June 28, 1966 J. F. LAWRENCE, JR 3,258,707

VARIABLE GAIN AMPLIFIER SYSTEM UTILIZING A SOLID ELECTROLUMINESCENT CELL

Filed May 3, 1962

Fig. 1

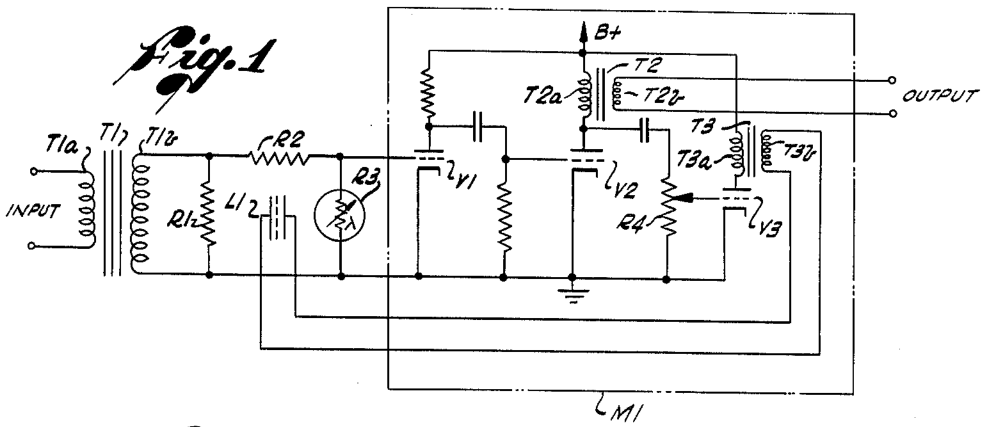


Fig. 2

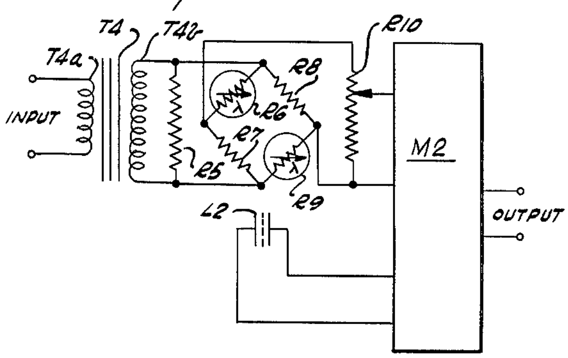


Fig. 5

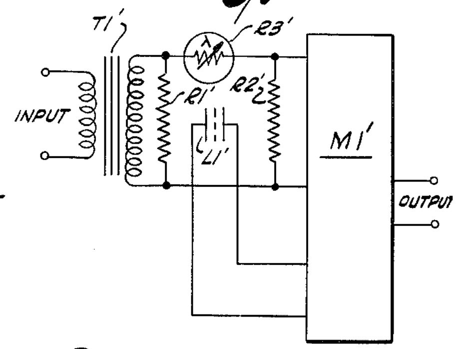


Fig. 3

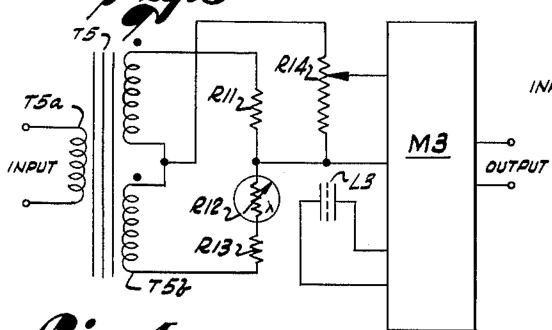


Fig. 6

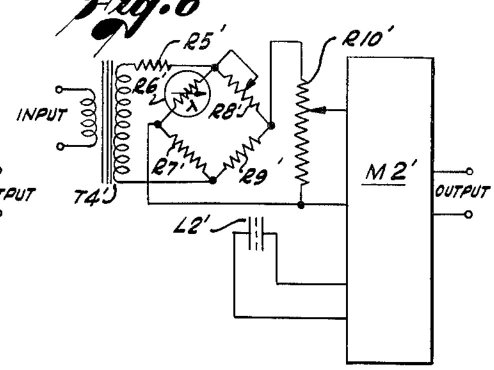
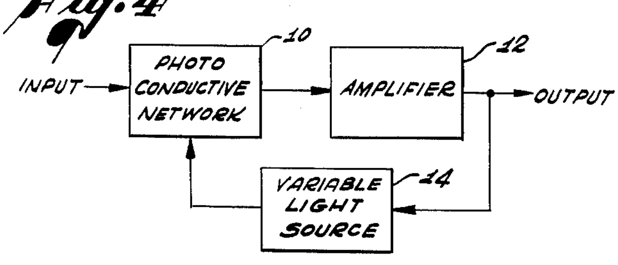


Fig. 4



INVENTOR.
JAMES F. LAWRENCE, JR.
BY Forrest J. Lilly
ATTORNEY

United States Patent Office

3,258,707

Patented June 28, 1966

3,258,707

VARIABLE GAIN AMPLIFIER SYSTEM UTILIZING A SOLID ELECTROLUMINESCENT CELL

James F. Lawrence, Jr., 465 Sequoia Drive, Pasadena, Calif.

Filed May 3, 1962, Ser. No. 192,100
6 Claims. (Cl. 330—59)

My present invention relates generally to variable voltage attenuators, and more particularly, to an amplifier system including a variable voltage attenuator for varying the gain of the amplifier system as a function of the output voltage thereof.

As is well known, the gain of an audio compression and limiting amplifier is varied in accordance with the amplitude of the signal being amplified. The gain is normally reduced when the signal is large, and is increased when the signal is small. The gain of most compression and limiting amplifiers is controlled by a voltage which is used to vary the amplification of one or more amplifier stages of the amplifier. This control voltage is usually derived from a rectified portion of the output voltage of an amplifier stage and is used to vary the bias of another amplifier stage so that its amplification or gain decreases, for example, when the control voltage is large. Automatic control of audio level and reduction of audio peaks are achieved for such purposes as reducing volume range in recording sound, and preventing overmodulation of radio transmitters. Control obtained by varying bias, however, tends to increase the distortion generated in the controlled amplifier stage because the operating point of the amplifier stage is shifted from optimum.

In addition to providing a large amount of compression or limiting of audio signals with a minimum of waveform distortion, the criterion for a desirable audio compression and limiting amplifier includes fast response to audio peaks for efficient control thereof. Where bias is varied in order to increase or decrease amplification, careful circuit design including proper consideration of time constants of the components involved is required to secure rapid increase or decrease of amplification.

It is an object of my invention to provide a variable gain amplifier system in which large amounts of compression or attenuation of the signal being amplified are automatically achieved with little or no increase in waveform distortion.

Another object of the invention is to provide a variable gain amplifier system in which highly rapid and efficient control of the level of the signal being amplified is obtained.

A further object of the invention is to provide a variable gain amplifier system in which variation of bias and its attendant disadvantages in controlling gain are avoided.

A still further object of this invention is to provide a variable gain amplifier system wherein extremely large values of compression or attenuation of the signal being amplified are readily achieved.

Briefly, and in general terms, the foregoing and other objects are preferably accomplished by providing a variable gain amplifier system comprising a novel combination of a photoconductive network, an amplifier and a variable light source. An input signal is applied to the amplifier through the photoconductive network which includes one or more photoconductive cells placed in proximity to the variable light source. The amplifier produces an amplified system output signal from the input signal, and this output signal is also used to energize and control the light output of the variable light source. The light source is preferably a low power electroluminescent device which is characterized by instantaneous light response to applied voltage and substantially linear variation of light output with variation in applied voltage. The light source produces a variable light output which resistively varies the photoconductive network by means of photoconductive cells so as to vary the input signal applied thereto in accordance with the light output from the variable light source. An increased light output from the variable light source causes the photoconductive network to attenuate the input signal provided to the amplifier, and a decreased light output increases this input signal. The result is that the gain of the system is reduced with an increased system input signal, and the gain is increased with a decreased system input signal. A modified version of the photoconductive network causes the gain of the system to be increased with an increased system input signal, and decreased with a decreased system input signal.

My invention will be more fully understood, and other objects and advantages of the invention will become apparent, from the following description of a few illustrative embodiments of the invention to be taken in conjunction with the attached drawing, in which:

FIGURE 1 is a circuit diagram of a first embodiment of my invention;

FIGURE 2 is a circuit diagram of a second embodiment of the invention;

FIGURE 3 is a circuit diagram of a third embodiment of the invention;

FIGURE 4 is a generalized block diagram of my invention;

FIGURE 5 is a circuit diagram of a variation of the circuit of FIGURE 1; and

FIGURE 6 is a circuit diagram of a variation of the circuit of FIGURE 2.

A first embodiment of my invention is shown in FIGURE 1. An input signal, such as an audio voltage is applied to the primary winding T1*a* of an input transformer T1. This audio voltage is transformed and appears across the secondary winding T1*b* of the input transformer T1. A resistor R1 of, for example, 100 kilohms, is connected across the secondary winding T1*b* to provide a constant load on the transformer T1 to preserve a proper transformer primary impedance. A series combination of resistor R2 and photoconductive cell R3 is connected across the secondary winding T1*b* and serves as a voltage divider, the output of which is applied to the control grid of amplifier tube V1. The resistor R2 is, for example, a 1 megohm resistor, and the resistor R3 is preferably a photoconductive cell whose resistance may range from many megohms in darkness to only a few hundred ohms when excited by light. The voltage across the photoconductive cell R3 applied to the tube V1 is proportional to the resistance value of photoconductive cell R3, since the resistor R2 remains constant in value.

The output voltage from tube V1 is preferably further amplified by amplifier tube V2 and applied to the primary winding T2*a* of the output transformer T2. A system output signal is obtained from the secondary winding T2*b* of the transformer T2. The output voltage from tube V2 is also applied to amplifier tube V3 through a potentiometer R4. The output voltage of the tube V3 is applied to the primary winding T3*a* of the transformer T3. The secondary winding T3*b* of the transformer T3 is connected to a variable light source L1 which is preferably an electroluminescent device or other low power, linear light source having essentially instantaneous response to applied voltage and located in proximity to the photoconductive cell R3. The photoconductive cell R3 is thus exposed to light from the electroluminescent device L1.

The light output from the electroluminescent device L1 is dependent upon the voltage developed across the secondary winding T3*b* of the transformer T3. This voltage in turn is dependent upon the output voltage from tube V3, and is therefore proportional to the amplified output voltage of the tube V2. Since the output from the tube V2 is applied to the output transformer T2, the light output from the electroluminescent device L1 is also proportional to the system output signal from the secondary winding T2*b* of the output transformer T2.

As the audio voltage applied to the input transformer T1 is increased, the amplified output voltage from the tube V2 will tend to increase a certain amount so that the output voltage from the tube V3 and transformer T3 will also tend to increase a certain amount. Since the output voltage of the transformer T3 is supplied to the electroluminescent device L1, the resulting increase in light will reduce the resistance of the photoconductive cell R3 such that a lower voltage is applied to the tube V1. The amplified output voltage from the tube V2 and from the output transformer T2 thus will not be increased the full amount for the increase of the audio voltage applied to transformer T1. Since the system output voltage from the output transformer T2 is not increased a full amount for the increased voltage to the input transformer T1, the gain of the system is reduced with an increased input signal. The adjustment setting of potentiometer R4 determines the amount of gain reduction which is to take place in the system.

A second embodiment of this invention is shown in FIGURE 2. Two photoconductive cells are utilized in conjunction with a variable light source in an arrangement which has increased sensitivity and is capable of complete decrease in output signal regardless of the minimum resistance capability of the photoconductive cells. The input transformer T4 in FIGURE 2 corresponds to the input transformer T1 of FIGURE 1. An input signal is applied to the primary winding T4*a* of the input transformer T4 and an output voltage is obtained across the secondary winding T4*b*. A resistor R5 is connected across the secondary winding T4*b*, as shown in FIGURE 2. The resistor R5 is provided for the same reason as the resistor R1, and is similar in value to the resistor R1.

The ends of a bridge circuit having two parallel branches are connected to respective ends of the secondary winding T4*b*. One branch of the bridge circuit is formed from a series combination of a photoconductive cell R6 connected in an upper arm of the branch and a resistor R7 connected in a lower arm. The other branch is formed from a series combination of a resistor R8 connected in an upper arm of this branch and another photoconductice cell R9 connected in a lower arm. A potentiometer R10 is connected between the centers of the two branches of the bridge circuit, and the output from the potentiometer is applied to an amplifier tube (not shown) corresponding to the tube V1 of FIGURE 1 in the block M2.

The circuitry of the block M2 is identical to that in the block M1 of FIGURE 1, and has not been repeated in FIG. 2. An output from the block M2 is obtained from an output transformer (not shown) in block M2 corresponding to transformer T2 of block M1 in exactly the same manner as shown in FIGURE 1. Similarly, the electroluminescent device L2 from the block M2 is connected to another transformer (not shown) in the block M2 corresponding to the transformer T3 of block M1 in exactly the same manner as shown in FIGURE 1. The electroluminescent device L2 is positioned in proximity to the photoconductive cells R6 and R9 so as to illuminate these cells equally.

The values of both the resistor R5 and the potentiometer R10 are 100 kilohms, and the values of the resistors R7 and R8 are 10 kilohms, for example. When an input signal is applied to the input transformer T4, an appropriate voltage is produced across the potentiometer R10 and an appropriate light output from the electroluminescent device L2 is provided on the photoconductive cells R6 and R9 so that a properly reduced amplified output signal is obtained from the output of the block M2 in a manner similar to that for the circuit of FIGURE 1. As the input voltage to the transformer T4 is increased a certain amount, a greater output votlage from the potentiometer R10 will tend to increase the amplified output signal from the block M2 a certain amount. As before, however, the light output from the electroluminescent device L2 is increased to reduce the resistance of the photoconductive cells R6 and R9. The result is that the output voltage from the potentiometer R10 is correspondingly reduced so that the amount of increase in the amplified output signal from the block M2 is reduced a desired amount (as set by a potentiometer in block M2 corresponding to potentiometer R4 in block M1 of FIGURE 1) for the corresponding increase of the input voltage to the input transformer T4. That is, the gain of the system is reduced with an increased input signal to transformer T4.

When the increase in input voltage to the input transformer T4 is such that the light output from the electroluminescent device L2 is increased to a point where the resistance of the cell R6 is equal to that of the resistor R8, and the resistance of cell R9 is equal to that of resistor R7, then the bridge is in balance and the voltage applied to the potentiometer R10 is zero. The values of the resistors R7 and R8 are selected low enough so that the resistances of the cells R7 and R9 do not become less than that of the resistors to cause unbalance of the bridge by very high light outputs on the cells. The output signal from the block M2 is therefore reduced to zero for large increases of the input signal to the input transformer T4. In effect, infinite attenuation has been achieved, even though the resistances of the photoconductive cells R6 and R9 have remained finite. It is thus seen that the gain of the system shown in FIGURE 2 is increasingly reduced for increasing input signals being amplified, and for very large input signals, the gain is effectively reduced to zero so that an output signal will not be obtained from the block M2. In practice, however, this condition is only approached, since some signal must pass through the amplifiers to excite the electroluminescent device L2.

A third embodiment of the invention is shown in FIGURE 3. The circuit of FIGURE 3 uses a method of voltage cancellation to achieve large values of attenuation, but requires only a single photoconductive cell. The input transformer T5 has a primary winding T5*a* and a split secondary winding T5*b*. A series combination of a resistor R11, photoconductive cell R12, and resistor R13 is connected to the ends of the split secondary winding T5*b* and a potentiometer R14 is connected to the center of split secondary winding T5*b* and to the common junction between the resistor R11 and the photoconductive cell R12. The output from the potentiometer R14 is applied to an amplifier tube (not shown) in the block M3, corresponding to transformer T2 in the block M1 of FIGURE 1. Similarly, the electroluminescent device L3 is connected to another transformer (not shown) in the block M3 corresponding to the transformer T3 in the block M1 of FIGURE 1.

The split secondary winding T5*b* is wound and connected so that when an input voltage is applied to the primary winding T5*a*, an additive voltage from end to end of the split secondary winding T5*b* is obtained and applied across the series combination of resistor R11, photoconductive cell R12, and resistor R13. Thus, equal and opposite voltages are obtained at the ends of the split secondary winding T5*b* when considered with respect to the center thereof. It can be seen that if the combined resistances of photoconductive cell R12 and resistor R13 are equal to the resistance of resistor R11, the potentials at the ends of the potentiometer R14 will be equal, and the voltage applied thereto is zero. The resistance of the photoconductive cell R12 need decrease only to such a value that its resistance plus that of resistor R13 equals the resistance of resistor R11, and infinite attenuation of the input signal to transformer T5 is effectively obtained. In practice, however, this condition will be only approached, since some signal must pass through the amplifiers to excite the electroluminescent device L3.

The operation of the circuit of FIGURE 3 is generally similar to that of the circuit of FIGURES 1 and 2. When an input signal is applied to the input transformer T5, equal and opposite voltages appear at the ends of the split secondary winding T5*b* relative to the center thereof. The loop currents due to their respective opposing voltages of the two halves to the split secondary winding T5*b* are varied in magnitude according to their loop resistances and are differentially combined in the potentiometer R14. A resultant voltage is developed across the potentiometer R14 and an output voltage therefrom is applied to the block M3 to produce an output signal at the output thereof. This output signal, of course, includes the effect of the light output from the electroluminescent device L3 on the photoconductve cell R12 decreasing its resistance a certain amount. When the input signal to the input transformer T5 increases, the equal and opposite voltages at the ends of the split secondary winding T5*b* increase to produce a greater output voltage from the potentiometer R14. The light output from the electroluminescent device L3 is also increased to decrease the resistance of the photoconductive cell R12. This produces a decreased output voltage from the potentiometer R14 such that an output signal which is appropriately reduced a desired amount is obtained at the output of the block M3. The gain of the system is thus effectively reduced for an increased input signal to the transformer T5.

When the input signal to the input transformer T5 is sufficiently large to cause the light output from the electroluminescent device L3 to increase to a point where the resistance of the photoconductive cell R12 is decreased so that its resistance in combination with that of the resistor R12 is substantially equal to the resistance of the resistor R11, the voltage across the potentiometer R14 approaches zero so that the output signal from the block M3 is greatly reduced. The resistance of the resistor R11 is preferably selected to approximately equal the minimum operating resistance of the cell R12 combined with that of the resistor R13 so that the voltage across the potentiometer R14 will not increase again after it is made nearly zero by the increasing input signal. The gain of the system of FIGURE 3 is thus reduced with increasing input voltages to the system, and increased with decreasing input voltages thereto.

A block diagram of my invention is shown in FIGURE 4. This block diagram is, of course, applicable to all three embodiments of the invention as described above. An input signal is applied to a photoconductive network **10** and the output of the network **10** is applied to an amplifier **12** which produces an amplified system output signal. The output of the amplifier **12** is also applied to a variable electroluminescent light source **14**, which proproduces a light output that regulates the photoconductive network **10** so that the output from the network **10** is varied according to the light output from the variable light source **14**. Since the light output from the variable light source **14** is dependent upon the output of the amplifier **12**, the output from the photoconductive network **10** is being varied according to the input signal to the network **10**.

The gain of the system is reduced by having an increasing output signal from the amplifier **12** produce an increasing light output from the variable light source **14** to regulate the photoconductive network **10** such that a reduced output is obtained from the network **10**. The input signal to the amplifier **12** is thus reduced to produce a lower amplified system output signal. The gain of the system is effectively reduced for an increased input signal and the network **10** is therefore a variable attenuator which increasingly attenuates an input signal to be amplified as the input signal increases in magnitude.

The photoconductive network **10** corresponds to the voltage divider including resistor R2 and photoconductive cell R3 in FIGURE 1. In FIGURE 2, the bridge circuit including the resistor R7 and R8 and the photoconductive cells R6 and R9 corresponds to the photoconductive network **10** of FIGURE 4. In FIGURE 3, the network connected to the split secondary winding T5*b* and including the resistors R11 and R13 and the photoconductive cell R12, broadly corresponds to the photoconductive network **10** of FIGURE 4. Since the secondary winding of the input transformer T5 in FIGURE 3 is a split secondary winding T5*b*, the center of which is connected to one end of the potentiometer R14, the photoconductive network **10** indicated in FIGURE 4 actually includes the split secondary winding as part of the network **10**.

The input signal indicated in FIGURE 4 would generally correspond to the voltage across the secondary windings of the input transformers T1, T4 and T5 of FIGURES 1, 2 and 3. The amplifier **12** corresponds to the two-stage amplifier including tubes V1 and V2 of FIGURE 1, and similarly in FIGURES 2 and 3, since the blocks M2 and M3 are identical in circuitry to the block M1 of FIGURE 1. The variable light source **14** of FIGURE 4, of course, corresponds to the electroluminescent devices L1, L2 and L3 of FIGURES 1, 2 and 3 respectively.

The photoconductive network **10** of FIGURE 4 can be constructed so that an increasing light output from the variable light source **14** will cause an increasing output from the network **10**. This can be accomplished, of example, by interchanging positions of the resistor R2 and the photoconductive cell R3 in the voltage divider of FIGURE 1. FIGURE 5 illustrates the resulting circuit. Resistor R2′ and photoconductive cell R3′ are the interchanged elements. When the resistance of the cell R3′ is decreased with an increased light output from the electroluminescent device L1′, the voltage across resistor R2′ increases to produce a greater output signal from block M1′. The circuitry in block M1′ is, of course, identical to that in block M1 of FIGURE 1. In this variation of the circuit of FIGURE 1, the gain of the system is increased with an increased input signal to the system. The amplified output signals from the amplifier **12** will be progressively increased with an increasing input signal to the photoconductive network **10**. The system then functions as an expander which expands the input signals to the system.

A variation of the circuit of FIGURE 2 is shown in FIGURE 6. The bridge circuit used requires only a single photoconductive cell R6′. The resistors R7′ and R9′ are fixed resistances of, for example 70 kilohms. The resistor R8′ is adjustable and is preferably set to a low value. The limiting resistor R5′ is, for example, 10 kilohms. The remainder of the circuit of FIGURE 5 is similar to that of FIGURE 2.

When the resistance of the cell R6′ becomes equal to the resistance of resistor R8′, the voltage drop across the potentiometer R10′ is substantially zero so that no input voltage is provided to the block M2′ for amplification. As noted previously, this condition is only approached since some signal must pass through the amplifiers in block M2′ to excite the electroluminescent device L2′. In order to prevent further bridge unbalance or reversal following the equalling of resistances of cell R6′ and resistor R8′ due to further decrease in resistance of the cell R6′ to a value less than that of R8′, the resistance of R8′ is adjusted to a value lower than that to which the cell R6′ can ever reach. In fact, the resistance of resistor R8′ is preferably adjusted to zero in the circuit of FIGURE 6.

Variable gain amplifier systems according to this invention are desirably used to control the left and right signals in a stereo system. The two variable gain amplifiers are essentially independently associated with their respective left and right signals except that the electroluminescent devices of the variable gain amplifiers are connected in parallel. Thus, any variation of the signal being amplified by one amplifier will not only affect the gain of that particular amplifier but also the gain of the other amplifier.

Each of the electroluminescent devices and their respectively associated photoconductive cells are, of course, mounted and contained in a suitably closed housing. The advantages of using an electroluminescent material or device as a light source are that its light output is in direct linear proportion to the exciting voltage as well as very fast action or response, and that no thermal lag exists as would be the case of an incandescent light source. It is also apparent, however, that other types of light-producing devices which produce an increasing light output for an increasing signal applied thereto can be used in place of the electroluminescent devices. Thus, it is to be understood that the particular embodiment of the invention described above and shown in the drawing are merely illustrative of, and not restrictive on my broad invention, and that various changes in design, structure, and arrangement may be made without departing from the spirit and scope of the broader of the appended claims.

I claim:

1. A network having its gain controlled in response to the amplitude of an input signal source applied thereto comprising a constant, predetermined gain amplifier having the input terminals thereof responsive to said signal source for deriving an output that is a replica of the signal at said input terminals, a solid electroluminescent light source coupled to the amplifier output and responsive to a voltage that is a replica of the amplifier output, the light intensity deriving from said light source being substantially linearly related to the amplitude of the voltage applied thereto and responding substantially simultaneously to the variations in the amplitude of the voltage applied thereto, an attenuating network connected to said input terminals for coupling the signal of said signal source to said input terminals, said attenuating network including a photoconductive resistive element optically coupled to be responsive to the light deriving from said light source.

2. The network of claim 1 wherein said photoconductive element is connected in shunt with the input terminals of said amplifier.

3. The network of claim 1 wherein said photoconductive element is connected in series between one input terminal of said amplifier and a terminal of said signal source.

4. The network of claim 1 wherein said attenuating network includes a bridge having a pair of branches across each of which the voltage deriving from said signal source is developed, the opposite ends of said branches being connected together by a pair of common terminals, each of said branches including impedance means having a tap, and means for coupling the voltage between said taps to said input terminals, said photoconductive element being connected in one of said branches between one of said input terminals and one of said common terminals.

5. The network of claim 4 further including another photoconductive resistive element optically coupled to be responsive to the light deriving from said light source in substantially the same manner as the other named photoconductive element, said another photoconductive element being connected in the other of said branches between the other one of said input terminals and the other of said common terminals.

6. The network of claim 4 wherein one of said branches comprises a tapped transformer winding responsive to said signal source, and the other branch comprises: a first resistance in series with said photoconductive element and connected between said one input terminal and said one common terminal, and a second resistance connected bebetween said one input terminal and the other of said common termianls.

References Cited by the Examiner

UNITED STATES PATENTS

2,836,766	5/1958	Halsted.	
3,020,488	2/1962	De Miranda et al. ----	330—59
3,167,722	1/1965	Weller --------------	330—59

ROY LAKE, *Primary Examiner.*

N. KAUFMAN, *Assistant Examiner.*

An Improved Method of Audio Level Control for Broadcasting and Recording

By JAMES F. LAWRENCE, JR.

An improved audio compressor-limiter system has been developed by making use of a new linear optical attenuator. The shortcomings of earlier systems are overcome by producing light instantly and in direct proportion to audio level through the use of electroluminescence. The light controls amplifier input level by means of a photoconductive cell. There is no distortion due to limiting, and the attack time for the system is 10 microseconds.

THE VOLUME COMPRESSOR OR limiter is commonly used in broadcasting and recording studios to prevent distortion and over-modulation from sudden audio peaks or loud program passages. Such a device is usually used to supplement or assist the operator in holding levels within predetermined limits.

Constant improvement of audio equipment together with higher standards of broadcasting and recording are more than ever emphasizing the shortcomings of the conventional compressor or limiter. When used as a link in a quality audio chain it is a never-ending source of irritation to the quality-conscious engineer. The advent of stereo broadcasting as well as a long-standing need for a low-distortion method of automatic gain control instigated the development of a device which very closely approaches the ideal. Before describing this device, the operation of compressors and limiters is reviewed.

As illustrated on Fig. 1, if the amplifier input level is plotted horizontally, and the output level plotted vertically on equal db scales, a straight line will be obtained, making an angle of 45° with the horizontal. This indicates that the output is proportional to the input. If the amplifier exhibits the properties of a compressor or limiter, the 45° line will suddenly bend toward the horizontal when compression begins. The point at which the line bends away from 45° (1:1) is called the "breakaway point" or point of "commencement of compression."

The difference between the actual output when compression is taking place and the output that would be obtained if there was no compression is the amount of compression in db. In the example, the reduction due to compression is 21.5 db at the point where the input increased 30 db and the output only 8.5 db. It can be seen that the slope of the line is approximately 4:1. The slope is called the compression ratio.

An ideal limiter or compressor should provide a maximum of 30 to 40 db of limiting or gain reduction with no increase in waveform distortion, and have an attack and release time which will provide a smooth inaudible transition between the limiting and nonlimiting condition.

Conventional limiters control the amplifier gain by applying a variable-control grid bias voltage to the amplifier stages in order to cause a reduction of the stage gain. This shift of the operating bias from optimum causes a rapid increase in distortion as the amount of limiting or gain reduction increases. Distortion values of 2 to 10% are common for conventional limiters operating at 10 to 15 db of gain reduction. Since negative feedback loops are usually not practical around variable-gain stages, the nonlimiting distortion figures are high and tube aging and operating parameters become a maintenance problem if low distortion is to be retained.

The leveling amplifier system described here will produce essentially instantaneous gain reduction of over 40 db with no increase in harmonic distortion.

A typical gain reduction curve for this system is illustrated on Fig. 2. It is interesting to note that a somewhat mild compressor action occurs from the breakaway point at −30 db input and up to −20 db, at which point the curve becomes horizontal to exhibit limiting action. The input increases an additional 20 db, but the output increases less than 1 db.

The leveling amplifier thus combines the characteristics of a compressor and limiter. A reasonable amount of care in gain riding will restrict normal operation to the compressor region, but uncontrolled levels will be prevented by the limiter action.

The heart of the leveling amplifier is the electrooptical attenuator which is placed ahead of the first amplifier stage. The actual stage gains and tube operat-

Presented on April 15, 1964, at the Society's Technical Conference in Los Angeles, by James F. Lawrence, Jr., Teletronix, Division of Babcock Electronics Corp., 2952 Randolph St., Costa Mesa, Calif.
(This paper, first received on March 9, 1964; and in final form on July 14, 1964.)

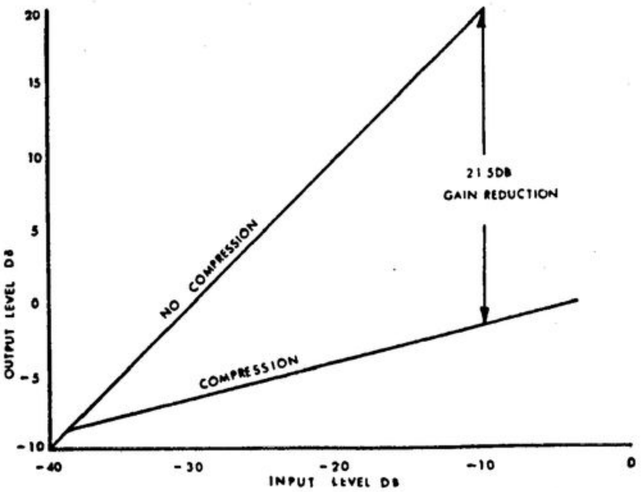


Fig. 1. Typical compressor curve.

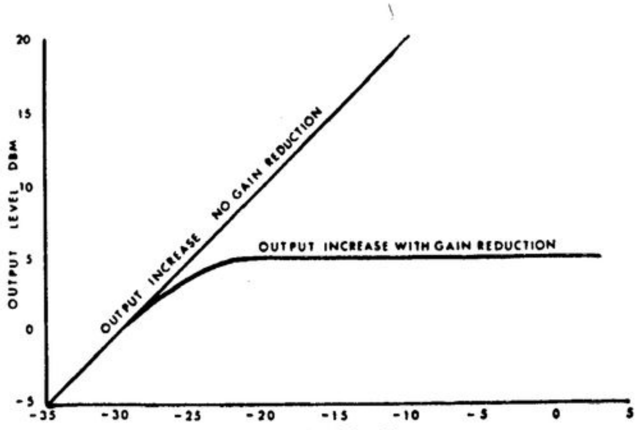


Fig. 2. Typical gain-reduction plot for model LA-2 leveling amplifiers.

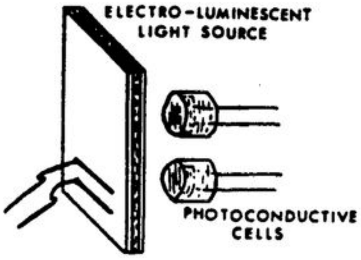


Fig. 3. Optical attenuator.

ing parameters are not varied, permitting the tubes to operate at optimum conditions regardless of the amount of gain reduction.

Referring to Fig. 3, the optical attenuator consists of a photoconductive cell which is optically coupled to an electroluminescent light source. The electroluminescent device provides a light intensity which is proportional to the audio voltage applied to its terminals.

For those not familiar with the phenomenon of electroluminescence, it is a method of producing light by the passage of current through a thin layer of phosphor. Not unlike a capacitor in construction the electroluminescent lamp consists of a plate of glass or plastic coated with a clear conducting material on one side and a thin layer of phosphor on the other side. A metallic plate contacts the phosphor coating. As alternating current is applied to the conducting plates the phosphors are excited by the voltage across the dielectric and light is produced. The amount of light depends upon the applied voltage and frequency.

The gain- or level-controlling element is the photoconductive cell. The resistance of the cell decreases with an increase in the impinging light. The photosensitive resistor has been used by others[1] for the purpose of audio gain control and peak limiting. All of these systems have utilized neon or incandescent lamps as the source of control light. These systems were investigated during the early development phases of the equipment described here, but were discarded for several reasons. A light source was desired which would produce light output immediately upon application of audio voltage, that is, instantaneous response. This precluded the use of a filament-type lamp, because of the thermal inertia of the filament. The light output should be proportional to the applied audio voltage. This eliminated the use of the neon lamp.

After experimenting with several cathode-ray types of light sources, the electroluminescence light source was selected. Since the light is produced directly from the audio voltage the response is instantaneous. Rectification and filtering of the audio to produce a control signal are not necessary as in the case of conventional limiters. This new system results in automatic level control whose speed of operation is limited only by the response of the variable-resistance photocell used.

A cell is selected which provides minimum attack time, and a release time which requires about 60 milliseconds for 50% release, and then a gradual release over a period of 1 to 15 seconds to the point of complete release.

The photoconductive cell has a "memory" that provides a more rapid reduction of resistance when gain reduction has occurred within the past 20 or 30 seconds. Measured attack time for the system is 10 microseconds for 50% of full gain reduction when the cell has been active within the previous 30 seconds; and approximately 50 to 100 microseconds, if no previous gain reduction has occurred.

The photoconductive cell depends on the energy received from light to reduce the adherence of outer orbit electrons in the atoms which make up the cadmium sulfide crystals. The electrons actually detach themselves and become free to cause electrical conduction. Conductivity depends on the amount or intensity of light striking the crystals. The decrease in resistance from dark to light is much more rapid than return to the dark value. After light is removed the electrons do not recombine immediately. Return to dark condition is much slower when large numbers of electrons have been released or after high light intensity has occurred. The return to dark conductivity when resistance is plotted as a function of time approximates a log function. This interesting and useful feature of the variable-resistance cell used in the attenuator provides a release time that is dependent upon the amount of gain reduction just prior to release. Five or six db of limiting will permit full release in about 2 seconds, while 20 or 30 db of limiting will require a release time of 5 to 10 seconds; 50% release in either case occurs in less than 1 second. This characteristic, together with the fast and smooth attack provides a system which is free of thump and the usual working sounds peculiar to limiters and compressors.

Other types of cells such as the cadmium selenide can be used in place of the cadmium sulfide unit used here to produce very fast release times in the order of 0.1 to 1.5 seconds.

Referring to Fig. 4, a functional block diagram, the input signal is applied directly to the optical attenuator from the high-impedance winding of the input transformer. As explained previously, the amount at attenuation introduced by the optical attenuator is controlled by the audio voltage applied by the 6AQ5 luminescent driver amplifier. The amount of signal applied to the 12AX7 voltage amplifier is also controlled by the manual gain control. The voltage amplifier stage provides a gain of 40 db. Overall voltage amplifier feedback of approximately 20 db provides low distortion, flat response, and gain stability.

The output stage is somewhat unconventional in that a totem pole or double cathode follower[2] is used. An output stage was desired which would tolerate great amounts of output impedance mismatch, but retain low distortion and flat frequency response. The totem pole cathode follower was selected because its output admittance

$$Y_0 = \frac{u+1}{r_p + R_1} + \frac{1 + \dfrac{u(u+1)}{1 + r_p/R_1}}{r_p}$$

$$\doteq u\,gm, \text{ or } Z_0 \doteq \frac{1}{u\,gm}.$$

For the conventional cathode follower

$$y_0 = \frac{1+u}{r_p}, \text{ or } Z_0 \doteq \frac{1}{gm.}.$$

Thus it can be seen that the totem pole circuit will provide an output impedance which is a twentieth that of a conventional cathode follower when a tube having a u of 20 is used in both cases.

A portion of the input is fed through the gain reduction control to the 12AX7 control amplifier. The output of this stage is applied to the stereo balance control and is also brought out to a terminal on the chassis. For stereo operation this terminal is connected to the

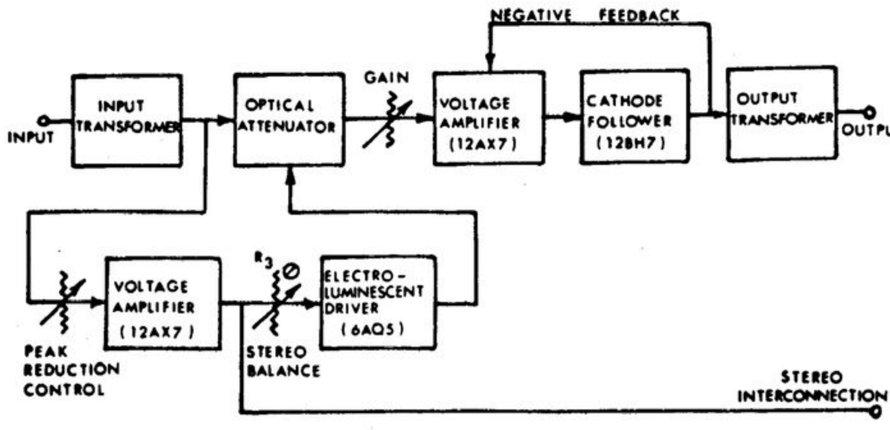
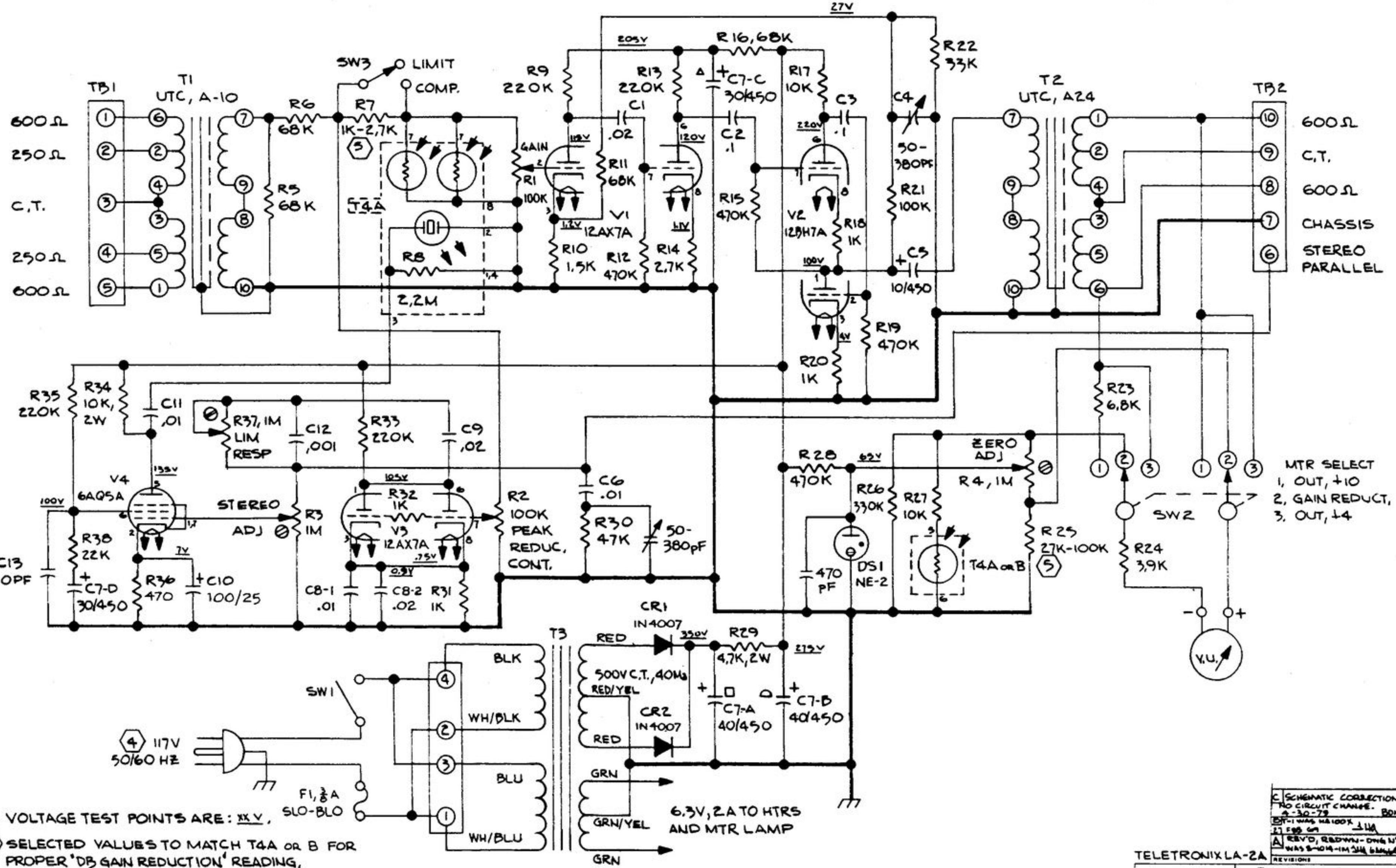


Fig. 4. Limiter block diagram.



6. VOLTAGE TEST POINTS ARE: XX V.

(5) SELECTED VALUES TO MATCH T4A OR B FOR PROPER 'DB GAIN REDUCTION' READING.

(4) FOR 220 V CONNECTION, SEE MANUAL.

3. PATENT Nº 3258707 ON PORTIONS OF THIS EQUIPMENT.

2. CAPACITORS IN µFD.

1. RESISTORS IN OHMS, ½ W, 5%.

NOTES, UNLESS SPECIFIED:

C	SCHEMATIC CORRECTIONS NO CIRCUIT CHANGE. 4-30-79 BDM
B	R1 WAS 100K; F1 WAS ...
A	REV'D, REDWN - DWG Nº WAS ...
REVISIONS	

TELETRONIX LA-2A

UNITED RECORDING ELECTRONICS INDUSTRIES	SCHEMATIC, LEVELING AMPLIFIER	
	C-10953	C
REP	DATE 6 AUG 68	ISSUE 3
DEPARTMENT	CHECKED	APPROVED
LOS ANGELES CALIFORNIA		