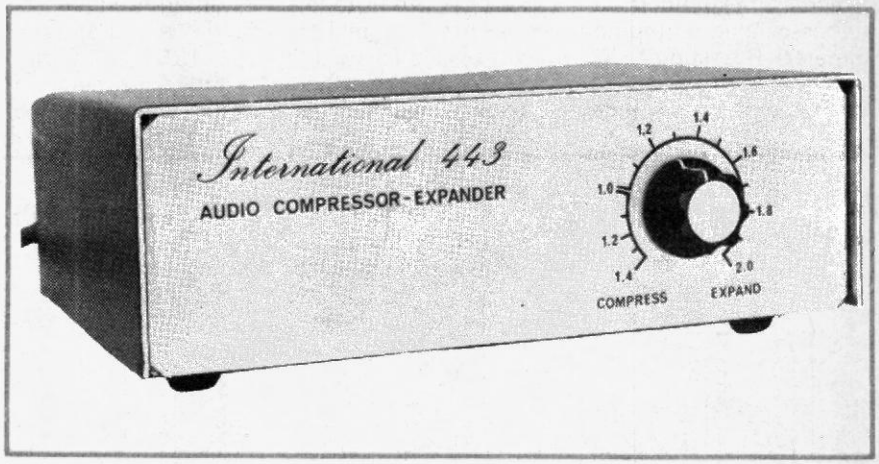
AUDIO EXPANDER-COMPRESSOR

Increase dynamic range of tape recordings or reduce record surface noise with this versatile unit.



MANY OF US have tapes in either the reel to reel format or on cassettes which leave a lot to be desired in terms of signal to noise ratio. It is not that we necessarily made a bad job of the recording in the first place, but rather the limitations of our equipment and tape were generally just a little bit too much compared with what is available today. And because the signal to noise ratio is so poor, many of these tapes (and quite a few records as well) tend to lie on the shelf because of their audible inadequacies. Apart from this it is by no means unknown for commercially pre-recorded tapes and records to be below an acceptable standard.

Many people arbitrarily think that this problem is what the Dolby system is intended to resolve. But this is not so. The Dolby system helps *maintain* the original signal to noise ratio when recording from one medium to another but it has very little to offer when faced by *existing* inadequacies.

DYNAMIC RANGE

Another problem that plagues many of us is the poor dynamic range of our tape recorders or of the pre-recorded material that we buy. For example, the majority of cassette recorders are hard pressed to offer even a 55 dB dynamic range. Many of them offer little more than 40 dB. As if this were not bad enough, few records have a dynamic range exceeding 50-55 dB and even this is soon degraded to 40-45 dB after a dozen or so playings in a dusty environment.

THE SOLUTION

Audio volume expansion is the simplest and most effective way of increasing the apparent signal to noise ratio of a worn or noisy recording. There is also no more effective way of preserving the full dynamic range of a sound than by recording with volume compression, and replaying with equal volume expansion. However, for these applications, the compression and expansion must be done in a precise and reproducible manner; which is by no means as simple as it first appears.

The Compressor-Expander described here is relatively inexpensive to build, yet its performance is quite adequate for all practical purposes. It is sufficiently versatile to interface with most existing audio equipment, at nominal signal levels from about 25 millivolts to 1 volt.

CONSTRUCTION

Due to the relative complexity of the circuit a double-sided printed-circuit board has been used to simplify the construction, and we strongly recommend that this board be used. A single-sided board would be much larger and would require a great number of wire links.

Begin construction by assembling the components to the board in accordance with the component overlay Fig. 2. Take particular care with the orientation of components as marked on the overlay. When soldering component leads to the top of the printed-circuit board use a soldering iron which has a small tip and use a small gauge of solder (1 mm recommended). Take care not to bridge solder between the IC pads. It is easy to miss soldering connections on the component side of the board and these should be double checked.

Take care to insert the electrolytics with the polarity as marked on the overlay and even more care with the orientation of the diodes. A reversed diode can result in the destruction of one or more of the dual transistors.

The resistors in the signal side of the circuit and those in the current-sink circuit should be 2% or better. Alternatively they may be selected from 5% values. In selecting values an ordinary multimeter (operated at about the centre of the range) suffices. The resistors in question are all values between R37 and R65.

For best results the two 12 volt zeners should also be matched but in practice any slight discrepancy may be compensated by using the normal stereo-balance control.

A value of 1 microfarad for C5 allows compression or expansion to follow the signal amplitude so rapidly that the ear is unlikely to detect the attack or release, which is virtually complete in about 20 milliseconds. However, with this value, low frequency signal components (50 Hz or lower) will not be averaged out in obtaining the gain control voltage, and severe intermodulation and 3rd harmonic distortion will result. At the other extreme, a value of 4.7 microfarads for C5 will prevent this distortion right down to the lower audible limit, but the attack and release time

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(about 100 milliseconds) is so long that the effects can be audible, although not necessarily unpleasant. A value of C5 equal to 4.7 microfarads will be found quite acceptable by most people.

Potentiometer R_{24} is used to match the signal levels of the compressor-expander with those of the associated equipment. Potentiometer R_{34} should be a wire-wound type, and for the front-panel calibration to apply, it should have an effective electrical rotation of 280°, and the midpoint of rotation should be set opposite the 1.0 index line.

Capacitor C5 should be chosen in accordance with the particular compromise that suits the user of the unit. Alternatively a switch may be used to select different values.

The box used in our prototype measured 200 × 125 × 63 mm and, although a little cramped did adequately hold the unit. The next larger box available was thought to be too big. The printed-circuit board is mounted at the rear of the box to allow room for the front panel potentiometer to be mounted. The board is mounted on 6 mm spacers and the transformer is then mounted directly onto the rear panel together with the phono input and output sockets.

POWER SUPPLY

The output of the transformer is rectified by a full-wave bridge to provide ±22 volts, as set by the Zener diodes. The voltages obtained from the MC1468L regulator are the ±15V required for correct operation of the compressor-ex-

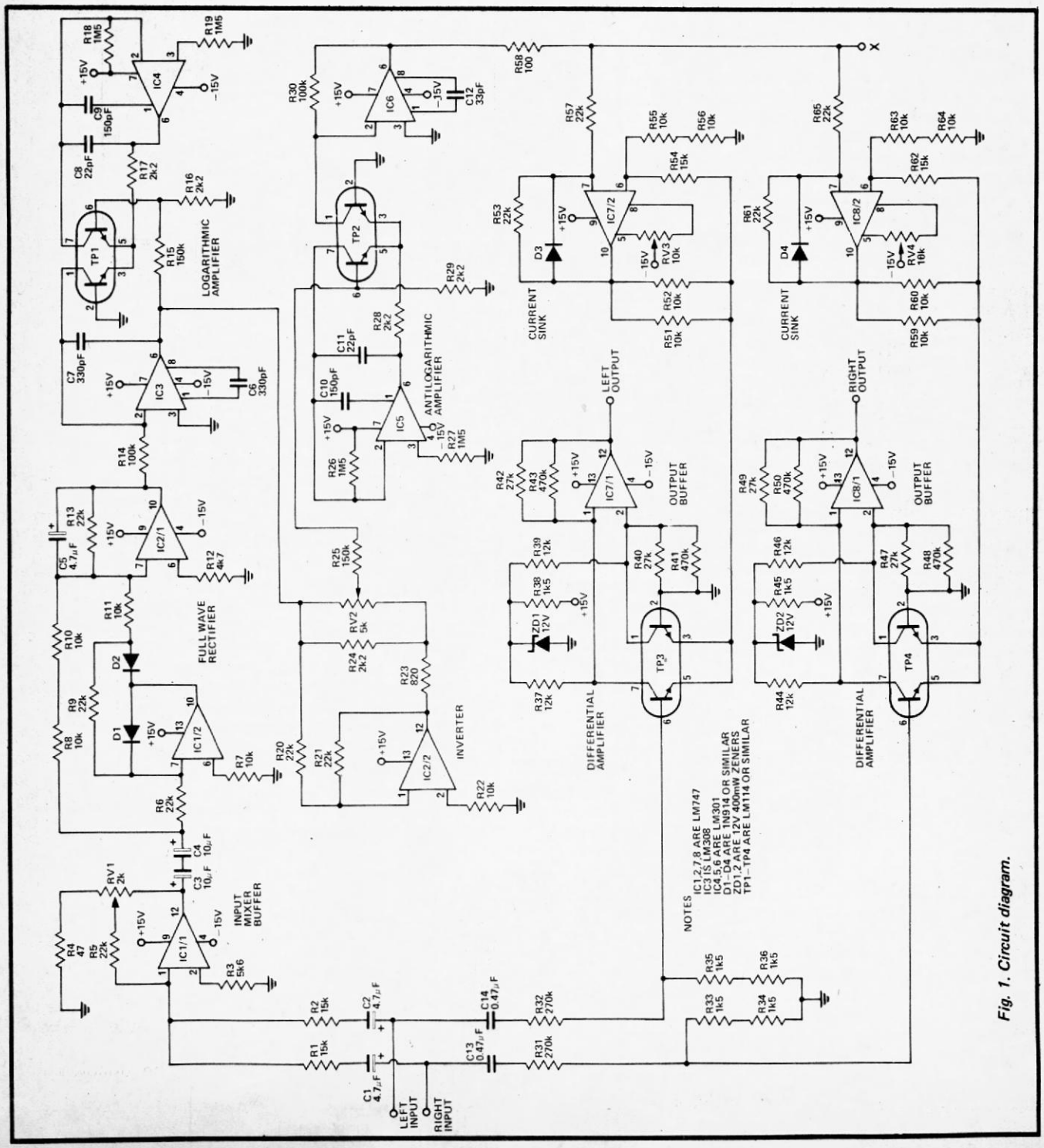
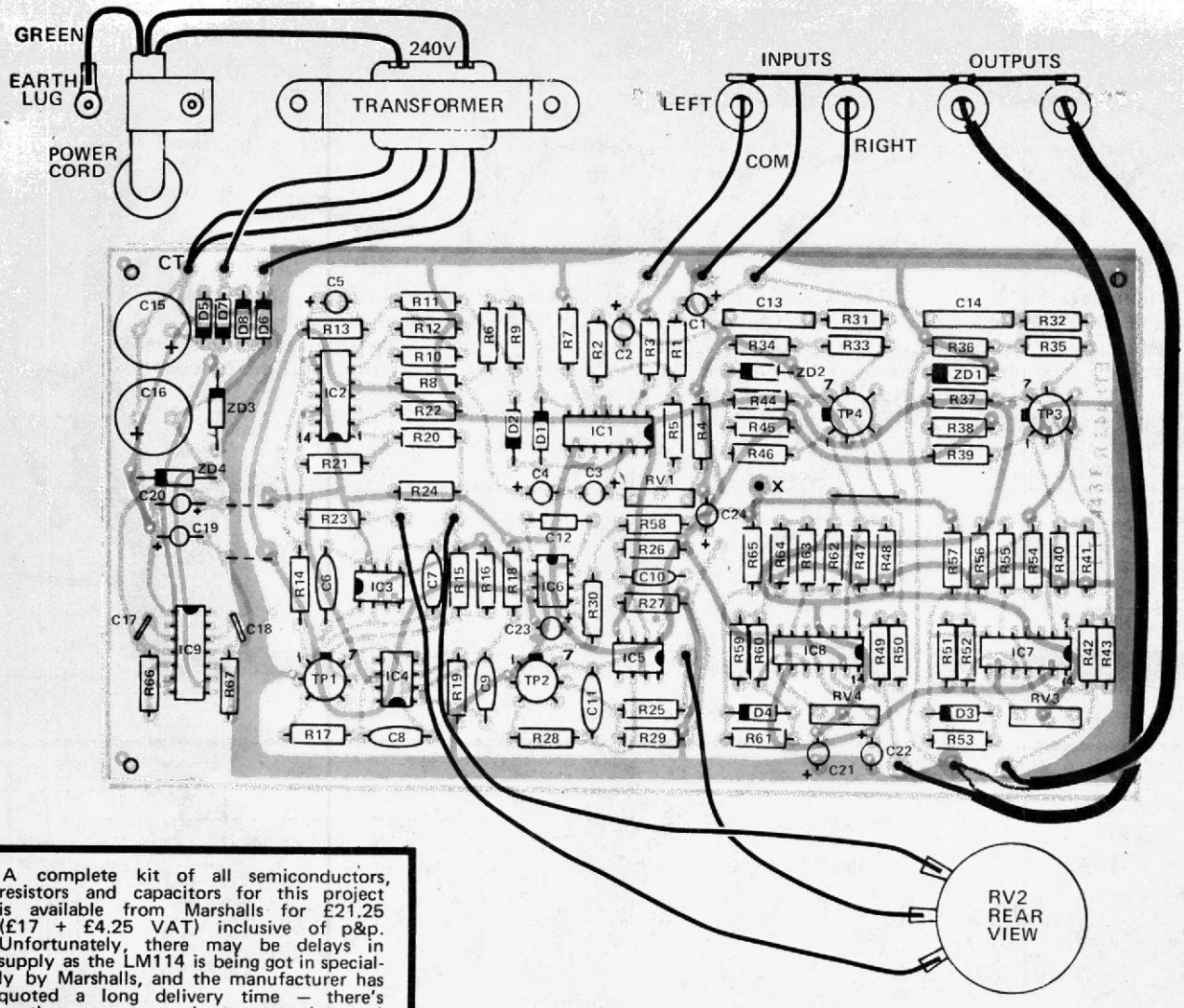


Fig. 1. Circuit diagram.



A complete kit of all semiconductors, resistors and capacitors for this project is available from Marshalls for £21.25 (£17 + £4.25 VAT) inclusive of p&p. Unfortunately, there may be delays in supply as the LM114 is being got in specially by Marshalls, and the manufacturer has quoted a long delivery time — there's another component shortage on the way!

Fig. 2. Component overlay (not full size)

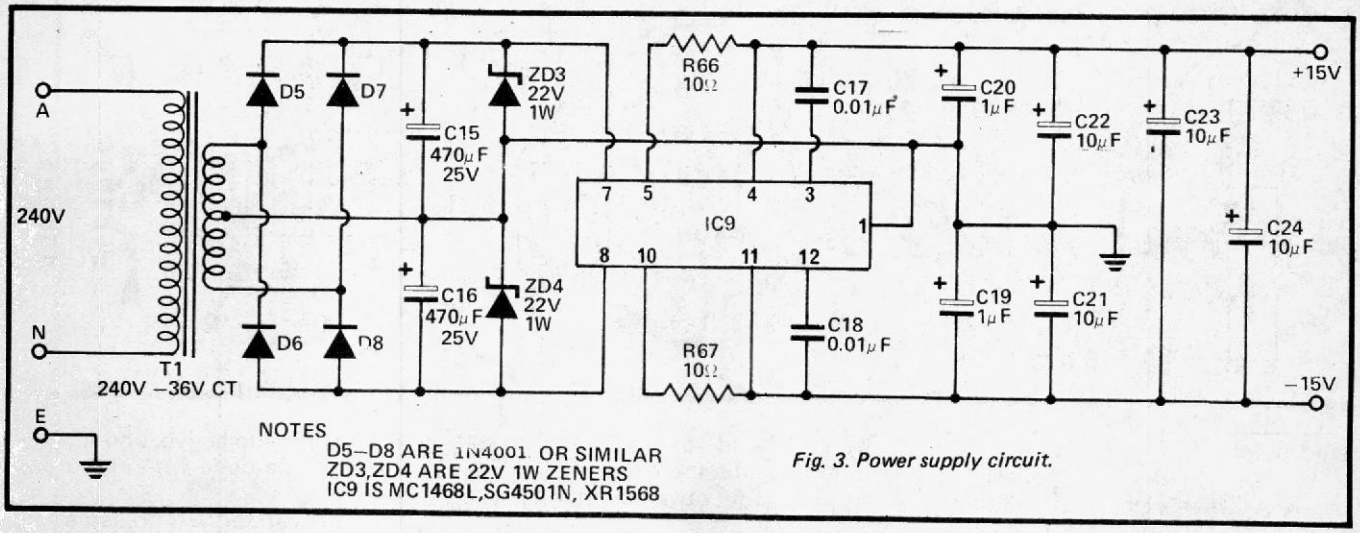


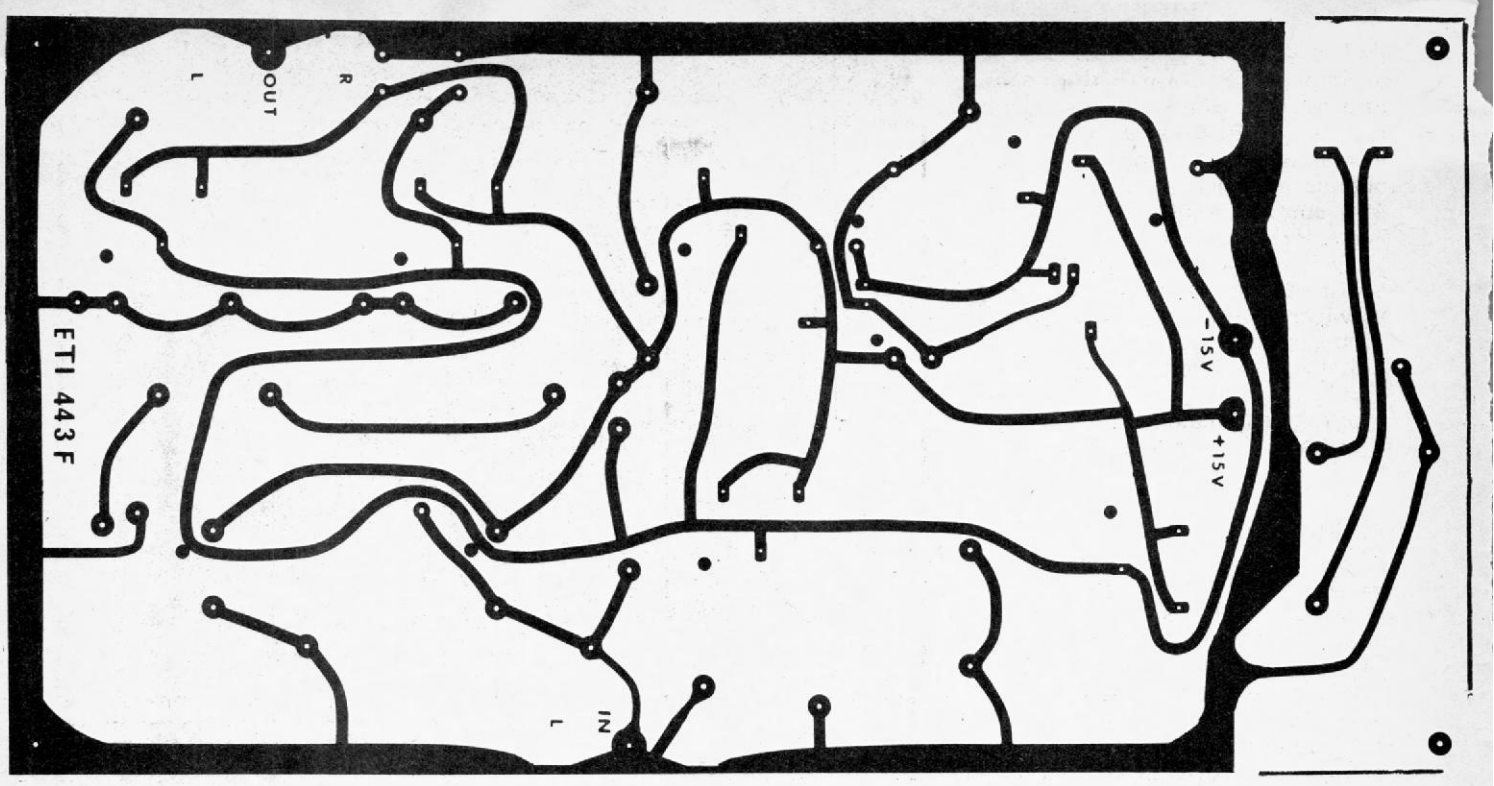
Fig. 3. Power supply circuit.

pander.

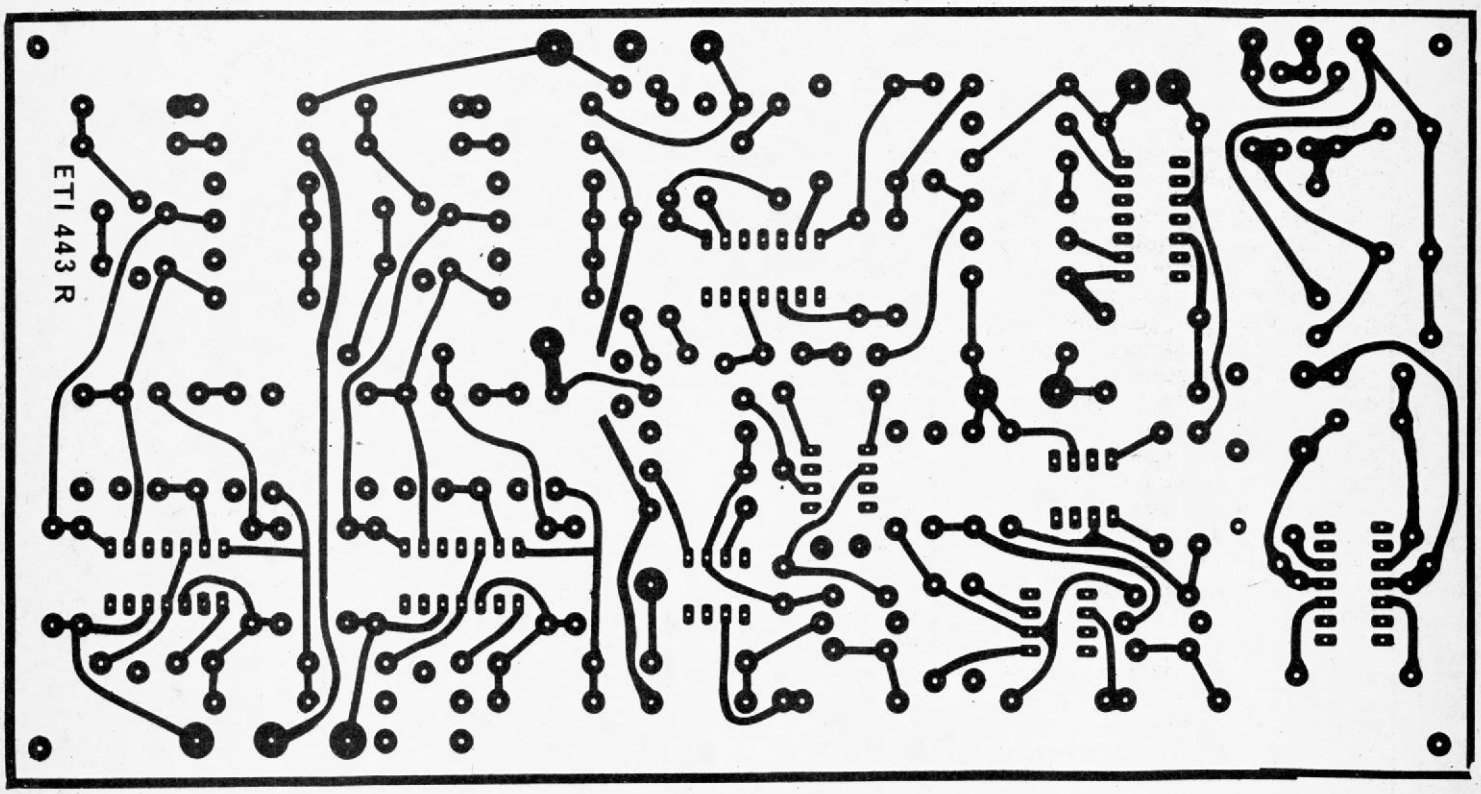
SETTING UP

With the power supply connected (check for correct polarity), apply a strong (about 1 volt) audio signal to both stereo inputs, while the point marked 'X' is shorted to ground. Monitor the left channel output with a high sensitivity meter (or amplifier) and adjust RV3 to the point where the output JUST disappears. Repeat with the right channel and RV4. This procedure balances out the input offset voltage of the current sinks, and ensures that the audio gain will be controlled correctly at the low end. Remove the input signal and the short circuit.

RV1 is set by the following



Double-sided PCB pattern (full size).



procedure:

(1) Connect the compressor-expander to its associated equipment, and supply an input of moderate level (e.g. music of average loudness). RV1 should be fully clockwise when viewed from the input edge of the board.

(2) Turn the compress-expand control to full compression, and adjust RV1 to bring the output up to its original level (loudness).

(3) Turn the compress-expand control towards the expansion end, and note any obvious change in output level.

(4) If a decrease in level occurs, turn RV1 slightly anticlockwise; if an increase occurs, turn RV1 slightly clockwise.

(5) Repeat steps (3) and (4) until the level remains reasonably constant over the whole range of compression and expansion. Note that this adjustment is subjective, and it does not need to be done with any great accuracy.

If RV1 cannot be adjusted as described, it means that the signal level is outside the optimum range of the compressor-expander. Somewhat higher signal levels can be accommodated by increasing the value of R1 and R2, whilst for lower signal levels, R4 should be decreased. If correct adjustment of

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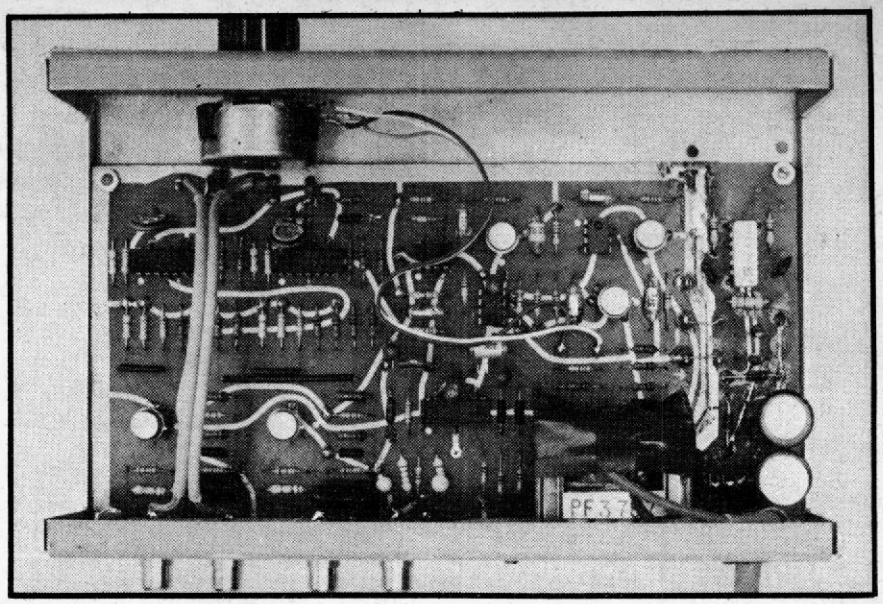
RV1 is obtained well towards the anticlockwise end, then an improved signal-to-noise ratio results if R34 and R36 are increased to 18K, and the stereo outputs are each attenuated by a 470 ohm/3.9K divider. However, this modification is not essential.

With no input signal applied adjust RV2 such that the voltage at its wiper is zero volts. Now fit the knob such that the pointer lines up with the 1.0 calibration. Now check that the potentiometer travel approximately matches the scale. If not reverse the two outside leads to it.

HOW TO USE

The use of a compressor-expander need not be confined to those situations where such a device is really needed. Practically all tapes and many records become more listenable with a small amount of expansion.. On the other hand, background music is far less obtrusive if the volume is compressed to some extend. The key to listening pleasure lies in the handling of the compress-expand control. Don't move it far from the 1.0 position unless there is some definite reason.



Interior of the unit.

One final word of warning — this device is quite capable of outputting a signal of 10 volts. It would be wise to ensure that your amplifier is capable of accepting this voltage without damage.

HOW IT WORKS

The heart of an audio compressor-expander is invariably a voltage controlled amplifier; that is, an amplifier whose gain is set by means of an applied voltage. This voltage itself must be derived from the amplitude of the audio input signal, averaged over some preset period, and modified to give the required compression or expansion characteristics. In the circuit of Fig. 1, each portion of the circuit is identified according to its function. These portions, in turn, are grouped into three main sections; an AC to DC converter, a power function generator, and a stereo analogue multiplier.

The two channels of stereo input are mixed in buffer amplifier IC1/1, and the gain of this stage is set so that an output of about 1 volt is given by a signal which corresponds to moderate loudness. Amplifers IC1/2, and IC2/1 are used to obtain precision full-wave rectification of the mixed input, and the resulting positive DC voltage is stored in capacitor C5. The choice of value for C5 is important, and it will be discussed in detail later on.

Amplifiers IC3 and IC4 together with the transistor pair TP/1 constitute a logarithmic amplifier. With the components shown, the behaviour of this amplifier is described by the equation:

$$E_{out} = -4.151ogE_{in}$$

The inverse of E_{out} is obtained from amplifier IC2/2 and by connecting the compression-expansion control potentiometer as shown between the input and output of this stage, any voltage between E_{out} and $-0.3E_{out}$ can be obtained. IC5, IC6 and TP_2 are combined as an antilogarithmic or exponential amplifier which is the exact inverse of the logarithmic amplifer, so that the effect of all these operations on the input signal is to give to a positive DC output voltage, equal in magnitude to the input voltage raised to the power k, where k can have any value from —0.3 to 1.

In the analog multiplier sections, this voltage (E_{in}) is converted to current by amplifiers IC7/2 and IC8/2 thus setting the effective gain of the differential amplifiers TP_3 and TP_4. These are directly coupled into the output buffers IC7 and IC8/1 so that the stereo signals reaching the outputs have been amplified by a factor which depends on the average amplitude of the signals, and the compression-expansion control setting. The actual voltage gain can vary from 0.0004 to 14, which represents a power gain range of 97dB.

PARTS LIST — ETI443

R1, R2	15k
R3	5k6
R4	47R
R5, R6, R9, R13, R20, R21	22k
R7, R8, R10, R11, R22	10k
R12	4k7
R14, R30	100k
R15, R25	150k
R16, R17, R24, R28, R29	2k2
R18, R19, R26, R27	IM5
R23	820R
R31, R32	270k
R33, R34, R35, R36	1k5
R66, R67	10R
All ½W, 5%	
R37, R39, R44, R46	12k
R38, R45	1k5
R40, R42, R47, R49	27k
R41, R43, R48, R50	470k
R51, R52, R55, R56, R59, R60, R63, R64	10k
R53, R57, R61, R65	22k
R54, R62	15k
R58	1k
All ½W, 2% (may be selected from 5% resistors)	
RV1	2k trimmer
RV2	5k wirewound pot
RV3, RV4	10k trimmer
C1, C2, C5	4.7µF 25V tantalum
C3, C4	10µF 25V tantalum
C6, C7	330pF
C8, C11	22pF
C9, C10	150pF
C12	33pF
C13, C14	0.47µF polyester
C15, C16	470µF 25V electrolytic
C17, C18	0.01µF polyester
C19, C20	1µF 25V tantalum
C21, C22, C23, C24	10µF 35V tantalum
TP1, TP2, TP3, TP4	LM114 Dual transistor or equivalent
IC1, IC2, IC7, IC8	LM747
IC3	LM308
IC4, IC5, IC6	LM301
IC9	MC1468L or equivalent
D1, D2, D3, D4	1N914
D5, D6, D7, D8	1N4001
ZD1, ZD2	12V, 400mW
ZD3, ZD4	22V, 1W
T1	240V/36V CT transformer
PCB ETI 443	
4 Phono sockets 4 6mm spacers	
chassis and cover 200x63x125mm approx	
nuts, bolts and assorted hardware	