Bridging adaptor converts Series 5000 Power Amp into 300 W mono amplifier

Here's how to operate the two ETI-477 MOSFET power amplifier modules in the Series 5000 amp in bridge configuration with the addition of a simple, inexpensive module.

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THE AMOUNT of power an amplifier can deliver into a certain load is determined by the simple equation:

$$P = V^2/R$$

where V is the supply voltage and R is the resistance of the load. To achieve more power we must either decrease the resistance of the load or increase the supply voltage. Either of these will cause an increase in the amount of current to flow, and this must be catered for in the design. Unfortunately, power transistors are limited by the maximum voltage they can withstand so the supply voltage cannot be increased indefinitely. An amplifier with a supply voltage around 50 V is probably capable of supplying around 40 V peak to the load, the remaining 10 V being dropped by the output transistors, driver transistors and the power supply. This corresponds to a power level of around 100 W RMS into an 8 ohm load. In order to increase this the load could be decreased to 4 ohms, for example. The simple equation above predicts a power level twice that of the 8 ohm case. In practice this ideal is never met since the increased current causes increased voltage drops. In the case of a MOSFET output stage such as the ETI-477, the relatively high on resistance will cause quite a high voltage drop, decreasing the maximum output power to around 150 W for a 4 ohm load.

In order to increase the power of audio amplifiers it would seem we must increase the supply voltage and design the amplifier so that it is capable of withstanding higher signal currents. A closer inspection of Figure 1, however, reveals another alternative. The conventional power amplifier consists of the amplifier itself and a power supply, as shown in the diagram. The power supply is represented by the pair of capacitors. These correspond to the main storage capacitors in the power amp. The rest of the power supply has been omitted since its purpose is simply to maintain the necessary dc voltage differential between the ends of the capacitors. In a class B output stage only one of the output capacitors is supplying energy to the load at any given time. The arrows in the diagram indicate the direction of the current flow when the power amp is delivering a positive-going output signal. As can be seen, the large signal current flows from the positive supply capacitor to the power amplifier, through the load and via an earth return path to the electrolytic capacitors. Every wire in this current path has resistance, so voltage drops occur at all points in the circuit. These voltage drops can be extremely significant in the performance of the power amplifier. The distortion figure for the ETI-477 module, usually around 0.001%, can be degraded to worse than 0.3% if the resistance in the power supply leads exceeds a small fraction of an ohm. If extremely low distortion figures are required the entire heavy current path and earth leads should be wired with one of the very *low resistance* speaker cables available.

We have seen above that at any given time in a class B power amp only one of the capacitors is supplying power to the load. So the load has access to only one of

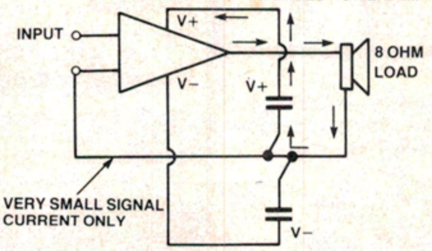


Figure 1. **Single-ended power amp showing how current flows in the power supply and the load.**

SPECIFICATIONS OF BRIDGED SERIES 5000 AMPLIFIER

Power output
300 W RMS into 8 ohms
(at onset of clipping)

Frequency response
8 Hz to 20 kHz, +0 −0.5 dB
(determined by passive filters)

Input sensitivity
1 V RMS for 100 W output

Hum and Noise
−100 dB below full output, or better

Total Harmonic Distortion
less than 0.003%

Stability
Unconditionally stable.

the supply rails. If both supply rails could be used at the same time the voltage available to the load would be doubled without having to redesign the amplifier, so long as the resulting current were within its capabilities. This is the purpose of the bridge configuration with power amps, sometimes referred to as 'bridging'. The principle is shown in Figure 2. Two identical power amplifiers have been used here, the output of each going to opposite ends of the load. The input signal is fed to the input of the first amp in exactly the same way as in the more conventional approach. The arrows indicate the direction of current flow for a positive-going signal voltage. At the same time, the input signal is fed to the second power amp via a unity gain phase inverter. A positive-going input signal voltage becomes a negative-going signal at the input of the second amp. While the output of the first power amp is swinging positive the output of the second amp is swinging negative, so the load experiences double the supply voltage (neglecting for a moment the increased voltage drop due to increased signal current).

In the 4 ohm case discussed earlier the signal current is doubled, while the supply voltage remains much the same; the maximum power is therefore doubled. In the bridge case, however, the maximum signal voltage is doubled, increasing the current. Since power is given by the product of voltage and current the power increases by a factor of *four*. In a real amplifier, of course, this power is never achieved. Once again the voltage drops across the output transistors, etc, will decrease the power considerably, and this is especially true when using MOSFET output devices. To make a closer estimate of the power that can be expected of an amplifier when connected in bridge, determine the power delivered into a load of half that used in the bridge and double this value. If the bridge is to be used with an 8 ohm load, for example, determine the power delivered by one amplifier into a 4 ohm load and double this figure. In the case of the ETI-477 module the power into 4 ohms is around 150 W RMS, so the power achieved by two 477s in bridge should be around 300 W RMS. Measurements carried out with the bridging adaptor gave power figures between 280 and 300 W RMS, in good agreement with the estimate.

There are also limitations, however, which must be considered for successful operation of a bridge amplifier. Firstly, since each amp is effectively driving a load half that of the real load, the load resistance connected to a bridge amplifier must be twice the minimum load specified for individual power amps. Since the minimum load recommended for the ETI-477 module is 4 ohms the minimum load used in bridge should be 8 ohms.

Another problem associated with bridging is that both power amps used should share the same power supply to ensure the integrity of the earthing system. If this condition is not met, the distortion figure and stability margin of the amp will almost certainly be degraded. In Figure 2, two independent power amplifiers are connected in bridge. This is done by joining their earth reference points together and driving the loudspeaker with out-of-phase signal voltages. Current resulting from a positive-going signal voltage flows from the positive supply through the first power amp and through the loudspeaker to the second power amp, and then to the negative supply rail of the second power amp. The circuit is completed by the connection between the two earth points. The problem is that, since this connection has a finite resistance, a voltage drop will occur across it, varying with the signal voltage and modulating the earth current for the second power amp. The solution is to operate both power amps from a single power supply. Figure 3 shows a pair of amps connected in bridge and using a common supply. Once again, the arrows show the direction of current resulting from a positive-going signal voltage. Notice that in this case the connection between earth reference points has been eliminated and both power amps ▶

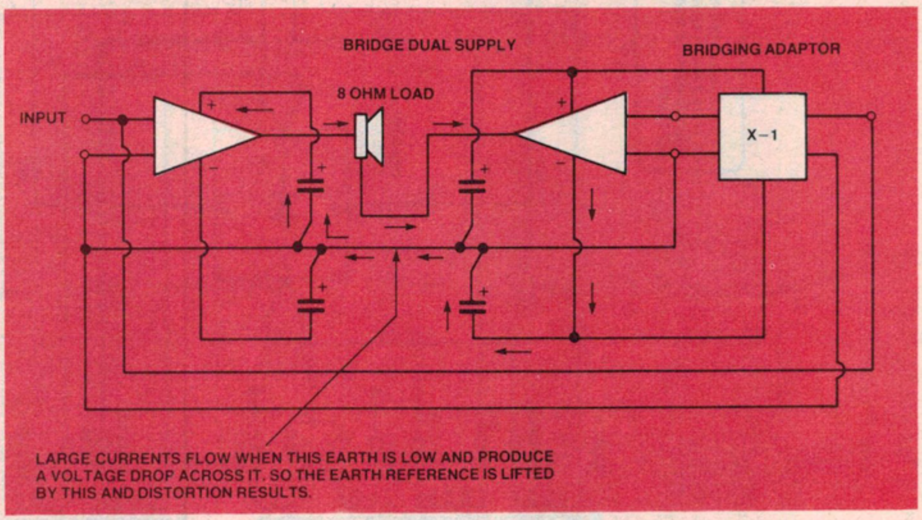


Figure 2. **Two separate power amplifiers in 'bridge' configuration showing how the individual power supply currents and the load current flows.**

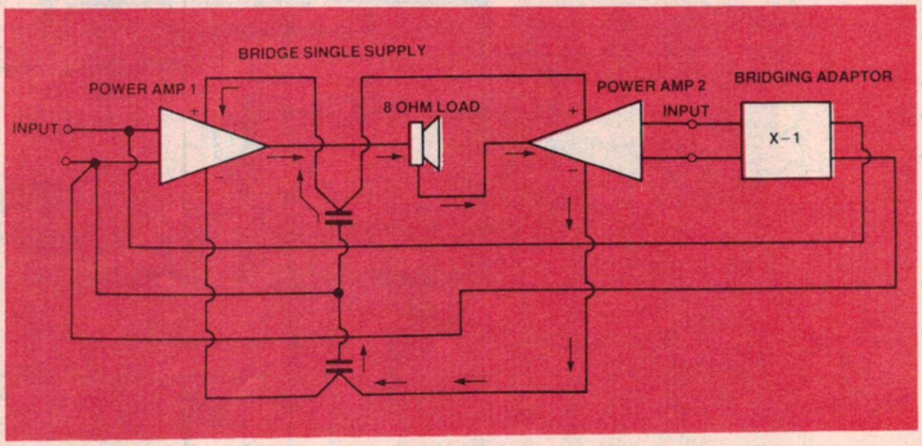
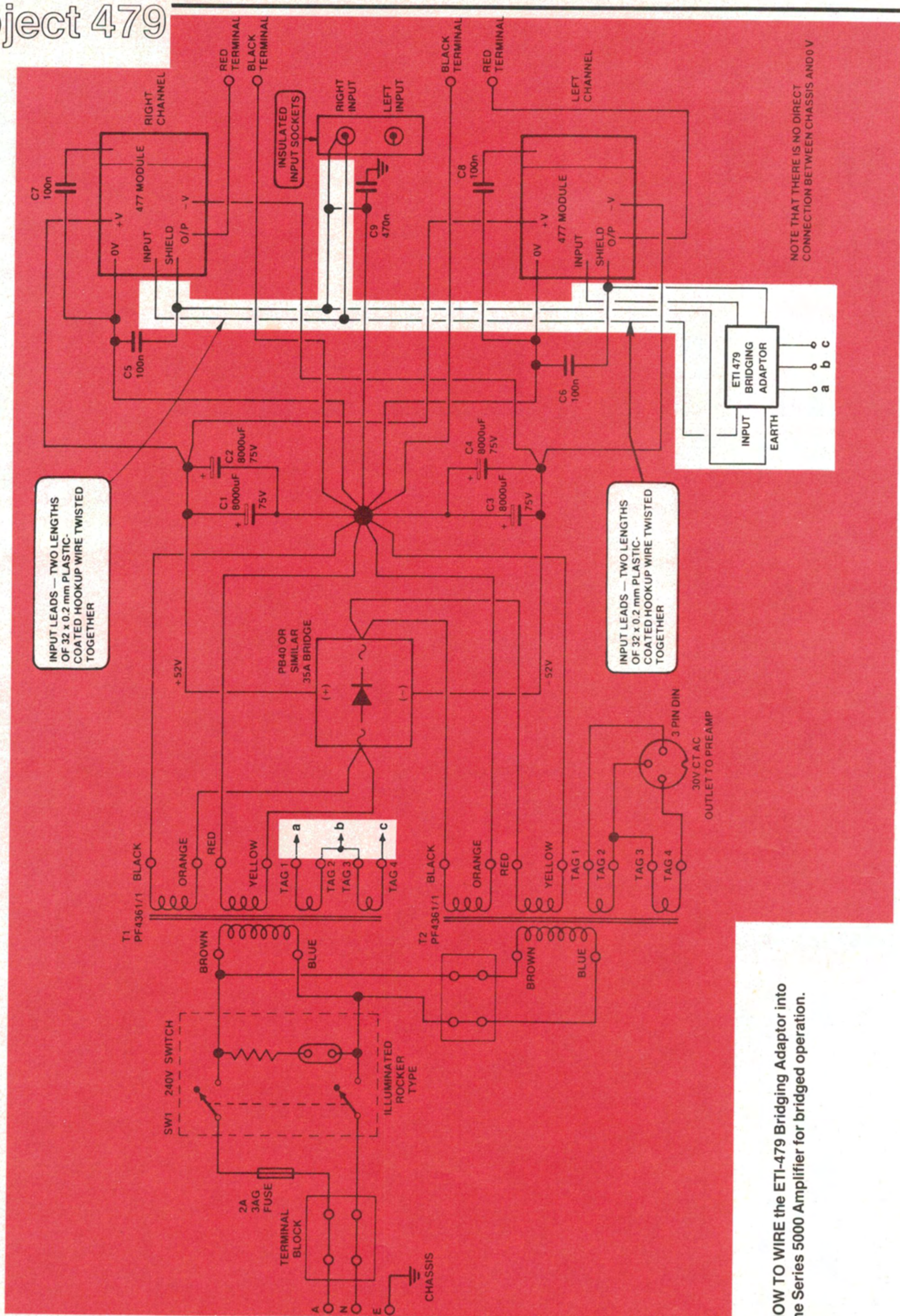
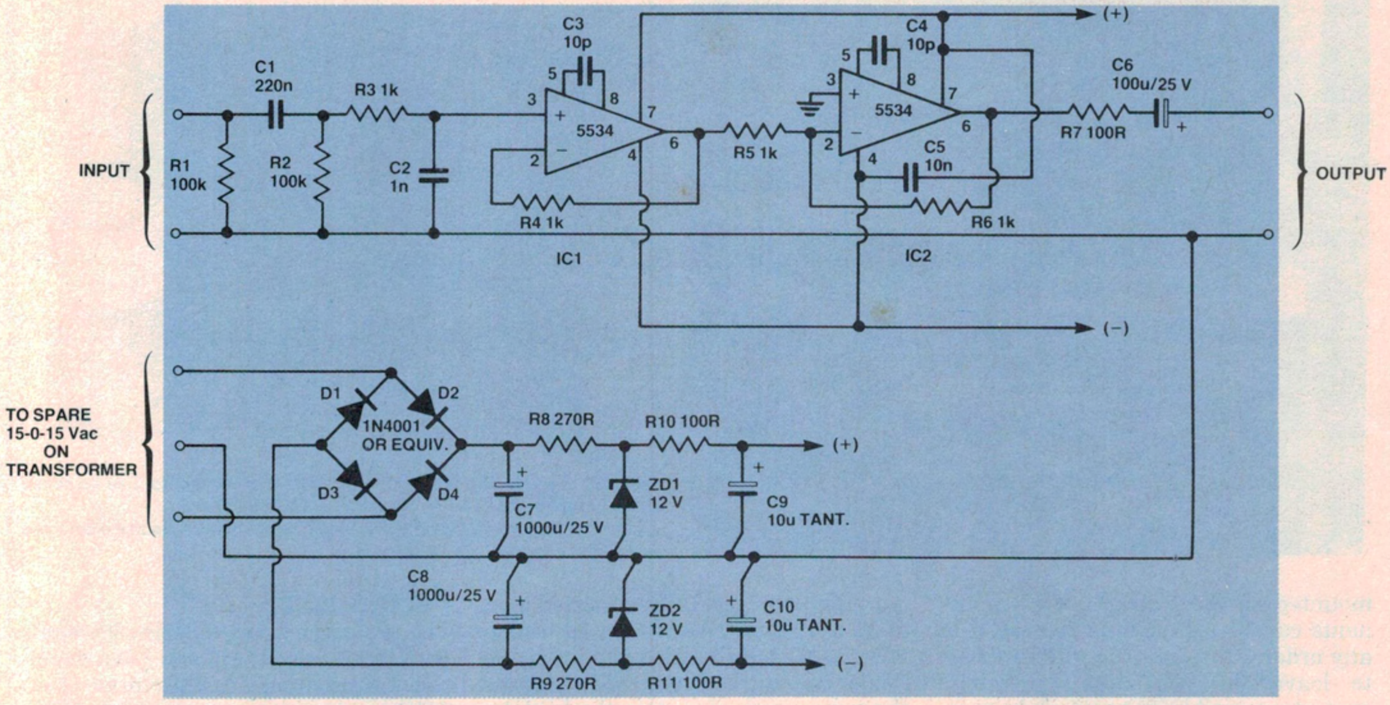


Figure 3. **Bridged power amplifier and single supply showing load and supply current flow.**



HOW TO WIRE the ETI-479 Bridging Adaptor into the Series 5000 Amplifier for bridged operation.



have access to the same single reference point. This is one of the reasons the Series 5000 power amplifier was configured with a single supply even though two power transformers and a total of four electrolytics were used. The two channels in a stereo power amp should be bridged, forming a mono power amp. For stereo operation two such amplifiers are required.

HOW IT WORKS — ETI-479

The Bridging Adaptor is a unity gain (i.e: gain of 1x) inverting stage that has its input in parallel with one power amplifier module and its output driving the other power amplifier module. Thus the power amp module it drives operates out of phase with the other power amp module.

The bridging adaptor has two stages — a non-inverting input buffer stage and an inverting output stage. The active device in each stage is an NE5534 high performance op-amp. A rectifier on-board provides dual supply rails regulated by two zeners.

Input is coupled to the non-inverting input of IC1 via an RC network consisting of C1, R2, R3, and C2. Resistor R1 provides a dc return for the input line. Resistor R3 is a low value to ensure good noise performance for IC1, and together with C2, a lowpass filter is established to limit the slew rate of incoming signals to prevent slew-induced distortions. Feedback for IC1 is provided by R4, connected between the output and the inverting input. The output of IC1 drives the inverting input of IC2 via R5. Feedback around IC2 is provided by R6. The feedback constants for both IC1 and IC2 are arranged so that each stage has a gain of one.

The output from IC2 is coupled via R7 and C6, which provide a low frequency rolloff, C6 also providing dc blocking.

The bridging adaptor is powered from the unused 15-0-15 Vac winding on one of the Series 5000 amplifier power supply transformers. Diodes D1 to D4 form a bridge rectifier providing about ±20 Vdc with respect to the winding centre tap. Capacitors C7 and C8 provide smoothing. Two zener diodes, ZD1 and ZD2, are used to provide regulated positive and negative 12 Vdc supply rails for the two ICs. Resistors R8 and R9 provide current dropping for the two zeners and R10/C9, R11/C10 provide further filtering. Capacitor C5 provides a high frequency bypass for the supply rails. Capacitors C3 and C4 provide frequency compensation for IC1 and IC2 respectively.

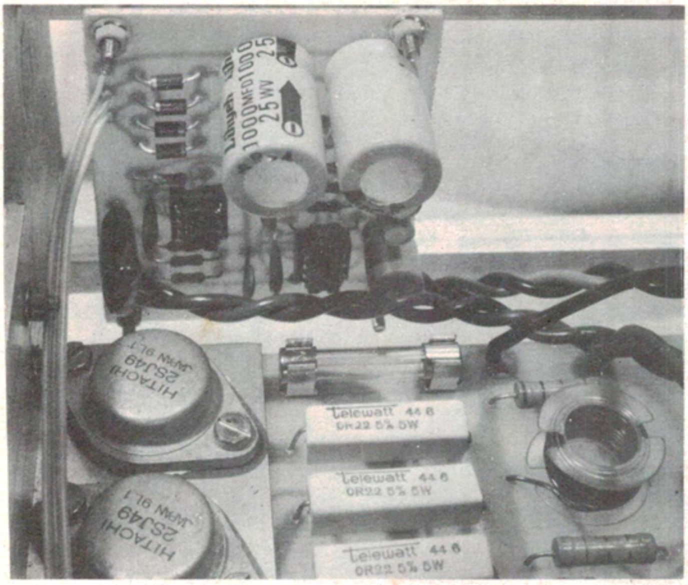
Bridging adaptor

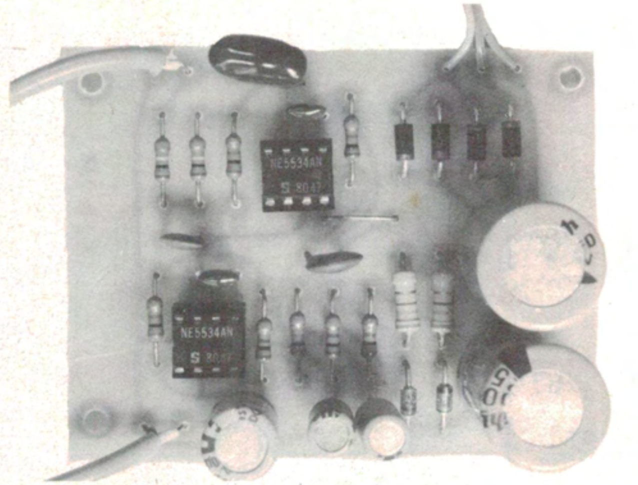
This project consists of a unity gain phase inverter that can be installed within the Series 5000 power amp. The input to one of the power amps is disconnected from the input socket and is wired to the output of the bridging adaptor. The input of the bridging adaptor is connected in parallel with the input of the other channel. This leaves one of the input sockets unused, although it could be connected to the other input socket if required.

The bridging adaptor must not degrade the distortion figures of the amplifier to which it is connected. Similarly good noise figures and freedom from slew-induced distortions must be ensured through careful design of the unity gain amplifier stages. Unfortunately, amplifiers with a gain of one tend to be the most difficult to stabilise because of the relatively high amounts of negative feedback. To overcome this problem and to maintain good noise figures, NE5534N op-amps were used in the design. The conventional way to achieve an inverting amplifier is to ground the non-inverting input and insert the input signal into the inverting input via a resistor. In this configuration the inverting input is also connected to the output of the op-amp through another resistor and forms a virtual earth point. The input resistor therefore forms the input resistance of the stage. Since this is connected to the output of the preamplifier the value of this resistor must be high, i.e: around 10k-100k. Unfortunately, this would seriously degrade the noise performance. To overcome this problem the bridging adaptor has been broken into two stages. The first is simply a unity gain buffer. This stage has low noise figures and an output impedance low enough to drive the following inverter stage. Since the input resistor has been kept to a small value in the second stage a good noise figure results.

Construction

Construction of the bridging adaptor is not difficult since all components are ▶





ABOVE: The bridging adaptor board. Note that we did not use screened cable to install the board in the Series 5000 Stereo Amp.

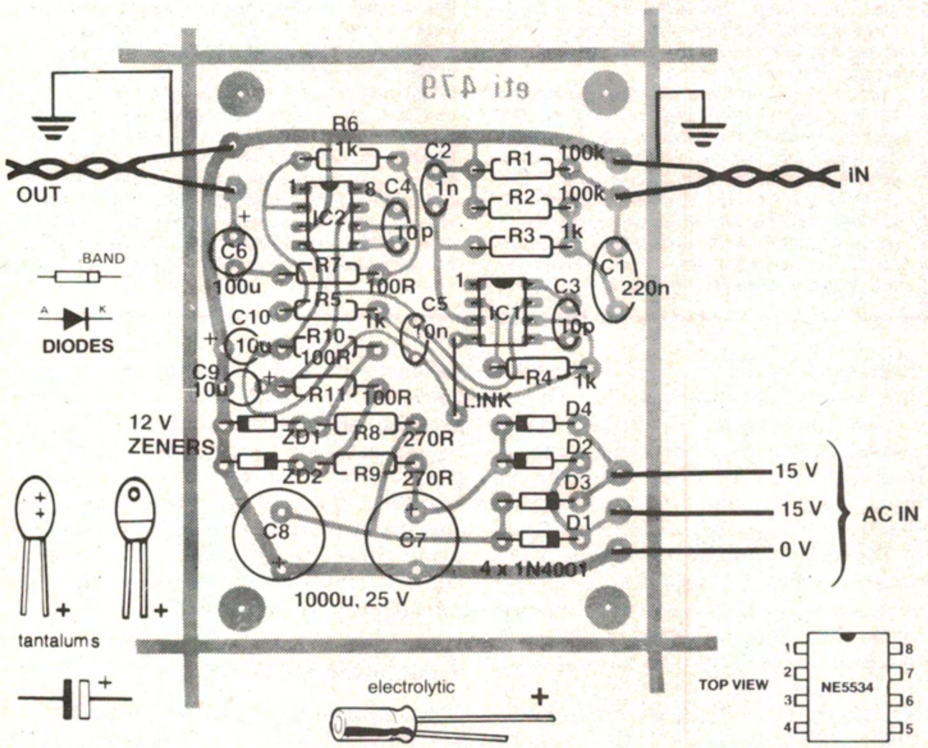
LEFT: The board is installed in the Series 5000 Stereo Amp at the left hand end of the chassis.

mounted on the pc board. The components can be mounted on the board in any order, although it is probably best to leave the two large electrolytic capacitors until last. As usual, be careful of the orientation of all polarised components such as the electrolytic capacitors, ICs and diodes.

Solder input and output leads to the board and bolt to the side bars on the left hand side of the power amp, as viewed from the front, as shown in the accompanying photograph. Use twisted pairs of 32 x 0.2 mm plastic-covered hookup wire, as with the existing input wiring. Solder the output directly to the input of the power amp closest to the bridging adaptor. Solder the input leads of the bridging adaptor to the input socket of the other power amp. Included here is the block diagram of the Series 5000 power amplifier showing suitable modifications to incorporate the bridging adaptor.

Performance

The prototype bridged Series 5000 amp performed favourably and gave distortion figures around the resolution of our THD analyser (approx. 0.003%). Similarly, noise figures were not degraded and the adaptor tested was free of slew-induced distortion. The power output achieved was around 300 W RMS when connected to an 8 ohm load. Connection to a 4 ohm load is *not* recommended for the reasons given earlier in this article.●



PARTS LIST — ETI-479

Resistors .... **all ½ W,5%**
R1,R2 .... 100k
R3,R4,R5,R6 .... 1k
R7,R10,R11 .... 100R
R8,R9 .... 270R

Capacitors
C1 .... 220n greencap
C2 .... 1n greencap
C3,C4 .... 10p ceramic
C5 .... 10n greencap
C6 .... 100u/25 V electrolytic
C7,C8 .... 1000u/25 V electrolytic
C9,C10 .... 10u/20 V tantalum

Diodes
D1-D4 .... 1N4001 or equivalent
ZD1,ZD2 .... 12 V 400 mW zeners

Integrated Circuits
IC1,IC2 .... NE5534N

Miscellaneous
ETI-479 printed circuit board; assorted mounting hardware; hookup wire.

Price estimate

We estimate the cost of purchasing all the components for this project will be in the range:

$12-$14

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project, such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel supplied (if used), etc — whether bought as separate components or made up as a kit.