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2,561,747

VOLUME LIMITING AMPLIFIER.

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FIG. 1.

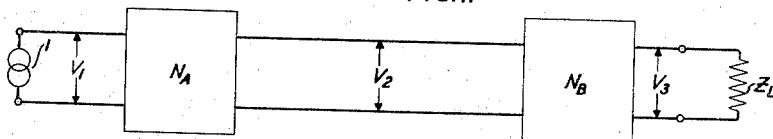


FIG. 2.

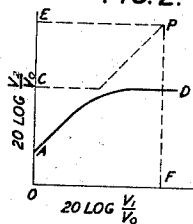


FIG. 3.

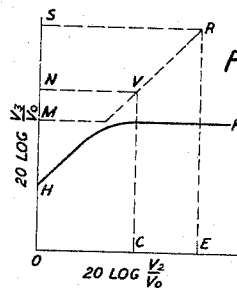


FIG. 4.

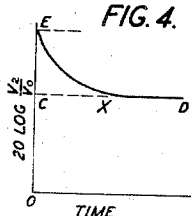


FIG. 5.

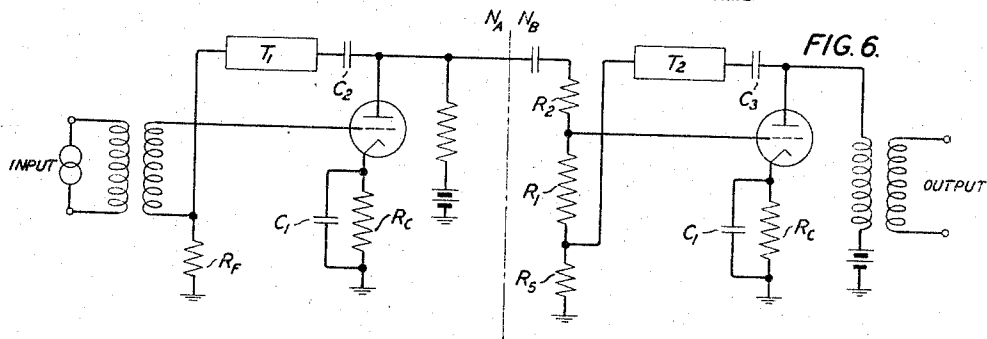
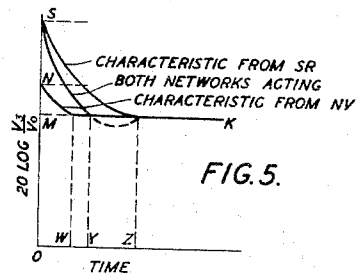
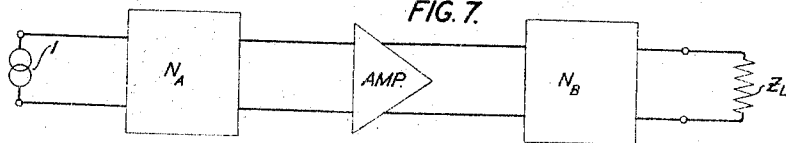


FIG. 7.



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VOLUME LIMITING AMPLIFIER

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1 Claim. (Cl. 179—171)

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This invention relates to signal transmission systems and particularly to the control of amplification in such systems by the use of volume limiters.

One object of the invention is to provide a substantially constant speech level output circuit in which the gain is varied automatically by a combination of volume limiters having non-linear elements such as thermistors to maintain the output level constant or within predetermined limits without introducing objectionable distortion of the signals.

Another object of the invention is to provide a substantially constant speech level output circuit which affords the required degree and speed of control, and the operation of which is more economical than that of comparable circuits.

A feature of the invention is the employment of non-linear elements such as thermistors which are inherently slow acting, non-distorting devices but which, when operated in combination, interact to obtain a relatively fast attack time without the introduction of distortion.

Various automatic volume control systems have been proposed heretofore. In some of these a portion of the signal is rectified and used as a variable grid bias to control the gain of one or more amplifying tubes to compensate for changes in the input level. While systems of this type can be devised in accordance with well-known circuit theory to meet almost any particular requirements, they involve one or more additional vacuum tubes and other circuit elements which often unduly increase the cost of the system.

To provide a more economical system it has been proposed to employ a non-linear resistor in series with a negative feedback path around the amplifier, or in some cases in shunt to the transmission path. There are two well-known types of non-linear resistors; namely, "thermistors" which vary in resistance relatively slowly in accordance with the heating effect of the current and "varistors" which vary in resistance instantaneously in accordance with the magnitude of the current. If the action of the thermistor is too fast it may follow the syllabic variations of speech. Such action is undesirable in a volume limiter as it introduces distortion. Therefore, a relatively slow thermistor element necessarily must be used. However, such an element reacts too slowly to large, sudden changes in speech volume level to be entirely satisfactory when used alone. On the other hand while a varistor acts instantaneously, it introduces objectionable distortion by suppressing or chopping off the individual signal peaks.

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According to this invention, fast acting automatic volume control is obtained in a very inexpensive manner and without the introduction of distortion by the use, in combination, of two relatively slow acting non-linear networks. These networks may in their simplest form consist of two thermistors connected as series elements in negative feedback connections of two tandem amplifier stages, or two thermistors connected as simple shunts to the input and output circuits of a fixed gain amplifier. In either case the reduction in the attack time obtained is believed to be brought about by the "over driving" of the second thermistor produced by the thermal lag in the first thermistor which is in a lower level portion of the circuit. In accordance with the theory it is found that in an entirely passive circuit where no amplification is provided, faster attack is also obtained with two shunt thermistors directly in parallel provided one thermistor is of greater sensitivity than the other; that is, one thermistor will react at lower signal voltage.

In the associated drawing Fig. 1 is a limiting system according to the invention. Figs. 2, 3, 4 and 5 are diagrams illustrating the operation of the thermistor networks according to the invention. Fig. 6 is a two-stage feedback amplifier adapted for operation as a fast operating limiter. Fig. 7 is a fixed gain amplifier adapted for operation as a fast operating limiter.

Referring to Fig. 1 of the drawing, signals from the source 1 are transmitted to the load Z_L through the networks A and B which maintain the voltage across the load either constant or within a certain range of values as required. Networks A and B are volume limiters employing thermistors and having input-output characteristics shown in Figs. 2 and 3, respectively.

As shown in Figs. 2 and 3 these networks provide at low input levels a certain amount of amplification. Network A provides a gain equal to the line OA and network B provides a gain represented by line OH. It is not a requirement that amplification be provided. However, if amplification is not provided and we have an entirely passive circuit, it is essential that one network be of greater sensitivity than the other; that is one network will react at lower signal voltage. In principle, the networks may be of different sensitivity, or if they are of the same sensitivity, they must be connected to the circuit at points of different signal level.

Referring to Figs. 2, 3, 4 and 5 of the drawing, the input and output of networks A and B are

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expressed in decibels. The input to network A is therefore designated

$$20 \log \frac{V_1}{V_0}$$

and the output is designated

$$20 \log \frac{V_2}{V_0}$$

where V_0 is an arbitrary reference voltage, V_1 is the input voltage and V_2 the output voltage. In network B, V_2 is the input voltage and V_3 the output voltage.

Network A is shown as limiting along the line CD while network B is shown as limiting along the line MK. The maximum "steady state" voltage output of network A is represented by OC. Let us assume that at the time O, a sudden large input voltage OF is applied to network A. At the time O, network A will not be in the limiting condition and the voltage output will therefore be OE. Voltage OE will be applied to the input of network B which also will not be in the limiting condition and will therefore have a voltage output OS. If the input voltage OE applied to network B were constant, we could assume that the output of network B would decrease with time as shown by the curve SZ of Fig. 5. At some time as defined by the point Z, the voltage would reach a constant value. Thus, for constant input voltage OE the time required for the output to diminish to its limiting value would be Z. However, the input voltage to network B is not constant but is decreasing. At the time O, the output voltage of network B as shown in Fig. 5 is not only decreasing at the rate

$$\frac{dV_3}{dt}$$

the rate of change of the curve SZ, it is decreasing at a faster rate because V_2 at the time O is also decreasing as shown by the curve EXD of Fig. 4. The voltage V_3 is directly related to V_2 by a factor μ so that V_3 is equal to μV_2 where μ is the gain of network B. This gain, of course, changes with input voltage V_2 in the limiting range of network B but at the time O it will have a definite value. Likewise at other times near O the rate of decrease of V_3 will be greater than it would be if V_2 were constant. However, as the voltage V_2 diminishes, a point will be reached where V_3 will no longer decrease at a greater rate than it would have if V_2 had been held constant. The curve that shows a simultaneous action of both networks is designated SYZ on Fig. 5. The addition of network A to the system has decreased the attack time by YZ as shown on Fig. 5.

The use of more than one limiting network increases the limiting range. For example, the range of the system consisting of networks A and B will be broader than the range of either network alone. There are two reasons for this: first, the power handling capacity of the system has been increased by the addition of more elements each capable of dissipating a certain amount of power; and second, the networks are designed to start limiting at different levels. One network will account for the beginning portion of the limiting characteristic and the other will act on the higher input level. In regions where only one network is acting the attack time will not be as fast as it will be on the overlap portion of the

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characteristic where both networks are limiting in the manner described above. Therefore, where the attack time is a major consideration the overlap portion of the range should be as broad as possible. Where range alone need be considered the overlap can be narrow; one network acting after the other has completed its limiting.

Fig. 6 of the drawing shows a particular structure of the networks A and B. This is a simple type of feedback circuit well known in the art with the thermistors T_1 and T_2 being the non-linear elements providing the limiting action. The constants are so related as to provide the desired over-all input-output characteristic and a relatively fast attack time. It will be observed that the two stages of amplification are not independent of each other. The feedback voltage from the second stage appears across the output circuit of the first stage. This in turn affects the amount of feedback in the first stage and thereby affects the limiting action.

Fig. 7 of the drawing shows a combination of volume limiters together with a fixed gain amplifier to provide a fast operating circuit which gives constant output level for speech input levels within a predetermined range. Networks A and B may be two identical thermistors employed to introduce loss into the circuit. The operation of this circuit is similar to that of the circuits shown in Figs. 1 and 6.

What is claimed is:

In a signal transmission system, a signal transmission line comprising input and output terminals and adapted to receive and transmit signals through said terminals, a source of signals connected to said input terminals, and volume limiting means operatively connected to said line for controlling the energy level of the signals from said source including an amplifier comprising at least two tandem stages of amplification where-in each succeeding stage provides an energy level for said signals greater than that provided by the stage preceding it, and each of said stages has an individual degenerative feedback circuit and a thermally sensitive resistor connected as a series element in said feedback circuit, said resistor having a specific resistance which is not directly affected by the magnitude of the signals in said feedback circuit and cannot be caused to vary while the temperature of said resistor remains constant but is caused to vary non-linearly and inversely as the temperature of said resistor varies under the thermal influence of the signals in said feedback circuit.

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