

HANDY-AMP

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A useful multi-purpose amplifier.



UNTIL recently, the author's household hi-fi system had a piece of screened cable hanging down the back. This was left connected to the amplifier's high-level (auxiliary) input. When some piece of experimental audio equipment needed to be tested, the cable could be retrieved and connected to the circuit. It was then possible to listen to the result.

NOT GOOD

This method was far from satisfactory, so a small battery-operated "bench" amplifier was designed for such purposes. As well as having an in-built loudspeaker, it has the facility for connecting personal stereo type headphones or an external loudspeaker. Also, it will accept both high-level and low-level input devices.

Magnetic record player cartridges and dynamic microphones provide a low-level output while the "line output" socket fitted to many pieces of consumer equipment (such as CD players and video recorders) provide a high level.

Many readers will, no doubt, wish to construct the amplifier for experimental purposes. However, it could have a variety of other applications. Examples include a small practice amplifier for electronic musical instruments and as the basis for an intercom, or toys and games.

Being battery-operated it may be set up outdoors and, with just a microphone (possibly with an extension lead) and a pair of headphones connected, it could be used to listen to wildlife.

Readers should note that the amplifier has been designed to be small and relatively inexpensive to construct. Although the maximum output power (one watt approximately) and sound quality are perfectly adequate for the applications suggested earlier, it is not suitable for critical applications such as serious music listening.

WATT'S ENOUGH?

The stated power rating of 1W is applicable when the amplifier is connected to an 8-ohm load. If a 4-ohm loudspeaker were to be used, the rating would be some 1.5W. In fact, the subjective difference between the two is not great and battery life is reduced at the higher power. It is therefore recommended that an 8-ohm loudspeaker is used. A 4-ohm unit had to be used in the prototype for availability reasons.

The low-level input has its own gain control while the overall gain is set using the master volume control. This allows just about any input source to be connected, including microphones, musical instruments and consumer audio equipment.

Although not ideal, the headphone socket fitted to many pieces of electronic equipment provides a signal which will drive the high-level amplifier input. When doing this, the volume control on the equipment would need to be adjusted to obtain the correct input level. When this was tried with a small TV, the sound was better than from the TV itself.

Most of the time, the amplifier will probably be used in conjunction with the

internal loudspeaker. However, better sound quality is obtained when using either headphones or a good-quality external loudspeaker. Although the amplifier is monophonic (that is, not stereo), when used with headphones, the output is applied equally to each one. This gives a more comfortable effect than with only one headphone operating.

ON THE PANEL

The completed Handy-Amp is shown in the photograph. For convenience, the rotary controls and all sockets and switches are mounted on the front panel. These are a jack and phono-type socket for the Low-level and High-level inputs respectively, together with the input selector switch, low-level Gain and master Volume controls, light emitting diode (l.e.d.) indicator and on-off switch, headphone jack socket, external loudspeaker sockets and output selector switch. On top, there is a matrix of holes to allow the sound to pass out from the internal loudspeaker.

There are several possible battery arrangements and the one chosen will be determined largely by the space available inside the case. This, in turn, will depend to a great extent on the dimensions of the internal loudspeaker. Whatever battery is used, it must have a nominal voltage of 9V (say, six 1.5V cells connected in series).

Cells should not have a capacity less than alkaline "AA" size. Note that a PP3 type battery would be totally unsuitable. The prototype unit was powered using two 4.5V alkaline "3LR12" batteries taped together and connected in series. These have around twice the capacity of alkaline "AA" cells.

The standby current requirement of the circuit depends on the load. In the prototype, it is 100mA. However, there will be peaks of several hundred milliamps and, depending on how the amplifier is used (operating time, load and volume), a life of some 15 hours may be expected from a pack of "AA" alkaline cells. This would be sufficient for occasional use.

With headphones connected, the standby current requirement of the prototype unit was only 50mA giving a longer battery life. The l.e.d. indicator reminds the user to switch off the unit after use.

Although battery operation is convenient and safe, for long periods of operation the use of a plug-in power supply unit might be more appropriate. More will be said about this later.



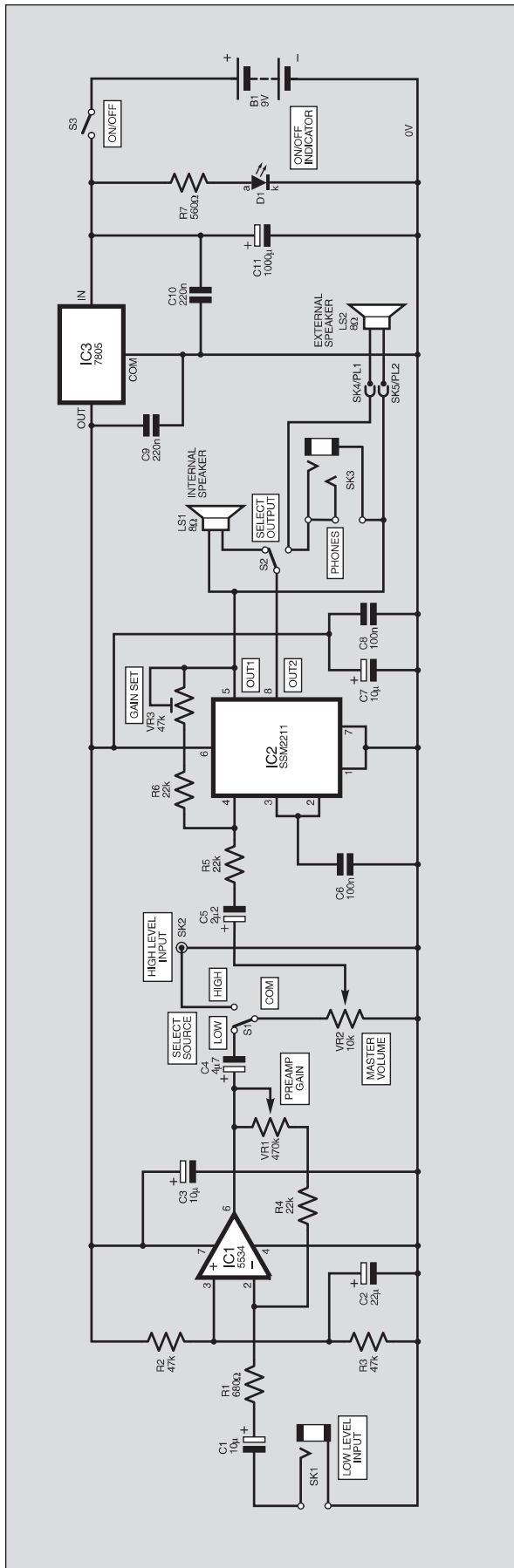


Fig. 1. Complete circuit diagram for the Handy-Amp.

CIRCUIT DESCRIPTION

The full circuit diagram for the Handy-Amp is shown in Fig. 1. The design uses two main integrated circuits (i.c.s), IC1 and IC2, together with voltage regulator IC3.

Battery B1 provides a nominal 9V supply to the regulator which then gives a 5V supply for the main circuit. This will be maintained until the battery voltage falls to some 7V, whereupon the regulated output will fail. Thus, as the battery ages, the supply will remain constant throughout its useful life.

Note that the l.e.d. on-off indicator, D1, is connected in series with current-limiting resistor R7 directly across the battery supply – that is, it is not subject to the effect of the regulator. It will be obvious when the batteries need to be replaced because the amplifier output will become weak and distorted and the l.e.d. will become dimmer.

Capacitors C9 and C10 promote stability of the regulator. Capacitor C11 charges up from the battery and can then maintain the supply on the output current peaks when the amplifier is delivering maximum power. This helps to provide a distortion-free output.

If using a plug-in power supply unit, C11 will provide additional smoothing if a poorly-smoothed supply is used. This should not be necessary with a good-quality unit but will be useful with inexpensive ones.

FIRST BOOSTER

When a low-level device such as a microphone is connected, via socket SK1, its output voltage is first boosted using a low-noise pre-amplifier based on operational amplifier (op.amp), IC1. High-level (line) signals are input via socket SK2, thus bypassing IC1.

COMPONENTS

Resistors

R1	680Ω
R2, R3	47k (2 off)
R4 to R6	22k (3 off)
R7	560Ω

All 0.25W 5% carbon film

Potentiometers

VR1	470k min. panel mounting, lin or log rotary carbon
VR2	10k min. panel mounting, log rotary carbon
VR3	47k min. preset, vertical carbon

Capacitors

C1, C3, C7	10μ radial elect. 63V (3 off)
C2	22μ radial elect. 63V
C4	4μ7 radial elect. 63V
C5	2μ2 radial elect. 63V
C6, C8	100n polyester, 5mm pin spacing (2 off)
C9, C10	220n polyester, 5mm pin spacing (2 off)
C11	1000μ radial elect. 16V

Semiconductors

D1	red l.e.d., 3mm
IC1	NE5534AN op.amp
IC2	SSM2211 power amplifier
IC3	7805 5V 1A voltage regulator

Miscellaneous

SK1	6.35mm plastic body mono jack socket
SK2	phono jack socket, single-hole fixing (see text)
SK3	6.35mm stereo jack socket, plastic body
SK4, SK5	2mm socket or as required (see text) (2 off)
S1, S2	s.p.d.t. toggle switch (2 off)
S3	s.p.s.t. toggle switch
LS1	small 8-ohm loudspeaker, 2W rating minimum (see text)

Printed circuit board, available from the *EPE Online store* code 273; aluminium case, 203mm x 127mm x 51mm; 8-pin d.i.l. socket (2 off); 3mm l.e.d. panel clip; control knob (2 off); alkaline AA-size cells (6 off – see text); holder and connector for cells (or as required).

Approx. Cost
Guidance Only

\$29.60
excluding batts. and case

See
SHOP
TALK
page

The signal source is selected by switch S1 and, via volume control VR2, passed on to the power amplifier section centred on IC2.

Op.amp IC1 is configured as a voltage amplifier used in inverting mode. Pins 7 and 4 are the positive and 0V supply inputs respectively. Blocking capacitor C1 allows the alternating current signal from a source connected to socket SK1 to pass via resistor R1 to the inverting input, at pin 2.

The input impedance is set by the value of R1 and this will provide a good match for dynamic microphones. The op-amp non-inverting input, pin 3, receives a d.c. voltage equal to one-half that of the supply (nominally 2.5V) due to equal-value resistors, R2 and R3, which form a potential divider connected across the supply.

NO PAIN, NO GAIN

The pre-amp gain is set by the ratio of feedback resistance (R4 plus VR1) to input resistance, R1. With VR1 set to minimum, this provides a gain of about 32 and at maximum, rather more than 700 (the fact that this is an inverting amplifier and the gain has a negative sign is of no real consequence here and may be disregarded).

This range of gain will suit microphones and other low-level input devices. VR1 is the low-level gain control (labelled simply "Gain" on the front panel). In use, this will be adjusted to take account of the sensitivity of individual input devices.

MAKING THE SWITCH

The output from IC1 appears at pin 6. This passes via blocking capacitor C4 to the "Low level" (Low) contact of two-way "Select Source" switch, S1. With this set as shown, any low-level signal passes to the common contact and hence through the track of potentiometer VR2 to the 0V line.

The sliding contact (wiper) of VR2 draws off the required fraction of the signal voltage and passes it, via capacitor C5 and resistor R5, to the input of the power amplifier (IC2 pin 4). If switch S1 is set to the alternative position (High), the output from IC1 is disconnected from VR2 but now any signal applied to the high-level input socket, SK2, is directed through VR2 instead. VR2 is the master volume control (labelled "Vol" on the front panel).

INTERNAL STRUCTURE

Power amplifier IC2 is an interesting device and a block diagram showing its simplified details is given in Fig.2. Basically, it consists of two operational amplifiers, A and B. The output of op.amp A (pin 5) provides one of the outputs (Out 1). However, it also feeds the inverting input of op.amp B (via the 50kΩ input resistor) whose output (pin 8) becomes Out 2. The loudspeaker is connected directly between Out 1 and Out 2.

Op.amp A is configured as an inverting amplifier. Thus, the signal appearing at Out 1 is an amplified and inverted version of that at the input, pin 4. Referring back to Fig.1, its gain is set by the value of external fixed resistor R6 and preset VR3 connected between Out 1 and input pin 4.

The non-inverting input (pin 3) is connected externally to pin 2 which sets it at a

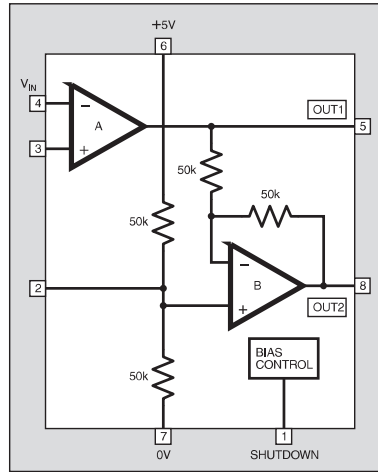


Fig.2. Block diagram of the SSM2211 power amplifier.

d.c. voltage equal to one-half that of the supply. This is due to the potential divider consisting of two internal 50kΩ resistors connected between supply positive (pin 6) and 0V (pin 7). Pins 2 and 3 are then connected to one end of the external bypass capacitor, C6, with the other end connected to the 0V line. This may be compared with the biasing arrangement used for IC1.

Op.amp B is also configured as an inverting amplifier and because the internal input and feedback resistors have equal values (50kΩ), the gain is set at minus one. Thus, any signal appearing at Out 2 is an inverted copy of that at Out 1. In this way, the input signal at pin 4 has an amplified but inverted copy of itself at

5 and a "straight" copy of itself at pin 8 amplified by the same amount. This is known as a bridge output configuration. Correct working depends on the two op.amp sections being exactly balanced but, of course, this is not easy to achieve precisely.

In theory, when no input signal is present, Out 1 and Out 2 will be at the same voltage. No current will then flow in a loudspeaker connected between them. When a signal is present, either Out 1 will drive current through the loudspeaker winding, which then sinks into Out 2, or Out 2 will drive current through the loudspeaker in the opposite direction and sink into Out 1. This will then reproduce the positive and negative excursions of the a.c. waveform presented to the input.

In practice, there will be a small voltage difference between the outputs in the absence of an input signal. A small standing current will then flow through the loudspeaker coil and the lower its impedance, the greater this current will be. This is added to the small current needed by the i.c. itself (for the working of op.amps A and B, and for the current drain through the internal potential divider). The overall current requirement is therefore somewhat load dependent.

SHUTDOWN

The SSM2211 amplifier used as IC2 has a shutdown feature. Thus, if pin 1 is made high, the i.c. is put into "sleep" mode and requires very little current. However, this feature is not used here and is disabled by connecting pin 1 to the 0V line along with pin 7.

The gain of IC2 is calculated by the ratio of feedback resistance (VR3 plus

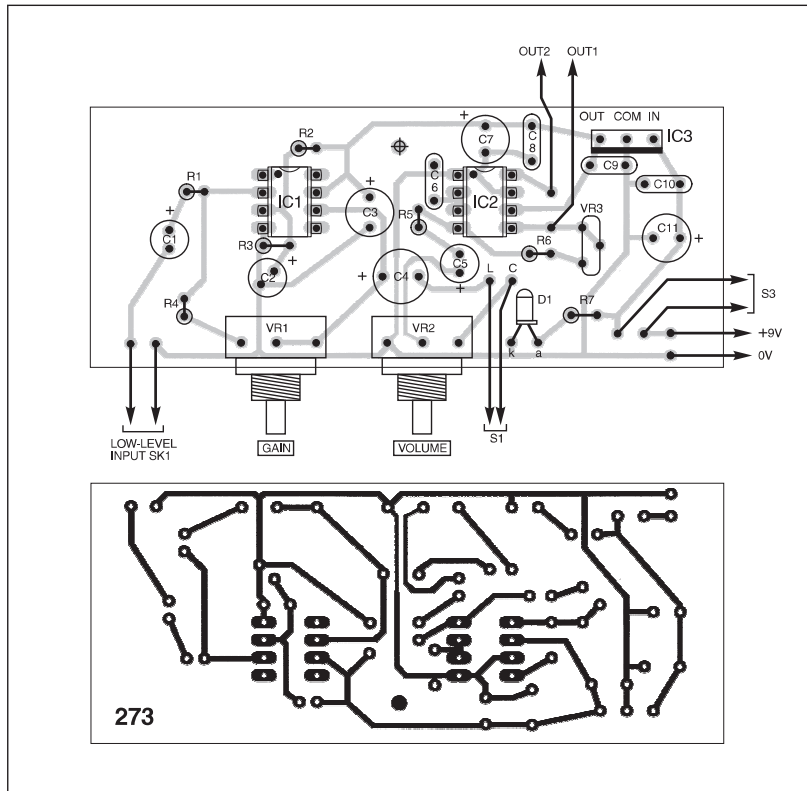


Fig.3. Handy-Amp component layout and full size copper foil track master pattern.

R6) to input resistance (R5) multiplied by two. This "multiplied by two" aspect comes about because of the bridged output configuration giving twice the voltage swing to the loudspeaker compared with a single op.amp.

With VR3 set to minimum resistance the gain is therefore two, and at maximum resistance is just over six. VR3 is a preset potentiometer which allows adjustment for the desired gain.

OUTPUT ARRANGEMENTS

With switch S2 ("Select Output") in the position shown in Fig.1, the internal loudspeaker is connected between Out 1 and Out 2. With the switch in the alternative position, the output is directed to both the "Phones" socket, SK3, and the external loudspeaker sockets (SK4 and SK5).

It is thought unlikely that anyone would wish to connect an external speaker and a pair of headphones to the amplifier at the same time. However, even if they did, the load would not fall below the minimum impedance providing an 8-ohm loudspeaker was used.

When using headphones, a greatly reduced power is available to them compared with a loudspeaker. This is because the (usually) higher impedance allows less current to flow. The impedance of typical personal stereo type headphones is about 30 ohms for each unit.

In this design, the left and right units are connected in parallel giving a combined impedance of some 15 ohms. However, because headphones provide acoustic energy direct to the ears, only a very small amount of power is needed for them to sound with acceptable loudness.

CONSTRUCTION

A metal case should be used as an enclosure for the Handy-Amp. A vinyl-effect aluminium box was used for the prototype unit because it gave a good appearance. Do not use a plastic box since this will not provide any screening and hum pick-up might be a problem.

Construction is based on a single-sided printed circuit board (p.c.b.). The topside component layout and full size underside copper track foil master are shown in Fig.3. This board is available from the *EPE PCB Service*, code 273.

Most of the components are mounted on the p.c.b. although there are quite a few off-board parts which will be hard-wired

to one another and to various points on the p.c.b. later.

Begin by drilling the fixing hole in the p.c.b. then solder the sockets for IC1 and IC2 in position (but do not insert the i.c.s themselves at this stage). Follow with all fixed resistors and capacitors. Note that the resistors are mounted vertically.

There are seven electrolytic capacitors and it is important to solder all of these with the correct polarity. The negative (-) end is clearly marked on the body and the corresponding lead is slightly shorter than the positive (+) one. Solder preset VR3 in place but not panel potentiometers VR1 and VR2 yet.

Fit the control knobs to VR1 and VR2. Measure how much of each spindle needs to be cut off then remove the knobs again. Hold the end of the spindle (not the potentiometer body or it could be damaged) in a vice and cut off the required length using a small hacksaw. Smooth the cut edges using a file and check that the knobs fit correctly.

Cut off the panel-location tags fitted to most potentiometers. If these are left in place, the bodies will not seat flat against the front panel when the p.c.b. is in position. The potentiometers should now be soldered to the p.c.b.

RIGHT LEADS

Identify the l.e.d. end leads. The cathode (k) is usually shorter than the anode (a) lead. Also the body has a small "flat" to denote the cathode end. Solder the leads to the "D1" pads on the p.c.b. observing the correct polarity. Bend them through right-angles, as shown in the photograph, so that the body ends up in line with the centre of the potentiometer spindles and standing out to about the centre of the bushes.

Solder pieces of light-duty stranded connecting wire to the following points on the p.c.b.: "Low-Level Input", "S1" (L and C), "Out 1" and "Out 2". Using different colours of wire will help to prevent errors when connecting them up.

Solder the red and black battery connector wires to the "+9V" and "0V" points respectively on the p.c.b. (or use pieces of similarly-coloured stranded wire if soldered connections are needed to the batteries). Adjust the wiper of preset VR3 to approximately mid-track position.

Solder regulator IC3 in position noting that the back is towards the centre of the p.c.b. (the part that protrudes is towards the edge).



Close-up detail of heatsink mounted on IC3.

Note that the specified regulator has a current rating of 1A. Although the average requirement of the circuit is much smaller than this, in use there are peaks of several hundred milliamps and this regulator will cope well.

Due to the low average current, only a small heat sink is needed. In the prototype, this consisted of a piece of sheet aluminium size 50mm x 15mm bent through right angles as shown in the photograph. It was drilled with a small hole and attached securely to the back of IC3.

When choosing the internal loudspeaker also take into account the size of the battery pack to be used. The loudspeaker used in the prototype was a 90mm x 50mm elliptical type as used in small radios and TV receivers. Make sure that the power rating is sufficient because many small loudspeakers are inadequate in this respect. Do not use one having a rating of less than 2W.

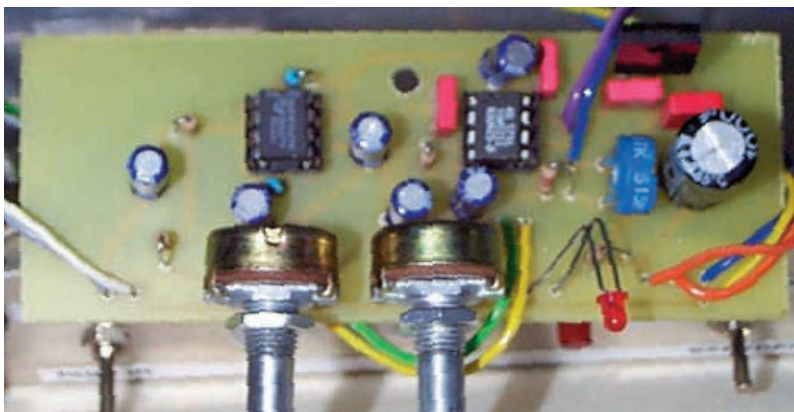
Decide on a position for the p.c.b. and battery pack by arranging them on the bottom of the box. Consider also the loudspeaker which will be mounted on the lid section and the various off-board sockets and switches.

When the p.c.b. is finally attached, there must be several millimetres of clearance between the copper tracks and the bottom of the box. This will avoid any possibility of short-circuits. Take care that the heat sink does not touch wiring or other electrical connections.

BORING BUSINESS

Mark the positions of the holes for the mounting bushes of potentiometers VR1 and VR2, also for the l.e.d. mounting clip. Drill these through and, gently bending the l.e.d. leads out of the way for the moment, secure the p.c.b. to the case using the potentiometer fixing nuts. Place washers (or spare fixing nuts) on the bushes on the inside of the case so that only a small amount of each bush protrudes through its hole. Mark through the p.c.b. fixing hole then remove the board again.

Mark the positions of the switches, the low-level input jack socket (mono 6 35mm type), the phono socket, the headphones



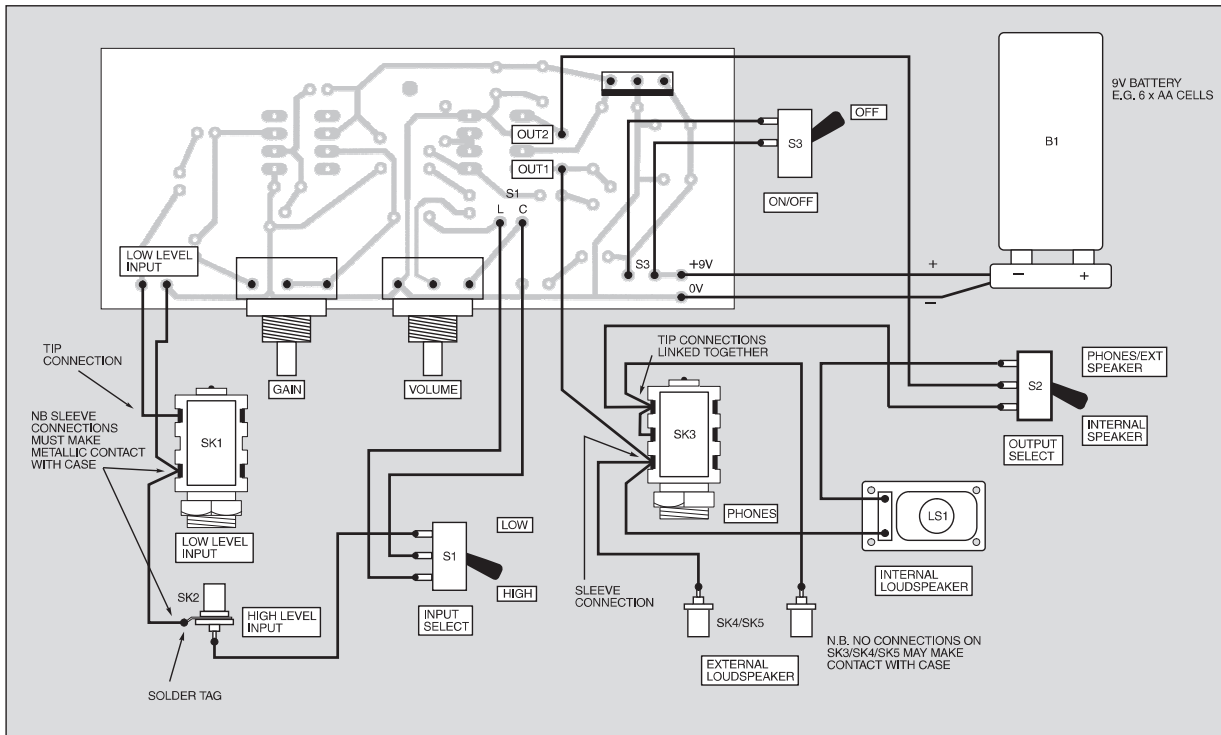


Fig.4. Off-board component connection details.

output jack socket (stereo 6.35mm – see Important Note) and external loudspeaker sockets. In the prototype, 2mm sockets were used for the loudspeaker, but the type used will depend on personal requirements. Drill the holes and mount the sockets, switches and l.e.d. clip.

IMPORTANT NOTE

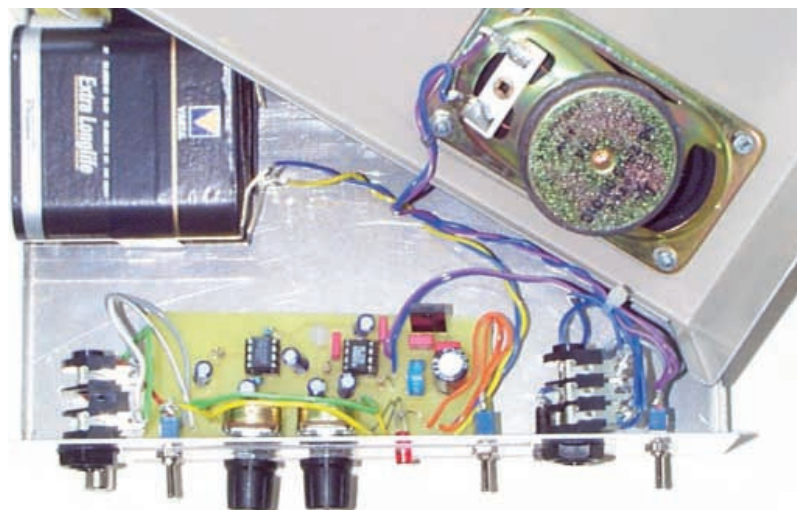
The case itself is connected to 0V (earth). It is not acceptable for the headphone stereo output socket, SK3, to be of a type where any of its contacts touch the case. If they were to, a short-circuit would be formed and this could damage IC2. This precludes using the ordinary metal sleeved type of 3.5mm jack socket because, when mounted in position, its outer (sleeve) connection would make contact with the metalwork.

There are various ways to avoid this. One method would be to use an insulating sleeve and insulating washers on a standard 3.5mm unit. However, the method used in the prototype was to use a 6.35mm plastic body stereo jack socket. This had all its connections isolated from the case. Headphones are then connected to it via a 6.35mm to 3.5mm converter.

Mount the socket and check, using a meter, which tag is which and that none of its tags make contact with the case.

The mono jack socket, SK1, used for the low-level input, unlike the headphone output socket *must* have its sleeve connected to 0V (earth). Since this socket will probably have a plastic body, it will not be done automatically and the sleeve connection will need to be hard-wired to a solder tag attached to the case.

The phono socket (SK2 – high-level input) must also have its sleeve connected to 0V. If using the specified single-hole fixing type, this will be done automatically. Note that this socket usually has a solder



tag on its bush and this may be used for the SK1 earth connection. If the phono socket is of a fully-insulated type, you will need to make a connection between the sleeve tag and the case using a solder tag (which will also be used for SK1).

HARD WIRING

Referring to Fig.4, carry out all the internal wiring using light-duty stranded connecting wire. By using different colours, you will avoid errors (rainbow ribbon cable is ideal). Note that the two non-sleeve (tip) tags of the headphone socket are joined together so that both headphone units are connected in parallel.

Remember to leave all wires interconnecting the various points on the p.c.b. with off-board components long enough to enable the p.c.b. to be removed without straining them, should this ever become necessary. Also, the loudspeaker wires

should be sufficiently long to allow the lid of the box to be removed without straining them.

Place the loudspeaker in position and mark the fixing holes on the lid of the case. Take care to avoid the p.c.b. (especially the heat sink on IC3) and battery pack positions.

Mark out the holes which are needed to allow the sound to pass through. Drill these using a small (say, 1.5mm) drill then increase the diameter to 5mm approximately. Work carefully because the appearance of the finished project will be spoiled if the holes are drilled carelessly.

Carefully clean away any metal particles then attach the loudspeaker. Solder the wires to its tags and apply some strain relief so that they cannot pull free when removing the lid of the case. In the prototype, this was done using a solder tag



having a long "tail". This was attached to one of the loudspeaker fixings.

The wires were protected using a short piece of sleeving and the tail of the solder tag was gripped gently around them. Take care that the wires are not so tightly held that a short-circuit is produced.

Attach the p.c.b., making sure that it is parallel with the base of the box. Measure the clearance between the copper track side and the bottom of the case. Cut a plastic stand-off insulator to the same length. Slide it into position and secure the p.c.b. using a thin nylon nut and bolt.

Gently bending the leads as necessary, push the l.e.d. into its clip. Attach the control knobs to the potentiometer spindles. If the knobs have a white line or spot, this should be arranged to be vertically upwards when the control is at its half-way position.

FINAL ASSEMBLY

Fit self-adhesive plastic feet to the bottom of the case to protect the work surface. Attach the battery pack using a small bracket or adhesive fixing pads (sticky Velcro pads were used in the prototype). Do not connect the battery yet.

Immediately before unpacking and handling IC1 and IC2, touch a metal object which is earthed (such as a water tap). This will remove any static charge which might exist on the body. This is a wise precaution because the i.c.s are static-sensitive and could be damaged by such charge. Insert them into their sockets with the correct orientation.

Place the lid of the case in position but do not actually attach it. Make a final check that nothing is obstructed and, especially, that the heat sink on IC3 is completely free of all wiring and internal components.

Make sure switch S3 is off. Before connecting the battery, make certain the polarity is correct. The circuit will be damaged if the polarity is incorrect. Make certain the positive battery connection cannot make contact with the case or the battery will be short-circuited. This could result in damage to p.c.b. tracks. Switch on S3 and check that the l.e.d. indicator lights up.

TESTING

Begin testing by using the amplifier with a high-level input source, such as the line output of a CD player, cassette deck or the audio output from a video recorder; if this is stereo, use only one channel. Connect it to the phono socket using a piece of mono screened lead with suitable connectors at each end. Set switch S1 to "High" and S2 to "Internal Speaker". Turn both VR1 and VR2 fully anti-clockwise.

Switch on the input device and slowly increase VR2. The sound should be heard clearly. Adjust preset potentiometer VR3 so that the sound is undistorted when VR2 is at maximum. You will find that the setting is not particularly critical. Almost maximum resistance was correct for the prototype (that is, the sliding contact almost fully clockwise when viewed from the right-hand edge of the p.c.b.).

Leave the system operating for about ten minutes then switch off and check that the regulator heat sink is not excessively

hot. If it is uncomfortable to touch, increase its area. When satisfied on this point, attach the lid section.

Turn VR2 to minimum again. Switch S1 to "Low" and connect a dynamic microphone to the low-level input jack. Increase VR2 to approximately one-third of its total clockwise rotation then increase VR1 slowly while speaking into the microphone. The sound should be clearly heard.

If the controls are turned up too far, or the microphone is placed too close to the unit, acoustic feedback will become evident. This usually manifests itself as a loud squealing noise from the loudspeaker.

Acoustic feedback is a potential problem with any loudspeaker/microphone system. It comes about because sound from the loudspeaker re-enters the microphone and builds up in a positive feedback loop. To prevent it, turn down the controls, move the microphone away and/or point it in the opposite direction to the loudspeaker. Acoustic feedback may be largely eliminated by using headphones instead of a loudspeaker.

It is unlikely that the low-level gain will need to be increased. If it is found to be necessary, decrease the value of resistor R1 to 560 ohms or even 470 ohms. Note that excessive gain leads to instability.

When connecting an external loudspeaker, always remember to switch off the amplifier first. This will avoid any possibility of loudspeaker connections touching the case and possibly damaging IC2.

POWER ADAPTOR

If you wish to use a plug-in power supply instead of a battery, use a 9V d.c. type having a current rating of 800mA minimum. A fuse and polarity-protection diode need to be included (see later) if damage to the unit itself or to the circuit are to be avoided.

Attach a power-in type socket to the rear of the box to suit the output plug on the power supply unit. If its sleeve connection does not make contact with the metalwork automatically, you will need to hard-wire this to a solder tag attached to the case.

Preferably, the power supply unit should have a fixed polarity with the centre (pin) on the output plug being the positive and the sleeve the negative. If the polarity can be reversed, make sure that the pin is made positive. If the polarity is incorrect, the circuit will be damaged. This is why a diode should be connected in the positive feed wire. If the polarity is incorrect, the diode will not conduct and nothing will happen. The fuse protects against possible short-circuits.

Referring to Fig.5, sleeve both end wires of a type 1N4001 diode. Solder the anode (non-striped end) to the centre (pin) connection of the socket. Attach a 20mm chassis fuse holder to the bottom of the box in such a position that the cathode of the diode can reach one of its tags. Solder this in position. A wire from the other fuse tag should then be taken to the "+9V" point on the p.c.b.

Insert a 20mm 1A quick-blow fuse in the fuse holder. Make sure none of the connections to the diode or fuse can touch the case. Use insulation if necessary. □

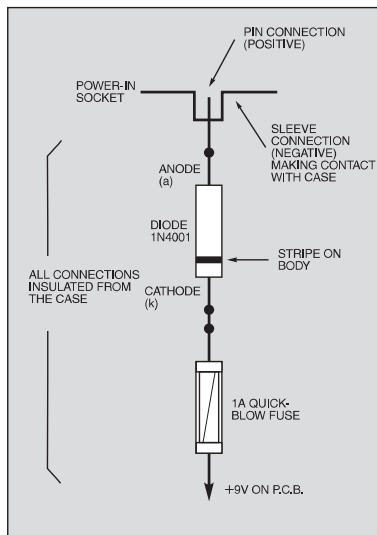


Fig.5. Using a fuse and diode as protection devices when a power supply adaptor is used.