Versatile public address amplifier

Featuring 'speech filtering' and ALC on the mic inputs to improve intelligibility, an 'insert' input and a power MOSFET output stage delivering 150 W RMS maximum output to 100 V, 70 V or low impedance lines, this PA amplifier has much to offer.

Geoff Nicholls

THIS PROJECT has been designed specifically for use in large open areas where ambient noise levels are often high, such as outdoor sporting events. It features *two microphone inputs,* which can be configured for *high or low impedance* microphones, as desired, when the project is constructed. The microphone signal path incorporates *speech filtering* to increase the intelligibility of the voice signal under 'difficult' conditions where other noises compete for the audience's attention. *Automatic level control* (ALC) is included to decrease the variation in voice level between different commentators using the PA and, again, improve 'penetration' where extraneous noise is present. This feature may be switched in or out, as desired.

An *auxiliary input* is provided, which can be used to connect a line level signal or a speaker output from a radio, etc. A *preamp output* enables several power amplifiers to be 'slaved' from the one preamp, and provides a high-level signal for output to a tape recorder, for example.

The *insert* socket allows further signal processing devices to be 'inserted' in series with the signal path from the output of the preamp to the input of the power amp.

The completed amplifier has actually been used at a large, noisy outdoor venue driving eight horn speakers. It gave an excellent account of itself, especially when compared directly against a system using two of our old ETI-480 100 W modules (circa 1976) driven by an ETI-419 preamp (circa 1973!).

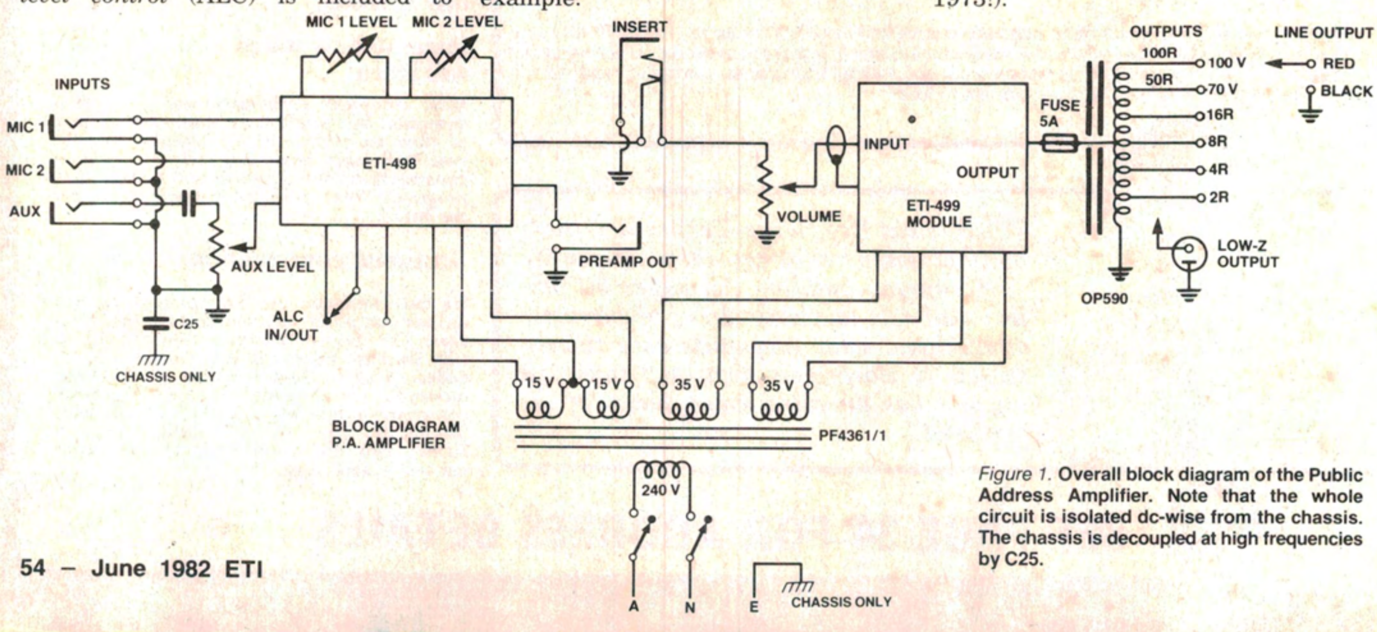


Figure 1. **Overall block diagram of the Public Address Amplifier. Note that the whole circuit is isolated dc-wise from the chassis. The chassis is decoupled at high frequencies by C25.**

Design notes

Most public address set-ups, for all but the largest outdoor events, generally use a single announcer or commentator, occasionally two. Thus as more than two microphones are rarely required, only two microphone inputs have been provided. This allows the constructor either to provide two low impedance inputs, two high impedance inputs or one of each. In a pinch, a low impedance input could be used with a high impedance, high output mic, provided the level control is near minimum. The auxiliary input is shunted by a low value resistor to provide loading for the earphone or external speaker output of radios, cassette decks, etc. It also terminates a line level output correctly.

The signal 'earth' is isolated at low frequencies from the chassis and mains earth to eliminate the possibility of hum loops brought about by connecting external mains powered equipment to the amplifier. The chassis is ac-coupled to the signal earth to higher frequencies as the impedance of capacitor C25 (which couples the chassis to the signal earth) decreases.

The frequency response of the microphone preamps is rolled off rapidly below 150 Hz. This allows the output transformer to deliver more useful power than would be the case if a flat frequency response were employed. The distortion is also reduced by rolling off the low frequencies. Distortion and frequency response curves for the OP590 are illustrated in the accompanying graphs (courtesy Ferguson Transformers).

Automatic Level control (ALC) is included, the purpose of which is to maintain a nearly constant output level with large excursions in signal level. For a signal input level range of greater than 20 dB, the output level will only vary by 3 dB or less for typical microphone input levels. This greatly improves intelligibility and 'punch' of the sound produced, particularly where all sorts of extraneous sounds are about, interfering with the audience's ability to hear the PA.

To provide ALC, I have used half of an NE570/571 audio compressor IC. The basic circuit employed is shown in Figure 2. Inside the NE570/571 are a precision rectifier (the block shown with the diode inside), a variable gain cell (△ G) and an op-amp. Resistors R1, R2 and R3 are inside the chip. The rectifier and variable gain cell operate in the feedback circuit of the op-amp, the gain of which is varied with signal level. At high input levels, the op-amp gain is reduced, at low input levels the gain is increased. Resistor R_x is used to set the maximum gain. The gain of this circuit is given by:

$$K = \frac{R1\,R2\,I_B}{2R3V_{IN\,(avg)}}$$

where $I_B = 140$ uA

and $$\frac{V_{IN}}{V_{IN\,(avg)}} = \frac{\pi}{2\sqrt{2}}$$

for sine waves

The maximum gain is limited (by R_x) to prevent high output levels occurring at low input levels (such as background noise).

The maximum gain is given by:

$$\frac{\frac{R1 + R_x}{1.8}\,.\,R2.\,I_B}{2R3}$$

The output voltage is determined by:

$$V_{out} = \frac{R1R2I_B}{2R3} \cdot \frac{V_{IN}}{V_{IN\,(avg)}}$$

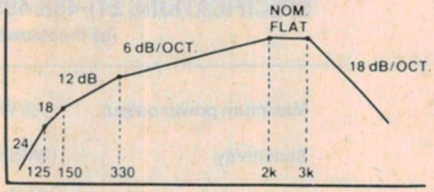
The time constant is important as the circuit needs to react quickly to plosive sounds, yet 'hang on' following peaks. The ALC time constant is determined by:

$$\tau = R1.C_{RECT}$$

The value of C_{RECT} affects the distortion, so its choice is a compromise between providing an effective time constant and keeping the distortion within bounds. Reducing C_{RECT} improves the time constant but increases the distortion; increasing it reduces the distortion but reduces the ALC effectiveness. Distortion is determined by:

$$\text{Distortion} = \frac{100n}{C_{RECT}} \cdot \frac{1\text{ kHz}}{\text{freq.}} \cdot 2\,(\%)$$

The frequency response of the mic signal path is 'tailored' to improve speech intelligibility. There is much redundant energy in the spectrum produced by the voice. Reducing those components below 300 Hz and rapidly attenuating components above 3 kHz removes the redundancy and subjectively provides improved intelligibility for the listener — particularly where extraneous noise is present. Speech 'weighting' filters are used to great effect in communications equipment. In the preamp, the response below 330 Hz is rolled off at 12 dB per octave down to 150 Hz, where an extra filter section provides 18 dB/octave roll-off down to 125 Hz, where the roll-off is further increased to 24 dB/octave. Between 330 Hz and about 2 kHz, the preamp has a response rising gently at 6 dB/octave. Between. 2 kHz and 3 kHz, the response is essentially flat. At 3 kHz the response rolls off steeply at 18 dB/octave.



Generalised shape of the preamp mic signal path response showing the rolloff frequencies and attenuation rates. This response provides an effective 'speech weighting' filter to improve 'punch' under noisy conditions.

The steep roll-off below 150 Hz reduces distortion contributed by the output transformer at low frequencies, as mentioned earlier.

The combination of ALC and speech filtering has an additional advantage in that it permits greater sound levels to be achieved before howl-round feedback becomes a problem.

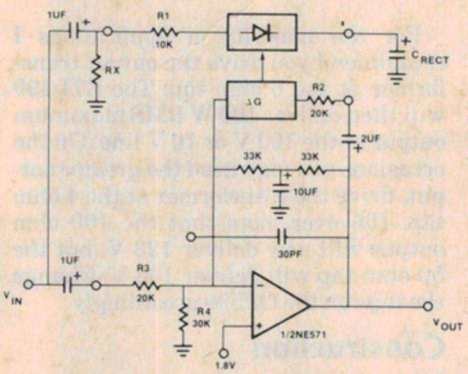
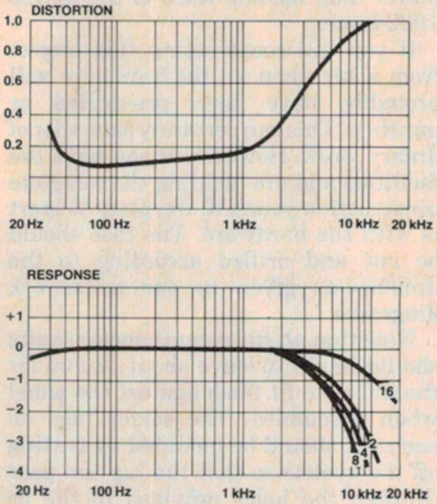


Figure 2. **General circuit of the NE570/571 audio compressor chip connected as an automatic level control (ALC). Note that R1, R2, R3 and R4 are inside the chip.**



Distortion and frequency response characteristics of the Ferguson OP590 line output autotransformer (courtesy Ferguson Transformers). ▶

SPECIFICATIONS ETI-498/499 PUBLIC ADDRESS AMPLIFIER
(as measured on prototype)

Maximum power output		150 W RMS (at onset of clipping)	
Sensitivity		(RMS input for full output)	
		1 kHz	**2 kHz**
	MIC 1	50 mV 1 mV	15 mV (level at min.) 0.3 mV (level at max.)
	MIC 2	100 mV 30 mV	35 mV (level at min.) 10 mV (level at max.)
	AUX.	60 mV	60 mV (level at max.)
Signal/noise ratios			
(level controls set to provide rated output for the quoted input levels at 2 kHz — ALC off)			**MIC 1** −71 dB re 1 mV **MIC 2** −73 dB re 50 mV **AUX.** −74 dB re 100 mV
Outputs		2 ohms, 4 ohms, 8 ohms, 16 ohms	
(selectable)		50 ohms (70 V nom.), 100 ohms (100 V nom.)	

For the majority of applications I recommend you drive the output transformer at the 8 ohm tap. The ETI-499 will then deliver 100 W RMS maximum output to the 100 V or 70 V line. On the occasions you may need the greater output, drive the transformer at the 4 ohm tap. However, note that the 100 ohm output will now deliver 123 V, but the 50 ohm tap will deliver 108 V. Change the taps on the OP590 accordingly.

Construction

This article covers construction of the ETI-498 preamp board and assembly of the preamp and ETI-499 power amp module into the case. For details on constructing the ETI-499 150 W MOSFET power amp module refer to the March 1982 issue.

If you are constructing this project from a kit, then all the hardware will probably have been pre-drilled or punched. This can certainly save a lot of dreary work. However, if you have the facilities and are tackling the complete construction yourself, the place to start is with the hardware. The case should be cut and drilled according to the dimensions given in our metalwork diagrams.

Note that all the potentiometer shafts should be cut to leave about 12 mm for the knobs to fit flush against the panel when assembled. The solder lugs on each pot should be modified by cutting off the eyelets so that the lug can pass through the holes provided in the pc board for soldering directly to the relevant pad. Pads for the pot lugs should be drilled with a 2 mm diameter hole. When cutting the eyelets from the lugs, make sure you leave as much of the stem of the lug as you can, otherwise they may not reach through the pc board. Note that the volume control pot, RV4, has only one lug soldered to the pc board — check the photo of the assembled pc board and only modify the relevant lug. The auxiliary level pot, RV3, has only two lugs modified.

Bend the modified lugs down *toward the pot shaft* and install each pot on the pc board. Pass the pots through the board from the *non-copper* side and secure them with *one nut* on the copper side.

Next mount the jack sockets. Orientate them so that their lugs are adjacent to the relevant holes in the pc board, and tighten the nuts firmly.

Mount R1, R6 and R15 between the switch and tip lugs on the two MIC jacks and AUX jack, respectively. Extend the switch lug end of the resistor pigtails to the sleeve lug in each case, as shown in the accompanying drawing.

General assembly of the pc board-mounted components follows. Note that *all soldered joints on the copper side of the board should be 'clinched' or cut short* as the board is mounted close behind the front panel of the case.

Mount R21 and R22 between the pc board and the lugs of the PREAMP OUT and INSERT jack sockets, as shown on the component overlay.

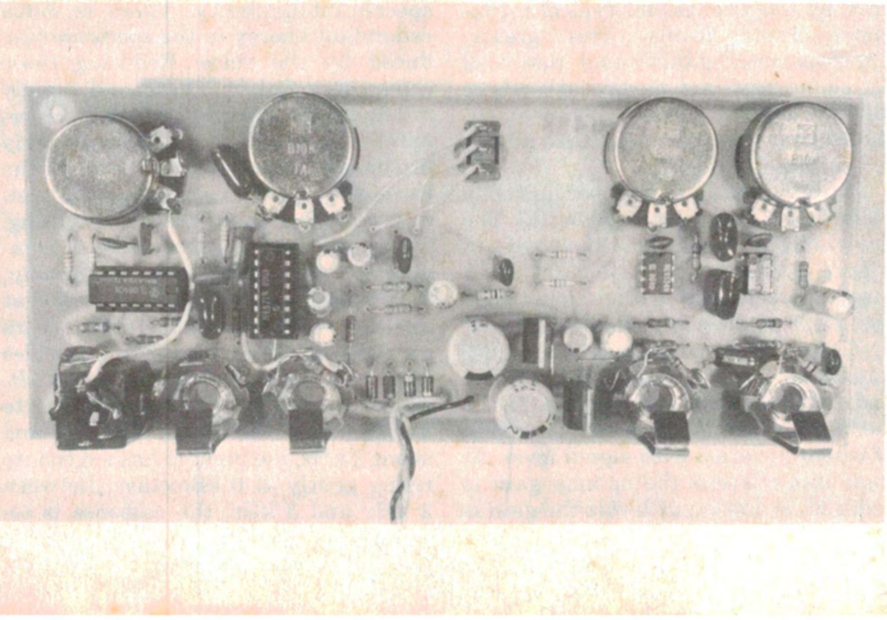
Probably the easiest order of construction is to first install all the resistors, then the ICs and diodes, followed by the capacitors. Watch the orientation of the ICs, the four diodes and the tantalum and electrolytic capacitors. The component overlay shows the appropriate orientation of all these components. Note there are a number of links on the board. Use insulated hookup wire for these.

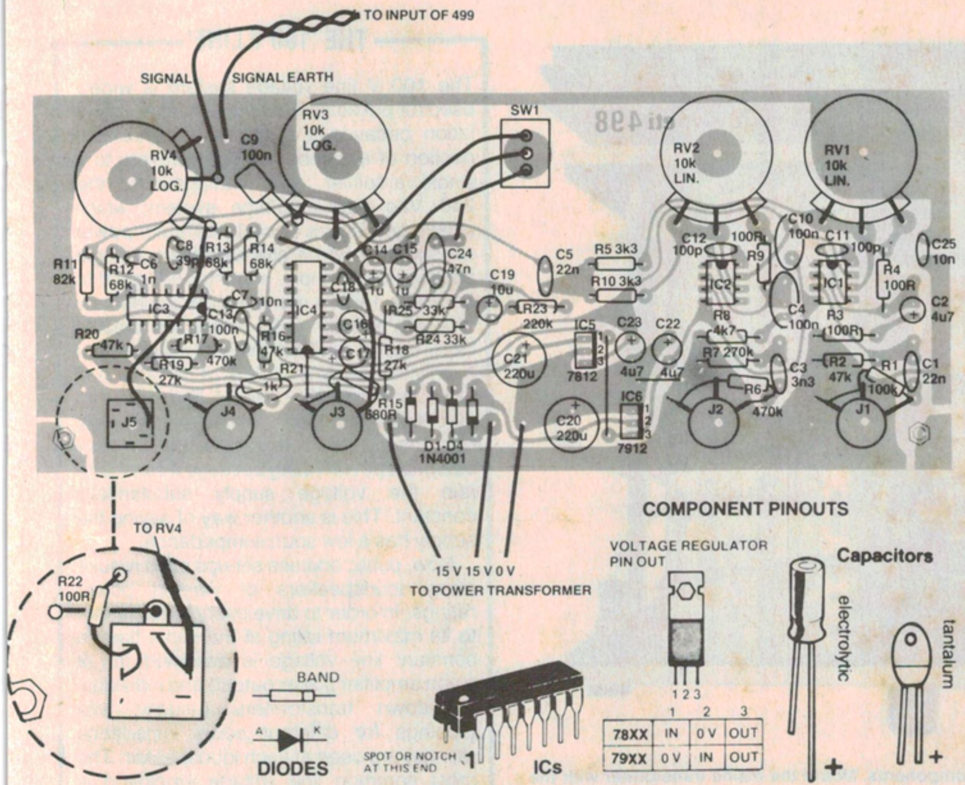
Having finished the assembly of the components to the board, check it carefully to see that you have everything in its correct place and that there are no suspect joints, missed joints or solder bridges on the copper side of the board.

Now solder the two 15 V windings of the PF4361/1 power transformer to the preamp board (make sure they're correctly phased) and attach about 100 mm of twisted-pair hookup wire from the preamp output. Use hookup wire at least as big as 24 x 0.2 mm for this twisted-pair lead.

Mount two countersunk 8 BA x 12 mm screws in the appropriate front panel holes and secure them with *one nut and*

The completed preamp board (but I hadn't put C25 on yet . . .).





PARTS LIST — ETI 498

Resistors	all ½W, 5% unless noted
R1	100k
R2, 16, 20	47k
R3, 4, 9, 22	100R
R5, R10	3k3
R6, R17	470k
R7	270k
R8	4k7
R11	82k
R12, 13, 14	68k
R18, R19	27k
R21	1k
R23	220k
R24, R25	33k
Potentiometers	
RV1, RV2	10k lin.
RV3, RV4	10k log.
Capacitors	
C1, C5	22n greencap
C2, 22, 23	4u7/50 V RBLL
C3	3n3 greencap
C4, 9, 10, 13	100n greencap
C6	1n greencap
C7 C25	10n greencap
C8	39p ceramic
C11, C12	100p ceramic
C14, C15	1u/25 V electro.
C16	2u2/25 V electro.
C17	470n/20 V tant.
C18	33p ceramic
C19	10u/25 V electro.
C20, C21	220u/35 V electro.
C24	47n greencap
Semiconductors	
IC1, IC2	NE5534, NE5534A
IC3	TL074, uA774
IC4	NE570, NE571
IC5	7812
IC6	7912

Miscellaneous
ETI-498 pc board; 4 x 6.5 mm mono phono jack sockets — shorting type; 1 x 6.5 mm stereo phono jack socket with switch (closed when empty); SW1 — SPDT miniature toggle switch; etc.

Other components to complete PA amplifier
ETI-499 150 W MOSFET Module (March ETI); 1 x PF4361/1 Ferguson power transformer; 1 x OP590 Ferguson line output transformer; 1 x DIN-type polarised speaker connector; 1 x front-loading fuse holder and 5 A fuse; spring terminal type speaker connector strip; K&W case, model C1284; Scotchcal or silk-screened front panel to suit; heatsink — e.g: Rod Irving type HS5 300 mm length black anodised flat-sided, fan-finned type or similar; 4 x 6.5 mm long stand-off pillars; four knobs to suit; mains cable, cable clamp and plug; hookup wire, nuts, bolts & etc.

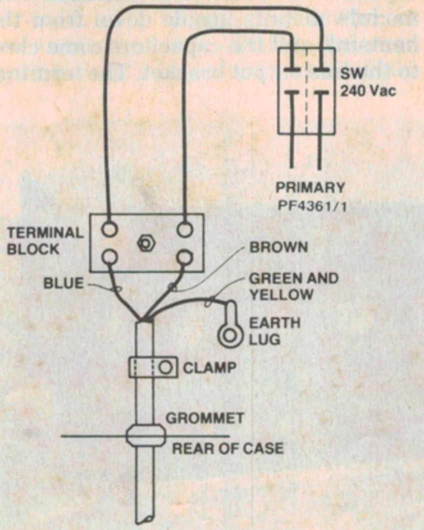
Price Estimate $230—$240 inclusive

two flat washers each. Cut a piece of thin cardboard to fit between the rear of the pc board and the rear of the case front panel. Cut out clearance holes for the pot shafts and jack sockets. Mount the assembled preamp board to the front panel, not forgetting the cardboard cut-out, which prevents any possibility of shorts between the rear of the pc board and the front panel. Sit the power transformer inside the case as you do this. Check that all sockets clear the case. Use a shakeproof washer (8 BA) and nut on the *component* side of the pc board when securing it to the two screws previously mounted to the case front panel. We used a metal Scotchcal label to 'dress up' the front panel and indicate what controls and sockets were what. This should be attached next. Take care aligning it and smoothing it in place. When you've got it right, install a nut on each pot shaft and all will be secured. Put insulation tape on the case bottom beneath each jack socket to preclude the possibility of the jack contacts touching the bottom of the case.

Next, install the low-Z output socket on the rear of the case. This is a polarised DIN-type socket and installs from the outside. Secure it with two 8 BA x 12 mm screws — nuts on the inside of the case. Install a grommet in the rear panel of the case for the mains cord. We used a Heyco nylon insulated bushing type A2030.

Now for the heatsink, which I presume has already been drilled to take the power amp mounting bracket. There are six other holes in the heatsink: four for the mounting bolts, one to allow access to the low-Z output socket and one for the mains cord. Another grommet should be installed in the latter. Then feed the mains cord through this and through the mains-entry grommet in the rear of the chassis. Just let the mains cable 'hang loose' for the moment.

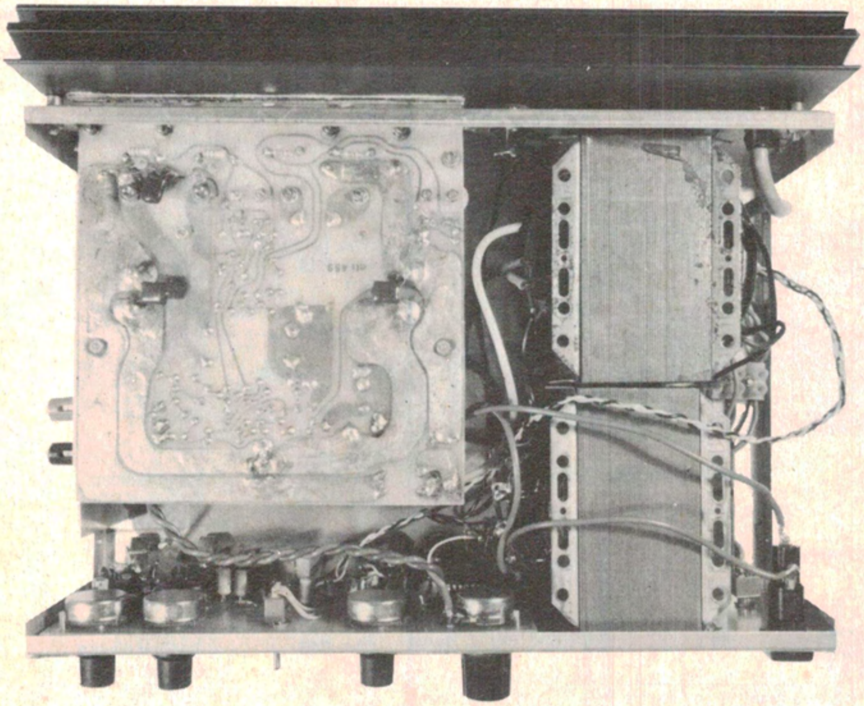
Mount the heatsink using 6 BA x 20 mm long screws and 6 mm long brass spacers to hold off the rear panel.



Mains cable wiring. Be sure to sleeve all exposed connections for your own protection.

Use lock washers and nuts on the inside of the case, passing the screws through the heatsink and spacers.

Now you can mount the mains terminal block; expose the three wires at the end of the cable inside the case, remove about 20 mm of the mains cable outer sheath and clamp the cable securely to the bottom of the case with a cable clamp. Make sure the mains wires can ▶



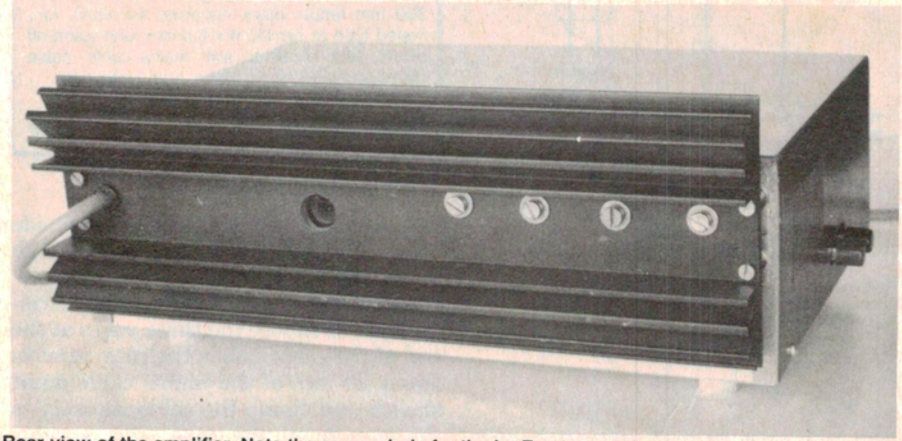
General view inside the case showing location of components. Mount the mains transformer with the 15-0-15 V winding tags uppermost for easiest access.

be easily terminated in the terminal block.

Now install the mains on/off switch on the front panel and wire it up to the terminal block *exactly as shown*. Sleeve all exposed mains connections on the rear of the switch.

Connect the two 35 V windings on the PF4361/1 power transformer to the ETI-499 module (which I presume is ready assembled and waiting). Make sure they're correctly phased. Bolt the transformer in position using 4 BA x 6 mm bolts and lock washers under the nuts. Solder its primary leads to the power on/off switch (sleeve exposed connections, as before).

Install the line output terminals next. I used a spring terminal pair mounted on a strip. These are common speaker connectors, mounted on an angle bracket at the left hand side of the case (when viewed from the front). If you have to fabricate the bracket yourself, do this now. We'll leave the exact details to you as you may have different terminals from the ones I used. The angle bracket is mounted to the bottom of the case with a couple of 8 BA x 6 mm screws. Make sure the bracket clears the filter capacitors on the ETI-499 module. This module mounts upside down from the heatsink and the capacitors come close to the line output bracket. The terminal



Rear view of the amplifier. Note the access hole for the Lo-Z output socket in the heatsink, just left of centre, and the line output terminals protruding from the right hand side of the case.

THE '100 V LINE'

The 100 V line voltage system is widely used for public address loudspeaker reticulation because it simplifies the interconnection of a number of loudspeakers to a single amplifier. It is analagous to the 240 Vac mains voltage system, which allows appliances of vastly different power consumption to be operated from a single supply. For example, a toaster designed to consume 1 kW is made with an impedance of $(240)^2/1000$, or 58 ohms. An electric clock can be run from the same supply, but it only draws 3/5 of 5/8 of 30% of half of . . . and probably has an impedance of 10 000 ohms or more. The ac mains supply can drive many different loads to their designed power rating because it can maintain the voltage supply substantially constant. This is another way of saying the supply has a low source impedance.

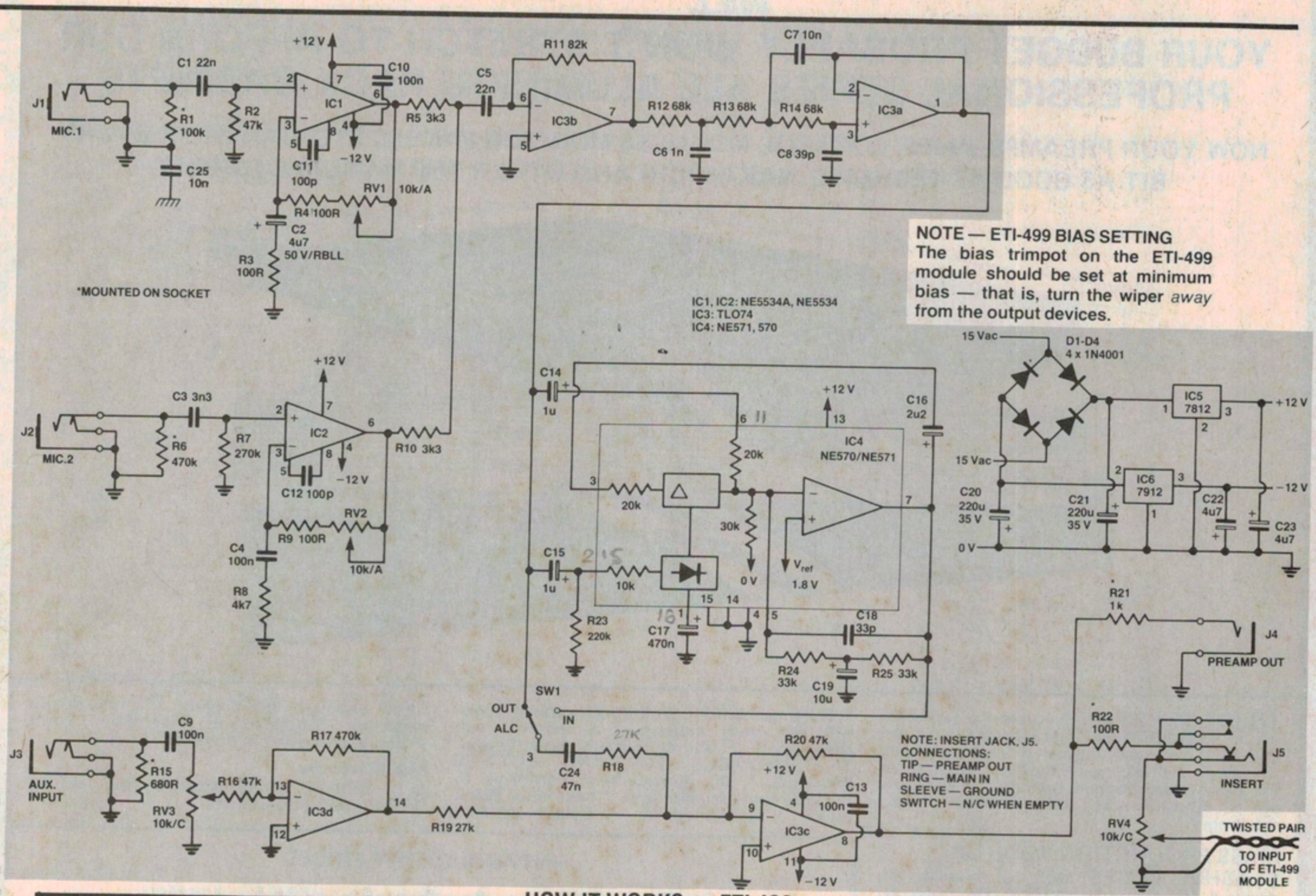
Now, public address set-ups often require many loudspeakers of varying power ratings. In order to drive every loudspeaker to its maximum rating at the same time, a constant line voltage is assumed (for a given amplifier power output) and individual step-down transformers (usually with tappings for different power/impedance ratings) are used at each loudspeaker. The most common line voltage employed is 100 V. This means that each loudspeaker will deliver its rated power when fed with a 100 V signal.

For example, a loudspeaker with an 8 ohm voice coil impedance and a 30 W maximum rating will require a drive voltage of $\sqrt{(8 \times 30)} = 15.5$ V to achieve full output. Thus it will require a step-down transformer having a turns ratio of 100:15.5. With tappings at greater ratios, less power will be delivered to the speaker; i.e: at a tapping providing a ratio of 100:11, 15 W will be delivered to the speaker; at a ratio of 100:9, 10 W will be delivered, and so on.

Any other loudspeaker power/impedance combination with a suitable transformer ratio can be connected to the same 100 V line and driven to the power rating selected, provided that the total loudspeaker power requirement can be supplied by the amplifier driving the line. That is, if ten 10 W-rated loudspeakers are connected to the line, the amplifier must be rated to deliver 100 W. Alternatively, a 100 W amplifier may be employed to drive four 10 W-rated loudspeakers and two 30 W-rated loudspeakers, all connected to the same line.

In practice, horn loudspeakers — which are commonly employed in PA applications — are usually operated at about ¼ to ½ of their maximum rated power, so that a 150 W amplifier with a 100 V line output (such as the one described in this article) will happily drive 15 or 20 horns with maximum ratings of 20 to 30 watts.

Note that a 70 V line system is sometimes employed, but this is less common than 100 V line systems. It works in the same way.



HOW IT WORKS — ETI 498

The overall circuit arrangement and design features are explained in the general text, so this explanation will be confined to specific circuit description.

MIC INPUTS

We have designated MIC 1 as a low-impedance input and MIC 2 as a high-impedance input. Signals from the MIC 1 input are amplified by IC1. The gain of this stage can be varied by varying RV1, a potentiometer connected in the feedback loop of IC1. The gain can be varied between about 2 and 102. Signals from the MIC 2 input are amplified by IC2, the gain of which can be varied in the same way as IC1. RV2 here can vary the gain between 1 (unity gain) and 3. Resistors R1 and R6 provide dc return for each input capacitor, preventing 'clicks' or 'pops' when inserting or unplugging a mic.

An RC network on each of the MIC 1 and MIC 2 inputs forms single-pole high-pass filters with a breakpoint set at about 150 Hz to reduce low frequency output (the reason for this is explained in the main text). C1-R2 are the relevant components on the MIC 1 input, C3-R7 on the MIC 2 input. A further single-pole high-pass filter is introduced in the feedback network of each mic amp stage: C2-R3 for IC1 and C4-R8 for IC2. The breakpoint is set at 340 Hz and is the lower roll-off point for the speech filtering.

MIC SUMMING

The amplified microphone signals are summed at the outputs of IC1 and IC2, at the junctions of R5 and R10. Another high-pass pole is introduced by these two resistors, in conjunction with C5. This too, is part of the speech filtering.

IC3b buffers the summed mic signals and provides a further amount of gain. The output of this stage, pin 7, drives a low-pass filter stage comprising R12, 13 and 14, capacitors C6, 7 and 8 and IC3a. This filter has a breakpoint set at 3 kHz, providing a sharp roll-off above this frequency.

The net effect of the high and low-pass filters up to this stage provides filtering of the voice frequency spectrum to improve 'intelligibility' where listeners to the PA have to contend with a variety of interfering noises from numerous sources at open-air events.

ALC

The 'automatic level control' (ALC) circuit centres on IC4, an NE570 or 571 'compander' IC. This circuitry attempts to maintain a near-constant output, provided the input from the microphone stages exceeds a threshold level determined by the value of R23. Decreasing R23 *increases* the threshold, reducing the effect of the ALC. The ALC prevents 'soft' sounds from being lost in external noise while helping prevent clipping from plosive sounds ('p' and 't' for example) in speech.

The 'attack' time of the ALC is determined by C17. Decreasing the value of this capacitor improves the transient response of the stage (helping it cope with plosives) but has the drawback of increasing the distortion. We chose the value shown as a compromise between these two parameters and it seems to work well in practice.

The input to the ALC circuit (from pin 1, IC3a) and the output (from pin 7, IC4) go to SW1, a SPDT switch, which selects ALC IN or ALC OUT.

AUX INPUT

The auxiliary input is meant for low impedance, 'line level' signals, such as from the output of a tape recorder. Input impedance is determined largely by R15 and is around 600 ohms or so. IC3d provides amplification, having a gain of 10. The input level may be attenuated by RV3. This, in conjunction with C9, provides a single-pole high-pass filter.

INPUT MIXING

The MIC and AUX inputs are summed at the input of IC3c (pin 9). C24 and R18 provide a further high-pass filter for the MIC-ALC stages with a breakpoint at 125 Hz, further increasing the attenuation below this region.

OUTPUTS

The output of IC3c (pin 8) passes to the input of the ETI-499 power amp module via the INSERT jack (J5) and the volume control, RV4. A PREAMP OUTPUT is provided too, at J4.

The INSERT jack is a stereo/switched type and provides a point where a graphic equaliser or howl-round stabiliser can be introduced (see the ETI-485 Graphic Equaliser and the ETI-486 Howl-Round Stabiliser in our publication '30 Audio Projects').

Resistors R21 and R22 provide isolation between the outputs and short-circuit protection for the output of IC3c.

POWER SUPPLY

The on-board power supply derives its input from the two 15 Vac windings on the PF4361/1 power transformer used to supply the ETI-499 module. These two windings are connected to provide a centre-tapped 30 Vac supply (15-0-15). Two full-wave capacitor input rectifiers, comprising D1 to D4 and C20-C21, then provide about ±20 Vdc input to a pair of three-terminal regulators: a 7812 which provides a +12 V rail, and a 7912 which provides a −12 V rail.

To page 65

From page 59

strip should be mounted to the bracket with countersunk 8 BA x 6 mm screws — secure them well so that the screw heads are flush. A cutout is necessary in the case lid to clear these terminals.

Mounting of the OP590 output transformer comes next. First, solder three lengths of heavy gauge hookup wire to the appropriate lugs on the transformer. Use 24 x 0.2 mm insulated hookup wire, at least. Bolt the OP590 in place using 4 BA x 6 mm bolts and lock washers under the nuts. Wire the output of the ETI-499 module to the fuseholder. Then wire up the OP590, the low-Z output socket and line output terminals.

The ETI-499 power amp module can now be mounted. First, however, wire up the twisted-pair input from the preamp. Apply thermal compound to the heatsink bracket on the power amp module and then bolt the module to the heatsink using 2 BA x 12 mm screws and lock washers under the nuts.

Now do a double check of all your interwiring. Using an ohmmeter, ensure there is no dc path between the preamp-power amp signal earth and the case. If all seems well, install a three-pin on the mains cable and you're ready to power up for a test run.

Testing it

Set all level controls to the minimum position (fully anti-clockwise). Connect a loudspeaker to the appropriate output (either low-Z or line output). Turn the ALC off. Insert a microphone in the appropriate jack — according to what mic you have and how you've configured the inputs. Hold your breath . . . and turn on. Advance the mic level control and the volume control and talk into the mic. The sound should be clear and undistorted. If you have any problems, switch off and trace the fault before continuing.

Assuming all is well at this stage, obtain a cassette deck or tape recorder and plug it into the auxiliary input. Play a pre-recorded tape and see that the sound is clear and that the gain controls have plenty of 'room to move'. Next, try recording on tape, taking the recorder input from the preamp output jack while speaking into the mic.

Try out the effect of the ALC. There should be a dramatic difference in the dynamic range when speaking, without noticeable distortion.

Note that the speech filtering in the mic circuits reduces the bass and 'softens' plosive sounds like 'p' and 't'. The steep roll-off above 3 kHz contributes to making the voice sound less 'natural', but dramatically improves intelligibility when extraneous noise is present. There is no filtering on the auxiliary input and the bandwidth is only limited by the output transformer.

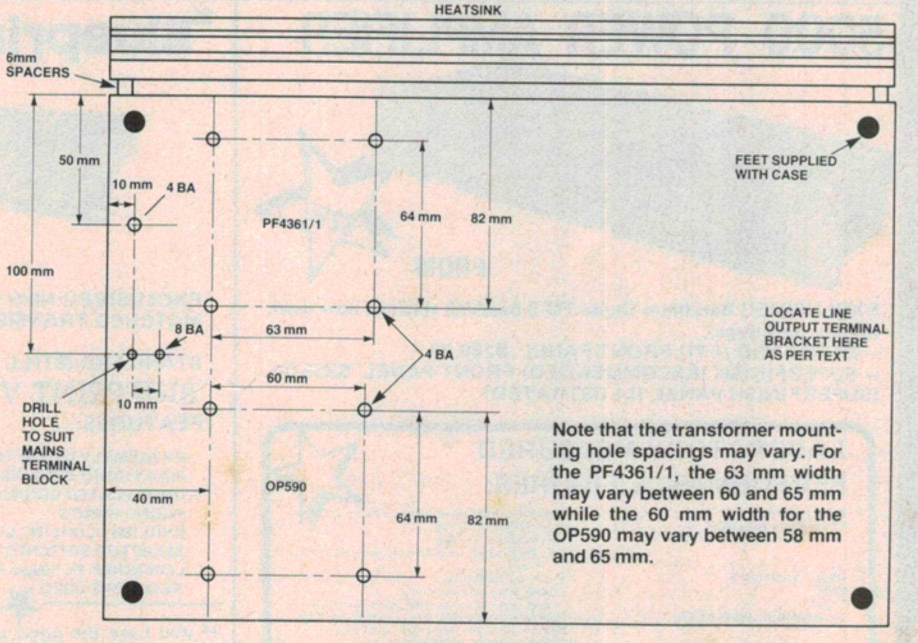
Conclusion

In use, the ALC needs to be employed with care — it is not necessary on all occasions. It is generally most effective when other sources of extraneous noise are present in the area.

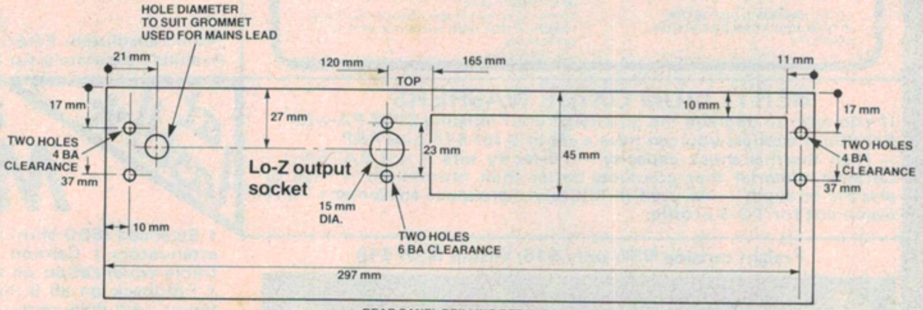
The heatsink proved more than adequate for the job, from experience, barely getting warm to the touch.

I think you'll find the ETI-488/499 PA very effective — may it 'cut through the mush' for you every time! ●

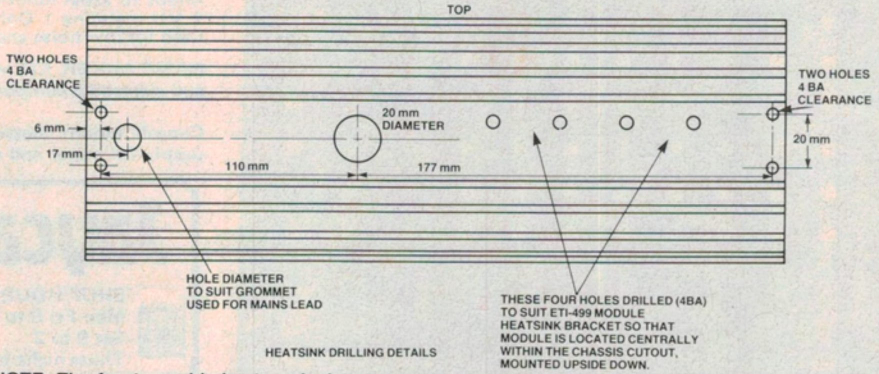
ARTWORK: Full-size reproductions of the pc board and front panel artwork are available from ETI by sending an A4 stamped, self-addressed envelope to ETI-498/499 Artwork, 15 Boundary St, Rushcutters Bay NSW 2011.



DRILLING DETAILS — BOTTOM OF CASE



REAR PANEL DRILLING DETAILS



HEATSINK DRILLING DETAILS

NOTE: The front panel is best marked out and drilled using the preamp pc board as a template. The output fuseholder and mains power switch are located at the extreme right of the front panel, at top and bottom, respectively. The front panel artwork or Scotchcal panel may be used to locate hole centres for these, and they mount directly on the panel. Drill clearance holes for the preamp controls and input jacks, 2 — 3 mm oversize.