

Jan. 6, 1948.

R. L. HAYNES

2,434,155

ELECTRONICALLY CONTROLLED VARIABLE GAIN AMPLIFIER

Filed Sept. 27, 1943

2 Sheets-Sheet 1

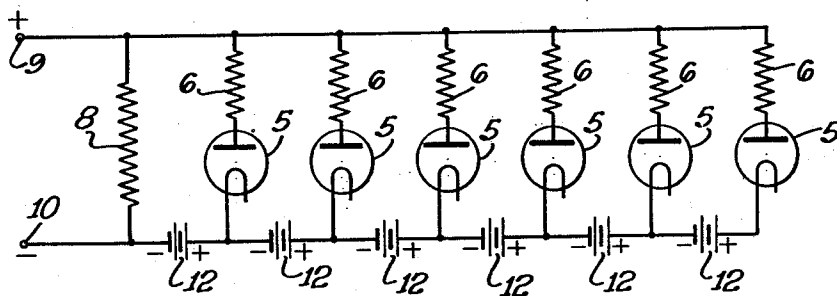


Fig. 1.

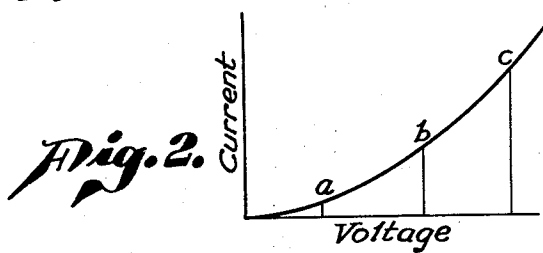


Fig. 2.

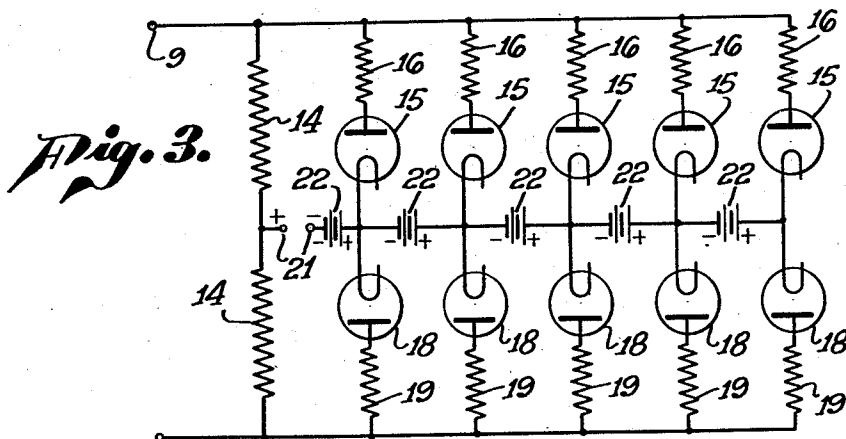


Fig. 3.

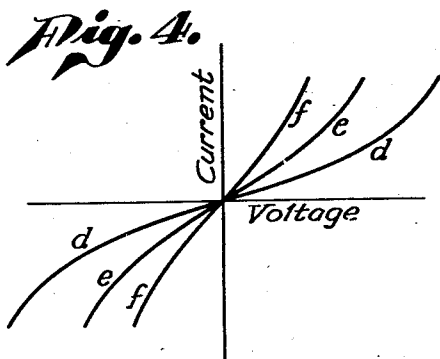


Fig. 4.

ROBERT L. HAYNES,
INVENTOR.

BY *Carl R. Goshaw*
ATTORNEY.

Jan. 6, 1948.

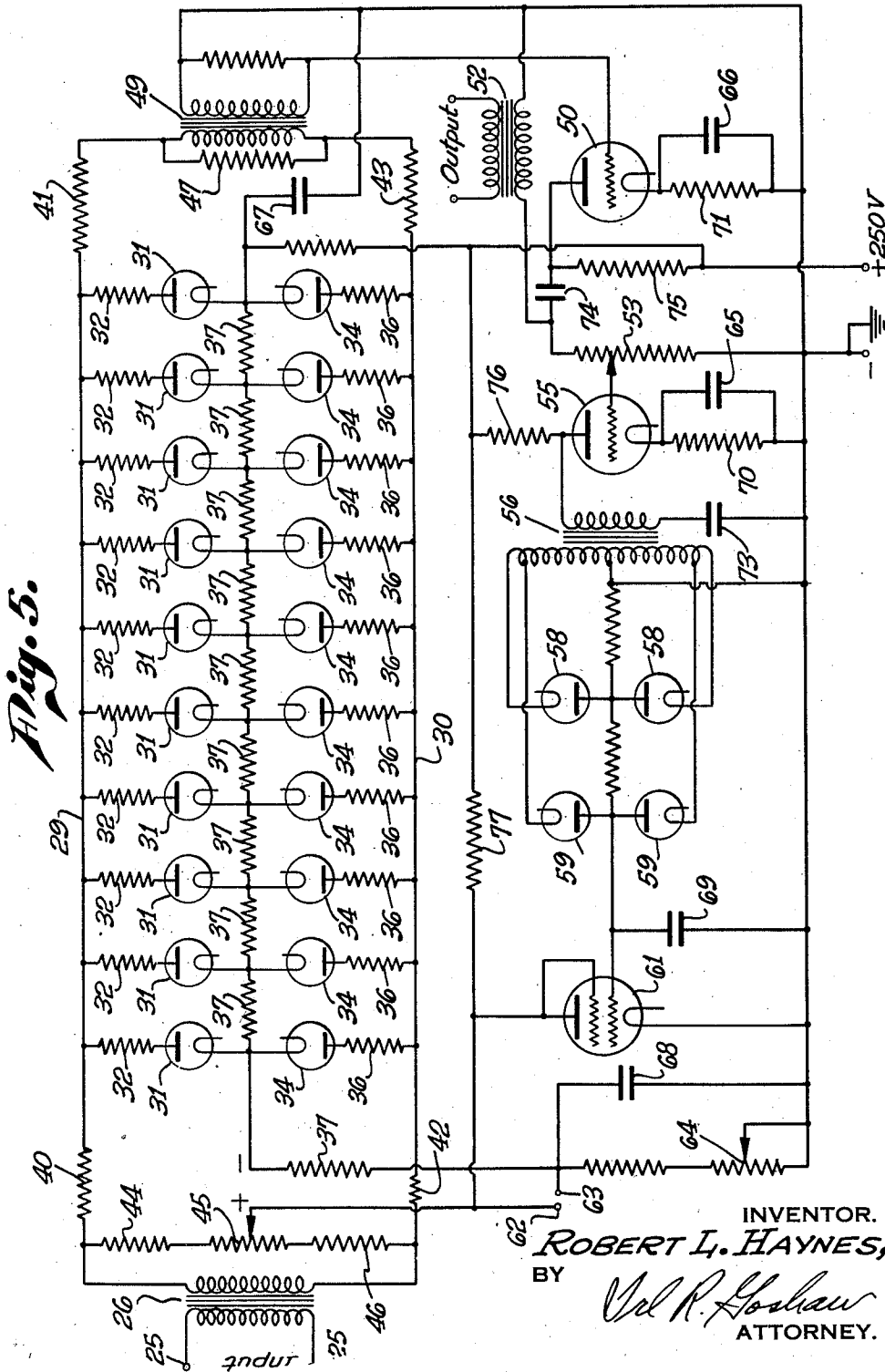
R. L. HAYNES

2,434,155

ELECTRONICALLY CONTROLLED VARIABLE GAIN AMPLIFIER

Filed Sept. 27, 1943

2 Sheets-Sheet 2



INVENTOR.
ROBERT L. HAYNES,
BY
Vol. R. Goshaw
ATTORNEY.

UNITED STATES PATENT OFFICE

2,434,155

ELECTRONICALLY CONTROLLED VARIABLE
GAIN AMPLIFIERRobert L. Haynes, Indianapolis, Ind., assignor to
Radio Corporation of America, a corporation
of Delaware

Application September 27, 1943, Serial No. 503,971

7 Claims. (Cl. 178-44)

1

This invention relates to electrical current transmission systems and particularly to a system wherein the recorded or reproduced volumes of the signals are varied with respect to the original volumes during the transmission of the signals.

The use of compression and expansion in sound recording, broadcast, public address, and other types of sound reproducing systems, is well-known, a typical sound recording compressor system being disclosed and claimed in Singer Patent No. 2,255,683 of September 9, 1941. Miller Patent No. 2,136,723 of November 15, 1938, also discloses and claims both a compression and expansion system for sound films.

The present invention is directed to an improvement in compression and expansion systems, and utilizes, to some extent, the principle disclosed in Strieby Patent No. 1,776,322 of September 30, 1930. The improvement over these prior types of volume control systems results in a lower amount of distortion, a very low "thump" disturbance, a simplification of the usual critical balancing procedure, and the avoidance of specially selected vacuum tubes. Thus, the compressor described hereinafter provides these new results together with a smooth variation in volume differential over the range desired.

The principal object of the invention, therefore, is to facilitate compression and expansion of the amplitudes of electrical currents corresponding to sound signals.

Another object of the invention is to provide means for obtaining variations in attenuation or loss in an electrical transmission system in accordance with the original volume of the signal.

A further object of the invention is to provide means for varying the attenuation of a signal in accordance with its volume with the minimum of distortion and "thump" disturbance.

A still further object of the invention is to provide a balanced, electrically variable attenuator whose balance is not critical.

Although the novel features which are believed to be characteristic of this invention will be pointed out with particularity in the appended claims, the manner of its organization and the mode of its operation will be better understood by referring to the following description read in conjunction with the accompanying drawings forming a part hereof, in which:

Fig. 1 is a schematic circuit diagram illustrating a fundamental principle of the invention.

2

Fig. 2 is a graph illustrating the operation of the circuit of Fig. 1.

Fig. 3 is a schematic circuit diagram illustrating the method of applying the basic principle of the present invention.

Fig. 4 is a graph illustrating the operation of the circuit of Fig. 3, and,

Fig. 5 is a schematic diagram of a compressor circuit embodying the invention.

Referring now to Fig. 1, a plurality of diodes 5 are shown connected in series with a respective number of resistors 6, all of which are in shunt to a resistor 8 across terminals 9 and 10. Each of the diodes is differently biased by respective batteries 12 having polarities as indicated. With such a circuit, small values of voltage applied to terminals 9 and 10 with the polarity shown, result in a resistance which is equal to the resistance of resistor 8, since all of the diodes 5 have a negative plate voltage and do not conduct. As the applied voltage across terminals 9 and 10 is increased, the first diode begins to conduct when its plate voltage becomes positive and its resistor 6 is then shunted across resistor 8. As the applied voltage increases, the other diodes will be successively shunted across resistor 8, the effective resistance across the line becoming lower and lower as the applied voltage is increased. As the normal diode rectifier has a rounded cut-off characteristic, the curve for the plurality of rectifiers 5 will appear as shown in Fig. 2, three different values of bias *a*, *b*, and *c* being shown on the curve plotted between applied voltage and current.

Although the above circuit may be used in a variable attenuator, such an attenuator will have several disadvantages, such as the introduction of second harmonic distortion and the production of objectionable "thump" in the output when the gain or loss in the system is changed rapidly. These disadvantages, however, may be eliminated or, at least, minimized to a tolerable extent, by using two identical diode elements connected in a push-pull relationship and biasing them equally but with opposite polarities. Such a circuit is shown in Fig. 3 shunting terminals 9 and 10 as in Fig. 1. In the circuit of Fig. 3, resistor 14 corresponds to resistor 8 of Fig. 1 and determines the highest resistance to the applied voltage which is effective for small values thereof. The remainder of the circuit comprises a plurality of diodes 15 with their respective resistors 16 similar to those of Fig. 1, and a second identical plurality of diodes 18 in series with their respective resistors 19, all of which are in

shunt to the line having terminals 9 and 10. A polarizing potential is connected across terminals 21 and a series of biasing batteries 22 provide a successively higher bias for each pair of diodes 15 and 18.

The voltage-current curves for the circuit of Fig. 3 are shown in Fig. 4 for three different biases *d*, *e*, and *f*, curve *d* being for a low value of bias and curves *e* and *f* being for successively higher values of bias, the effective resistance of the combination to small audio signals being indicated by the slope of the curves at the origin. From these curves, it will be noted that the effective resistance may be varied over a wide range by shifting the bias. The use of two identical elements, such as the respective pairs of diodes 15 and 18 and the respective resistors 16 and 18 used in the manner shown in Fig. 3, prevents the objectionable "thumps" and second harmonic distortion. It is true that third harmonic distortion may be present, but this distortion is of a very low amplitude and may be further minimized by keeping the audio signal level low.

The above type of volume control circuits are of the non-linear type, as shown by the curves in Figs. 2 and 4, and some of the disadvantages of such circuits are that they usually must be perfectly balanced or matched to avoid distortion, that their characteristics generally vary with ambient temperature, and that they introduce distortion because of the attenuation at high frequencies due to the high capacitance in the elements themselves. My arrangement of these tubes in the push-pull relationship shown in Fig. 3, however, reduces these disadvantages to a minimum and reduces the tolerance to which the balance must be held, both of the tubes and of their series resistors.

Referring now to Fig. 5, wherein is shown an actual compressor circuit arrangement, it being understood that an expander utilizes the same principle in reverse, the incoming signal to be compressed is impressed across terminals 25 connected to an incoming line and transmitted over transformer 26 to the line 29 and 30, between which are located 10 shunting circuits made up of a plurality of diodes 31 with their respective series resistors 32 and a like number of diodes 34 with their respective series resistors 36. It will be noted that this circuit arrangement is similar to the arrangement of diodes and resistors in Fig. 3, the batteries 22 of Fig. 3 now being replaced by bias resistors 37. In the circuit of Fig. 5, the diodes 31 and 34 with their respective resistors 32 and 36 form the variable shunt resistor of an H-pad, resistors 40, 41, 42, and 43 forming the series elements of the pad. Resistors 44, 45, and 46 form the terminating resistance for the secondary of transformer 26, while resistor 47 performs a similar function for the primary of output transformer 49.

After the electrical currents are transmitted by transformer 49, they are amplified by an alternating current amplifier 50, the output of which, after passage through coupling condenser 74, is divided between the output transformer 52, the output terminals of which are connected to an outgoing line connected to the load, and the coupling potentiometer resistor 53. Varying amounts of the voltage developed across resistor 53 are impressed upon the second alternating current amplifier 55, the output being impressed upon a transformer 56, the secondary of which is connected to a pair of high voltage rectifiers 58 and a pair of low voltage rectifiers 59. This particu-

lar type of rectifier system is disclosed and claimed in my United States Patent No. 2,359,989 of October 10, 1944. The output of the rectifiers 58—59 is impressed on a direct current amplifier 61 which controls the over-all impedance across the line 29—30. Variable resistor 64 controls the initial bias applied to the diode circuit, while the system includes the usual by-pass condensers 65, 66, 67, 68, and 69 and bias resistors 70 and 71. Coupling condensers are shown at 73 and 74, while anode load resistors are shown at 75, 76, and 77.

As mentioned above, the above system operates as a compressor since the attenuation elements of the H-pad, comprising the fixed series resistors 40, 41, 42, and 43, and the variable shunting resistor composed of the plurality of diodes 31 and 34 with their associate resistors 32 and 36, is varied in accordance with the amplitude of the signal across terminals 25. Suitable different bias voltages are provided for each pair of the diodes 31 and 34 by the respective resistors 37 in the voltage divider circuit connected across the 250-volt plate potential supply. The attenuation or loss introduced by the pad is determined by the voltage existing between terminals 62 and 63. When terminal 62 is negative with respect to terminal 63, or when the difference between the potential at terminals 62 and 63 is zero, none of the diodes is conducting and the effective value of the shunt impedance of the H-pad is infinite, which provides the minimum loss condition. In one particular circuit, the loss thus introduced was about 14 db. When the terminal 62 is 70 volts positive, with respect to terminal 63, all the diodes are conducting and all of the resistors 32 and 36 are effective as shunt resistors in the H-pad, and, in one type of circuit, this shunt impedance was about 2000 ohms introducing a loss of 34 db. At intermediate values of control voltage, only certain of the diodes are conductive, and the loss was smoothly variable between 14 and 34 db. In this circuit, the bias on the successive diodes differed by about one-half a volt and the individual diode plate characteristics were sufficiently curved to produce a smooth variation of gain with control voltage with no abrupt amplitude changes.

The above-described compressor was found to be an improvement over prior compressors in that it had a particularly low transmission distortion, a lower "thump" disturbance, and was less critical to unbalance, thus not requiring specially selected tubes. The circuit does not drift off balance, thus reducing readjustments. About 20 db. of compression was obtainable, the shape of the compression curve being determined by the value of resistors 53 and 64, resistor 64 determining the initial bias applied to the diode circuit which, of course, determines the point at which compression starts.

Although my special rectifier system is illustrated at 58—59, it is to be understood that any standard full wave filter-rectifier circuit may be substituted, although the rectifier circuit shown in Fig. 5 is preferred since it was found to give approximately a 6 to 8 db. improvement in filtering with no sacrifice in timing characteristics.

I claim as my invention:

1. An electrical current transmission system comprising an incoming line and an outgoing line, a resistor connected in shunt to said line for determining the maximum impedance across said line, and a plurality of pairs of diodes connected in shunt across said line for reducing the impedance across said line below that of said re-

5

sistor, the diodes of each pair having their cathodes connected together, said diodes being arranged in pairs and each pair being connected in parallel and provided with successively higher biases for successively decreasing the impedance across said line in accordance with the voltage applied thereto.

2. An electrical current transmission system comprising an incoming line and an outgoing line, an impedance network interconnecting said lines, said network comprising a plurality of series resistors and an intermediate variable impedance element, said variable impedance element including a plurality of diodes arranged in pairs in shunt to said line, the diodes of each pair having their cathodes connected together, means for obtaining a different bias for each pair of diodes, and means for applying a voltage to the anodes of said diodes simultaneously in accordance with the amplitude of the signal present in said incoming line for varying the impedance across said line.

3. An electrical transmission system in accordance with claim 2 in which said last mentioned means includes a rectifier for producing a voltage corresponding to the peak value of the amplitude of said signal currents, said voltage being impressed simultaneously on all the anodes of said diodes.

4. A compressor circuit comprising an incoming line for signal currents, an outgoing line for said currents, and a variable impedance interconnecting said lines, said variable impedance including a plurality of diodes connected in pairs across said line, the diodes of each pair having their cathodes connected together and each pair of diodes being connected in parallel, means for obtaining a different bias on each parallel pair of diodes, and means for varying the anode potential on all of said diodes simultaneously for varying the attenuation of said signal currents before impression on said outgoing line in accord-

6

ance with the peak value of the amplitude of said signal currents.

5. A compressor circuit in accordance with claim 4 in which said last mentioned means includes a rectifier having its input connected to the output of said variable impedance and its output connected to the anode polarizing circuit for said plurality of diodes.

6. An electrical compressor circuit comprising an incoming signal line and an outgoing signal line and a network interconnecting said lines for varying the amplitude of transmission of the signal currents between said lines, said network including a variable electronic impedance including a plurality of pairs of diodes, the diodes of each pair having their cathodes connected together, each pair of diodes being connected in parallel and having a successively higher bias, and means for simultaneously varying the anode potential on said diodes in accordance with the peak value of the amplitude of said signal currents.

7. An electrical compression circuit in accordance with claim 6 in which said network is in the form of an H-pad having a plurality of series resistors, said plurality of diodes forming the shunt arm of said H-pad.

ROBERT L. HAYNES.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,208,923	Curtis	July 23, 1940
2,215,946	Von Radinger	Sept. 24, 1940
2,298,657	Smith et al.	Oct. 13, 1942

FOREIGN PATENTS

Number	Country	Date
478,137	Great Britain	Jan. 10, 1938