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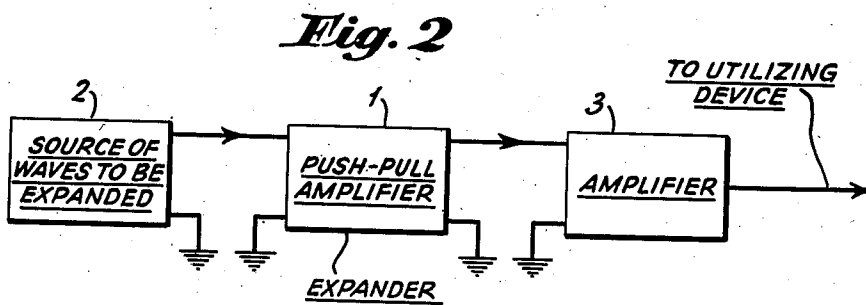
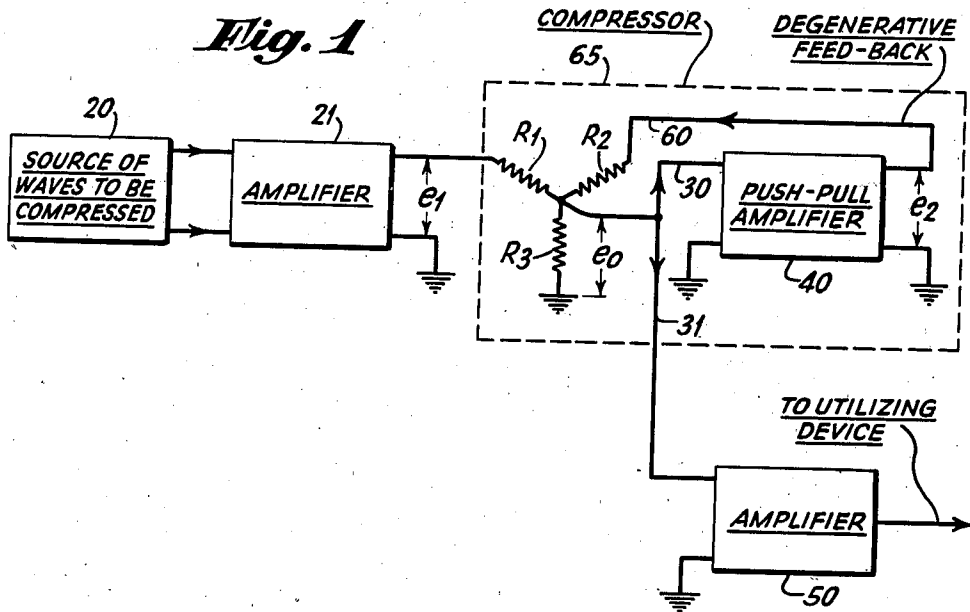
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2,266,531

COMPANDER SYSTEM

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2 Sheets-Sheet 1



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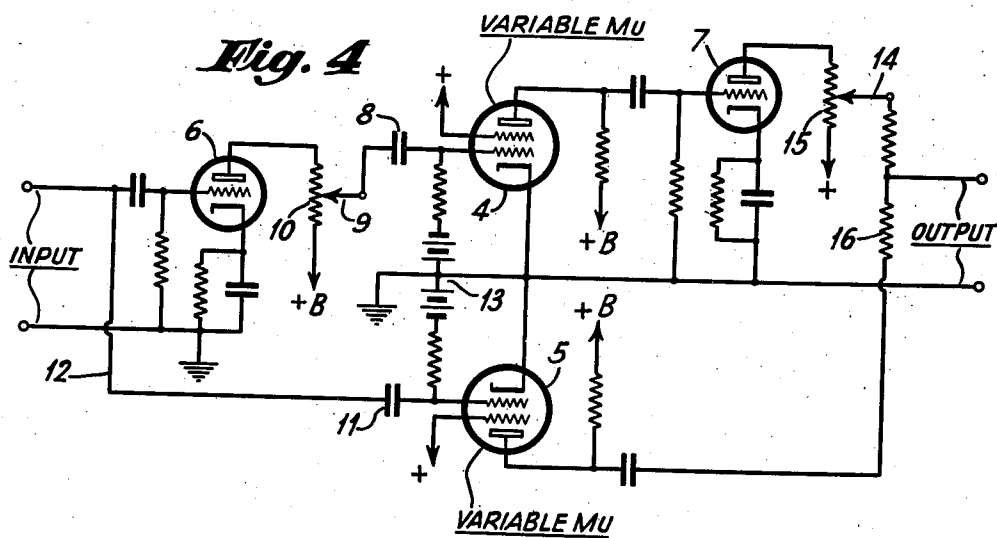
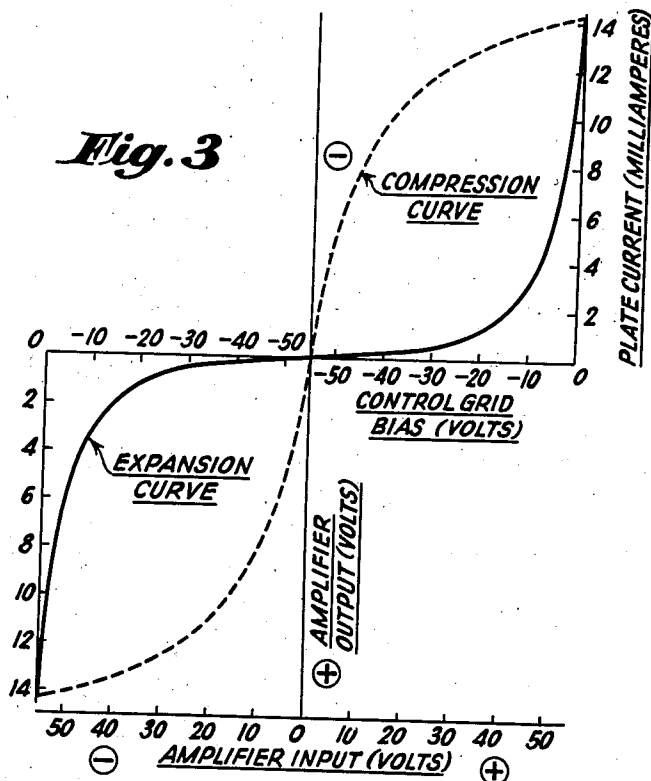
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2 Sheets-Sheet 2



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COMPANDER SYSTEM

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5 Claims. (Cl. 178-44)

My present invention relates to compander systems, and more particularly to a novel method of, and means for, compressing and expanding the amplitude range of an audio, or other, signal for the purpose of transmission or recording.

As is well known in the prior art in transmitting or recording modulated signals, it is difficult to handle a volume level which keeps the soft passages above the extraneous noise level and still not overload the system on the loud passages. Accordingly, various types of compander systems have been devised wherein at the transmitter, or recorder, the volume range of the signals, whether of audio or higher frequency, is compressed, and at the receiver or reproducer the volume range is inversely expanded so as to restore the original signal amplitude range. However, prior expander arrangements have either been complicated in structure, or have not proved to be satisfactory in operation.

My present invention has as its main object the provision of a simplified expander arrangement utilizing a pair of electron discharge devices in push-pull, and the devices having grid voltage—output current characteristics of the remote cut-off, or exponential, type; and the compressor network of the system employing a push-pull network of the same type as is employed at the expander, but utilizing negative feedback action in such a manner that the effect of the compressor characteristic is in the inverse, or reciprocal, of the expander characteristic.

Another important object of this invention is to provide a network adapted for use at a transmitter for compressing the volume range of signals to be transmitted, and the receiver employing a similar network; the transmitter compressor network essentially comprising a pair of variable mu tubes arranged in push-pull, but including negative feedback so as to have its push-pull characteristic in inverse relation to that of the push-pull tubes at the expander network of the receiver.

Another object of this invention is to provide a compression network for transmitter, or recorder, wherein the compressor comprises a pair of variable mu tubes arranged in push-pull relation and including degenerative feedback between its output and input circuits.

Still another object of this invention may be stated to reside in the provision of an expansion network for audio signals, wherein the expander

comprises merely a pair of remote cut-off tubes arranged in push-pull relation.

Still other subjects of my invention are to include generally the simplicity and efficiency of volume range compression and expansion networks, and more especially to provide compander systems which are not only efficient and reliable in operation, but are economically manufactured and assembled.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims; the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawings in which I have indicated diagrammatically a circuit organization whereby my invention may be carried into effect.

In the drawings,

Fig. 1 schematically shows an electrical wave transmission system embodying a volume range compressor network according to my invention,

Fig. 2 shows an electrical wave transmission system embodying, in schematic fashion, an expander network according to my invention,

Fig. 3 graphically shows the compression and expansion characteristics of the networks illustrated in Figs. 1 and 2 respectively,

Fig. 4 shows the electrical connections of the push-pull amplifier, using tubes of the variable mu type, and which may be utilized in each of the schematic circuits of Figs. 1 and 2.

Referring now to the accompanying drawings, reference is first made to Fig. 3. The full line characteristic, denoted as "Expansion curve" illustrates the net control grid bias-plate current characteristic of a pair of electron discharge tubes of the variable mu type operated in push-pull. The tubes in question may be, for example, of the 58 type; in general, the tubes may be of any well known type providing the characteristic is of the remote cut-off, or exponential, type. Even so-called linear tubes can be used if operated with very low plate voltages, or high biases with low driving voltages. As is well known, the characteristic is secured by plotting "plate current" as ordinates against "control grid bias" as abscissae. An examination of the full line curve, shown in Fig. 3, will show that there is secured increasingly greater amplification for large grid swings. Hence, the curve is suitable for use at the receiving, or reproducing, end of the system to expand the amplitude range of signals whose volume range was compressed

at the transmitter, or recording, end of the same system. A variable- μ tube of the 58 type has a plate current-grid voltage characteristic essentially as shown by either half of the full line curve in Fig. 3; the other half of the curve is a similar curve drawn with reversed polarities. The complete curve represents the net characteristic of two variable- μ tubes operated in push-pull.

Referring to Fig. 2, the numeral 1 schematically represents a push-pull amplifier which functions as an expander network. The push-pull amplifier includes a pair of variable- μ tubes, such as of the 58 type, connected to have a characteristic as shown by the full line curve in Fig. 3. Numeral 2 denotes a source of waves whose volume range is to be expanded, and the waves from source 2 are fed to the expander network 1. The numeral 3 denotes an amplifier to which the expanded amplitude signals may be fed prior to utilization.

More specifically, in Fig. 4 is shown the electrical connections to the input circuit and output circuit of the push-pull expander network. Thus, the tubes 4 and 5 are variable- μ tubes having their input electrodes arranged in push-pull relation. Assuming that the waves to be expanded in amplitude are of audio frequency, these waves are impressed between the input electrodes of the input tube 6; the latter functions as a phase reversing tube, it being understood that if push-pull transformers were employed to feed the variable- μ tubes then the phase reversing tubes 6 and 7 could be omitted. The signal input grid of tube 4 is connected by an audio coupling condenser 8 and the variable tap 9 of the resistive load 10 to the plate circuit of the phase reversing tube 6. The signal input grid of tube 5 is connected through the audio coupling condenser 11 and lead 12 to the signal input grid of tube 6. The signal grids of tubes 4 and 5 are established at proper negative biases by any well known means 13. The output electrodes of tube 4 are coupled to the input electrodes of the phase reversal tube 7. One of the output terminals of the network is established at ground potential, while the other output terminal is connected to the variable tap 14 arranged to be adjusted along the resistive load 15 disposed in the plate circuit of the phase reversal tube 7.

The output electrode of the tube 5 is coupled to the tap 14 through resistor 16 such that the outputs of tubes 5 and 7 are essentially combined, or added, in proper proportion. In this way the tubes 4 and 5 have their input and output circuits in push-pull relation without the use of push-pull transformers. A push-pull arrangement is employed in order to treat the positive and negative portions of the audio waves alike. It is to be understood that there would be used in the network 1 of Fig. 2 the entire circuit arrangement shown between the input and output terminals of Fig. 4. In other words, the network between the input and output terminals of Fig. 4 comprises a volume range expander by virtue of the fact that the full line curve shown in Fig. 3 inherently has the accurate general shape for expanding the volume range of the waves at the receiving, or reproducing, end of the system.

Looking now to the transmitter, or recording, end of the system, it is necessary to have a compression characteristic which is accurately inverse to that of the expander characteristic. In

accordance with the present invention a pair of tubes are utilized at the compressor network which are of the same type as used in the expander network, but are connected so that they act with strong negative feedback action whereby the net effect is a characteristic which is essentially the inverse, or reciprocal, of that of the two tubes themselves. It will now be demonstrated from a theoretical aspect that such an inverse characteristic can be secured.

Considering the push-pull amplifier shown in Fig. 4, the amplifier has a characteristic;

$$e_4 = -e_3 m$$

where m is the overall amplification for the expander values of input voltage and has the shape of the full line curve in Fig. 3; e_4 is the output voltage; and e_3 is the input voltage. Now for recording, or transmitting, it is necessary to use in the amplifier system a unit which has an output voltage which varies as the reciprocal of μ . It is improbable that a pair of tubes could be found which would have such a characteristic. According to the present invention a pair of tubes is employed at the compressor which is similar to the pair of tubes used at the expander, but the circuit arrangement is so developed that the dotted line curve shown in Fig. 3, and denoted "Compression curve" is secured. This is accomplished by means of a negative feedback circuit as shown in Fig. 1.

The wave transmission system shown in Fig. 1 comprises the source 20 which will be understood as comprising any well known source of waves whose amplitude range is to be compressed. For example, the source 20 can be a microphone of a recording system, or the microphone of a radio transmitter. The waves from source 20 are amplified by amplifier 21, and the output voltage of the latter amplifier is assumed to have a magnitude e_1 . The output voltage e_1 is impressed on one end of resistor R_1 . The output of amplifier 40 is impressed upon one end of R_2 . The junction of these resistors is connected by a lead 30 to the input of the push-pull amplifier 40 and to ground through R_3 . A second lead 31 connects the junction of resistors R_1 and R_2 to the input terminal of the amplifier 50. The voltage developed across R_3 , and impressed upon the input terminals of amplifier 50, is denoted by the symbol e_0 .

It will, therefore, be seen that there is impressed upon the input terminals of amplifier 50 and the push-pull amplifier 40 the voltage e_0 . The output voltage of the amplifier 40 is denoted by the symbol e_2 . This voltage is fed back in degenerative phase by a lead 60 and resistor R_2 to the junction of resistors R_1 and R_3 . Again it is emphasized that network 40 in Fig. 1 may be constructed in the manner shown in Fig. 4, and that the network 1 in Fig. 2 is also constructed in the manner shown in Fig. 4. Since both networks 40 and 1 are constructed in the manner shown in Fig. 4, it is not believed necessary to reproduce the circuit of Fig. 4 in each of Figs. 1 and 2.

It can be shown, and it is well known, that three resistors arranged in the manner of R_1 , R_2 and R_3 in Fig. 1 have the effect of combining the voltages e_1 and e_2 so that the voltage e_0 is proportional to their sum. Hence, it can be stated that if R_1 is equal to R_2 and equal to R_3 it follows that:

$$e_0 = \frac{1}{3}e_1 + \frac{1}{3}e_2 \quad (1)$$

The characteristic of the amplifier 40 is such that:

$$e_2 = -m e_0 \quad (2)$$

It is to be understood that the minus sign is due to a net phase reversal. Solving (1) and (2) for e_0 in terms of e_1 we have:

$$e_0 = \frac{e_1}{3+m} \quad (3)$$

Now, if m is made large with respect to 3, then:

$$e_0 \approx \frac{1}{m} e_1 \quad (4)$$

The curve defined by this equation is the reciprocal of that defined by Equation 2. Then, since the voltage e_0 is amplified linearly to drive the utilizing device, as, for example, a recorder, the output of the utilizing device will pre-distorted according to the compression curve shown in Fig. 3. It follows that at the receiver the reciprocal expansion curve will accurately correct for the pre-distortion.

In general, it will be seen that the compander system of the present invention consists of a distorter at the recording end of the system which distorts the signal in such a way as to be transmitted at more nearly uniform level, though its original amplitude should vary widely; and in the use of a restorer at the reproducing end which restores the signal to its original proportions. Both the compressor and expander are exactly similar in construction with the exception that the compressor utilizes sufficient degenerative feedback so that its net characteristic is the reciprocal of the expander characteristic. The present system is applicable to transmission by radio or by radio frequency distribution lines to rise above interference, as well as to phonograph recording wherein it is desired to raise the soft passages above "scratch" level. It may also be employed for short wave transmission of sound to accompany television.

In the case of a recording system the network 20 of Fig. 1 would be a microphone, and the utilizing device fed by an amplifier 50 would be the recording element adapted to produce the record on the master plate. In that case the source 2 of Fig. 2 would be the usual record pick-up device, and the utilizing device would be a loudspeaker. Where the system of the present invention is applied to radio reception the utilizing device in Fig. 1 would be the antenna, whereas the network 20 would be the modulation signal input network; the source 2 of Fig. 2 would be a collector device followed by the usual amplification and detection networks, and the utilizing device would be a loudspeaker. It is to be understood that many other uses could be found for this compander system. Essentially the present method utilizes degenerative feedback for the purpose of converting the characteristic of a tube with pronounced curvature into an effective characteristic which is the reciprocal of the first named characteristic whereby the former may be used for volume range expansion and the latter can be utilized for volume range compression.

My invention has been explained in connection with push-pull circuits since in audio systems the signal is generally symmetrical about the alternating current axis, i. e., the positive and negative swings are similar. However, in certain applications, as for example in video circuits for television, the push-pull system of Fig. 1 would be replaced by a single-ended system by remov-

ing tube 5 (or tubes 6, 4, and 7 of Fig. 4). In that case the characteristic output curve would be as shown in the righthand half of Fig. 3.

While I have indicated and described a system for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organization shown and described, but that many modifications may be made without departing from the scope of my invention, as set forth in the appended claims.

What is claimed is:

1. In combination with a source of audio waves, an amplitude compression system comprising a wave transmission network including a pair of tubes connected in push-pull relation each of said tubes having a variable mu characteristic, a degenerative audio voltage feedback path connected between the output and input of said network for giving said transmission network a compression characteristic which is the inverse of its original expansion characteristic.

2. In an audio wave volume range compression system, a pair of variable-mu tubes arranged in push-pull relation, a source of waves to be compressed, a resistor network comprising three arms and having a pair of said arms connected across the source, means for applying voltage developed across one of said arms upon said push-pull tubes, and means for feeding back audio voltage in degenerative phase from the output of said push-pull tubes to the input thereof through the third of said resistive arms.

3. An electric wave transmission system for providing a non-linear input versus output characteristic which comprises a source of input voltage for said system, a system output circuit, an amplifier having a pair of electron discharge tubes arranged to produce a second non-linear input versus output characteristic which is substantially the inverse of said first-named characteristic and having an input circuit and an output circuit, means for feeding a portion of the signal in said amplifier output circuit into said amplifier input circuit in reverse phase whereby said second non-linear characteristic is inverted to said first non-linear characteristic, means for also feeding a portion of said input voltage for said system into said amplifier input circuit, and means for feeding a portion of the total signal in said amplifier input circuit into said system output circuit.

4. An electric wave transmission system for providing a non-linear input versus output characteristic which comprises a source of input voltage for said system, a system output circuit, an amplifier having a second non-linear input versus output characteristic which is substantially the inverse of said first-named characteristic and having an input circuit and an output circuit, means for feeding a portion of the signal in said amplifier output circuit into said amplifier input circuit in reverse phase whereby negative feedback is obtained, means for also feeding a portion of said input voltage for said system into said amplifier input circuit, and means for feeding a portion of the total signal in said amplifier input circuit into said system output circuit, said amplifier employing at least two tubes of the variable-mu type connected in push-pull to provide said second non-linear characteristic.

5. In a compression network having input and output terminals, at least two tubes arranged in push-pull relation, said tubes having a pair of

input terminals and a pair of output terminals, each of said tubes having an input voltage-output current characteristic of the remote cut-off type and provided with such curvature that the output current of the tube increases at a more rapid rate for increased input voltage, a resistive network comprising at least two arms, said arms being connected across said network input terminals, said pair of input terminals being con-

5 nected across one of said two arms, said network output terminals being connected across said one arm, and a degenerative feedback path being connected between said pair of output terminals and the said one arm whereby the effective input voltage-output current characteristic of said network is the inverse of the aforesaid characteristic.

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