

PATENT SPECIFICATION

(11)

1279 634

1279 634

DRAWINGS ATTACHED

- (21) Application No. 51985/68 (22) Filed 1 Nov. 1968
- (21) Application No. 36466/69 (22) Filed 21 July 1969
- (23) Complete Specification filed 20 Oct. 1969
- (45) Complete Specification published 28 June 1972
- (51) International Classification H04B 1/64
- (52) Index at acceptance
H4R 18AX 22B
- (72) Inventor RAY MILTON DOLBY



(54) SIGNAL COMPRESSORS AND EXPANDERS

(71) We, DOLBY LABORATORIES INC., Incorporated in the State of New York, United States of America, of 333 Avenue of the Americas, New York 10014, N.Y., United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

10 Introduction

This invention relates to signal compressors and expanders such as are disclosed in the specifications of British Patent No. 1,120,541 and British Patent Application No. 1540/68 (Serial No. 1,253,031). The invention is applicable to both Type I and Type II devices, as defined in the second of these specifications and concerns further improvements in devices of the nature disclosed in Fig. 11 of the first of these specifications.

The main characteristic of all the devices described in both the abovementioned specifications is that no attempt is made to establish the required compression or expansion law by operating upon the whole dynamic range of the signal. Rather a main, straight-through signal path is provided, through which signals, and in particular high level signals, can pass undistorted i.e. with dynamic range linearity. With these signals is combined the output of a further path, which can take its input either from the input to or the output from the device. This output, at low signal levels, either boosts or bucks the main signal to provide compression or expansion, respectively. However, the further path includes a limiter so that, at higher signal levels, the output of this path is negligible compared with the main signal, resulting in minimal boosting or bucking. In this way, a compression or expansion characteristic is derived with substantial avoidance of the severe problems inherent in previously known devices which operate on the whole signal in accordance with a non-linear law. It is particularly important that compressors and expanders according to the invention can be made truly

complementary, so that a complete noise reduction system can be provided which does not itself introduce distortion.

For convenience, idealised block diagrams of Type I and Type II devices are shown in Figs. 1 and 2 of the accompanying drawings.

It is well known that noise reduction is desirably effected selectively throughout a signal band, e.g. an audio band, usually in an upper band and/or a lower band of the overall signal band. The aforementioned Fig. 11 concerns the use of a further path with a variable cut-off filter which restricts the compression or expansion to an extreme (i.e. high pass or low pass) band of the signal band. As the output amplitude of the signal passed by the filter increases, the cut-off frequency is automatically shifted nearer to the relevant extreme of the signal band; the pass band of the filter is thereby narrowed, so allowing noise reduction still to take place within this narrowed band without being influenced by the larger amplitude signals excluded by the shift of the filter cut-off frequency.

The Invention

The present invention is concerned with an improved filter configuration in the further path enabling suitable variable cut-off characteristics to be obtained while requiring only a single voltage controlled variable resistance device for varying the cut-off frequency.

The present invention provides a signal compressor or expander comprising a main signal path adapted to pass signals with dynamic range linearity and means for combining with the signals therein, so as to boost or buck such signals, the output signal of a further path which takes its input either from the input to or the output from the compressor or expander and which includes both means for limiting the amplitude of the said output signal and a variable cut-off filter for restricting signals passing through the further path to a restricted band extending to one limit of the overall signal band, the variable filter being responsive to the amplitude of the signal level in the compressor or expander

[Price ...]

SEE FRONT SLIP ATTACHED

to shift the cut-off frequency away from the other limit of the overall signal band as the said amplitude increases, the filter configuration comprising two filters in cascade, namely a first filter comprising fixed-value components and a second filter with a variable cut-off frequency which, under quiescent conditions, lies further from the said one limit than the cut-off frequency of the first filter, the second filter including a controlled variable impedance device responsive to the said amplitude to vary the parameters of the filter and shift the variable cut-off frequency away from the said other limit.

The variable impedance device is preferably a field effect transistor.

The advantages of the invention will become clear in the following description of detailed embodiments of a compressor and an expander. These embodiments are Type I devices, but essentially the same circuitry could be employed in the different configurations appropriate to Type II devices. These embodiments are designed for operation at the upper end only of the audio signal band, as they are intended for use in conjunction with domestic tape recorders. Thus the said one limit of the signal band is the upper limit of the band. The invention could equally well be employed at the lower end of the audio band (the relevant said one limit being the lower limit of the band) in which case the high pass filters hereinafter described would have to become low-pass filters (with appropriate redesign of the circuit throughout). The invention is furthermore not limited to audio applications, and it will be appreciated that the following description is throughout by way of example.

The Drawings.

Figs. 1 and 2 are the aforementioned diagrams of Type I and II devices,

Fig. 3 is a more detailed block diagram of a Type I sliding band compressor,

Fig. 4 is a circuit diagram of a compressor embodying the present invention,

Fig. 5 is a circuit diagram of a complementary expander,

Fig. 6 is a partial circuit diagram of a switched compressor/expander,

Fig. 7 shows a simple passive equalizing network,

Figs. 8 and 9 show characteristic curves of the compressor,

Figure 10 is a circuit diagram of an improved variable filter, and

Figs. 11 to 13 show characteristic curves relating to the embodiment of Fig. 10.

Background.

Figs. 1, 2 and 3 all relate generically to the improvements in the previously mentioned specification as well as to the present invention. Figs. 1 and 2 have already been des-

cribed. Fig. 3 shows a Type I sliding band compressor in more detail; the expander and Type II variants will be apparent from Figs. 1 and 2.

In Fig. 3 the input signal applied to a terminal 1 passes through a resistor 2, constituting the main path, to be summed at an output terminal 3 with the signal from the further path provided through a resistor 2a. The further path comprises a variable filter 4 with input A and output B, followed by an amplifier 5 and clipper 6, which eliminates any transient overshoots remaining in the signal passed by the essentially syllabic limiter 4. The syllabic action is obtained by applying a smoothed control signal to a control terminal C of the variable filter 4. This control signal is derived from the output and/or input of the further path (lines 7 and 8 of which only one need be provided) via an amplifier 9, rectifier 11 and smoothing circuit 13. A filter 8a may also be provided in line 8. When the control signal increases in amplitude, it narrows the pass band of the variable filter 4.

A Compressor embodying the present Invention.

The circuit of Fig. 4 is specifically designed for incorporation in the record channel of a domestic tape recorder, two such circuits being required for a stereo recorder. The input signal is applied at terminal 10 to an emitter follower stage 12 which provides a low impedance signal. This signal is applied firstly through a main, straight-through path constituted by a resistor 14 to an output terminal 16 and secondly through a further path the last element of which is a resistor 18 also connected to the terminal 16. The resistors 14 and 18 add the outputs of the main and further paths to provide the required compression law.

The further path consists of a fixed filter 20, a variable cut-off filter 22 including a FET 24 (these filters constituting the variable filter), and an amplifier 26 the output of which is coupled to a double diode limiter or clipper 28 and to the resistor 18. The amplifier 26 increases the signal in the further path to a level such that the knee in the characteristic of the limiter 28, comprising silicon diodes, is effective at the appropriate signal level under transient conditions. The resistors 14 and 18 are so proportioned that the required compensating degree of attenuation is then provided for the signal in the further path.

The output of the amplifiers 26 is also coupled to an amplifier 30 to the output of which is rectified by a germanium diode 31 and integrated by a smoothing filter 32 to provide the control voltage for the FET 24. The points A, B and C are marked in correspondence with Fig. 3.

3 band
er and 65
a Figs.
a ter-
stitut-
in out- 70
further
The
4 with
ampli-
es any 75
signal
iter 4.
lying a
ol ter-
control
r input
which
applier
13. A
When 85
ude, it
filter 4.
nt In-
ly de- 90
chan-
o such
corder.
nal 10
h pro- 95
gnal is
raight-
14 to
ough a
h is a 100
nal 16.
outs of
de the
1 filter 105
ding a
variable
put of
liter or
ampli- 110
r path
charac-
silicon
signal
resis- 115
at the
uation
further
coup- 120
which
d inte-
ide the
points
ndence 125

The Variable Filter:

To simple RC filters are used, though equivalent LC or LCR filters could be used. The fixed filter 20 provides a cut-off frequency of 1700 Hz, below which diminishing compression takes place. The filter 22 comprises a series capacitor 34 and shunt resistor 36 followed by a series resistor 38 and the FET 24, with its source-drain path connected as a shunt resistor. Under quiescent conditions with zero signal on the gate of the FET 24, the FET is pinched off and presents substantially infinite impedance; the presence of the resistor 38 can then be ignored. The cut-off frequency of the filter 22 is thus 800 Hz, which it will be noted is substantially below the cut-off frequency of the fixed filter 20.

When the signal on the gate increases sufficiently for the resistance of the FET to fall to less than say 1 K, the resistor 38 effectively shunts the resistor 36 and the cut-off frequency rises to 3500 Hz, markedly narrowing the pass band of the filter. The rise in cut-off frequency is of course a progressive action.

The use of a FET is convenient because, within a suitable restricted range of signal amplitudes, such a device acts substantially as a linear resistor (for either polarity signal), the value of which is determined by the control voltage on the gate.

The use of two cascaded filters (12 dB/octave) is important because this results in less noise modulation than a simple one-stage variable cut-off frequency filter (6 dB/octave). However, the phase delay, varying as a function of frequency, produced by two filters in cascade is such as to give a compression versus frequency characteristic as is illustrated in Fig. 8 by curve 40 for an input signal 44 dB down on a peak input taken as 0 dB, rather than the desired shape of curve 42. By putting the quiescent cut-off of the filter 22 well below that of the filter 20 it is possible to achieve a compromise such as curve 44, which is based on an actual measurement and in which the high frequency end is about 10 dB up on the low frequency end. Curves for inputs at -16 dB, -10 dB and 0 dB are also shown to illustrate how the compression action is progressively lessened as the input amplitude increases and the band of the filter 22 narrows. In the drawing shown, the curves are closed together in the vertical scale more than they are in actuality.

The variable band action is illustrated more clearly by the curves of Fig. 9, which show the results of putting a strong (0 dB) signal at a fixed frequency on the input terminal 10 and superimposing a weak (-41 dB) signal which is swept through the whole frequency spectrum. The output on terminal 16 at the frequency of the weak signal is detected by a wave analyser and naturally exhibits a strong

signal at the frequency of the fixed frequency strong input and also exhibits the high frequency lift provided by the compression action. It can be clearly seen how the increasing frequency of the strong signal (200 Hz, 400 Hz, 700 Hz, 1 KHz, 2 KHz) gradually narrows the band within which compression takes place.

Returning to the description of Fig. 4, the resistor 36 and FET 24 are returned to an adjustable tap 46 in a potential divider which includes a temperature compensating germanium diode 48. The tap 46 enables the compression threshold of the filter 22 to be adjusted.

Amplifier and Limiter.

The amplifier 26 comprises complementary transistors giving high input impedance and low output impedance. Since the amplifier drives the diode limiter 28, a finite output impedance is required and is provided by a coupling resistor 50. The diodes 28 are, as already noted, silicon diodes and have a sharp knee around $\frac{1}{2}$ volt.

The signal on the limiter and hence on the resistor 18 can be shorted to ground by a switch 53 when it is required to switch the compressor out of action.

Control Amplifier and Smoothing Filter.

The amplifier 30 is an npn transistor with an emitter time constant network 52 giving increased gain at high frequencies. Strong high frequencies (e.g. a cymbal crash) will therefore lead to rapid narrowing of the band in which compression takes place, so as to avoid signal distortion.

The amplifier is coupled to the smoothing filter 32 through the rectifying diode 31. The filter comprises a series resistor 54 and shunt capacitor 56. The resistor 54 is shunted by a silicon diode 58 which allows rapid charging of the capacitor 56 for fast attack, coupled with good smoothing under steady-state conditions. The voltage on the capacitor 56 is applied directly to the gate of the FET 24.

The Complementary Expander.

A complete circuit diagram is provided in Fig. 5, but a full description is not required as substantially all the circuit is identical to Fig. 4; component values are therefore not for the most part shown in Fig. 5. The characteristic curves, although not shown, are complementary to those of Fig. 8.

The differences between Figs. 4 and 5 are as follows:—

In Fig. 5 the further path derives its input from the output terminal 16a, the amplifier 26a is inverting, and the signals combined by the resistors 14 and 18 are applied to the input (base) of the emitter follower 12, the output (emitter) of which is coupled to the terminal 16a. To ensure low driving impedance,

the input terminal 10a is coupled to the resistor 14 through an emitter follower 60. Suitable measures must be taken to prevent bias getting into the expander.

- 5 The amplifier 26a is rendered inverting by taking the output from the emitter, instead of the collector, of the second (pnp) transistor. This alteration involves shifting the 10 K resistor 62 (Fig. 4) from the collector to the emitter (Fig. 5) which automatically gives a
- 10 suitable output impedance for driving the limiter. The resistor 50 is therefore omitted in Fig. 5.

- 15 It should be noted that it is important in aligning a complete noise reduction system to have equal signal levels on the emitters of the transistors 12 in both compressor and expander. Metering terminals M are shown connected to these emitters.

- 20 Switched Compressor/Expander.

- In a high quality tape recorder, a separate compressor and expander can be provided in the record and playback channel respectively. However, a more economical proposition is to
- 25 utilize a single compressor/expander with a mode switch for selecting the compressor or expander configuration. The further path for this compressor/expander can be as shown in Fig. 5—i.e. everything to the right of the
- 30 points X and Y in Fig. 5 is used unchanged, but the circuitry to the left of points X and Y is changed as shown in Fig. 6.

- In Fig. 6 the input signal on terminal 10b is applied to a first emitter follower stage
- 35 70, the output of which is applied through a resistor 72 to another emitter follower stage 74 (corresponding to the stage 12 of Figs. 4 and 5). The emitter of this stage is connected to the point X to provide the non-inverted
- 40 input to the further path. It will be recalled from the description of Fig. 5 that, in this embodiment, the further path effects inversion. Accordingly the signal received at the point Y, and applied in the record mode by a mode
- 45 switch 76 to the output terminal 16b through the resistor 18, is an inverted signal. To obtain compressor action, the main path must also effect inversion, which is achieved by means of a further transistor 78 with its base
- 50 driven from the emitter follower 74. The main path signal is taken from a collector load resistor 80.

- In the playback (i.e. expander) configuration, the signal from the further path is
- 55 applied by the switch 76 to the base of the emitter follower 74, i.e. before the inverter stage 78. The signal from the further path therefore combines subtractively with the signal in the main path to give expander action.

- 60 Simple Equalization.

The compressor and expander are provided for incorporation in a high quality tape recorder, permitting the user thereof to record

and replay his own tapes with noise reduction. Such a tape recorder can obviously also play back pre-recorded tapes which have been recorded using the compressor of Fig. 4 or a compressor with like characteristics. In order to make it possible for such tapes to be marketed for universal consumption it is desirable to provide a cheaper means of equalizing the signal for incorporation in less expensive recorders. Only by the use of a complementary expander can an undistorted signal be recovered but, to the uncritical ear, the only noticeable defect in the compressed signal is an undue emphasis of high frequencies. This emphasis can be approximately corrected by a simple, passive, treble cut circuit (which acts upon the whole signal). One suitable circuit is illustrated in Fig. 7, the component values being suitable for equalizing a signal recorded through the compressor of Fig. 4.

Further Improvement of the Variable Filter.

In the simplified audio noise reduction system as so far described, it has been pointed out that the variable filter circuit used represents a compromise. For best noise reduction results, especially with regard to noise modulation effects, it is necessary to use a further path filter which has an attenuation rate of at least 12 dB per octave. The high-pass filter required for hiss reduction is conveniently obtained by the use of the two-section cascaded RC network. The last capacitor is paralleled by the FET 24 which can shift the cut-off frequency of the last section upwards to effect limiting of the signal.

Unfortunately, the phase shift produced by the two-section filter results in a mid-band dip in the compressor frequency response. The disadvantages or inconveniences of the dip include an increase in noise level in the few hundred Hertz region (as opposed to noise reduction) and a disparity in signal level (about 1 dB) in the 1 kHz region at high levels when the further path component is switched on and off (noise reduction on-off). An improved variable filter circuit is now described which overcomes the mid-band dip problem and also results in other advantages, notably in decreased dynamic and frequency response errors under conditions of imperfect compressor and expander matching.

Fig. 10 shows the improved circuit, for replacing the circuit between points A, B and C in Figs. 4 and 5. When the FET 24 is pinched off, the second RC network 22 is inoperative, and the first RC network 20 then controls the response of the further path. The improved circuit combines the phase advantages of having only a single RC section under quiescent conditions with the 12 dB per octave attenuation characteristics of a two-section RC filter under signal conditions.

In the practical circuit, using MPF104

reduc- 65
isly also
ve been
4 or a
n order
to be
is desir- 70
ualizing
pensive
ement-
l be re-
he only 75
signal is
es. This
ed by a
ich acts
circuit
t values
ecorded

Variable 85
ion sys-
pointed
i repre-
duction
modu- 90
further
rate of
ass filter
ntly ob-
ascaded
aralleled
-off fre-
o effect

uced by 100
id-band
se. The
dip in-
the few
noise re- 105
l (about
h levels
switched
An im-
scribed 110
problem
notably
response
t com-

for re- 115
3 and C
pinched
erative,
rols the 120
proved
of hav-
uiescent
attenua-
C filter 125
APF104

5 FET's, the 39 K resistor 36a is necessary in order to provide a finite source impedance to work into the FET. In this way the compression ratio (decibel changes in the input divided by decibel changes in the compressor output) at all frequencies and levels is held to a maximum of about 2. The 39 K resistor 36a serves the same compression ratio limiting function in the improved circuit as the resistor 36 in the circuit of Fig. 4 or Fig. 5. In addition this resistor provides a low frequency path for the signal.

10 Fig. 11 is a chart recording of the input-output response of the compressor as a function of frequency using the improved variable filter of Fig. 10 and the values 47 ohms and 0.1 μ F in the emitter time-constant circuit 52 of the control amplifier, instead of the values of 220 ohms and 0.15 μ F shown in Fig. 4. 15 Fig. 12 is a plot of the response of the circuit below the compression threshold; the expander response is also shown.

20 It can be seen that with the circuit of Fig. 10 the mid-band dip of Fig. 8 is absent. The tendency for the noise reduction system to increase the noise level in the region of the dip is eliminated, and an improved overall noise reduction effect is thereby achieved. The elimination of the dip at high levels should also be noted. Thus, when the noise reduction action is switched on and off, there will be no change in level and therefore no ambiguities in measuring or specifying levels for standardization purposes. The high-level dip elimination is brought about by the favourable phase characteristics of the improved circuit under high compression conditions, notably by the provision of a low and mid-frequency path by the resistor 36a. By adjusting the value of the 39 K resistor 36a in the second RC network 22 it is possible to achieve either a dip or a hump in the mid-frequency region.

30 A further aspect of the improved circuit of Fig. 10 is that it is possible to achieve greater effective limiting of the further path component at high frequencies without adversely affecting the matching characteristics. The improved performance is brought about by the leading phase shift introduced at high frequencies by the fully sliding band circuit. In addition, the gain of the control amplifier is increased at high frequencies. The reduction in threshold and the increased compression at high frequencies can be seen in Fig. 11. The characteristics shown result in minimal possibility of tape overload at short wavelengths, although the limiting threshold level is progressively increased with decreasing frequency in order to reduce noise modulation effects.

35 A further aspect of the improved circuit also concerns noise modulation effects. In the circuit of Fig. 4, the variable band action changes to normal compression when the FET resistance decreases below that of the 10 K resistor 38 in series with the FET. The highest 40

turnover frequency of the variable filter is high enough to provide acceptably low noise modulation effects under normal tape recording noise levels. Cassettes, however, have very high noise levels and it has been found best to eliminate the 10 K resistor 38 and to depend solely on the sliding band action to effect limiting. The further path then has better high frequency transmission in the presence of high amplitude, lower frequency signals (which necessarily cause the circuit to operate).

70 The variable band action of the improved circuit can be seen in Fig. 13, which is produced in the same manner as Fig. 9 by plotting the compressor frequency response by means of a low-level probe tone (the level of which is below the compressor threshold) in the presence of a high-level signal; the probe is detected at the compressor output by means of a tracking filter. The high-level signal causes the compressor circuitry to operate, the graph showing the effect on the turnover frequency of the filter. It can be seen that the variable band circuitry, particularly if using the fully sliding configuration, will provide a significant reduction of high frequency noise under signal conditions. Figs. 11, 12 and 13 are all taken from actual chart recordings obtained from the improved circuit of Fig. 10.

75 A correctly adjusted compressor and expander pair should match at all levels and frequencies to within about ± 1 dB; experimental results have shown this to be attainable at all signal levels. In practice it is important that the errors produced under mismatch conditions should not noticeably affect the quality of reproduction. The errors produced by the improved variable filter circuit of Fig. 10 are less than in the circuit of Fig. 4. It has been shown experimentally that a 2 dB gain or loss between the compressor and expander results in errors such that the change in response as a function of frequency reaches a maximum rate of only about 2-3 dB per octave, which is low enough to avoid introducing any significant colouration into the reproduced signal.

WHAT WE CLAIM IS:—

1. A signal compressor or expander comprising a main signal path adapted to pass signals with dynamic range linearity and means for combining with the signals therein, so as either to boost or buck such signals, the output signal of a further path which takes its input either from the input to or the output from the compressor or expander and which includes both means for limiting the amplitude of the said output signal and a variable cut-off filter for restricting signals passing through the further path to a restricted band extending to one limit of the overall signal band, the variable filter being responsive to the amplitude of the signal level in the com- 115
120
125

ise reduc-
iously also
have been
fig. 4 or a
In order
es to be
it is desir-
equalizing
expensive
nplement-
nal be re-
the only
l signal is
cies. This
ected by a
which acts
ble circuit
ent values
l recorded

Variable

iction sys-
n pointed
sed repre-
reduction
ise modu-
a further
n rate of
pass filter
iently ob-
cascaded
paralleled
ut-off fre-
to effect
duced by
mid-band
onse. The
he dip in
the few
noise re-
vel (about
high levels
switched
An im-
described
problem
s, notably
response
ect com-

it, for re-
B and C
is pinched
operative,
ontrols the
improved
es of hav-
quiescent
e attenua-
RC filter

MPF104

FET's, the 39 K resistor 36a is necessary in order to provide a finite source impedance to work into the FET. In this way the compression ratio (decibel changes in the input divided by decibel changes in the compressor output) at all frequencies and levels is held to a maximum of about 2. The 39 K resistor 36a serves the same compression ratio limiting function in the improved circuit as the resistor 36 in the circuit of Fig. 4 or Fig. 5. In addition this resistor provides a low frequency path for the signal.

Fig. 11 is a chart recording of the input-output response of the compressor as a function of frequency using the improved variable filter of Fig. 10 and the values 47 ohms and 0.1 μ F in the emitter time-constant circuit 52 of the control amplifier, instead of the values of 220 ohms and 0.15 μ F shown in Fig. 4. Fig. 12 is a plot of the response of the circuit below the compression threshold; the expander response is also shown.

It can be seen that with the circuit of Fig. 10 the mid-band dip of Fig. 8 is absent. The tendency for the noise reduction system to increase the noise level in the region of the dip is eliminated, and an improved overall noise reduction effect is thereby achieved. The elimination of the dip at high levels should also be noted. Thus, when the noise reduction action is switched on and off, there will be no change in level and therefore no ambiguities in measuring or specifying levels for standardization purposes. The high-level dip elimination is brought about by the favourable phase characteristics of the improved circuit under high compression conditions, notably by the provision of a low and mid-frequency path by the resistor 36a. By adjusting the value of the 39 K resistor 36a in the second RC network 22 it is possible to achieve either a dip or a hump in the mid-frequency region.

A further aspect of the improved circuit of Fig. 10 is that it is possible to achieve greater effective limiting of the further path component at high frequencies without adversely affecting the matching characteristics. The improved performance is brought about by the leading phase shift introduced at high frequencies by the fully sliding band circuit. In addition, the gain of the control amplifier is increased at high frequencies. The reduction in threshold and the increased compression at high frequencies can be seen in Fig. 11. The characteristics shown result in minimal possibility of tape overload at short wavelengths, although the limiting threshold level is progressively increased with decreasing frequency in order to reduce noise modulation effects.

A further aspect of the improved circuit also concerns noise modulation effects. In the circuit of Fig. 4, the variable band action changes to normal compression when the FET resistance decreases below that of the 10 K resistor 38 in series with the FET. The highest

turnover frequency of the variable filter is high enough to provide acceptably low noise modulation effects under normal tape recording noise levels. Cassettes, however, have very high noise levels and it has been found best to eliminate the 10 K resistor 38 and to depend solely on the sliding band action to effect limiting. The further path then has better high frequency transmission in the presence of high amplitude, lower frequency signals (which necessarily cause the circuit to operate).

The variable band action of the improved circuit can be seen in Fig. 13, which is produced in the same manner as Fig. 9 by plotting the compressor frequency response by means of a low-level probe tone (the level of which is below the compressor threshold) in the presence of a high-level signal; the probe is detected at the compressor output by means of a tracking filter. The high-level signal causes the compressor circuitry to operate, the graph showing the effect on the turnover frequency of the filter. It can be seen that the variable band circuitry, particularly if using the fully sliding configuration, will provide a significant reduction of high frequency noise under signal conditions. Figs. 11, 12 and 13 are all taken from actual chart recordings obtained from the improved circuit of Fig. 10.

A correctly adjusted compressor and expander pair should match at all levels and frequencies to within about ± 1 dB; experimental results have shown this to be attainable at all signal levels. In practice it is important that the errors produced under mismatch conditions should not noticeably affect the quality of reproduction. The errors produced by the improved variable filter circuit of Fig. 10 are less than in the circuit of Fig. 4. It has been shown experimentally that a 2 dB gain or loss between the compressor and expander results in errors such that the change in response as a function of frequency reaches a maximum rate of only about 2-3 dB per octave, which is low enough to avoid introducing any significant colouration into the reproduced signal.

WHAT WE CLAIM IS:—

1. A signal compressor or expander comprising a main signal path adapted to pass signals with dynamic range linearity and means for combining with the signals therein, so as either to boost or buck such signals, the output signal of a further path which takes its input either from the input to or the output from the compressor or expander and which includes both means for limiting the amplitude of the said output signal and a variable cut-off filter for restricting signals passing through the further path to a restricted band extending to one limit of the overall signal band, the variable filter being responsive to the amplitude of the signal level in the com-



- pressor or expander to shift the cut-off frequency away from the other limit of the overall signal band as the said amplitude increases, the filter configuration comprising two filters in cascade, namely a first filter comprising fixed-value components and a second filter with a variable cut-off frequency which, under quiescent conditions, lies further from the said one limit than the cut-off frequency of the first filter, the second filter including a controlled variable impedance device responsive to the said amplitude to vary the parameters of the filter and shift the variable cut-off frequency away from the said other limit.
2. A signal compressor or expander according to claim 1, wherein the variable impedance device is a field effect transistor.
3. A signal compressor or expander according to claim 1 or 2, wherein the first and second filters are both RC filters.
4. A signal compressor or expander according to claim 1, 2 or 3, wherein the second filter comprises a series arm constituting of a capacitor in parallel with a resistor and a resistive shunt arm comprising the variable impedance means.
5. A signal compressor or expander according to claim 1, 2 or 3, wherein the second filter comprises a series capacitor followed by a shunt resistor followed by a series resistor followed by a resistive shunt arm comprising the variable impedance means.
6. A signal compressor or expander according to any of claims 1 to 5, wherein the variable filter is responsive to the amplitude of the output thereof.
7. A signal compressor or expander according to any of claims 1 to 6, comprising switching means arranged to select a compression mode in which the combining means causes the further path output signal to boost the main path signal or an expansion mode in

which the combining means cause the further path output signal to buck the main path signal.

8. A signal compressor or expander according to claim 7, wherein, in the compression mode, the switching means connect the input to the further path to a point in the main path preceding that at which the main path and further path signals are combined, whereas in the expansion mode the switching means connect the input to the further path to a point in the main path following that at which the main path and further path signals are combined.

9. A signal compressor or expander according to claim 7 or 8, wherein the combining means comprise first and second serially connected combining circuits in the main path, the input to the further path being connected to the output of the first combining circuit and the switching means connecting the output of the further path selectively to the first or second combining circuits, the polarities throughout the circuit being such that the output of the further path boosts the signal in the main path when applied to one of the combining circuits and bucks the signal in the main path when applied to the other of the combining circuits.

10. A signal compressor or expander substantially as described with reference to and as shown in Fig. 4, 5 or 6 of the accompanying drawings.

11. A signal compressor or expander substantially as described with reference to and as shown in Fig. 4, 5 or 6 as modified by Fig. 10 of the accompanying drawings.

REDDIE & GROSE,
Agents for the Applicants,
6, Bream's Buildings,
London, EC4A 1HN.

Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1972.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

PATENTS ACT 1977

SPECIFICATION NO 1279634

The following corrections were allowed under Section 32 on 11 May 1982

Page 1, lines 1 to 4, *delete* whole lines *insert* (71) We, Dolby Laboratories Licensing Corporation, of 731 Sansome Street, San Francisco, California 94111, United States of America,

THE PATENT OFFICE
20 January 1983

Bas 94525/11

