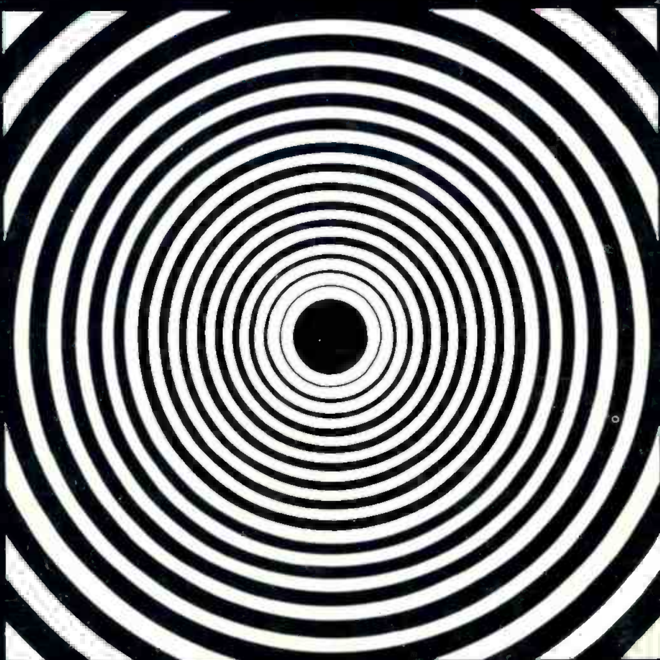
Handbook of IC Audio Preamplifier & Power Amplifier Construction

F.G. RAYER, T. Eng. (CEI), Assoc. IERE



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HANDBOOK OF IC AUDIO PREAMPLIFIER AND POWER AMPLIFIER CONSTRUCTION

by

F.G. RAYER, T.Eng.(CEI), Assoc.IERE

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PART I
UNDERSTANDING AUDIO ICs

The integrated circuit audio amplifier has many advantages over amplifiers, which are built from separate, individual components. An IC allows more advanced circuits, with fewer components. A single IC can contain the equivalent of a score or more of transistors, diodes and resistors, matched and encapsulated together. ICs are also available in a wide range of types – for low-level amplifiers and pre-amplifiers, medium outputs, or high outputs, and for use with a whole range of operating voltages.

An audio IC may operate alone, receiving input from a pick-up or other source, and delivering output for a loudspeaker. Or it can be used in conjunction with IC or transistor pre-amplifiers or other units or may even drive high power transistor output stages. In all cases direct coupling and correct operation of all stages results in an extended frequency response and excellent results are obtainable with a minimum of difficulty.

Audio ICs find wide use in mono systems, but have obvious advantages for stereo, allowing matched amplifiers to be built readily. Indeed it is difficult to think of a purpose where audio amplification is not best obtained from an IC, instead of discrete components throughout.

Many audio ICs have 'bonus' factors such as automatic overload or short circuit protection which would usually be absent in other amplifiers.

This book shows what audio ICs are, as well as how to use them, and some understanding of their inner functions will help clarify the actual purpose of external circuits and components employed with them.

An audio amplifier based on an IC might be divided into two sections. First, there is the IC itself, which consists of transistors, resistors, and diodes in most examples. Then there is the board with its additional components – usually capacitors and resistors, whose purpose is to provide correct operating conditions for the IC.

WHAT AN IC IS

The integrated circuit has many individual parts which are all combined into a whole. The individual elements are mostly PNP and NPN transistors, diodes, and resistors, but may also include silicon controlled rectifiers or capacitors. Of these, transistors, diodes and resistors are most usual, and capacitors are not practical in large values.

The elements are produced directly in chips of semiconductor material and lie close together, occupying only a minute volume. Required internal connections are provided by the arrangement of elements, or connective elements. Many of the internal elements will have no external connection.

External connections are of course necessary for input, output, supply and other points. For these, internal conductors run to the external means of connecting the IC – generally leads or pins coded by position and often placed to match holes in matrix boards. From the user point of view, it is only necessary to identify and connect leads or pins, as when fitting a transistor or other component.

The microcircuit which is the basis of an IC may be formed upon a slab of N-type silicon semiconductor material, upon which silicon dioxide is deposited. A much-reduced image, obtained photographically by projection allows the silicon dioxide to be etched where required, so that P-type diffusion areas can be produced under the apertures. Smaller apertures allow diffusion of N-type areas into the P-type, thus forming NPN transistors.

Similar processes allow a whole array of transistors, diodes, and other elements to be produced together. Diodes can be produced by a single PN junction, and resistors from the semiconductor material. Insulation or isolation can be arranged by regions of P-type material which in effect are reverse-biassed junctions.

Once designs have been set and the processes arranged, the IC can be reproduced with sufficiently accurate duplication of characteristics. Stabilisation circuits incorporated cover the spreads in individual transistor or other elements, so that with a given external circuit all stages operate correctly with any sample of the IC (some types require external bias adjustment).

Conductive pads and leads are added to the slab, so that the whole IC can be cased and provided with 8-lead, 10-lead (Fig.1), dual-in-line or other package, as required.

SIMPLE 3-STAGE IC

An audio integrated circuit may be a very complex device, having numerous transistors and other components. This will be seen with some of the sophisticated ICs which include thermal stabilisation, automatic overload protection, and other elements. However, the equivalent circuits of the simpler ICs are much more readily followed. Fig.2 shows the circuit of an IC designed for audio amplification, particularly for hearing aids.

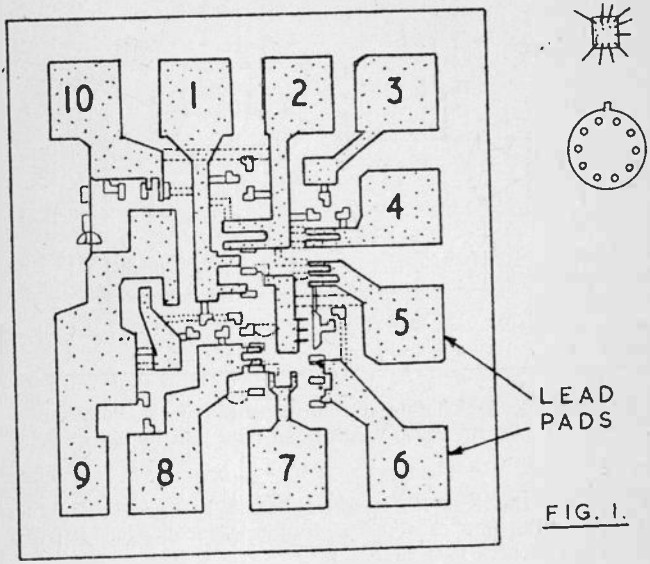


FIG. 1.

This particular IC has a plastic encapsulation 2.8 x 2.27 x 1.1 mm in size, with four lead-outs numbered by their positions in Fig.2. These serve for securing the device, as well as for connections.

Referring to the equivalent circuit, it will be seen that 4 is the connection to the base of TR1, which is the first amplifier. TR1 collector has load resistor R1, and is directly coupled to the base of TR2. Direct coupling is similarly used from TR2 to TR3, with collector resistor R2.

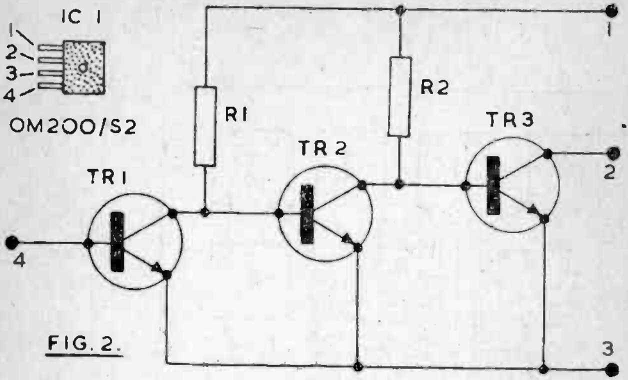


FIG. 2.

The final amplifier TR3 has its collector taken to point 2. Point 3 is the negative line for the emitters, and point 1 the positive line for R1 and R2.

This consists of the actual IC. Resistive elements such as R1 and R2 are usually present in an IC, together with other elements which it is practical or preferable to include.

The IC itself does not include *all* the required circuit elements, and these are added externally. The number of peripheral components supplementing the IC in this way will depend on the IC itself, and the manner in which it is to be used. Often the values of external components will be chosen to obtain the particular working conditions wanted, and frequently the same IC can be operated in a number of ways.

Fig.3 shows the same IC, connected into a circuit having the external components R1, R2, R3 and C1.

Point 4 is the IC input, and R1 represents the source impedance. A microphone could be the source of input to TR1 base at point 4.

Points 1 and 3 are taken to the positive and negative supply lines of the equipment. Point 2 is TR3 collector, and R2 represents the collector load. The audio output available at 2 could be taken to a later

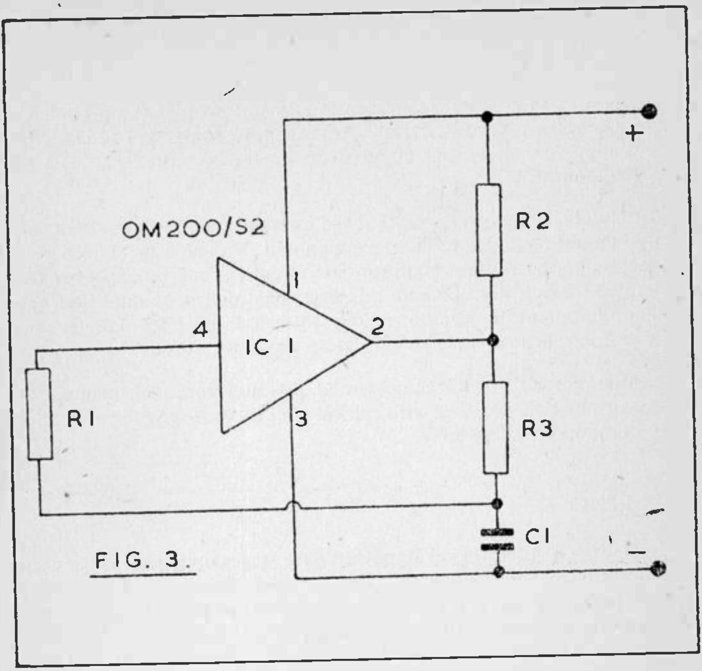


FIG. 3.

amplifier. Otherwise the audio power available here is used without further amplification. R2 is then an earpiece.

R3 is a feedback resistor, to set and stabilise working conditions. With many amplifiers feedback of similar type is present, and the amount of feedback may be adjusted by selection of values. C1 is a large audio by-pass capacitor, as in this particular circuit the feedback is to obtain correct working of the directly coupled amplifiers by DC feedback from TR3 collector to TR1 base.

Typical values for this circuit would be 5k for R1, with load R2 of 500 ohm and 1.5k impedance, with R3 about 390k. (R3 may be modified to obtain the wanted direct-current conditions and expected battery drain.) C1 can be 200μF. These values are for a 1.3v supply, with collector current of TR3 at 0.7mA. Current drain of TR1 and TR2 will be about 0.3mA.

Audio ICs in general use have substantially more elements than this 3-stage IC, and as a result their equivalent circuits are much more complicated. They will, however, break down into smaller and more readily understood sections, such as preamplifier, main amplifier, stabilisation and protection circuits.

Where the circuit of an IC is to be studied, it is useful to do this in conjunction with a typical application which includes the peripheral components. Input, output, and power supply points will be immediately apparent, and other circuits can be traced with these as a starting point.

Fortunately, there is no need that the internal or equivalent circuit of an IC should be understood, or even known. Provided the device is correctly connected in an appropriate circuit, it can be expected to operate satisfactorily. Despite this, few constructors of amplifiers or other equipment are content merely to regard any part of them as 'black boxes' whose functions are in no way understood.

Equivalent circuits of ICs can often be obtained from their manufacturer or supplier, together with typical circuits showing the connections and component values to fit.

PUSH-PULL IC

Preamplifiers and low level amplifiers have stages operating under Class A conditions where a single transistor or equivalent device can amplify the whole audio cycle. The Class A stage is not driven into cut-off conditions, and has a uniform operating current in terms of the load imposed on the power supply. If more than low power audio output is required from a Class A stage, operation becomes generally uneconomical. The stage passes a high current at all times, resulting in increased power dissipation in the device, and a large current load on the power supply.

With Class B output stages, greatly increased efficiency is obtained. Where individual transistors are used, a Class B output stage is always present except in particular circumstances which make this method of operation unnecessary. That is, for low power amplifiers, or larger amplifiers where current is available for a suitable Class A stage (such as with an accumulator powered car radio).

Class B stages with discrete transistors may use various forms of transformer coupling, or a complementary stage requiring no transformer. The latter type of stage has the advantage of eliminating expensive and bulky transformers, and complementary output stages are largely found in ICs. They may consist of PNP-NPN elements, or Darlington combinations.

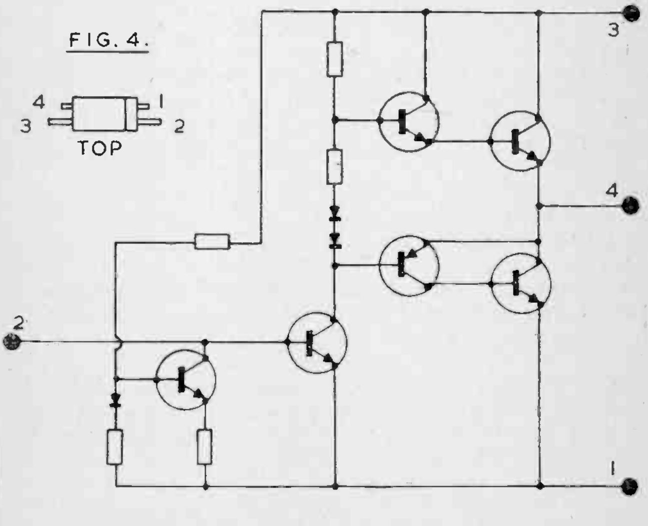
With the Class B stage, resting or no-signal current taken by the output pair is low. Positive and negative half cycles of the audio signal drive one or other of the output transistors into conduction. Thus large output powers are available, while power dissipation in the transistors is lower. This reduces heating and the amount of heat sinking required, as well as being economical in terms of power drawn from the battery or other supply.

ICs intended for radio receivers or small amplifiers, and with push-pull output, may be low power devices for outputs of 250mW (¼ watt) or less. Larger devices provide for a power output of some watts, while the large-power ICs for powerful amplifying equipment can provide many watts.

¼w IC

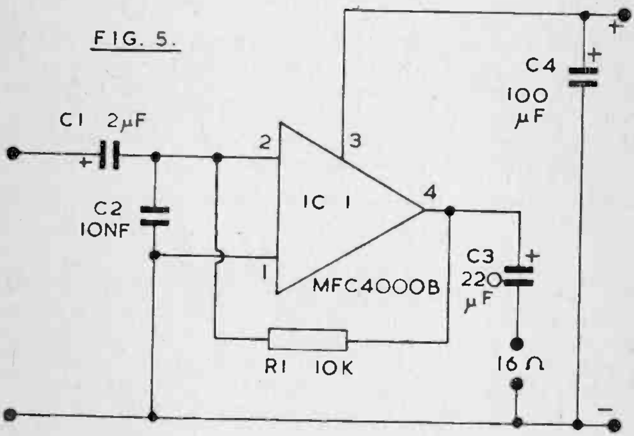
The low power ICs naturally have fewer components in their equivalent circuits than the large ICs, so are more easily understood. Fig.4 shows an IC which is a driver-output device. When used with a 9v supply, it is capable of an output of 250–350mW into a 16 ohm speaker. Current drain is typically 3.5mA with no signal, this rising to about 40mA for 100mW, and 60–70mA for the fully output.

FIG. 4.



The equivalent circuit, Fig.4, contains one PNP and five NPN transistors, with three diodes and five resistive elements. Basically the device is a driver stage followed by push-pull output, with stabilisation of working conditions. Audio input is between points 2 and 1, with output between points 4 and 1. Point 1 is also the negative line, and point 3 the positive line.

Fig.5 is an amplifier incorporating this IC, and requiring few additional components. C1 is a coupling capacitor, giving DC isolation from



earlier circuits. In most applications, audio input would be from a single transistor preamplifier, though this naturally depends on the audio level available and output wanted.

C2 (0.01µF) is a by-pass capacitor to assist in maintaining stability. C3 is to couple the output to the 16 ohm speaker, and C4 across the supply offers a low impedance circuit when the battery is somewhat discharged and its internal resistance is rising.

R1 provides audio feedback from output to input, and also DC feedback to maintain correct working conditions. Shifts in the voltage at 4 modify driver base current at 2. This in turn changes the driver collector current and the operating point of the output transistors. DC stabilisation of this type is found also in directly-coupled driver-output circuits assembled from individual transistors.

This circuit is for 9v, and capacitor values could be changed according to requirements. The speaker impedance could also be increased, with a reduction in power output available, but saving in battery current.

Since C1 provides direct current isolation from any earlier circuit, the operating conditions of the IC do not depend on that part of the equipment.

An IC can generally be employed in optional circuits, and Fig.6 is a further amplifier for this IC. Note that here the preamplifier is directly coupled to the input of the IC. In these circumstances, the DC operating conditions of both preamplifier and IC depend on each other. (This is not so with Fig.5 for the reason explained.) The feedback circuit is also changed, as TR1 derives its emitter current from this.

Though TR1 and IC1 operating conditions are associated, C1 gives DC isolation of earlier parts of the equipment. The audio signal might be from the diode or detector of a radio tuner, or from a pick-up, preamplifier, or other source.

IC amplifiers of low power and simple type are very useful for pre-amplifier or microphone amplifier applications; and also as headphone amplifiers, or for modest power outputs for small speaker receivers, intercom systems and similar purposes. Because of their simplicity, they form a good starting point for anyone interested in the practical use of IC amplifiers. The circuitry they offer is straightforward and readily understood, and they are an excellent introduction to more complex ICs.

The larger type of IC will not necessarily require more peripheral components than small amplifiers, though this will often be so. As with the small IC just described, this may depend on the type of circuit. Other factors may also arise – as example, numerous components might be present for tone-control purposes, but might be omitted or reduced in number for a simpler piece of equipment using the same IC.

Larger ICs will be found to have a greater number of external connections. Some of these may allow optional features, such as an internal preamplifier to be employed if wanted.

Though it is useful to understand at least some part of the internal working of an IC, a complete analysis of this would be out of place, and serve little purpose, where the larger ICs are concerned. An IC

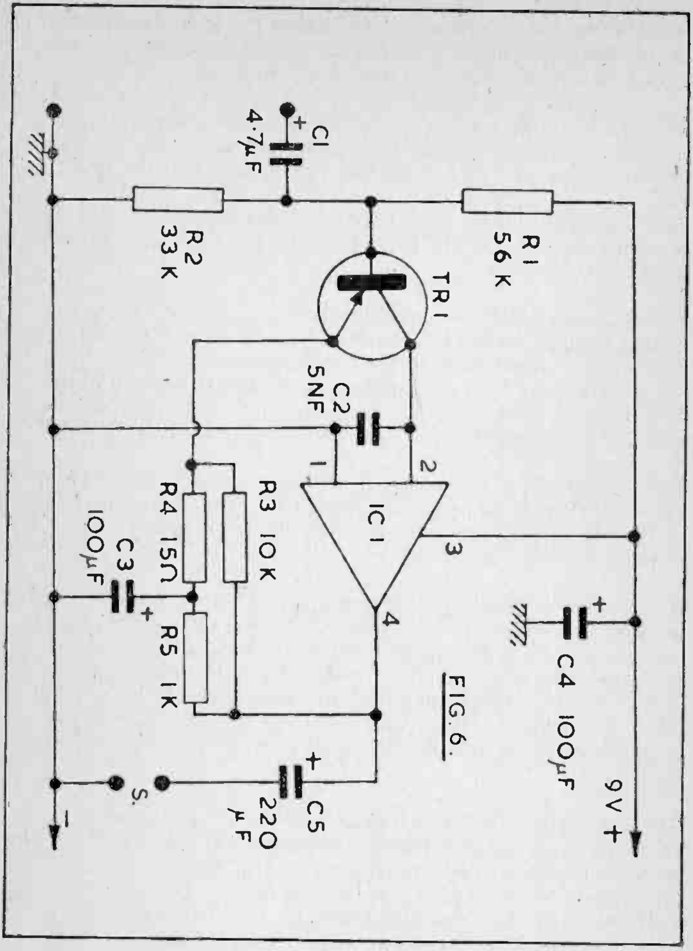


FIG. 6.

may have scores of transistors and other items, and fortunately there is no need that anyone using such an IC has an equivalent circuit for it. Generally, the internal arrangement of the IC only need be known so far as this applies to some characteristic which may need special mention, such as the adjustment of resting current, or the use of certain pins for heat sinking. In fact, one of the great advantages of an IC is that it forms the basis of an amplifier with only the addition of a few external components. This enormously simplifies constructional work, and enables comprehensive equipment to be built with an ease otherwise impossible.

IC FEATURES

Though the internal arrangement of an integrated circuit can be shown by discrete components – resistors, diodes and transistors appropriately connected – these are not of course separate items in the IC. They are formed on various areas of the chip as explained, and the equivalent circuit is a convenient representation of the circuit which is provided. It is useful to examine some of the features of an IC individually, as these are of importance when deciding on the external circuit, and when providing correct operating conditions. Naturally not all these features will be found in every IC, but they are characteristic of what is often provided.

PREAMPLIFIER

Some ICs have a separate preamplifier incorporated. This can have an individual output point, which may be connected to the main amplifier input, or to other circuits, such as are necessary for tone controls.

Fig.7 shows such a preamplifier. Audio input is to B, and the base of TR1. TR1 and TR2 operate as emitter followers, and the input is high impedance. Base bias for TR1 will be provided by the external circuit.

TR3 is a common emitter amplifier, with feedback over the emitter resistor R1. R2 is the collector load, and audio output is from E.

C is the input ground line and F the common negative supply line. R3 is a decoupling resistor for these three transistors, and A allows an external decoupling capacitor to be connected – this could be about 22µF to 100µF. R3 and this capacitor avoid instability due to feedback from output to input circuits, and provide a hum-free supply for the preamplifier. In some applications of such an IC the preamplifier might be left unused. This would depend on the main amplifier sensitivity, and input available for it with the preamplifier omitted.

MAIN AMP INPUT

The input and driver stages of the main amplifier are shown in Fig.8. Input is to A, and TR1 and TR2 use the same circuit as in the preamplifier. R2 is the collector load for TR3, with TR4 and TR5 following, so that B provides audio drive for the output stage. R4 supplies emitter current for TR4.

It will have been noticed that directly-coupled stages are provided. These give extended frequency response, need no capacitors (which would have to be provided externally) and allow stabilisation by direct

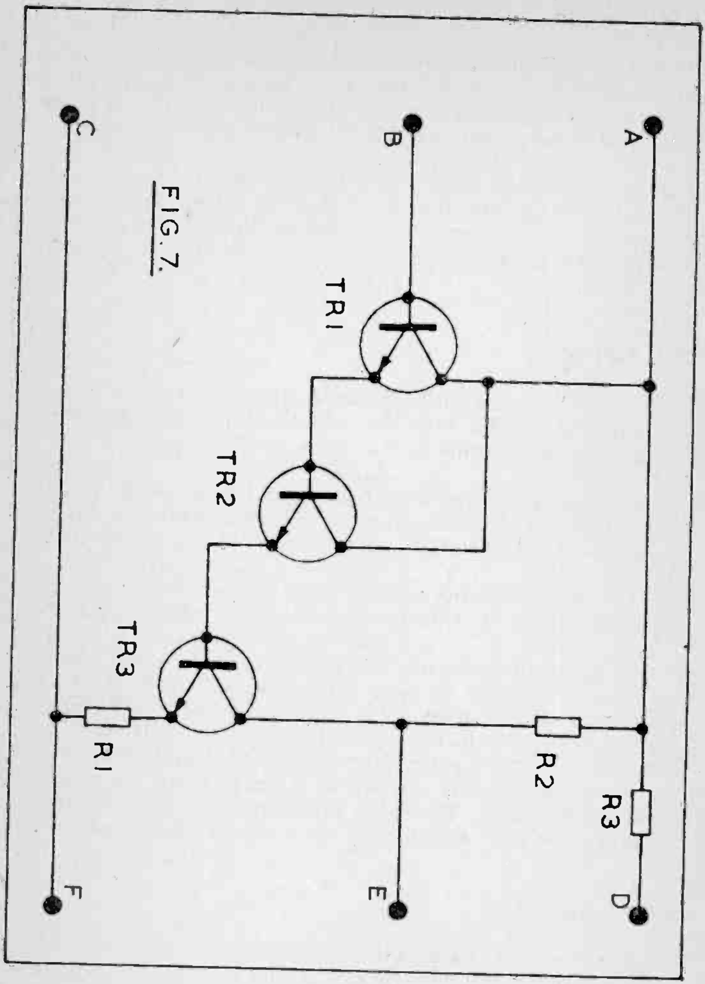


FIG. 7.

current feedback over several stages. This feedback is necessary to maintain proper operating conditions despite spreads in manufacturing and changes in temperature or voltage.

The actual gain of both preamplifier and main amplifier can cover wide limits, depending on the type of IC. Both sections could have a voltage gain of about 25dB, as example, thus providing very high gain when

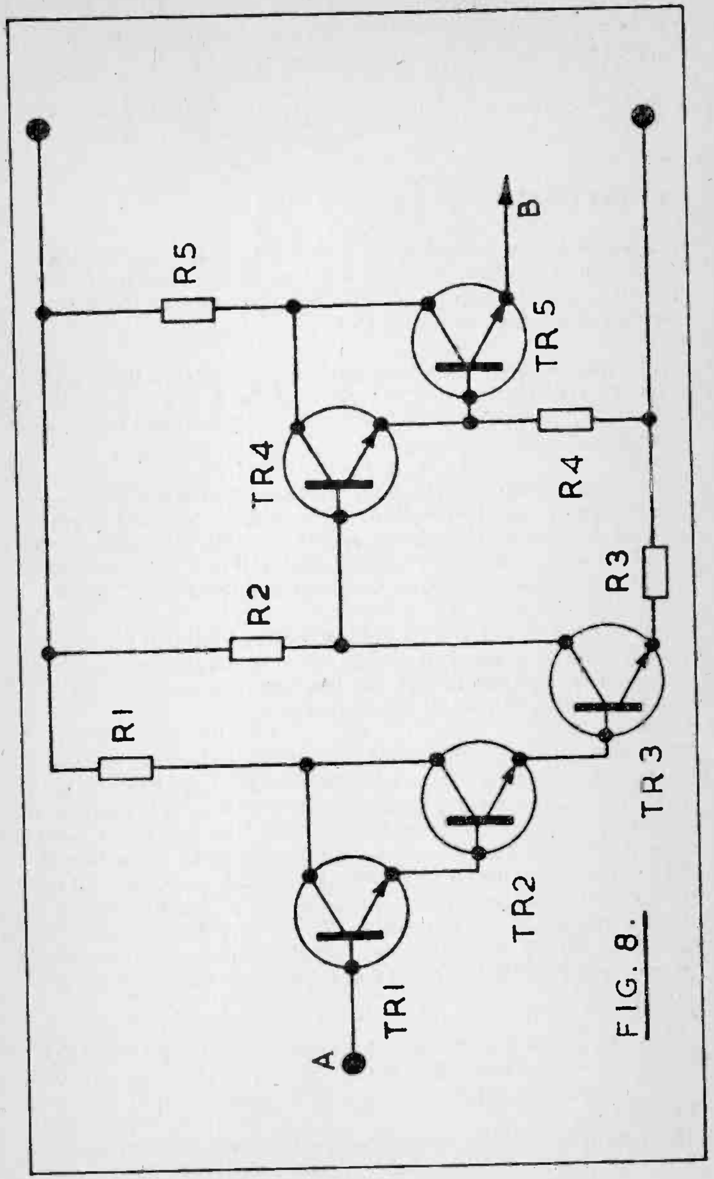


FIG. 8.

they are operated in cascade. That is, with the preamplifier output coupled to the main amplifier input.

Where the IC contains the main amplifier only, a separate preamplifier can of course be included where the signal level has to be raised.

DC STABILISATION

The 3-stage directly coupled amplifier in Fig.9 will help clarify how direct current stabilisation may be obtained. Audio input is to point A, and TR1is the first amplifier, with collector resistor R3 and direct coupling to the driver transistor TR2.

TR2 drives TR3 and TR4; whose bias is developed across R5. As TR3 is of NPN type and TR4 of PNP type, these two form a complementary pair – TR3 conducts when its base is driven positive, and TR4 conducts when base drive to it is negative.

Disregarding audio operation of the stages, output point B should rest at a potential equal to one-half the supply voltage. In these circumstances, operating conditions are correct. However, the base potential of TR1 is set by resistors R1 and R2, which form a divider, and TR1 is monitoring the voltage at point B, since its emitter circuit is via R4.

Assume that TR3 and TR4 are not matched, so that point B is more negative than half the supply voltage. There would be more than half the supply voltage across TR3, and less than half available for TR4. The feedpoint for R4 would have moved negative.

The emitter of TR1, supplied from R4, also moves negative. As the base of TR1 is held by the potential divider R1/R2, the base of TR1 is now more positive, relative to the emitter. TR1 is of NPN type, and its collector current rises. Collector current is through R3. The increase in current through R3 causes a higher voltage drop in R3, so the base of TR2 is moved negative. TR2 is PNP, and its collector current also rises. This in turn causes an increased voltage drop in R5 and R6, thereby moving the base of TR3 in a positive direction. TR3 emitter current thus rises, moving point B positive. At the same time TR4 emitter current falls (it is PNP), so point B can shift to the half supply voltage position.

Due to the overall amplification of the circuit, the changes which can take place are very small. Should the potential at B be too positive, then correction is applied in the opposite direction.

The purpose of direct current feedback is to set and maintain proper working conditions. It thus has a different purpose to the negative

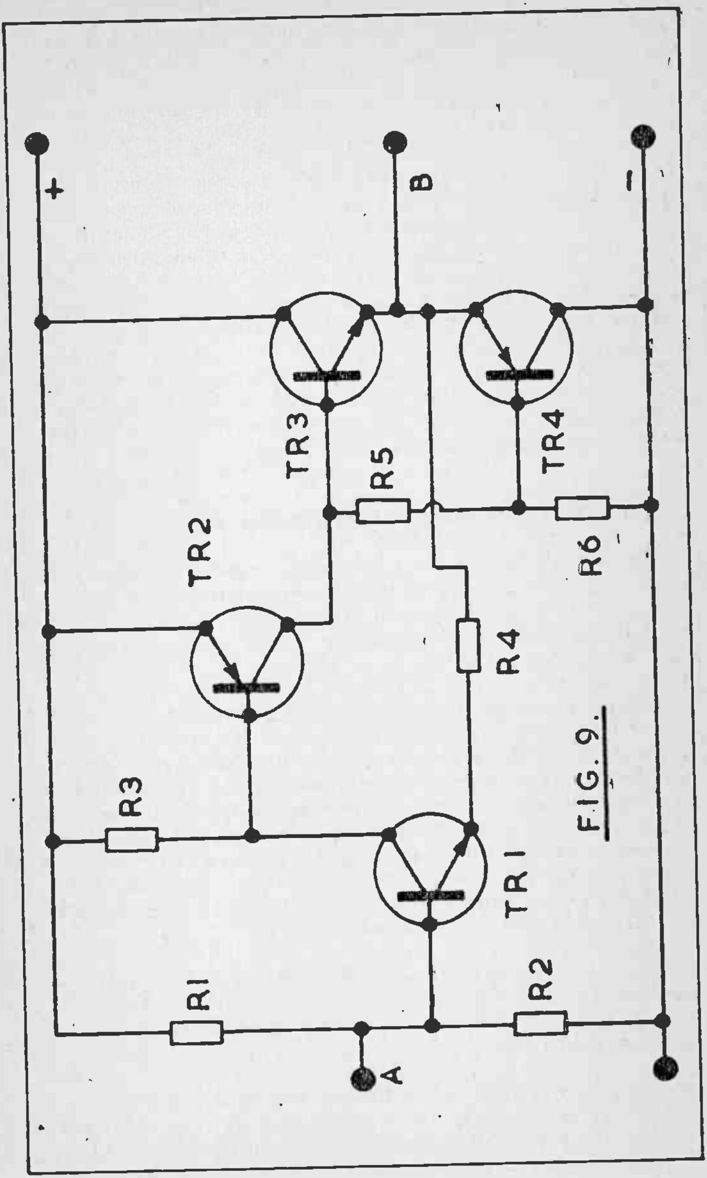


FIG. 9.

feedback employed to improve fidelity, though the feedback circuits may be common to each other in some respects. DC stabilisation may be arranged over the number of stages required. It may include pre-amplifier stages, and with some ICs there can be external means of adjusting bias when first setting up the equipment.

Stabilisation diodes are often present, for the output transistors (Fig.4) and other stages. These compensate for changes due to temperature, so that the device can maintain suitable working conditions over a substantially greater range of temperature than would otherwise be possible. The diode areas of a chip can be closely associated with the transistor regions, so that changes in temperature are easily sensed. The resistance of the diode elements changes with temperature. This change in temperature is arranged to counteract changes in the transistor characteristics which arise from alteration of temperature. As example, where a rise in temperature causes an increase in collector current, the diode compensation will shift bias conditions, to reduce current. In this way more satisfactory working conditions are maintained.

COMPLEMENTARY AND QUASI-COMPLEMENTARY

With a PNP transistor, negative drive raises emitter-collector current. The NPN transistor operates in the reverse manner, and positive drive increases emitter-collector current. Therefore PNP and NPN transistors can be combined in a complementary output stage, operating in push-pull.

In Fig.10 A is a complementary stage. TR1 is NPN, and TR2 is PNP. The circuit is arranged so that bias is developed across R1. The input is directly to the base of TR1, but R1 is of low value, so has no significant effect on input of the audio signal to TR2 base. TR1 and TR2 will be driven into conduction on alternative halves of the audio cycle. The emitters or output point will thus swing up and down, and can be coupled to the speaker by a capacitor. There is no need for means of reversing phase at the input to one transistor, nor is an output transformer necessary. (Other resistors and components are not shown here, but will be needed in the completed circuit.)

With circuit A, TR1 and TR2 are of complementary types, but are not an identically made pair, since one is PNP and the other NPN. By adopting a quasi-complementary stage, exactly identical transistors of NPN type can be used as at B.

Input is as before, while TR1 is NPN and TR2 PNP. So TR1 conducts with positive input, and TR2 with negative input, driving the output pair TR3 and TR4 on alternative halves of the audio cycle. Output coupling can be as for A, the whole circuit being arranged as described

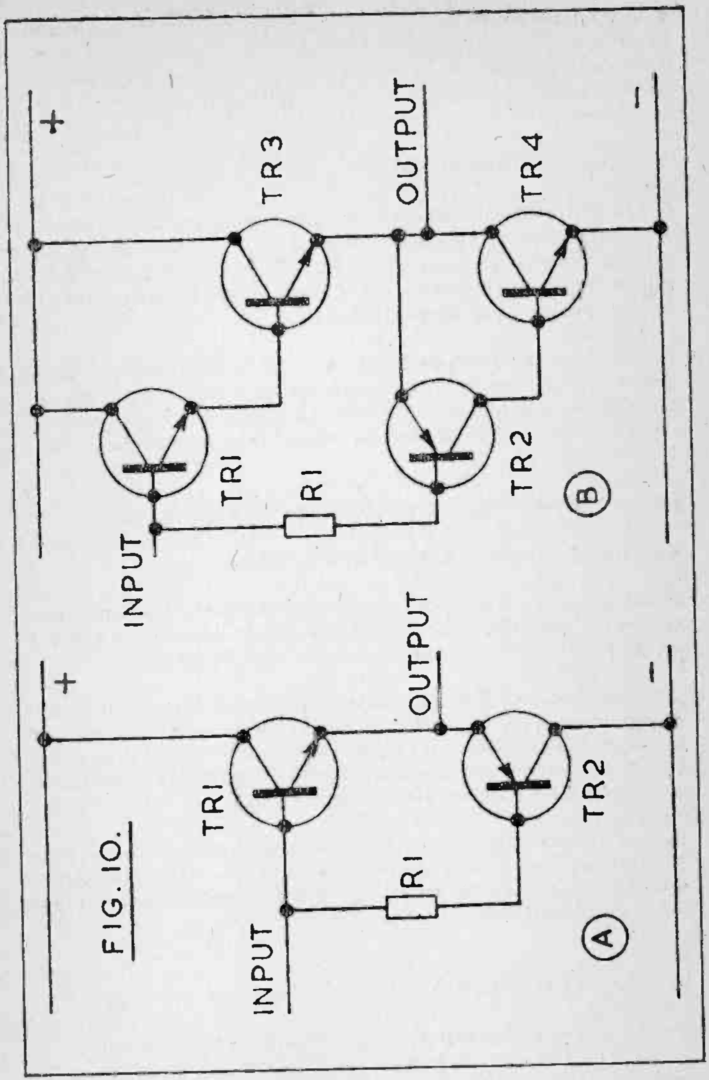


FIG. 10.

so that all stages receive correct potentials. The needed resistor network and other features will be present in the IC, so that only external items (e.g. capacitor and speaker) have to be added.

Because of their gain, power-handling ability, and simplicity in terms of peripheral components, circuits of this kind are very largely used. They can also function at a low distortion level over a wide range of operating voltages.

IC AND EXTERNAL CIRCUIT

Fig.11 shows both the internal circuit arrangement of a small audio IC and the external circuit and components for use with it. This is the TAA300, intended for a supply of 9v, and giving outputs up to 1 watt into an 8-ohm speaker. An input of about 8.5mV is required for this output, and the input impedance is 15k.

Various features already dealt with will be found in this IC and circuit. Audio input is from the isolating capacitor C1, and C2 is an external decoupling capacitor. Negative feedback is effectly from the output pair at 2 to the first audio stage, set by external components C3 and R1.

C4 is the speaker coupling capacitor, and C5 a by-pass capacitor to help maintain stability. VR1 allows adjustment of bias conditions and is set for a quiescent or no-signal current of 8mA.

The IC has a TO-74 case with 10 common to it, and a heat sink clip will be approximately 8mm in diameter and can be bolted to a blackened aluminium 16swg plate about 4 x 5cm, or of larger area.

Usual precautions will be necessary to avoid instability. Input circuits should be clear of output circuits, and are screened if required. A capacitor of about 470μF is used from 4 to earth line and the negative battery or power circuit should not run to the earth line at any input circuit point, but to 1 and 10 as shown.

Fig.11 well illustrates the complex circuitry which is available with an IC, with very few external components. Other ICs will need different components of course, depending on their type and purpose, but these external items are always relatively few in number.

INTERNAL PROTECTION

Some ICs have no internal protective circuits. These ICs may be damaged by excessive rise in temperature, excess supply voltage, or too heavy output stage current caused by short-circuited or too low impedance load, etc. With these, the external circuit values must be so arranged that no important rating is exceeded, with the worst operating conditions likely. The most arduous conditions will be those of maximum

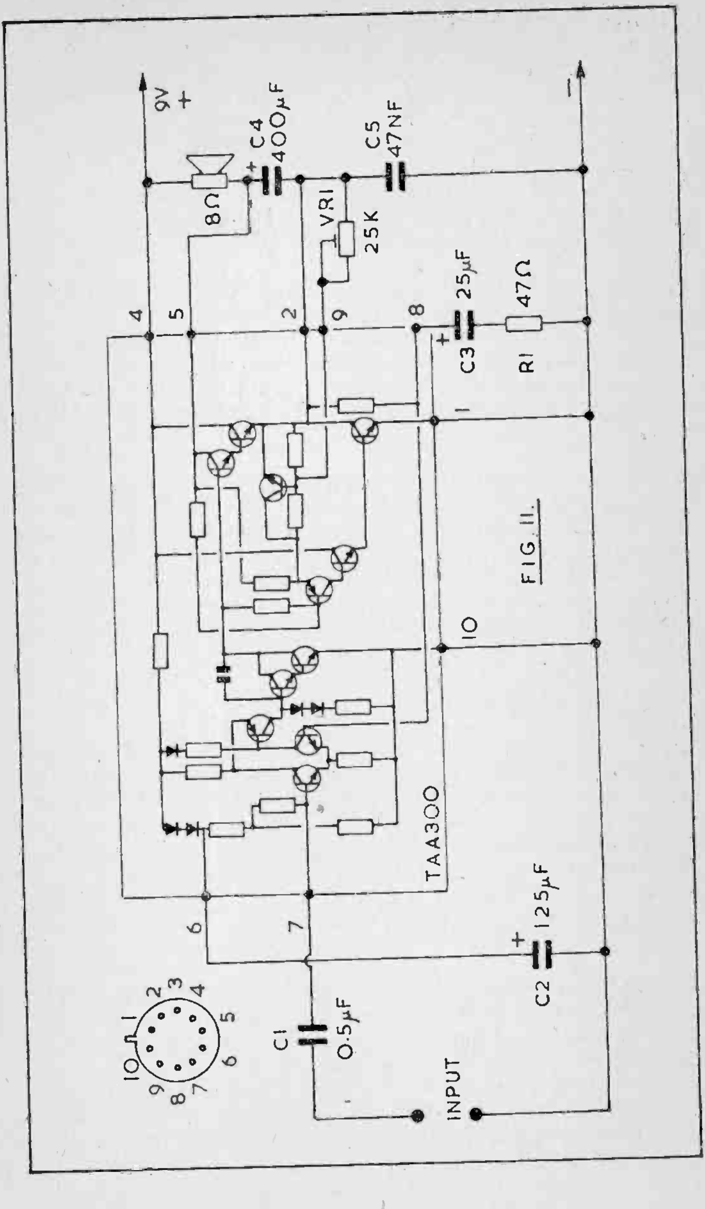

9V +
C4 400μF
C5 47NF
8Ω
VR1
25K
C3 25μF
R1 47Ω
TAA300
C2 125μF
C1 0.5μF
INPUT
4
5
2
9
8
1
10
6
7

FIG. 11.

voltage, current and temperature. Even with the highest supply voltage which will arise, current and temperature ratings must not be exceeded. The IC can then be expected to operate satisfactorily. Damage would be avoided, unless unusual conditions which had not been allowed for were to arise. These could be an increase in supply voltage, an unusually high ambient or device temperature, or shorted output circuit.

Other ICs have various forms of protection provided internally. Protection may be against excess voltage, excess current, abnormally high temperature, or output short-circuiting.

Protection against excess supply voltage can be by a transistor monitoring the potential applied, and so connected that it shifts the output stage bias to cut off these devices if the voltage is too high. This in turn prevents damaging current levels. When the excess voltage is removed normal working is restored. This excess-voltage trip will be arranged to come into action only when the absolute maximum voltage rating for the IC is exceeded.

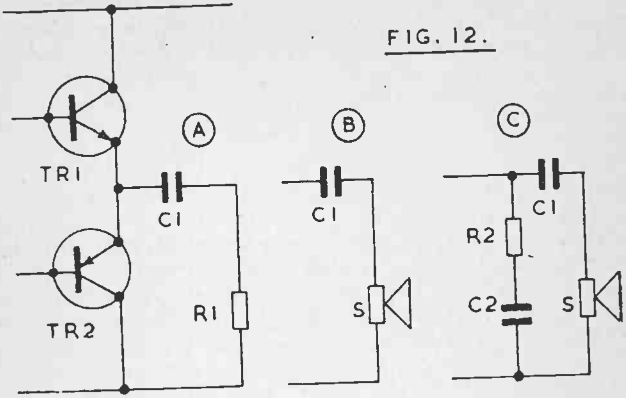
Protection of the output stage may be by a silicon controlled rectifier. This is a device in which negligible current will normally flow. When sufficient voltage is applied to its gate, an avalanche discharge arises and continues until voltage across the SCR is reduced or removed. The gate voltage can depend on the output stage current, and when the SCR is conducting it can be arranged to close down the output stage. If this happens, working is restored by switching off the power supply.

EXTERNAL CIRCUITS

The way in which these govern operating conditions in the IC is important. Some may be readily modified, but others may not. It is upon the external circuits that such factors as operating voltage and current, input and output, speaker load, bias, gain or degree of negative feedback will depend. It is thus worth looking at the most important features here to see the effects modifications can have.

ZOBEL NETWORK

In Fig.12 A shows an output stage reduced to its simplest terms, with complementary transistors TR1 and TR2. Output is taken from C1. The output load is assumed to be resistor R1, selected to suit operating conditions. TR1 and TR2 will conduct alternately, swinging the voltage across R1 up and down. The change of voltage at C1 cannot exceed the supply voltage. R1 is purely passive, consuming power delivered, and if operating conditions are correct a damaging voltage cannot arise across TR1 or TR2.



At B, the moving coil speaker S has a winding which has inductance so that the load is no longer purely resistive. An inductance stores energy in its surrounding field, and can deliver part of this energy back into the circuit to which it is connected. This energy may not be important, especially with a low power amplifier, so that the speaker can be connected as at B. Here, it is supposed that all operating conditions of the output stage are still within the ratings of the devices. So speaker S may safely replace R1.

In circuit C, energy stored in the inductance S may be sufficient to cause a breakdown in the output devices, when returned to the circuit. The Zobel network R2 and C2 gives protection to the output stage against this. By the use of suitable values, R2, C2 and S combined can be arranged to be an almost completely resistive load similar to R1 at A. The difficulties associated with B are thus removed. R2 and C2 become more important as output increases, and may be essential at maximum output. This depends on the circuit, other means of protection, supply voltage and other factors which may protect the output stage.

Components arranged as are R2 and C2 may be provided for frequency compensation, as they form a 'top cut' type of tone control. With some circuits R2 and C2, or C2 alone, prove to be necessary to maintain stability by avoiding high frequency feedback to input circuits.

HF INSTABILITY

High frequency instability may be above audibility, and will then be shown by a raised input current while the amplifier is apparently delivering no output power. This may be caused by the layout only, or by the omission of C2. Where C2 is required for this reason, it should be fitted close to the IC, directly from output to ground pins. Other means of retaining stability are covered in the section on the layout of circuits.

GAIN

The overall gain of an IC amplifier can be adjusted within wide limits by the amount of negative feedback. With very high gain there is increased distortion, and instability is more likely than with smaller gain. Some ICs have provision for the user to alter the gain to suit the purpose in view, while with others the gain may often be changed from that generally obtained, by modification to some external component values.

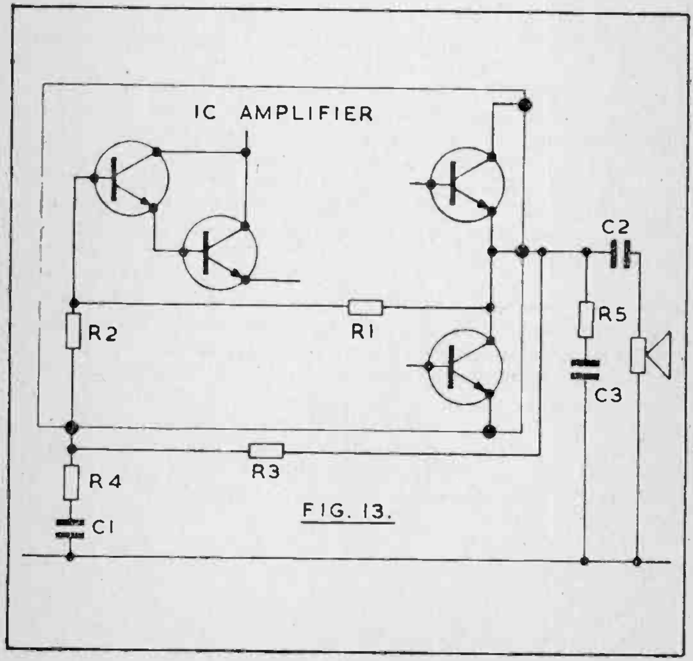


FIG. 13.

In Fig.13 the output stage provides negative feedback via R1 to a stage in the input part of the IC. R1, together with R2, and the external components R4 and C1, largely determine the feedback used. R3 may be added as an external component, or may not be present.

With this circuit, reducing the value of R3 will increase feedback, and so reduce gain. Alternatively, if R3 is already present, it may be in order to increase its value, to reduce feedback and improve gain. In a similar manner, reducing the value of R4 will improve gain. C1 is generally of quite large value, and is for DC isolation of the feedback circuit.

As in this circuit R1 and R2 are present in the IC, if R3 is not employed, gain can be adjusted by chagning R4. With some ICs a range of possible values for R4 may be listed, so that the user can select the wanted amplification level.

The speaker is coupled by C2, and C3 and R5 are returned to the earth line in the way described earlier.

Where optional values are quoted – such as those for R4 – they can be fitted without any particular precautions. But modifications outside these limits may cause troubles such as instability. With some circuits a particular value may be required in a position such as R3, to obtain correct bias conditions in the amplifier.

INPUT/OUTPUT

An IC amplifier can of course only provide the maximum power output for the rated voltage when input is sufficient. As example, an IC may be quoted as delivering 5 watts with a 24v supply, for an input of 70mV. Clearly many circuit applications can arise where the 70mV input will not be available except with the use of a preamplifier. In these circumstances, if this IC were used alone, the power obtained can be expected to correspond to the lower input which is available. So if the unit supplying audio signals had a maximum output of say 35mV under the conditions of use, only 2½w could be anticipated.

With insufficient input, quality remains satisfactory for all settings of the volume control, but the wanted volume is simply not available. Should operation at low settings of the volume control appear to be satisfactory, but distortion set in and full volume not be realised for higher settings, the cause has to be sought elsewhere. An inadequate power supply could be responsible; or high frequency instability at all but low volume control settings.

In the same way, an IC amplifier designed for a high input and operating correctly might be wholly inadequate in output when a different and lower input is provided.

BIAS TRIMMING

Some ICs have provision for the external adjustment of bias, so that the output voltage is centred at half the supply voltage. This may be required to obtain best results from an individual amplifier; or it may be necessary to match amplifiers used for stereo.

In Fig.14 TR2 base bias is from TR1, but also through R3 from the resistors including R1 and R2. In addition, VR1 allows close adjustment of bias, deriving its supply from the decoupled point R2/R3. TR2 is directly coupled to later stages, and through these to the output stage. Adjusting VR1 thus alters DC operating conditions through the amplifier, allowing the output voltage to be moved in a positive or negative direction, as required to centre it from the supply voltage.

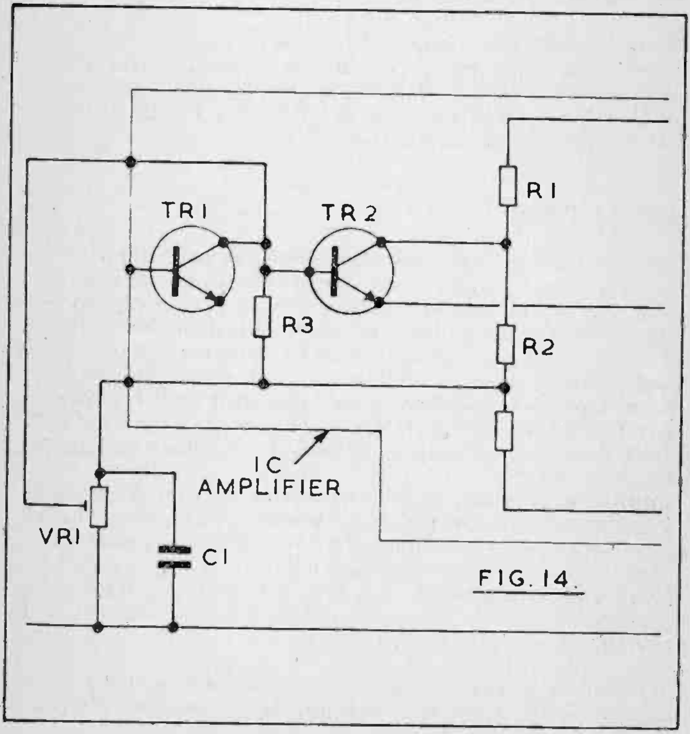


FIG. 14.

VR1 will generally be a pre-set on the circuit board. The amplifier may be adjusted by rotating VR1, while measuring the output voltage point with a meter. Maximum undistorted output is expected when the voltage of the output point is half the supply voltage. Whether or not such bias adjustment must be made depends on the IC, its type, and purpose, as well as upon the voltage and whether the maximum undistorted power is necessary. In many circuits the drift from centre voltage of the output point, due to tolerances in production, temperature, or supply voltage, may not be important.

BY-PASSING

Except with small ICs it is often necessary to have a by-pass capacitor of quite large value between positive and negative supply lines. It is usually better to have this capacitor near the IC, on the IC board, rather than in the power pack when this is on a separate board. The length of lead between the IC and its reservoir or supply capacitor will have no importance from the DC operating point of view, but even a few inches of lead here may cause HF instability.

In other parts of the external circuit it may be necessary to fit decoupling, HF by-pass, or compensation capacitors. Again, these ought to be immediately adjacent to the pins concerned.

In some circuits two capacitors may be used in parallel. The smaller one will be primarily to maintain stability, and can be at the IC. The larger one may be for usual smoothing purposes, and may then be incorporated with transformer and rectifiers in the power unit.

Some amplifiers incorporate a small capacitor from input to earth line. This is particularly likely to be wanted to avoid HF instability when a high impedance input circuit is provided.

The purpose of these measures is to afford an easy path to the earth line for very high frequencies which may cause instability. Without them, the amplifier may go into a state of oscillation, unless it has relatively low gain, and operates at low power. Oscillation would cause high current and power dissipation, and should not be allowed to continue if present when first testing an amplifier.

INVERTING INPUT

An IC may have only one audio input point, and this is so with the simpler type of IC. The input is generally to the base of the first device and the return circuit for the input will be the ground or negative line also. With such an IC, there is no means of selecting or changing the relative phase of input and output signals.

Many other ICs have non-inverting and inverting input points, which may be used as necessary. In Fig.15, A is such an IC, with non-inverting input marked positive, and inverting input marked negative.

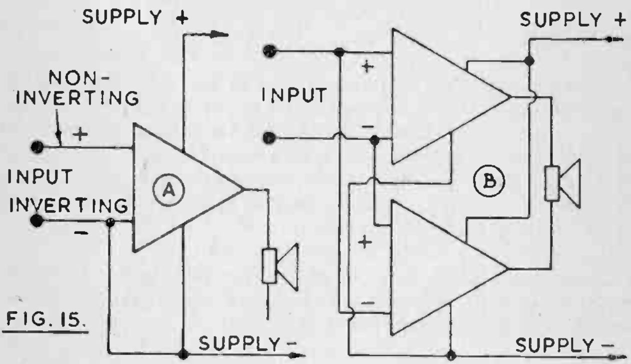


FIG. 15.

These positive and negative signs are merely to indicate the non-inverting and inverting inputs respectively. At A, the audio signal is taken to the non-inverting input, and the inverting input is grounded to the negative line. The IC has a separate lead for its negative supply line. (With the simpler type of IC mentioned earlier, the situation resembles A except that the non-inverting input is the only one available, and the inverting input is not present, the input return being to the negative line.)

With the circuit connected as at A, a particular phase will exist between the audio input to the IC, and audio output to the speaker. If the non-inverting input were grounded to the supply line, and audio signals were taken to the inverting input, the phase would change by 180 degrees, or half a cycle.

This allows ICs to be used in push-pull, as at B. Audio input is to the non-inverting point on one IC and the inverting point on the other IC, so that outputs are of opposite phase, and can be coupled to a speaker exactly as with a push-pull stage consisting of separate transistors.

This allows a doubling of power output.

The choice of inputs can also be important in other circuit arrangements. An IC may have an input return lead, to allow the emitters or other 'ground' point of early stages to be kept separate from negative power circuits; or a feedback input point may be present, generally employed for negative feedback purposes. These are not equivalents of the inverting or non-inverting inputs of the type just described.

IC DISSIPATION

With preamplifiers and low power amplifiers generally, the power dissipated in the IC will usually be so small that it is easily within the device rating. This means that there will be no danger of the IC overheating. As example, the MFC4000 (dealt with earlier) is intended for a power output of 250–350mW. When this IC is soldered to a circuit board, in a position allowing free air circulation, its maximum power dissipation is 1 watt, at 25°C. (This is reduced by 10mW for each 1°C rise in temperature.) Thus in normal circumstances operating conditions will be easily within safe limits.

The power dissipated in a device is Input Power *less* Output Power. Power will be expressed in Watts, and IE = W. That is, Current in Amperes *times* Voltage = Watts.

Suppose the IC were drawing 15mA from a 9v supply, and giving no output. Power dissipated is 0.015 x 9 = 0.135W, or 135mW. This is the dissipation with no signal present.

If drive is now applied so that the current rises to, say, 50mA, input to the IC is now 450mW. In these circumstances, a useful power output of 150mW might be obtained. Of the 450mW consumed from the supply, 150mW is thus output, while 300mW is dissipated in the IC. Both these sets of operating conditions are well within the 1W limit for the IC.

As a result, with low power amplifiers power dissipation in the IC is much less than that which the IC could safely handle. So there is no need to provide heat-sinking, or take any special precautions to avoid damage from overheating.

This is not so, however, with larger power circuits. Here, the limiting factor will often be the rise in temperature of the IC, due to power dissipated in it. The IC may be operated with limited current and voltage, so that its dissipation is not exceeded. Or it can be provided with some form of heat sink, which carries away heat produced in it. This, in turn, will allow higher current and voltage ratings, with an increase in the power output obtainable.

For power ratings of a few watts, sufficient heat sinking may be obtained by the circuit board foil, and heat is carried away by the normal soldered connections between IC and foil. Other ICs have tabs or fins, which may stand clear of the board, or use seperate heat sinks.

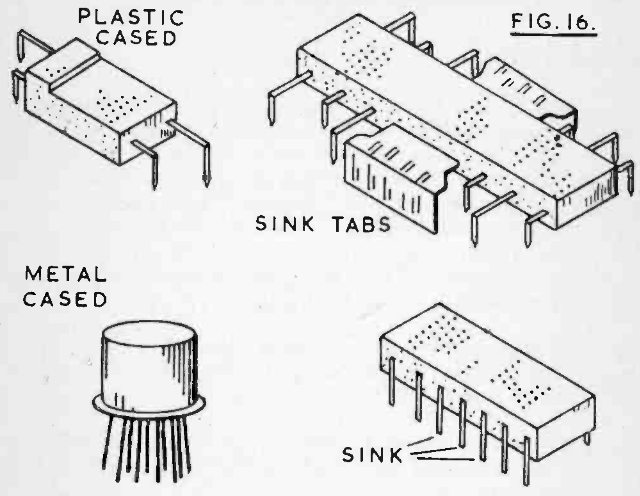


Figure 16

The SL414/5 ICs are an example of how power dissipation permissible in the device depends on heat sinking. With an ambient temperature of 250°C and no heat sink, dissipation is limited to just under 2.5W. With an 18swg aluminium heat sink approximately 4 x 6cm in size, dissipation is raised to over 6 watts. The heat sink is thus an essential part of most IC amplifier designs, and must not be omitted.

WORKING CONDITIONS

To secure maximum output from an IC, it will have a large heat sink, and be operating at near maximum voltage and current, with a particular speaker load. It will also receive an input which will allow maximum output. For reduced power, any of these conditions may be modified.

For somewhat reduced power, a smaller or less effective heat sink may be used. For much reduced power, no sink may be needed at all. Reduction of power may require no changes whatever except the lowering of the supply voltage. This will also result in the IC drawing a reduced current. In some circumstances, however, it may be necessary to change some external resistor values, to compensate for the lower supply voltage. There are also minimum voltages, below which the IC will give an unsatisfactory performance, or cease to work at all.

Reduced power is also often possible by increasing the load impedance of the speaker. Except with small, low power amplifiers, it is wise to do this only when alternative loads are specified. Where permitted, an increase in speaker impedance can be expected to reduce power output and peak current and thus lower dissipation in the IC.

Lower signal levels naturally reduce power output, and current peaks. Whether or not such lower inputs give enough volume depends on the purpose in view.

It is thus often possible to operate an amplifier at a lower power level than that for which it was designed, but the opposite is not generally so. Increased voltage and current, or lower impedance loads than intended, can be expected to cause overheating, or damage if severe. (Some ICs have internal overload protection, dealt with elsewhere.)

SOLDERING ICs

Individual hand soldering of IC leads will be usual in home-built equipment and requires only radio and electronic type cored solder, and a 15 to 25 watt iron, as for other wiring.

The iron should have reached its proper temperature, and the cored solder is applied together with the iron in the usual way. It is important that the IC is properly seated on its board before any leads are soldered.

The degree of heating which can be allowed without damage depends somewhat on the IC, and whether other conductors rapidly carry the heat away. In this respect the work is similar to that of soldering transistors – there is no need to 'cook' a joint, and once the solder is seen to flow correctly and the joint is made, the iron is removed. Soldering will normally be at some distance from the IC, where leads project under the circuit board. Even with ICs which rest flat on the board, the millimetre or so of lead extending from the IC through the board is important in helping to avoid too much heat inside the IC. Maximum soldering time may be taken as not more than 5 seconds if the iron is at 300–400°C, or not more than 10 seconds for under 300°C. Normally joints will flow and make in a second or two. If there are relatively large areas of foil or other items which conduct heat away from some joints, the iron must be at maximum temperature, or a slightly larger iron may be preferred.

Blowing on the joint immediately the iron is removed is quite an effective way of helping to cool it if necessary.

With clean surfaces and a clean iron at correct temperature, no soldering difficulty is likely, provided the cored solder is melted at the joint, so that its flux can take effect where required. With 0.1in matrix boards and many ICs there is very little free space between leads. Small, neat joins thus become essential. If solder should bridge adjacent leads, it can be heated and shaken off, or taken off with solder wick or suction, or removed by careful scraping. A final check can be made that all joints are well made, but with no fragments which may cause shorts being allowed to remain.

The unsoldering of an IC, to correct errors or to remove it for replacement, can be a rather more difficult procedure. Where the IC is wire-ended and leads are long enough, they can be unsoldered one at a time, and gently eased up through the board. Avoid lengthy heating just as when soldering an IC in. In this way all the leads can be got free, without damage.

It is often quite practical to assemble an IC on a plain perforated board, with wire connections underneath. This is especially easy with those ICs which will fit 0.15in matrix boards. An IC can then be removed without damage, by unsoldering these wires, which can be replaced later.

The situation is worse when a multi-lead IC such as a dual-in-line soldered directly into a printed circuit board. For the IC to be lifted straight out, *all* leads need unsoldering simultaneously. This really requires a device which allows heat to be applied to the rows of pins at the same time. Obtaining such a tool is scarcely justified for an occasional unsoldering job. Without it, leads have to be unsoldered individually or two or three at a time (again avoiding overheating if the IC is to be saved). Solder is removed by shaking or wick, until the IC can be raised, probably beginning at one end. Great care is needed if IC and board are to be used again (perhaps because an IC has been inserted wrongly).

If a circuit is assembled with an IC and fails to operate, all other items are best checked first. Faults may include short-circuits, omission of some lead, or severe error in resistor value due to wrongly read coding. A capacitor or similar item can be tested by unsoldering one end only. It would also be obvious to check input and output circuits before suspecting the IC, as well as the presence of normal operating voltages.

Where an IC may be destroyed during removal, unsoldering is relatively easy, and leads may be snipped off and removed individually so as to avoid damage to the board.

With some ICs it is possible to prize up leads one by one, using a sharply pointed tool above the board, while holding the iron below. An adjustable clamp or similar means of securing the board is then very helpful.

COMPONENT VALUES

Capacitor values may be marked in various ways by the manufacturer. For example, 0.005 microfarad (μF), 5 nanofarad (nF) and 5,000 picofarad (pF) are actually all of the same value. It is worth noting the following:

$$0.001\mu F = 1nF = 1{,}000pF$$
$$0.01\mu F = 10nF = 10{,}000pF$$
$$0.1\mu F = 100nF = 100{,}000pF.$$

From this, it is easy to see other values. As example, 47nF is 0.047μF or 47,000pF. Similarly, 2.2nF is 2,200pF.

With preferred value capacitors now generally used, values such as 2.2μF or 47μF are often seen, and are virtually direct replacement components for 2μF or 50μF. Electrolytic capacitors may often be produced with a tolerance of minus 20% to plus 50% of the marked value. So where circuits show, as example, values of 2.2μF, 47μF, or perhaps 470μF, components of 2μF, 50μF and 500μF would be equally suitable. In the same way, a 320μF position could be occupied by a 300μF, 330μF or 350μF capacitor, just as 6.8μF or 10μF could be used instead of 8μF. So 200μF or 250μF capacitors would be perfectly good substitutes for 220μF, and so on. If there is some good reason why a value should have a closer tolerance than that usual with an electrolytic capacitor, this is normally shown in a circuit.

Similar considerations apply to the voltage rating. As example, 6.4v capacitors can substitute for 6v, or 64v ratings for 50v. However, the rating must not be lower than the actual voltage, so a check should be made that *lower* voltage components are not used as substitutes unless the rating is still adequate.

PART II
PREAMPLIFIERS, MIXERS AND TONE CONTROL

A preamplifier raises the signal level from a magnetic pick-up, micro-phone, or other low-output device to that required by the main amplifier. It may well incorporate equalisation or tone control circuits to suit particular classes of input for which it is intended; or may have general purpose tone controls, or provision for mixing two or more inputs.

With experimental equipment and home-built items which are added to from time to time, a preamplifier may well be a separate unit, in its own case, connected to the main amplifier. But for convenience preamplifier and main amplifiers are often in the same case, even if assembled on separate circuit boards.

A printed circuit board allows the duplication of a tested design, and is often preferred. But such boards are not essential, and where it is wished to avoid the cost of obtaining them, or the work of producing a single board for a project, it is often possible to use a wired board instead. The cost is extremely low, changes can be easily made, and a layout does not have to be planned so completely in advance.

When using practical layouts which are given here, it should not be overlooked that a wired board can usually be duplicated in printed circuit form quite readily, just as in other cases a wired board can sometimes be used instead of a printed circuit board. Because of the convenience of a printed circuit board, it is worth looking into its preparation, to see what work is necessary.

PRINTED CIRCUIT BOARDS

Commercial PCBs have obvious advantages where many amplifiers of the same type are to be assembled. Once the layout has been prepared and boards produced, components can be inserted automatically. For home constructional projects, PCBs are normally made individually by methods which can give one board only. If two boards of the same type are wanted (as for stereo) a second one can be copied from the first.

The making of a PCB need not be a very long or laborious matter, and it will allow a neat and permanent unit to be assembled, with the appearance and reliability of a commercially manufactured item. PCB making can also prove to be an interesting aspect of electronic construc-tion on its own.

In brief, a PCB is made by first laying out components to decide where conductors need to be provided. The board has foil one side and these conductors are masked with varnish or other means. The unmasked foil is then etched away with a solvent so that conducting areas are left only where needed.

It is worth looking into these processes in more detail, so that it is clear exactly how a PCB may be prepared. There is no reason whatever why the first PCB made should not be completely satisfactory. Even if through some small slip an error should be made, this may not mean that the PCB is useless. If a conductor is left where it should not be, it can be cut out with a sharply pointed knife. In a similar way, if some connection is imperfect or omitted, it can be made by soldering on a wire replacement.

Naturally corrections of this kind are not wanted, but they can save a PCB which is otherwise perfect.

LAYOUT

A neater layout is likely to be obtained if the components are positioned with their leads occupying points on a regular matrix. An easy way to achieve this is to use a plain perforated board as guide, marking through the holes of this on to the PCB. As the PCB will require two or more holes for mounting bolts, these can be used to secure perforated board and PCB together, while marking out.

Perforated board commonly has a matrix of 0.1in and 0.15in. Some ICs fit the 0.1in spacing, and others the 0.15in spacing, so use a board to suit the ICs to be fitted.

It will probably help to make a rough sketch on paper first, to a larger size. Arrange the components systematically, moving them around as necessary to allow short connections from one item to the next. Note how capacitors and other components on top of the board can bridge over foil conductors under the board, so that no cross-overs are necessary for the latter. With a little manipulation of components a suitable layout should be found fairly easily.

Input and output circuits should be separated at different ends of the board, especially with high gain amplifiers. Earth returns should be positioned to avoid loops which may cause feedback and instability. If a cross-over seems unavoidable, it can be a lead taken point to point on top of the board.

When the positions of all leads have been marked on the foil, the perforated board guide can be removed. Areas of foil to remain now have to be protected.

ETCH-RESIST

The use of an etch-resist pen is probably the most easy method of protecting the foil to be left on the board, as both thin lines and larger areas can be covered with it. It resembles a felt-tipped pen delivering a quick drying varnish. Larger areas of foil can also be covered with nail-varnish instead.

Transfers are available for ICs and components, and are probably most helpful with the 0.1in matrix ICs where many conductors are close together.

The copper surface must be absolutely clean before any resist is applied to it. It can be rubbed with a cloth slightly moistened with petrol, and afterwards the board should only be handled by its edges.

Conductors and connecting points are then marked with the pen. Take special care with thin tracks to see that the resist line is continuous. Also check that there is clearance at ICs and where circuits must not join. Use a ruler or similar guide for straight lines. Give the board a final examination, checking what you have drawn.

ETCHING

Ferric chloride can be used for the solution. This *must* be kept away from children, foodstuffs, clothing, hands, face and eyes. Take care to avoid any splashes or spots. If any arise, wash contaminated area immediately with running water.

The strength of solution is not too critical. Weak solutions take longer to work, but solutions which are too strong can be unsatisfactory. The amount of ferric chloride needed depends on the area of copper to be removed. About 2oz in 6 to 8 tablespoonfuls of water should easily do an average board of about 3 x 4 in or 75 x 100 mm.

Do not pour the water on the ferric chloride, but add the ferric chloride slowly to the water, stirring with a piece of wood or unwanted plastic spoon. This mixing can be done in a jam jar, but should not be too hasty because of the heat produced.

A plastic photographic dish not much larger than the board is ideal for immersion, but any convenient vessel (not of metal) can be used. Place the board copper side up and pour in the solution. Rock the dish from time to time. The copper will begin to disappear, and the etching should be finished in 20 to 30 minutes or so. Take the board out with plastic photographic tongs, or pour the liquid away, and flush the board under running water, mop it off, and leave to dry. The usual PCB resist does not prevent soldering, but can be cleaned off if wished with a solvent such as petrol.

DRILLING

This can be done before painting resist on the board; or after the board is otherwise finished. Drilling after painting but before etching is likely to let etching solution penetrate round the holes, which become enlarged and irregular in the foil. No difficulty of this kind can arise if drilling is last.

A very small drill is required – about 0.036 or 1/32in. It need be no larger than to give ready clearance for the wire ends of components, or a 22swg or 20swg wire. Particular care should be taken with alignment and position of holes for ICs, and a perforated board is a helpful guide here, as mentioned.

COMPONENT ASSEMBLY

It is only necessary to insert the components, turn the board over, and solder to the foil. Afterwards snip off excess leads. This can be done item by item, or several components at a time.

An extremely sharp, right-angle bend immediately against the body of a resistor is not recommended, as the wire may fracture. A check should be made of values, and the polarity of electrolytic capacitors, as they are inserted. Also watch that the solder flows properly at each joint.

Some ICs fit only one way. If not, be sure the IC is placed the correct way round. If preferred, an IC holder can be used. This is soldered in, and the IC is later inserted in it, with care that each lead-out engages properly with its socket.

AUDIO LEADS

The lead carrying audio signals from a microphone, pick-up, pre-amplifier, or other item is screened, to avoid picking-up hum or amplified signals such as those present in output circuits. The need for complete screening increases in proportion to the amount of amplification to follow. As example, the introduction of slight hum into the input of a high-gain preamplifier is likely to spoil results, as progressive stages of amplification will raise this unwanted signal voltage to troublesome levels. A similar degree of hum pick-up by the input to a main amplifier having relatively low gain might be quite unimportant.

Audible hum will also depend on the bass response of the equipment, and could well be troublesome with bass boost, but inaudible with bass cut. Where the hum level rises as bass is increased, clearly a significant part of the pick-up is arising before the circuit providing tone control.

Screening of audio connections is by the usual shielded lead, with the outer conductor forming the 'earth' return. This conductor ought not to be called upon to furnish a negative power line return for a pre-amplifier or other equipment.

It should be remembered that having an amplifier or preamplifier circuit board out of its case may cause an abnormally high level of hum due to the absence of the usual screening of input components. In these circumstances, the level of hum may vary considerably according to the position of the user's hands, mains leads, or test equipment. Instability, otherwise absent, can also be caused.

With a large amplifier, audio currents of considerable magnitude will flow in some circuits, especially loudspeaker and power supply conductors. The layout and screening of audio leads, as well as correct earthing of various circuits, should be arranged to avoid coupling any of these signals back into the input.

Screened audio leads, made with screened or shielded connectors, should be used as a matter of course for all input circuits to a main amplifier, and for input and output circuits of preamplifiers and other units supplying the main amplifier. Plastic sleeved plugs may not cause trouble in a circuit where there is a fairly high signal voltage, but are as well avoided. Screened plugs are available in a wide range of types, for 2.5mm, 3.5mm and other size jack sockets. Jumper cables can also be bought or made up. Various adapters, such as 3.5mm plug to standard jack, or standard jack plug to 3.5mm socket, are also available, and are handy where equipment is not standardised. There are also numerous audio connectors of multi-pin type, as well as one-to-two-way adapters, and other fittings. These can provide a very easy way of providing two or more output circuits, or alternative inputs.

741 PREAMPLIFIERS

The 741 IC has a wide range of utility for preamplifiers of all kinds. The metal can 741 (μA741CE) is convenient for most uses as its leads may be arranged for 0.15in, 0.1in matrix or other boards, and the can is connected to the negative line, lead 4. Up to 36v supply may be used with these circuits.

Fig.17(a) shows a basic audio preamplifier using the metal can 741. Fig.17(b) is a printed circuit layout for this amplifier. Lead 3 is the

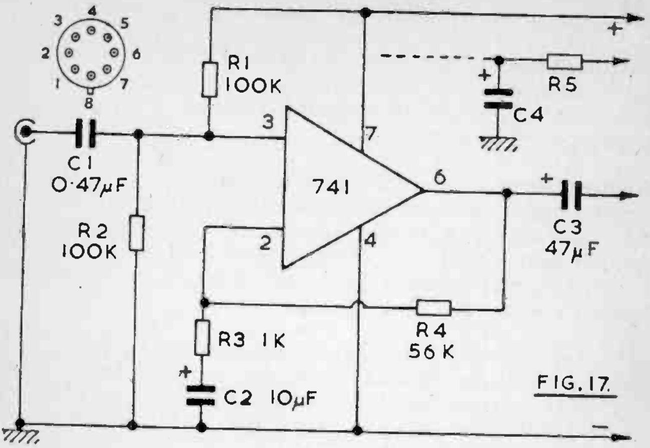


FIG. 17.

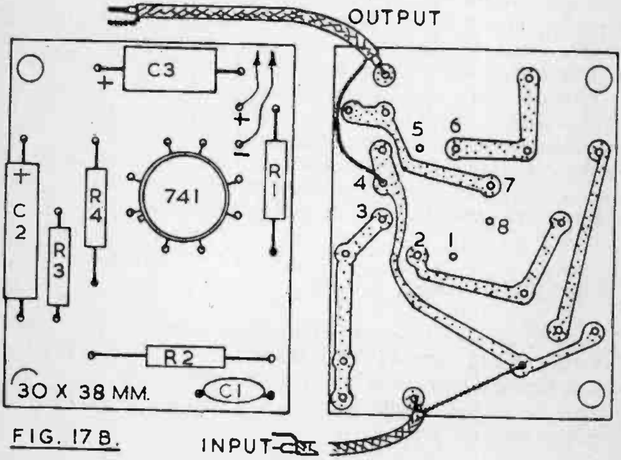


FIG. 17 B.

non-inverting input, and 2 the inverting input, used for negative feedback. Lead 4 is negative line and lead 7 positive. Output at 6 is from a complementary pair. Leads 1 and 5 are offsets, to emitter circuits. The μA741CP has the same numbering as shown, but the μA741CJ has pin connections as follows: inverting input 4 (2 in Fig.17(a)), non-inverting input 5 (3), negative 6 (4), positive 11 (7), output 10 (6), and offsets 3 and 9 (1 and 5).

The divider R1/R2 sets the base input bias point. C2 is a by-pass capacitor with low reactance at audio frequencies, but need not be 10μF. However, large values here will result in an appreciable charging time, especially when R4 is of higher value. In this circuit, the relative values of R3 and R4 determine the amount of feedback, which can be modified over wide limits. Reducing R3 increases gain by reducing feedback, while increasing R3 has the opposite effect. Increasing the value of R4 reduces feedback, thus raising gain. In general, R4 may be increased to as much as 1 megohm (C2 can be reduced to 2μF for the reason mentioned). Variable gain, or a wanted level of pre-set gain, can be obtained by making either R3 or R4 variable. For this purpose, R3 can be a 2.2k or 5k pot with 220 ohm resistor in series. Chances of instability increase as the gain rises, and a small capacitor from 6 to 2 may become necessary to avoid high frequency instability. This can be about 56pF.

Frequency-dependent networks may be placed in the feedback circuit (see Fig.18) for tone control purposes, or to compensate for the characteristics of the type of input used.

R5 and C4 will often not be required. However, if the supply has appreciable impedance, this may cause low frequency instability, and this is corrected by adding C4. A suitable value here is 100–470μF. R5 decouples from subsequent circuits, or improves smoothing if necessary, or allows the voltage to be reduced, if this is required. It would generally be from about 1k upwards in value.

ALTERNATIVE INPUT PREAMP

In Fig.18 Input A is substantially flat, while Input B is for a magnetic pick-up. The 2-way switch allows either input to be chosen at will, and also changes the feedback character for equalisation. Gain for the A input can be modified by altering the value of R5, higher values increasing gain.

This circuit is otherwise the same as Fig.17(a) but shows how two or more inputs can be provided, with individual frequency compensation.

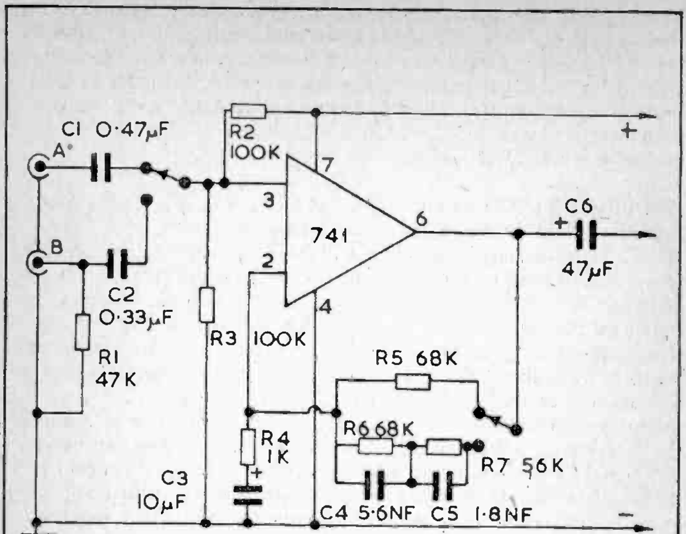


FIG. 18.

MIXER-PREAMPLIFIER

A mixer allows two or more inputs – as for example from microphones, microphone and pick-up, etc. – to be combined or faded in or out in any wanted combination. With many mixers it is possible to increase the number of channels by duplicating the input circuits. In a similar way, a mixer-preamplifier can be used as a preamplifier for one input only, simply by ignoring the other inputs, or even building the circuit without them if preferred.

The simpler type of mixer can have two or three inputs of the same type, for general use for pick-up, tuner, tape or other sources of programme material. More advanced mixers will have inputs which are intended for particular classes of input (such as microphone, magnetic pick-up, etc.) and can then include frequency compensation and other circuits for the individual inputs.

Where the mixer gives 'level' response straight through on all inputs, individual adjustment has to be made later by means of the usual tone controls. This can be satisfactory for simple equipment. It also has no disadvantage where magnetic pick-up units or other inputs have their own preamplifiers, with compensation or tone controls, which in turn feed the mixer. In this case, the individual inputs can be set to give the wanted results without difficulty. Otherwise there is the limitation that all inputs will receive the same frequency correction or tonal adjustment, when the only means of doing this follows the mixer.

MONO MIXER

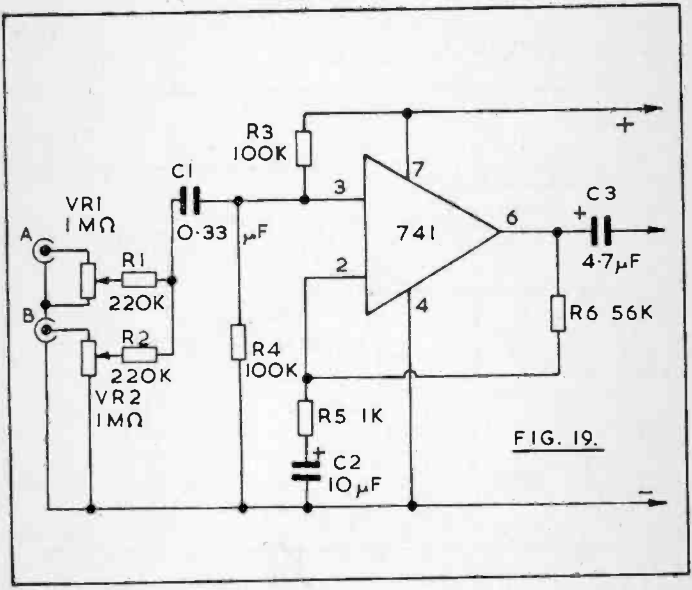


FIG. 19.

Fig.19 shows the 741 IC used in a 2-channel mixer. Sockets A and B provide alternative inputs, and each has its own individual level control VR1 and VR2. Resistors R1 and R2 are to provide isolation of one channel from the other and avoid one input circuit being shorted when the other level control is set at zero. This circuit will accept signals at widely differing levels. Socket A and VR1 should be close together, and away from socket B and VR2, or a high level signal may couple through from one input to the other so that it cannot be faded out entirely when the other channel is at full gain. Alternatively, screened internal leads can be used here. VR1 and VR2 are the usual log type of control, but need not be 1 megohm each, or even be of the same value. In some cases other values may be more suitable for the inputs to be used.

The circuit gives a very useful gain. If wished this can be adjusted to some extent by changing the value of R6, higher values here resulting in increased gain. Actual inputs may be from a radio tuner, crystal microphone or crystal pick-up, or for general purposes, to provide background music for speech, or to fade in one channel and fade out the other, in the usual way.

The operating voltage is not very important, provided it is not too great for the IC of course, and will usually be about 12v to 24v or so.

3-CHANNEL MIXER

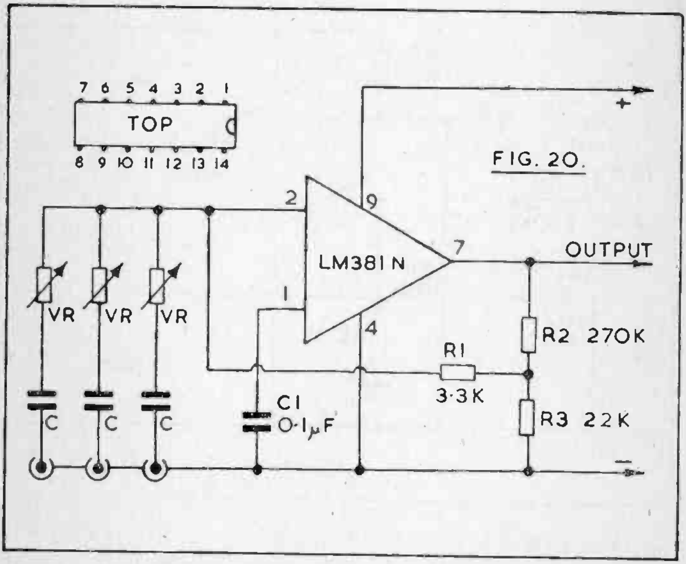


Fig.20 is a 3-channel mixer for inputs of medium impedance, and needs few components. Each input has an isolating capacitor C, the value being about 0.5μF. VR for each channel is the volume control allowing individual adjustment of signal level, and can be about 470k.

R2 and R3 form an output divider, and feedback is via R1. Output from 7 is taken through an isolating capacitor, which can be 4.7μF.

This IC is particularly suitable for preamplifiers, as its internal circuits provide rejection of hum on the supply line, and a very low noise level. It has output short circuit protection, and can be used with 9v to 40v, but will generally be operated in conjunction with equipment having a supply of about 12v to 30v. The voltage gain actually obtained depends on the circuit, but can be 50–60dB. The input impedance is about 100k and the output impedance 150 ohm. Current drain is about 10mA.

The IC is a dual amplifier, and Fig.20 shows connections for one half. For the second half, 13 is input, 14 goes to C1, and 8 is output. It thus allows duplication of amplifiers for stereo purposes; or provides amplifiers for different classes of input, for mono equipment.

PICK-UP TYPES

The output voltage of crystal and ceramic pick-ups is in relation to the amplitude of the movement of the stylus, so can be reasonably equal over a range of frequencies. So little equalisation need be used. Output can be around 100mV to 350mV, or over 500mV for high-output units. Load impedance may be up to 2 megohm. Such a pick-up is useful for general purposes, and the large output types are favoured for amplifiers which have rather limited gain as the high input allows the amplifier to provide its full rated output.

A magnetic pick-up may be expected to have an output of about 1mV to 3mV, so has to be followed by an amplifier of greater sensitivity, or is used with a preamplifier between pick-up and main amplifier. The output depends on the stylus velocity, so is lower at low frequencies, and an equalisation circuit is added to help compensate for this. The load is also usually around 47k.

Outputs of all types depend on the actual unit, and tend to be lowest with a transcription arm with low tracking weight. Details of individual types are supplied by the maker. No particular difficulty should arise if the need for checking the type of pick-up is kept in mind. As example, replacing an inexpensive but high-output crystal unit by an expensive magnetic unit might only result in low output and unsatisfactory reproduction if the amplifying equipment is not suitable.

EQUALISATION

Individual preamplifiers allow equalisation to suit the purpose in view. Fig.21 shows a circuit intended for a magnetic pick-up, or for tape playback purposes, values of components being adjusted to suit, from the component list.

Selective feedback is provided from 7 to 2. For a magnetic pick-up R1 is the load, and gain falls as frequency increases, to give compensation.

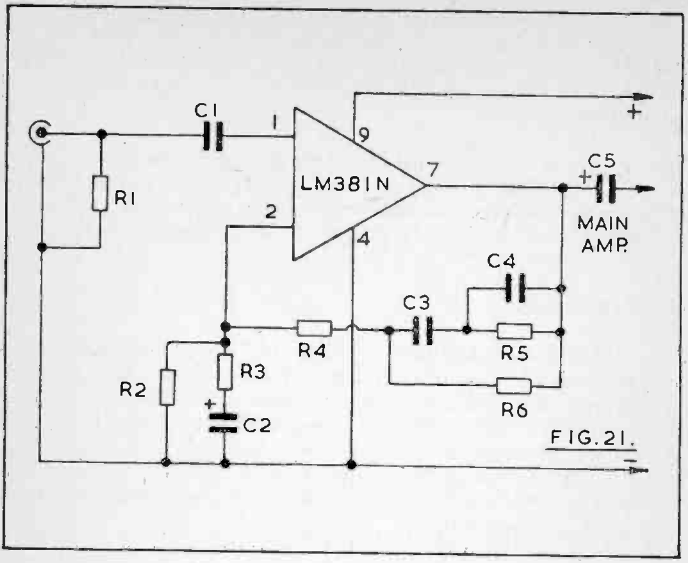


FIG.21.

For tape, a similar effect is produced by the feedback being greatest at high frequencies, but values are intended for typical playback purposes.

With individual preamplifiers designed for the purpose required, each is used only for the particular type of input intended. The outputs of the individual preamplifiers can be selected by switching, for quick changing from one to another. Individual gain controls may be incorporated with advantage, so that the main amplifier receives an input at a similar signal level, on all occasions. This avoids the need for adjustment at each change, or bursts of unwanted volume when changing from a low level signal to a higher level.

VALUES FOR FIG.21 (½-LM381N)

Magnetic Pick-Up

R1	47k
R2	100k
R3	240 ohm
R4	2.4k
R5	100k
R6	1.2 megohm
C1	0.1μF
C2	20μF

C3	3nF
C4	1nF
C5	4.7μF

Tape Playback

R1	omit
R2	240k
R3	180 ohm
R4	omit
R5	62k
R6	2.2 megohm
C1	0.1μF
C2	20μF
C3	1.5nF
C4	omit

PLAY-THROUGH

When various inputs are used with an amplifier, some will often be available at a much higher level than others, while some may need equalisation, while others do not. In circumstances such as these, a preamplifier with play-through capability such as that in Fig.22 will prove useful.

Here, three input sockets are available. One can be used for a radio tuner, which will generally have adequate output, and not need any particular frequency compensation. The Auxiliary input is for general purposes, and might take a crystal pick-up or microphone, or the audio signal from another preamplifier unit, or any other signal which is at sufficient level for the following amplifying equipment, and which does not need any frequency compensation other than may be offered by tone controls in the main amplifier.

The third input is for a magnetic pick-up, R1 providing the load for this, and the feedback having a network to provide equalisation for this purpose. For other uses, the feedback could be modified.

The 3-way switch gives immediate selection of any of the inputs. It is also easy to provide an individual level control for each input so that all can be adjusted to give about the same audio output from the speaker. It is, in fact, not difficult to combine level controls, alternative inputs, and equalisation circuits or preamplifiers in any wanted combination.

MC1339P

This is a dual low noise preamplifier operated from a 12v to 16v supply, with a current drain of about 20mA. Power supply filtering by transistor

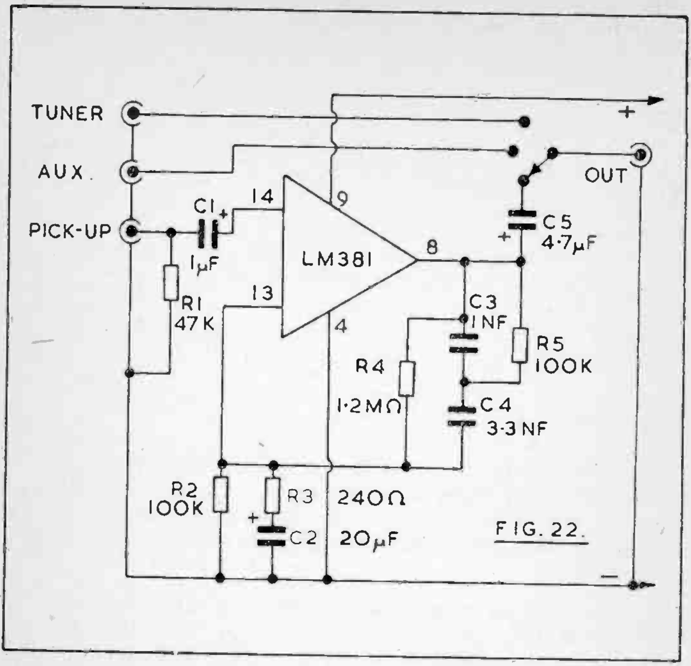


FIG. 22.

regulators is included, giving excellent freedom from the effects of ripple.

Fig.23 A shows an amplifier for general purposes, intended for low signal levels. C1 is the input isolating capacitor, and R1 is from input base to the emitter of a further amplifier in the IC while 6 is the input return point, and has negative feedback from the final emitter circuit at 5, via R3. The voltage gain is about 40dB. Input impedance is 10k and the output load should be around 3k. The value of C3 may be modified. This component is from input transistor collector circuit to ground, and may be reduced to 680pF for circuit B described later. Lead equivalents for the second half of the IC are as follows: 3:12, 4:11, 5:10, 6:9, 7:8. Lead 13 is the regulator ground and 14 the amplifier ground for both preamplifiers. It will be noted that input and other audio circuits (leads 3 to 12) are similarly placed each side the IC, e.g. Input 1 to 7, Input 2 to 8; Output 1 to 5, Output 2 to 10, and so on. This facilitates checking a stereo layout.

The circuit is modified at B by replacing R3 with the components shown, to shape response for tape playback purposes. Feedback

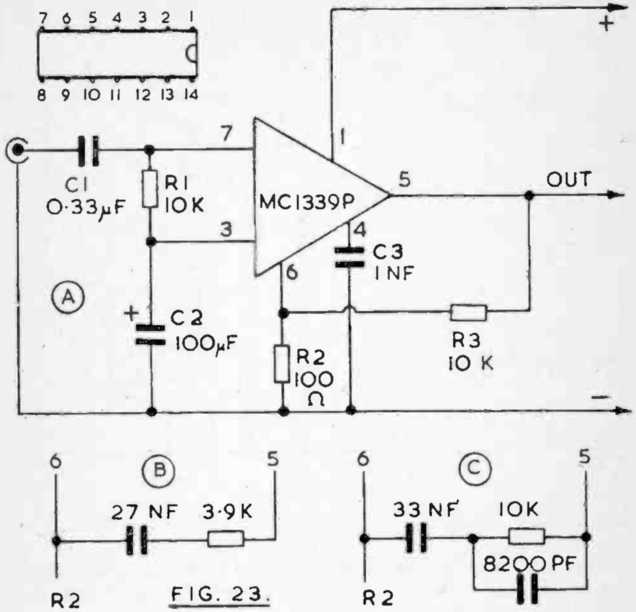


FIG. 23.

increases as frequency rises, reducing gain with higher frequencies. C has a similar effect, R3 being replaced by the items shown. This allows equalisation of the preamplifier for use with a magnetic pick-up. R1 is changed to 47k.

In Fig.24 switch-selection of channels is provided by the 3-way 2-pole switch S1/S2. Input socket A is for signals needing no correction, and has isolating capacitor C1, and feedback through the resistor R5. Socket B is for tape playback, and C5 and R6 are then in circuit in the feedback loop. C is intended for magnetic pick-up input, and C6, C7 and R7 are then present in the feedback circuit. Any of the inputs can thus be used immediately, with correction when required.

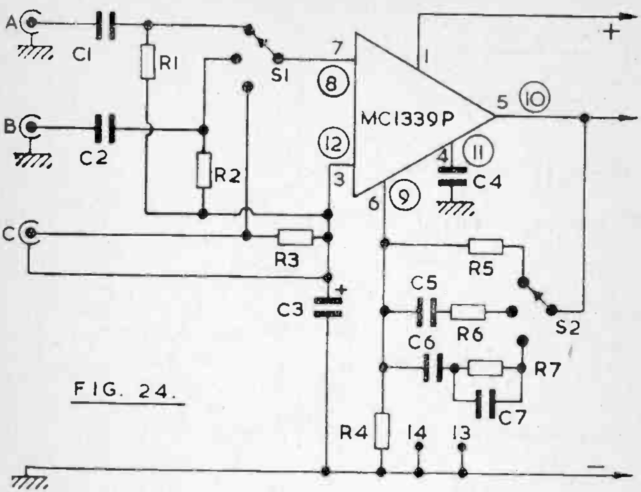


FIG. 24.

It will be seen that this circuit is developed from the earlier circuit, where values were shown to suit a particular type of input. The ringed numbers refer to leads for the second half of the MC1339P which will be used for an identical preamplifier for stereo. A 12v supply is suitable, and positive lead 1 is common to both halves, as are ground returns 13 and 14. A 4-pole switch will be necessary to duplicate S1/S2.

VALUES FOR FIG.24 (½/MC1339P)

C1	0.33μF
C2	0.33μF
C3	100μF
C4	680pF
C5	27nF
C6	33nF
C7	8.2nF
R1	10k

R2	10k
R3	47k
R4	100 ohm
R5	10k
R6	3.9k
R7	10k

PASSIVE TONE CONTROL

A passive tone control may be placed between the source of the audio signal and the first stage or input to the amplifier; or it may be connected between a preamplifier and the main amplifier. Audio signals may be from a radio tuner, crystal or magnetic pick-up, or other sources. Some of these units will probably not need any additional amplification over that available from the main amplifier (as example, a radio tuner) while others (e.g., magnetic pick-up) will probably need the signal level to be raised for full amplifier output. This may decide the best position for a tone control circuit, and it can often be placed between preamplifier and main amplifier with advantage.

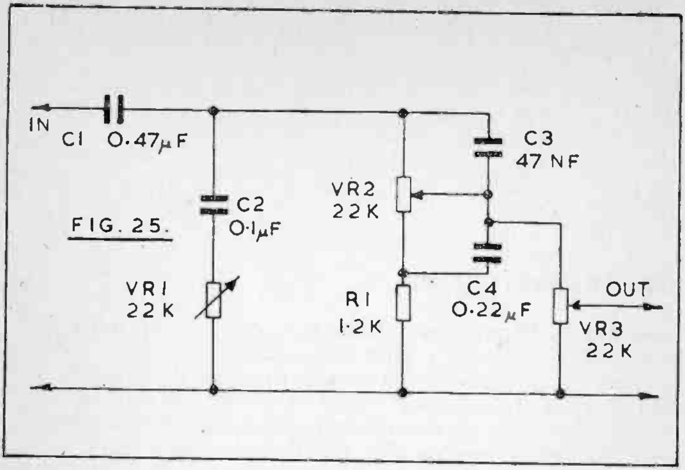
TOP CUT

Some small units have a control which gives variable attenuation of the higher frequencies as the sole means of tone control, but a similar circuit can be incorporated in a more ambitious circuit.

In Fig.25 VR1 and C2 form a top cut control. The audio input at C1 may be from a preamplifier. The reactance of C2 falls as frequency rises. If C2 is 0.1μF, its reactance is over 15,000 ohms at 100 Hz, falling to near 1500 ohms at 1kHz, and to near 150 ohms at 10kHz. Its shunting effect across the audio circuit thus increases as frequency rises, so that high frequencies are reduced more than low frequencies. The manual control VR1 gives adjustment over the effect obtained, top cut being at maximum with VR1 at minimum value.

Values for C2 and VR1 (or other components) can vary greatly, depending on the degree of control to be provided, and on the impedance and other characteristics of the circuit., Some tone control circuits have values which allow extremes of reproduction which will scarcely ever be wanted in practice.

This circuit has the further tone control potentiometer VR2. With the slider towards R1, audio is mainly through C3, which is of relatively



low value. Its reactance is lower at higher frequencies and in this position it thus allows higher frequencies to pass to VR3, providing emphasis of upper tones. This effect falls off as VR2 is adjusted away from R1, until the other maximum position of VR2 effectively removes C3 from circuit, while C4 reduces the upper frequencies. VR3 is the volume control.

TREBLE-BASS CONTROL

A circuit with separate treble and bass controls is shown in Fig.26. Here, VR1 is the volume control.

VR2 is for treble control. With VR2 slider near C1, high frequencies obtained from C1 pass to the following amplifier, so treble is prominent. When VR2 is turned towards C2 treble is reduced because C2 bypasses the higher frequencies to the ground line.

VR3 is the bass control. With VR3 slider towards R2, C4 in series with R3 is effectively across the audio circuit, giving most prominence to the lower frequencies. This effect falls off as the slider of VR3 is moved downwards, and an increasing audio signal is obtained through C3, which favours higher frequencies.

Very many circuits of this and similar type merely provide frequency-selective attenuation or weakening of the audio signal. However, cutting treble has a similar effect as boosting bass, if enough overall amplification is available. In a similar way, a bass cut control of simple

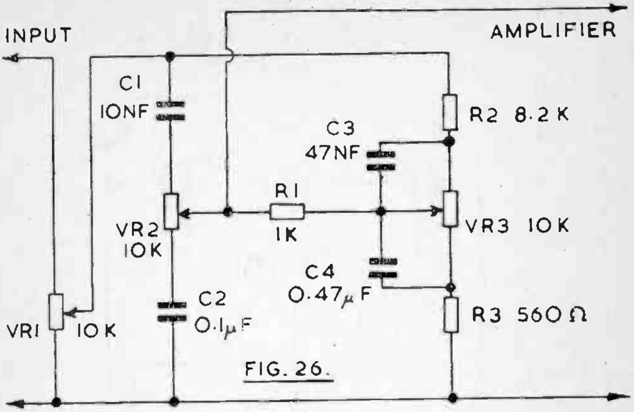


FIG. 26.

type could be likened to a treble boost control. Simple equipment may have a top-cut control only, with circuitry which tends to emphasise treble. Other circuits may use a single potentiometer, arranged to lift treble at one extreme, and lift bass at the other. Slightly more complicated are circuits such as those shown, which give a useful degree of control over treble and bass with separate potentiometers.

Some relatively simple controls do not allow any particular emphasis of a range of frequencies, but have a gradual effect, shifting general reproduction from 'mellow' through 'normal' to 'brilliant'. This in fact proves to be satisfactory for many general purpose entertainment amplifiers. The user can obtain some compensation for tonal deficiencies and obtain an audio output of the character he wants.

ACTIVE COMPREHENSIVE CONTROL

A circuit which will be found to give very good results is shown in Fig.27. Negative feedback is used to provide both treble boost and treble cut, and bass boost and cut. VR1 is the gain control, and can be omitted if not required. In many circuits a volume control will be present later, and VR1 is then only necessary either to prevent overloading or to adjust the audio level separately from other units. If a

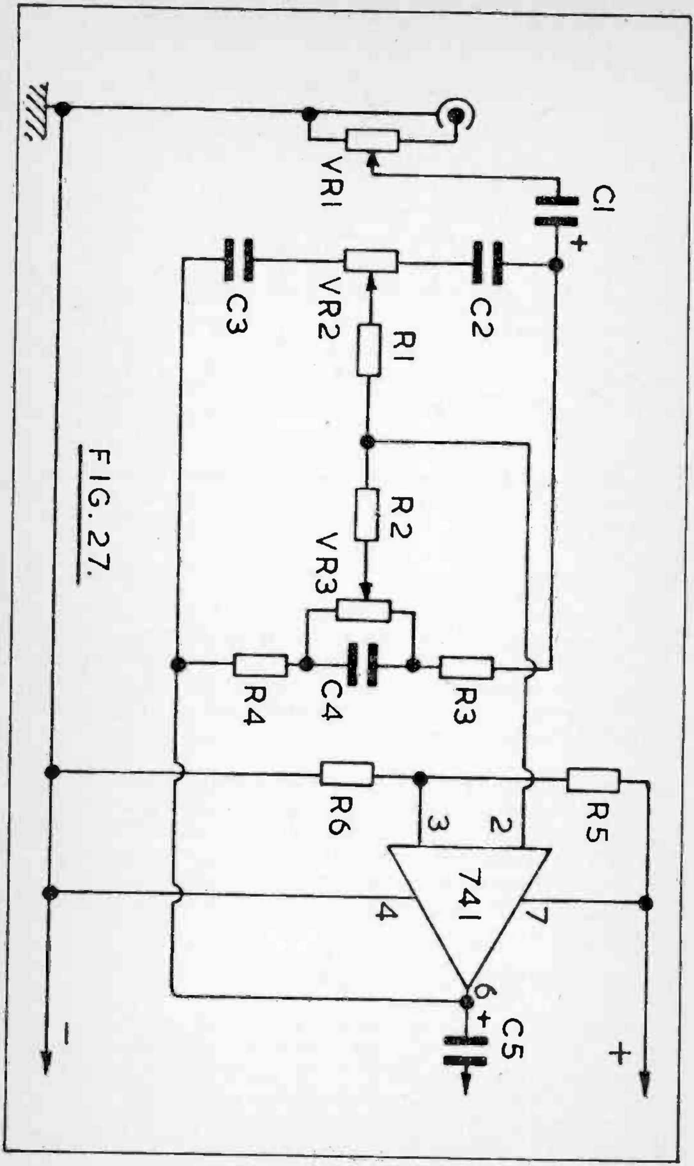


FIG. 27.

pick-up, microphone or other low level input is to be used, overloading here would not arise.

VR2 is for treble boost and cut. Signals are taken via R1 to the inverting input 2. The reactance of C2 is relatively low at high frequencies, so treble is boosted with VR1 slider this way. At the same time, negative feedback of higher frequencies from 6 of the IC is present via C3, so that feedback is increased for these when VR2 slider is towards C3, and gain is selectively reduced. VR3 operates in a similar way, except that it is the bass control, with feedback via R4. Central settings of VR2 and VR3 should give flat reproduction.

R5 and R6 divide the supply voltage for point 3. The supply can be 9v or more. It is convenient to use a higher voltage such as may be available from the main amplifier, though this does not have a very great effect on the gain. A well-smoothed supply is required, and can easily be provided by placing a 2.7k resistor in the positive supply line, with a 100µF or similar capacitor from 7 to negative line.

Audio output from C5 should be by the usual shielded lead. Due to the operation of the tone control circuits, overall gain is low and the circuit is not intended for operation as a preamplifier.

VALUES FOR FIG.27 (741 ACTIVE TONE CONTROL)

C1	4.7µF
C2	2.2nF
C3	2.2nF
C4	47nF
C5	47µF
R1	5.6k
R2	33k
R3	4.7k
R4	4.7k
R5	100k
R6	100k
VR1	100k log potentiometer
VR2	100k linear potentiometer
VR3	100k linear potentiometer

INPUT TONE CONTROL

This circuit, Fig.28, is suitable for mono or stereo pick-up, being duplicated for the latter. VR1 is the treble control, with capacitors

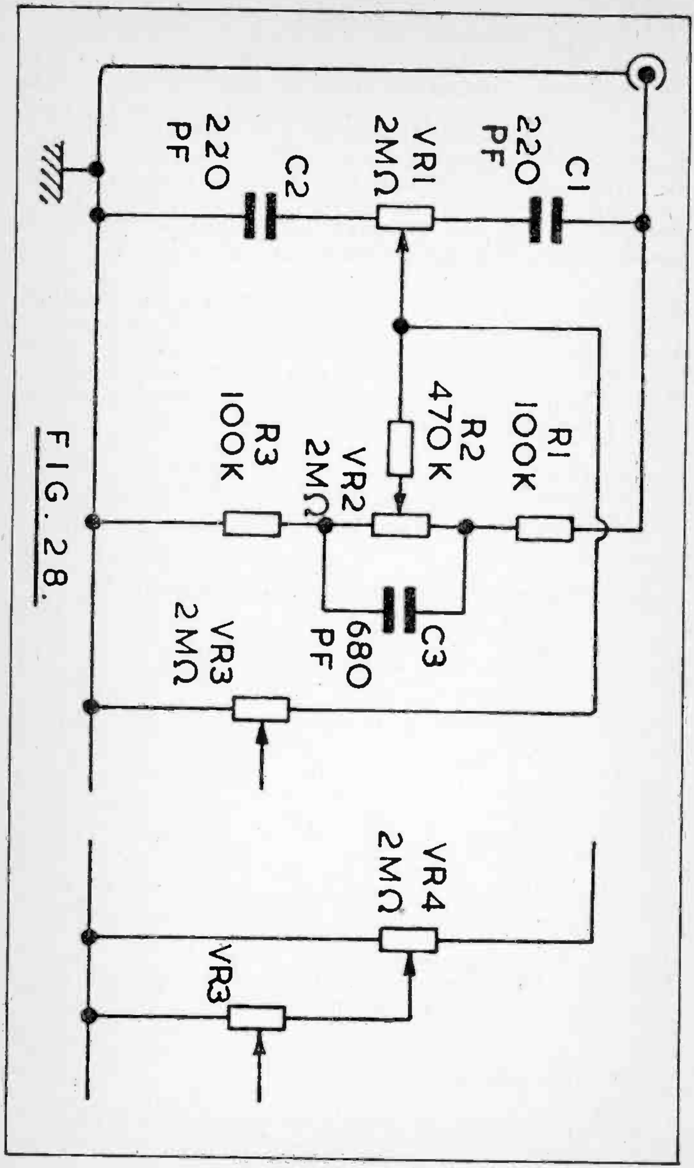

C1
220
PF
VR1
2MΩ
C2
220
PF
R1
100K
R2
470K
VR2
2MΩ
R3
100K
C3
680
PF
VR3
2MΩ
VR4
2MΩ
VR3

FIG. 28.

C1 and C2. VR2 is for bass control, with C3 in parallel. Tone controls using this type of circuit may have a wide range of component values, depending on the purpose in view, degree of control wanted and impedance, or even the personal preferences of the builder.

Output from the tone control is to VR3, which is the volume control for mono purposes. VR3 slider is connected in turn to the preamplifier input.

For stereo purposes, the balance control VR4 is added. VR3 for both right-hand and left-hand inputs can then be ganged.

An advantage of this type of control is that it can be added to existing equipment without any disturbance to the preamplifier or main amplifier circuits themselves. A shielded box will prevent picking up hum or similar troubles, though it should often be possible to fit VR1 and VR2, with the few associated components, in the same case as that housing a preamplifier or main amplifier. The latter would need to have adequate sensitivity if used alone to compensate for losses in the tone control elements.

PART III
POWER AMPLIFIERS AND SUPPLIES

This section is concerned mostly with the main amplifier, though as some ICs contain a preamplifier in addition to the main amplifier, further information on circuits of preamplifier type, including tone controls, is included. Where a preamplifier is present in the IC with the main amplifier, it may be internally connected to the latter, or have separate output leads. This naturally influences the kind of circuit which may be used.

As the sensitivity of IC amplifiers varies considerably, according to the type or operating conditions, a preamplifier will be needed for low-level inputs when using an insensitive amplifier, to secure the full rated output. This preamplifier can employ circuits from the previous section.

Some further amplifier circuits will also be found in the first section. The amplifiers here will fill a wide range of purposes. Details of even further amplifiers will be found in *Audio Hi-Fi Constructional Projects* (Book No. BP29) which includes 12.5 watt stereo and 14 watt quadrophonic designs.

TBA800

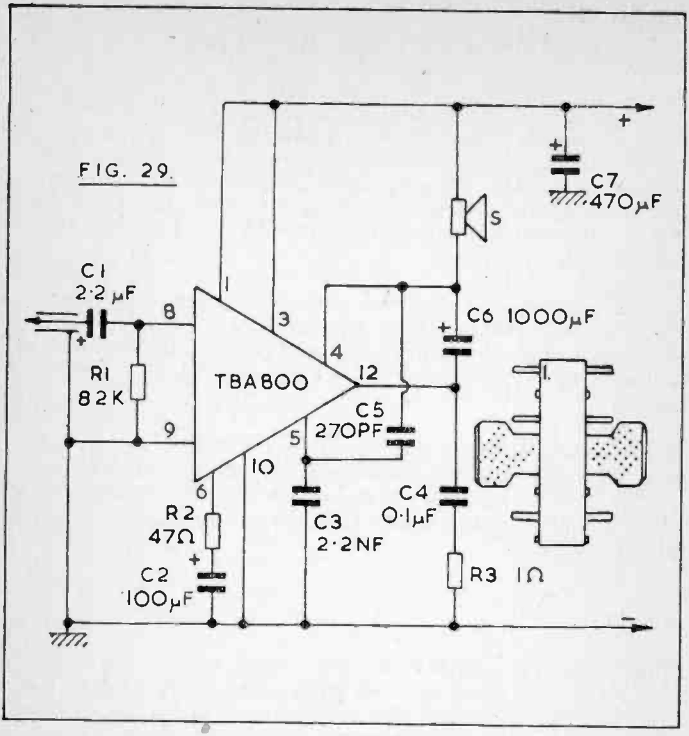
This is a useful IC suitable for a range of supply voltages between 6v and 24v, and providing up to 4.5 watts output. It thus has a wide range of application in domestic amplifiers. As Fig.29(a) shows, external circuitry is simple and requires relatively few components.

Sensitivity may be altered by changing the value of R2, which controls feedback. For 4W output, sensitivity is 40mV for 47 ohm here, 80mV for 100 ohm, and 120mV if R2 is 150 ohm. R2 may generally be 47 ohm or 56 ohm.

Input is to 8 via an isolating capacitor. C3 and C5 should be close against the pins to which they are connected.

The low quiescent current makes this IC suitable for battery equipment, as well as low voltage supplies. With a 9v supply, an output of 1W may be obtained, with a little over 2W with 12v to 14v. The supply should not exceed 30v.

An 8 ohm speaker may be used for up to 20v supply, and will allow up to 4W. For a higher voltage supply, the speaker should be increased to 16 ohm. No heat sinking except for the tabs fitted is necessary for 1W.



For outputs of over 1W, the tabs must be soldered to a heat sink. This can be arranged by passing them down through slots in a printed circuit board, so that they can be soldered to an area of at least 2 x 2 in (50 x 50 mm) provided on the board. Tags fit 0.1 in matrix board; or 0.15 in matrix if the IC is placed diagonally.

Figs.29(b) and (c) show a ready-made circuit board which is available for this IC. Should a volume control be required in this part of the equipment, a 100k log pot may be substituted for R1, with 8 taken to the slider tag. Alternatively, the gain control can be installed before C1. The screened input lead for the board will run to a socket, or volume control, as wanted.

Two such amplifiers can be used for stereo, and can be fed from a 2-channel preamplifier, such as shown in the previous section. Tag 1 of the IC is as shown in Fig.29(a) but the quad-in-line spacing means that the IC will only fit in one position. A suitable power supply for

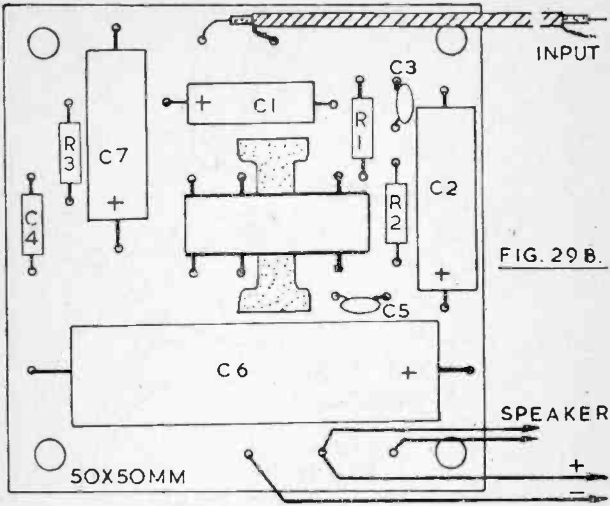


FIG. 29 B.

this IC, as for other amplifiers, can be constructed from the circuits shown later.

LM380 AMPLIFIER

The LM380N is a suitable IC amplifier for outputs up to about 2.5W, and needs few additional components. A printed circuit for this IC is thus easily prepared.

The IC is protected against excessive current such as could arise from shorting the output or loudspeaker circuit. It also has excess-temperature protection, which is a safeguard against over-running or inadequate heat-sinking. This protection is to avoid destruction of the IC under conditions which might arise from overloads or heating as mentioned, and *not* a safeguard against misuse such as wrong supply polarity. It will normally be operated from about 12v to 18v, but can be used with satisfactory results with 9v.

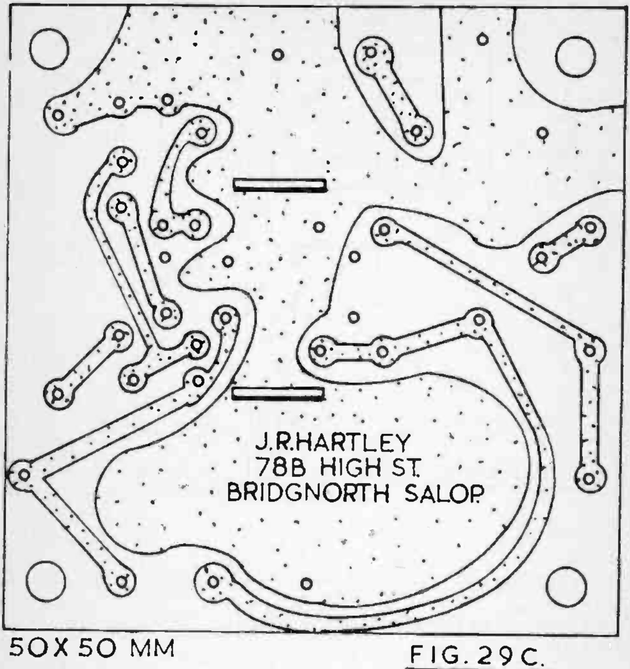
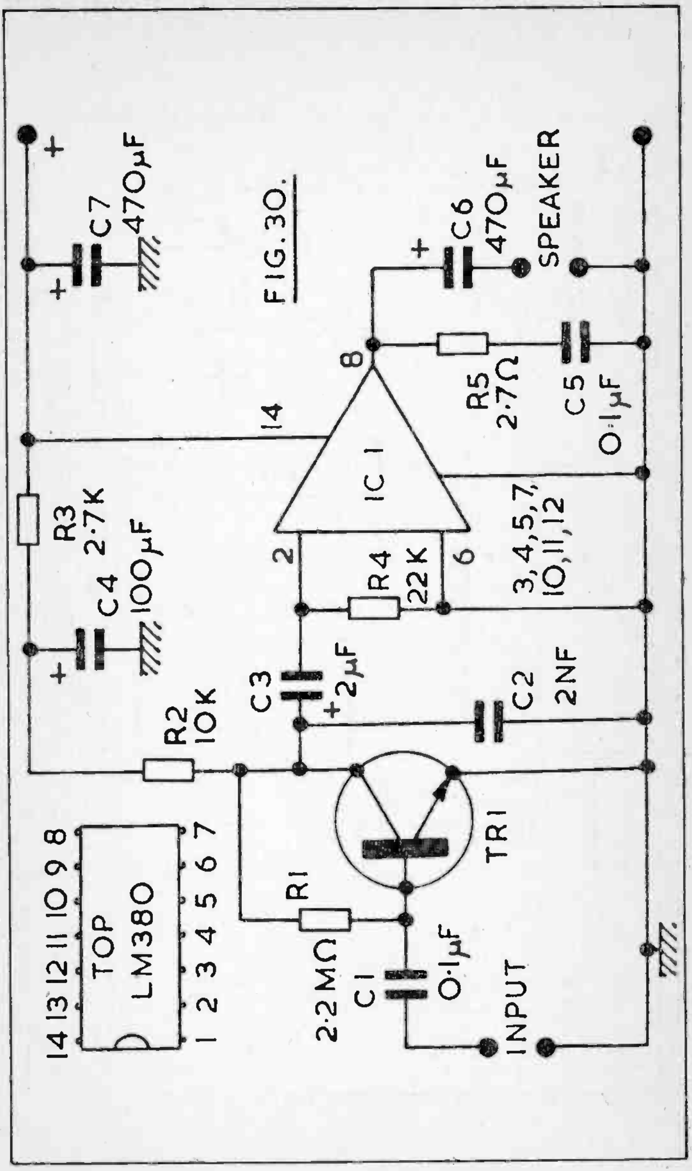


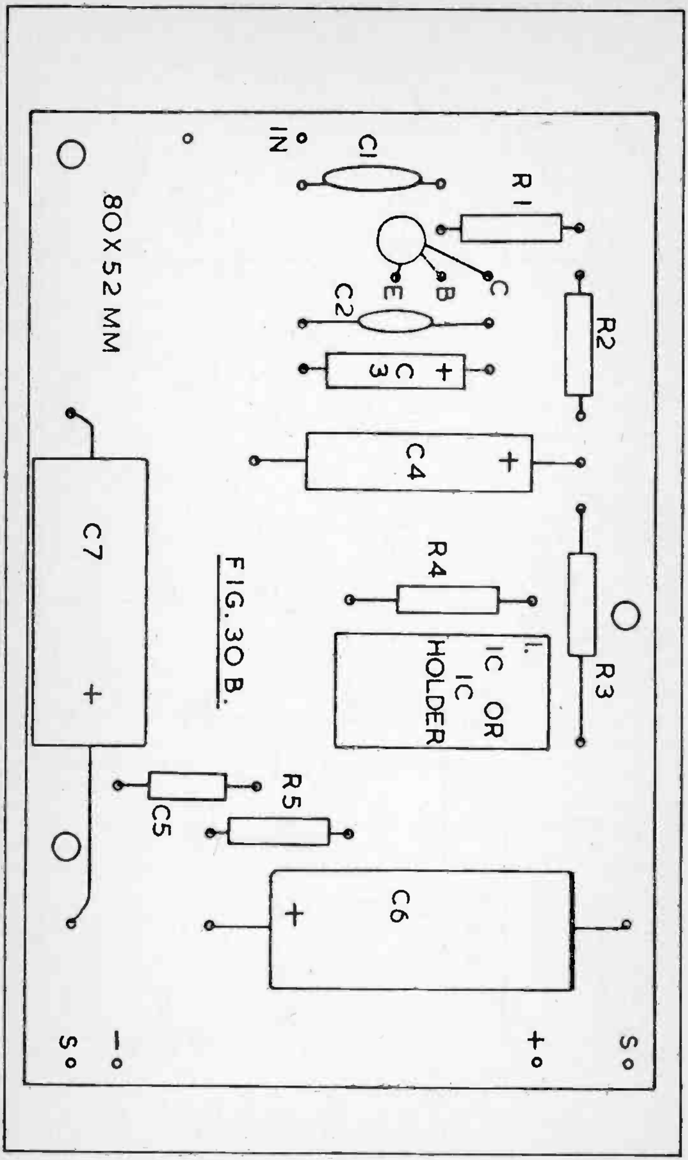
FIG. 29C.

Gain is sufficient for use with a radio tuner, ceramic pick-up or similar inputs. For lower inputs, a single stage preamplifier can be added.

Fig.30(a) is a circuit including a preamplifier, which may be omitted if circumstances permit. Should the preamplifier not be necessary, C1, C2, C3, C4, R1, R2, R3 and TR1 are not required. R4 can then be a 22k potentiometer for volume control.

Any low-noise audio preamplifier transistor is likely to be suitable here (BC109, BC149) and general purpose types (2N3707, 2N706A). Component values could be modified.


C7 470µF
R3 2·7K
C4 100µF
R2 10K
C3 2µF
R4 22K
IC 1
14
2
6
8
R5 2·7Ω
C5 0·1µF
C6 470µF
SPEAKER
3, 4, 5, 7, 10, 11, 12
C2 2NF
TR1
R1 2·2MΩ
C1 0·1µF
INPUT
TOP
LM380
14 13 12 11 10 9 8
1 2 3 4 5 6 7
FIG. 30.


80X52 MM
IN
C1
R1
E
B
C
C2
C3
R2
C4
R4
R3
IC OR
IC
HOLDER
C7
R5
C5
C6
S
-
+
S
FIG. 30 B.

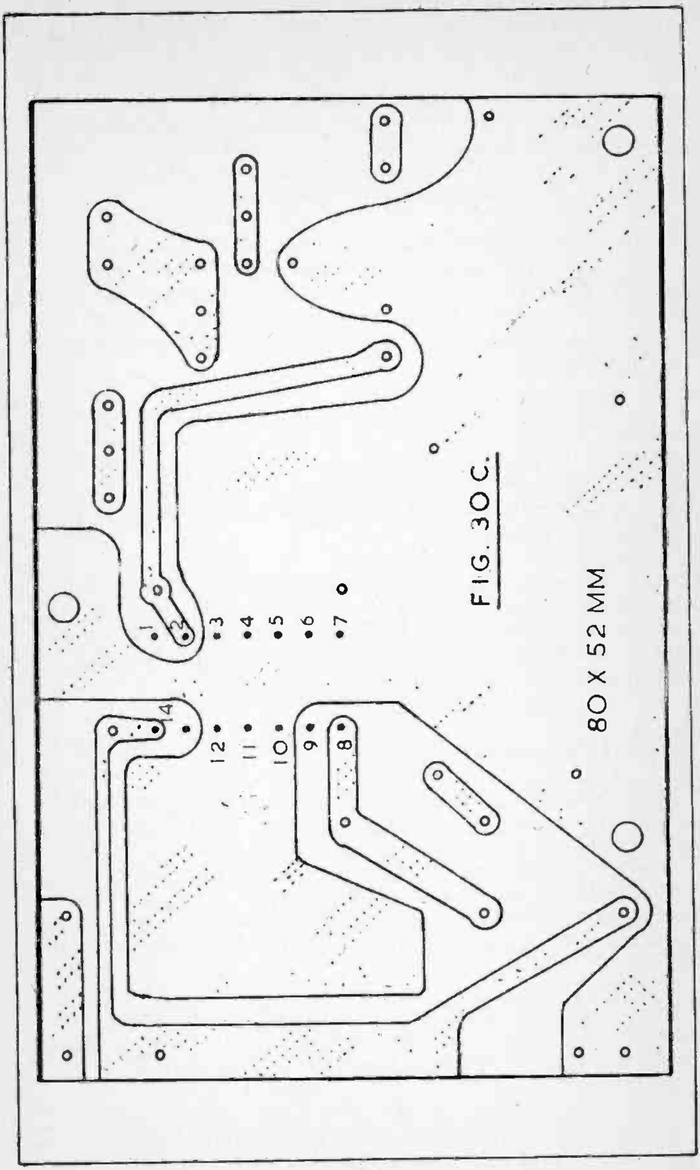


FIG. 30C.

80 X 52 MM

C3 provides audio to the non-inverting input 2, and inverting input 6 is grounded. Heat-sinking is by 3, 4, 5, 10, 11, 12 to the PCB foil. Best thermal conduction is with the IC soldered directly in place. Vertical copper or tinplate fins, cut to solder to these pins each side, would improve the heat sink. With no heat sink, the power dissipated in the IC should not be over 1.25W (25°C). If the builder is other than an absolute beginner at soldering, and does not wish to check other ICs of the same type, the holder is best omitted.

Figs.30(b) and (c) show top and foil sides of the PCB, which is prepared as described. The large areas of foil remaining reduce the amount of metal to be etched away, while the largest area is the heat sink and permits grounding to a metal case by three fixing bolts. These require extra nuts or spacers. It should be a simple matter to omit the pre-amplifier stage.

External connections can be by pins, or more easily by flying leads passing up through the board. Colour coding of these is always helpful. Red would be suitable for positive, black for negative, and green for speaker. Input will be by a screened lead, in which the outer brading goes to the negative line, and inner conductor to C1. All component values can be seen in Fig. 30.

The speaker can be 4 to 16 ohm. With the 4 ohm unit, a 14v supply can be used, increased to 18v for 8 ohm or 16 ohm speakers. The absolute maximum is 22v. A 4.7μF by-pass capacitor may be used between 1 and negative line, but is not necessary with a battery supply or adequately smoothed mains power supply.

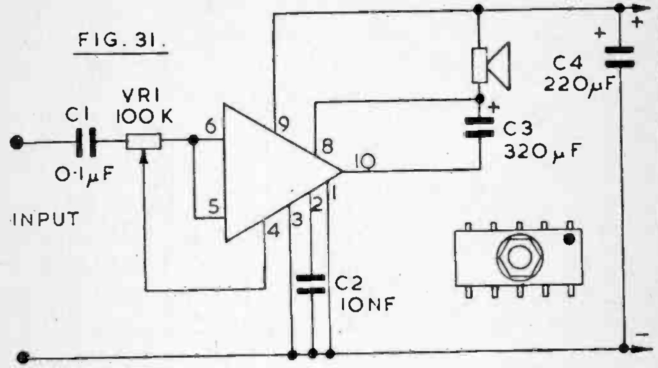
SL402/3, SL414A/415A

These ICs have a wide field of application and can be used in various circuit arrangements to suit the gain required. The 402 and 403 are replaced by the 414A and 415A and all may be used in the same circuits. However, typical output ratings are 2W for the 402, 3W for the 403, 3W for the 414A and 5W for the 415A. This is with a supply voltage of 14v for 2W, 18v for 3W and 24v for 5W. It is thus necessary to limit the supply voltage to that required by the particular type of IC fitted.

The IC contains preamplifier and main amplifier, with voltage gains of 24dB and 26dB. A 7.5 ohm speaker is specified, but an 8 ohm unit is suitable. With a 15 ohm load, power falls to 2.2W and 3.8W for the 414 and 415.

A simple circuit requiring few components is shown in Fig.31. This joins preamplifier input and output, using this to bias the main amplifier. Sensitivity is 250mV. The input impedance is 100k. The actual IC shown is the SL414/SL415 with stud heat-sink, lead 1 being as indicated.

FIG. 31.



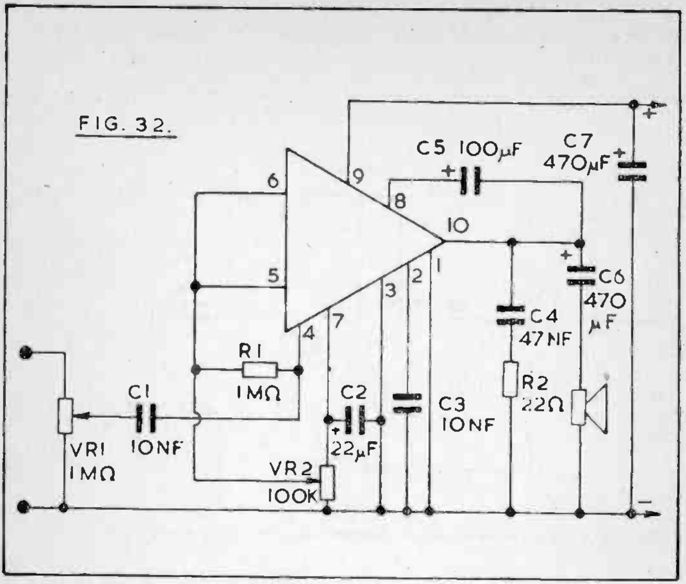
The layout should place the by-pass capacitor near 9 and 1. No instability difficulties should arise with normal separation of input and output circuits.

Fig.32 is a circuit giving rather greater power output, also with 250mV input, and is less susceptible to ripple. Here, VR2 is a pre-set control to allow adjusting bias until the potential at 10 is approximately half the supply voltage. R2 and C4 are for high frequency compensation. C5 provides feedback from output to driver circuits. Lead 7 is a decoupling point.

HIGHER GAIN

As separate leads are provided for preamplifier output and main amplifier input, the preamplifier can operate the main amplifier directly. With the preamplifier feeding the main amplifier, sensitivity is raised to 25mV.

The separate connections also allow a tone control to be placed between preamplifier output and main amplifier input. With a passive



control circuit of the type shown in Fig.33 losses are off-set by the preamplifier, so that sensitivity is approximately 250mV.

Input to the preamplifier is at 6, from volume control VR1 and isolating capacitor C1. The preamplifier output is at 5, and is coupled to the tone control network by C2. C3 is a small HF by-pass capacitor.

VR3 is the bass control. Values of C5, C6, R3 and R4 allow a bass cut or boost of about 12dB. VR4 is the treble control, with similar cut or boost. Further details of how controls of this kind operate will be found in relation to Fig.26. Output from the tone control circuit is at the junction of R6 and VR4, to lead 4, which is the main amplifier input. Note that this, like the earlier circuits, provides a DC path from preamplifier to main amplifier input, as this is required to set bias conditions.

If the tone-control is omitted, sensitivity is 25mV. In these circumstances, VR3 and VR4, with associated components, will not be required. Omit also R5 and C7. R2 is 220k, and a capacitor of 0.1μF is required from the junction of R1/R2 to negative line. Connect 4 and 5 directly, eliminating the tone control, and take this point to the slider of the 100k bias trimming potentiometer, which connects from 7 to chassis as in Fig.32 with a 22μF parallel capacitor.

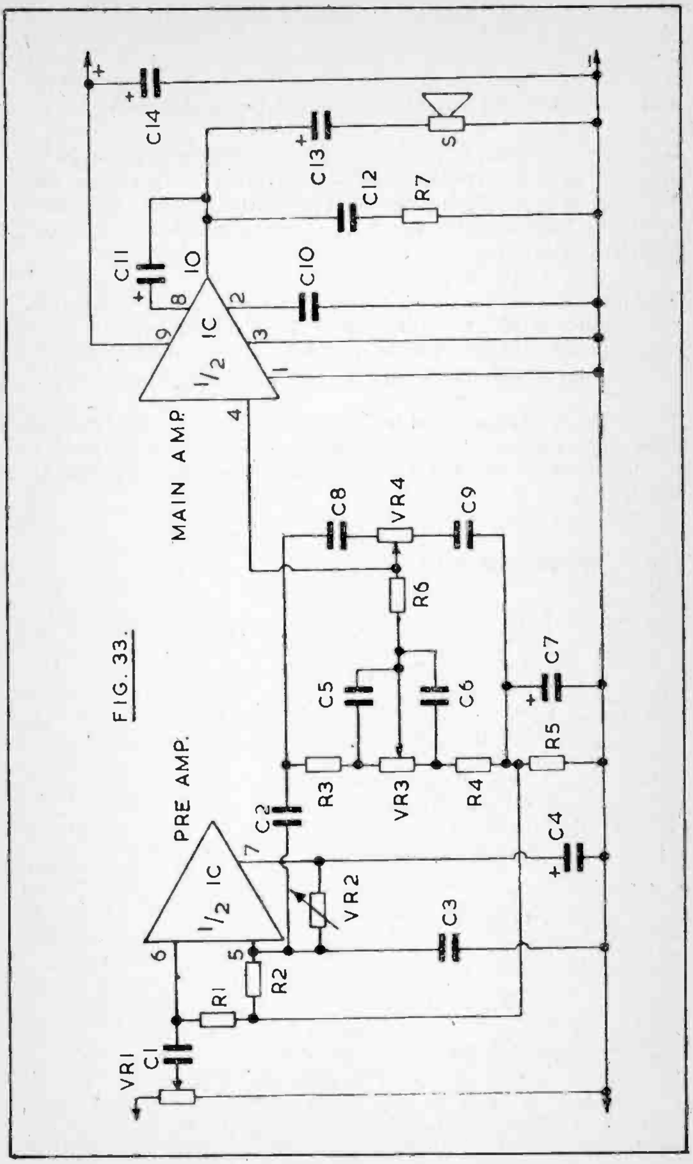

PRE AMP.
MAIN AMP.
1/2 IC
1/2 IC
VR1
C1
R1
R2
C2
C3
C4
VR2
R3
VR3
R4
R5
C5
C6
C7
C8
VR4
C9
R6
C10
C11
C12
R7
C13
C14
S

FIG. 33.

With the amplifier sections in cascade gain is high, and the layout should separate input and output circuits and components. C3 should be close up to leads 4 and 5. Both preamplifier and main amplifier have very high impedance inputs, and with some layouts a low value HF by-pass capacitor may also be required for the preamplifier input.

With a 7.5 ohm speaker and 1,000μF coupling capacitor, a straight line response can be expected from about 75Hz to over 5kHz and the 3dB down points extend from about 20Hz to 15kHz. C10 may be substituted by a 2.2nF capacitor and 22 ohm resistor in series, for reduced harmonic distortion.

With no heat sink, dissipation should be limited to about 2½W (for temperatures of 25°C). With a sink of 18swg aluminium, 5 x 5cm minimum size, dissipation is just over 6W, the maximum permitted power falling to about 5½W with the ambient temperature at 50°C.

The device has overload and short-circuit protection, which in some cases may be operated by severely incorrect adjustment of the bias potentiometer. Operation is restored after interrupting the power supply.

COMPONENTS FOR FIG.33

R1	1 megohm
R2	150k
R3	33k
R4	3.3k
R5	68k
R6	10k
R7	22 ohm
VR1	2 megohm log potentiometer
VR2	100k linear pre-set
VR3	220k log potentiometer
VR4	220k log potentiometer
C1	22nF
C2	0.22μF
C3	680pF
C4	22μF
C5	100nf
C6	47nF
C7	2.2μF
C8	1nF
C9	10nF
C10	10nF
C11	125μF

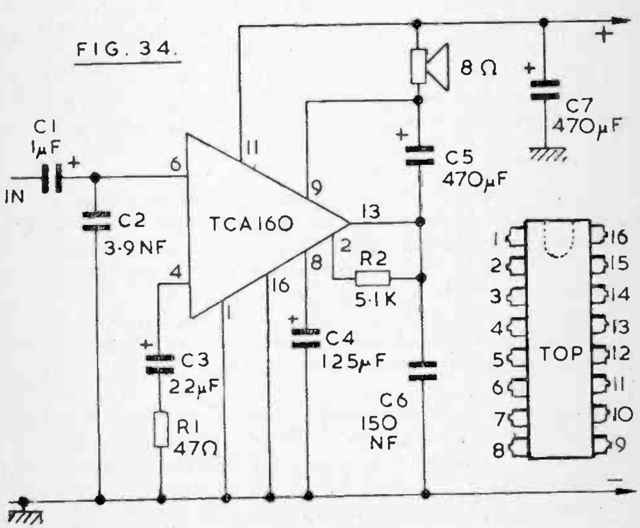
C12	47nF
C13	1000μF
C14	1000μF
IC	SL402D, SL403D, SL414A, SL415A

TCA160, TCA160A, TCA160Q

The 160/160A is 16 lead dual in-line (as shown) while the 160Q is quadruple in-line. The IC is intended for 5v to 16v supply, and will deliver over 1W into an 8 ohm speaker with a 9v supply, so is particularly suitable for battery operated equipment or small amplifiers operated from main supplies. Temperature correction and stabilisation result in low cross-over distortion throughout the supply voltage range. The IC has high sensitivity (10mV).

Quiescent current is typically under 9mA for 7.5v to 12v supplies, the maximum current is typically 190mA for full output at 9v; and 250mA for full output at 12v, 2W being obtainable.

FIG. 34.



In Fig.34 coupling to the input is via C1. C2 may be modified in value. Its purpose is to limit upper frequencies, and to avoid instability if the input is not connected. In a similar way, C3 may be increased in value to obtain an extended bass performance. R1 may also be adjusted to change gain. However, values shown are typical and can generally be used.

As lead 1 is the earth of the early stages, and lead 16 the emitter of one of the output pair, C7 and power supply connections should be to 11 and 16, as shown, with lead 1 connected to the negative line, but not carrying supply line currents.

If the supply is from rectification and has considerable ripple results are improved by positioning the speaker at the negative line. Replace the 8 ohm speaker by a 100 ohm resistor, and C5 by a 32μF capacitor, retaining the polarity shown. C5 is now placed from 13 (positive) to speaker (negative) and the latter is connected to the negative line. The purpose of the additional resistor and capacitor is to supply the driver stages (lead 9).

SN76023N

With a 28v power supply, maximum output of this IC is approximately 8 watts. This voltage should not be exceeded. Very useful outputs may be obtained with a reduced voltage – approximately 6W with 25v, or 4 watts with 22v. With a 12–15v supply, output is around 2W. The load is normally 8 ohm, but speakers of up to 20 ohm may be used, with a falling off in power to a little over half of that achieved with the 8 ohm unit.

Fig.35 shows an amplifier suitable for record playing and similar purposes. VR1 is the volume control. R1 and R2 set bias conditions. The amount of negative feedback can be modified by changing R3 or R4. A useful feature of this IC is that it incorporates its own heat sink, which projects upwards with the usual board mounting of the IC. This can simplify constructional work for the user, it only being necessary to leave space for the finned sink plates. The IC can operate with a supply as low at 9v, but output is naturally much reduced.

Normal precautions to preserve stability should be observed. These include placing C8 adjacent to pins 10 and 3/14, or fitting another capacitor here if C8 is in the power supply. (This extra capacitor can be of much smaller value – 0.1μF to 4.7μF.) The layout should also place C1 and input circuit components away from output circuits.

As preamplifier and main amplifier stages are internally connected, a tone-control cannot be placed between. However, tone control can be provided by selective feedback. This means that the simple feedback network R4, R3, C3 is replaced by a frequency-sensitive network, in which the amount of feedback at treble and bass frequencies can be manually adjusted. This provides selective reduction of gain by the amount of feedback.

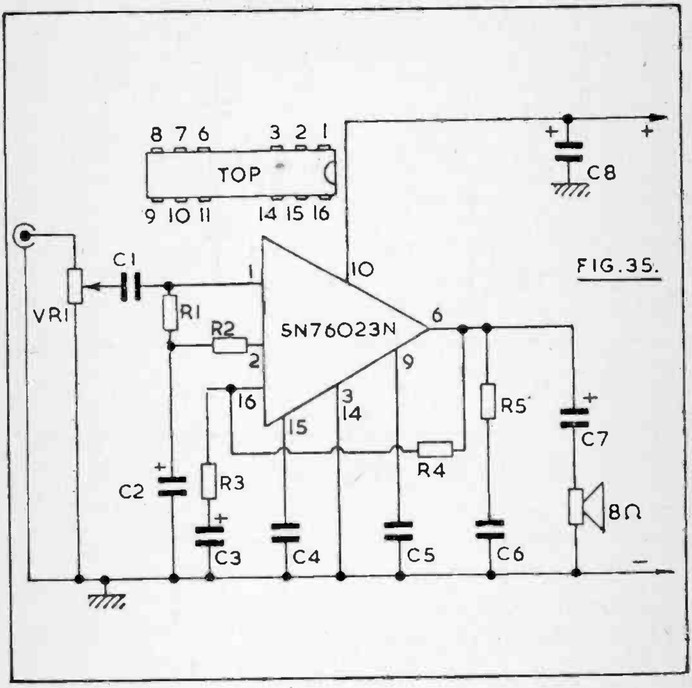
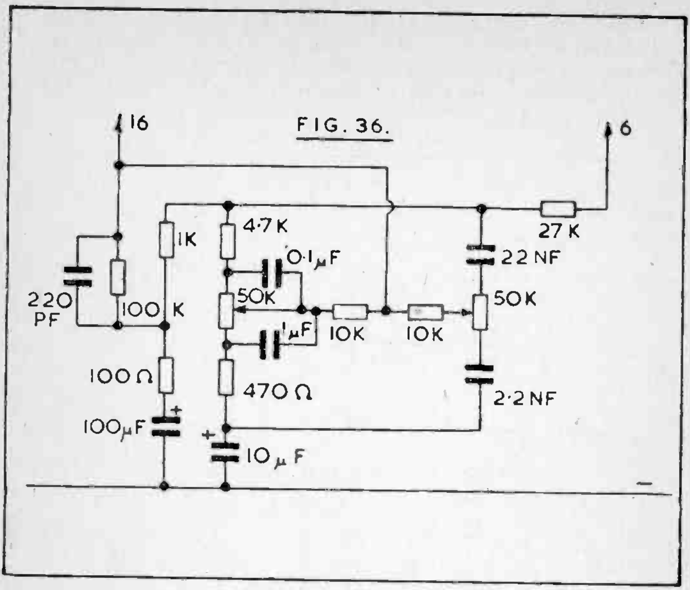


FIG.35.

Fig.36 shows a circuit of this type, and having both treble and bass control. The way in which this tone control operates can be seen by referring to the section on preamplifiers with tone controls. The degree of control obtained makes this a useful circuit for many purposes. Overall gain is reduced to only a small extent.

It is not necessary to use the exact capacitor values shown, as some modification to these will modify the degree of tone control obtained at maximum settings.

An alternative would be a passive tone control, of the type shown earlier, between VR1 and C1. A preamplifier may then have to be added to compensate for the loss of signal level in the tone control.



COMPONENTS FOR FIG.35 (SN76023N)

R1	270k
R2	150k
R3	100 ohm
R4	27k
R5	18 ohm
VR1	1 megohm log potentiometer
C1	0.1μF
C2	8.2μF 15v
C3	100μF 15v
C4	1nF
C5	500pF
C6	10nF
C7	470μF 15v
C8	470μF 30v

STEREO

For stereo reproduction, two identical amplifiers are needed. They may be constructed as a single unit; or may be separate when a further amplifier is added to a mono system.

When a second amplifier has been added to develop a mono system for stereo purposes, separate volume controls will be present. If this is not wanted, a single ganged control can be introduced, to adjust the volume of both amplifiers simultaneously. It will then be necessary to add a balancing control. This enables the output of one channel to be reduced, while that of the other is increased, so that equal volume is secured from each speaker. Such a control can be situated at the inputs of the main amplifiers.

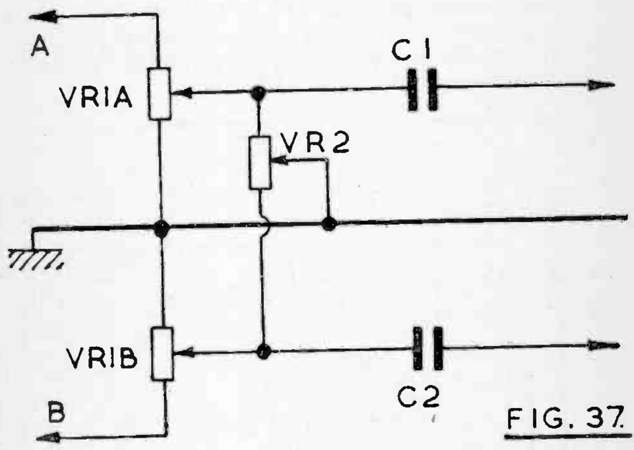


FIG. 37

Fig.37 shows a circuit of this kind. Inputs A and B are from pre-amplifiers or other source, and volume is controlled by the ganged potentiometer VR1A/B. Here, 220k controls will often be suitable, though this can depend on other parts of the circuit. VR2 is the balancing control, and can generally be a 470k or 1 megohm linear potentiometer. C1 and C2 couple signals to the respective amplifiers. Other means of balancing will be found in the section on preamplifiers.

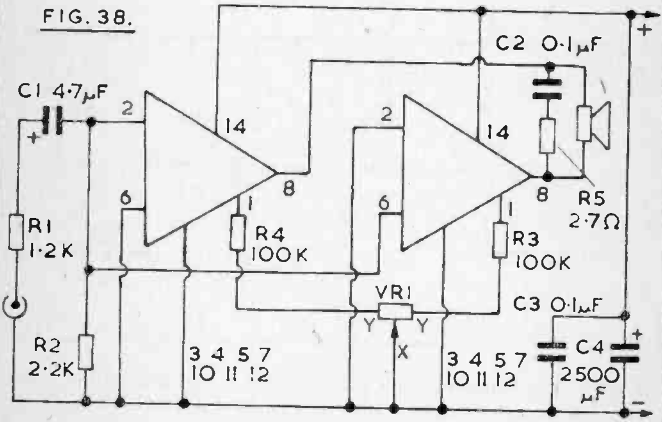
When adding a second channel to an existing amplifier it will not be overlooked that the power requirements are doubled. Two separate power supplies may be used, and do in fact have some advantages.

With a common power supply wiring needs to be arranged so that supply circuits do not have an impedance common to either input. Use negative line input circuits and negative line power circuits as explained for single amplifiers.

PUSH-PULL LM380s

Details of the LM380 will be found in reference to Fig.30. As explained in Fig.15 two ICs may be used in an opposite phase or 'push-pull' arrangement, to double maximum output. Fig.38 is a circuit of this type. Input is to 2 of one IC and 6 of the other, with 6 and 2 grounded as shown. A speaker coupling capacitor is not necessary as points 8 should be at the same potential when no signal is present. VR1 is a trimming potentiometer, and can be 470k or 1 megohm linear. When first setting up the circuit, connect a meter on a 500mA or similar range in series with the speaker, and adjust VR1 (with no signal) so that current shown by the meter is at a minimum.

FIG. 38.



C3 across C4 is to help avoid HF instability (possibly not audible) which will cause heavy current, but very poor reproduction. The speaker and output circuits should be removed from input circuits, for the same reason.

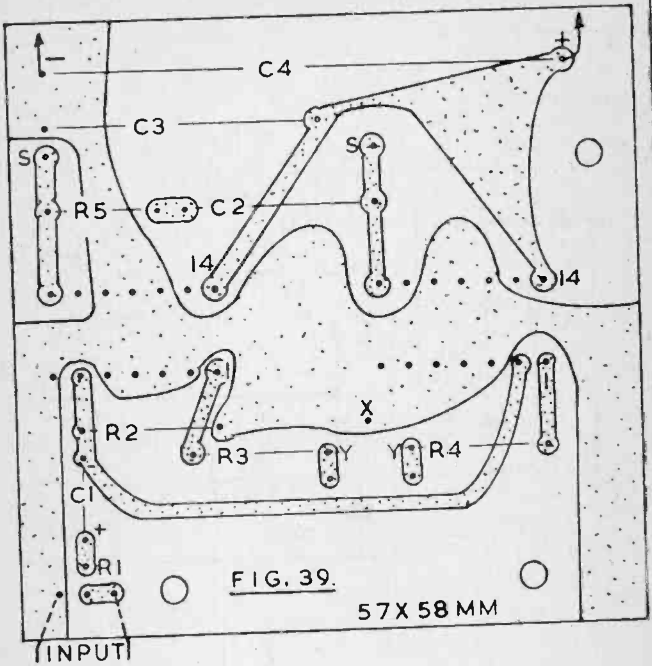


FIG. 39.

Fig.39 is a suitable printed circuit layout. For maximum power rating additional heat sinking is needed to that provided by the foil. Copper fins cut to solder to 3, 4 and 5 one side, and 10, 11 and 12 the other side of each IC may be used; or smaller copper flanges which can later be bolted in intimate thermal contact with larger areas of aluminium, or ready-made heat sinks. The ICs incorporate thermal protection. If this operates, heat sinking is insufficient for the output, so sinks must be improved, or output reduced. (Working is restored when the IC temperature falls.) The speaker is an 8 ohm unit.

TDA2020

This IC can supply up to 20 watts output, using the circuit shown in Fig.40. Audio input is via C1 to 7, while R3, with R2 and C2 form the feedback network to 8. C8 is for compensation, and output is from 14, no speaker coupling capacitor being required.

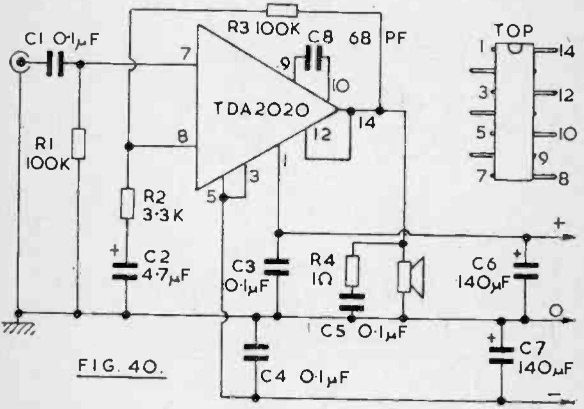
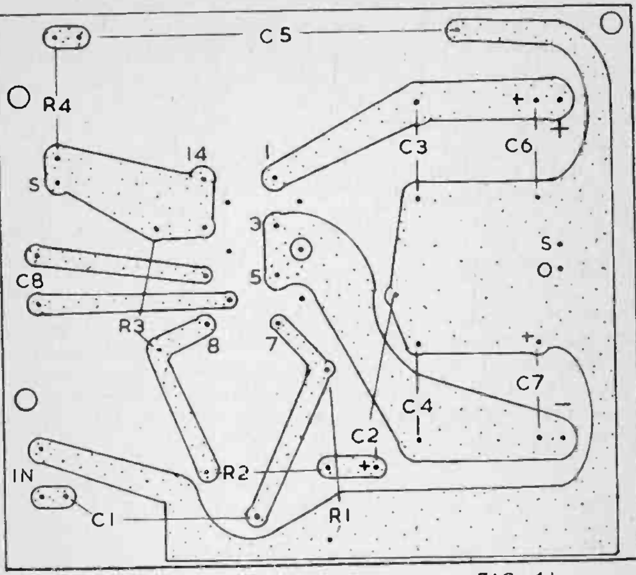


FIG. 40.

A split power supply is required, but can be readily arranged as shown later (Fig.51). Minimum output rating of this IC is 15w with a supply providing 17–0–17v and 4 ohm speaker, the typical rating being 18.5w. With an 18–0–18v supply, typical outputs are 16.5w for an 8 ohm speaker, and 20w for a 4 ohm speaker. Sensitivity for 15w output is 260 to 380mV input. Input impedance is 1 megohm.

Quiescent current is 50mA, and maximum current 3.5A, and the IC has thermal and short-circuit protection. It can be used at substantially lower ratings with a much lower voltage supply, or from a single output supply by providing the '0' voltage point at the junction of two resistors in series across the supply. The values of these resistors should be the same, and as low as the supply output current permits.



58X68 MM

FIG. 41.

For other than low power, adequate heat sinking is essential. Heat transfer to the sink is from a metal insert on top of the IC. A spacer fits under the IC, giving support to a flat sink surface which passes across the IC. These surfaces must meet correctly, and are smeared with silicone grease for thermal conduction. The sink should be of 2–8°C/W type. It is preferable to obtain the sinks made to suit this IC. Alternatively, it is possible to make or adapt a sink, especially for lower ratings. Sinks of this type made from flat sheet metal have to be rather large. For such a sink, 20 x 20cm of 14swg aluminium can be used, folded but mounted vertically. Finned heat sinks offer equal dissipation in a much smaller space. Components within the heat sink area on the circuit board must be kept below the sink level, and it is best to allow adequate clearance between sink and resistors or capacitors. The sink can be shaped to facilitate this, and larger items will in any case have to be mounted a little away from the IC, clear of the sink. Finned sinks will be about 3 x 8cm to 8 x 8cm. If the sink cannot carry away the heat produced so as to keep the IC temperature sufficiently low, the amplifier will have to be operated at a lower output rating.

Fig.41 shows a circuit board layout for the amplifier, and the IC can only be inserted the correct way. C3/C6 and C4/C7 are in addition to parallel capacitors in the power supply, to maintain stability. The sink surface is common to pin 5. The input is screened, and an initial meter check of current should be made to assure that HF instability is not present, causing a very high current to be drawn from the supply. The load should be around 50mA with no signal, peaking up to some amperes at maximum output.

BASIC CIRCUITS

The IC amplifiers already shown cover a wide range of operating voltages and output powers. The basic circuits here are additional to them, and give essential connecting data and component values. Assembly on a printed circuit board can be along the general lines shown earlier and these circuits should be useful to show how the ICs to which they refer can be employed.

SL630

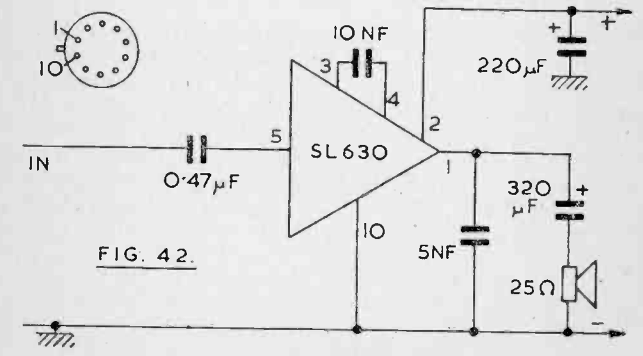


FIG. 42.

This small audio IC can be used with up to 12v, giving adequate power output for headphones, or speaker reproduction for relatively low volume purposes. Fig.42 is a simple circuit. Current drain is about 10mA, with about 150mW output.

MFC8010

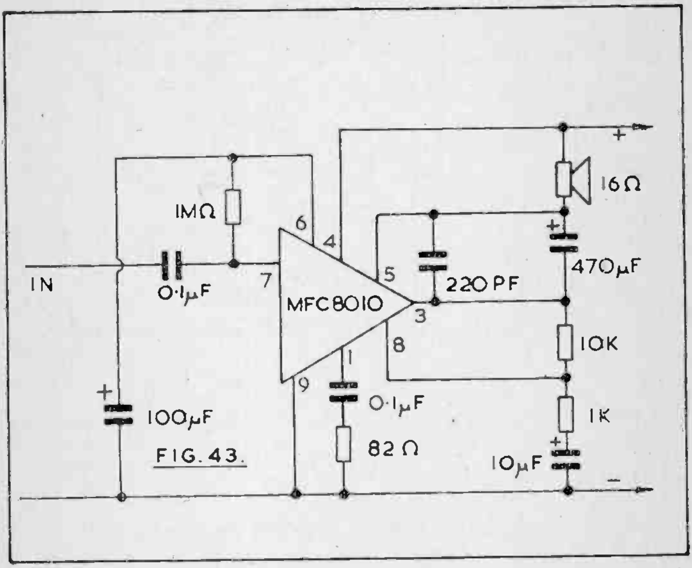
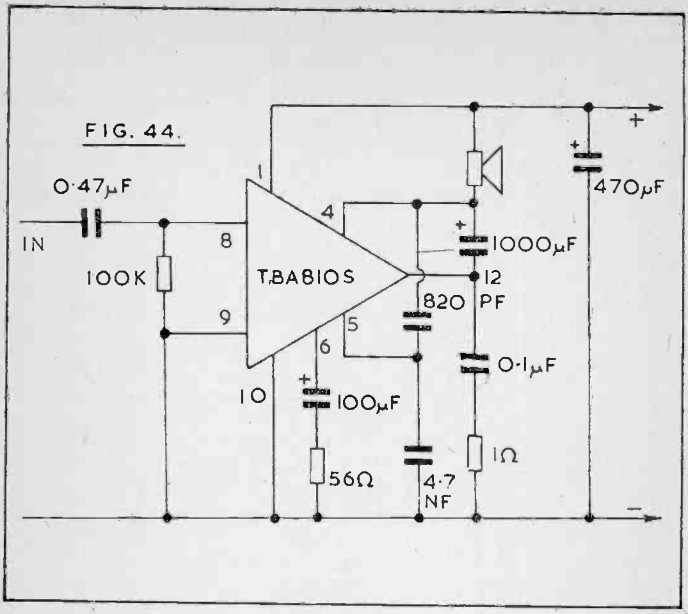


FIG. 43.

Fig.43 is a circuit for this IC, providing about 1 watt with an 18v power supply, with an input of 400mV. If necessary, sensitivity can be raised by increasing the 10k feedback resistor to 51k, at the same time reducing the 1k value to 100 ohms and changing the 82 ohm resistor to 2.2k. The output mentioned should then be obtained with 10mV input. To maintain stability 100pF capacitors may then be inserted from 7 to negative, and 5 to negative. A capacitor of 220μF to 470μF should be across the supply near the IC.

TBA810S

Fig.44 shows a circuit for this IC (see also Fig.29) which can provide up to 8 watts with a 4 ohm speaker and 18v supply. Output with a 12v supply is about 4.5W. The tabs should be soldered or bolted to a heat sink.



LM377N

This IC has two amplifiers, for stereo, Fig.45. With 8 ohm speakers, output is up to 2W per channel, with an 18 to 22v supply. A 16v supply will provide over 1.5W per channel. The IC has thermal and short circuit protection, and heat sinking is from pins 3, 4, 5, 10, 11, 12, which are soldered to an area of copper on the board, or other sink. With no sink, output should be kept to a maximum of about 1W per channel, using a 14v supply.

POWER SUPPLIES

Dry batteries are practical for powers of a few watts, and are used for small equipment and when portability is necessary (e.g., for a loud hailer). Dry batteries can provide quite large currents on an intermittent, short-duty basis, are not very bulky or heavy, so find service for larger equipment where no other supply will be available and operation is only for short periods. But for general continuous use, dry batteries cease to be very practical, except for low power amplifiers.

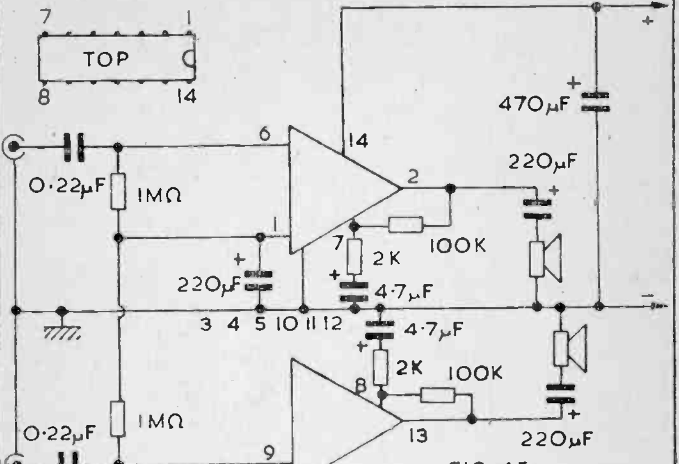


FIG. 45.

For larger power equipment, especially when likely to have continuous operation, accumulators are suitable when mains supplies are not available. Accumulators are produced in many types and sizes, and may be used singly or in series for higher voltages. Thus two 12v accumulators would provide a 24v supply. Accumulators of large ampere-hour capacity become relatively bulky and heavy, but moderate AH capacity batteries will give useful periods of service between charges. As example, a 10AH capacity accumulator would be expected to deliver a current of 1 ampere for 10 hours, or the equivalent (such as 2 amperes for 5 hours). Where accumulators are used for portable entertainment or other amplifiers, a charger should be available so that they can be kept in a correctly charged condition. An estimate of the likely period of working before the battery voltage begins to fall off can be made if the amplifier drain at its wanted output is known, or checked with a meter.

Most generally, operation will be from AC mains, by means of a power pack incorporated in the equipment. The three basic circuits for this purpose are shown in Fig.46.

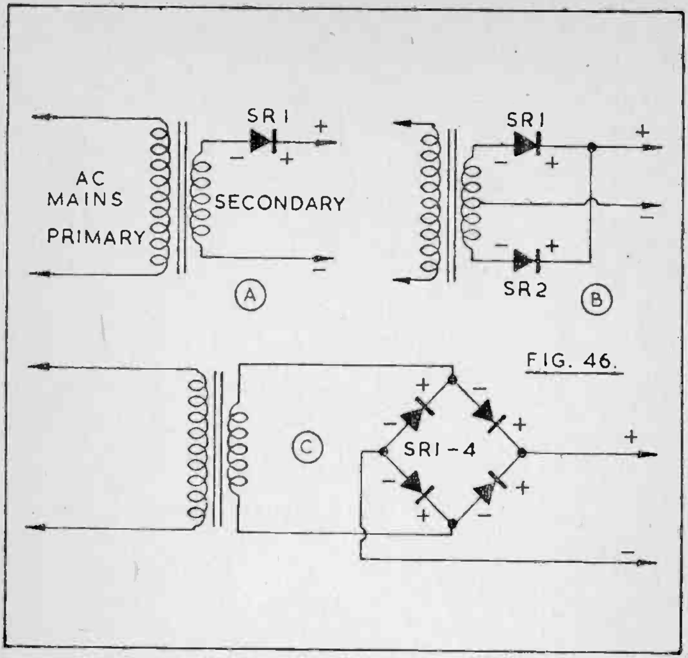


FIG. 46.

HALF-WAVE RECTIFICATION

This is found only occasionally in the cheapest equipment and has a relatively poor performance. The circuit 'A' has a single silicon or other rectifier SR1. The transformer receives power from the AC mains at its primary, and reduces this to the required low voltage, which is obtained from the secondary. The transformer primary may be wound or tapped for 240v, or 200–250v, or any other required voltage. In a similar way the secondary is wound to provide the wanted low voltage – often in the 12v to 30v range.

SR1 allows current to flow in one direction only, so that pulsating direct current is obtained, with the polarity shown. With 50Hz mains, ripple in the secondary circuit will also be 50Hz. This is later smoothed for the amplifier. The circuit offers no advantage except simplicity and the supply obtained from it is prone to cause 50Hz hum.

'B' is a full-wave circuit, in which the secondary is centre-tapped. SR1 and SR2 rectify alternative half-cycles. With 50Hz mains, ripple is 100Hz. This is more easily smoothed. Circuit 'B' has been largely employed, and is satisfactory and gives good results. However, it does not allow the simplification of the transformer which is achieved with 'C' so the latter is now almost exclusively used.

At 'C' the four rectifiers SR1 to SR4 may be discrete items, or may be integrated into a bridge rectifier. The latter has AC (~) input tags to take to the secondary of the transformer, and positive and negative output tags. The secondary of the transformer for 'C' can be the same as for 'A' As example, for a nominal 15v supply 'A' and 'C' would have a 15v secondary. However, 'B' would require a winding with an overall voltage of twice this. That is, a 15–0–15v winding, or 30v winding with centre tapping.

ISOLATION

The main transformer not only reduces the voltage to that wanted, but isolates the amplifying equipment from the mains. This is a necessary safety precaution to avoid the possibility of shocks when handling the equipment, or ancillary units such as tuners, preamplifiers, etc.

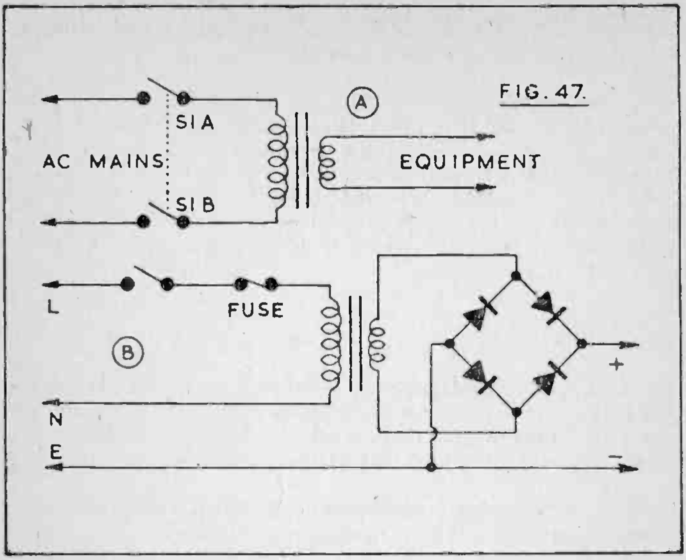
Where a *double-insulated transformer* not requiring earthing is used, the mains power supply can be arranged as at 'A' in Fig.47.

S1A-S1B is a double-pole switch, so that the transformer is completely disconnected from the mains when 'off'. Power may be drawn from a reversible 2-pin plug or adapter, and the L and N conductors will then depend on which way the plug is inserted.

The N or Neutral mains supply conductor of the normal AC mains is earthed or at low potential relative to earth. The L, Live or line conductor is at high voltage relative to earth. Where a single pole on-off switch is used, it must always be in the L circuit, and this can only be assured with a 3-pin or non-reversible plug. If a single-pole switch were placed in the N conductor, this would of course switch off the equipment, but would leave the transformer primary alive at full mains voltage.

'B' shows a supply operated from a 3-pin plug. The 13A type of plug should be fitted with a 2A or other low rating fuse. Use a 3-core cord, with blue for N, brown for L, and yellow-green for E circuits. The single pole switch is included in the L circuit at the equipment, and any additional fuse is also in this conductor. Such a fuse could usually be 500mA.

Earthing is as shown, so that metal cases and other items are grounded. If a short-circuit in the mains transformer or adjacent mains items were to place a mains voltage on the equipment side of the transformer,



current flowing through the earth return would blow the protective fuse, so that the equipment remains safe.

A fuse may be included in the secondary circuit to the rectifiers. However, this has no bearing on mains safety, and is to protect the transformer, rectifiers or other items if a fault arises which causes a large current in the equipment. This fuse has to be of larger rating than a primary fuse, so that it will not blow when switching on, or during normal high current demands of the amplifier.

INDICATORS

Some form of indicator is often present, to show when power is on. Fig.48 shows four common circuits for this purpose.

At 'A' a neon operated from the high voltage or mains side of the transformer is used. Neons and fittings may be obtained for use with a series resistor R1, or direct supply from 200/250v. For the small wire ended, MES and miniature bayonet cap neons, a typical resistor value is 270k, ½ watt.

'B' is a circuit in which a filament lamp is run directly from the transformer secondary. A 100mA or other small-current bulb may be used

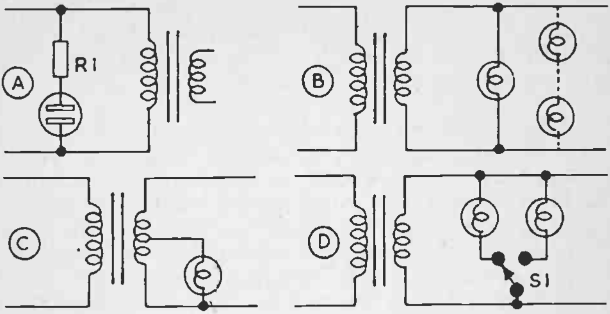


FIG. 48.

to minimise the additional load on the transformer. Two bulbs of the same current rating may be in series, to obtain a higher voltage with readily-available low-voltage bulbs.

At 'C' the transformer secondary has a tapping, so that a suitable low voltage is available for the bulb, and in circumstances where the whole secondary has to provide a rather higher voltage.

At 'D' S1 is one section of a multi-pole switch, which selects alternative inputs, or performs some other function. The indicator lamps (which may be more than two in number) automatically light to show the switch position and function.

TRANSFORMER RATING

Some transformers are wound for approximately 240v mains, and have no alternative primary taps. If the mains are above or below this figure, the transformer output voltage will vary in proportion, but this is generally not important within the small limits likely to be encountered. Other transformers have alternative primary taps, often for 200v, 220v and 240v. If so, select the tap to suit the mains voltage. Where the main voltage falls between two taps, it is general to use the higher tap, e.g., 240v tapping for 230v mains.

The voltage of the secondary will be specified for the amplifier. Normally, a slightly lower voltage would be in order, though with some sacrifice of maximum audio output. A higher voltage should not be used unless it has been checked that the amplifier is still within its ratings. For experimental work or a general purpose power supply for several different amplifiers, a multi-ratio transformer can be used. These have numerous secondary tappings, enabling various voltages to be chosen. Typical transformers of this kind are able to supply 6–8–9–10–12–15–18–20–24–30v, 19–25–33–40–50v, or up to 60v in the larger sizes.

The minimum current rating of the secondary will be that which can supply the full amplifier load at maximum volume, without overheating. Where the current drain is not known, it can be measured. Amplifiers of a few watts output will not usually need more than 250mA to 500mA, but larger amplifiers will require ratings of much more than this. Current depends also on operating voltage. The current load of a 10w amplifier operating from 15v as example, would be about twice that of a 10w amplifier designed to operate from 30v.

A transformer having a higher current rating than needed may be used, but would increase cost and weight.

With home built equipment using a separate power supply, non-reversible connectors should be used.

A transformer that has been operating at near its maximum rating for a lengthy period can be expected to feel very warm to the hand. Adequate ventilation will help prevent overheating.

RECTIFIER RATINGS

Silicon and other rectifiers of adequate current rating are readily available. It is merely necessary that the current rating is equal to that of the transformer or actual current to be drawn; the rating can be larger.

The voltage rating of the rectifier seldom needs much attention with the lower voltage supplies. However, with higher voltages in particular it is necessary to remember that the Peak Inverse Voltage across the rectifier may be higher than anticipated. As example, consider 'A' in Fig.46. Assume the secondary is rated to deliver 15v. This is actually the RMS (root mean square) voltage, as shown by an AC meter, and the peak voltage is about 1.414 times this, or 21.21v. If no current is drawn from the supply, the reservoir capacitor will charge to this value, and during reversed half cycles both this and the transformer voltage will appear across the rectifier, so that it experiences a PIV of 42.42v. This figure will fall slightly when current is drawn. A 50PIV rectifier would normally be used here, and when voltages are higher the PIV ratings will be appropriately greater. Circuit 'B' (Fig.46) has the same PIV requirement as 'A' but 'C' halves the PIV ratings. The 1N4001 and 1N4002 (see Fig.51) silicon rectifiers are suitable for 1A (50 PIV and 100 PIV), while the 1S410 is 3A 100 PIV. Numerous other suitable rectifiers are available.

SMOOTHING

The rectifier output is pulsating DC, and this is smoothed by one or more capacitors. These are charged by the current from the rectifiers and act as reservoirs to deliver current when the AC cycle is at zero and no current is available from the rectifier circuit.

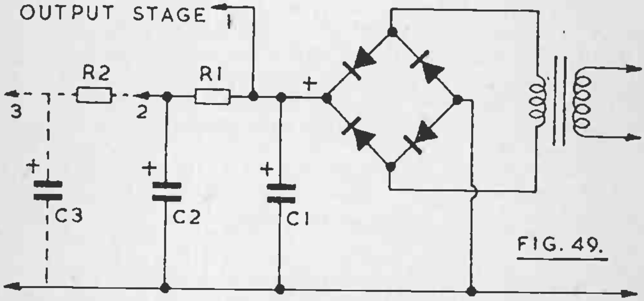


FIG. 49.

In Fig.49 C1 is charged by the rectifiers. Current is usually taken from here, at 1, for the output stage, and often driver/output stages. Some ripple is present, but maximum voltage and current are available at this point, and hum will not usually arise if C1 is of adequate capacitance.

The ripple across C1 is further reduced by supplying C2 through resistor R1. So point 2 can supply earlier audio stages. Current required by these is relatively small, so that little voltage is lost in R1.

Most ICs have built in ripple rejection, so that the chances of hum being introduced are greatly reduced compared, as example, with an amplifier constructed from individual transistors. However, a preamplifier or other unit such as a tuner may require a well-smoothed supply, such as available from C2. Occasionally, a further resistor R2 and capacitor C3 may be present in a transistorised preamplifier or tone control circuit, and will avoid the introduction of hum through the supply line, or unwanted coupling effects.

C1 is of large value – typically 2000μF. A high-ripple capacitor is most suitable here. Many amplifiers employ a power supply consisting of transformer, rectifier and C1 as in Fig.49. Where further smoothing or decoupling is required for earlier stages, components which are the equivalent of R1 and C2 will be present at the amplifier itself.

OTHER POINTS

With commercial equipment, particular points introduced by the manufacturer may be encountered. A motor may be arranged to provide a low voltage output from a secondary winding, to substitute for a transformer. A choke winding may be fitted to some other component. An auxiliary mains outlet may be fitted, or a thermistor to reduce surge when switching on. A transformer may have links or taps for 110/130v, and 200/250v. Circuit elements of this and similar kind will usually become clear on examination, and should not cause any particular difficulty.

CAPACITOR VOLTAGES

Capacitor voltage ratings for power supplies or other circuit positions need to be at least equal to the actual voltage present, as described. The question of voltage rating most usually arises with electrolytic capacitors. This, in turn, may depend on the supply voltage to be used. As example, if an amplifier is to be powered from a 20v supply no capacitor need have a higher rating, and 25v capacitors would probably be used. But this could be inadequate where the same amplifier is going to be run from a 30v supply, when 35v capacitors would be needed in some positions.

If necessary, it is easy to check the actual voltage across a supply or other capacitor, using a high-resistance meter. The voltage should be lower than the component rating. Substantially lower voltages than those of the power supplies will be found across many capacitors, depending on their circuit position.

Other capacitors can be polystyrene, ceramic, mica, etc. Here, 50v, 150v or similar capacitors can often be used throughout, and will be more than adequate for the actual voltages present.

POWER SUPPLY COUPLING

It is sometimes overlooked that an extremely small common impedance in the negative or earth return line of equipment can introduce instability. At A in Fig.50 the situation is very poor. The speaker will require high currents, which are obtained from the negative supply line, which is so connected that the supply-speaker circuit has loops common to input and preamplifier. A large current gain will exist between input and output circuits. Even with a negative return of virtually negligible impedance, speaker currents may cause input voltages which will be amplified to significant levels. Such methods of connection should be avoided.

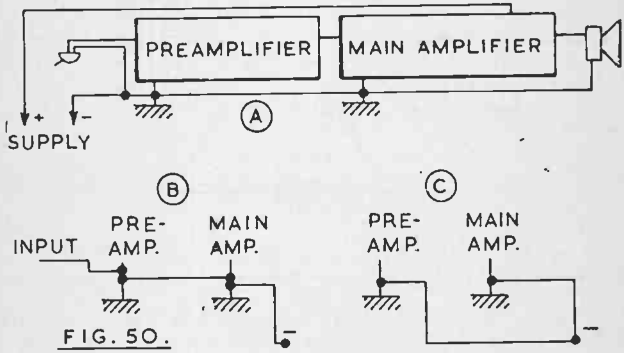


FIG. 50.

At B, current for the main amplifier and speaker does not flow in return circuits used by the preamplifier or input. At C, the power supply negative terminal is taken separately to both preamplifier and main amplifier, with a similar effect.

A correct and logical connecting up of units will result in circuits like B and C. But if it is felt that the common negative return is 'earth' to be used in any way chance dictates, then circuits similar to A in some respects may easily arise, and will cause howling or other troubles, unless gain and power are low.

Unwanted feedback of this kind is unlikely through the positive supply, which normally runs to the power amplifier first, then on to earlier sections of the equipment, and is in any case not used as a return for inputs.

SPLIT POWER SUPPLY

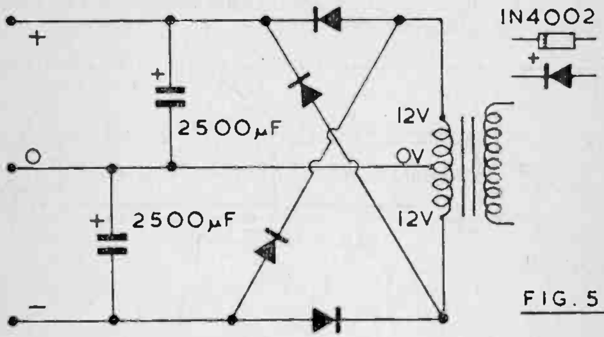


FIG. 51.

The circuit in Fig.51 can be used when a split power supply is required. In Fig.46 the use of a centre-tapped transformer and two rectifiers provides a positive supply line with the centre-tap of the secondary as negative line. By adding further rectifiers as in Fig.52 an equal but opposite polarity supply is obtained, with reference to the centre tapping.

Mains primary connections are arranged in the way already explained. Proper safety precautions at this side of the circuit should always be taken.

The 1N4002 rectifiers are suitable for 100PIV 1A. Other rectifiers and capacitor values are satisfactory. The ratings of these components will have the same relationship to output voltage and current as explained for Fig.46, and described earlier.

BLEEDERS

A bleeder is a resistor placed across the supply, and drawing a steady current. (Two bleeders, one across each capacitor, would be used for

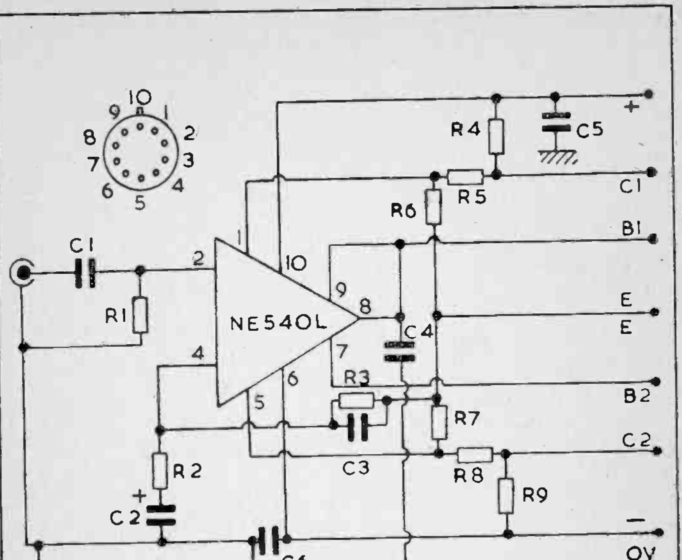


FIG. 52.

Fig.51.) This steady load results in a better regulated output voltage – voltage does not rise so much when the current draw is small. Current drawn by the bleeder is not available for the amplifier so is wasted, but this is unimportant if the transformer and rectifiers are of adequate rating. The higher the bleeder current, the better does regulation become. The resistor wattage should be adequate, bearing in mind that some rise in voltage may occur. As example, a 100 ohm resistor across a 12v supply would pass 120mA, and a 2w to 3w component would be preferred.

PART IV
HYBRID CIRCUITS

When very large power outputs are required it is generally necessary to use high power output transistors for the final or earlier stages. However, these may be driven by an IC, so that the overall circuit is still considerably less complicated than with an amplifier using separate transistors throughout.

The NE540L is an IC particularly intended for driver purposes in amplifiers of up to 35 watts output. The driver part of such an amplifier is shown in Fig.52.

Audio input is via C1 to 2. Output for the final stage is from 8/9 for one transistor at point B1, and from 7 to the other transistor at B2. Points C1 and C2 are collectors of the output transistors, which receive their supplies through R4 and R9. Feedback via R5 and R8 to 1 and 5 of the IC, and from the emitters by means of R3 to the negative input 4, stabilises the whole circuit. For full output, a 25–0–25v supply is required, and should be of adequate current rating (say 3A) as the drain of the output pair has also to be met. Fig.52 shows leadouts, and a clip-on heat sink can be used on the IC with advantage.

Fig.53 shows a printed circuit layout for this IC. This does not include the output transistors, which have to be mounted on their own heat sink. Input is by means of the usual screened lead, with outer brading taken to the 0V or 'earth' foil. A volume control can be incorporated in the usual way.

Red and black leads run from positive and negative lines (near C5 and C6) to the positive and negative points of the power pack. Good results can be obtained with 15–0–15v upwards, though maximum output is naturally reduced. The power supply 0V or centre line and loudspeaker lead S are situated as shown in Fig.53. Flexible leads are provided from B1, B2, C1, C2 and E, for base, collector, and emitter connections.

Fig.54 shows the output pair. When a common heat sink is used, one transistor must be insulated from it. This is done with the thin washer and two small bushes provided for the purpose. The sink must also be isolated from other circuits. An alternative is to use separate heat-sinks, or to insulate both transistors from the sink. A finned sink at least 3 x 4 in (75 x 100 mm) is recommended. One of the heat transfer compounds available for the purpose should be smeared on meeting surfaces before bolting the transistors in place. The board is best near the sink, to avoid long leads, and the remaining speaker connection is from the emitters as in Fig. 54.

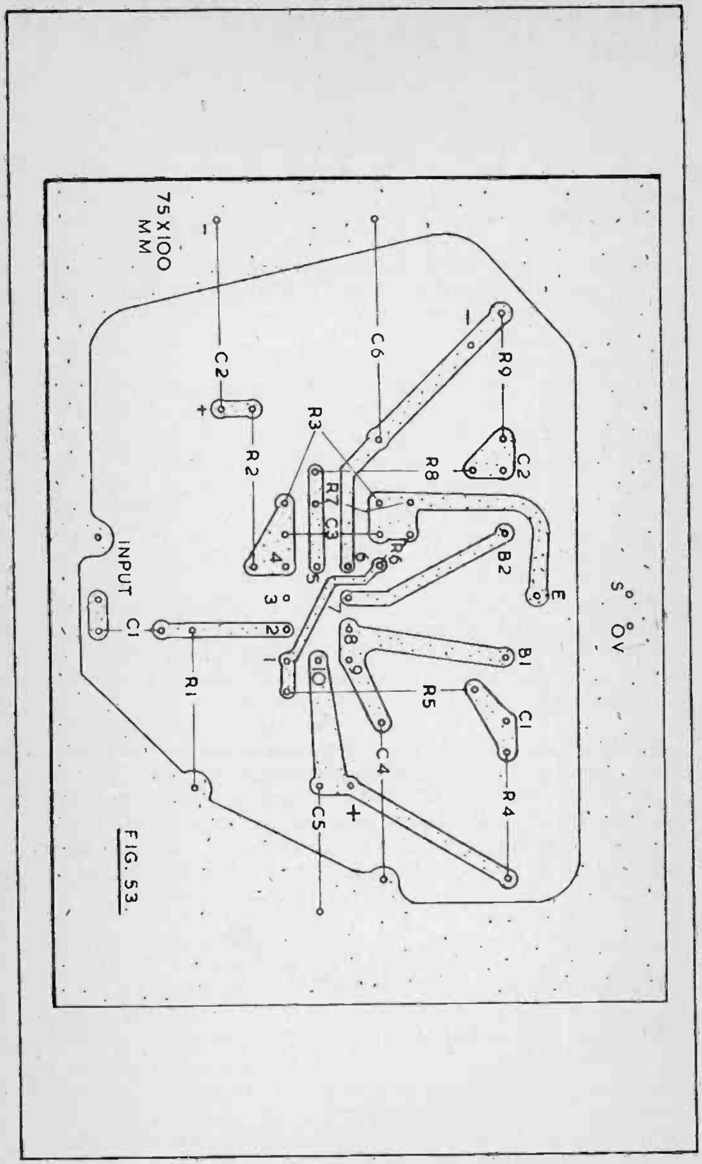

75 X 100
MM
INPUT
C1
R1
C2
R2
C6
R9
R3
R8
R7
C3
R6
B2
E
S
OV
B1
R5
C4
R4
C5

FIG. 53

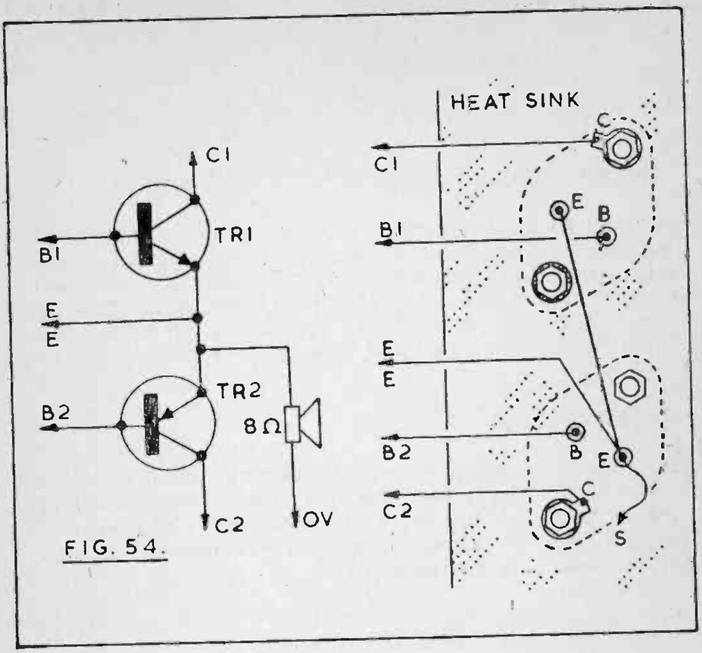


FIG. 54.

OUTPUT PAIR

Note that TR1 is NPN, and TR2 PNP. Various large power complementary pairs may be used, such as the 2N3055 for TR1, and MJ2955 for TR2. Maximum output will be achieved with transistors giving large gain. With high power output transistors, the output driving capacity of the IC can be exceeded before the transistors themselves are giving maximum power. With the IC providing maximum undistorted drive, the upper limit of power obtained from the amplifier thus depends on the gain of the output pair.

VALUES FOR FIG.52

R1	10k ¼w
R2	100 ohm ¼w
R3	10k ¼w
R4/R9	0.18 ohm 5w
R5/R8	56 ohm ¼w
R6/R7	8.2k ¼w

C1	0.47µF
C2	47µF
C3	10pF
C4	2.2nF
C5/C6	0.1µF

LIMITING VALUES

In Fig.52, R4 and R9 are of the same value. This value can be found for operating conditions of an output pair by R = 650mA/I , where I is the peak current. Other values thus allow setting the current limit as required, e.g., I is to be 2A. 0.65/2 = 0.33 ohm approx. R5 = R8 in value, and R6 = R7. R6 (and R7) = VC/3mA, e.g., for collector voltage VC at 25v, 25/0.003, or 8.33k (8.2k used).

RELATIVE POWER

It is generally considered that a person will notice that an increase in power has arisen when power has been doubled. A power ratio is usually expressed in decibels. A dB is one-tenth of a bel, which is the common log of the ratio of two powers. The relationship between dB and power ratio is shown below:

1dB	1.26
2dB	1.58
3dB	2.0
4dB	2.51
5dB	3.16
6dB	3.98
7dB	5.01
8dB	6.31
9dB	7.94
10dB	10.0
15dB	31.6
20dB	100.0
30dB	1000.0

Thus an increase of power to twice its original level, or by 3dB, is the smallest likely to be worthwhile. A doubling of power in this way will represent an increase of 3dB, no matter what the power level was originally. If output was 1 watt and were increased to 2w, power has been raised by 3dB. Similarly, increasing 5w to 10w is also only an increase of 3dB. It is for this reason that at higher power levels an increase in power which may seem very great is not in effect as apparent as may be expected. As example, an increase from 50w to 60w – though adding 10w – would normally be entirely insignificant, while increasing power from 50w to 100w is a power ratio increase of only 3dB. So when planning larger equipment so that more volume is available it is wise to think in terms of at least an increase of several times the original power.

BRIDGE AND PARALLEL

The way in which two amplifiers may be used in a bridge circuit to increase power is shown in Fig.38. A pair of TDA2020 ICs used in a bridge circuit can provide up to 36 watts, with an 8 ohm speaker. A pair of 540 drivers, each with its output pair, can be used for up to 70 watts with an 8 ohm speaker.

For higher power, output transistors of the types listed and similar devices, may be used in parallel. This requires that base connections are connected together, as are collectors. Individual emitter resistors should if possible be included for each transistor, to help equalise currents. For high power transistors, these can usually be 0.15 ohm to 0.33 ohm each. Without such resistors, one of a pair may dissipate substantially more power than the other.

With transistors in parallel, the drive requirements of the stage are doubled. So is the current drain from the power supply. The load impedance can usually be halved, where maximum possible output is required.

OUTPUT TYPES

With high power transistors, heavy currents can flow. Damage can arise if no output short-circuit or power limiting protection is present. The likelihood of damage depends on the voltage and other circumstances. Some measure of protection can be obtained if necessary by using fuses in the power circuits, employing the lowest rating. Adequate heat sinks also become important when the output devices dissipate appreciable power. Suitable sinks will usually be those of about 2–4°C/W, but sinks of under 2°C/W will be needed for large transistors run near maximum ratings.

Fig.55 shows ratings of some suitable transistor types for output purposes. These can be used in complementary pairs. The power dissipation is for a single transistor.

Many other power transistors of similar type exist, and all may of course be used with a lower collector/emitter voltage than that shown. Emitter resistors may sometimes be added, to help stabilise working conditions.

Type	*Watts*	*CE Max.*	*HFE*	*Case*	
BD165	20	45v	40	A	NPN
BD166	20	45v	40	A	PNP
BD175	30	45v	40	A	NPN
BD176	30	45v	40	A	PNP
BD189	40	60v	40	A	NPN
BD190	40	60v	40	A	PNP
BD595	55	45v	25	B	NPN
BD596	55	45v	25	B	PNP
BD607	90	60v	15	B	NPN
BD608	90	60v	15	B	PNP

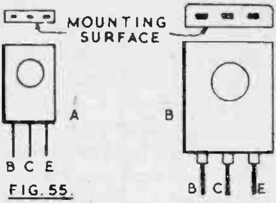


FIG. 55.

POWER DRIVER

Manufacturer's information shows that the 303D IC power driver can be used in circuits intended for an output of 100 watts. Though this is a relative large IC made even more bulky by its special heat sink and is by no means inexpensive, a basic circuit showing its use is given in Fig.56.

The input impedance is 200k, and C1 is an isolating capacitor. Signal input is to 1, and 2 is the inverting input. Feedback reaches 2 via R3 from the output circuit. Maximum dissipation in the IC itself is 20w, with supply lines up to 50v maximum. Points 3 and 9 are the positive supply and bias connections, and 4 and 7 are the negative supply and bias connections.

Points 8 and 10 are outputs to drive a complementary pair, MJ802 and MJ502. Other complementary pairs, from the list, or types such as the 2N3055 and MJ2955 should be satisfactory. The trimming points 5 and 6 allow adjustment of the crossover bias by means of VR1. If bias is low, objectionable crossover distortion will be audible; if too high, the resting current of the output pair will be unnecessarily heavy. These transistors will of course need adequate sinks. Emitter resistors R4 and R5 help stabilise working conditions, and also help limit peak current in this stage. With other transistors the output load might need modification.

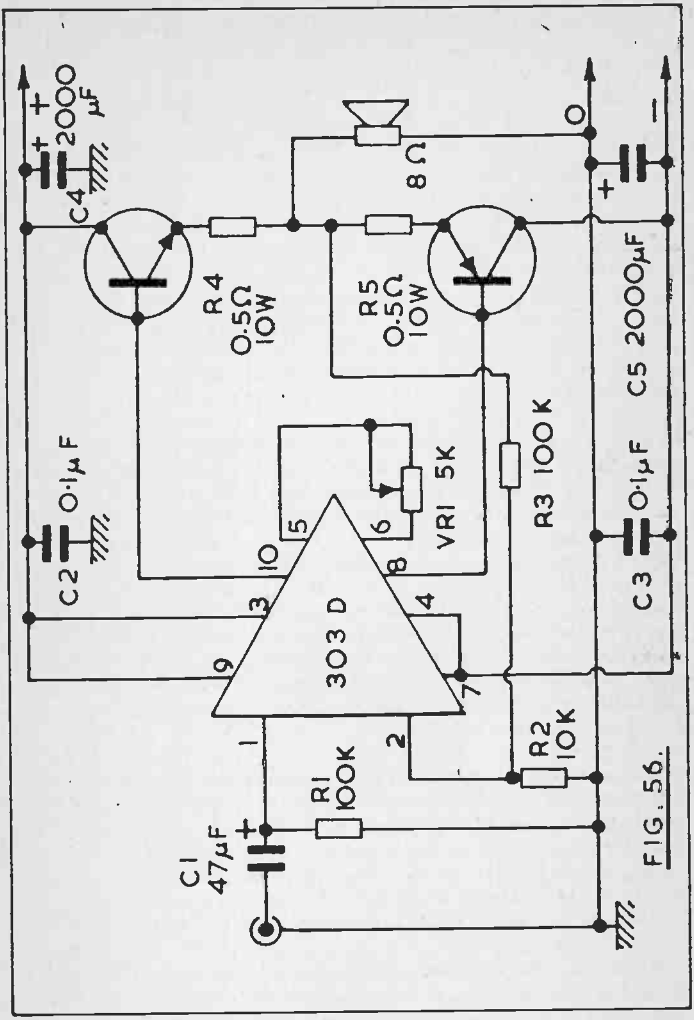


FIG. 56.

C2 and C3 are HF by-pass capacitors. Whether C4 and C5 are needed may depend on the power supply.

The construction of such an amplifier would have to include care to avoid any common impedance between output and input circuits, as peak currents would be very large. Input would be from a preamplifier, which could with advantage have its own power supply.

TESTING

When first testing any amplifier, it can be worthwhile to have some means of limiting the current. This can apply both to small amplifiers where current may be quite low, or to those where currents may be very heavy. Then if it is apparent that the current drawn by an IC or transistor output stage is going to be too heavy, it may be possible to switch off power and look for a fault, without any actual damage arising. Apart from obvious faults such as shorts to heat sinks or omitted or wrong connections, look for fragments of solder bridging pins or conductors, or wrong resistor values. It may occasionally be necessary to disconnected suspected items, such as capacitors, to test them individually.

Means of obtaining reduced power include using alternative taps on a power supply transformer. It is also possible to reduce voltage and limit current by temporarily placing a high wattage resistor in series with the primary circuit. Variable resistors, in either primary or preferably secondary circuits, offer means of temporarily reducing the voltage, but an adequate resistor load needs adding in parallel to the power supply output circuit, to avoid the voltage soaring when current drain is low. Methods using series resistors will result in the power supply having poor regulation, and are of course only temporary for an initial test. A fully adjustable, regulated supply from a power pack of this type will be excellent for an initial test, and many such units have adjustable current limiting. Assuming that all is in order, the usual power pack can then be substituted.

One cause of heavy, continuous current, sometimes not suspected, is instability, and the frequency at which the IC is being driven may be inaudible. Inadequate screening of input circuits, or poor layout, is a probable cause. A check for this can be made by placing a by-pass capacitor (say 1nF) across the input. If operation is then normal, layout should be improved so that this capacitor is not necessary. Running output leads near inputs may also be responsible,

If satisfactory results are being obtained, and voltages and currents are normal, it may be assumed that all is in order. To determine what output power is available it is necessary to use a suitable power load, with a sine wave input, and preferably a scope to check that output is not flat-topping or otherwise distorted. Such tests would be considered essential with experimental circuits, but fortunately the user of an IC, following its maker's data, need usually make no tests when operating the IC correctly, with the voltage and load specified by its manufacturer.

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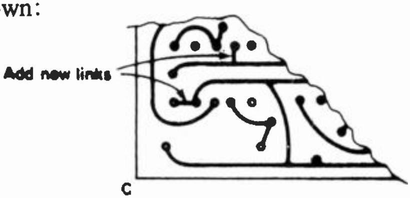
CORRIGENDA & AMENDMENTS

Page 10, Fig. 2.6: 4.7k resistors should be inserted with ends of VR1 and VR6. Add D1–3 in series with S7–9, cathodes towards these switches. Add to parts list D1–3 1N914.

Page 33, Fig. 3.12: R1 should read 330R not 330k.

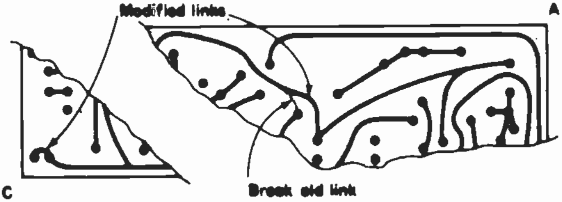
Page 59, Fig. 5.2b: Copper pattern should be modified as shown:



Page 61, Fig. 5.3: IC3 should read 4049 not 4001.

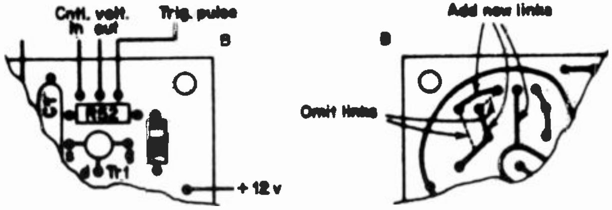
Page 65, Fig. 6.2: Values of VR5 and VR6 have been omitted. VR5 100k lin, VR6 25k lin.

Page 67, Fig. 6.4b: Copper pattern should be modified as shown:



Page 76, Fig. 8.5: Insert one 10k resistor between switches S50–98 and 0v.

Page 77, Fig. 8.6a, 8.6b: Diagram and copper pattern modified as shown:



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Part I	Understanding Audio IC's
Part II	Preamplifiers, Mixers and Tone Controls
Part III	Power Amplifiers and Supplies
Part IV	Hybrid Circuits

- An ideal book for both beginner and advanced enthusiast alike.

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