

SPECIFICATION

Apparatus for compressing or expanding the dynamic range of an audio frequency signal

The present invention relates to apparatus for compressing or expanding the dynamic range of an audio frequency signal.

- 10 It is known to improve the quality of reproduction of audio frequency performances by increasing the signal-noise ratio by a compression-expansion system (so-called compander system). The useful signals are compressed in
- 15 amplitude before the disturbed transmission path e.g. line or sound tape, and are expanded after transmission. In the case of companders for professional use an endeavour is made to obtain a fully constant slope of the
- 20 compander and expander characteristics over as wide a range of regulation as possible. The advantage of such characteristics is that the input level of the expander may deviate from the output level of the compressor without the
- 25 dynamic variation of the reproduced signal differing from the dynamic variation of the original signal.

- This wide range of regulation desired for professional use cannot however be combined, with the compatibility required for consumer use, with transmission devices of constant amplification. The reproduction of such a compressed signal without an expander has a poor sound since e.g. interference in pauses
- 30 of the input signal is greatly increased. Likewise unsatisfactory is the audio impression with an uncompressed signal which is reproduced via an expander having an above-mentioned regulating characteristic. In this case a
- 35 very much exaggerated dynamic of the reproduction occurs. An example of a compander having a wide range of regulation is disclosed in British Patent 1 500 192.

- An object of the invention is to provide an apparatus which, in use in a compander, permits compatibility with a linearly operating system as regards dynamic and in which the independence of compressor output signal and expander input signal is retained to a
- 40 great extent.

- According to one aspect of the invention, there is provided a compression circuit, for audio input signals, comprising an amplifier device connected to receive said input signals,
- 45 the device having a feedback path connected thereacross, a further amplifier device connected to receive output signals derived from the first-mentioned amplifier device and having a feedback path connected thereacross,
- 50 wherein each of said feedback paths contains a respective variable impedance element and a respective means connected to said element for determining maximum and minimum impedances of the respective feedback path and wherein a control voltage generator is con-

- nected to receive output signals derived from said further amplifier device and arranged to provide control signals for controlling the impedance of said variable impedance elements,
- 70 the compressed signals being derived from the output of said first-mentioned amplifier device and the said control signals being limited so that the degree of compression effected by said circuit assumes a variable
- 75 value for input signals with amplitudes within a predetermined range and a constant value for input signals with amplitudes outside said range.

- Another aspect provides apparatus for compressing the dynamic range of an audio frequency signal comprising: a first signal path including control means for varying the transmission of the path to the said signal; a
- 80 second signal path branched from the output of the first path and including further control means for varying the transmission of the path to the said signal; each control means including an amplifier provided with a negative feedback path having a variable resistance
- 85 device and at least one resistor arranged to provide a predetermined limit to the range of variation of resistance of the feedback path by variation of the resistance of the said device; a control voltage generator means arranged in
- 90 the second path and connected to the said devices to derive from the said signal, and apply to the said devices, control voltages to vary the resistances of both feedback paths in
- 95 senses to perform compression, and limiting means associated with the control voltage generator means to provide a predetermined limit to the range of variation of the control voltage.

- According to another aspect, there is provided apparatus for expanding the dynamic range of an audio frequency signal comprising: a first signal path including control means for varying the transmission of the path to the said signal; a second path branched from the
- 100 input of the first path and including further control means for varying the transmission of the path to the said signal, each control means including an amplifier provided with a negative feedback path having a variable resistance device and at least one resistor arranged to provide a predetermined limit to the
- 105 range of variation of resistance of the feedback path by variation of the resistance of the said device; a control voltage generator means arranged in the second path and connected to the said devices to derive from the said signal, and apply to the said devices, control voltages to vary the resistances of both feedback paths
- 110 in senses to perform expansion; and limiting means associated with the control voltage generator means to provide a predetermined limit to the range of variation of the control voltage.

- For a better understanding of the invention, reference will now be made, by way of exam-
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ple, to the accompanying drawings, in which:—

Figure 1 is a diagram illustrating compression characteristics,

5 Figure 2 is a circuit diagram of a compressor and,

Figure 3 show a modification of the compressor.

10 In Fig. 1 there is reproduced a level diagram in the usual form. The input signals U_1 , to be processed, of a compression circuit lie on the abscissa and increase in absolute value from left to right. The output signals U_2 of the compression circuit lie on the ordinate and increase upwardly. The broken straight line 1 gives the relationship between the compressor output signal U_2 and the compressor input signal U_1 . In the ideal case this characteristic extends as a straight line of infinite extent through the first and third quadrants and through the zero point of the diagram illustrated. With an assumed degree of compression of 2:1 the slope of the compression characteristic is 1:2.

25 The input signals U_3 of an expansion circuit complementary to the compression circuit likewise lie, in the level diagram illustrated, on the abscissa and rise from left to right. The output signals U_4 lie on the ordinate and rise upwardly. The relationship of the expander output signals to the expander input signals is shown by the dotted line characteristic 5. In the ideal case this characteristic also extends as a straight line of infinite extent through the first and third quadrants as well as through the zero point of the diagram illustrated. Its slope is accordingly 2:1 corresponding to a degree of expansion of 1:2.

By superimposing the characteristics 1 and 5 there is obtained a characteristic 3 which is illustrated in the drawing as a straight chain line with a slope of 1:1. The practical design of an amplifier operated as a compressor or an expander in accordance with the characteristics 1 and 5 would mean that its propagation constant must be adjustable to values between zero and infinity. This requirement is not practicable; an endeavour is made, however, so to establish the limits of the range of variation of the propagation constant that the characteristic is linear within the working range used. The range of level above the amplifier's own noise and below the exaggeration limit is to be regarded as the operating range.

60 In order to achieve, in accordance with the problem underlying the invention, compatibility with lineary operating systems the amplifier—departing from this principle—is so designed that its propagation constant is variable only between a first and a second input level. By first and second input level is understood that in a predetermined mode of operation these levels have a fixed value. It may of course be possible to provide a plurality of

modes of operation in which the levels can be selectively determined.

In a practical form of the invention, for the compander input signal the first (low) level is 70 — 30 dB and the second (high) level is + 10 dB. Between these two levels the compression characteristic of the practical form according to the invention therefore coincides with the above-described ideal characteristic 1. Below 75 the first level and above the second level the characteristic changes direction in such manner that the corresponding parts of the characteristic proceed with a slope of 1:1. This means that below the first level and above the second level the amplifier has a constant 80 amplification, the amplifying factor in the case of the first level having a different level from that in the case of the second level.

The expander characteristic is designed to 85 be complementary to the compression characteristic. The first level is with an expander input signal of — 15 dB, the second level is with an expander input signal of + 5 dB. Below the first level and above the second 90 level the expander characteristic 4 also proceeds with a slope of 1:1, i.e. the amplification factor of the expander circuit is in this range independent of the input level; the amplification factor associated with the first 95 and second levels are therefore different.

Superimposition of the compressor and expander characteristics leads to a resultant characteristic that corresponds to the straight chain line 3 of slope 1:1. The dynamic variation of a useful signal processed by the compressor and the expander therefore corresponds to the dynamic variation of the original signal.

The limitation of the range of level in which 105 the signals are compressed or expanded has the effect that very weak signals are excluded from compression or expansion. The compander therefore processes these signals exactly like a linear amplifier of constant amplification. Also, signals of particularly high amplitude are processed by the compander in the same manner as in the case of a linear amplifier of constant amplification. This processing of the useful signals permits compatibility of the systems with linearly operating 115 amplifiers.

In the reproduction, without an expander, of signals processed by a compressor alone no extreme raising of the interference level in the 120 input signal occurs since weak signals e.g. noise of an input amplifier are increased only by the compression effect in accordance with characteristic 2 by 15 dB and not substantially in accordance with characteristic 1. Also 125 the reproduction of uncompressed signals via the expander does not lead to the exaggerated dynamic impression, mentioned above; signals of high amplitude are not further increased and signals of low amplitude are not 130 further reduced. The ranges of level that are

critical for compatible treatment are therefore linearly processed.

Owing to the constant degree of compression or expansion between the first and second level—illustrated by the linear parts of the characteristics between the first and second level—even with differences of level between the compressor output signal and the expander input signal the original dynamic variation is retained. Only at the junctions of the characteristics 1/2 and 4/5 with low and high levels can there be dynamic distortions—with differences of level between the compressor output signal and the expander input level.

The circuit is therefore advantageously so designed that the range below the first level and above the second level in the case of the audio programme provided is seldom controlled. Moreover, an audio impression shows that dynamic distortions in these ranges are not received so distorted as in the middle group. The said dependence of level mentioned in connection with the ideal compander, between the compressor output and the expander input signal is therefore retained to a large extent with the invention.

In Fig. 2 is illustrated a practical example of the invention. The circuit shows a dynamic compressor with a degree of compression of 2:1. It includes first and second similar amplifiers 9 and 15 connected in series with electronically controllable resistors 12 and 18 in the feedback paths for varying the respective propagation constants. Each electronically controllable resistor 12, 18 has a respective control input 13, 19 which is connected to the output of a common control voltage generator 21. An input of the control voltage generator 21 is connected to the output of the second chain amplifier 15. The useful signal is fed to an input terminal 6 which is connected via a resistor 8 to the input of the first amplifier 9. The compressed useful signal can be taken off at an output terminal 7 which is connected to the output of the first amplifier 9. The output of the first amplifier 9 is connected via a resistor 14 to the input of the second amplifier 15.

In accordance with the invention there is arranged between the control inputs 13, 19 of the electronically controllable resistors 12, 18 and the output of the control voltage generator 21 a limiting circuit 20 by which the lower and upper limits of the range of variation of the control voltage are determined. This limiting circuit may also be integrated in the control voltage generator 21, or the control voltage generator 21 may itself be so designed that it serves as a limiter.

Beyond these steps, in the circuit arrangement illustrated there is connected to each electronically controllable resistor 12, 18 a parallel impedance 11, 17 and a series impedance 10, 16. Thereby the adjustment of the range of the impedances arranged in the

feedback path of the chain amplifiers is as a whole narrowed.

The circuit according to Fig. 2 may be so designed that in parallel with the electronically controllable resistors 12, 18 there is arranged a series arrangement of an impedance 11, 17 and an impedance 10, 16.

Another variant is shown in the part drawing in Fig. 3 of the circuit elements 12, 11, 10. Here the series impedance 10 is connected in series with the electronically controllable resistor 12 and the parallel impedance 11 is arranged in parallel with the series circuit.

There is also suitable an electronically controllable resistor which from its design has an upper and/or lower limit value of resistance.

It is also possible, in apparatus according to the invention, to provide only one controllable resistor of limited range of adjustment or only one limiter of the control voltage. Further, it is possible to determine the one limit for the variation of the propagation constant by an electronically controllable resistor of limited adjustment range and the other limit by a limiter of the control voltage.

The upper limit of the range of variation of the propagation constant can also be determined by providing, instead of the chain of amplifiers illustrated in Fig. 2 in an inverted connection, a chain of amplifiers in a non-inverted connection.

Furthermore, for a compander system in which the dynamic is not reduced by the control voltage generator to the static value of 0 dB there is also the possibility of providing a limiter in relation to the alternating input voltage of the control voltage generator.

The circuit of Fig. 2 or Fig. 3 may be modified to form an expander by disconnecting resistor 14 from impedance 12 and connecting said resistor instead to the input 6. Additionally an inverter is required for inverting the control voltage applied to the resistor 12.

An alternative formation of expander is achieved by disconnecting resistor 10 from the input of the amplifier 9 and taking expanded signals from the disconnected terminal of the resistor 10. A non-variable negative feedback path is additionally connected across the amplifier 9.

The characteristic shown in Fig. 1 is valid for useful signal frequencies up to 1 kHz only. Above 1 kHz the levels are shifted downwards. For example at 10 kHz the levels of -30 dB and +10 dB on the compression characteristic (defining the range of amplitude-dependent compression) fall to -50 dB and -10 dB. This is due to a constant pre- and de-emphasis, so that the control means respond to lower levels when supplied with high frequency signals than with low frequency signals. This pre- and de-emphasis is used to avoid overriding of magnetic tape with regard

to high frequencies.

CLAIMS

1. A compression circuit, for audio input
5 signals, comprising an amplifier device connected to receive said input signals, the device having a feedback path connected thereacross, a further amplifier device connected to receive output signals derived from the first-
10 mentioned amplifier device and having a feedback path connected thereacross, wherein each of said feedback paths contains a respective variable impedance element and a respective means connected to said element for
15 determining maximum and minimum impedances of the respective feedback path and wherein a control voltage generator is connected to receive output signals derived from said further amplifier device and arranged to provide control signals for controlling the impedance of said variable impedance elements, the compressed signals being derived from the output of said first-mentioned amplifier device and the said control signals being
25 limited so that the degree of compression effected by said circuit assumes a variable value for input signals with amplitudes within a predetermined range and a constant value for input signals with amplitudes outside said
30 range.

2. Apparatus for compressing the dynamic range of an audio frequency signal comprising: a first signal path including control means for varying the transmission of the path to the
35 said signal; a second signal path branched from the output of the first path and including further control means for varying the transmission of the path to the said signal; each control means including an amplifier provided with a negative feedback path having a variable
40 resistance device and at least one resistor arranged to provide a predetermined limit to the range of variation of resistance of the feedback path by variation of the resistance of the said device; a control voltage generator means arranged in the second path and connected to the said devices to derive from the said signal, and apply to the said devices, control voltages to vary the resistances of both
45 feedback paths in senses to perform compression, and limiting means associated with the control voltage generator means to provide a predetermined limit to the range of variation of the control voltage.

3. Apparatus according to Claim 2, wherein the negative feedback path of each control means includes a first resistor in parallel with the said device and a second resistor in series with the first resistor and the said
60 device.

4. Apparatus according to Claim 2 wherein the negative feedback path of each control means includes a series arrangement of a first resistor and the said device, and a
65 second resistor in parallel with the series ar-

rangement.

5. Apparatus according to Claim 2, 3, or 4 wherein the limiting means is distinct from, and arranged to receive from, the control
70 voltage generator means the control voltage, the voltage of which is to be limited.

7. Apparatus according to Claim 2, 3 or 4 wherein the limiting means is distinct from the control voltage generator means, and is arranged to limit the range of the input to the generator means.

8. Apparatus according to any one of claims 2 to 7, arranged to: apply a predetermined gain, independent of signal magnitude,
80 to audio frequency signals having a magnitude less than -30dB ; compress the dynamic range of audio frequency signals having magnitudes in the range of -30dB to $+10\text{dB}$ by applying to them a gain which varies linearly with signal magnitude in that range; and apply a further predetermined gain, independent of signal magnitude, to audio frequency signals having a magnitude greater than $+10\text{dB}$.

9. Apparatus according to Claim 8, wherein the gain applied to the signals of magnitude less than -30dB is $+15\text{dB}$.

10. Apparatus according to Claim 8 or 9, wherein the gain applied to the signals of
95 magnitude greater than $+10\text{dB}$ is -5dB .

11. Apparatus for compressing the dynamic range of an audio frequency signal, substantially as hereinbefore described with reference to Figs. 1 and 2, optionally as
100 modified by Fig. 3, of the accompanying drawing.

12. Apparatus for expanding the dynamic range of an audio frequency signal comprising: a first signal path including control means for varying the transmission of the path to the
105 said signal; a second path branched from the input of the first path and including further control means for varying the transmission of the path to the said signal, each control means including an amplifier provided with a negative feedback path having a variable resistance device and at least one resistor arranged to provide a predetermined limit to the range of variation of resistance of the feedback path by variation of the resistance of the
110 said device; a control voltage generator means arranged in the second path and connected to the said devices to derive from the said signal, and apply to the said devices, control voltages to vary the resistances of both feedback paths in senses to perform expansion; and limiting means associated with the control voltage generator means to provide a predetermined limit to the range of variation of the control
120 voltage.

13. Apparatus according to Claim 12, arranged to expand the dynamic range of an audio frequency signal by: applying a predetermined gain, independent of signal magnitude, to audio frequency signals having a
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to high frequencies.

CLAIMS

1. A compression circuit, for audio input signals, comprising an amplifier device connected to receive said input signals, the device having a feedback path connected thereacross, a further amplifier device connected to receive output signals derived from the first-mentioned amplifier device and having a feedback path connected thereacross, wherein each of said feedback paths contains a respective variable impedance element and a respective means connected to said element for determining maximum and minimum impedances of the respective feedback path and wherein a control voltage generator is connected to receive output signals derived from said further amplifier device and arranged to provide control signals for controlling the impedance of said variable impedance elements, the compressed signals being derived from the output of said first-mentioned amplifier device and the said control signals being limited so that the degree of compression effected by said circuit assumes a variable value for input signals with amplitudes within a predetermined range and a constant value for input signals with amplitudes outside said range.
2. Apparatus for compressing the dynamic range of an audio frequency signal comprising: a first signal path including control means for varying the transmission of the path to the said signal; a second signal path branched from the output of the first path and including further control means for varying the transmission of the path to the said signal; each control means including an amplifier provided with a negative feedback path having a variable resistance device and at least one resistor arranged to provide a predetermined limit to the range of variation of resistance of the feedback path by variation of the resistance of the said device; a control voltage generator means arranged in the second path and connected to the said devices to derive from the said signal, and apply to the said devices, control voltages to vary the resistances of both feedback paths in senses to perform compression, and limiting means associated with the control voltage generator means to provide a predetermined limit to the range of variation of the control voltage.
3. Apparatus according to Claim 2, wherein the negative feedback path of each control means includes a first resistor in parallel with the said device and a second resistor in series with the first resistor and the said device.
4. Apparatus according to Claim 2 wherein the negative feedback path of each control means includes a series arrangement of a first resistor and the said device, and a second resistor in parallel with the series ar-

range.

5. Apparatus according to Claim 2, 3, or 4 wherein the limiting means is distinct from, and arranged to receive from, the control voltage generator means the control voltage, the voltage of which is to be limited.
7. Apparatus according to Claim 2, 3 or 4 wherein the limiting means is distinct from the control voltage generator means, and is arranged to limit the range of the input to the generator means.
8. Apparatus according to any one of claims 2 to 7, arranged to: apply a predetermined gain, independent of signal magnitude, to audio frequency signals having a magnitude less than -30 dB; compress the dynamic range of audio frequency signals having magnitudes in the range of -30 dB to $+10$ dB by applying to them a gain which varies linearly with signal magnitude in that range; and apply a further predetermined gain, independent of signal magnitude, to audio frequency signals having a magnitude greater than $+10$ dB.
9. Apparatus according to Claim 8, wherein the gain applied to the signals of magnitude less than -30 dB is $+15$ dB.
10. Apparatus according to Claim 8 or 9, wherein the gain applied to the signals of magnitude greater than $+10$ dB is -5 dB.
11. Apparatus for compressing the dynamic range of an audio frequency signal, substantially as hereinbefore described with reference to Figs. 1 and 2, optionally as modified by Fig. 3, of the accompanying drawing.
12. Apparatus for expanding the dynamic range of an audio frequency signal comprising: a first signal path including control means for varying the transmission of the path to the said signal; a second path branched from the input of the first path and including further control means for varying the transmission of the path to the said signal, each control means including an amplifier provided with a negative feedback path having a variable resistance device and at least one resistor arranged to provide a predetermined limit to the range of variation of resistance of the feedback path by variation of the resistance of the said device; a control voltage generator means arranged in the second path and connected to the said devices to derive from the said signal, and apply to the said devices, control voltages to vary the resistances of both feedback paths in senses to perform expansion; and limiting means associated with the control voltage generator means to provide a predetermined limit to the range of variation of the control voltage.
13. Apparatus according to Claim 12, arranged to expand the dynamic range of an audio frequency signal by: applying a predetermined gain, independent of signal magnitude, to audio frequency signals having a

- magnitude less than -15 dB; expanding the dynamic range of audio frequency signals having magnitudes in the range -15 dB to $+5$ dB by applying to them a gain which
- 5 varies linearly with signal magnitude in that range; and applying a further predetermined gain, independent of signal magnitude to audio frequency signals having a magnitude greater than $+5$ dB.
- 10 14. Apparatus according to Claim 12, wherein the gain applied to signals of magnitude less than -15 dB is -15 dB.
- 15 15. Apparatus according to Claim 14 wherein the gain applied to signals of magnitude greater than $+5$ dB is $+5$ dB.
16. Apparatus for expanding the dynamic range of an audio frequency signal, substantially as hereinbefore described with reference to the accompanying drawings.