Low cost Bench Amp/Signal Tracer

Here is an invaluable piece of test gear which offers high input impedance, a wide range of input sensitivities, and up to 5 watts of output power.

by ROB EVANS

OK, lets face it, the world has gone digital. Very few facets of our lives are not effected by digital technology, whereas analog techniques are tending to be used as an interface between the technology and we mere humans. However, our analog senses are not about to be digitised by an over-zealous "Big Brother" and will always be with us. Hence the future of analog technology is assured, because after all, electronics has no other purpose than to serve us!

If this analog circuitry is to be designed and maintained, there is an equally important role for analog test equipment in present day electronics. Most well equipped workshops will satisfy the visual senses with an oscilloscope, yet our well-trained ears are rarely catered for. Indeed, a means of audibly tracing through a circuit or listening to the end result is a most welcome facility.

In many workshops, one channel of a spare hi-fi amplifier is pressed into service for this purpose, although it is hardly an ideal solution. The input stage will offer only a moderate impedance and sensitivity, and may overload on large signals. It also takes up more than its share of bench space, not to mention the size of its associated loudspeaker.

What we need is an amplifier designed with this task in mind. It requires a high input impedance to minimise loading of the circuit under test, and a wide range of input sensitivities for the variety of signals encountered. Also, it should be physically small yet contain an internal loudspeaker.

So here it is, the EA Bench Amp. It easily meets the above requirements, is simple to build at quite a low cost, and isn't digital! It has an input impedance of over 1M ohm and selectable input sensitivities of 10mV, 100mV, 1V, and 10V. An input overload indicator has been included, as well as facilities for connecting an external speaker. The external speaker may have a minimum impedance of 4 ohms and will produce a surprisingly high volume when driven by the Bench Amp.

Also, for those who service and experiment with radio, stay tuned to EA for an active RF probe designed to connect to the Bench Amp.

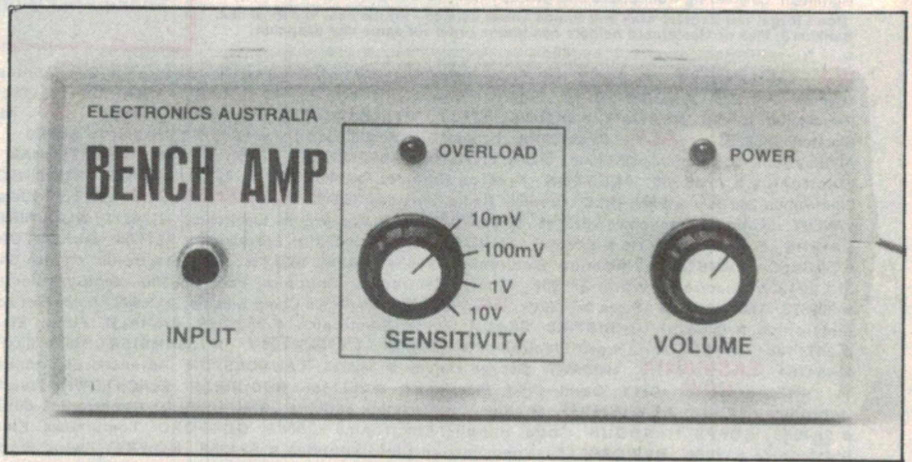
The Circuit

The circuit diagram of the Bench Amp may be divided into four main sections; preamp, overload indicator, power amp, and power supply. These sections are split between two small printed circuit boards (PCBs) with only three interconnecting wires. The preamp and overload indicator circuits are on one PCB which mounts behind the front panel, while the power amp and power supply occupy the other PCB which is mounted on the bottom of the case.

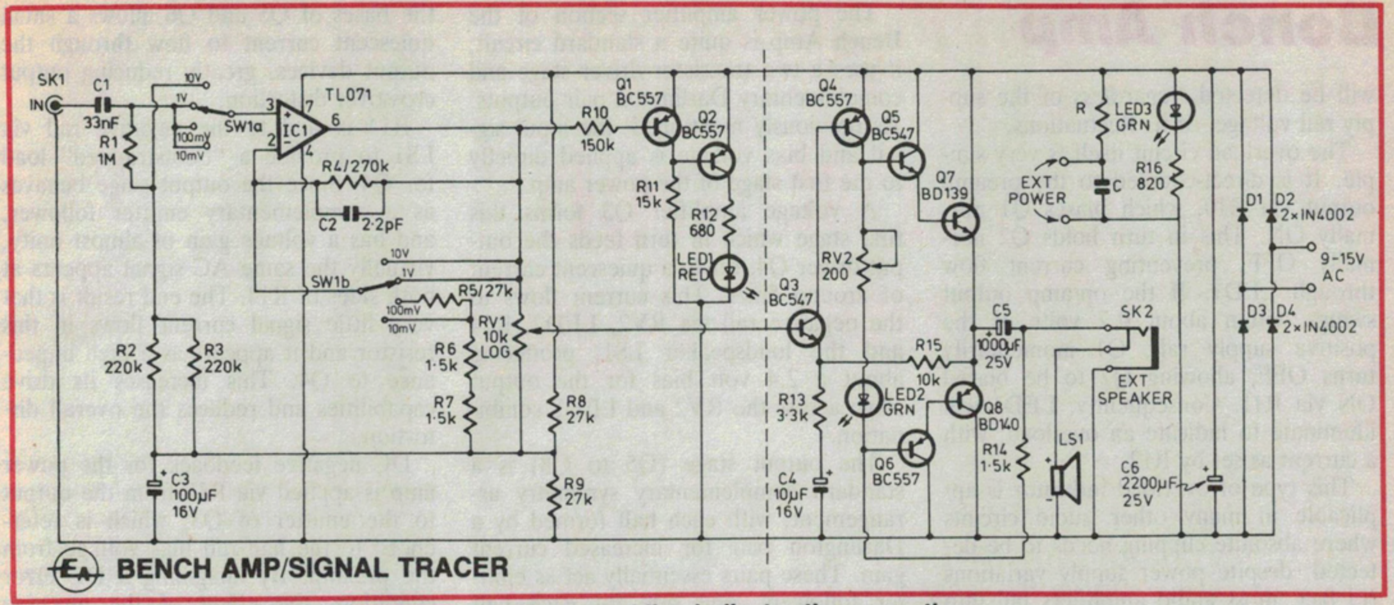
The preamp circuit is based around a TL071 Bi-FET op-amp (IC1), which is arranged as a non-inverting amplifier. The total gain (or attenuation) of the preamp is selected by the two sections of SW1, providing ranges of –20dB, 0dB, +20dB, and +40dB. For convenience, the switch positions are labelled with the approximate voltage required to run the amplifier at a reasonable level. This also provides the user with a rough idea of the signal level under test. For nominal input levels of 10V, 1V, 100mV, and 10mV respectively, the preamp produces a 1 volt output.

When the 10V range is selected, SW1a applies the input signal to IC1 via the DC isolating capacitor C1 and the 20dB input attenuator formed by R1, R2, and R3. Also, SW1b selects a 0dB gain for the op-amp IC1.

The 1V position is effectively



Two simple controls allow the Bench Amp to monitor almost any audio signal.



The circuit is split between two PC boards; the dashed line indicates the separation.

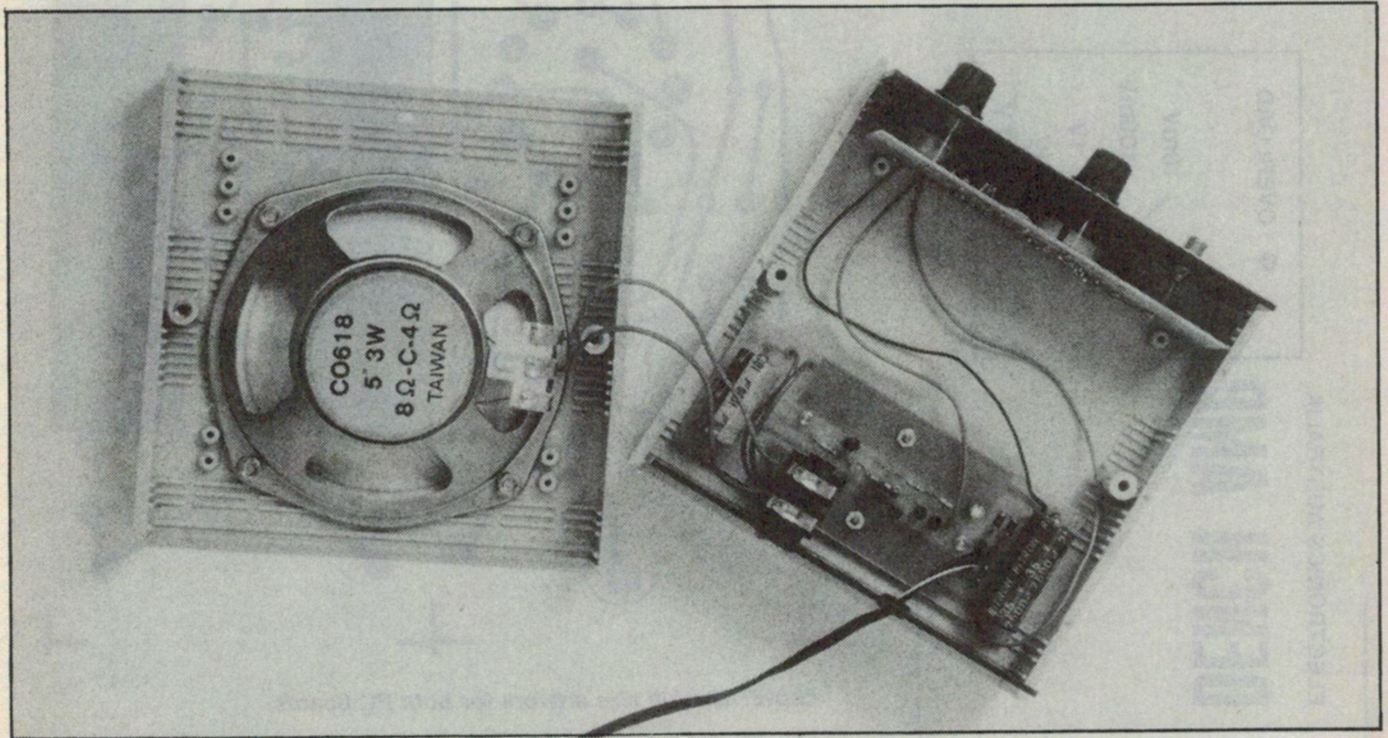
"straight through" with no attenuation or gain applied, the preamp simply acting as a high impedance buffer. The attenuator is also bypassed by SW1a in the 100mV and 10mV positions, while SW1b selects gains of +20dB and +40dB respectively.

To ensure a symmetrical voltage swing at the preamp output, the inputs of IC1 are biased at half of the supply rail voltage. This is derived from the voltage divider R8 and R9, whilst any remaining power supply ripple is filtered by C3. Further filtering of the supply to the TL071 op-amp was found to be unnecessary, due to its excellent supply rail ripple rejection.

The final preamp output is DC coupled to the power amp via the volume control RV1, which is referenced to the half-rail bias supply. This simple arrangement avoids the complications of coupling capacitors, and separate biasing for the power amp input.

Since a large range of signal levels are to be handled by the Bench Amp, the preamp's output may be driven into clipping due to an incorrect setting of the Sensitivity control (SW1). The resulting distortion could easily be interpreted as a fault in the circuit under test. This situation is avoided with an overload indicator circuit which will detect preamp overload, and (hopefully!) prompts the user to reduce the Sensitivity control by one "notch".

The design of the overload circuit is slightly unusual in that it senses the difference between the op-amp output and the supply rail, rather than some predetermined output level. The advantage of this type of sensing is that clipping



Quite a large loudspeaker (125mm) is used, for the best possible sound quality.

Bench Amp

will be detected, *regardless* of the supply rail voltage, or its fluctuations.

The overload circuit itself is very simple. It is direct-coupled to the preamp output via R10, which biases Q1 normally ON. This in turn holds Q2 normally OFF, preventing current flow through LED1. If the op-amp output swings within about 0.7 volts of the positive supply rail, Q1 momentarily turns OFF, allowing Q2 to be biased ON via R11. Consequently, LED1 will illuminate to indicate an overload, with a current as set by R12.

This type of overload indicator is applicable in many other audio circuits where absolute clipping needs to be detected, despite power supply variations (in fact, most audio amplifiers fall into this category).

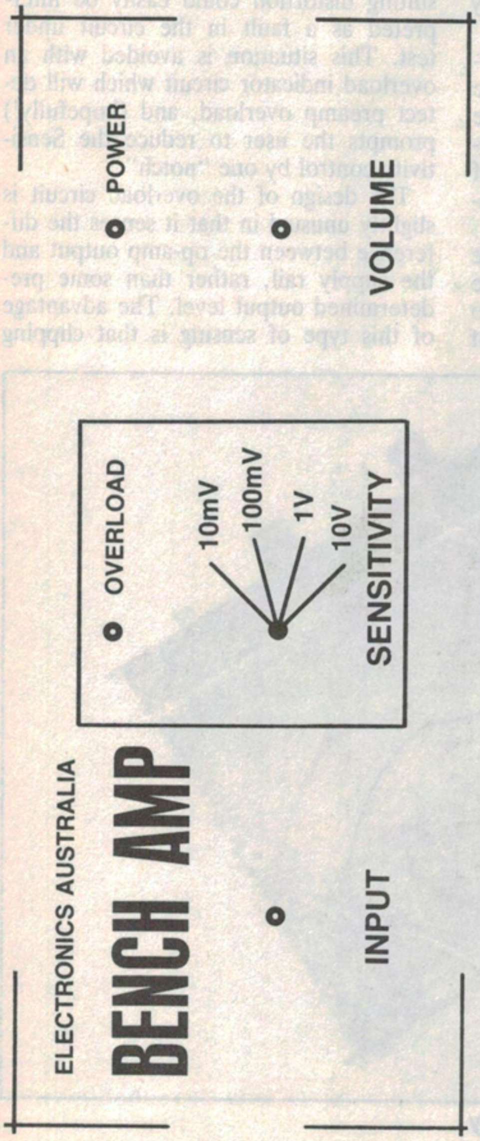
The power amplifier section of the Bench Amp is quite a standard circuit; it uses a two transistor driver stage and complementary Darlington pair outputs. As previously mentioned, the input signal and bias voltage is applied directly to the first stage of the power amp.

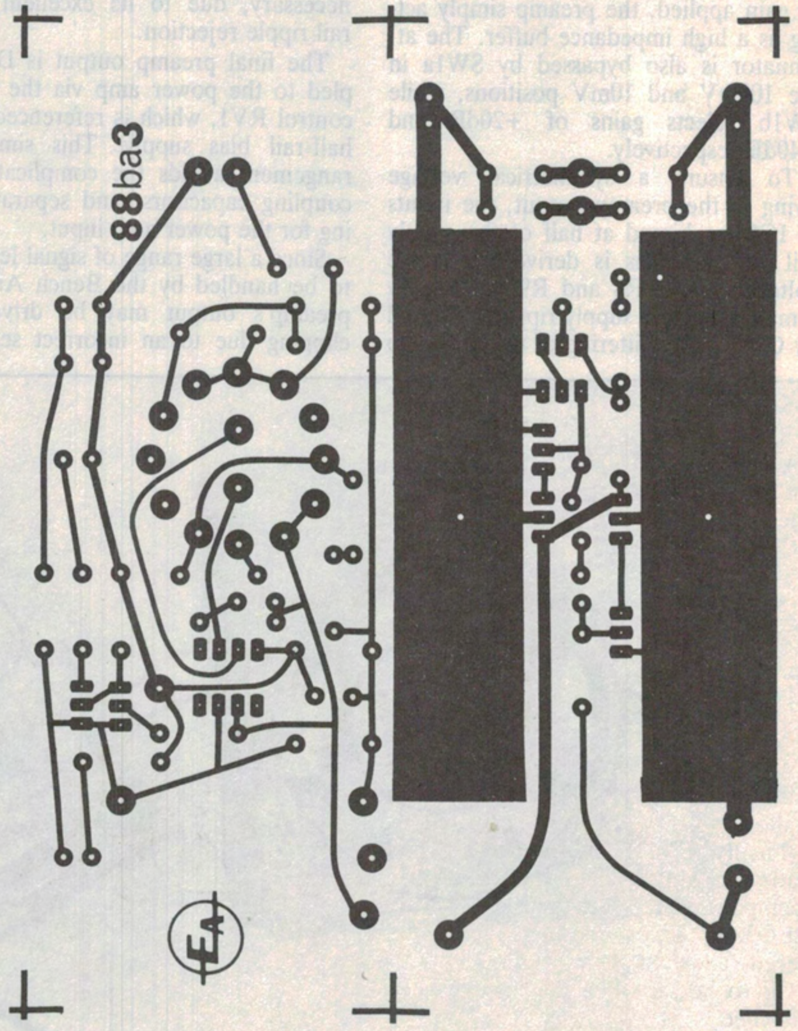
A voltage amplifier Q3 forms this first stage which in turn feeds the output driver Q4, set to a quiescent current of around 5mA. This current flows to the negative rail via RV2, LED2, R14 and the loudspeaker LS1, producing about a 2.4 volt bias for the output stage across the RV2 and LED2 combination.

The output stage (Q5 to Q8) is a standard complementary symmetry arrangement, with each half formed by a Darlington pair for increased current gain. These pairs essentially act as emitter followers, one side for each half cycle. The 2.4 volt difference between the bases of Q5 and Q6 allows a small quiescent current to flow through the output devices, greatly reducing output crossover distortion.

R14 is tied to the negative rail via LS1 to provide a "bootstrapped" load for Q4. Since the output stage behaves as a complementary emitter follower, and has a voltage gain of almost unity, virtually the same AC signal appears at both sides of R14. The end result is that very little signal current flows in this resistor and it appears as a high impedance to Q4. This increases its drive capabilities and reduces the overall distortion.

DC negative feedback for the power amp is applied via R15 from the output to the emitter of Q3, which is referenced to the half-rail bias voltage from the preamp. By imagining a DC error condition, the effect of the negative feedback is quite easily followed.





Above: The full size artwork for both PC boards.

Left: The actual size artwork for the front panel.

If the output is (say) low, R15 will increase the bias on Q3, turning it on a little harder. This also increases the bias on Q4, causing more current to flow in its load. Therefore, more voltage will be developed across R14, raising the voltage at the bases of the Darlington pairs (there will be little increase *between* the bases due to the low effective resistance of RV1 and LED2). Finally, this higher voltage is transferred to the output by the Darlington pairs, thereby correcting the error.

AC negative feedback is also applied via R15, but reduced by the voltage divider action of R13. This resistor only effects the AC feedback due to the coupling capacitor C4. The overall voltage gain of the power amp is about 4 as set by R13 and R15.

The final output of the power amp is AC coupled to the loudspeaker LS1 by C5, via the external speaker socket SK2. This socket enables a higher quality speaker to be used (with a minimum impedance of 4 ohms), and automatically disconnects the internal speaker.

Since the power transformer for the Bench Amp is an external plug-pack, only a low AC voltage enters the unit which avoids the need for mains wiring and switching. The AC voltage is full-wave rectified by D1 to D4, and filtered by C6. LED3 acts as a "power on" indicator, while "R" and "C" may provide a filtered power output to extra circuitry.

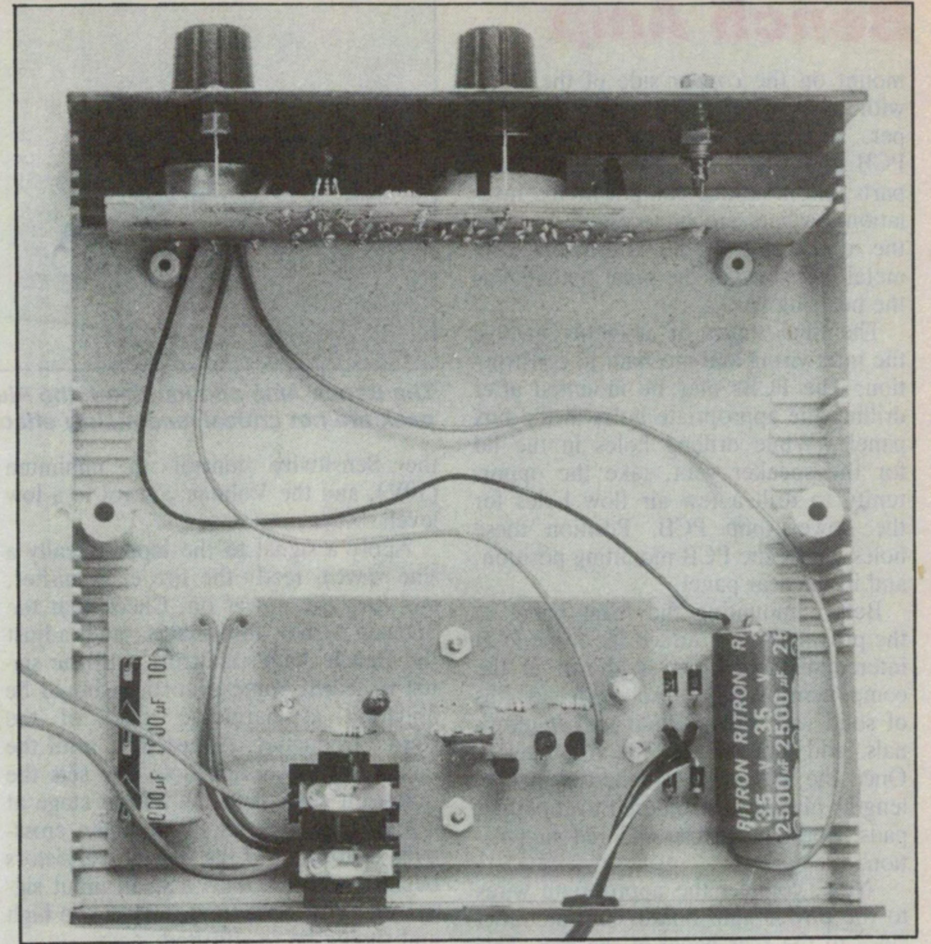
Construction

To begin the assembly of the PCBs for the Bench Amp, the two halves of the board must be separated, and checked for any etching errors. The PCB is coded 88ba3, and measures 132 x 100mm.

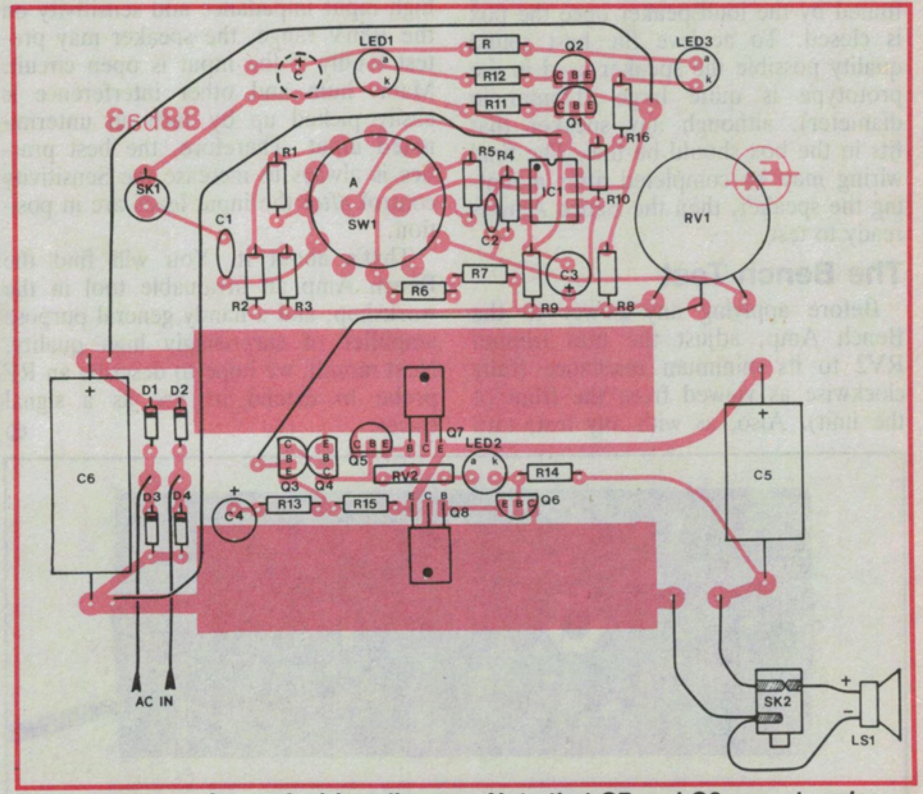
Starting with the preamp PCB, mount the lower profile components first. Using the component overlay as a guide, pay particular attention to the orientation of any polarised components (IC1, Q1, Q2, C3, etc). The controls SW1 and RV1 should be installed last, with SK1 left until the front panel is installed.

Finally, RV1 is attached to the PCB pads via short lengths of solid wire (component leg offcuts). LED1 and LED3 should be installed but not soldered, allowing their height above the PCB to be set when the front panel is attached.

The power amp board may now be assembled, taking the same care with component orientation. Note that the output power transistors Q7 and Q8



Inside the Bench Amp. Note the mounting positions of the PCBs



Component overlay and wiring diagram. Note that Q7 and Q8 mount under the PCB.

Bench Amp

mount on the *copper* side of the PCB, with their metal faces against the copper. This allows the large tracks of the PCB to act as heatsinks, avoiding extra parts and mounting complications. Insulation washers are unnecessary because the collectors of the transistors (the metal face), are at the same potential as the heatsink tracks.

The final stages of assembly involve the interwiring and mechanical construction. The PCBs may be mounted after drilling the appropriate holes in the box panels. While drilling holes in the lid for the speaker vent, take the opportunity to drill a few air flow holes for the power amp PCB. Position these holes below the PCB mounting position, and in the rear panel.

Before mounting the front panel to the preamp board, attach the three PCB interconnection wires as shown in the component overlay. Also, solder lengths of solid wire to the input socket terminals, and mount it on the front panel. Once the PCB is installed, these short lengths of wire are soldered to the input pads, and the LEDs soldered in position.

Next, connect the appropriate wires to the power amp board, and mount it close to the rear panel of the box. This prevents the PCB components being fouled by the loudspeaker once the box is closed. To achieve the best sound quality possible the speaker used in the prototype is quite large (125mm in diameter), although any speaker that fits in the box should be fine. The final wiring may be completed after mounting the speaker, then the Bench Amp is ready to test.

The Bench Test

Before applying any power to the Bench Amp, adjust the bias trimpot RV2 to its minimum resistance (fully clockwise as viewed from the front of the unit). Also, as with any test, turn the Sensitivity control to minimum (10V), and the Volume control to a low level.

Apply a signal to the input (ideally a sine wave), ready the fire extinguisher, and turn the power on. Check that the "power" LED illuminates, and adjust the Bench Amp's controls until the signal is heard. Some distortion should be apparent as harmonic tones of the source frequency. Adjust RV2 until the distortion *just* disappears. This sets the quiescent current in the output stage at a high enough level to eliminate crossover distortion. If the output transistors begin to run hot with a small input signal, the quiescent current is set too high and should be re-adjusted.

Because the Bench Amp has a very high input impedance and sensitivity on the 10mV range, the speaker may protest loudly if the input is open circuit. Mains hum and other interference is easily picked up by such an unterminated input. Therefore, the best practice is always to increase the Sensitivity control *after* the input leads are in position.

That's about it. You will find the Bench Amp an invaluable tool in the workshop, and a handy general purpose amplifier of surprisingly high quality. Next month, we hope to describe an RF probe to extend its use as a signal tracer. EA

The Bench Amp and its friend, the Plug Pack. The specifications of the plug pack are not critical, and mainly effect the amplifier' s maximum power.

Parts List

- 1 instrument case, 150x160x66mm
- 1 125mm (or smaller) loudspeaker
- 1 PCB, code 88ba3, 132x100mm
- 1 2-pole, 4-position PCB mount sealed rotary switch
- 2 knobs
- 1 RCA chassis socket
- 1 6.5mm mono chassis socket (switched)
- 1 plug pack, 9 to 15 volts AC, approx 500mA

Semiconductors

- 1 TL071 BIFET op-amp
- 2 BC547 NPN transistors
- 4 BC557 NPN transistors
- 1 BD139 NPN transistor
- 1 BD140 PNP transistor
- 2 5mm green LEDs
- 1 5mm red LED
- 4 1N4002 diodes

Capacitors

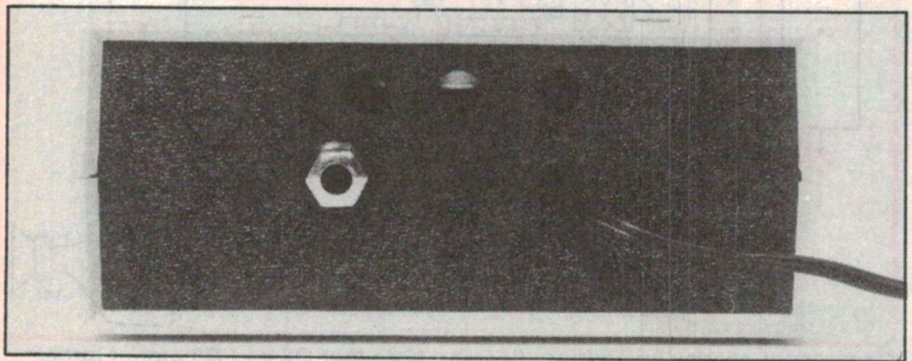
- 1 2.2pF ceramic
- 1 33nF metallised polyester
- 1 10uF 16VW PCB mount electrolytic
- 1 100uF 16VW PCB mount electrolytic
- 1 1000uF 25VW axial mount electrolytic
- 1 2200uF 25VW axial mount electrolytic

Resistors (all 0.25W, 5%)

1 x 680Ω, 1 x 820Ω, 3 x 1.5k, 1 x 3.3k, 1 x 10k, 1 x 15k, 3 x 27k, 1 x 150k, 2 x 220k, 1 x 270k, 1 x 1M, 1 x 200Ω horizontal miniature trimpot
1 x 10k log potentiometer

Miscellaneous

Spacers, nuts and bolts, hookup wire, rubber grommet, Dynamark front panel.



Holes in the rear panel provide air flow for the power amp PCB.