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 28, 1964, at the Society's Technical Conference in Los Angeles, by James F. Lawrence, Jr., Teletronix, Division of Babcock Electronics Corp., 1962 Randolph St., Costa Mesa, Calif.
(This paper, first received on March 9, 1964; and in final form on July 24, 1964.)

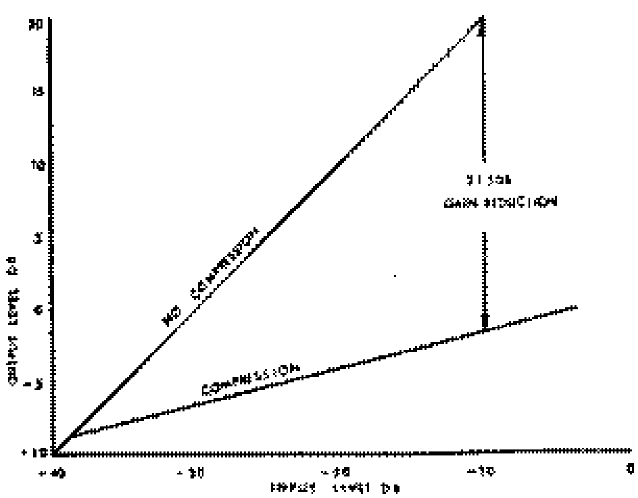


Fig. 1. Typical compressor curve.

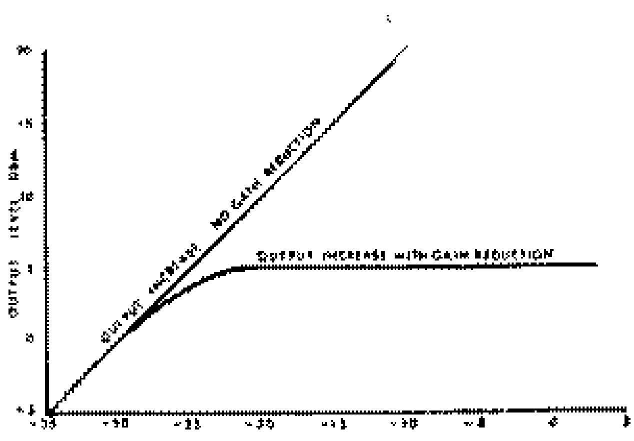


Fig. 2. Typical gain-reduction plot for model LA-2 leveling amplifiers.

A.

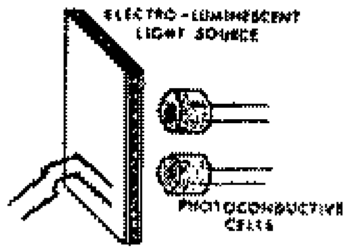


Fig. 3. Optical attenuator.

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 of 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* 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

$$y_0 = \frac{\mu + 1}{r_p + R_1} + \frac{1 + \frac{\mu(\mu + 1)}{1 + r_p/R_1}}{r_p}$$

$$\doteq \mu g_m, \text{ or } Z_0 \doteq \frac{1}{\mu g_m}.$$

For the conventional cathode follower

$$y_0 \doteq \frac{1 + \mu}{r_p}, \text{ or } Z_0 \doteq \frac{1}{g_m}.$$

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 μ 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

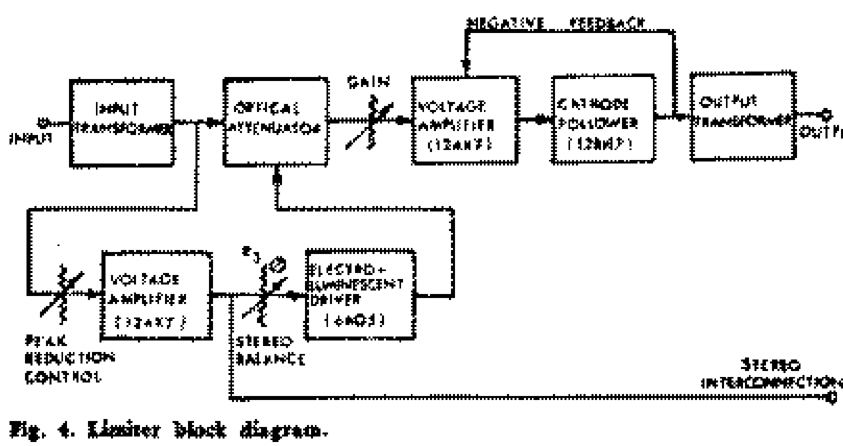
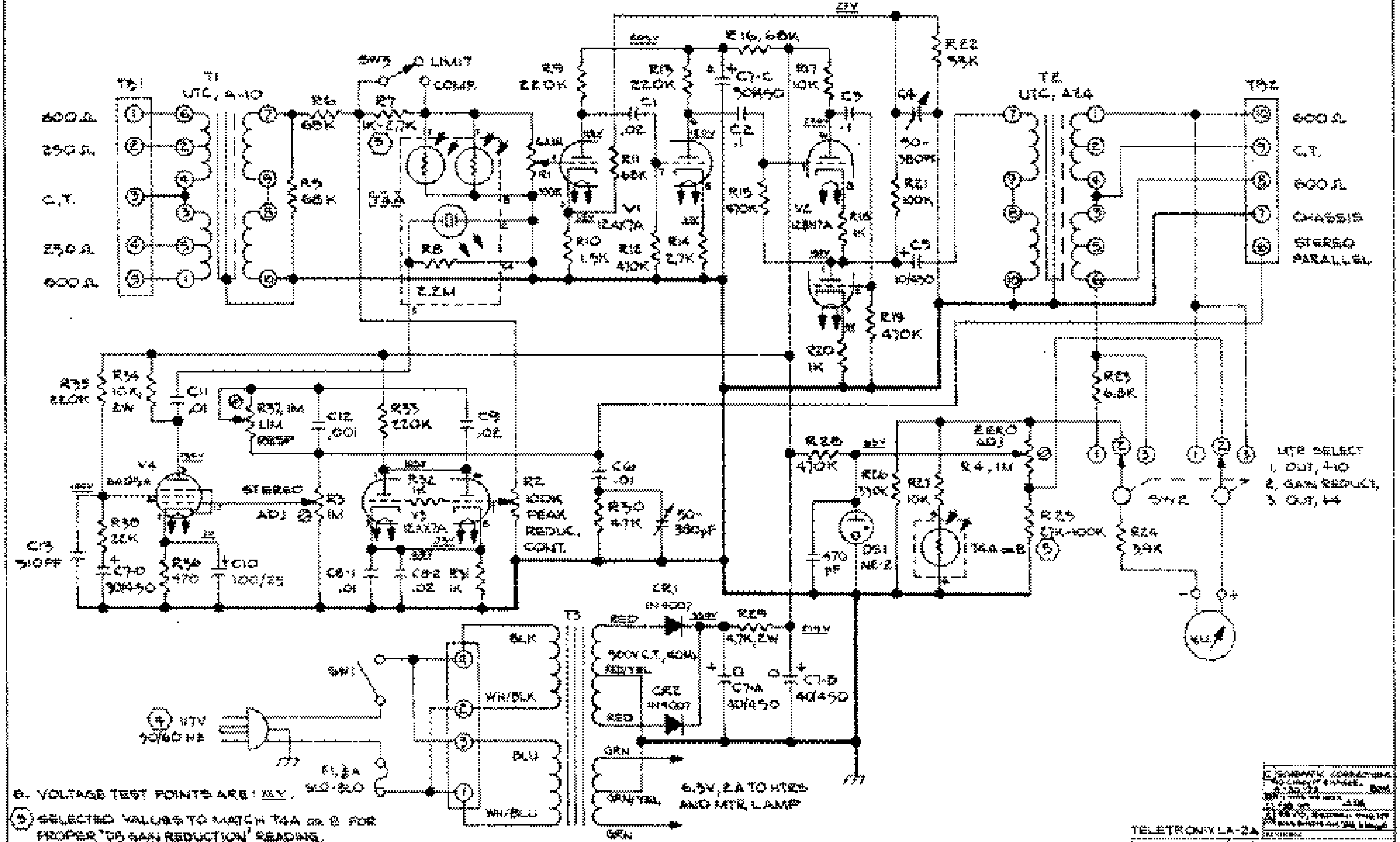


Fig. 4. Limiter block diagram.



6. VOLTAGE TEST POINTS ARE: XXV.

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

(4) FOR 220 V CONNECTION, SEE MANUAL.

3. PATENT US3258707 ON PORTIONS OF THIS EQUIPMENT.

2. CAPACITORS IN UFD.

1. RESISTORS IN OHMS, ½ W, 5%.

NOTES, UNLESS SPECIFIED:

TELETRONIX LA-2A

UNITED RECORDING ELECTRONICS INDUSTRIES

SCHEMATIC, LEVELING AMPLIFIER

C-10953 C

R&P

DATE 6-1-65

SHEET 3

LOS ANGELES CALIFORNIA