compressor

Compressors are now being used on an ever-increasing scale. They may be found in tape recorders, intercom systems and baby alarms, public address systems, discotheques and of course broadcast transmitters. A compressor supplements a manual volume control and allows a system to adjust itself to a wide range of input signals with little distortion.

The design described here should find a wide range of applications with the electronics enthusiast.

The aim of compression

Where signals with a wide dynamic range have to be processed it is desirable that as little distortion as possible should occur. The designer of, say, a public address system may have given much thought to achieving a good distortion figure, but this is of no avail if the system is overloaded by an enthusiastic speaker shouting into the microphone. It is of course possible to prevent a circuit from being overloaded by attenuating the input signal with a fixed or manually variable attenuator, but then in the example above the person who mumbles into his notes would certainly not be heard.

This is where a dynamic range compressor comes in. A compressor is basically an attenuator, or variable gain amplifier, which is controlled by the signal it is attenuating, either directly or by a control voltage derived from the signal. As the signal increases so does the degree of attenuation, so the compressor tries to keep the output signal constant whatever the input. This cannot be achieved in practice, but it is possible to limit the output to a narrow range over a wide range of input signals. In a p.a. system (figure 1) a compressor could be included between the microphone preamp and the normal volume control. The compressor, like death, is a great leveller.

Compressor Transfer Functions

At first sight it would seem to be an admirable aim to control the output signal amplitude with the input signal as in figure 2. This system has an overall gain of $\frac{K}{v_i}$, where K is a constant and v_i is the input voltage (for an attenuator of course the gain is less than 1).

$$So \ V_o = \frac{v_i K}{v_i} = K.$$

The output voltage is therefore constant for all input voltages. This seems admirable until one considers what happens

Figure 1. Block diagram of a p.a. system including a compressor.

Figure 2. A first approach to a transfer function for a compressor. This is doomed to failure however.

Figure 3. Black-box representation of a square-law compressor.

Figure 4. a. Voltage-current curve of a filament lamp. The resistance increases with increased current.
b. Compressor using a lamp and a fixed resistor.
c. Transfer function of the compressor.

Figure 5. a. Voltage-current curve of a VDR.
b. Compressor using a VDR and a fixed resistor. c. Transfer function of the compressor.

Figure 6. Dynamic characteristics of various types of compressor in response to a sudden burst of signal.

Figure 7. Block diagram of an active compressor using a peak detector to derive a control voltage which alters the attenuator.

Figure 1.

Figure 2. $gain = \frac{K}{V_i}$

Figure 3. $gain = \frac{K}{V_o}$

Figure 4. a, b, c.
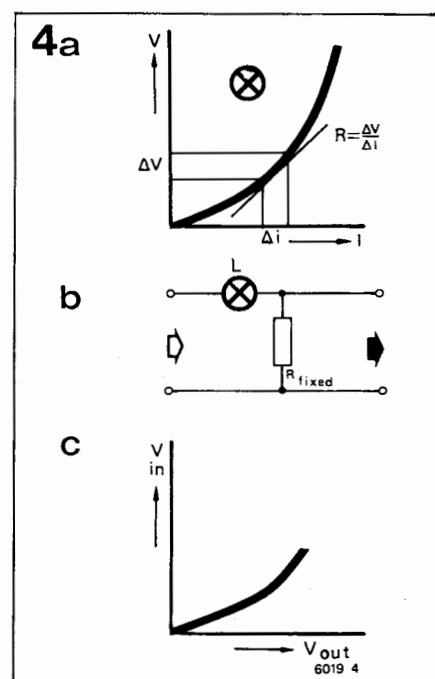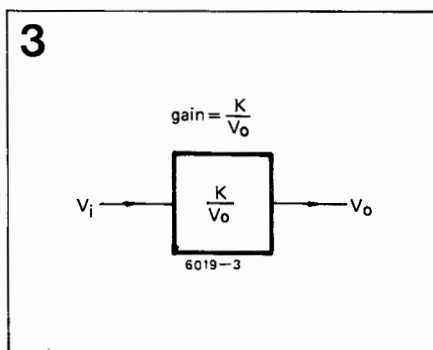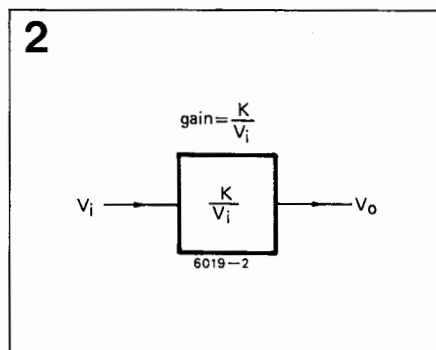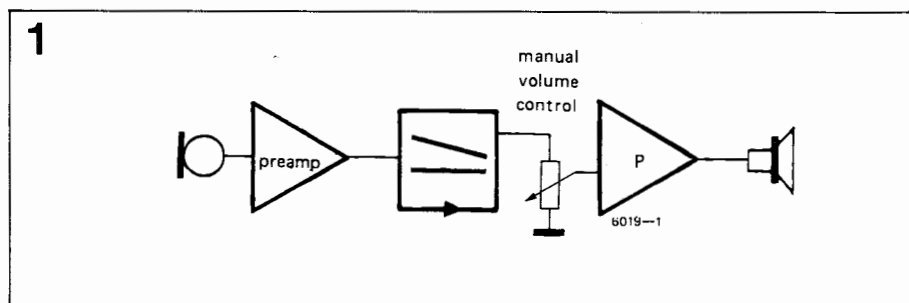
when v_i is zero. The gain then becomes infinite and this idea becomes unnattractive.

A much better solution is to control the output signal with the output signal, which at first sight may seem odd. In figure 3 however it can be seen that the gain is $\frac{K}{v_0}$.

Therefore $v_0 = \frac{Kv_i}{v_0}$.

or $v_0^2 = Kv_i$

This is a square-law compressor function. Of course, other functions may be achieved, notably logarithmic, where $v_0 = K \log v_i$.
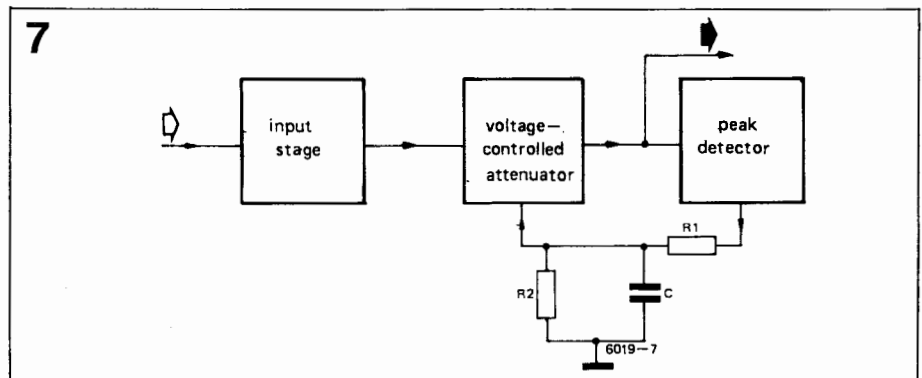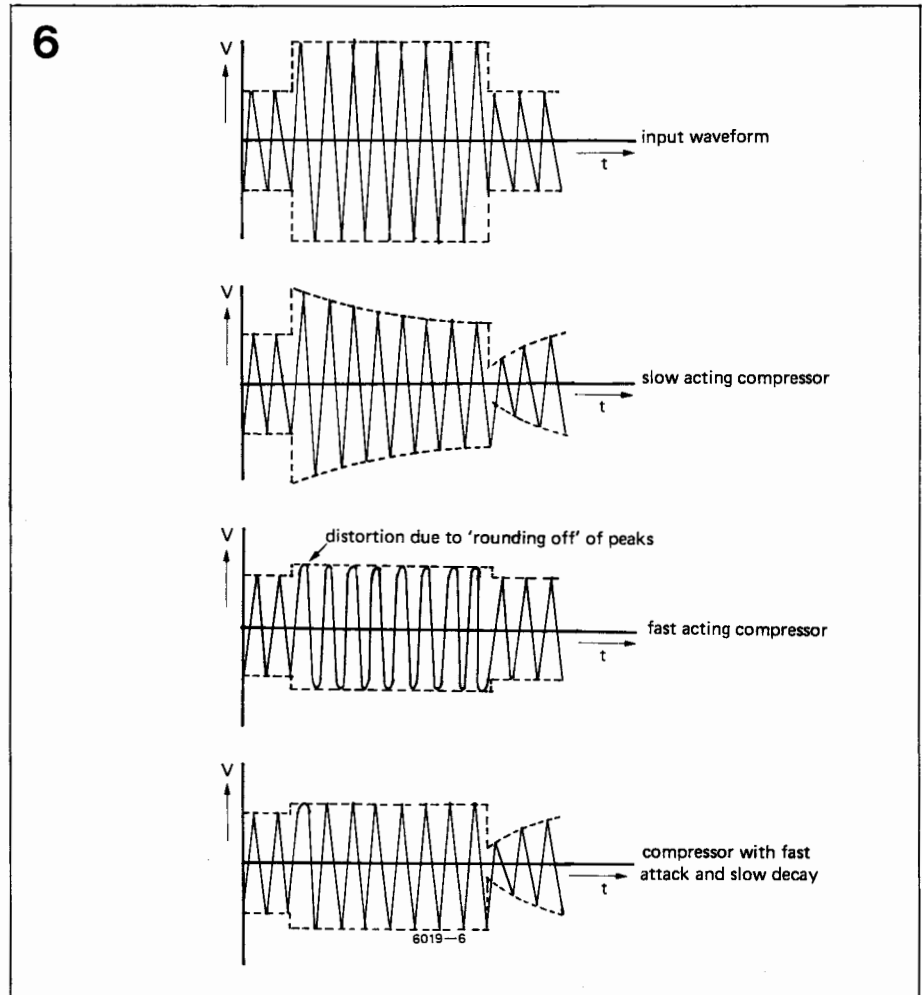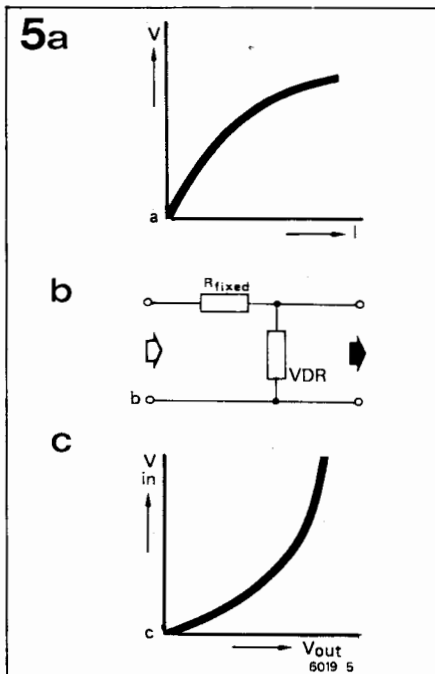
Practical Compressor Circuits

There are many different kinds of compressor circuit. One of the oldest and simplest circuits makes use of the nonlinear resistance of an incandescent lamp, whose resistance increases as the current through the filament increases. In figure 4 the resistance of the lamp, which forms the upper limb of the attenuator, is low at low signal levels so only a small portion of the signal voltage is dropped across it. At higher signal levels the resistance increases and a larger proportion of the signal voltage is dropped across the lamp. The output signal therefore does not increase as much as it would with a normal attenuator. The thermal inertia of the lamp filament means that this circuit cannot follow the actual signal waveform but only the envelope (provided the frequency is not too low) so distortion produced by the circuit is fairly small. The thermal inertia of the filament means, however, that the circuit cannot respond quickly to sudden increases in signal, so that associated circuitry may be overloaded whilst the lamp resistance is changing. Also the range of this type of compressor is limited.

An alternative solution would seem to be the use of a voltage-dependent resistor (VDR) as in figure 5. This has a voltage versus current curve which is approximately the inverse of that of the lamp, so it is included in the lower limb of the attenuator. As the signal is increased the resistance of the VDR decreases so a smaller proportion of the signal appears across it. The response time of a VDR is quite fast so that it will follow sudden increases in signal amplitude, but unfortunately it can also follow the signal waveform so that instead of compressing the envelope amplitude whilst preserving the waveshape it simply 'rounds off' the signal peaks thus introducing distortion. Nonetheless, in certain applications where distortion can be tolerated, such as amateur radio transmitters or intercoms, it does have its uses.

It thus appears that the compressor designer is caught between two stools. A slow-acting device will cause little distortion on sustained large signals, but will not react sufficiently quickly to prevent momentary overloads of the equipment, whereas a fast-acting compressor will react in time to prevent overload, but will of itself introduce distortion. Here, however, an unusual aural phenomenon comes to the designer's aid. The ear is incapable of detecting even large amounts of distortion in transients, so that if a fast-acting compressor is applied to a sudden increase in signal it will prevent gross overloading of the system whilst the distortion it introduces will be unnoticed. Once the compressor has limited the signal, however, the ear can detect the distortion it introduces, so on sustained loud passages the slow response of the lamp-type compressor is required. In fact what is required is a compressor with a fast attack and slow decay characteristic.

input waveform

slow acting compressor

distortion due to 'rounding off' of peaks

fast acting compressor

compressor with fast attack and slow decay

6019—6

5a

b

c

6019 5

7

input stage

voltage—controlled attenuator

peak detector

R1

R2

C

6019—7

The characteristics of various types of compressor are given in figure 6. The triangular waveform was used to show how distortion is caused by a fast-acting compressor.

The discussion has so far been confined to passive devices that are controlled directly by the signal on which they operate, but for a device with different attack and decay time constants it is necessary to turn to active circuits. In figure 7 the signal passes through the input stage and into a voltage-controlled attenuator. The output voltage is taken

Figure 8. An LDR used in a voltage-controlled attenuator. This circuit suffers from slow response due to the inertia of the lamp and LDR.

Figure 9. An r.f. carrier type of compressor. The filter eliminates harmonic distortion of the carrier caused by the attenuator and also eliminates control-voltage noise.

Figure 10. Voltage-current curve of a diode and circuit of a simple diode attenuator.

Figure 11. Balanced type of diode attenuator eliminates control-voltage noise which appears in common mode.

Figure 12. The circuit of the final compressor design.

Figure 13. The printed circuit board and component layout of the compressor.

parts list:

resistors 1/4 Watt:
R_1, R_4, R_{10}, R_{12} = 10 k
R_2, R_9, R_{21}, R_{22} = 220 k
R_3 = 4k7
R_5 = 220 Ω
$R_6, R_{17}, R_{20}, R_{26}$ = 22 k
R_7 = 1 k
R_8, R_{15}, R_{16} = 330 k
R_{11} = 270 k
R_{13}, R_{14}, R_{25} = 3k3
R_{24} = 47 k
R_{27} = 120 k
P_1 = preset 22 k

transistors:
T_1, T_3 to T_9 = BC 109C
T_2 = BC 179C

capacitors:
C_1 = 100 n
C_2, C_{11} = 1 μ, 10 V
C_3 = 180 p
C_4 = 100 μ, 16 V
C_5, C_9, C_{10} = 560 n
C_6 = 100 μ, 4 V
C_7, C_8 = 2,2 μ, 10 V
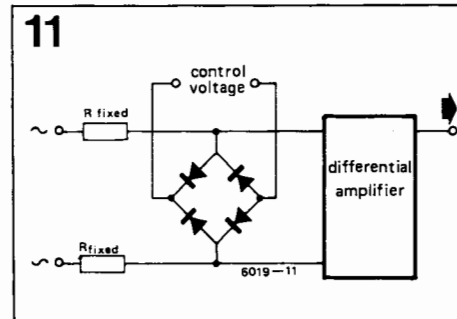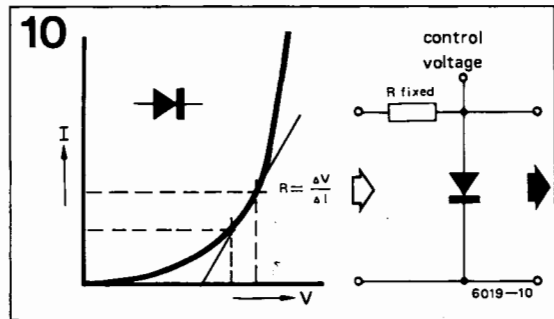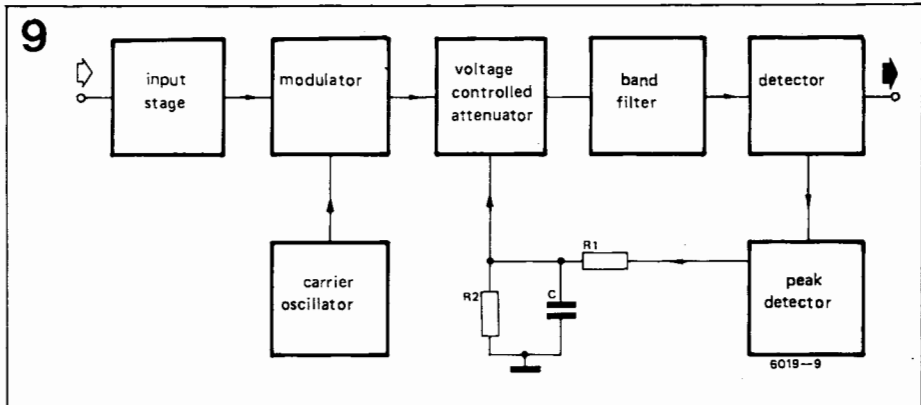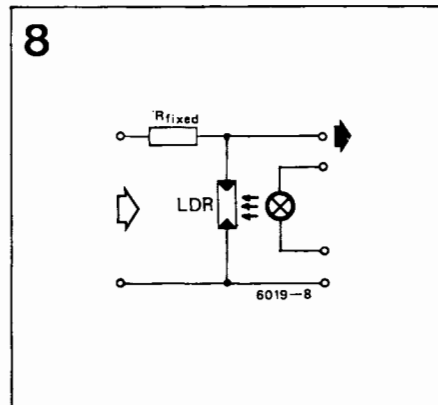
C_{12}, C_{13} = 47 μ, 10 V
D_1 = zener diode 2,7 V
D_2 to D_5 = germanium diode matched pairs AA 119
D_6 to D_8 = silicon diode 1N914 or 1N4148

for V_b = 9 Volt: R_{18}, R_{19} = 270 Ω and R_{23} = 1k8
for V_b = 12 Volt: R_{18}, R_{19} = 330 Ω and R_{23} = 1k5

8

6019—8

9

6019—9

10

6019—10

11

6019—11

Quiescent D.C. test voltage measured with 50 k/V meter

Emitter T_1	: 2.4 V
Emitter T_2	: 8.8 V
Collector T_2	: 5 V
Collector T_3	: 5.5 V
Emitter T_3	: 3.3 V
Collector T_4 and T_5	: 6 V
Collector T_6	: 2 V

12

6019-12
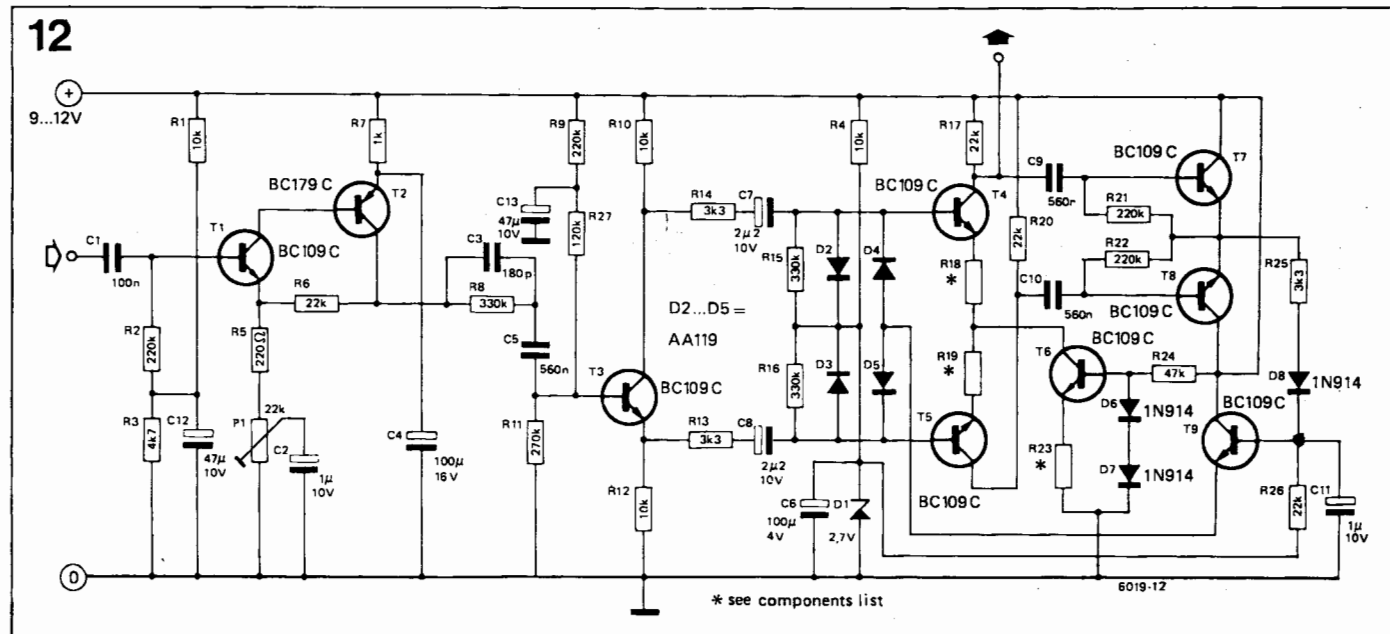
* see components list

from the output of the attenuator and is also fed to a peak detector which rectifies the signal. The rectified voltage charges up the capacitor C via the potential divider consisting of R_1 and R_2. The time constant is $\frac{(R_1 + R_2)}{R_1 . R_2} C$.

The voltage on C increases the attenuation of the voltage-controlled attenuator as the signal increases. If R_1 is small C charges up quickly but since the discharge path for C is via R_2 only, the decay time constant can be made as large as desired so that the voltage on C will not follow the signal waveform.

The voltage-controlled attenuator

Whilst the derivation of a control voltage from the signal is a relatively simple matter the design of a suitable voltage-controlled attenuator is another matter. Ideally the attenuator should be electrically isolated from the control voltage

as otherwise the variations in control voltage with varying signal levels will appear as spurious noise at the output. One way of achieving this would be by using a light-dependent resistor (LDR) as the lower limb of the attenuator, as in figure 8. This would be controlled by a lamp driven from the control voltage.

Unfortunately problems arise due to the slow response of both the lamp and the LDR. Another rather elegant solution is to amplitude-modulate the signal onto a carrier and to vary the modulation depth by a voltage-controlled amplifier stage (figure 9). The compressed modulated signal is then filtered to remove control voltage noise and distortion (mainly second harmonic) and is then demodulated, resulting in a 'clean' compressed signal. Intermodulation distortion can still occur, but this can be minimised by proper circuit design. The design chosen for the final circuit

to be described was a diode attenuator. In its simplest form (figure 10) it suffers from two disadvantages.

1. The signal voltage will itself vary the attenuation as with a VDR thus causing distortion.

2. The control voltage will appear at the output superimposed on the signal thus producing spurious noise.

The first problem may be overcome by making the signal small compared with the control voltage so that it has little effect. The second may be prevented by using a balanced attenuator of four diodes as in figure 11. The signal appears differentially at the input of the differential amplifier and is therefore amplified. The control voltage, however, appears in common mode and is therefore rejected.

The Final Circuit

Figure 12 shows the circuit of a simple

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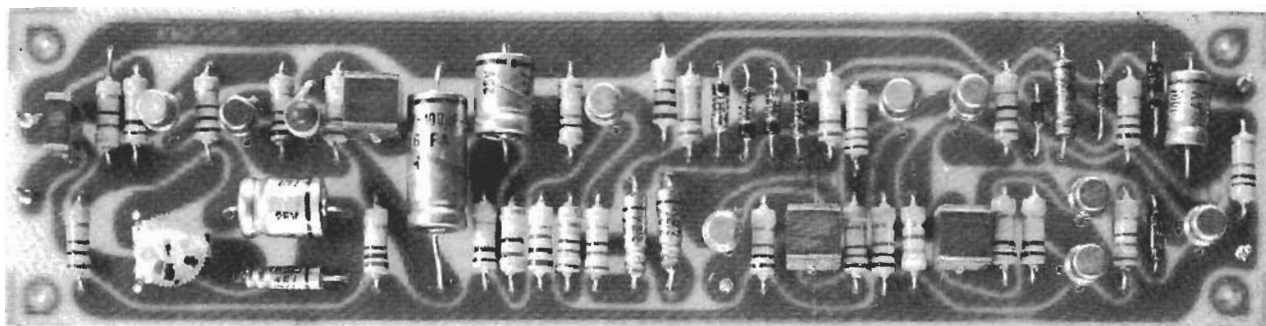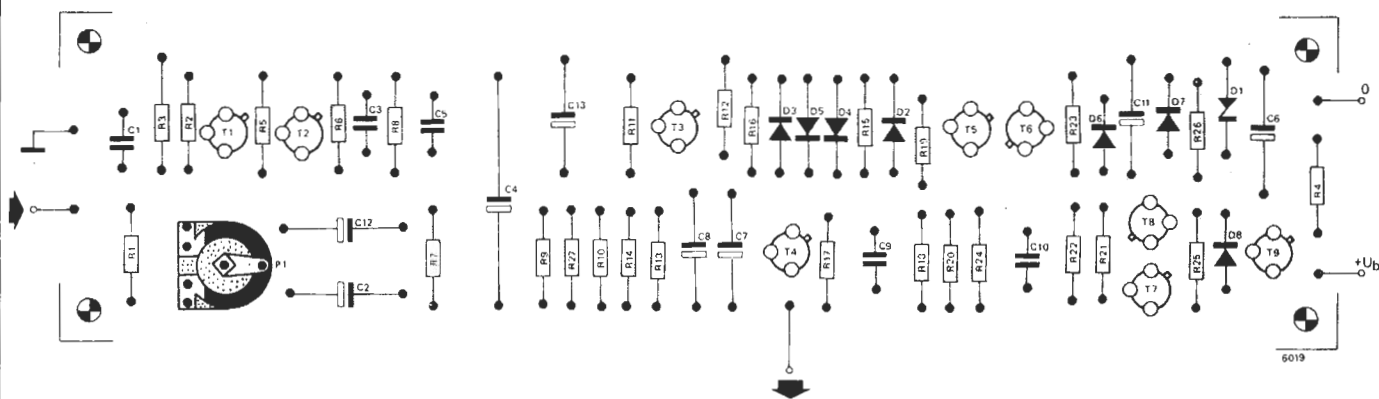
Compressor Specification	
Input impedance	: 180 k
Output impedance	: 25 k (do not load with less than 100 k)
Gain with P_1 at minimum	: 60 (max. input voltage = 1 V)
Gain with P_1 at maximum	: 150 (max. input voltage = 30 mV)
Maximum (compressed) output voltage	: 500 mV
Maximum distortion (gain = 60) a. below compression threshold	: 0,4%
b. at maximum (1 V) input	: 5%
Maximum control current through diode bridge	: 350 μA
Power consumption	: 10 mA at 9 V

compressor intended principally for speech applications. The circuit has an input stage with adjustable gain which is sensitive enough to be driven by a magnetic microphone. This is followed by a phase splitter which produces two antiphase signals to feed into the differential stage T_4, T_5. The compressed output is taken from the collector of T_4 which should not be loaded with anything less than 100 k as this would upset the circuit operation. A class B-type stage T_7, T_8 drives the peak detector D_8, C_{11}. The control voltage appearing on C_{11} is buffered by the emitter follower T_9 and is fed to the diode bridge D_2 ... D_5. D_1 is a threshold control which determines the point at which compression starts. T_6 is simply a constant current source for the differential pair.

The board and component layout for the compressor are given in figure 13 and the performance figures in the table. At first sight it may seem that the distortion with the compressor operating is rather high but compared with the distortion when an amplifier is overloaded it is minimal.

Applications of the compressor

This compressor is sure to find a whole host of applications. It can be used to control the recording level in a tape recorder to prevent overloading of the tape. It can be used in amateur radio installations to achieve the largest possible modulation without overmodulating so that maximum range can be achieved. It can be used in a car radio so that quiet passages may be heard above the engine noise without loud passages being unbearable. The range of applications is limited only by the ingenuity of the constructor - remember, a compressor rules the waves (somewhat straighter than they were originally!).   ◀

Bibliography:

Electronic Engineering, January 1973.

Radio Elektronika, January 1959.

LIMITING INDICATOR

+13V

+14V

TO
p8/R26/T9/C11
JUNCTION.

100K

47K

74I

10K

47K

470/1w