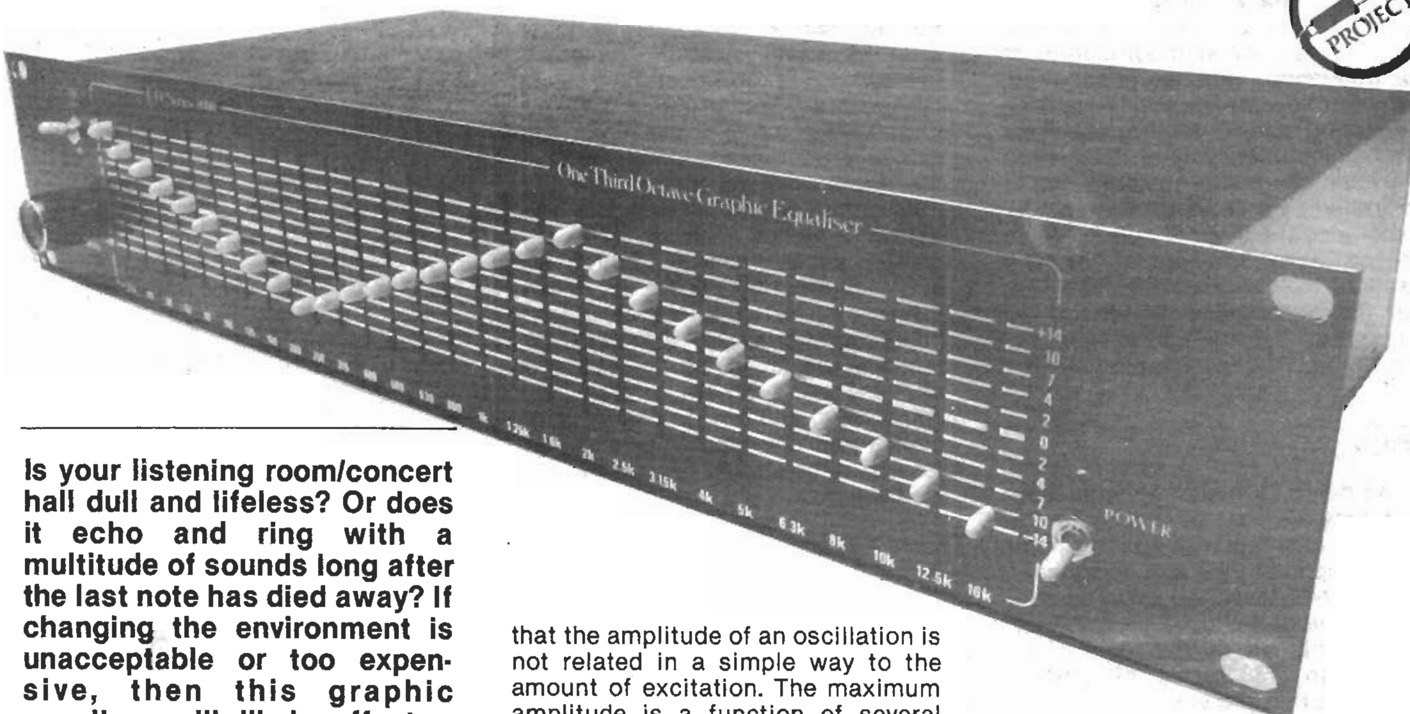
Graphic Equaliser

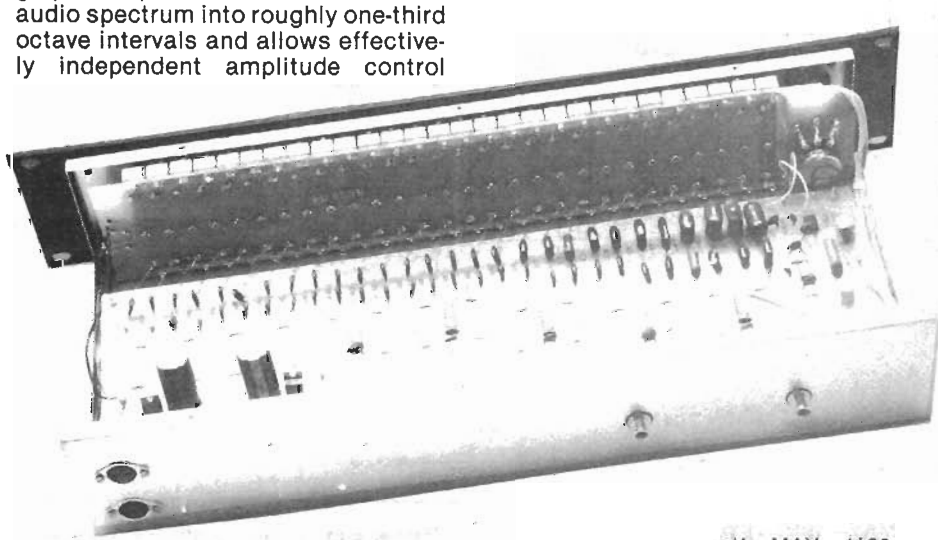
PROJECT



Is your listening room/concert hall dull and lifeless? Or does it echo and ring with a multitude of sounds long after the last note has died away? If changing the environment is unacceptable or too expensive, then this graphic equaliser will likely effect a distinct improvement. For obvious mechanical reasons, this is a mono unit; two are required for stereo.

SINCE THE Series 5000 preamplifier and power amplifier were published (during 1982) we have had many requests for this project. The inherent reliability and superlative performance of the MOSFET power stage makes the 5000 power amp ideally suited for use in professional applications. Unfortunately many of these applications are in difficult or 'problem' listening environments such as large halls or simply rooms with poor acoustic properties. Listening environments with too little damping lead to resonances and reverberation that can seriously degrade the intelligibility of music or speech. By contrast, rooms with too much damping lead to muffled and lifeless acoustic performance due to excessive attenuation of certain bands of the audio spectrum. To a certain extent these problems are unavoidable, at least with present technology. It is impossible to completely cure a listening environment of inherent problems such as resonances or excessive reverberation. The latter phenomena can cause feedback resulting in oscillation of the sound system. The problem is that the amplitude of an oscillation is not related in a simple way to the amount of excitation. The maximum amplitude is a function of several variables, one of which is the damping of the listening environment. This converts sound evergy into heat and prevents it from being reflected back into the room to further excite the resonance. The time taken for the resonance or oscillation to reach its maximum is also a function of the excitation level, i.e: the volume at which the sound is being reproduced. Problems associated with overdamped listening environments are slightly easier to correct, although a complete cure is again almost impossible, especially in bad cases.

The equipment used most often to correct faults in the listening environment is the one-third octave graphic equaliser. This divides the audio spectrum into roughly one-third octave intervals and allows effectively independent amplitude control over each of the frequency bands. To meet the demand for a full one-third octave equaliser we have designed the Series 5000 unit offering noise and distortion performance that will not seriously degrade the performance of a high quality system. It should be noted however, that the use of any one-third octave equaliser will affect the performance of the system simply because it is in circuit. Each of the filters has a relatively high Q and will therefore cause significant modification to the overall phase linearity as well as the frequency response when cut or boost is applied. I have seen many otherwise



high quality systems degraded significantly by the excessive use of one-third octave equalisers and we do not recommend the incorporation of these units into a high quality system unless a specific need is apparent. Nevertheless, when modification of the frequency response is required, no matter how drastic or how modest, a one-third octave graphic equaliser is an almost ideal way of doing this.

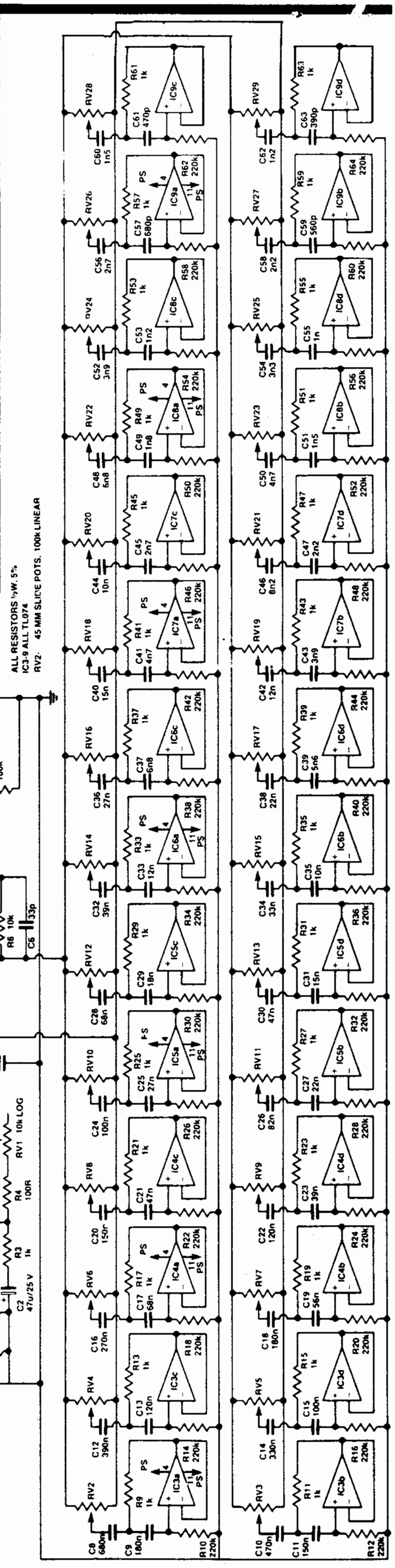
Each channel of the equaliser is controlled by a separate slide potentiometer so the array of pots gives an approximate indication of the response inserted by the device. Further, the relative ease of operation ensures that setting up can be accomplished in a reasonable time.

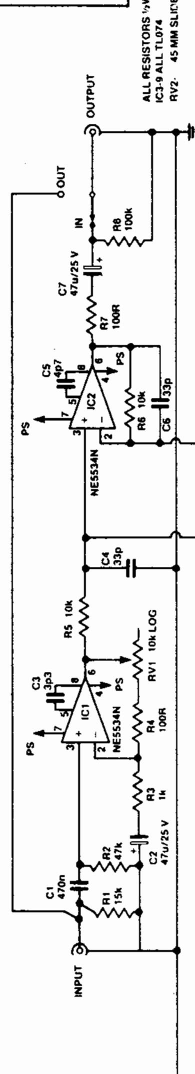
Design

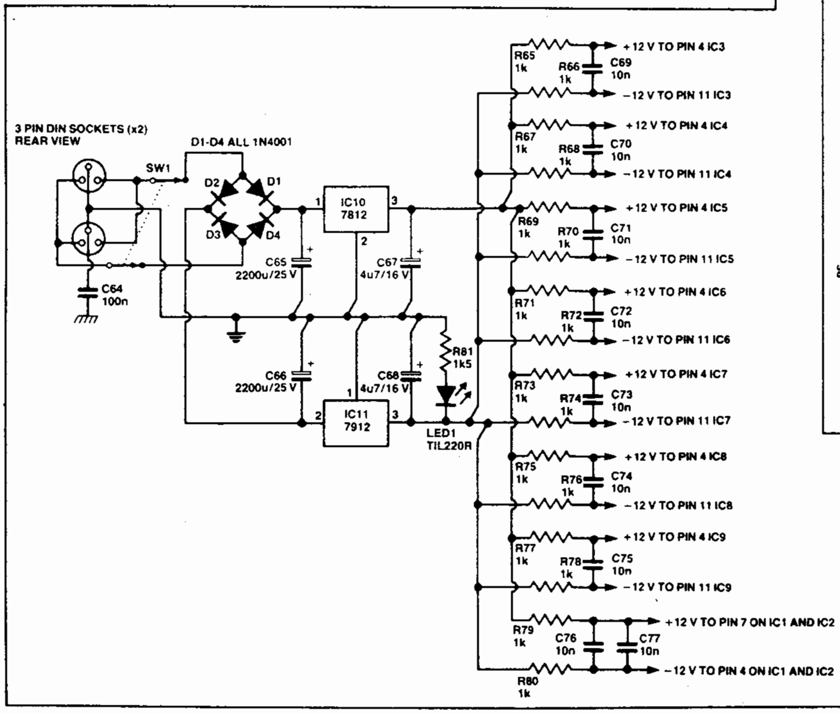
Each filter is formed by a series resonant network incorporated into the feedback loop of a high quality operational amplifier. In this case we have used the NE5534N, the same op-amp used in the Series 5000 preamplifier. The advantages of this device are covered in the series of articles describing that project.

'Gyrators' are used to simulate the inductors necessary for the series of bandpass filters so there are no coils to wind. The gyrator is covered in more detail in the How it Works section, but the main problem associated with this approach is caused by phase shifts occuring in the op-amps used in the gyrators. The basic principle of a gyrator is to invert the phase response of a capacitor to simulate the characteristics of an inductor. The problem is that all amplifiers introduce a phase shift which increases towards the extremes of the frequency response. For this reason, care must be taken when choosing op-amps for use in gyrators at the top end of the frequency spectrum. This problem is accentuated when the Q of the filters concerned is increased. Since the Q of the filters must be higher in a one-third octave equaliser than in a one-octave equaliser, an op-amp with greater phase linearity at high frequencies must be used. Fortunately, op-amps with the desired characteristics are not difficult to obtain and we are using the TL074 or uA774. These are both quad FET op-amps with almost identical performance and are capable of excellent results in the circuit, even at the topmost filter.

A kit of the case, pcb's and faders for this project will be available from Dacor Ltd., P.O. Box 683, Station Q, Toronto, Ontario M4T 2N5.







Power supply and equaliser schematic.

HOW IT WORKS

In order to illustrate the principle of operation of the graphic equaliser we first need to consider the operation of a simplified version of a single stage, as illustrated in Figure 1. Here, the input signal is fed to the non-inverting input of an op-amp through a 10k resistor. A potentiometer is connected between the non-inverting and inverting inputs with its wiper going to signal common (ground) via a network represented by Z. Here, a series-resonant circuit is employed. Feedback is provided between the op-amp output and the inverting input.

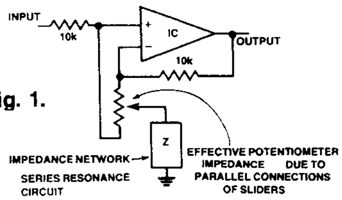


Fig. 1.

The input resistor forms a potential divider with part of the potentiometer (from the op-amp + input to the wiper) and the impedance Z to common. The ffedback resistor also forms a potential divider with the end of the pot from the inverting input and the impedance Z to ground.

If the wiper of the pot is set to mid-travel, the attenuation of the input signal due to the potential divider is compensated by the gain of the op-amp and the overall gain from input to output is unity. If the pot wiper is now moved toward that end of the pot connected to the op-amp's inverting input, the gain of the stage is increased as the feedback ratio is reduced owing to a reduction of the impedance from the op-amp's inverting input to common. At the same time less attenuation of the input signal occurs as the impedance from the non-inverting input to common is decreased. The stage will have gain, maximum gain being determined by the impedance of the series resonant network. If this is low, gain will be high. Series resonant networks exhibit very low impedance, rising either side of the frequency.

When the wiper of the pot is moved toward the non-inverting input of the op-amp, the attenuation due to the input potential divider is increased. The gain of the op-amp is decreased at the same time as the feedback ratio is increased because the impedance from the inverting input to common is increased. Once again, the overall gain of the circuit is a function of the impedance of the series resonant circuit, but this time the gain is at a minimum — in fact, attenuation occurs.

By choosing a suitable Q for the series resonant network, the bandwidth can be set to cover a desired frequency range. The potentiometer then sets gain or attenuation of the stage at the centre of the chosen frequency band.

The technique just described above can be used whenever it is desired to incorporate a relatively large number of filters into the signal path as in graphic equalisers or tone controls. The filter networks need not be bandpass or notch filters; simpler bass and treble controls can also be used.

Once this basic configuration is set up, all that remains is to design the filter networks. As mentioned before, series resonant networks were used since these give the required characteristic of low impedance at the resonant frequency. In their simplest form these networks consist of an inductor, capacitor and resistor in series. At the resonant frequency, the impedance of the circuit is equal to that of the resistor, asuming a perfect inductor and capacitor were used. To eliminate the inductor an op-amp circuit has been used to simulate the characteristics of an inductor. Such a circuit is called a 'gyrator'.

The gyrator circuit can provide both the inductance and the series resistance required in the network so this can simply be placed in series with the capacitor to form the required resonant circuit. This is shown in block diagram form in Figure 2.

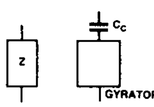


Fig. 2.

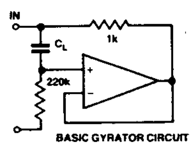


Fig. 3.

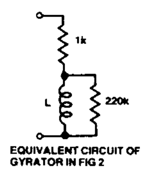
Figure 3 shows the general circuit of the gyrator used in this project. The amount of inductance 'generated' by this circuit is given by the simple equation:
$L = 1k \times 220k \times C_L$ in Henries
where the value of C_L is in Farads.
The equivalent circuit of the gyrator is shown in Figure 4. The series resistance is equal to the 1k resistor while the 220k resistor becomes the parallel resistance of the coil. This value is high enough not to affect circuit operation drastically. The resonant frequency of this filter is given by the standard formula:

$$F = \frac{1}{2\ \sqrt{LC}} \text{ in Hertz}$$

The general circuit, simplified, of the Series 5000 third-graphic equaliser is shown in Figure 5. IC1 is simply a variable gain stage which also provides some input buffering. IC2 is the filter stage with a group of 28 gyrator circuits, all connected in parallel, in the feedback circuit. Commencing at a centre frequency of 31.5 Hz, each gyrator filter has a Q chosen such that its bandwidth covers one-third of an octave. Thus the upper and lower 3 dB points of adjacent filters 'touch'. A total of 28 filters are required to cover the audio frequency band. Filters are not placed on the band limits of 20 Hz and 20 kHz as they are not really required. To reduce the IC count a set of seven quad op-amps (TL074s or uA774s) are used for the gyrators.

Slide pots are used to set the gain or attenuation inserted for each third-octave band as it is easy to see, at a glance, how much gain or attenuation has been set and, as all the pots are lined up in parallel across the front panel, one can instantly see the total modificatin made to the audio system's frequency response.

Fig. 4.



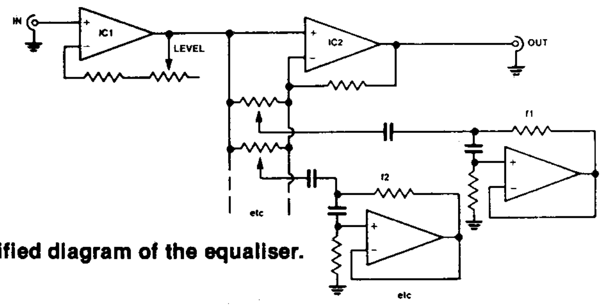


Fig. 5 Simplified diagram of the equaliser.

Construction

The one-third octave equaliser divides the audio frequency band into 28 segments, so a total of 28 slide pots are used. Cutting the required slots in a front panel is an extremely difficult task so this is one project that is probably best built from one of the kits, supplied by various outlets, which incorporate a pre-punched chassis and front panel. For those with the necessary equipment to construct their own chassis we have supplied detailed drawings fo the metal work required. Assuming that the project is constructed from a kit, most of the work is restricted to assembling two pc boards. One of these holds the bulk of the components while the other holds the slide pots and the 'power on' LED and its associated current limiting resistor.

Construction of the main pc board is not difficult. The usual precautions should be taken with the orientation of all polarised components such as electrolytic capacitors, transistors, diodes and ICs. Note that the two voltage regulator ICs are not mounted in the same direction. Check the component overlay for the correct orientation. It is probably wise to leave the insertion of the quad op-amps until last since these are FET devices and are therefore more sensitive to static electricity than the other components in the unit. Be careful when handling these devices before insertion on the board. Use a grounded soldering iron and discharge yourself by touching a grounded metal appliance before handling the ICs. The inputs are protected and should therefore be

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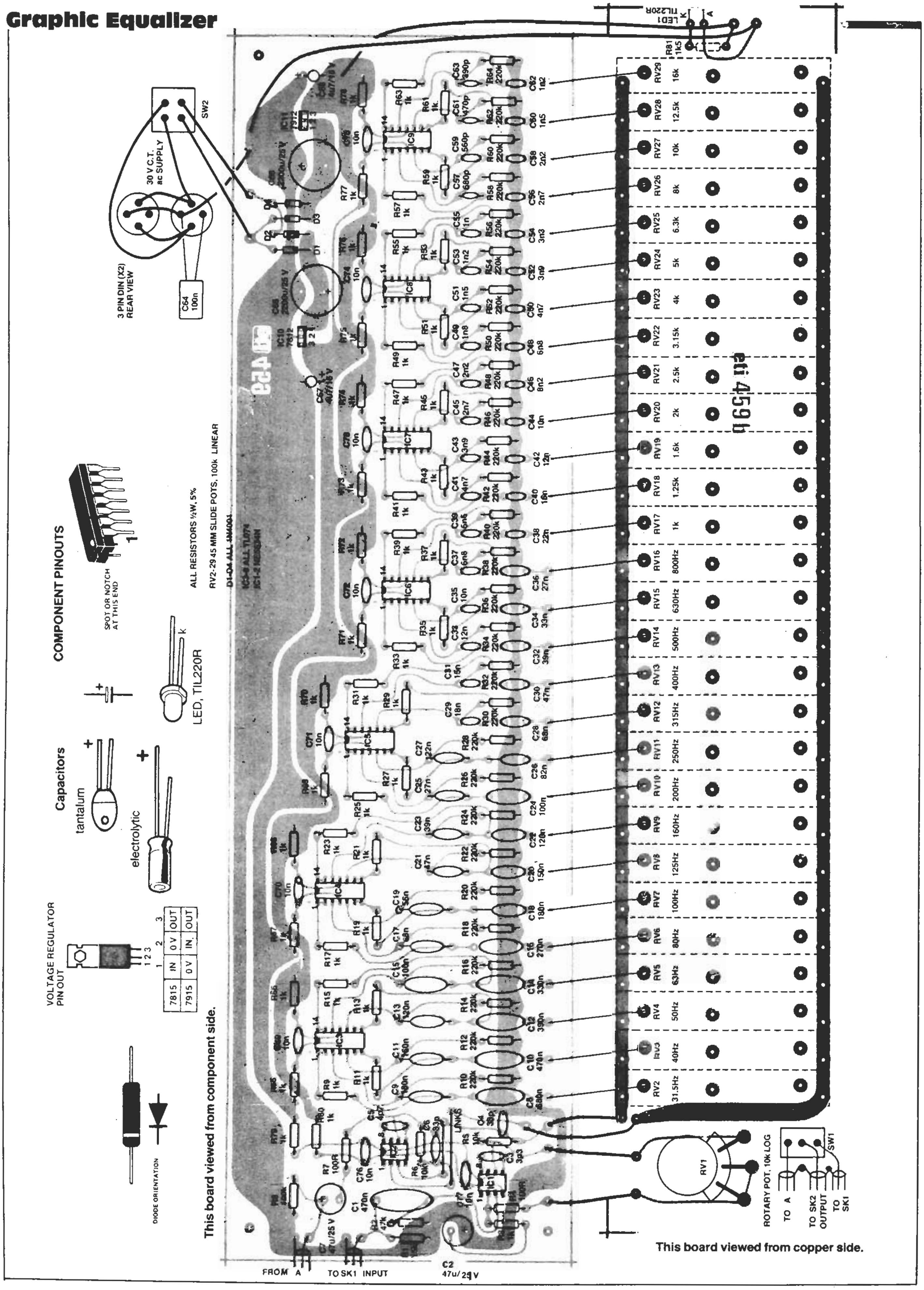


reasonably safe from damage by static electricity.

Construction of the second pc board is not difficult either, although some care should be taken to ensure that the slide pots are mounted so that their shafts are as close as possible to forming a right angle with the pc board. Probably the easiest way to do this is to first solder one pin of the slide pot and adjust the position of the slider while heating the joint with a soldering iron. When the pot position is satisfactory, solder the remaining pins and proceed to the next slider. The single resistor can be soldered on at this stage but I found it easier to leave the mounting of the LED until after the pc board is attached to the front chassis.

Mount the RCA sockets on the rear panel. Note that these sockets are insulated from the chassis. The same technique is used for this as was used in the Series 5000 preamplifier. First insert a rubber washer of the appropriate inside diameter into the holes drilled in the rear panel, then mount the sockets. A photograph has been included with the construction details to illustrate this.

The chassis of the unit is not connected directly to the power supply earth. A 100n capacitor is soldered between the 0V point on the power supply DIN sockets and the chassis to provide RF shielding to the rest of the circuitry but no dc connection should be used. This is consistent with the grounding principle of the entire Series 5000 range of components and is a good general principle to adopt to ensure freedom from ground loops. If you are constructing the unit for operation in systems not including a Series 5000 power amplifier you will need a small transformer to supply the necessary 30 V centre-tapped ac supply. There is sufficient room to allow mounting of the transformer on the back panel above the centre section of the pc board. When using a transformer inside the chassis the mains must of course be connected securely to the chassis using a solder tag bolted directly to the chassis. Do not however connect the chassis directly to the signal; use the 100n capacitor as mentioned before.

When the rear panel has been completed, the main pc board can be roughly positioned in place and all flying leads soldered to it, allowing sufficient length to run to front and back panels. The connection between the slide pot wipers and the main pc board is best done with tinned copper wire. The rest of the wiring should be done with insulated wire.

PARTS LIST

Resistors (all ½W, 5%)

R1,5,6	15k
R2	47k
R3,9,11,13, 15,17,19,21, 23,25,27,29, 31,33,35,37, 39,41,43,45, 47,49,51,53, 55,57,59,61, 63,65-80	1k
R4	100R
R7	100R
R8	100k
R10,12,14, 16,18,20,22, 24,26,28,30, 32,34,36,38, 40,42,44,46, 48,50,52,54, 56,58,60,62, 64	220k
R81	1k5
RV1	rotary pot, 10k log
RV2-29	45 mm slide pots, 100k or 50k linear.

Capacitors

C1,10	470n
C2,7	47u/25 V electro
C3	3p3 ceramic
C4,6	33p ceramic
C5	4p7 ceramic
C8	680n
C9,18	180n
C11,20	150n
C12	390n
C13,22	120n
C14	330n
15,24,64	100n
C16	270n
C17,28	68n
C19	56n
C21,30	47n
C23,32	39n
C25,36	27n
C26	82n
C27,38	22n
C29	18n
C31,40	15n
C33	12n
C34	33n
C35,44,69-77	10n
C37,48	6n8
C39	5n6
C41,50	4n7
C42	12n
C43,52	3n9
C45,56	2n7
C46	8n2
C47,58	2n2
C49	1n8
C51,60	1n5
C53,62	1n2
C54	3n3
C55	1n
C57	680p ceramic
C59	560p ceramic
C61	470p ceramic
C63	390p ceramic
C65,66	2200u/25 V electro.
C67,68	4u7/16 V tantalum

Semiconductors

IC1,2	NE5534N
IC3,4,5-9	TL074
IC10	7812
IC11	7912
D1-4	1N4001
LED1	any T-13/4 LED

Transformer

If used without Series 5000 preamplifier, requires 30V center-tapped transformer, about 150 mA, such as Hammond 166 E30.

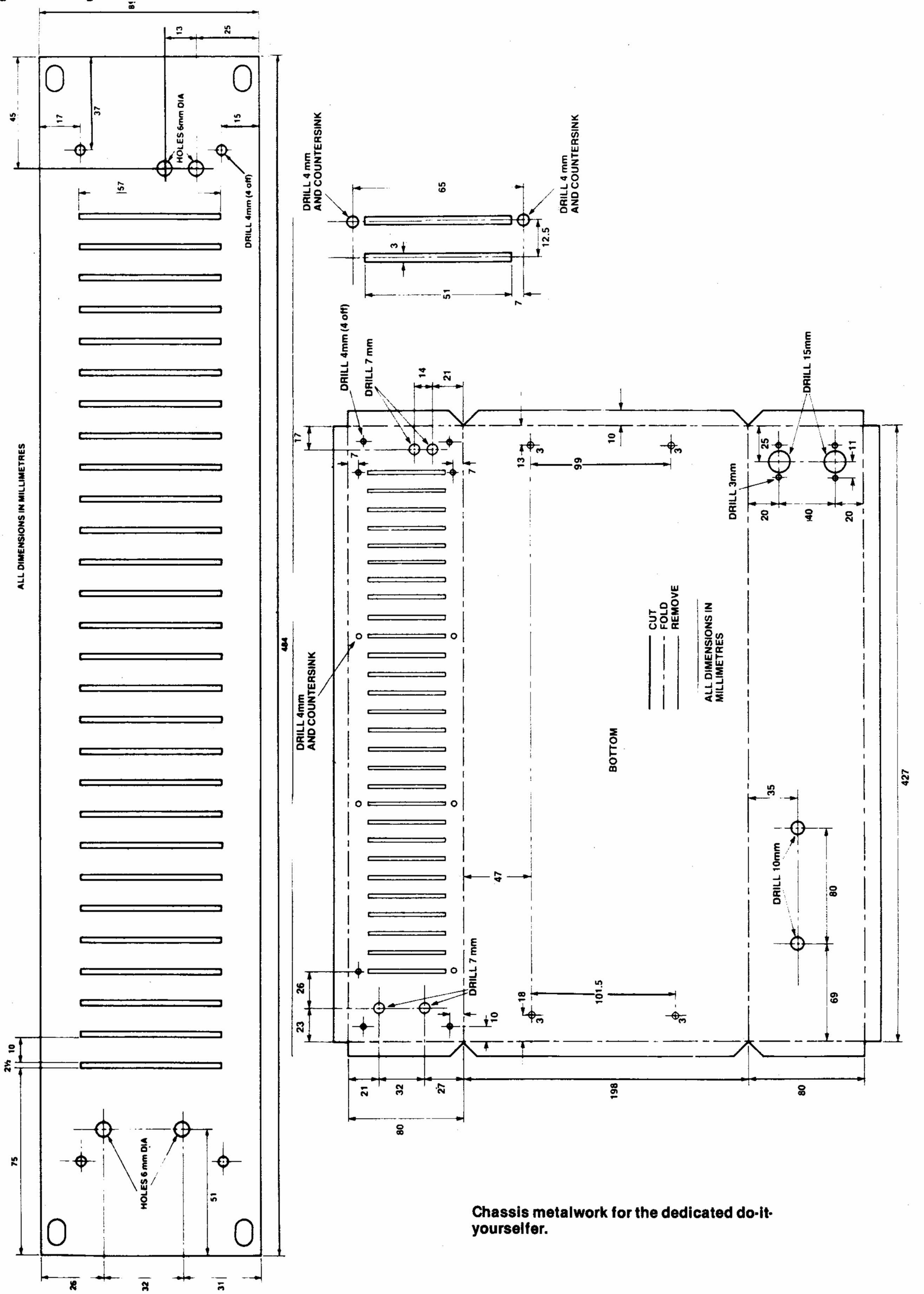
Miscellaneous

a & b pc boards; SW1 DPST toggle switch; chassis and panel as per drawings; two 3-pin DIN sockets; knobs for slide pots; SW2 — SPDT toggle switch; nuts, bolts, wire, etc.

The most difficult part of the construction is the mounting of the front panel components. The two switches are mounted directly to the front panel, behind the slide pot pc board. All wiring to these switches should be done before mounting since it is not possible to solder to these once the switches are in place. Shielded cable should be used for the three cables going to the equaliser in/out switch. Two of these must be sufficiently long to go to the input and output sockets on the rear panel, and the other must go to the input on the main pc board. The shields of the three cables going to this switch can be connected together using the unused half of the switch. Put a shorting link between the three unused contacts on the back of the switch and use this as a tag point. Now solder four wires to the power switch. Two of these must go to the rear panel and the other two to the power input points on the main pc board. Check the construction diagrams if in doubt about these connections.

The slide pot pc board is secured to the front panel by eight bolts that are screwed directly into eight of the slide pots. Countersunk bolts are used and the heads of these bolts are used and the heads of these bolts are concealed by the front panel. The two switches should first be placed in their respective holes and secured by nuts to the front of the chassis. These nuts must be removed later when fitting the front panel but are used at this stage to hold the switches in place while the front pc board is mounted.

The easiest way to mount this pc board is to pass all of the bolts through the chassis front securing them in place with a small piece of adhesive tape placed across the front



Chassis metalwork for the dedicated do-it-yourselfer.

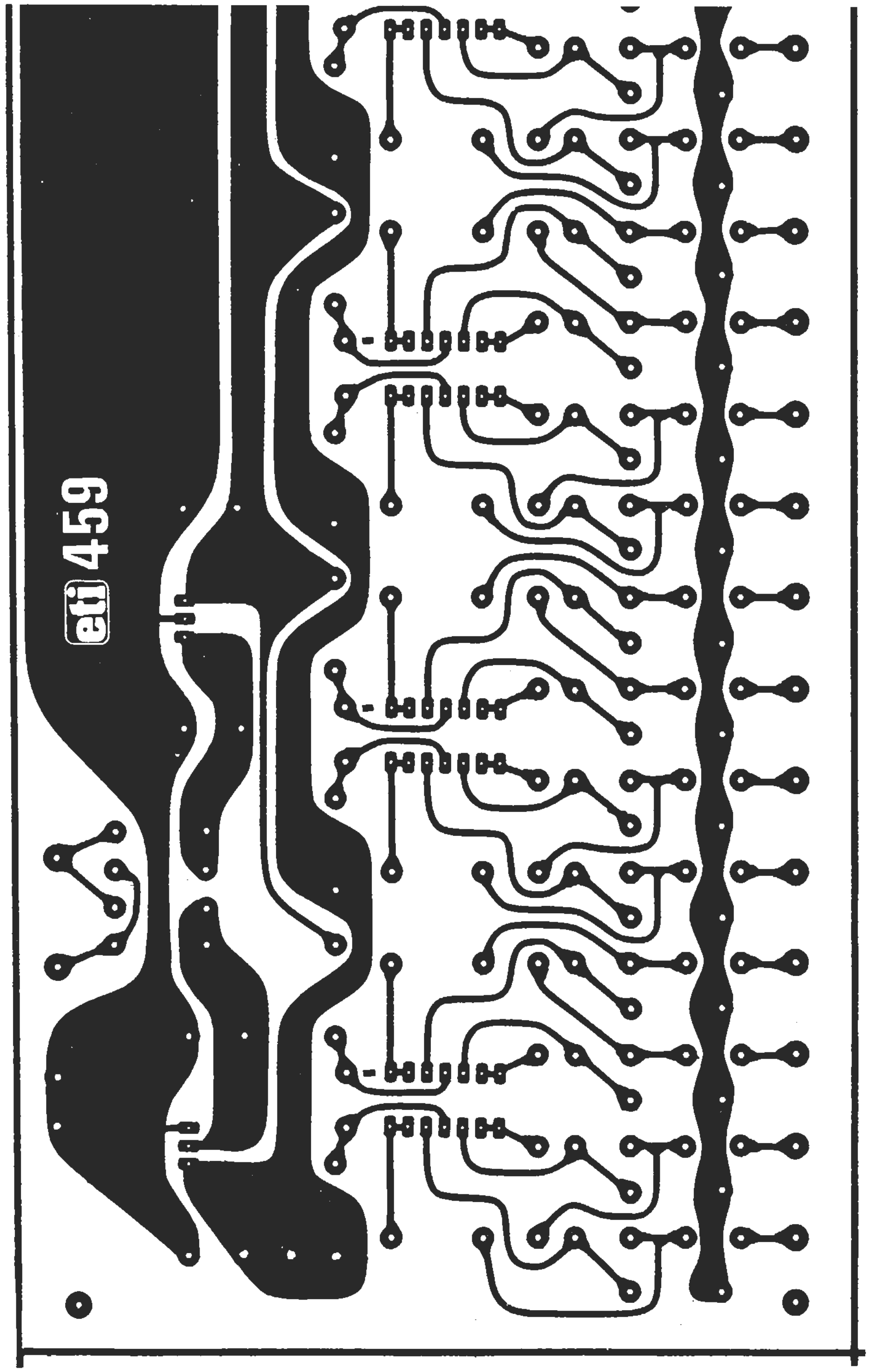
on the head. Slide brass spacers over the bolts, tilting the chassis up if necessary to keep these from sliding off the bolts. Now position the pc board in place, passing the slide pot shafts through their respective slots. One at a time the pieces of tape can be removed and the bolt screwed in the slide pots.

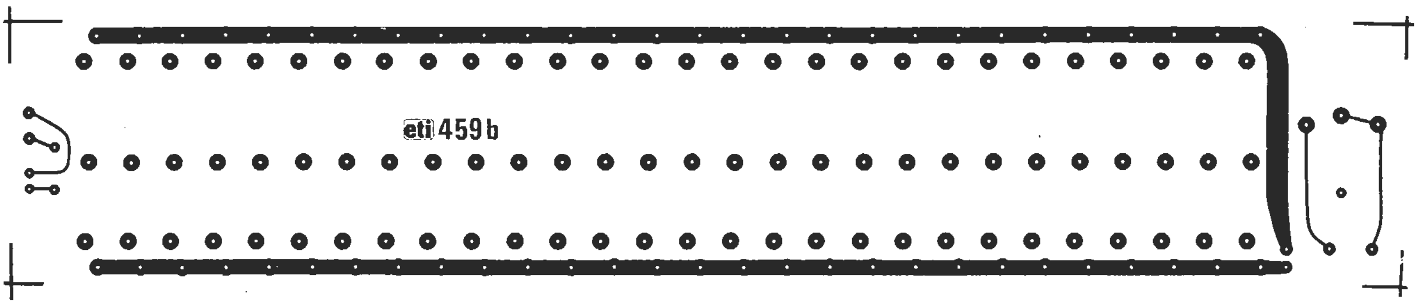
Mount the main pc board on spacers and carry out the necessary interconnections using the flying leads already secured to the board.

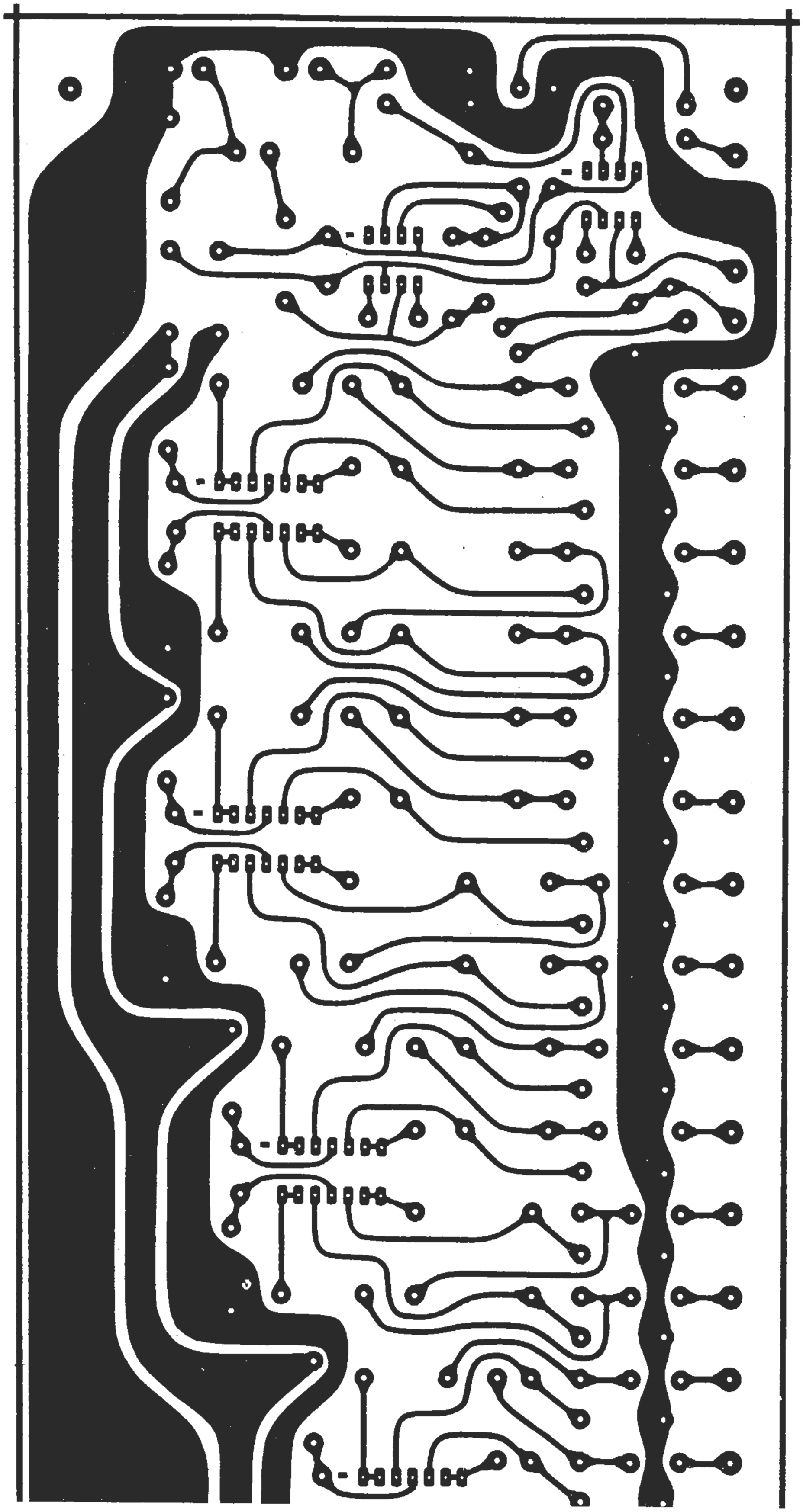
Finally, mount the front panel to the chassis. First remove the switch nuts. Secure the front panel with four 2 BA nuts and bolts. Use a washer between the front panel and the switch nuts when securing the switches to the front panel. This helps prevent the possibility of scratching the front panel when tightening the nuts. Push a LED mounting washer through the front panel. The LED can now be mounted. Be careful to insert the LED the correct way around.

Place the leads through the pc board and then push the LED into the washer from behind. You may have to bend the leads a little to get them into the holes in the pc board. Finally, solder leads. All that remains is to secure the cover. Use self tappers passed through the cover into the main chassis. Since the pots are mounted on half inch (12.5 mm) spacings there is not enough room for the usual slide pot knobs. We used small rubber covers supplied originally for use with small toggle switches. These are very common and are available in a variety of colours.

To avoid having to mail the PC art work to readers, we are publishing the main PC in two sections. They can be fitted together for reproduction. Since there are many variations on slide pots, we include a 45 percent reduction of a typical mounting board.







Power up

Once construction is complete, check all power supply wiring before powering up. This is especially important if a transformer has been included inside the chassis. In the latter case, make certain all 120 V connections are secure and check the chassis ground. If all is correct, power the unit up. The LED should light to indicate that the unit is on.

An equaliser in/out switch has been provided to ensure that a flat response can be obtained easily and without the necessity of changing the equalisation that may have taken some time to set up. The equaliser is intended for use immediately before the power amplifier. If used in this position the level control will probably not be used. In this case turn the control fully counterclockwise. The overall gain of the equaliser with the controls set at centre will be approximately unity. If the equaliser is intended for use from a typical line level output, the gain control can be used to supply the output levels needed by the power amplifier input. ETI