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

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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last mentioned circuits have been included, however, for the sake of completeness and so that the book will not be out of date for a long while to come.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.

The total current consumption is 2½ 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. 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 ½ 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.

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 a 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. 500 μW output amplifier.

Fig. 2. Direct coupled 1/2 mW 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, or, 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 at 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 load remains the same 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—R (see text), 1K ohm, volume control.
   22 ohm 1/10 watt.
Capacitors—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 1/2 mW with a fresh battery and the output with 500 ohm and 250 ohm earpieces will be 1 1/2 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. 0.5 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 $1\frac{1}{2}$ 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 13", 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 small 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
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.
The only cure for this is to include resistors R5 and R6 in the emitters of the first two transistors. These cannot 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%

**Table:**

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>12 K-ohms</td>
</tr>
<tr>
<td>R2</td>
<td>3.3 K-ohms</td>
</tr>
<tr>
<td>R3</td>
<td>12 K-ohms</td>
</tr>
<tr>
<td>R4</td>
<td>680 ohms</td>
</tr>
<tr>
<td>R5</td>
<td>2.7 K-ohms</td>
</tr>
<tr>
<td>R6</td>
<td>68 ohms</td>
</tr>
<tr>
<td>R7</td>
<td>3.3 ohms</td>
</tr>
<tr>
<td>R8</td>
<td>3.3 ohms</td>
</tr>
<tr>
<td>R9</td>
<td>100 K-ohms</td>
</tr>
<tr>
<td>C1</td>
<td>100 uF 6 V.W. (TSL)</td>
</tr>
<tr>
<td>C2</td>
<td>10 uF 12 V.W. (TSL)</td>
</tr>
<tr>
<td>C3</td>
<td>100 uF 3 V.W. (TSL)</td>
</tr>
<tr>
<td>C4</td>
<td>100 uF 6 V.W. (TSL)</td>
</tr>
<tr>
<td>Speaker</td>
<td>3 ohms LP 70 (TSL)</td>
</tr>
<tr>
<td>Tr1</td>
<td>GET 114</td>
</tr>
<tr>
<td>Tr2</td>
<td>GET 114</td>
</tr>
<tr>
<td>Tr3</td>
<td>GET 114</td>
</tr>
</tbody>
</table>
Transformer specifications

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

<table>
<thead>
<tr>
<th>Transformer specifications</th>
<th>R12</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>Tr1</th>
<th>Tr2</th>
<th>Tr3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turns Ratio</td>
<td>3:1</td>
<td>2 uF</td>
<td>50 uF</td>
<td>100 uF</td>
<td>500 uF</td>
<td>100 uF</td>
<td>100 uF</td>
<td>GET 114 or GET 15</td>
</tr>
<tr>
<td>Primary Inductance</td>
<td>4H</td>
<td>12 V.W.</td>
<td>12 V.W.</td>
<td>6 V.W.</td>
<td>6 V.W.</td>
<td>GET 114 or GET 15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary Resistance</td>
<td>150 ohms (each half)</td>
<td>500 ohms</td>
<td>40 ohms each half</td>
<td>40 ohms each half</td>
<td>40 ohms each half</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary Resistance</td>
<td>0.2 ohms</td>
<td>100 ohms</td>
<td>390 ohms</td>
<td>390 ohms</td>
<td>390 ohms</td>
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<td></td>
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</tr>
<tr>
<td>Suitable types are:</td>
<td>Belclere KN1936 or 4070</td>
<td>Colne Electric 04073 or 04070</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Suitable types are:

- Belclere KN1936
- Colne Electric 04073 or 04070
- Fortiphone Ltd. 4442 (7:1 + 1)

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
- 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: 114 or GET 15
- Tr2: 114 or GET 15
- Tr3: 114 or GET 15
- Speakers: 38 ohms CMS50 (TSL)

**Transformer specification**

- Turns ratio: 7 : 1 + 1
- Primary Inductance: 4H
- Primary Resistance: 250 ohms
- Secondary resistance: 40 ohms each half
- Suitable types are:
  - Belclere KN1936 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/s: 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: 85 mA
- Peak power dissipation of each output transistor: 100 mW
- Total harmonic distortion at 400 c/s at 450 mW output — less than 6%

**Fig. 20.**

- R1: 15 K-ohms
- R2: 8.2 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  
R1 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. 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  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

<table>
<thead>
<tr>
<th>Turns ratio</th>
<th>Primary Inductance</th>
<th>Primary resistance</th>
<th>Secondary resistance</th>
<th>Suitable types are</th>
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<tbody>
<tr>
<td>2 : 1 + 1</td>
<td>2H</td>
<td>20 ohms</td>
<td>5 ohms (each half)</td>
<td>Belclere</td>
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<td></td>
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<td></td>
<td></td>
<td>KN1839</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Colne Electric</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>04043 or 04047</td>
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<td></td>
<td></td>
<td></td>
<td>Parmeko</td>
</tr>
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<td>P2939 or P2941</td>
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<table>
<thead>
<tr>
<th>Turns Ratio</th>
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<th>Primary Resistance</th>
<th>Secondary Resistance</th>
<th>Suitable types are</th>
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<tbody>
<tr>
<td>2.25 + 2.25 : 1</td>
<td>50 mH (each half)</td>
<td>0.7 ohms (each half)</td>
<td>0.2 ohms</td>
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<td></td>
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<td>Parmeko</td>
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<td>P2940</td>
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</tbody>
</table>

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    360 mA

Fig. 22.

<table>
<thead>
<tr>
<th>R1</th>
<th>R7</th>
</tr>
</thead>
<tbody>
<tr>
<td>22 K-ohms</td>
<td>560 ohms</td>
</tr>
<tr>
<td>R2</td>
<td>R8</td>
</tr>
<tr>
<td>1.8 K-ohms</td>
<td>470 ohms</td>
</tr>
<tr>
<td>R3</td>
<td>R9</td>
</tr>
<tr>
<td>470 ohms</td>
<td>100 ohms</td>
</tr>
<tr>
<td>R4</td>
<td>R10</td>
</tr>
<tr>
<td>3 K-ohms</td>
<td>220 ohms</td>
</tr>
<tr>
<td>R5</td>
<td>R11</td>
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<td>220 ohms</td>
<td>22 ohms</td>
</tr>
<tr>
<td>R6</td>
<td>R12</td>
</tr>
<tr>
<td>3.9 K-ohms</td>
<td>5 ohms</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>C1</th>
<th>C2</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 uF 12 V.W. (TSL)</td>
<td>100 uF 12 V.W. (TSL)</td>
</tr>
<tr>
<td>C3</td>
<td>C4</td>
</tr>
<tr>
<td>100 uF 6 V.W. (TSL)</td>
<td>100 uF 6 V.W. (TSL)</td>
</tr>
<tr>
<td>C5</td>
<td>C6</td>
</tr>
<tr>
<td>100 uF 12 V.W. (TSL)</td>
<td>100 uF 6 V.W. (TSL)</td>
</tr>
<tr>
<td>C7</td>
<td>C8</td>
</tr>
<tr>
<td>500 pf</td>
<td>100 uF 6 V.W. (TSL)</td>
</tr>
<tr>
<td>Tr1</td>
<td>Tr2</td>
</tr>
<tr>
<td>V10/50A</td>
<td>V10/30A</td>
</tr>
<tr>
<td>Tr3</td>
<td>Tr4</td>
</tr>
<tr>
<td>V15/201P</td>
<td></td>
</tr>
<tr>
<td>L.S.</td>
<td></td>
</tr>
<tr>
<td>3 ohms LP45F (TSL)</td>
<td></td>
</tr>
</tbody>
</table>

Transformer Specification

<table>
<thead>
<tr>
<th>Turns ratio</th>
<th>Minimum primary inductance</th>
<th>Maximum primary D.C. resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 : 1</td>
<td>130 mH</td>
<td>1 ohm</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>R11</th>
<th>R12</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.1 K-ohms ± 5%</td>
<td>9.1 K-ohms ± 5%</td>
</tr>
<tr>
<td>C1</td>
<td>C2</td>
</tr>
<tr>
<td>10 uF 12 V.W. (TSL)</td>
<td>100 uF 12 V.W. (TSL)</td>
</tr>
<tr>
<td>C3</td>
<td>C4</td>
</tr>
<tr>
<td>100 uF 12 V.W. (TSL)</td>
<td>100 uF 12 V.W. (TSL)</td>
</tr>
<tr>
<td>C5</td>
<td>Tr1</td>
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<td>100 uF 12 V.W. (TSL)</td>
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</tr>
<tr>
<td>3 ohms LP31 (TSL)</td>
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</tr>
</tbody>
</table>
Tr. 2.

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.
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
Parmeke P2941 P2942

The Colne Electric and the Parmeke 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 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.** Newmarket two-watt class A amplifier.

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
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<td>50 K-ohms</td>
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<td>R2</td>
<td>5.6 K-ohms</td>
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<td>R3</td>
<td>470 ohms</td>
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<tr>
<td>R4</td>
<td>3.3 K-ohms</td>
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<tr>
<td>R5</td>
<td>470 ohms</td>
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<tr>
<td>R6</td>
<td>3.3 K-ohms</td>
</tr>
<tr>
<td>C1</td>
<td>10 uF 12 V.W. (TSL)</td>
</tr>
<tr>
<td>C2</td>
<td>100 uF 12 V.W. (TSL)</td>
</tr>
<tr>
<td>C3</td>
<td>25 uF 12 V.W. (TSL)</td>
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<tr>
<td>C4</td>
<td>10 uF 12 V.W. (TSL)</td>
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<td>C5</td>
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<tr>
<td>C6</td>
<td>1000 uF 12 V.W. (TSL)</td>
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<tr>
<td>L.S.</td>
<td>3 ohms (TSL HiQ Flexette)</td>
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<td>Tr1</td>
<td>V10/30A</td>
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<tr>
<td>Tr2</td>
<td>V15/201P</td>
</tr>
<tr>
<td>Tr3</td>
<td>V30/20P</td>
</tr>
</tbody>
</table>

**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

**Transformer specification**

<table>
<thead>
<tr>
<th>Transformer</th>
<th>Turns ratio</th>
<th>Maximum primary inductance</th>
<th>Maximum primary D.C. resistance</th>
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</thead>
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<td>T1</td>
<td>5 : 1</td>
<td>0.8H</td>
<td>20 ohms</td>
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<tr>
<td>T2</td>
<td>15 : 1</td>
<td>24 mH</td>
<td>0.5 ohms</td>
</tr>
</tbody>
</table>

---

**Fig. 28.**

- 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)
- Tr1 V10/30A
- Tr2 V15/201P
- Tr3 V30/20P

---

**Fig. 27.** Newmarket two-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 is 600mA.

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:

<table>
<thead>
<tr>
<th>Maximum power output at 1 Kc/s</th>
<th>5W (into 3 ohm load)</th>
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</thead>
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<tr>
<td>Frequency response</td>
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<tr>
<td>(a) 1W = 0 dB</td>
<td>-3 dB at 3 c/s &amp; 50 Kc/s*</td>
</tr>
<tr>
<td>(b) 5W = 0 dB</td>
<td>-3 dB at 7 c/s &amp; 40 Kc/s</td>
</tr>
<tr>
<td>Total harmonic distortion</td>
<td></td>
</tr>
<tr>
<td>(a) 1W at 1 Kc/s</td>
<td>0.3%</td>
</tr>
<tr>
<td>(b) 5W at 1 Kc/s</td>
<td>0.6%</td>
</tr>
<tr>
<td>Input impedance</td>
<td>8.3K ohms</td>
</tr>
<tr>
<td>* A peak of +2.5 dB occurs at 40 Kc/s following a continuous increase from 10 Kc/s (0 dB).</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 29.

- R1  56 K-ohms
- R2  12 K-ohms
- R3  10 K-ohms
- R4  3.3 K-ohms
- R5  22 ohms
- R6  8.2 K-ohms
- R7  1.5 K-ohms
- RV8 2 K-ohms Lin.
- R17 270 ohms ± 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.
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-inch strip (= 24 cm) of extruded aluminium, type Noral 6182. The strip as supplied is 4 x ½-inch (= 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 inch. (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.
TRANSISTOR AUDIO AMPLIFIER MANUAL

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
- **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. 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 20W 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 valued 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 Transformer 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.

**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 1/4" 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**

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<th>R1</th>
<th>150K ohms</th>
<th>C1</th>
<th>5 microfarads</th>
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</thead>
<tbody>
<tr>
<td>R2</td>
<td>220 ohms</td>
<td>C2</td>
<td>1500 microfarads</td>
</tr>
<tr>
<td>R3</td>
<td>100 ohms</td>
<td>C3</td>
<td>0.1 microfarads</td>
</tr>
<tr>
<td>R4</td>
<td>0.56 ohms</td>
<td>Cfb</td>
<td>0.1 microfarads</td>
</tr>
<tr>
<td>R5</td>
<td>100 ohms</td>
<td>Tr1</td>
<td>2N365 or equivalent</td>
</tr>
<tr>
<td>R6</td>
<td>400 ohms</td>
<td>Tr2</td>
<td>2N352 or OA70</td>
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<td>R7</td>
<td>400 ohms</td>
<td>Tr3</td>
<td>2N174 or equivalent</td>
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<td>R8</td>
<td>1.5K ohms</td>
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<tr>
<td>LS</td>
<td>8 or 16 ohms</td>
<td></td>
<td>L P312 (TSL)</td>
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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: 3/8"
- 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: 21/2" 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: 11/4"
- Depth: 3/4"
- 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.

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: 111/2" wide x 61/2" high x 71/4" 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: 61/4 ozs., super ALNI
- Cast girder frame
- Power rating: 30 watts
- Speech coil diameter: 11/4"
- Front to back depth: 61/2"
- Baffle opening: 101/4"
- 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)
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<th>No.</th>
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