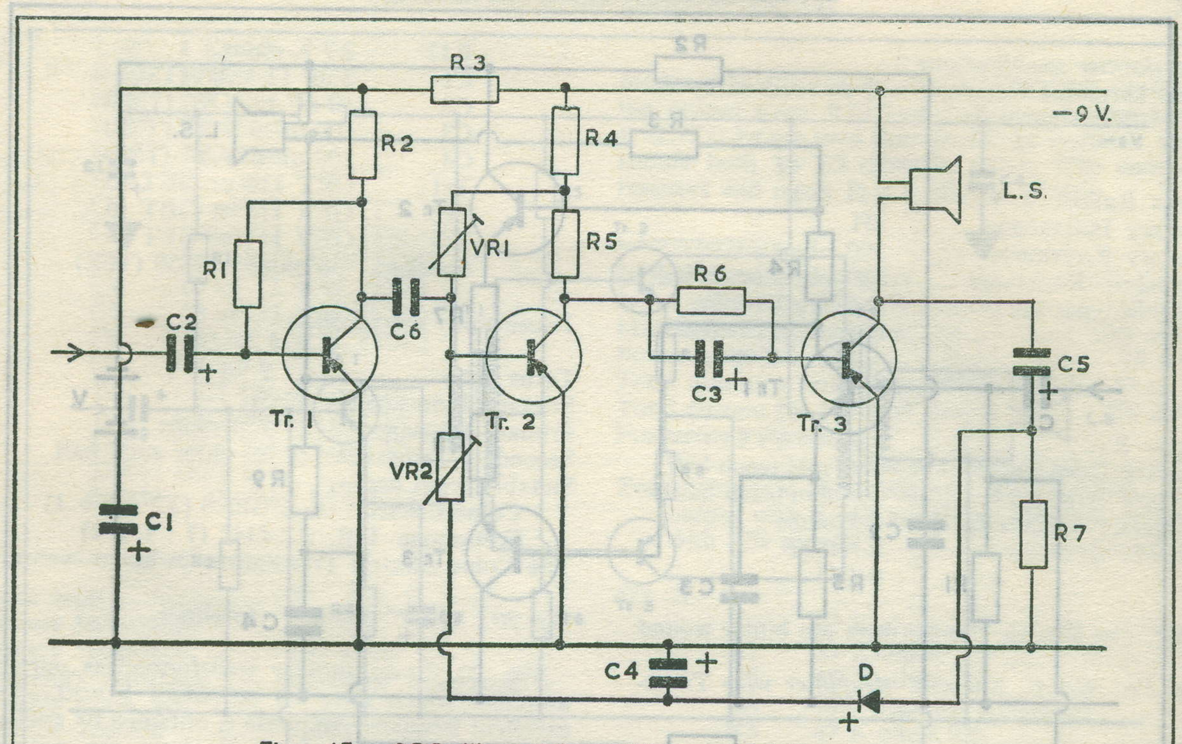

Fig. 15. 200mW. sliding bias amplifier.

Fig. 15.

R1	270 K-ohms
R2	2.2 K-ohms
R3	2.2 K-ohms
R4	560 ohms
R5	560 ohms
R6	3.9 K-ohms
R7	1.5 K-ohms
VR1	200 K-ohms Lin.
VR2	150 K-ohms
C1	100 uF 6 V.W. (TSL)
C2	2 uF 12 V.W. (TSL)
C3	2 uF 12 V.W. (TSL)
C4	25 uF 12 V.W. (TSL)
C5	2 uF 12 V.W. (TSL)
C6	2 uF 12 V.W. (TSL)
Tr1	OC71
Tr2	OC71
Tr3	OC81
D	OA51
Speaker	50 ohms (TSL) CMS50

Fig. 16. A possible configuration for a complementary symmetry amplifier

The possibility of constructing a completely transformerless class B amplifier using the principle of complementary was discussed in Book 1. In practice the transistors are not yet available in this country and only a typical circuit can be given without any component values.

Fig. 16 shows such a circuit in which the output transistors are operated in the common collector mode to avoid cross over distortion. They are driven by a single transistor to which they are directly coupled. The output of Tr1 is developed across R3 (R4 is very small in value and may be neglected). Because the common collector output stage gives no voltage gain Tr1 must develop the full output voltage. The current output of Tr1 will depend upon the current gains of Tr2 and Tr3. If these are low R3 will have to be low to achieve sufficient drive voltage and this will result in low gain and a loss of efficiency due to the high consumption of Tr1. The only alternative is to use transistors for Tr2 and Tr3 which have very high levels of Beta.

Fig. 17. Another possible complementary symmetry configuration

An alternative type of circuit is shown in fig. 17. In this case the driver stage, as well as the output stage, employs two transistors in class B push-pull. This makes the circuit more expensive but the gain is higher because all four transistors are operated in the common emitter mode. The only difficulty with this system is that, because of the D.C. coupling between the two stages, any change in the bias conditions of the first stage will cause a much larger change in the bias conditions of the output stage which may lead to instability.

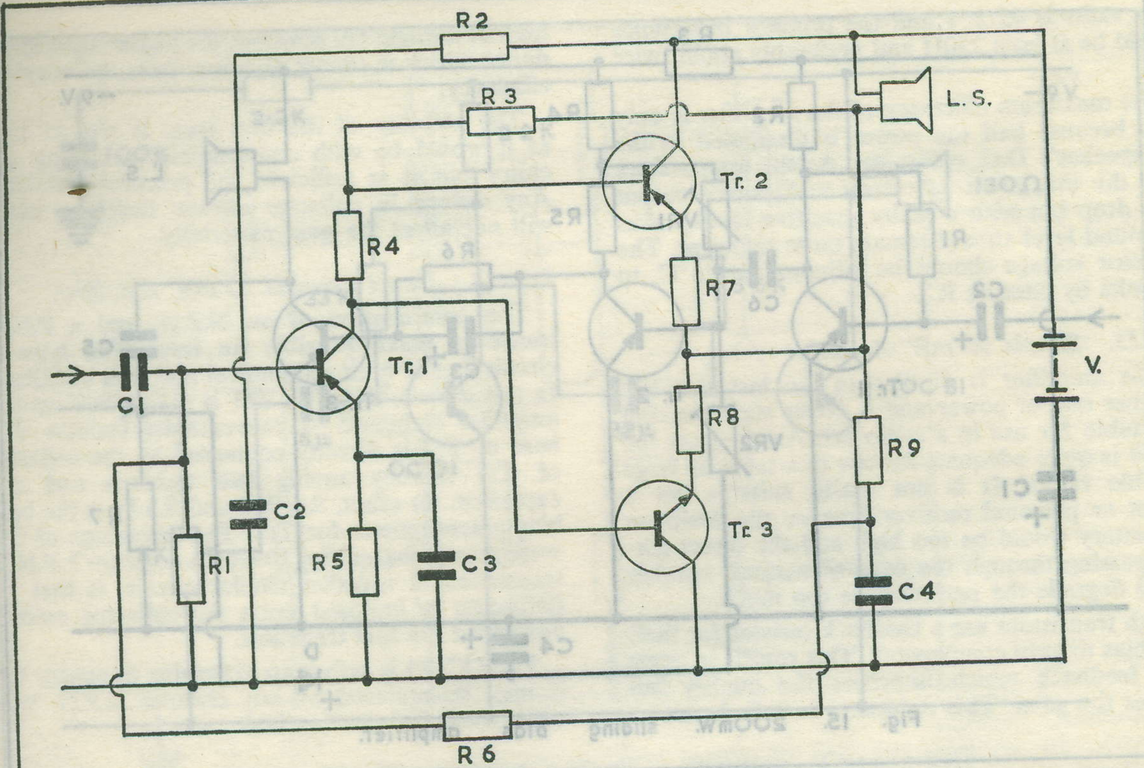

Fig. 16. A possible configuration for a complementary symmetry amplifier.

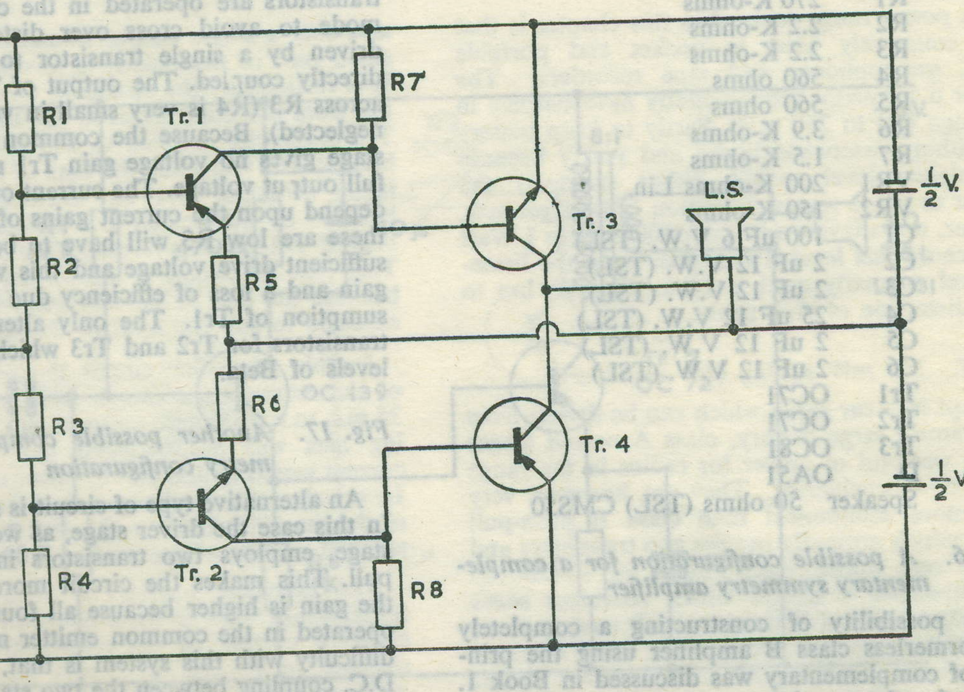

Fig. 17. Another possible complementary symmetry configuration.

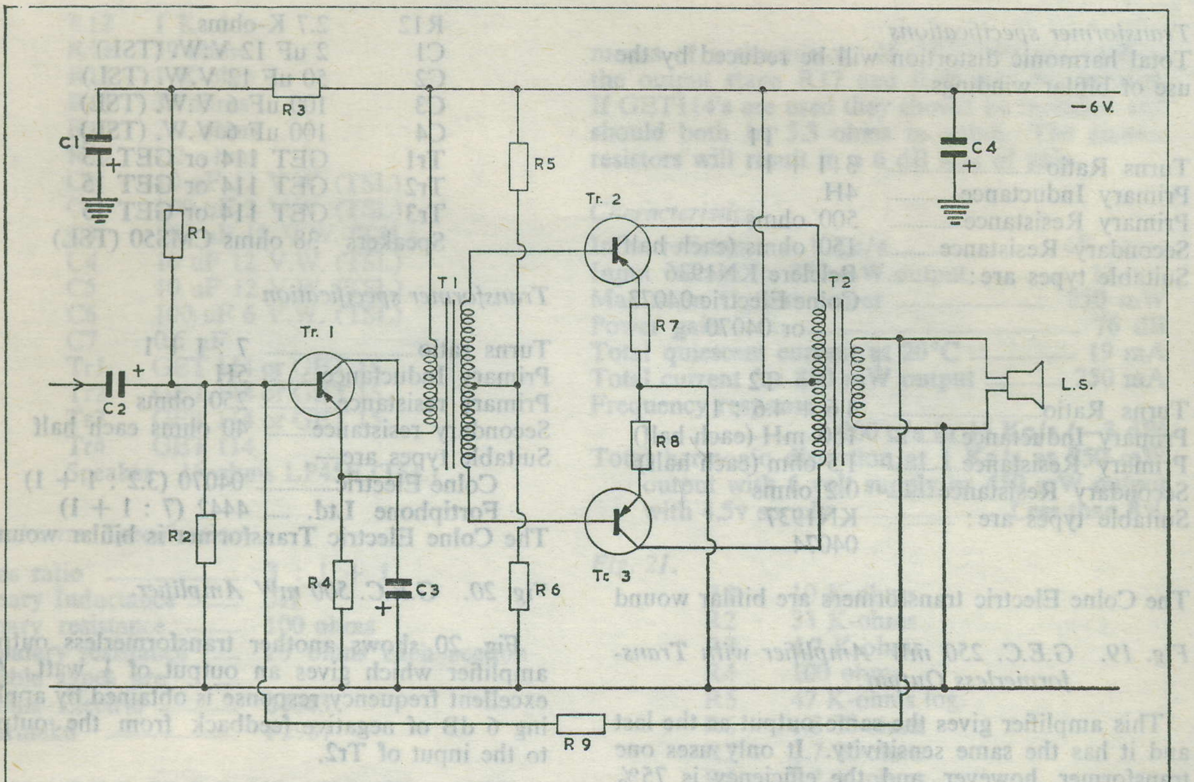

Fig. 18. G.E.C. 250mW. amplifier with symmetrical output.

The only cure for this is to include resistors R5 and R6 in the emitters of the first two transistors. These can not be bypassed by electrolytic capacitors in the normal way because the rectifying action of the base-emitter junction would charge them up to the point where they would alter the bias conditions themselves. R5 and R6, therefore, cause a loss of gain.

Fig. 18. G.E.C. 250 mW Amplifier with Symmetrical Output

This amplifier circuit, and quite a number of those further on, has been published by kind permission of the General Electric Co.

The circuit is typical of those commonly used in transistor portable radios and needs no explanation since all the design points were discussed in Book 1. Apart from the occasional comment, where required, all the amplifiers that follow will be described just by their specification. Transformer and other component details will also be given.

The characteristics of this amplifier are as follows :—

Input resistance at 1 Kc/s .... 400 ohms
Input voltage for 250 mW output .... 9 mV
Power gain .... 60 dB
Total quiescent current at 20°C .... 7 mA
Total current at 250 mW output .... 70 mA
Frequency response — 150 c/s to 20 Kc/s (—3dB)
Total harmonic distortion at 1 Kc/s for 250 mW .... Less than 8%

Fig. 18.

R1	12 K-ohms
R2	3.3 K-ohms
R3	12 K-ohms
R4	680 ohms
R5	2.7 K-ohms
R6	68 ohms
R7	3.3 ohms
R8	3.3 ohms
R9	100 K-ohms
C1	100 uF 6 V.W. (TSL)
C2	10 uF 12 V.W. (TSL)
C3	100 uF 3 V.W. (TSL)
C4	100 uF 6 V.W. (TSL)
Speaker	3 ohms LP 70 (TSL)
Tr1	GET 114
Tr2	GET 114
Tr3	GET 114

Transformer specifications

Total harmonic distortion will be reduced by the use of bifilar windings.

	T1
Turns Ratio	3:1 + 1
Primary Inductance	4H
Primary Resistance	500 ohms
Secondary Resistance	150 ohms (each half)
Suitable types are:	Belclere KN1936
	Colne Electric 04073 or 04070

	T2
Turns Ratio	4.6 + 4.6 : 1
Primary Inductance	150 mH (each half)
Primary Resistance	1.5 ohm (each half)
Secondary Resistance	0.2 ohms
Suitable types are:	KN1937
	04074

The Colne Electric transformers are bifilar wound

Fig. 19. G.E.C. 250 mW Amplifier with Transformerless Output.

This amplifier gives the same output as the last and it has the same sensitivity. It only uses one transformer, however, and the efficiency is 75% better, the maximum current drain being only 40 mA against 70 mA. The distortion is less but the frequency response is not so good. The main disadvantage is that a higher battery voltage is required but this may not matter in many applications.

Characteristics

Input resistance at 1 Kc/s	2.5K ohms
Input voltage for 230 mW output	25 mV
Power gain	70 dB
Total quiescent current at 20°C	7 mA
Total current for 230 mW output	40 mA
Frequency response	200 c/s to 11 Kc/s (—3 dB)
Total harmonic distortion at 1,000 c/s at 230 mW output	less than 6%

Fig. 19.

R1	5 K-ohms
R2	3.3 K-ohms
R3	33 K-ohms
R4	10 K-ohms
R5	15 ohms
R6	1 K-ohm
R7	680 ohms
R8	2.7 K-ohms
R9	100 ohms
R10	2.7 K-ohms
R11	100 ohms
R12	2.7 K-ohms
C1	2 uF 12 V.W. (TSL)
C2	50 uF 12 V.W. (TSL)
C3	100 uF 6 V.W. (TSL)
C4	100 uF 6 V.W. (TSL)
Tr1	GET 114 or GET 15
Tr2	GET 114 or GET 15
Tr3	GET 114 or GET 15
Speakers	38 ohms CMS50 (TSL)

Transformer specification

Turns ratio	7 : 1 + 1
Primary Inductance	5H
Primary resistance	250 ohms
Secondary resistance	40 ohms each half
Suitable types are—	
Colne Electric	04070 (3.2 : 1 + 1)
Fortiphone Ltd.	4442 (7 : 1 + 1)

The Colne Electric Transformer is bifilar wound.

Fig. 20. G.E.C. 500 mW Amplifier.

Fig. 20 shows another transformerless output amplifier which gives an output of ½ watt. An excellent frequency response is obtained by applying 6 dB of negative feedback from the output to the input of Tr2.

Characteristics

Input resistance of preamplifier at 400 c/s	4.5K ohms
Input voltage to preamplifier for 450 mW output	7.5 mV
Input resistance of driver at 400 c/t	250 ohms
Input voltage to driver for 450 mM output	20 mV
Power gain — with preamplifier	76 dB
Power gain — without preamplifier	54 dB
Total quiescent current at 20°C.	15 mA
Total current at 450 mW	85mA
Peak power dissipation of each output transistor	100 mW
Frequency response	90 c/s — 20Kc/s (— 3 dB)
Total harmonic distortion at 400 c/s at 450 mW output	Less than 5%

Fig. 20.

R1	15 K-ohms
R2	82 K-ohms
R3	5.6 K-ohms
R4	100 ohms
R5	1.5 K-ohms
R6	47 K-ohms log.
R7	2.2 K-ohms
R8	6.8 K-ohms
R9	390 ohms
R10	390 ohms
R11	100 K-ohms

R12	1 K-ohm
R13	39 ohms
R14	1 K-ohm
R15	39 ohms
R16	2.2 ohms
R17	2.2 ohms
C1	10 uF 12 V.W. (TSL)
C2	100 uF 3 V.W. (TSL)
C3	100 uF 12 V.W. (TSL)
C4	10 uF 12 V.W. (TSL)
C5	10 uF 12 V.W. (TSL)
C6	100 uF 6 V.W. (TSL)
C7	0.5 uF
Tr1	GET 114 or GET 15
Tr2	GET 114 or GET 15
Tr3	GET 114 or GET 15
Tr4	GET 114
Speaker	15 ohms LP45F (TSL)

Transformer Specification

Turns ratio	3 : 1 + 1
Primary Inductance	3H
Primary resistance	100 ohms
Secondary resistance	20 ohms each section
Suitable types are :	
Colne Electric	04043
Parmeko	P2937

Fig. 21. G.E.C. High Stability 850 mW Amplifier

The output stage of this amplifier, which is otherwise like the last, is thermally stabilised by means of a thermistor. If GET115's are used in the output stage R17 and R18 may be omitted. If GET114's are used they should be included and should both be 3.3 ohms in value. The emitter resistors will result in a 6 dB loss of gain.

Characteristics

Input resistance at 1 Kc/s	6K ohms
Input voltage for 850 mW output	12 mV
Maximum Output power	850 mW
Power gain	76 dB
Total quiescent current at 20°C	19 mA
Total current for 850 mW output	250 mA
Frequency response	200 c/s to 15 Kc/s (—3 dB)
Total harmonic distortion at 1 Kc/s at 850 mW output with 6 volt supply or 450 mW output with 4.5v supply	Less than 8%

Fig. 21.

R1	10 K-ohms
R2	33 K-ohms
R3	4.7 K-ohms
R4	100 ohms
R5	47 K-ohms log.
R6	1.8 K-ohms
R7	2.7 K-ohms
R8	8.2 K-ohms
R9	150 ohms
R10	220 ohms
R11	Stantel thermistor type K22

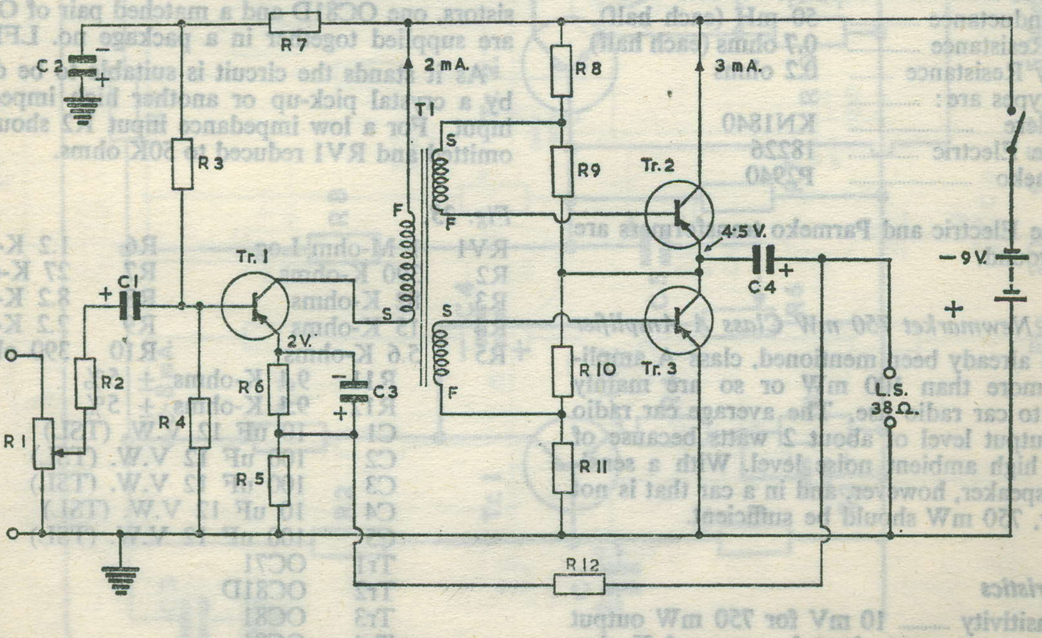

Fig. 19. G.E.C. 250mW amplifier with transformerless output stage.

R12	47 K-ohms
R13	68 ohms
R14	47 ohms Preset
R15	180 ohms
R16	680 ohms
R17, R18	See Text for values
C1	10 uF 12 V.W. (TSL)
C2	50 uF 3 V.W. (TSL)
C3	100 uF 6 V.W. (TSL)
C4	10 uF 12 V.W. (TSL)
C5	10 uF 12 V.W. (TSL)
C6	100 uF 3 V.W. (TSL)
C7	470 pf
C8	100 uF 6 V.W. (TSL)
Tr1	GET 114
Tr2	GET 114
D1	SX 640
Tr3 & Tr4	GET 114's or GET 15's or GET 115's
L.S.	3 ohms LP45F (TSL)

Transformer Specification

	T1
Turns ratio	2 : 1 + 1
Primary Inductance	2H
Primary resistance	20 ohms
Secondary resistance	5 ohms (each half)
Suitable types are :—	
Belclere	KN1839
Colne Electric	04043 or 04047
Parmeko	P2939 or P2941

	T2
Turns Ratio	2.25 + 2.25 : 1
Primary Inductance	50 mH (each half)
Primary Resistance	0.7 ohms (each half)
Secondary Resistance	0.2 ohms
Suitable types are:	
Belclere	KN1840
Colne Electric	18226
Parmeko	P2940

The Colne Electric and Parmeko transformers are bifilar wound.

Fig. 22. Newmarket 750 mW Class A Amplifier

As has already been mentioned, class A amplifiers of more than 100 mW or so are mainly confined to car radio use. The average car radio has an output level of about 2 watts because of the very high ambient noise level. With a sensitive loudspeaker, however, and in a car that is not too noisy, 750 mW should be sufficient.

Characteristics

Input sensitivity	10 mV for 750 mW output
Input impedance approximately	1 K ohm
Overall power gain	70 dB
Distortion for 750 mW	less than 10%
Battery current drain	300 mA

Fig. 22.

R1	22 K-ohms	R7	560 ohms
R2	1.8 K-ohms	R8	470 ohms
R3	470 ohms	R9	100 ohms
R4	3 K-ohms	R10	220 ohms
R5	220 ohms	R11	22 ohms
R6	3.9 K-ohms	R12	5 ohms

C1	10 uF 12 V.W. (TSL)
C2	100 uF 12 V.W. (TSL)
C3	10 uF 12 V.W. (TSL)
C4	100 uF 6 V.W. (TSL)
C5	10 uF 12 V.W. (TSL)
C6	100 uF 6 V.W. (TSL)
C7	500 uF 6 V.W. (TSL)
Tr1	V10/50A
Tr2	V10/30A
Tr3	V15/201P
L.S.	3 ohms LP45F (TSL)

Transformer Specification

Turns ratio	3 : 1
Minimum primary inductance	130 mH
Maximum primary D.C. resistance	1 ohm

Fig. 23. Mullard 540 mW amplifier

This amplifier uses the split load principle to achieve a reasonable compromise between gain and quality. The frequency response is 110 c/s to 4.3 Kc/s at the 3 dB down points. The sensitivity is between 250 and 350 mV with 10% total harmonic distortion. The driver and output transistors, one OC81D and a matched pair of OC81's are supplied together in a package no. LFH3.

As it stands the circuit is suitable to be driven by a crystal pick-up or another high impedance input. For a low impedance input R2 should be omitted and RV1 reduced to 50K ohms.

Fig. 23.

RV1	1 M-ohm Log.	R6	1.2 K-ohms
R2	390 K-ohms	R7	27 K-ohms
R3	82 K-ohms	R8	8.2 K-ohms
R4	15 K-ohms	R9	2.2 K-ohms
R5	5.6 K-ohms	R10	390 ohms

R11	9.1 K-ohms ± 5%
R12	9.1 K-ohms ± 5%
C1	10 uF 12 V.W. (TSL)
C2	100 uF 12 V.W. (TSL)
C3	100 uF 12 V.W. (TSL)
C4	10 uF 12 V.W. (TSL)
C5	100 uF 12 V.W. (TSL)
Tr1	OC71
Tr2	OC81D
Tr3	OC81
Tr4	OC81
L.S.	3 ohms LP31 (TSL)

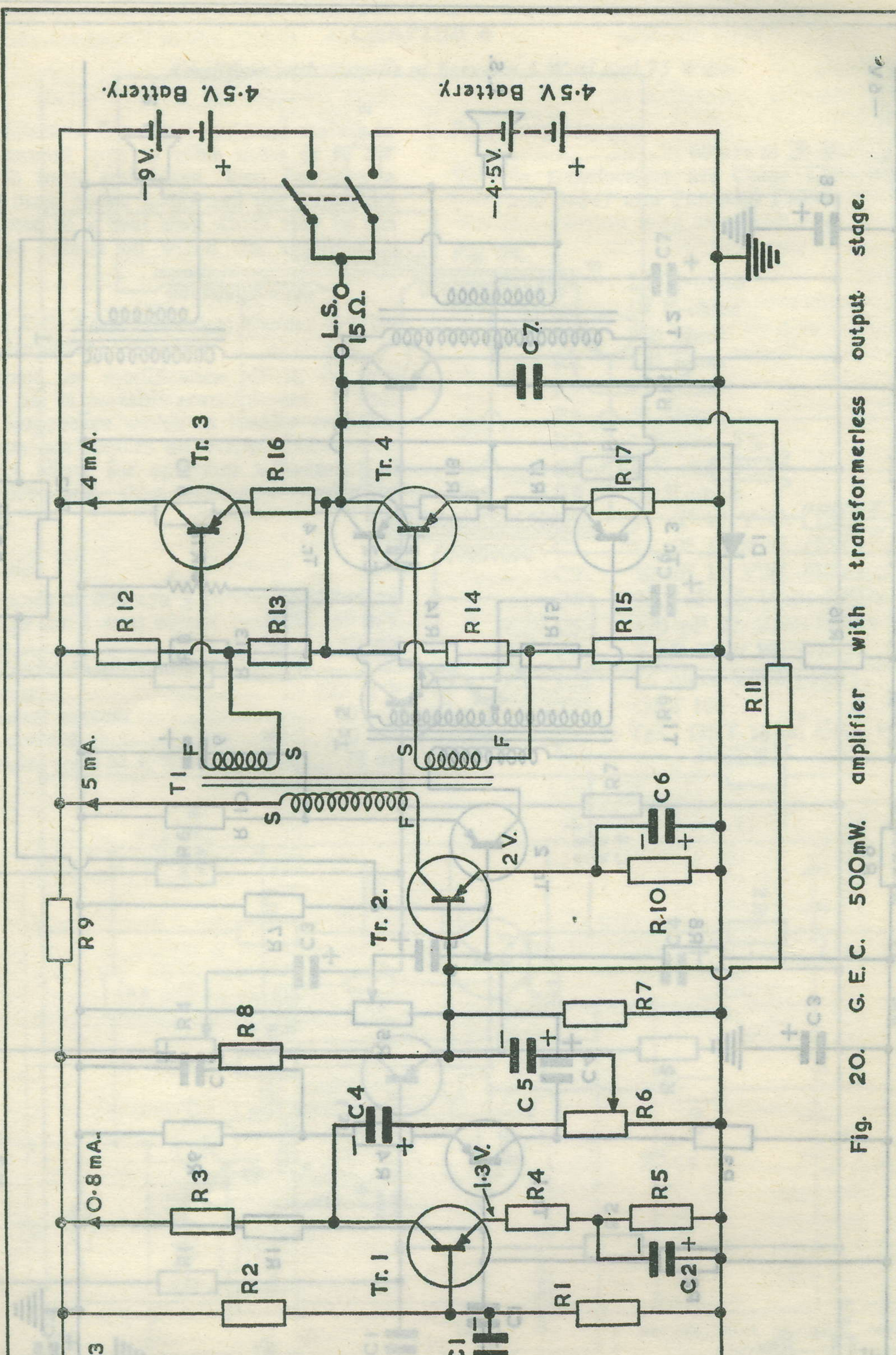

Fig. 20. G. E. C. 500mW. amplifier with transformerless output stage.

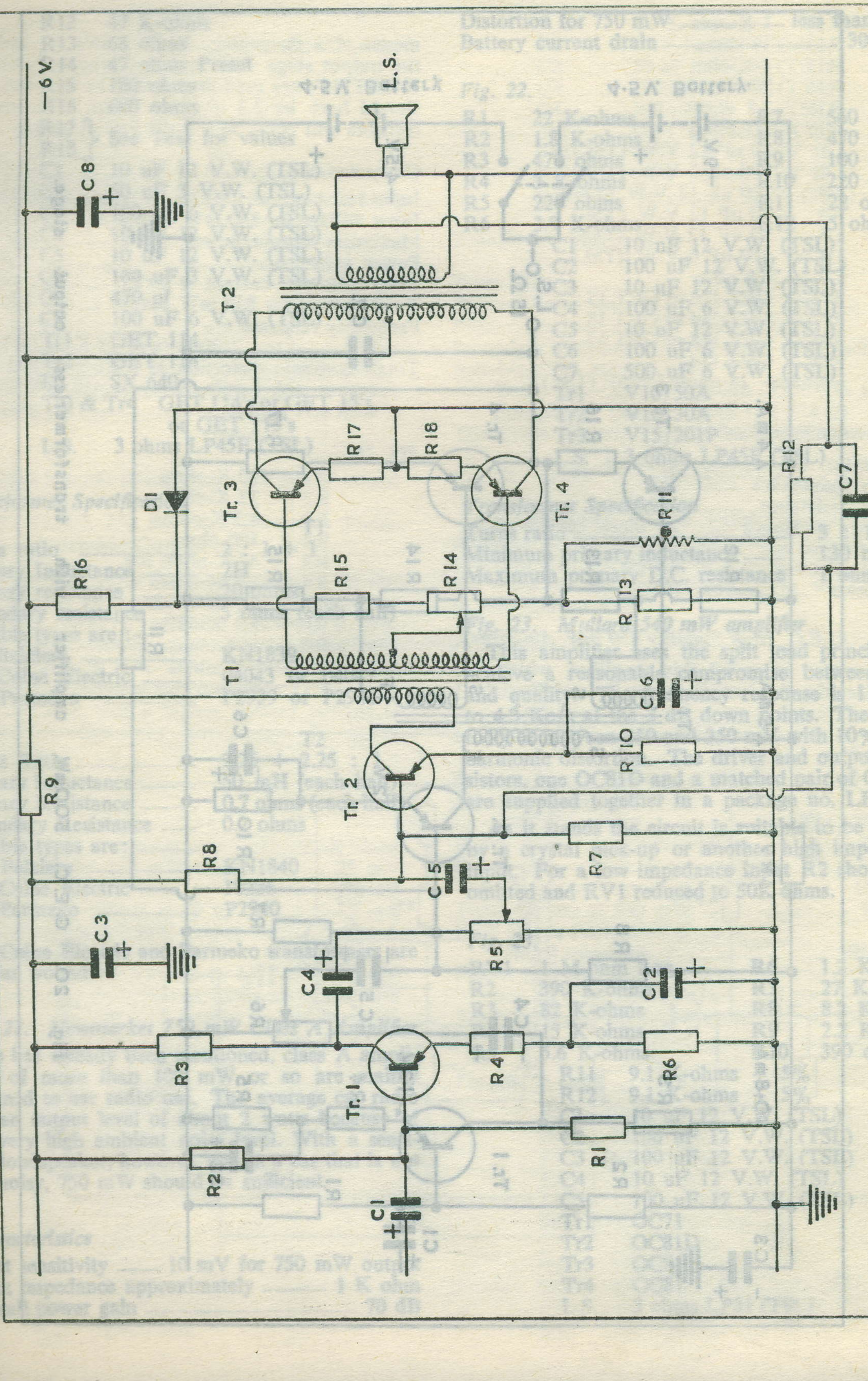

Fig. 21. G. E. C. high stability 850mW. amplifier.

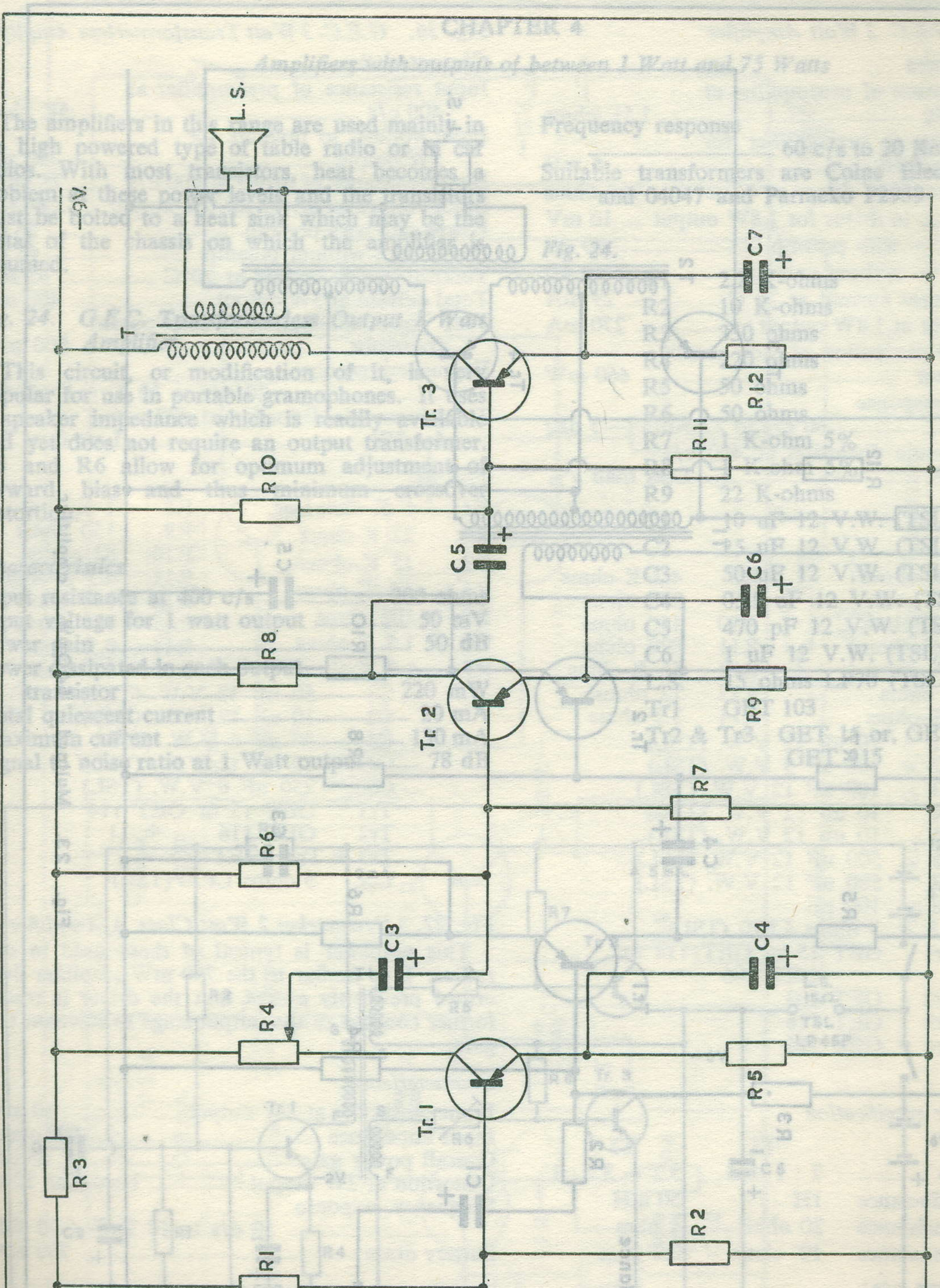

Fig. 22. Newmarket 750mW. class A amplifier.

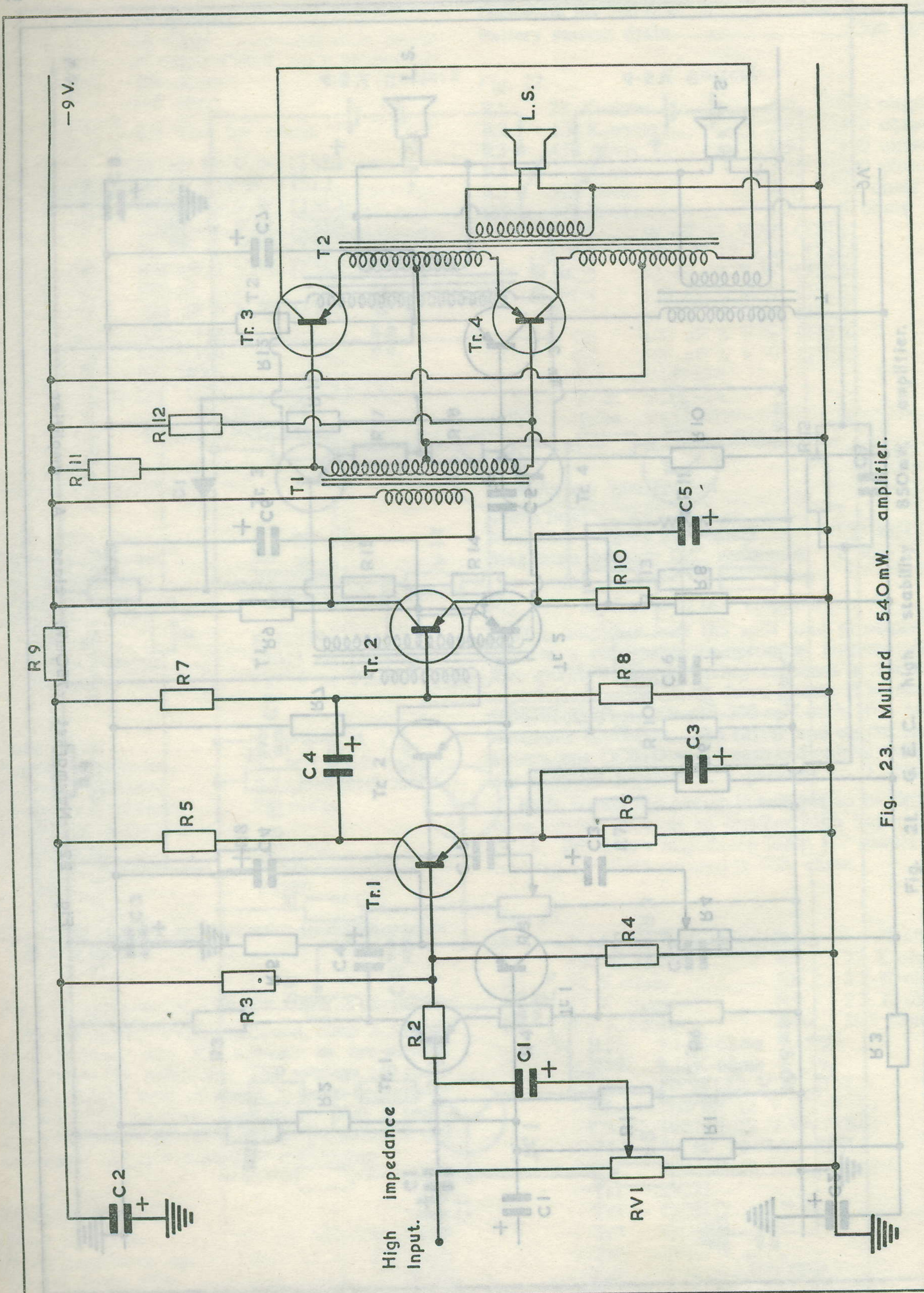

Fig. 23. Mullard 540mW. amplifier.

CHAPTER 4

Amplifiers with outputs of between 1 Watt and 75 Watts

The amplifiers in this range are used mainly in the high powered type of table radio or in car radios. With most transistors, heat becomes a problem at these power levels and the transistors must be bolted to a heat sink which may be the metal of the chassis on which the amplifier is mounted.

Fig. 24. G.E.C. Transformerless Output 1 Watt Amplifier

This circuit, or modification of it, is very popular for use in portable gramophones. It uses a speaker impedance which is readily available and yet does not require an output transformer. R5 and R6 allow for optimum adjustment of forward bias and thus minimum crossover distortion.

Characteristics

Input resistance at 400 c/s	300 ohms
Input voltage for 1 watt output	50 mV
Power gain	50 dB
Power dissipated in each output transistor	220 mW
Total quiescent current	20 mA
Maximum current	130 mA
Signal to noise ratio at 1 Watt output	78 dB
Frequency response	60 c/s to 20 Kc/s ± 2 dB

Suitable transformers are Colne Electric 04043 and 04047 and Parmeko P2939

Fig. 24.

R1	2.2 K-ohms
R2	10 K-ohms
R3	330 ohms
R4	220 ohms
R5	50 ohms
R6	50 ohms
R7	1 K-ohm 5%
R8	1 K-ohm 5%
R9	22 K-ohms
C1	10 uF 12 V.W. (TSL)
C2	25 uF 12 V.W. (TSL)
C3	50 uF 12 V.W. (TSL)
C4	0.25 uF 12 V.W. (TSL)
C5	470 pF 12 V.W. (TSL)
C6	1 uF 12 V.W. (TSL)
L.S.	15 ohms LP70 (TSL)
Tr1	GET 103
Tr2 & Tr3	GET 15 or, GET 114 or GET 115

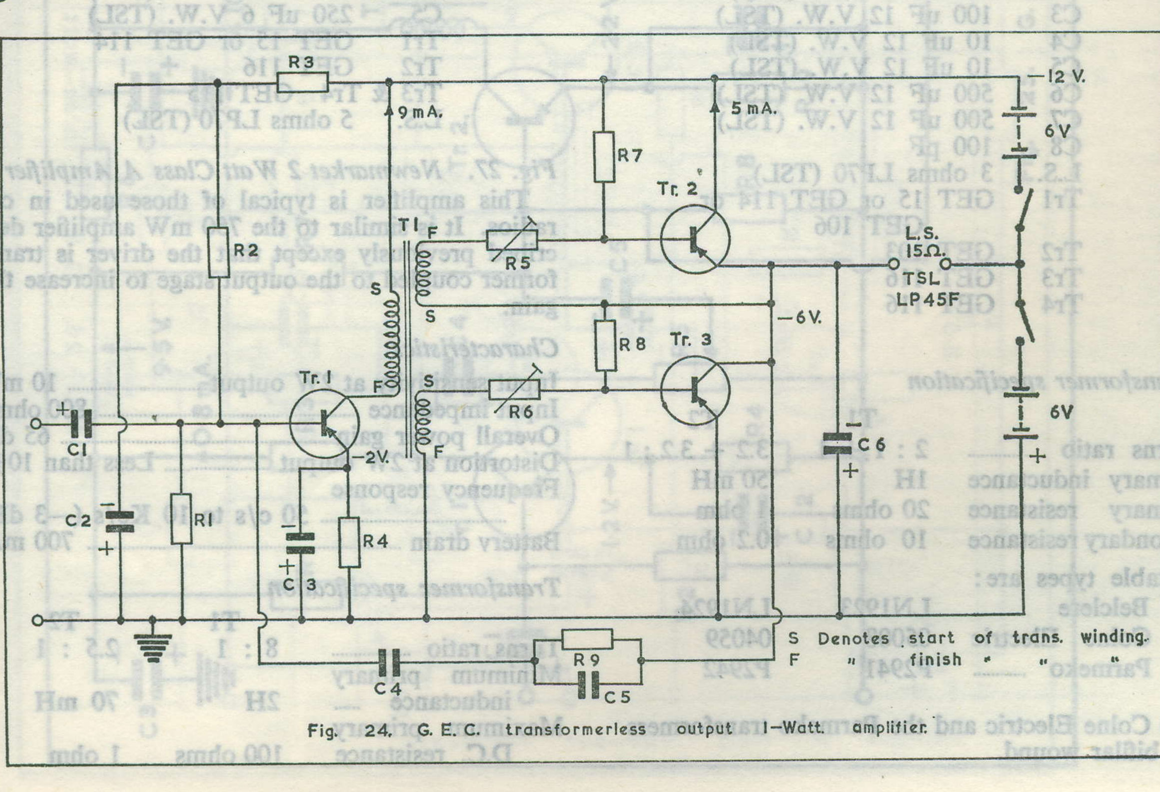

Fig. 24. G.E.C. transformerless output 1-Watt amplifier.

Fig. 25. G.E.C. 2 Watt Amplifier

Characteristics

Input resistance of preamplifier at 400 c/s	1.5K ohms
Input voltage to preamplifier for 1.8W output	5 mV
Input resistance of driver at 400 c/s	150 ohms
Input voltage to driver for 1.8W output	16 mV
Power gain — with preamp.	80 dB
Power gain — without preamp.	60 dB
Total quiescent current at 20°C	29 mA
Total current at 1.8W output	270 mA
Peak power dissipation of each output transistor	460 mW
Frequency response	60 c/s to 22 Kc/s (—3 dB)
Total harmonic distortion at 400 c/s at 1.8W	Less than 7%

Fig. 25.

R1	82 K-ohms	R8	4.7 K-ohms
R2	15 K-ohms	R9	220 ohms
R3	5.6 K-ohms	R10	150 ohms
R4	1.5 K-ohms	R11	820 ohms
R5	50 K-ohms	R12	56 K-ohms
R6	220 ohms	R13	12 ohms
R7	10 K-ohms	R14	3.3 ohms

C1	10 uF 12 V.W. (TSL)
C2	100 uF 3 V.W. (TSL)
C3	100 uF 12 V.W. (TSL)
C4	10 uF 12 V.W. (TSL)
C5	10 uF 12 V.W. (TSL)
C6	500 uF 12 V.W. (TSL)
C7	500 uF 12 V.W. (TSL)
C8	100 pF
L.S.	3 ohms LP70 (TSL)
Tr1	GET 15 or GET 114 or GET 106
Tr2	GET 103
Tr3	GET 116
Tr4	GET 116

Transformer specification

	T1	T2
Turns ratio	2 : 1 + 1	3.2 + 3.2 : 1
Primary inductance	1H	50 mH
Primary resistance	20 ohms	1 ohm
Secondary resistance	10 ohms	0.2 ohm
Suitable types are:		
Belclere	LN1923	LN1924
Colne Electric	05008	04059
Parmeko	P2941	P2942

The Colne Electric and the Parmeko transformers are bifilar wound.

Fig. 26. G.E.C. 3 Watt Transformerless Amplifier

Characteristics

Input resistance of preamplifier at 400 c/s	5K ohms
Input voltage to preamp. for 3W output	150 mV
Input resistance of driver at 400 c/s	75 ohms
Input voltage to driver for 3W output	80 mV
Power gain with preamp.	58 dB
Power gain without preamp.	45 dB
Total quiescent current at 20°C	65 mA
Total current at 3W output	400 mA
Peak power dissipation of each output transistor	800 mW
Frequency response	20 c/s to 30 Kc/s (—3 dB)
Total harmonic distortion at 400 c/s for 3W	Less than 5%

Fig. 26.

R1	5 K-ohm Log.	R8	1 K-ohm
R2	22 K-ohms	R9	150 ohms
R3	15 K-ohms	R10	82 ohms
R4	1.5 K-ohms	R11	4.7 K-ohms
R5	100 ohms	R12	270 ohms
R6	1.5 K-ohms	R13	270 ohms
R7	2.2 K-ohms	R14	0.5 ohms
		R15	0.5 ohms

C1	50 uF 12 V.W. (TSL)
C2	10 uF 12 V.W. (TSL)
C3	50 uF 6 V.W. (TSL)
C4	10 uF 12 V.W. (TSL)
C5	250 uF 6 V.W. (TSL)
Tr1	GET 15 or GET 114
Tr2	GET 116
Tr3 & Tr4	GET 115
L.S.	5 ohms LP70 (TSL)

Fig. 27. Newmarket 2 Watt Class A Amplifier

This amplifier is typical of those used in car radios. It is similar to the 750 mW amplifier described previously except that the driver is transformer coupled to the output stage to increase the gain.

Characteristics

Input sensitivity at 2W output	10 mV
Input impedance	800 ohms
Overall power gain	65 dB
Distortion at 2W output	Less than 10%
Frequency response	50 c/s to 10 Kc/s (—3 dB)
Battery drain	700 mA

Transformer specification

	T1	T2
Turns ratio	8 : 1	2.5 : 1
Minimum primary inductance	2H	70 mH
Maximum primary D.C. resistance	100 ohms	1 ohm

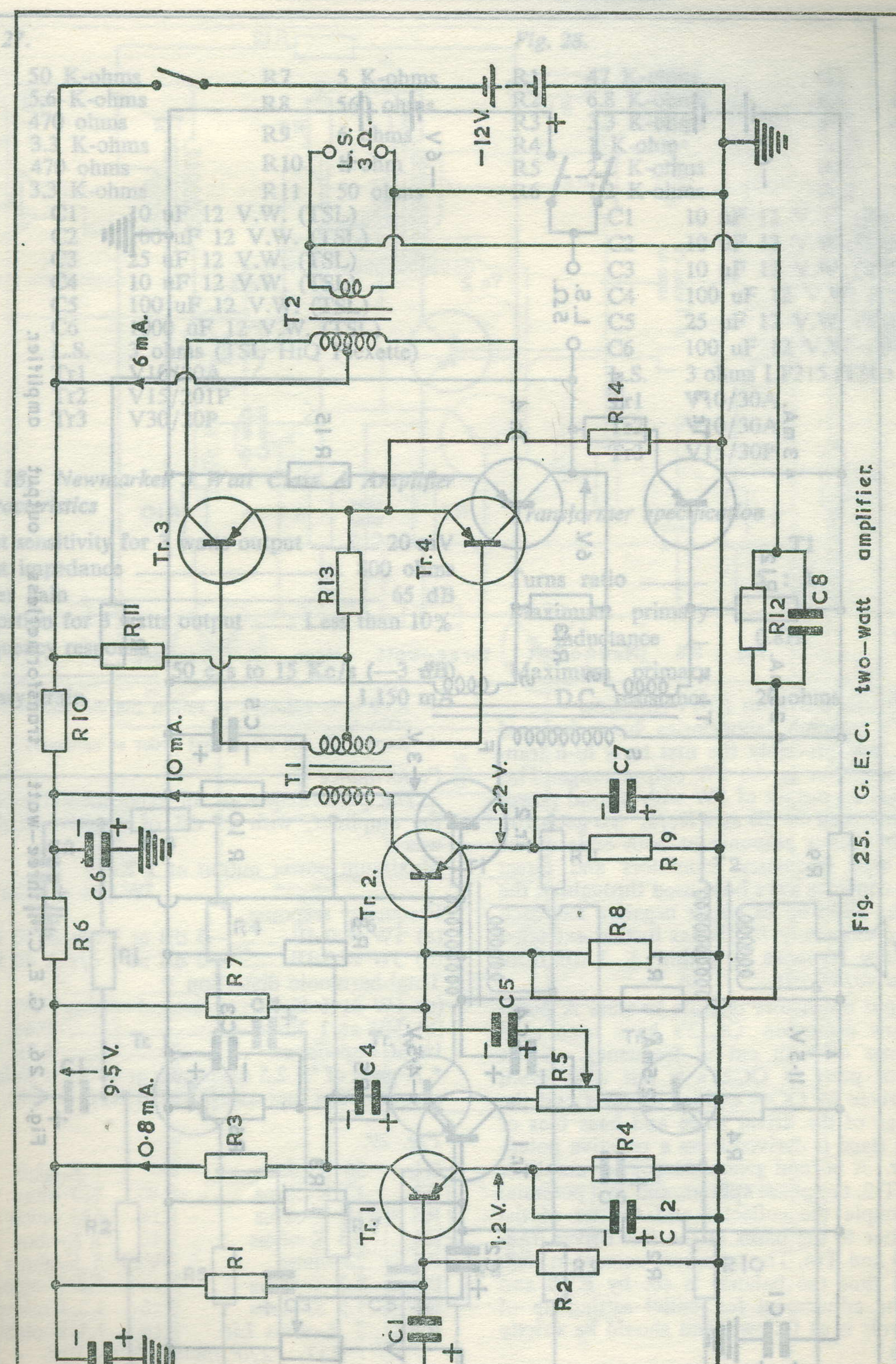

Fig. 25. G. E. C. two-watt amplifier.

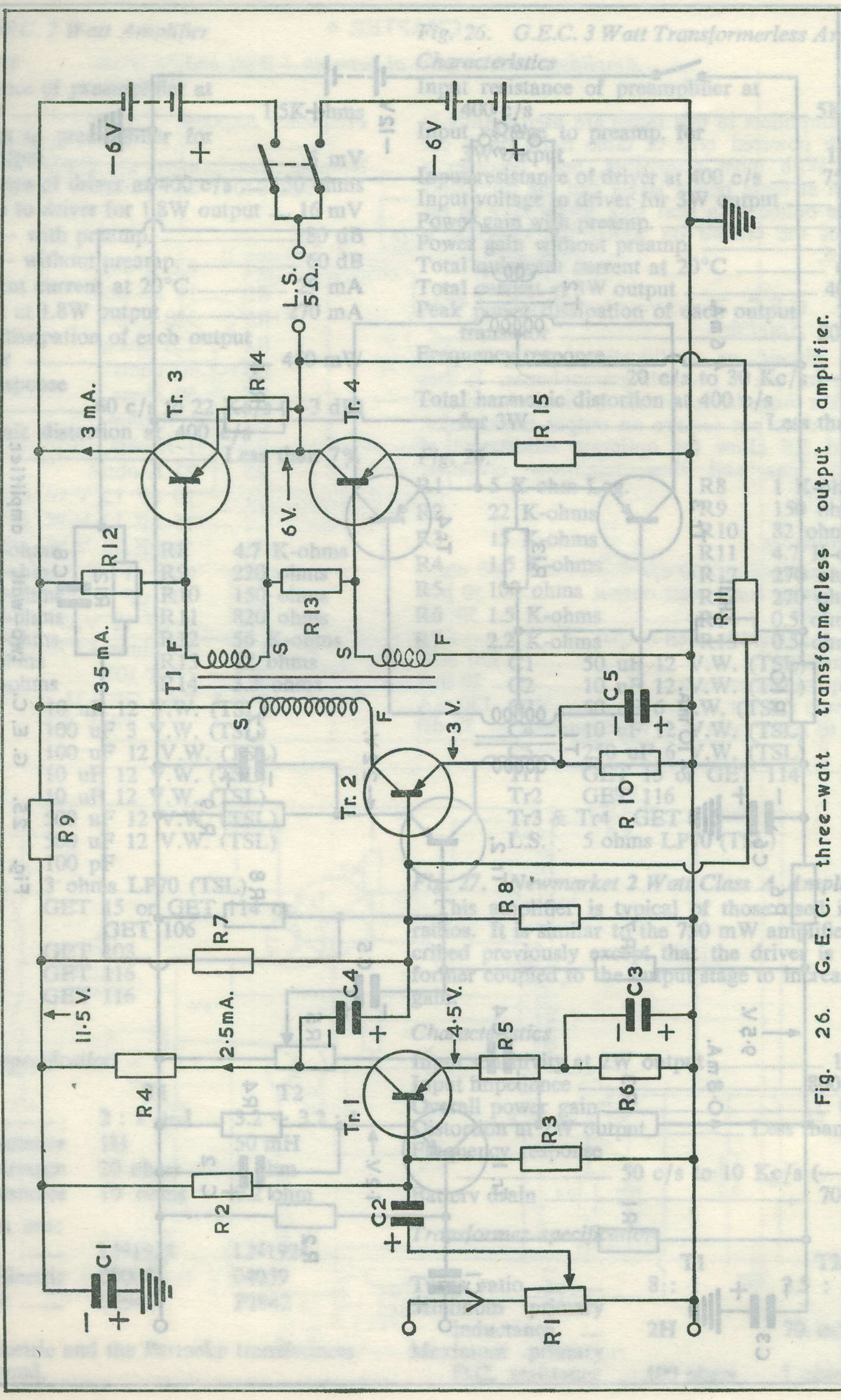

Fig. 26. G.E.C. three-watt transformerless output amplifier.

Fig. 27.

R1	50 K-ohms	R7	5 K-ohms
R2	5.6 K-ohms	R8	560 ohms
R3	470 ohms	R9	6 ohms
R4	3.3 K-ohms	R10	1 ohm
R5	470 ohms	R11	50 ohms
R6	3.3 K-ohms		

C1	10 uF 12 V.W. (TSL)
C2	100 uF 12 V.W. (TSL)
C3	25 uF 12 V.W. (TSL)
C4	10 uF 12 V.W. (TSL)
C5	100 uF 12 V.W. (TSL)
C6	1000 uF 12 V.W. (TSL)
L.S.	3 ohms (TSL HiQ Flexette)
Tr1	V10/30A
Tr2	V15/201P
Tr3	V30/20P

Fig. 28. Newmarket 3 Watt Class A Amplifier Characteristics

Input sensitivity for 3 watts output	20 mV
Input impedance	800 ohms
Power gain	65 dB
Distortion for 3 watts output	Less than 10%
Frequency response	50 c/s to 15 Kc/s (—3 dB)
Battery drain	1,150 mA

Fig. 28.

R1	47 K-ohms	R7	150 ohms
R2	6.8 K-ohms	R8	8 ohms
R3	3.3 K-ohms	R9	68 ohms
R4	1 K-ohm	R10	1 ohm
R5	2.2 K-ohms	R11	470 ohms
R6	1.2 K-ohms	R12	10 K-ohms

C1	10 uF 12 V.W. (TSL)
C2	10 uF 12 V.W. (TSL)
C3	10 uF 12 V.W. (TSL)
C4	100 uF 12 V.W. (TSL)
C5	25 uF 12 V.W. (TSL)
C6	100 uF 12 V.W. (TSL)
L.S.	3 ohms LP215 (TSL)
Tr1	V10/30A
Tr2	V10/30A
Tr3	V15/30P

Transformer specification

	T1	T2
Turns ratio	5 : 1	1.5 : 1
Maximum primary inductance	0.8H	24 mH
Maximum primary D.C. resistance	20 ohms	0.5 ohms

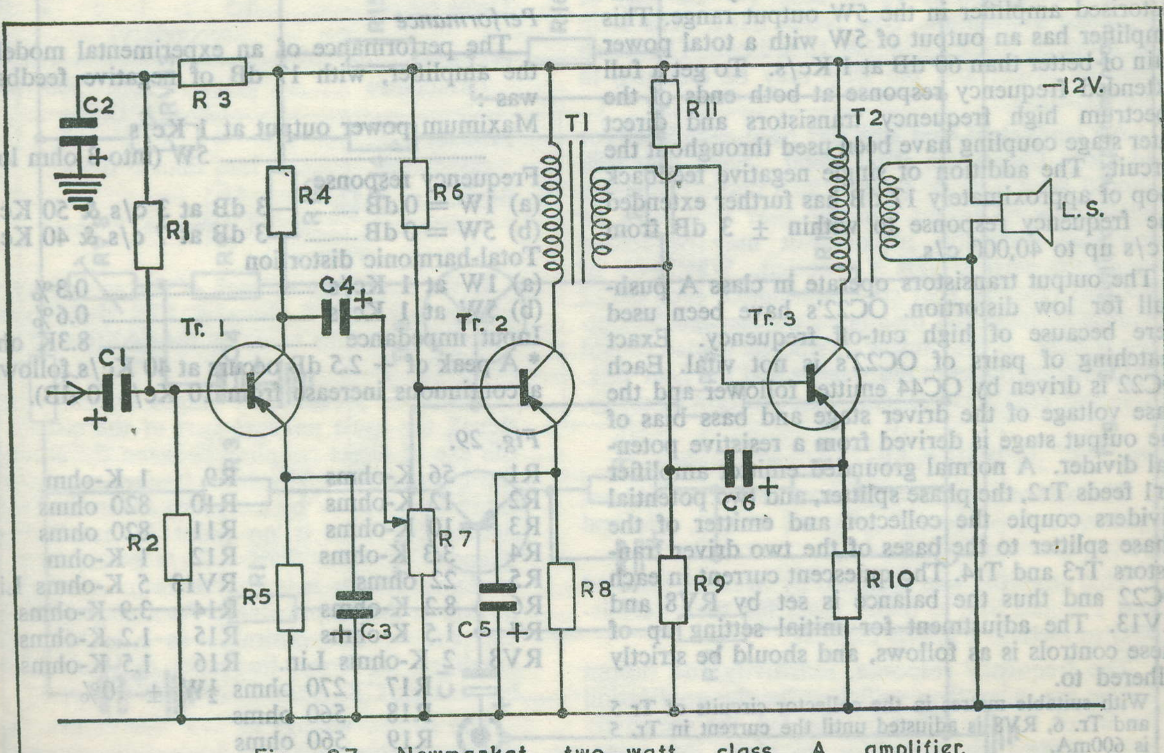

Fig. 27. Newmarket two-watt class A amplifier.

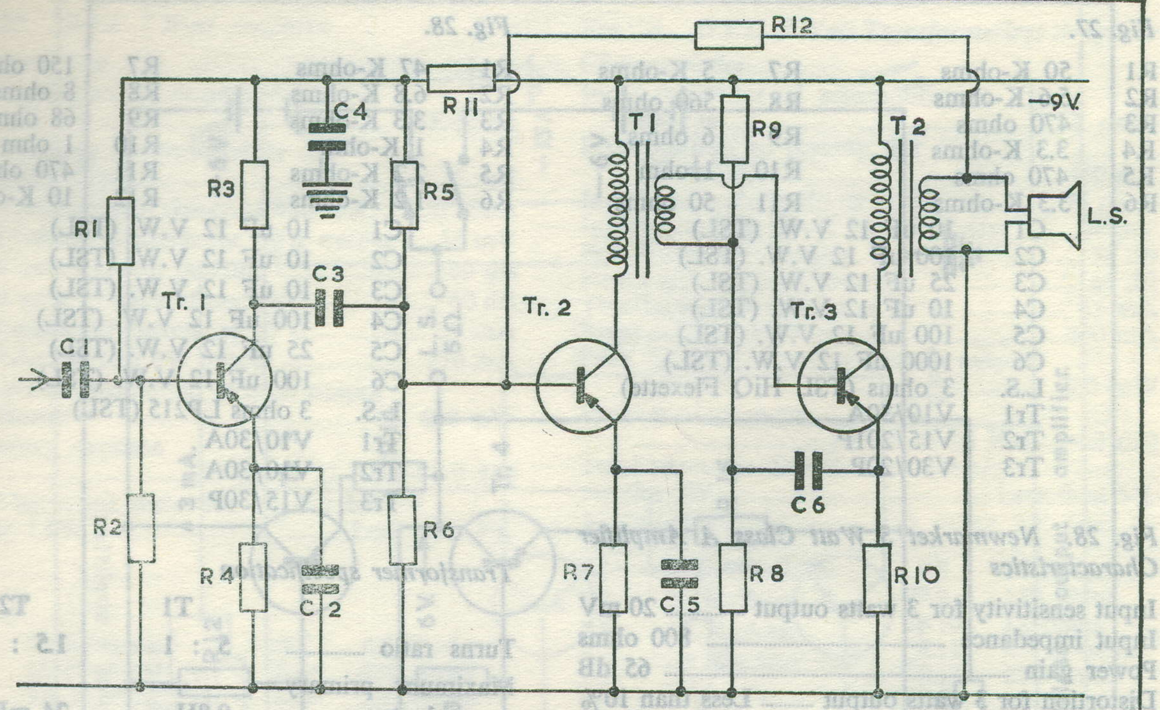

Fig. 28. Newmarket three-watt class A amplifier.

Fig. 29. Mullard 5 Watt Hi-Fi Amplifier

Mullard's research laboratories have designed with great care probably the first truly hi-fi transistorised amplifier in the 5W output range. This amplifier has an output of 5W with a total power gain of better than 60 dB at 1 Kc/s. To get a full extended frequency response at both ends of the spectrum high frequency transistors and direct inter stage coupling have been used throughout the circuit. The addition of single negative feedback loop of approximately 17 dB has further extended the frequency response to within ± 3 dB from 7 c/s up to 40,000 c/s.

The output transistors operate in class A push-pull for low distortion. OC22's have been used here because of high cut-off frequency. Exact matching of pairs of OC22's is not vital. Each OC22 is driven by OC44 emitter follower and the base voltage of the driver stage and bass bias of the output stage is derived from a resistive potential divider. A normal grounded emitter amplifier Tr1 feeds Tr2, the phase splitter, and two potential dividers couple the collector and emitter of the phase splitter to the bases of the two driver transistors Tr3 and Tr4. The quiescent current in each OC22 and thus the balance is set by RV8 and RV13. The adjustment for initial setting up of these controls is as follows, and should be strictly adhered to.

1. With suitable metres in the collector circuits of Tr 5 and Tr. 6, RV8 is adjusted until the current in Tr. 5 is 600mA.
2. RV13 is then adjusted to make the current in Tr 6 equal to 600mA.
3. RV8 is re-adjusted to return the current in Tr 5 to 600mA.
4. Repeat (2) and (3) in that order as necessary.

Performance

The performance of an experimental model of the amplifier, with 17 dB of negative feedback, was :

Maximum power output at 1 Kc/s .... 5W (into 3 ohm load)

Frequency response

(a) 1W = 0 dB .... —3 dB at 3 c/s & 50 Kc/s*

(b) 5W = 0 dB .... —3 dB at 7 c/s & 40 Kc/s

Total-harmonic distortion

(a) 1W at 1 Kc/s 0.3%

(b) 5W at 1 Kc/s 0.6%

Input impedance .... 8.3K ohms

* A peak of + 2.5 dB occurs at 40 Kc/s following a continuous increase from 10 Kc/s (0 dB).

Fig. 29.

R1	56 K-ohms	R9	1 K-ohm
R2	12 K-ohms	R10	820 ohms
R3	10 K-ohms	R11	820 ohms
R4	3.3 K-ohms	R12	1 K-ohm
R5	22 ohms	RV13	5 K-ohms Lin.
R6	8.2 K-ohms	R14	3.9 K-ohms
R7	1.5 K-ohms	R15	1.2 K-ohms
RV8	2 K-ohms Lin.	R16	1.5 K-ohms
R17	270 ohms ½W ± 10%		
R18	560 ohms		
R19	560 ohms		
R20	1.65 ohms 6W ± 10%		
R21	560 ohms		

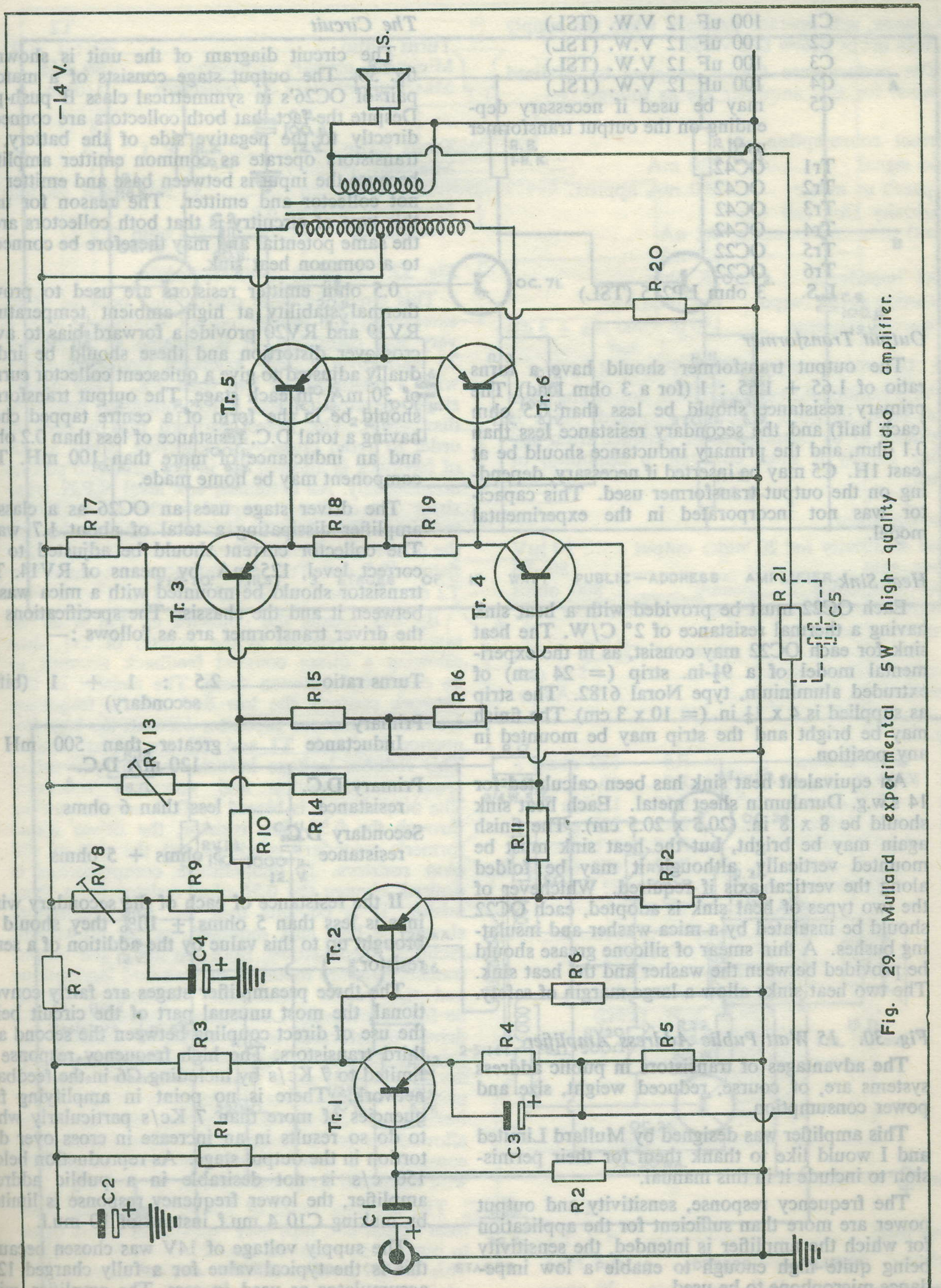

Fig. 29. Mullard experimental 5W high-quality audio amplifier.

C1	100 uF 12 V.W. (TSL)
C2	100 uF 12 V.W. (TSL)
C3	100 uF 12 V.W. (TSL)
C4	100 uF 12 V.W. (TSL)
C5	may be used if necessary depending on the output transformer used.
Tr1	OC42
Tr2	OC42
Tr3	OC42
Tr4	OC42
Tr5	OC22
Tr6	OC22
L.S.	3 ohm LP215 (TSL)

Output Transformer

The output transformer should have a turns ratio of 1.65 + 1.65 : 1 (for a 3 ohm load). The primary resistance should be less than 0.5 ohm (each half) and the secondary resistance less than 0.1 ohm, and the primary inductance should be at least 1H. C5 may be inserted if necessary, depending on the output transformer used. This capacitor was not incorporated in the experimental model.

Heat Sink

Each OC22 must be provided with a heat sink having a thermal resistance of 2° C/W. The heat sink for each OC22 may consist, as in the experimental model of a 9½-in. strip (= 24 cm) of extruded aluminium, type Noral 6182. The strip as supplied is 4 x 1¼ in. (= 10 x 3 cm). The finish may be bright and the strip may be mounted in any position.

An equivalent heat sink has been calculated for 14 s.w.g. Duralumin sheet metal. Each heat sink should be 8 x 8 in. (20.5 x 20.5 cm). The finish again may be bright, but the heat sink must be mounted vertically, although it may be folded along the vertical axis if required. Whichever of the two types of heat sink is adopted, each OC22 should be insulated by a mica washer and insulating bushes. A thin smear of silicone grease should be provided between the washer and the heat sink. The two heat sinks allow a large margin of safety.

Fig. 30. 15 Watt Public Address Amplifier

The advantages of transistors in public address systems are, of course, reduced weight, size and power consumption.

This amplifier was designed by Mullard Limited and I would like to thank them for their permission to include it in this manual.

The frequency response, sensitivity and output power are more than sufficient for the application for which the amplifier is intended, the sensitivity being quite high enough to enable a low impedance microphone to be used.

The Circuit

The circuit diagram of the unit is shown in fig. 30. The output stage consists of a matched pair of OC26's in symmetrical class B push-pull. Despite the fact that both collectors are connected directly to the negative side of the battery, the transistors operate as common emitter amplifiers because the input is between base and emitter and not collector and emitter. The reason for using this type of circuitry is that both collectors are at the same potential and may therefore be connected to a common heat sink.

0.5 ohm emitter resistors are used to provide thermal stability at high ambient temperatures. RV19 and RV20 provide a forward bias to avoid crossover distortion and these should be individually adjusted to give a quiescent collector current of 30 mA, in each stage. The output transformer should be in the form of a centre tapped choke having a total D.C. resistance of less than 0.2 ohms and an inductance of more than 100 mH. This component may be home made.

The driver stage uses an OC26 as a class A amplifier dissipating a total of about 1.7 watts. The collector current should be adjusted to the correct level, 125 mA, by means of RV14. The transistor should be mounted with a mica washer between it and the chassis. The specifications for the driver transformer are as follows :—

Turns ratio	2.5 : 1 + 1 (bifilar secondary)
Primary Inductance	greater than 500 mH at 120 mA D.C.
Primary D.C. resistance	less than 6 ohms
Secondary D.C. resistance	5 ohms + 5 ohms

If the resistance of each of the secondary windings is less than 5 ohms ± 10% they should be brought up to this value by the addition of a series resistor.

The three preamplifier stages are fairly conventional, the most unusual part of the circuit being the use of direct coupling between the second and third transistors. The high frequency response is limited to 7 Kc/s by including C6 in the feedback network. There is no point in amplifying frequencies of more than 7 Kc/s particularly when to do so results in an increase in cross over distortion in the output stage. As reproduction below 150 c/s is not desirable in a public address amplifier, the lower frequency response is limited by making C10 4 mu.f instead of 10 mu.f.

The supply voltage of 14V was chosen because this is the typical value for a fully charged 12v. accumulator as used in cars. The amplifier, will,

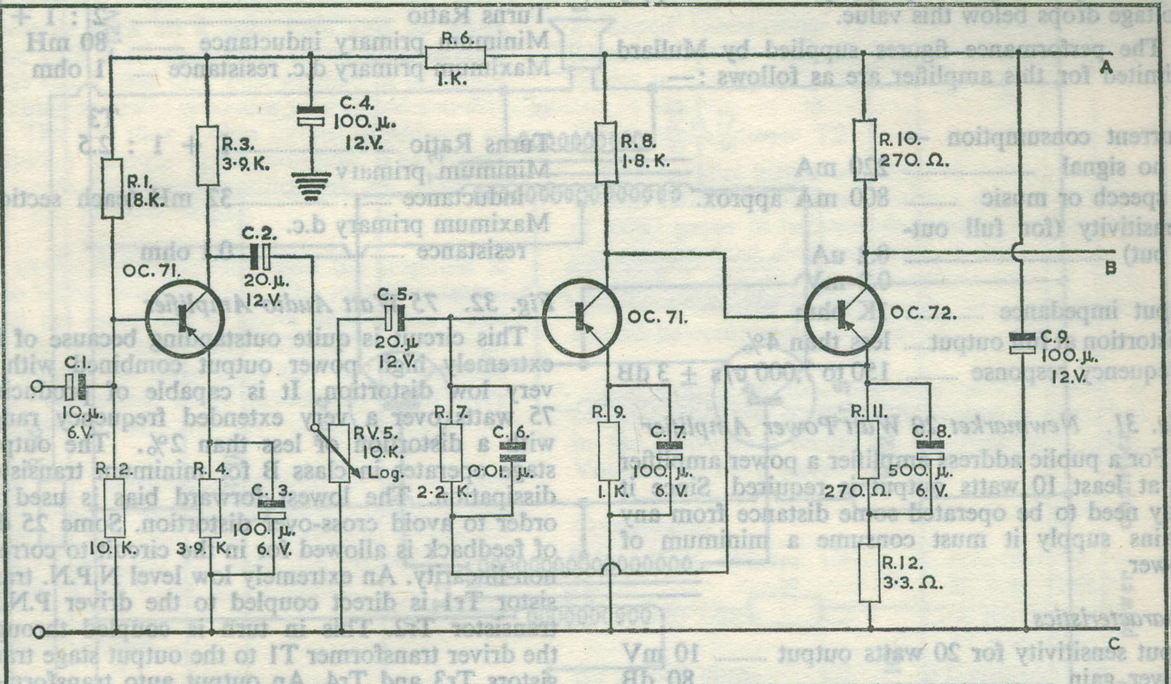

FIG. 30. FIRST 3 STAGES OF 15 WATT PUBLIC—ADDRESS AMPLIFIER.

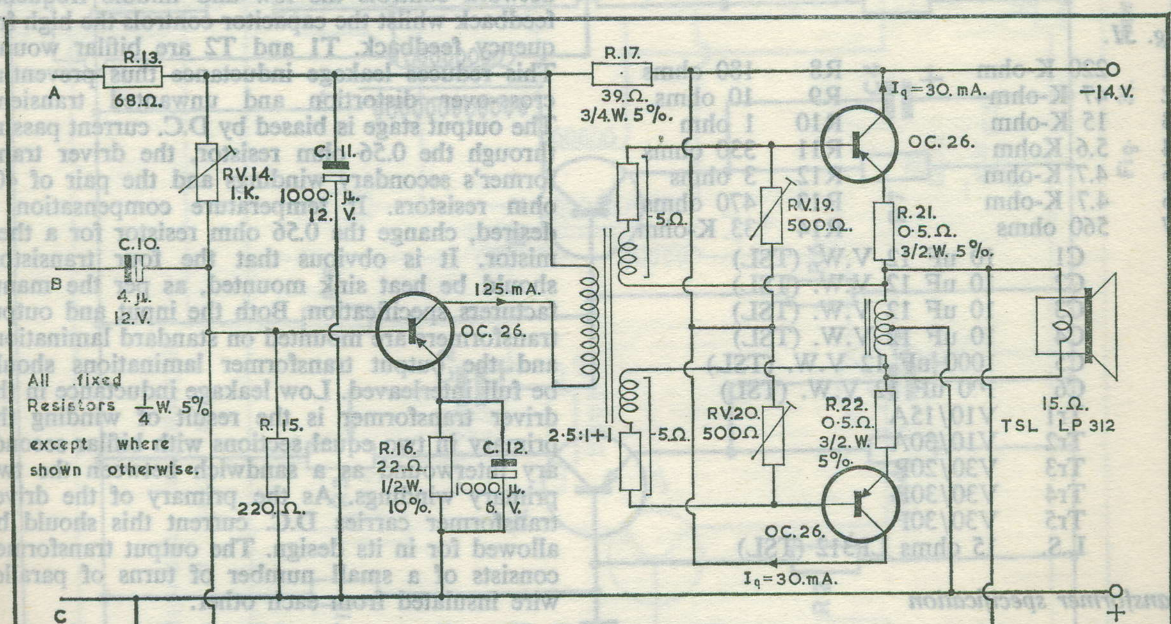

FIG. 30a. DRIVER AND OUTPUT STAGES OF PUBLIC ADDRESS AMPLIFIER.

of course, still operate properly when the supply voltage drops below this value.

The performance figures supplied by Mullard Limited for this amplifier are as follows :—

Current consumption —	
no signal	220 mA
speech or music	800 mA approx.
Sensitivity (for full output)	0.2 uA 0.2 mV
Input impedance	1K ohm
Distortion at full output	less than 4%
Frequency response	150 to 7,000 c/s ± 3 dB

Fig. 31. Newmarket 20 Watt Power Amplifier

For a public address amplifier a power amplifier of at least 10 watts output is required. Since it may need to be operated some distance from any mains supply it must consume a minimum of power.

Characteristics

Input sensitivity for 20 watts output	10 mV
Power gain	80 dB
Input impedance	800 ohms
Distortion at 20 watts output	Less than 10%
Frequency response	50 c/s to 15 Kc/s (—3 dB)
Battery drain no signal	550 mA
Battery drain full output	3.3 Amps.

Fig. 31.

R1	220 K-ohm	R8	180 ohms
R2	47 K-ohm	R9	10 ohms
R3	15 K-ohm	R10	1 ohm
R4	5.6 Kohm	R11	330 ohms
R5	4.7 K-ohm	R12	3 ohms
R6	4.7 K-ohm	R13	470 ohms
R7	560 ohms	R14	33 K-ohm

C1	10 uF 12 V.W. (TSL)
C2	10 uF 12 V.W. (TSL)
C3	10 uF 12 V.W. (TSL)
C4	10 uF 12 V.W. (TSL)
C5	1000 uF 12 V.W. (TSL)
C6	100 uF 12 V.W. (TSL)
Tr1	V10/15A
Tr2	V10/30A
Tr3	V30/20P
Tr4	V30/30P
Tr5	V30/30P
L.S.	15 ohms LP312 (TSL)

Transformer specification

	T1
Turns ratio	4 : 1
Minimum primary inductance	1.5 H
Maximum primary D.C. resistance	30 ohms

	T2
Turns Ratio	2 : 1 + 1
Minimum primary inductance	80 mH
Maximum primary d.c. resistance	1 ohm

	T3
Turns Ratio	1 + 1 : 2.5
Minimum primary inductance	32 mH (each section)
Maximum primary d.c. resistance	0.1 ohm

Fig. 32. 75 Watt Audio Amplifier

This circuit is quite outstanding because of its extremely high power output combined with a very low distortion. It is capable of producing 75 watts over a very extended frequency range with a distortion of less than 2%. The output stage operates in class B for minimum transistor dissipation. The lowest forward bias is used in order to avoid cross-over distortion. Some 25 dB of feedback is allowed for in the circuit to correct non-linearity. An extremely low level N.P.N. transistor Tr1 is direct coupled to the driver P.N.P. transistor Tr2. This in turn is coupled through the driver transformer T1 to the output stage transistors Tr3 and Tr4. An output auto transformer T2 couples the load to Tr3 and Tr4.

By this means the collector of Tr4 is at the same D.C. potential as the emitter of Tr1, thus allowing a direct coupled feedback network to be connected between them. The resistor in this network controls the low and middle frequency feedback whilst the capacitor controls the high frequency feedback. T1 and T2 are bifilar wound. This reduces leakage inductance thus preventing cross-over distortion and unwanted transients The output stage is biased by D.C. current passing through the 0.56 ohm resistor, the driver transformer's secondary windings and the pair of 400 ohm resistors. If temperature compensation is desired, change the 0.56 ohm resistor for a thermistor. It is obvious that the four transistors should be heat sink mounted, as per the manufacturers specification. Both the input and output transformers are mounted on standard laminations and the output transformer laminations should be full interleaved. Low leakage inductance in the driver transformer is the result of winding the primary in two equal sections with bifilar secondary interwound as a sandwich between the two primary windings. As the primary of the driver transformer carries D.C. current this should be allowed for in its design. The output transformer consists of a small number of turns of parallel wire insulated from each other.

The collector point of Tr4 is used as the common output and taps may be brought out in order to match any required impedance up to 16 ohms. This design gives practically perfect linearity and minimum distortion over a 70 dB dynamic range.

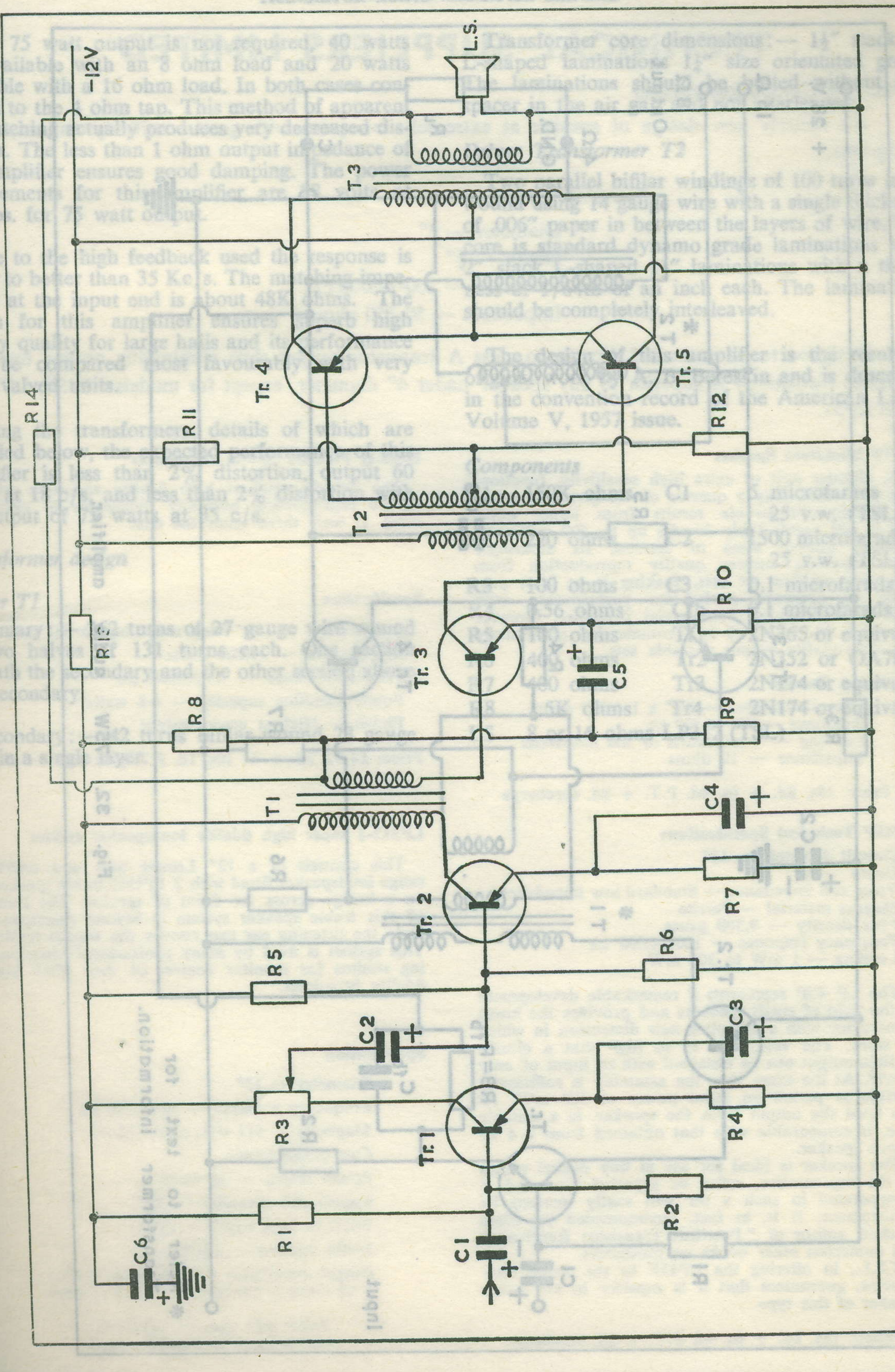

Fig. 31. Newmarket 20 W power amplifier.

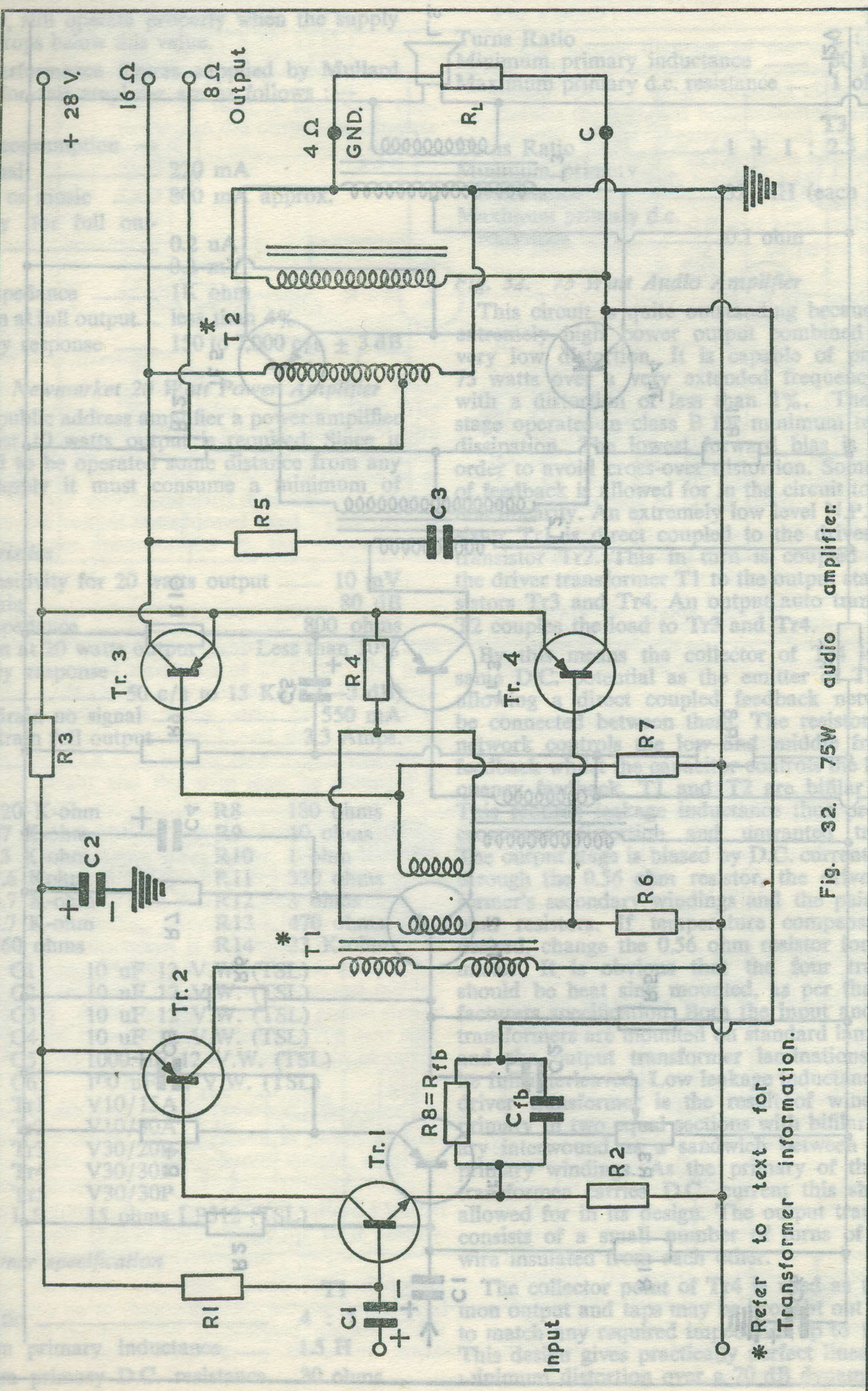

Fig. 32. 75W audio amplifier.

* Refer to text for Transformer information.

If the 75 watt output is not required, 40 watts are available with an 8 ohm load and 20 watts available with a 16 ohm load. In both cases connected to the 4 ohm tap. This method of apparent mismatching actually produces very decreased distortion. The less than 1 ohm output impedance of the amplifier ensures good damping. The power requirements for this amplifier are 28 volts at 4 amps. for 75 watt output.

Due to the high feedback used the response is linear to better than 35 Kc/s. The matching impedance at the input end is about 48K ohms. The design for this amplifier ensures superb high fidelity quality for large halls and its performance may be compared most favourably with very large valved units.

Using the transformers, details of which are specified below, the expected performance of this amplifier is less than 2% distortion, output 60 watts at 18 c/s, and less than 2% distortion with an output of 75 watts at 35 c/s.

Transformer design

Driver T1

Primary:— 262 turns of 27 gauge wire wound in two halves of 131 turns each. One section beneath the secondary and the other section above the secondary.

Secondary:— 42 turns bifilar wound 23 gauge wire in a single layer.

Transformer core dimensions:— 1½″ stack of L-shaped laminations 1¼″ size orientated grain. The laminations should be butted without any spacer in the air gap and not interleaved.

Driver Transformer T2

Two parallel bifilar windings of 100 turns layer wound using 14 gauge wire with a single thickness of .006″ paper in between the layers of wire. The core is standard dynamo grade laminations with 2″ stack L-shaped 1½″ laminations with a thickness of 1/64th of an inch each. The laminations should be completely interleaved.

The design of this amplifier is the result of original work by A. B. Bereskin and is described in the convention record of the American I.R.E. Volume V, 1957 issue.

Components

R1	150K ohms	C1	5 microfarads 25 v.w. (TSL)
R2	220 ohms	C2	1500 microfarads 25 v.w. (TSL)
R3	100 ohms	C3	0.1 microfarads
R4	0.56 ohms	Cfb	0.1 microfarads
R5	100 ohms	Tr1	2N365 or equivalent
R6	400 ohms	Tr2	2N352 or OA70
R7	400 ohms	Tr3	2N174 or equivalent
R8	1.5K ohms	Tr4	2N174 or equivalent
LS	8 or 16 ohms	LP312 (TSL)	

TECHNICAL SUPPLIERS LIMITED

TSL type CMS50 loudspeaker

An entirely new design of speaker at extremely low price with great sensitivity and superb response.

Technical Details.

Diameter — 2″
Depth — ⅝″
Response — 200-12,000 c/s
Impedance — 50-150 ohms

Designed to be connected directly to class A transistor output thus eliminating output transformers. Sensitivity is superior to any speaker under 4″ diameter, except for models LP45F, LP70 and LP31.

LP70 Miniature Speaker

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 amazingly 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 LP70 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: 18s. 8d. + 6s. 4d. P.T. + 8d. surcharge

LP45F Technical Specifications

Overall diameter — 1¾″
Depth — ¾″
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 LP 45F 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.

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

Price: 18s. 8d. + 6s. 4d. P.T. + 8d. surcharge

High-Q Flexette Sound reproducer

The world's smallest high fidelity enclosure with superb reproduction normally obtainable in enclosures at least three times the size.

Specification

Cabinet size — 11½″ wide x 6½″ high x 7½″ deep
Speaker flux — 11,000 gauss
Frequency range — 45-15,000 c/s
Power handling capacity — 4-8 watts
Finish — Highest grade walnut

Price: £4 9s. 2d. + £1 10s. 1d. P.T. plus 3s. surcharge

LP312-2 super high fidelity loudspeaker system

This consists of a 12″ Lorenz bass and middle range loudspeaker fitted with 2 LPH65 treble speakers on a bridge across the front of speaker. The result of this treble speaker system is beyond description. Only the listening ear can convey the superb results. This system is used by many professional broadcasting studios for monitor control of their VHF high fidelity broadcast.

Specification

Diameter — 12″
Frequency response — 20-17,500 c/s
Magnetic — 61½ ozs., super ALNI
Cast girder frame
Power rating — 30 watts
Speech coil diameter — 1½″
Front to back depth — 6¾″
Baffle opening — 10⅝″
Output impedance — a choice of 4, 8 or 16 ohms is available on every speaker

Price: £14 19s. 6d. complete
(not subject to Purchase Tax)

BERNARD'S AND BABANI PRESS RADIO BOOKS

No.		Price
BP1	Handbook of Transistor Equivalents and Substitutes	40p
BP2	Handbook of Radio, T.V. and Industrial Tube & Valve Equivalents	40p
BP3	Handbook of Tested Transistor Circuits	40p
BP4	International Handbook of the Worlds Short Wave, Med. and Long Wave Radio Stations & F.M. & T.V. Listings	35p
BP5	Boys Book of Simple Transistor Circuits	35p
BP6	Engineers & Machinists Reference Tables	20p
BP7	Radio & Electronic Colour Codes & Data Chart	15p
BP8	Sound and Loudspeaker Manual	50p
96	Crystal Set Construction	8p
100	A Comprehensive Radio Valve Guide, Book 1	30p
104	Three Valve Receivers	10p
121	A Comprehensive Radio Valve Guide, Book 2	30p
126	Boys' Book of Crystal Sets and Simple Circuits	18p
129	Universal Gram-Motor Speed Indicator	8p
138	How to Make F.M. and T.V. Aerials, Bands 1, 2 and 3	18p
141	Radio Servicing for Amateurs	20p
143	A Comprehensive Radio Valve Guide, Book 3	30p
146	High Fidelity Loudspeaker Enclosures	40p
156	Transistor Circuits Manual, No. 1	15p
157	A Comprehensive Radio Valve Guide, Book 4	30p
160	Coil Design and Construction Manual	30p
161	Radio, T.V. and Electronics Data Book	25p
163	Transistor Circuits Manual, No. 2	15p
168	Transistor Circuits Manual, No. 4	15p
170	Transistor Circuits for Radio Controlled Models	40p
171	Super Sensitive Transistor Pocket Radio	20p
173	Practical Transistor Audio Amplifiers, Book 1	20p
174	Transistor Subminiature Receivers	32½p
175	Transistor Test Equipment and Servicing Manual	25p
176	Manual Transistor Audio Amplifiers	40p
177	Modern Transistor Circuits for Beginners	40p
178	A Comprehensive Radio Valve Guide, Book 5	30p
181	22 Tested Circuits using Micro Alloy Transistors	25p
183	How to Receive Foreign TV Programmes on your set by Simple Modifications	32½p
184	Tested Transistor Circuits using Professional Printed Circuit Modules, Transistor Circuits Manual No. 3	20p
185	Tested Shortwave Receiver Circuits using MAT'S	30p
186	Tested Superhet Circuits for Shortwave and Communications Receivers using MAT'S	30p
187	The TSL Mark "4" Valved FM Tuner and its Construction	20p
191	Practical Car Radio Handbook	30p
501	ABC's of Magnetism	30p
502	ABC's of Missile Guidance	30p
	Resistor Colour Code Disc Calculator	10p

Titles in Preparation

BP9	36 Practical Tested Diode Circuits for the Home Constructor	35p
BP10	Modern Crystal Set Circuits for Beginners	35p
BP11	Practical Transistor Novelty Circuits	40p
BP12	HI-FI, P.A. and Discotheque Amplifier Design Handbook	75p