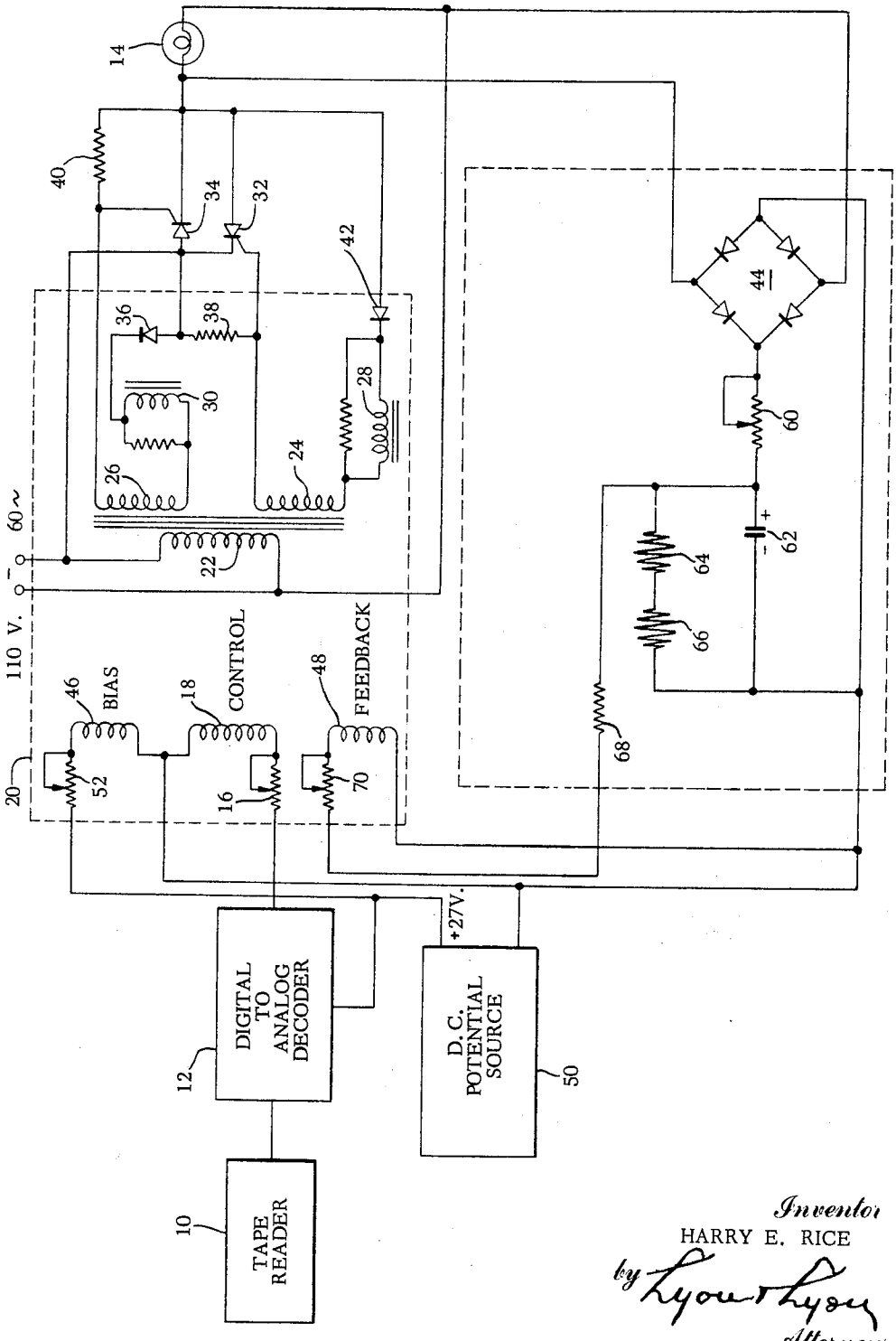
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PRINTER LIGHT INTENSITY CONTROL CIRCUIT

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PRINTER LIGHT INTENSITY CONTROL CIRCUIT

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This invention relates to control systems and, more particularly, to an improvement in a system for controlling the intensity of illumination of a printer light employed in a photographic printing process.

In the making of prints of motion-picture film, a system of printing has been developed wherein the exposures which are to be employed are recorded on tape. The tape, which has the exposure information punched therein, is read, and its output, comprising a digital signal, is converted into an analogue signal. This analogue signal is then employed to control the printer-light intensity. The present means of controlling printer-light intensity employs tapped series resistors, the taps being placed at logarithmic intervals in such a manner that light points will vary linearly as a function of the logarithm of the exposure (light intensity). When controlling 1000-watt printer lamps by this means, the series resistor steps are of low ohmic value, due to the high current in the lamp, and the contactors necessary to shunt out the resistance units, of necessity, must be capable of handling large increments of current and exhibit very low contact resistance. The digital-to-analogue conversion effectively requires that digital signals be employed for operating the contactors which, in response thereto, shunt out resistance units in a series resistor.

I will be appreciated that, besides large and expensive components being required for the abovementioned system, large amounts of power are dissipated due to the heavy currents being carried by resistors and contactors.

An object of this invention is to provide a novel and useful control circuit.

Another object of this invention is to provide a light-control system which is more efficient than the systems employed heretofore.

Still another object of this invention is the provision of a light-control system which is simple to construct and maintain.

Yet another of the present invention is the provision of an inexpensive light-control system.

These and other objects of the invention may be achieved in an arrangement wherein the analogue current, which is obtained by converting digital-control information, is applied as a control current to a magnetic amplifier. The current in the magnetic amplifier effectively controls the power which passes through silicon-controlled rectifiers to a printer light. Further, in order to properly control the printer-light intensity in accordance with the system just described, a relationship must be established whereby the D.C. control current in the magnetic amplifier is directly proportional in a linear fashion to the root mean square value of the output voltage applied to the printer light. In the operating range of the printer, the light output of the lamp is proportional to the applied root mean square voltage. A circuit is provided for sampling the voltage being applied to the printer light and for feeding back into the magnetic amplifier a feedback current derived from such voltage through a network which maintains the required linear relationship.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself, both as to its

organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawing, which is a circuit diagram of an embodiment of the invention.

Referring now to the drawing, there is seen a circuit diagram of an embodiment of the invention. The practice presently employed in making prints of motion-picture film is, first, to inspect a negative of the motion picture, to determine which exposures should be made in order to obtain optimum results. These exposures are recorded as perforations on paper tape, which is also indexed to provide association of the exposure data with the various scenes on the negative. Such punched paper tape is then run through a tape reader **10**, the output of which comprises digital signals. These are applied to a digital-to-analogue decoder **12**. The function of the digital-to-analogue decoder is to convert these digital signals to analogue signals. Heretofore, in order to control printing lamps, these analogue signals would comprise large amplitude currents. These are established by applying the operating potential for the lamp across a series of resistors. The digital signals are used to control relays having contacts which, when operated, short out certain ones of the resistors for the purpose of altering the current provided for the printer lamp.

In accordance with this invention, the output of the digital-to-analogue decoder need not be and is not a current having a high amplitude. The output of the digital-to-analogue decoder need only be a current having a level sufficient to control a magnetic amplifier, which, in turn, controls the current being supplied to a printer lamp **14**. The output of the digital-to-analogue decoder is a current, whose amplitude is representative of the digital code read from the tape. This current is applied through a suitable adjusting potentiometer **16** to the control winding **18** of a magnetic amplifier **20**, generally included in the dotted rectangle. This magnetic amplifier comprises an input transformer, having a primary winding **22** and two secondary windings **24**, **26**. There are also provided two saturable reactors, respectively **28**, **30**, represented by their windings.

The saturable reactor winding **28** is connected in series with one side of the secondary winding **24**, and the saturable reactor winding **30** is connected in series with one side of the winding **26**. The other side of the secondary winding **24** connects to the control electrode of a silicon-controlled rectifier **32**. The other side of the saturable-reactor winding **28** connects through diode **42** to the anode of the silicon-controlled rectifier **32** and to the cathode of the silicon-controlled rectifier **34**. The other side of the secondary winding **26** connects to the control electrode of a silicon-controlled rectifier **34**. The other side of the saturable-reactor winding **30** connects through a diode **36** to the cathode of the silicon-controlled rectifier **32** and to the anode of the silicon-controlled rectifier **34**. A resistor **38** is connected between the control electrode of the silicon-controlled rectifier **32** and the anode of the silicon-controlled rectifier **34**.

The control electrode of the silicon-controlled rectifier **34** is connected through resistor **40**, to the cathode of the silicon-controlled rectifier **34**. The junction of the anode and cathode of the respective silicon-controlled rectifiers **32**, **34** is also connected to one terminal of a rectifier bridge **44** and to one side of the printer lamp **14**. The other side of the printer lamp **14** is connected to one side of the input winding **22** of the transformer in the magnetic amplifier. The other side of the input winding **22** of the transformer is connected to the anode of the silicon-controlled rectifier **34** and to the cathode of rectifier **32**.

The control winding **18** is wound on the respective saturable reactors **28** and **30** in well-known manner, to control the state of magnetic saturation thereof and, thereby, the impedance of the saturable reactor to the flow of alternating current therethrough from the windings, respectively **24**, **26**. Also wound on the saturable reactors are a bias winding **46**, which applies flux to the saturable reactors in a manner to oppose that of the control winding, and a feedback winding **48**, which opposes the effects of the current in the control winding **18**.

As previously pointed out, the saturation point of the saturable-reactor windings **28**, **30** is established in response to the current in the control winding, the bias winding, and the feedback winding. The voltage applied to the control electrode of the silicon-controlled rectifier **32** is applied as a function of the time of the cycle at which the saturable reactor **28** becomes saturated. The voltage applied to the silicon-controlled rectifier **34** control electrode also is a function of the impedance of the saturable reactor **30** in series with the secondary winding **26**. Therefore, the amount of current which will flow through the respective control rectifiers **32**, **34** is determined by the time within the cycle at which the saturable reactor becomes saturated. The current applied to the lamp flows in a path from the side of the primary winding **22** through the silicon-controlled rectifiers **32**, **34** through the lamp **14**, and back to the other side of the primary winding **22**. A D.C. potential source **50** supplies a bias current to the bias winding **46**. The amplitude of this bias current is adjusted by a potentiometer **52**, which is in series with the bias winding.

Reviewing the description which has been given thus far, the output of the tape reader, comprising digital signals, is converted to analogue currents by a digital-to-analogue decorder **12**. These currents are applied to the control winding **18** of the D.C. amplifier. The control winding determines the amount of current which can flow through a pair of silicon-controlled rectifiers **32**, **34**, which are connected in series with the printing lamp **14**. This printing-lamp current is half-wave alternating current. Thus, the cyclic time of saturation of the low-power magnetic amplifier is varied by the D.C. control current derived from the digital-to-analogue decorder. However, the nature of the circuit described is such that the A.C. output root mean square voltage (R.M.S.) is not directly proportional to the D.C. control current in the magnetic amplifier, but, rather, the average value of the A.C. output voltage is directly proportional to the D.C. control current. Accordingly, in order to control the printer lamp intensity properly, a relationship must be established whereby the D.C. control current in the magnetic amplifier and the R.M.S. value of the output voltage are directly proportional in a linear fashion.

In accordance with this invention, in order to effectuate this purpose, the output voltage across the lamp **14** is sampled by means of a high-impedance bridge rectifier **44** connected across the lamp. Output is taken from the terminals of the bridge rectifier opposite to the input terminals. This output is connected through a filter, which produces a D.C. voltage proportional to the average A.C. voltage across the lamp terminals. This filter includes an adjustable resistor **60**, which is connected to one side of the output of the bride rectifier **44**. The other side of this resistor **60** is connected to a capacitor **62**, which is connected back to the other output terminal of the rectifier bridge **44**. In parallel with the capacitor there are connected one or more thyrite resistors **64**, **66**, commonly known as varistors.

The varistor has a characteristic such that its resistance varies inversely as the fourth power of the voltage applied across it. By shunting this varistor with a normal linear resistor whose value can be varied, the power relationship

can be varied from limits of one to four. This shunting resistor includes a series resistor **68**, connected to one side of the varistor **64**, a linear potentiometer **70**, which connects the other end of the series resistor **68** to one side of the feedback winding **48**. The other side of the feedback winding is connected to the other side of the varistor **66**.

The resultant voltage obtained across the combination of the linear resistor and the varistor, as shown in the drawing, is applied to the feedback winding on the magnetic amplifier in an inverse manner, such that the relationship of the D.C. control current into the magnetic amplifier to R.M.S. voltage across the lamp is linearized.

With a circuit arrangement in accordance with this invention, it was possible to obtain **64** discrete intensities of the printer lamp which are linearly proportional to the logarithm of the R.M.S. voltage by using a simple logarithmic resistive attenuator as the digital-to-analogue decorder, which was varied in response to six binary bits of digital information read from punched tape.

Accordingly, there has been shown and described herein a novel, useful, efficient, and simple system for controlling the current applied to a printer lamp such that the relationship of the D.C. control current into the magnetic amplifier to R.M.S. voltage across the lamp is linearized. While the embodiment of the invention has been described as providing a linear relationship between input current and the R.M.S. voltage applied to a printer lamp it should be understood that this is merely exemplary of a particular type of an energy emitting load and thus is not to be considered as a restriction upon the invention. It may be used, for example, to provide a linear relationship between input current and the R.M.S. voltage of a programmed temperature control system where heaters are used instead of a printer lamp, or for instrument light control in such instruments as a photometer.

I claim:

1. Apparatus for controlling the illumination of a lamp in response to a control current comprising a magnetic amplifier having a control winding and a feedback winding, silicon-controlled rectifier means having a control electrode, means for applying the output of said magnetic amplifier to said control electrode, a source of current for said lamp, means for connecting said silicon-controlled rectifier means in series with said lamp, means for connecting said series-connected silicon-controlled rectifier means and lamp across said source of operating potential, means for applying said control current to said magnetic-amplifier control winding whereby the current flowing through said series-connected silicon-controlled rectifier means and said lamp is a function of said control current, a feedback network coupled between said lamp and said feedback winding, said feedback network including rectifier means having input and output terminals, means connecting said input terminal to said lamp, a capacitor connected across said output terminal, a varistor connected to said capacitor and a resistor connected between said varistor and said feedback winding, said feedback network establishing a linear relationship between the control current applied to the control winding of said magnetic amplifier and the root mean square of the voltage output which is applied to said lamp.

2. In a system for controlling the current applied from an alternating-current source to a load with a magnetic amplifier which is responsive to a control current applied to its control winding, the improvement for linearizing the relationship of the control current to the root mean square value of the output voltage which is applied to the said load comprising a feedback winding on said magnetic amplifier, and feedback-network means connected between said load and said feedback winding, said feedback network means including a filter for rectifying the voltage applied thereto, and a variable resistance means having the characteristics such that its resistance varies substantially inversely with the fourth power of the voltage

applied across it, and means for connecting said variable resistance means across the output of said filter, said feedback network means establishing a linear relationship between the control current applied to said control winding and the root means square voltage existing across said load in response to the output of said magnetic amplifier.

3. In a system for controlling the energy output of an energy emitting load in response to a control current which is applied to the control winding of a magnetic amplifier, output of which is used for controlling the current applied to said load, the improvement comprising a circuit for linearizing the relationship between the root means square value of the voltage across said load and the control current applied to said control winding, said improvements including a feedback winding in said magnetic amplifier, rectifier means having a pair of input terminals and a pair of output terminals, means connecting said load across said input terminals, means connecting said network to said rectifier-means output terminals including a series resistor and a shunt capacitor, a variable

resistance means connected across said shunt capacitor, said variable resistance means having the property that its resistance varies inversely as substantially the fourth power of the voltage applied across it, and means including a variable linear resistor connecting said variable resistance means to said feedback winding.

4. In a system as recited in claim 3 wherein said energy emitting load is a printer lamp.

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