Compressor/Limiter

When it comes to compressing those troublesome signals that are prone to overload, this ETI project really does the job.

COMPRESSORS and limiters have many uses in professional recording and broadcasting, and they can also be pretty useful to the amateur. Perhaps the single most important use is for overload protection: the limiter is set up so as to remain inactive until a signal occurs which would overload following circuits (perhaps a radio transmitter or power amplifier), at which point gain reduction cuts in and, without being very noticeable about it, the unit prevents blown fuses, gross distortion or worse.

The circuit described here has been designed to be capable of both the compressing and limiting actions - it all depends on the signal size you apply and the gains you set in the circuit. With the component values shown, the specification of this unit is very similar to devices currently in use in stereo radio broadcasting.

On the Attack

In this circuit the attack has been made very fast indeed, the time constant being 220 microseconds: hence the time taken for the limiter to react fully to an overload above the limiting threshold is approximately 500 microseconds. The decay time was chosen to be 330 milliseconds; hence

How it Works

The left and right channels of the unit are identical, so this description will be confined to the left-hand channel.

IC1 forms a buffer, and its gain is adjustable by PR1 so that it can be used to set the input sensitivity. The variable gain cell is made up from IC2 and IC7a and their associated components. The configuration used is slightly unusual: IC2 forms a conventional inverting amplifier, its gain being determined by R_{FB} R_{IN} in the usual way. However, while R_{IN} is simply R2, R_{FB} is made up from R4 and IC7a which, as an operational transconductance amplifier, can be used as acurrent-controlled resistor. With the addition of a voltage-to-current converter to drive the control input of the LM13600, a complete VCA is formed which will produce a gain inversely proportional to the control voltage.

The first stage of the gain-control side chain is a full-wave rectifier made up from IC3a and IC6a. Q1 boosts the output current drive capability of the rectifier in order to produce a fast attack characteristic when charging C11.

From C11 onwards until the final voltage-to-current converters for the VCA, the two side chains are combined into one channel, the highest of the left or right input signals being registered on C11. In this way stereo ganging is achieved, and this prevents the stereo image from wandering from side to side during gain reduction (if the overload signal is in one channel only). The adjustment of the decay time and limiting threshold for both left and right channels is achieved easily and equally by R32 and PR5. IC8b is used as a high impedance buffer for the control voltage held on C11, which is discharged by R31. The output of this buffer is fed to PR5, which controls the side chain gain and hence the limiting threshold.

The only problem with the particular VCA configuration chosen is that should the control voltage (and hence control current being fed to IC7a) fall to zero, the gain of the VCA will increase to the open-loop gain of IC2, probably resulting in the VCA output reaching one of the supply raisl (as is usually the case when an IC amplifier loses its feedback). In order to prevent this from happening, the control voltage Vc is prevented from going below OV5 by zener ZD1 and preset PR6. Thus the higher of either V_{MIN} or the output of PR5 is passed viaD11 or D12 to the law-shaping amplifier IC8a.

The diode D13 and resistors R35, 36 are configured to make up for the voltage drop across D11 and D12, and maintain a tight compression ratio, typically 10:1. The output of the shaping amplifier provides a low source impedance to drive the voltage-to-current converter IC9a and Q3 (note that the left and right channels split again at this point).

TABLE 1

Measured performance of the prototype.

Gain:	0 dB (adjustable)
Bandwidth (3 dB points):	10 Hz and 30 kHz approximately
Input impedance:	22k
Output impedance:	100R
Limiting threshold:	0 dB (adjustable)
Compression ratio for signals exceeding threshold:	10:1

Crosstalk with non-speaking channel terminated with 600R (left-to-right or right-to-left):

100 Hz	1 kHz	10 kHz	20 kHz
-70 dB	-70 dB	-68 dB	-65 dB

Noise with input terminated as above: -70 dB
(this is the gain required to make noise at the output peak to 0 dB on a standard broadcast peak program meter, ie this is the peak noise. Should a measurement be made with an RMS reading meter, this measurement may improve by as much as 6 dB).

Control voltage breakthrough onto non-speaking channel with 20 dB of gain reduction occurring on the other channel:

100 Hz	1 kHz
-68 dB	-68 dB

Tracking between channels during gain reduction: better than 0.3 dB

Distortion at 1 kHz:

Input	Output	Distortion
-8 dB	-8 dB	-66 dB (.1%)
0 dB	-1 dB	-60 dB (.1%)
+10 dB	0 dB	-58 dB (.13%)

Distortion at 100 Hz:

Input	Output	Distortion
-8 dB	-8 dB	-58 dB (.3%)
0 dB	-1 dB	-45 dB (.6%)
+10 dB	0 dB	-38 dB (1.3%)

NB. These figures for 100 Hz distortion were measured with a recovery time constant of 100 milliseconds (total recovery time approximately 220 milliseconds), hence a certain amount of distortion due to the compression of individual waveforms is to be expected. Increasin the recovery time constant as in the final design will improve the low frequency distortion measurements, until for long recovery times (greater than 3 seconds) they will approach the values obtained for 1 kHz.

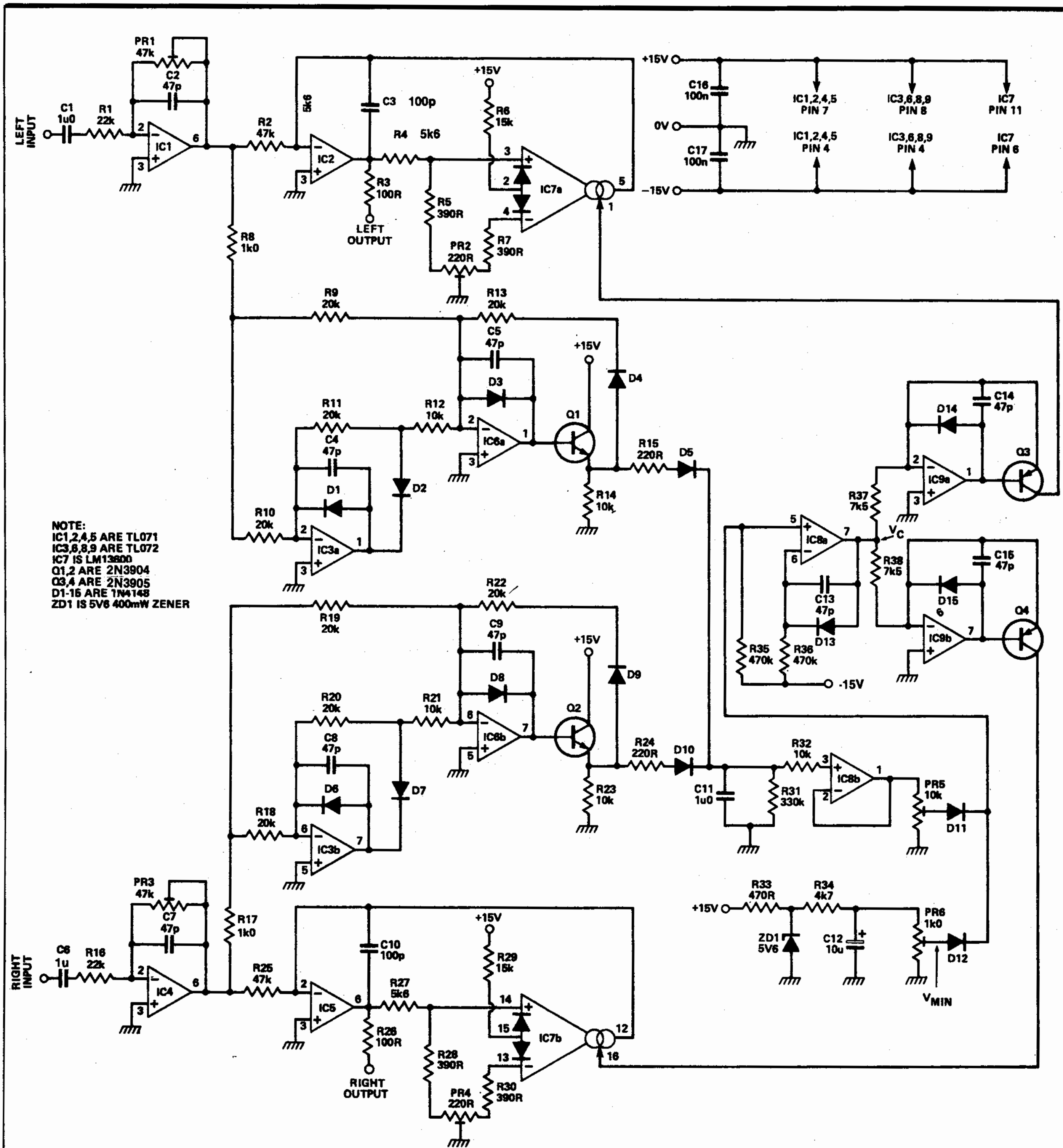

Fig 1. The schematic diagram of the stereo Compressor/Limiter.

full recovery takes place approximately 700 milliseconds after the overload has been removed from the input. This recovery time was chosen after much subjective assessment, and is the fastest possible without undue distortion of low frequencies (this being a common problem in all compressor/limiters). However, as this is a simple one-resistor adjustment it is easy to experiment and find the best compromise for different uses.

Shaping Up

The need for the shaping amplifier built around 1C8a arises because the side chain is, like most professional designs, an open loop system deriving its input from the incoming program material, not from the VCA output. This has the advantage that the limiting threshold and other dynamic characteristics may be altered easily.

Before installing the VCA ICs and powering up, it would be wise to check the side chain components; a fault which resulted in no control current to IC7 could damage the LM13600. Remove ICs 2 and 5; apply power and measure the current into pins 1 and 16 of IC7. This should read in the region of 65 uA. Vmin should be OV5, and there should be no signal present.

The setting up procedure is very simple indeed. PR6 should be adjusted so that Vc is held at OV5 with no input

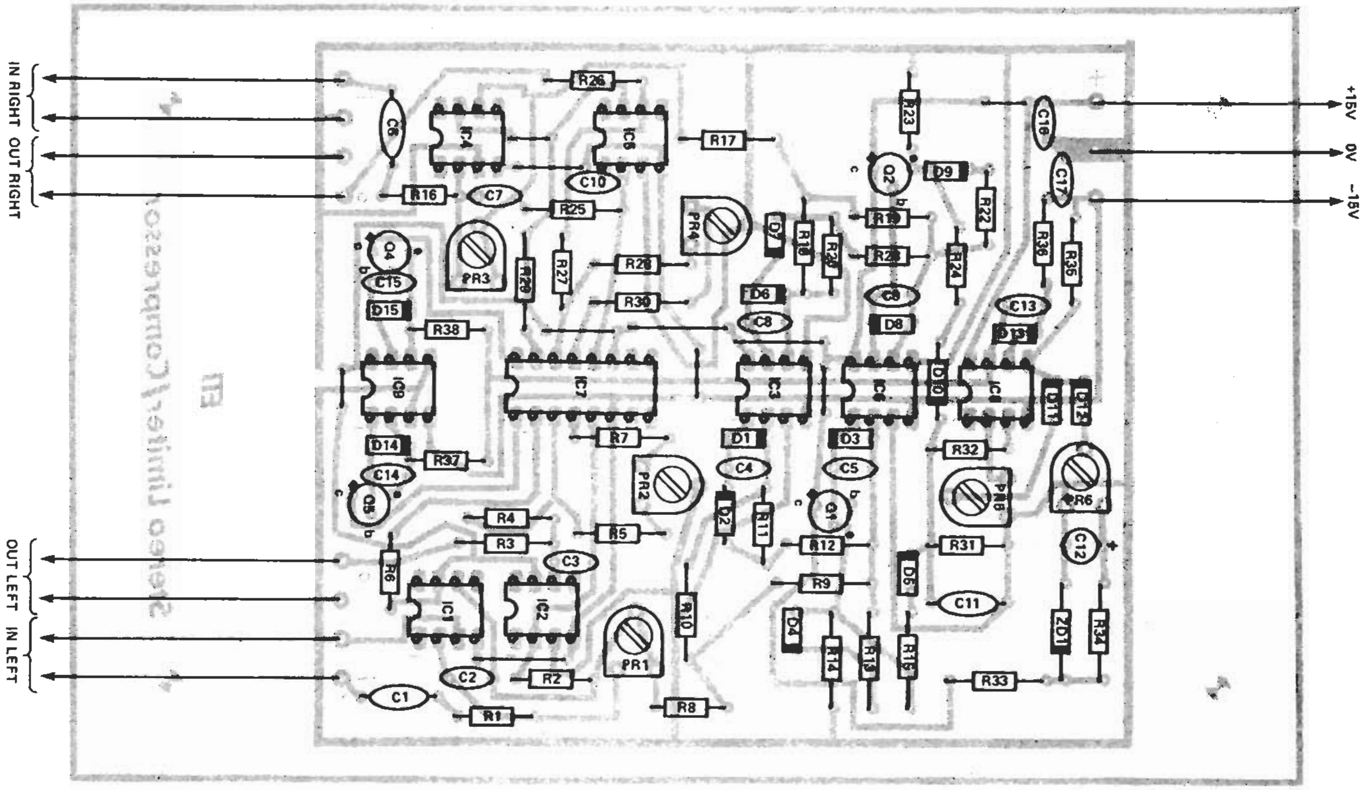

Fig 2. The component overlay.

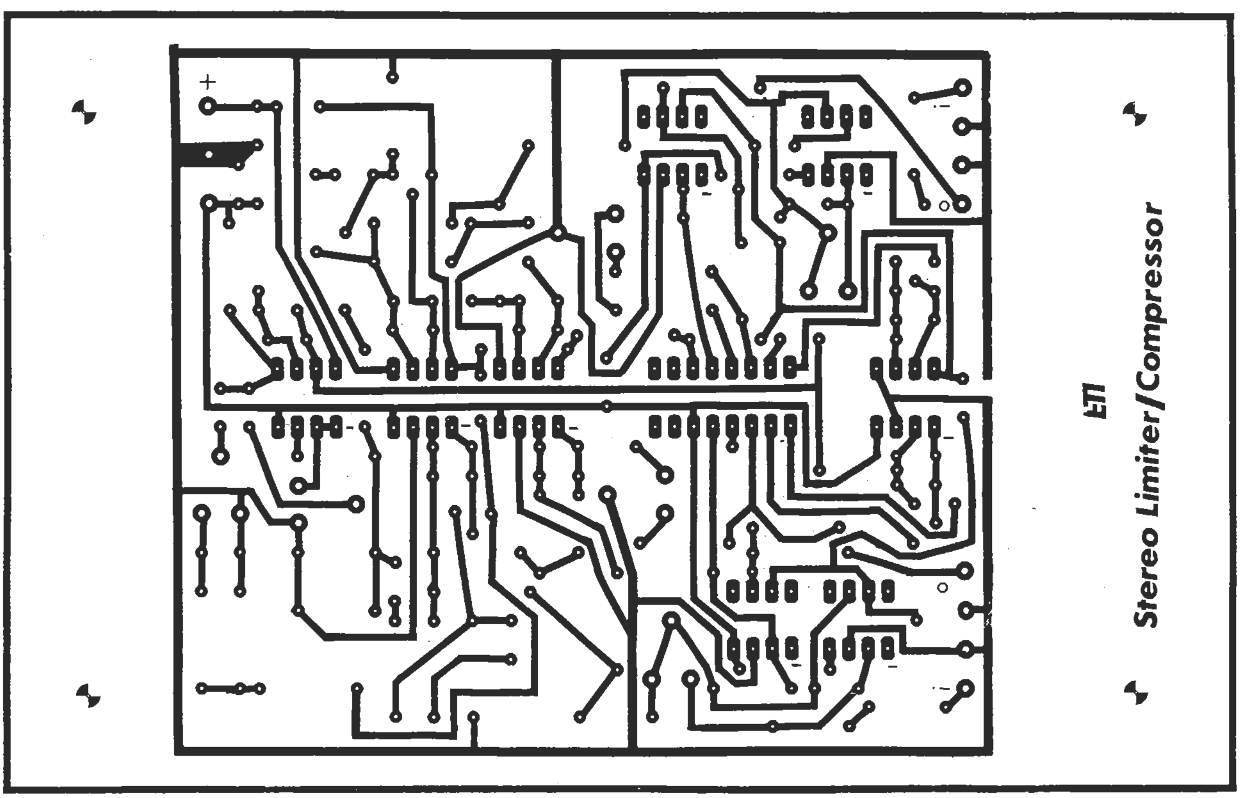

Fig 3. The printed circuit layout, foil side.

signal. PR1 and PR3 should then be adjusted to give the required gain from each channel (usually 0 dB). That concludes the static setting-up, except for PR2 and PR4 which should be adjusted for zero offset at the output of the VCA. This ensures minimal control voltage breakthrough onto the audio output during gain reduction.

To set the compression threshold, a high level signal (for example, +10 dB) should be applied to the input, and PR5 adjusted to give 0 dB at the limiter output.

If the above sequence is followed, the limiter will act as a normal unity-gain amplifier for all signals below 0 dB, and will reduce the gain of all signals above this threshold such that the output at no time exceeds 0 dB. Should the limiting threshold need to be reduced to, say, -10 dB to be more compatible with domestic equipment, then all that is required is an increase in the gain of the side channel by that amount. This is easily achieved by increasing R13 and R22 from 20k to, say, 47k. Should an indication of gain reduction be required, this is easily provided by buffering off Vc, the control voltage, by 1k0 or so to prevent any fault on the metering equipment affecting the operation of the limiter (or this metering equipment could consist of a simple bargraph driver and LEDs).

Parts List

Resistors (all ¼W, 5%)	
R1,16	22k
R2,25	47k
R3,26	100R
R4,27	5k6
R5,7,28,30	390R
R6,29	15k
R8,17	1k0
R9-11,13, 18-20,22	20k
R12,14,21, 23,32	10k
R15,24	220R
R31	330k
R33	470R
R34	4k7
R35,36	470k
R37,38	7k5
Potentionmeters	
PR1,3	47k miniature horizontal trim pot
PR2,4	220R miniature horizontal trim pot
PR5	10k miniature horizontal preset
PR6	1k0 miniature horizontal preset
Capacitors	
C1,6,11	1u0 polycarbonate
C2,4,5,7-9, 13-15	47pF ceramic
C3,10	100pF ceramic
C12	10uF 16 V tantalum
C16,17	100nF polycarbonate or ceramic
Semiconductors	
IC1,2,4,5	TL071
IC3,6,8,9	TL072
IC7	LM13600 (National)
Q1,2	2N3904
Q3,4	2N3905
D1-15	1N4148
ZD1	5V6 400 mW zener
PCB, suitable case, etc.	

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