Construction Project:

'Multimedia' Mini Amplifier

Here's a simple low-cost project that is so useful, you may well wonder how you've managed without it. It's a small high-quality speaker system with a versatile amplifier built into the base, allowing it to monitor almost any audio signal while delivering surprisingly good sound. Just the shot for improving the sound from your computer, or personal CD/tape player!

by ROB EVANS

As with most other truly useful pieces of equipment, this project was born out of necessity. What was needed was a small portable amplifier/speaker system that could easily monitor audio signals from a wide variety of sources, yet offered a clear and balanced sound so that the signal quality could be assessed, or simply enjoyed at near-hifi quality.

As it turns out, the range of uses for such a unit is much wider than we had imagined. Not only can it be used to monitor the sound from workbench projects, radio and video equipment, small personal CD and tape players; it's also ideal for boosting the signals from computer sound cards and CD-ROM players — hence the 'Multimedia Mini-Amp' tag.

The final project has more than met our original goals. It offers an amplifier which delivers around two watts with a distortion of less than 0.3% at the onset of clipping, and a speaker response which is quite flat over the range 80Hz to 10kHz. While these figures may not seem all that impressive in absolute hifi terms, rest assured that in practice the mini-amp delivers a surprisingly loud and clean sound for such a small unit.

In fact, the performance is such that two units could well be used as the basis for a very effective mini hifi system — all you need to add is a signal source and a couple of hookup cables. Since the mini-amp uses common low cost parts, the final system would be quite inexpensive.

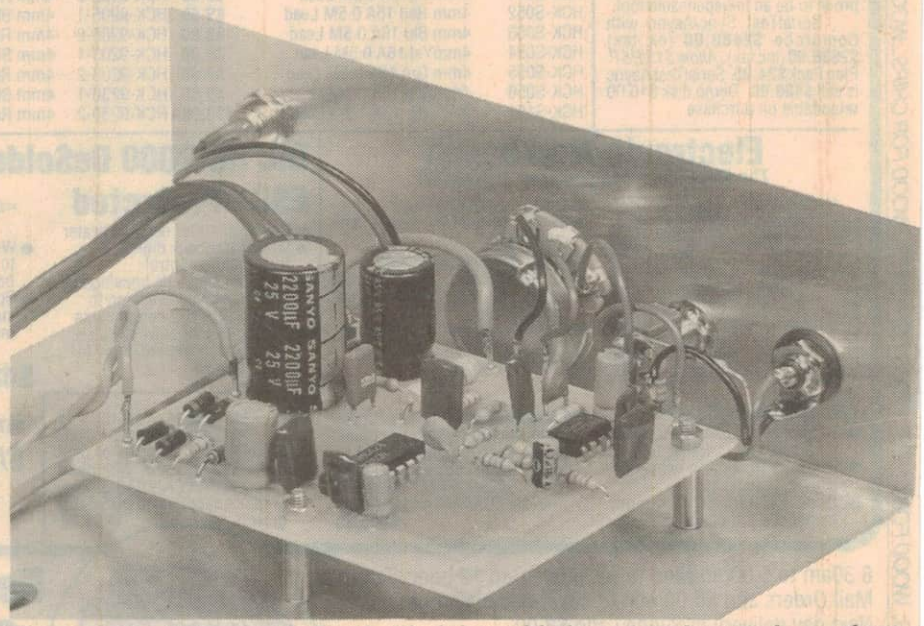
The mini-amp's speaker system is based around a low-cost ($12.95) twin-cone driver available from Jaycar Electronics (Cat. No: AS- 3011), which was designed for car sound applications. It has a generous magnet structure, a nominal diameter of 125mm, and comes equipped with its own protective grill. As a further indication of its car sound heritage, the driver has a rated impedance of four ohms and carries the well-known Clarion brand name.

After some testing, the driver was found to have a free-air resonance of 128Hz, a Vas figure of around 3 litres, and a total Q (Qts) of about 0.7. When installed in a 6-litre vented cabinet tuned to about 97Hz, this gave us reasonably smooth response down to about 80Hz and a very steep roll-off of about 35dB/octave below this point. (The same sized sealed enclosure would produce a response that begins to roll-off from about 200Hz, by the way.)

On the amplifier side of things, we found that the ubiquitous LM380 power amp IC couldn't really be bettered for our application. It's low in cost and readily available, uses very few external components, and has both short-circuit and thermal limiting capabilities — and of course, delivers quite acceptable noise and distortion performance. Since we had chosen a readily available and low-cost '2851' type transformer as the basis of the power supply, its 1.8VA rating limited our maximum audio output power to about 2 watts — quite within the capabilities of the LM380.

In practice however, we found that the LM380 could deliver a rather higher short-term power into our 4 ohm speaker load, since while the power supply is only capable of delivering a low *continuous* current (thanks to the modest rating of the 2851 transformer), its instantaneous current ability is mainly set by the size of the supply's filter capacitor. Needless to say, we fitted a generously-rated main filter capacitor.

The end result is that while the amp is rated at only 2 watts (continuous effective), it is able to produce a somewhat higher output for music signals. When



The amplifier PCB mounts just behind the unit's front panel controls, on three small standoffs. A rubber grommet is used to insulate the RCA socket from the chassis.

this is coupled to an efficient loudspeaker system, such as our car speaker in its vented box, there is more than enough acoustic output for any reasonable application.

During the development of this project however, we found that the efficient nature of the speaker had a rather unfortunate side effect. While the bass response was pleasantly extended (thanks to the vented enclosure), both subjective and objective tests indicated that the speaker exhibited a broad peak (around 10dB) in its response around the 1kHz region.

Since this produced a somewhat harsh sound and therefore didn't really fit into our design aims, we elected to include a corrective response curve into the amplifier itself.

As you would expect, the resulting equalisation curve has a 10dB dip in the same area where the speaker peaks. While some readers may consider this to be taking a 'band-aid' approach or even cheating, we can testify that the solution works extremely well in practice.

As you can see from the shots of the final design, the amplifier features a very simple front panel layout, with an RCA input connector, an input attenuator switch so the unit can cope with a wide range of signal levels, a volume control, and a power indicator LED.

While the amplifier has a tailored frequency response to suit the small speaker used in the project, its versatile nature means that it could also be used for a host of other applications — it's quite a simple operation to change or even bypass the equalisation. For that matter, there's no reason why the enclosure/ driver combination couldn't be put to use in other applications, provided some alternative form of equalisation is available.

Circuit description

The amplifier's circuit is quite straightforward, and uses just two ICs and a handful of other components. As shown in the schematic diagram, signals are first applied to the buffer/ equaliser stage based around a TL071 opamp (IC1), then passed via the volume control (RV1) to the LM380 power-amp chip (IC2).

Following the signal path through, you can see that the input socket is directly connected to an attenuator based around R1 and R2, which reduces the signal passed to IC1 by 20dB, when SW1 (level) is in the 'low' position. Conversely, with SW1 in the 'high' position, signals are passed at full strength.

The output of SW1 is then coupled to the non-inverting input (pin 3) of IC1 via coupling capacitor C1, where a bias level of about 4.5V (Vref) is applied by resistor R3. The combination of C1 and R3 also serves as a high-pass filter, attenuating unwanted signals below about 30Hz.

IC1 is arranged as a standard non-inverting amplifier, but with an increased gain at high frequencies as set by the feedback components R5 and C2. These progressively decrease the level of negative feedback for frequencies above about 700Hz (at a rate of 6dB per octave), until the gain is finally set by the combination of R6 and R5 for signals above about 8kHz.

The resulting output at pin 6 of IC1 has a gain of two (+6dB) at lower frequencies as set by R4 and R6, and moves to a gain of 14 (23dB) at high frequencies, as determined by the combination of R5 and R6 mentioned above. Note also that frequencies above the audio band are restricted by the feedback action of C3 in conjunction with R6. The frequency response of this first stage is shown as the top trace in Fig.1.

This treated signal is then passed to the volume control RV1 via coupling capacitor C5, and on to a *second* filter composed of R7, R8 and C6. In this case however, the components form a passive low-pass filter, and roll off the higher frequencies above about 100Hz at the same 6dB/octave rate. The effect then continues up to about 1kHz, where the attenuation levels off at -21dB, as shown by the lowest curve in Fig.1.

The combined effect of these cascaded filters results in the response which appears as the middle curve of Fig.1, between the two filter plots.

Note how the mid-range frequencies are reduced by about 10dB, and the extremes of the band are rolled-off due to the effect of C1 at the low end, and both C3 and C7 at high frequencies. This equalised signal is then applied directly to the LM380 power amp IC (at pin 6), which has a fixed gain of 50 (34dB).

The LM380 is arranged in an inverting mode, with the non-inverting input (pin 2) bypassed by C8, and its internal bias supply bypassed by C9 at pin 1. Pins 3, 4, 5, 7, 10, 11, and 12 are all at ground potential, and serve as a heat dissipation path for the IC's internal chip.

The final output at pin 8 is

bypassed by a Zobel network consisting of R9 and C11 — which applies a fixed load at high frequencies to maintain the amp's stability — and is coupled to the speaker load by the 1000uF capacitor C12.

Other stability components around the circuit include the supply bypassing capacitors C4 and C10 on IC1 and IC2, respectively.

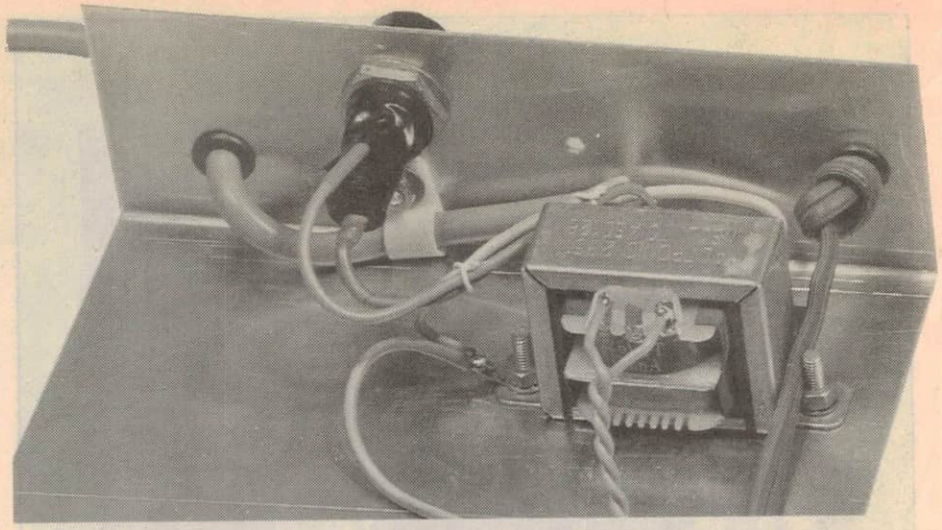
The remaining section of the schematic shows the amplifier's power supply, which is based on a low cost 2851-type transformer feeding a standard full wave rectifier circuit formed by diodes D1 to D4 and filter capacitor C13. The resulting voltage is applied to IC2 (at pin 14), the power indicator LED1 and its limiting resistor R14, and the voltage stabilising components R10 and zener diode ZD1.

R10 and ZD1 produce a fixed supply of about 9V, which is filtered by C14 and applied both to IC1 (at pin 7), and the bias supply components R11, R12 and C15. This circuit generates a stable reference voltage of about 4.5V (Vref), which is used to set the operating point of IC1 via components R3 and R4. By the way, the lone 10 ohm 1W resistor tied between the input 'ground' connection and the chassis is used to hold the amp's circuitry at mains earth potential, while still providing some resistance in the path.

The idea here is avoid a *direct* connection, which would tend to promote hum-inducing ground loops between the amplifier and an earthed signal source.

Some constructors may wish to omit this resistor and leave the amplifier circuitry 'floating' for a more versatile monitoring ability, or simply install a link to positively earth the system — strictly speaking, this is the safest approach.

If the recommended 10-ohm 1W resistor is installed however, there is a low enough resistance between the circuitry and the mains earth to blow the 250mA fuse in the transformer's primary circuit, in the unlikely event of a primary to secondary breakdown.



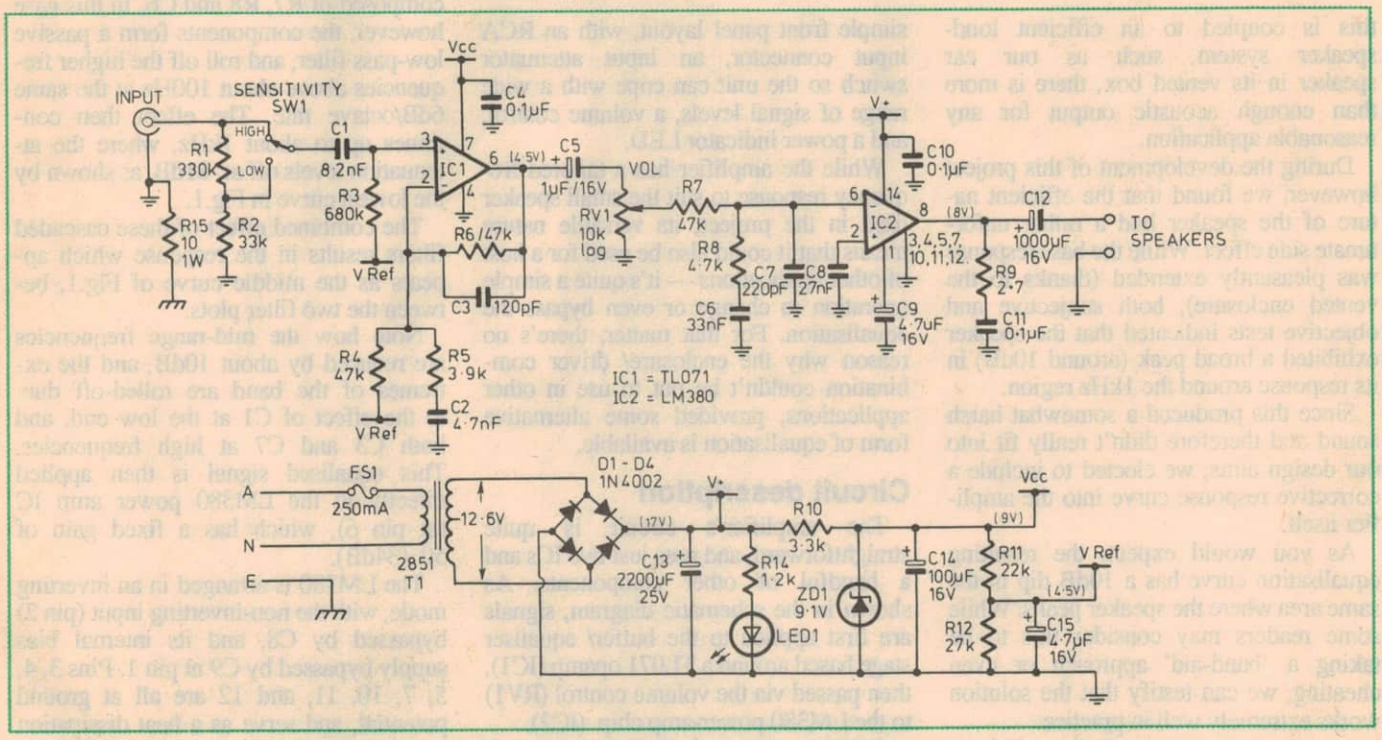
Make sure that the mains cable is quite secure, and all connections which are at mains potential are fully covered.

Amp construction

Our prototype amplifier is housed in a simple U-shaped section of aluminium plate, which was cut from a standard 300mm x 300mm sheet as sold by a number of component suppliers.

Since the opening in the speaker cabinet has a width of 150mm, this allows two such sections of plate (each measuring 300mm x 150mm) to be cut from the one standard sheet, which is convenient for those who wish to build a *pair* of units for stereo monitoring.

Bend the two ends of the plate to a depth of about 50mm to produce the



The mini-amp's circuit is based around a TL071 op-amp acting as a buffer/equaliser stage, and an LM380 power amp IC which delivers around two watts into a four ohm load.

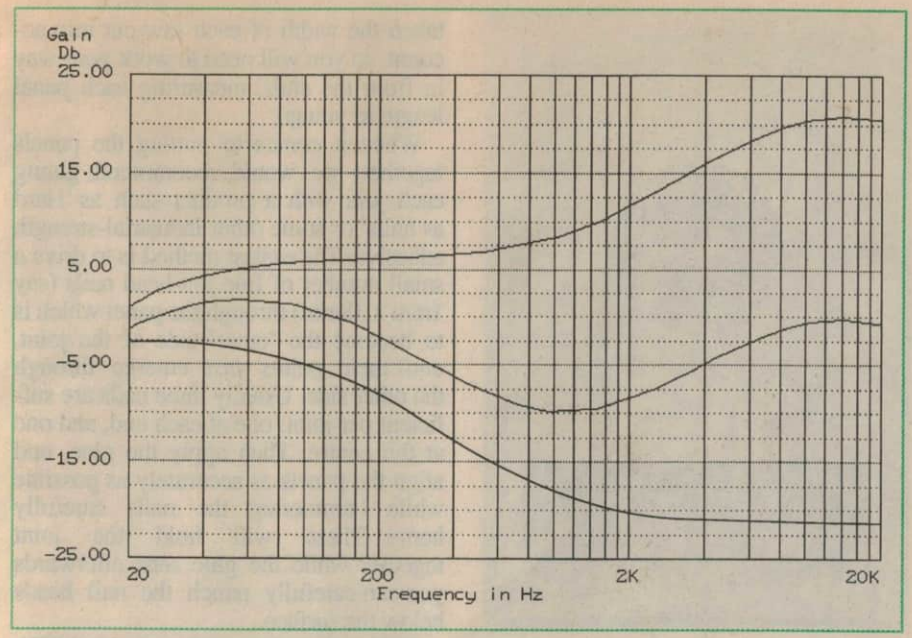


Fig.1: The upper curve shows the high-frequency boost applied by the amplifier's first stage, while the lower curve represents the cut applied to a following filter. The end result is the curve shown in the centre of the diagram, which is used to control the speaker's frequency response.

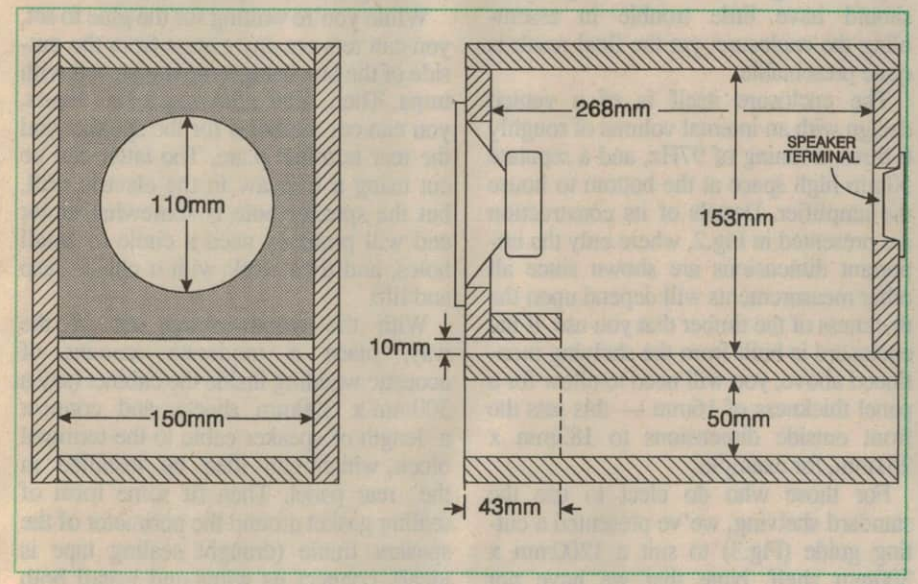


Fig.2: Use this construction guide when assembling the cabinet. Note that while the important dimensions are shown, the other measurements will depend upon the thickness of the timber.

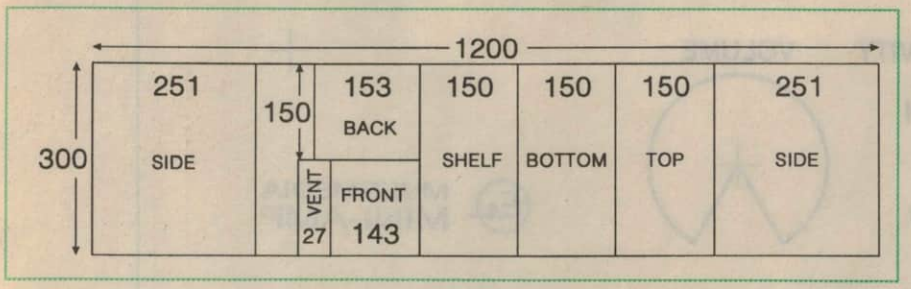


Fig.3: If you build the cabinet out of a standard laminated shelf as suggested in the text, follow this timber cutting guide. It assumes a timber thickness of 15mm, and doesn't allow for the timber lost with each saw-cut.

amplifier's front and rear panels, while making sure that the final chassis is a neat fit inside the speaker cabinet opening. The holes can then be drilled in the chassis to suit the various components and mounting bolts, and the front dress panel fitted (if available).

Note that the mounting bolts which are fitted to the bottom of the chassis will need to have *countersunk* heads and matching holes, so that the final amp will neatly slide into its opening in the speaker cabinet, without any protrusions to foul the bottom panel of the box.

Virtually all of the amplifier's components fit onto a small printed circuit board (PCB) measuring 79mm x 69mm, which is coded 92amp10 and has one relatively large section of copper pattern to act as a heatsink for the LM380 power amp IC.

The components should be fitted to the circuit board in the usual progressive manner, working your way from the low profile parts (resistors, etc) through to the larger items.

Use the supplied component overlay diagram during construction, and take particular note of the orientation of any polarised components — these include all of the semiconductors and the electrolytic capacitors. Also note that IC1 and IC2 are not installed with the same orientation, and pin 1 faces towards the perimeter of the PCB in both cases.

Once the PCB has been assembled to your satisfaction, the board can be mounted into the bottom of the chassis on small standoffs. The best position is close to the front panel and adjacent to the volume control and input socket/switch, as shown in the photographs of the prototype unit.

Next, all of the remaining parts can be installed in the chassis, and the interwiring completed as shown in the component overlay diagram. Note that R2 is mounted between the input socket's ground lug and SW1, while R1 is connected directly between the outer terminals of SW1.

Also note that the RCA input socket should be the type fitted with a plastic insulating bush — or alternatively, a standard socket which is mounted into the panel via a small rubber grommet, as in our prototype.

Take particular care when it comes to the mains wiring, since your life may depend upon the thoroughness of your work. The transformer should be securely attached to the chassis with nuts, bolts and lock washers, and a solder lug included on one side for the main earth connection. The mains lead should pass through the rear panel via a protective rubber grommet, and be

secured by a plastic P-clamp as shown in the prototype.

The earth lead (green/yellow) from the mains cable is soldered directly to the earth lug, the neutral wire (blue) goes straight to one side of the transformer primary, while the active lead (brown) is connected to the pin which is at the tip (or end) of the fuse holder. The holder's other pin (its 'output') should then be wired to the remaining side of the transformer primary. Note that any connections which are, or could be at mains potential (both the active *and* neutral wiring) should be thoroughly insulated using heat- shrink tubing, and insulation tape where necessary.

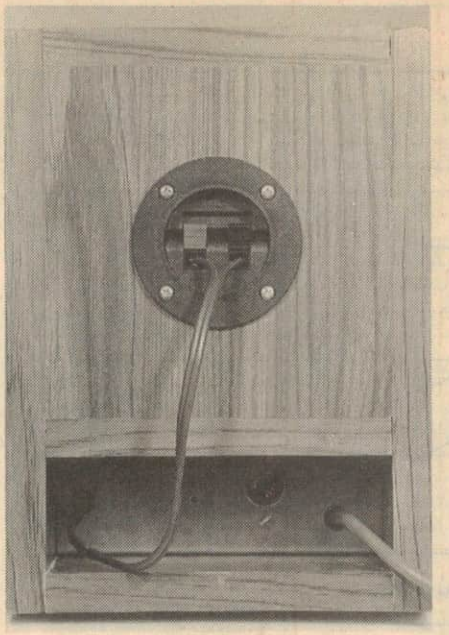
If the transformer at hand has flying lead connections rather than lugs, you will need to fit a small section of mains-rated terminal strip between the mains cable and the primary leads. This should be securely bolted to the amp's chassis, and again, any exposed mains wiring covered by some form of insulation.

Box construction

In the interests of simplicity, our prototype enclosure was built from a standard (1200mm x 300mm) length of particle board shelving, which comes with a convenient laminate finish. This modular shelving is available in a number of colours (white, beige, grey, and 'woodgrain'), is quite reasonably priced, and can be found at most of the larger hardware stores — it's an off-the-shelf item, so to speak...

After a little calculation, it was clear that if the required panels were cut from the shelf in a specific order, the 'finished' edge of the timber could be used on all visible sides of the box, whilst still using simple butt joins during its construction.

This is of considerable advantage, since a constructor with a minimum of both woodworking tools and experience should have little trouble in assembling the enclosure, yet the final result is quite presentable.



A rear shot of the unit. Note how far the amplifier sits into the cabinet opening.

The enclosure itself is of a vented design with an internal volume of roughly 6 litres, a tuning of 97Hz, and a separate 50mm-high space at the bottom to house the amplifier. Details of its construction are presented in Fig.2, where only the important dimensions are shown since all other measurements will depend upon the thickness of the timber that you use. If the enclosure is built from the shelving mentioned above, you will need to allow for a panel thickness of 16mm — this sets the front outside dimensions to 182mm x 251mm, for example.

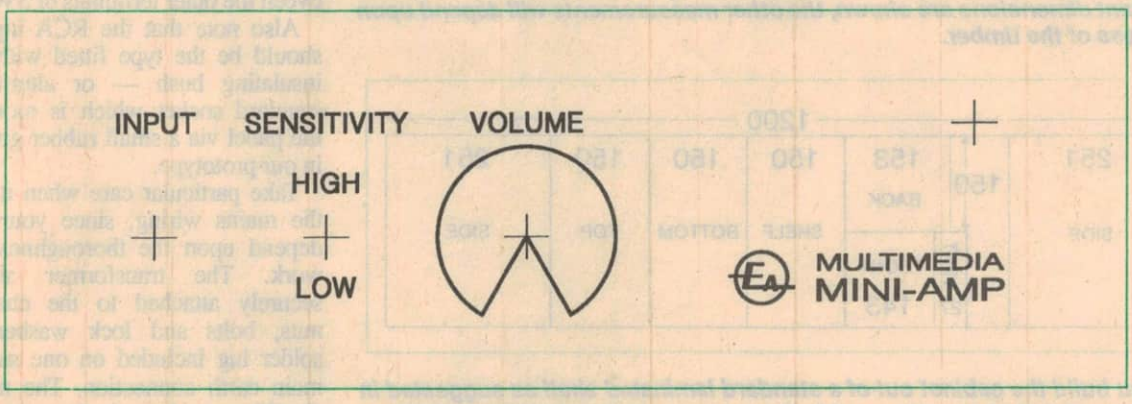
For those who do elect to use the standard shelving, we've presented a cutting guide (Fig.3) to suit a 1200mm x 300mm shelf. Note that we have not taken the width of each saw-cut into account, so you will need to work your way in from the ends, measuring each panel length as you go.

When it comes to putting the panels together, we would recommend gluing each join with a product such as 'Hard as nails' or some other industrial-strength adhesive. The easiest method is to drive a small number of fine jolt-head nails (say 1mm x 38mm) through the panel which is to become the 'outer' side of the joint, until their points *just* emerge through the other side. Usually three nails are sufficient per joint: one at each end, and one at the centre. Then apply the glue, and align the panels as accurately as possible while hammering the nails carefully home. These will hold the joint together while the glue sets; afterwards you can carefully punch the nail heads below the surface.

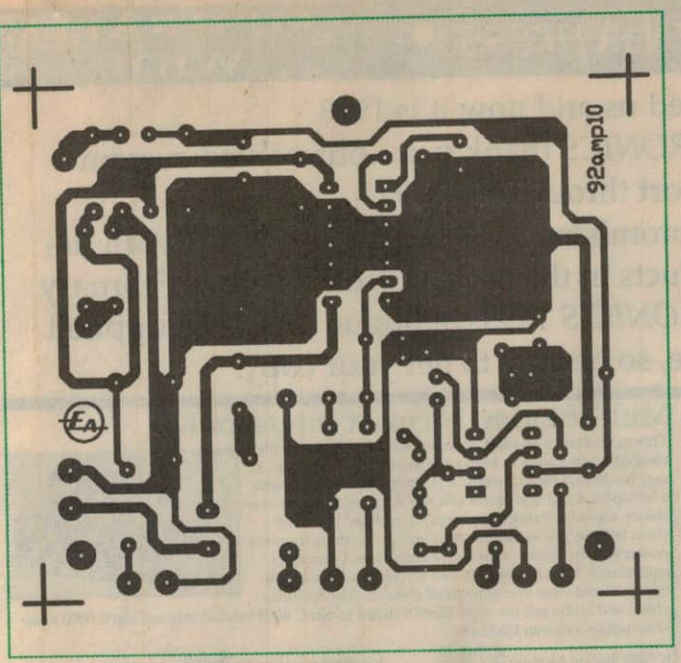
By the way, the common 'white' PVA woodworking glue is quite unsuitable for the job, since it won't bond to the smooth laminate finish, and just tends to soak into the end grain of the particle board.

While you're waiting for the glue to set, you can remove any excess from the outside of the box using a rag moistened with turps. Then, after allowing a few hours, you can cut the holes for the speaker and the rear terminal plate. The latter can be cut using a holesaw in the electric drill, but the speaker hole is somewhat larger and will probably need a circle of small holes, and then work with a chisel, rasp and file.

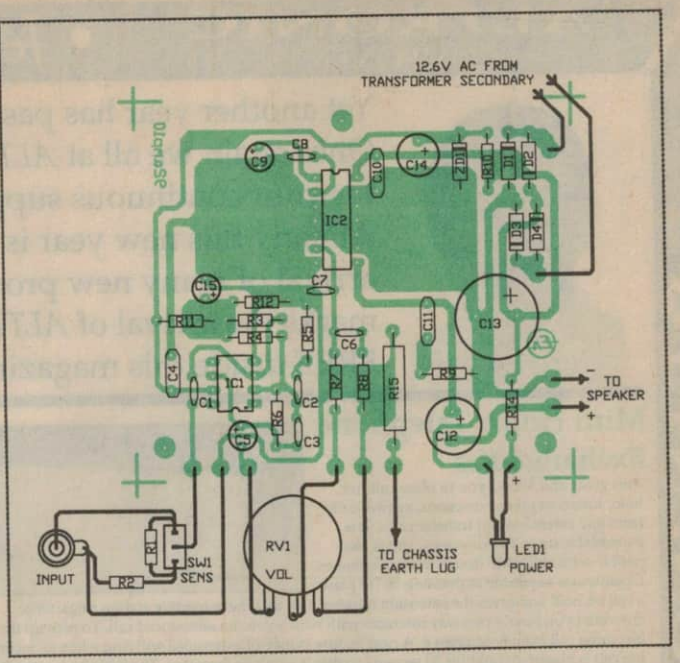
With the woodworking out of the way, place a moderate amount of acoustic wadding inside the cabinet (say a 300mm x 300mm sheet), and connect a length of speaker cable to the terminal block, which can then be installed in the rear panel. Then fit some form of sealing gasket around the perimeter of the speaker frame (draught sealing tape is ideal), connect its wires and install both



The front panel artwork, shown here actual size.



A full sized copy of the PCB artwork for the amplifier for those who wish to make their own.



Follow this component overlay diagram at all times during construction.

the driver and its protective dress cover in the cabinet.

Powering up

At this stage you're ready to give the system a trial run, just to make sure everything is working as it should. Before fitting the amplifier into its housing at the bottom of the speaker box, connect its output lead to the speaker and apply power. You should hear a small 'plop' from the speaker as the amp comes to life, then a very slight amount of hiss, depending upon how far the volume control is advanced.

Next, connect a signal source to the amp's input, wind up the wick, and check the audible results. If all is well, you should be pleasantly surprised by the quality of the overall sound, and find that quite a reasonable volume level is available before the amp begins to run out of steam.

If there appears to be a problem with the amplifier, immediately turn the power off, and double check your wiring. The circuit diagram includes the voltage levels at the important points around the circuit, and these can be checked against those in your unit, as a guide to faultfinding.

Finally, the amplifier can be installed in its rightful home and a couple of self-tapping screws used to lock it in position. These can be installed through the bottom of the cabinet into the amplifier chassis, and positioned so that they protrude through the aluminium at a safe distance from any of the amp's parts.

PARTS LIST

Resistors

(All 0.25W 5% unless noted):
1 x 680k, 1 x 330k, 3 x 47k, 1 x 33k, 2 x 27k, 1 x 4.7k, 1 x 3.9k, 1 x 3.3k, 1 x 1.2k, 1 x 10 ohms 1W, 1 x 2.7 ohms
1 10k logarithmic potentiometer

Capacitors

1 2200uF 25V PC-mount electrolytic
1 1000uF 16V PC-mount electrolytic
1 100uF 16V PC-mount electrolytic
3 4.7uF 16V PC-mount electrolytics
3 0.1uF metallised polyester
1 33nF metallised polyester
1 27nF metallised polyester
1 8.2nF metallised polyester
1 4.7nF metallised polyester
1 220pF ceramic
1 120pF ceramic

Semiconductors

1 LM380 14-pin power amp IC
1 TL071 opamp
4 1N4002 power diodes
1 9.1V 1W zener diode
1 LED in panel-mount bezel

Miscellaneous

1 125mm twin-cone speaker (Jaycar Cat. No. AS-3011 or similar)
1 Laminated pineboard shelf, 1200mm x 300mm x 16mm
1 PCB 69mm x 79mm, coded 92amp10
1 2851 power transformer, 12.6V at 150mA
1 Aluminium sheet, 300mm x 150mm
1 2-pole spring loaded speaker terminal
1 Insulated RCA socket (see text)
1 SPDT miniature toggle switch
1 3AG panel-mount fuse holder
1 3AG 250mA fuse
1 Mains lead with moulded plug
1 Plastic knob
Nuts and bolts, lock washers, rubber grommets, solder lug, hookup wire, speaker wire, plastic P-clamp, PCB spacers, heatshrink tubing, acoustic wadding (Innerbond or similar)

By the way, if the dimensions of our cabinet don't suit your purposes or perhaps the available timber, you might like to rearrange the enclosure's shape into something more convenient. Providing the the speaker cabinet's internal volume remains at 6 litres and both the tuning port's opening area (15cm^2) and its length (43mm) stay as specified, the speaker should deliver the same performance as in our prototype enclosure.

Also, while we used a low-cost Clarion speaker (from Jaycar) in our prototype unit, there's no reason why some other speaker with similar characteristics could not be pressed into service — provided that you're willing to experiment with the cabinet's tuning.

This is not as difficult as it might sound, since the tuning can be varied over a considerable range by simply changing the length of the 'shelf' that forms the top of the port.

By initially making the length a little short, the box could be tuned by adding strips of timber to the end of the shelf while monitoring the results with a sound level meter (or say, a tape deck and microphone) or simply by ear, until you've reached a satisfactory result.

On the other hand, the amplifier's equalisation curve (the electronic 'tuning') should suit most speakers of this type — since by nature, the combination of a small rigid cone plus the additional 'whizzer' cone tends to produce a substantial peak in the midrange area. Of course, this aspect can also be 'tuned' by ear through altering the values of the filter components. ❖