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GAIN CONTROL SYSTEM RESPONSIVE TO AN AVERAGE VALUE

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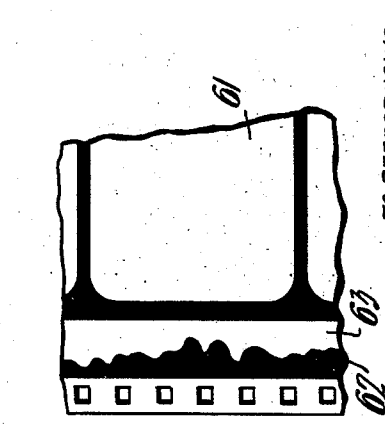


Fig. 3.

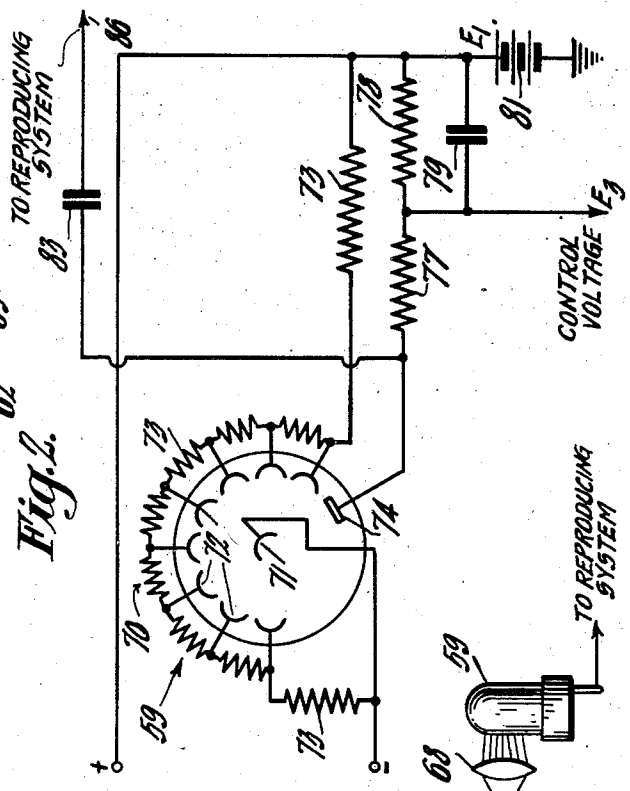


Fig. 2.

Fig. 4.

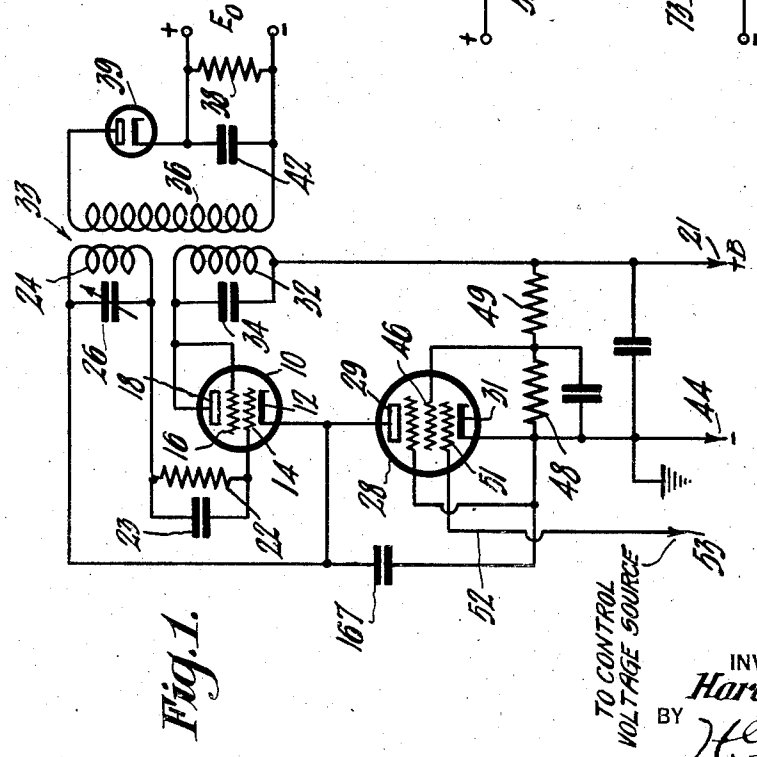


Fig. 1.

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GAIN CONTROL SYSTEM RESPONSIVE TO AN AVERAGE VALUE

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6 Claims. (Cl. 250—41.5)

1

The present invention relates to gain control systems and more particularly, but not necessarily exclusively, to a novel gain control system which is responsive to an average value of a characteristic such, for example, as the average of the light intensity impinging on a light sensitive electronic device, such as an electron multiplier phototube and the like, whereby to vary amplification.

In a system operating in accordance with this invention, a very small voltage change controls the high voltage output of a power supply. In combination with an electron multiplier phototube, the controllable power supply of this invention serves in a novel manner as a sensitive automatic gain control. In general, the invention provides a way to use an electron multiplier phototube to derive an alternating current voltage from an amplitude modulated light beam in any application where the average amount of light is nominally constant. The electron multiplier phototube possesses the highly desirable attributes of great sensitivity and low-noise level. In accordance with the invention the effects of all sources of gain variation in the system are minimized. Systems in which the average amount of light is nominally constant include, for example, light-beam communication systems, light-beam type phonograph pick-ups and reproduction of sound tracks on film, for example, not having ground-noise reduction. Solely, by way of example, a system for reproducing sound from the sound track of a film has been selected as an illustrative embodiment of the invention which may be readily understood and is convenient to describe. Where the small control voltage is derived as a result of reproducing a sound track on a transparent film, for example, a definite response level of the sound reproducing system to average values of light output from the optical system, including the interposed film, may be maintained. For example, in the embodiment selected for illustrating the controllable power supply of the invention combined with an electron multiplier phototube, an average value of light when directed in an appropriate manner through or upon a film bearing a sound-track will produce an average output current in the phototube upon which the light is directed.

It will be seen from the foregoing that the present invention deals with the combination of a controllable power supply and an electron multiplier phototube. The power supply selected for the purpose of illustrating the invention herein is disclosed and claimed in a copending application of the present inventor for Letters Patent for "Power supply for a light sensitive electronic device," filed December 26, 1946, Serial No. 718,375.

2

An important object of the present invention is to provide a novel signal reproducing system in which the system gain is controlled by the average signal value.

Another object is to provide a novel means for deriving a control voltage which is applied, effectively, to an electrode or electrodes of an oscillator tube thereby to vary the alternating current output voltage of the oscillator.

A further object of the invention is to provide a power supply of the type comprising an oscillator for generating a relatively high frequency current and a rectifier for rectifying the generated oscillations, combined with a novel means for deriving a control voltage which is applied to vary the voltage of the rectified direct current obtained from the oscillator.

Still another object of the invention is to provide a novel and improved arrangement for maintaining a substantially fixed signal level in a sound reproducing system.

Still another object is to provide a novel gain control system embodying an electron multiplier phototube in combination with a controllable power supply for the phototube.

Other objects and advantages of the present invention will, of course, become apparent and immediately suggest themselves to those skilled in the art to which the invention is directed from a reading of the following specification in connection with the accompanying drawings in which:

Fig. 1 is a schematic showing of a power supply system suitable for use in apparatus arranged in accordance with the invention;

Fig. 2 is a schematic showing, by way of example, of a sound reproducing system to be used in combination with the power supply of Fig. 1 to obtain automatic gain control;

Fig. 3 shows a fragment of a motion picture film having a sound track; and

Fig. 4 is a schematic showing of a typical optical arrangement.

Referring to Fig. 1 of the drawings there is shown a tube 10 which functions as an oscillator. It comprises a cathode 12, a control grid 14, a screen grid 16 and an anode 18. The anode and screen electrodes are maintained at a positive direct current voltage from a direct current source (not shown) which may be connected at the terminal indicated schematically at 21. The con-

trol grid 14 is returned to the cathode 12 through a path including a grid resistor 22 shunted by a capacitance 23 and a feed-back or tickler coil 24. The latter is tuned by a variable capacitor 26. The cathode 12 of the tube 10 is connected effectively to ground through the space discharge path of a tube 28 which comprises an anode 29 and a cathode 31 in parallel with the capacitor 167. The function and operation of the tube 28 will be described more in detail hereinafter. The anode circuit of the tube 10 includes a parallel resonant circuit which comprises the primary winding 32 of an output transformer 33. The primary winding 32 is tuned by a capacitance 34. The tickler coil 24, mentioned above, may be one of the windings of the transformer 33.

The secondary 36 of the transformer 33 is connected to a load resistor 38 through a diode rectifier 39. A capacitance 42 is shunted across the load resistor 38 to bypass the high frequency currents. The symbol E_0 represents the relatively high D. C. voltage which is available from the high voltage power supply source of Fig. 1.

The oscillator comprising the tube 10 as well as the transformer 33 are shown by way of example. Oscillating circuits for the tube 10 other than those shown and different transformer arrangements may be employed since details of these elements of the system are shown only by way of example. It will be understood that the coils 24, 32 and 36 are coupled magnetically and that this coupling with respect to one or all of the coils may be made adjustable if desired.

The space discharge path, and hence, the internal impedance of the tube 28, is in series with the anode circuit of the oscillator tube 10 to vary the effective plate supply voltage between its cathode 12 and its anode 18. The internal impedance of the tube 28 to alternating current is equal to its D. C. resistance, and would cause a large loss of high frequency power if the A. C. component of oscillator plate current flowed through it. Therefore, a capacitor 167 is connected in parallel with the internal impedance of the tube 28 to provide a low impedance to high frequency current. The tube 28 preferably has a high grid-plate transconductance. By way of example, a type 6AG7 tube is suitable. The plate voltage supply source (not shown) for the oscillator tube 10 will have its negative terminal returned to ground, the connection being indicated schematically and designated by reference character 44.

The screen grid 46 of the tube 28 is connected to an appropriate point on a voltage divider comprising resistors 48 and 49. The control grid 51 of the tube 28 provides for controlling the output voltage E_0 and is made available for this purpose by the provision of a conductor and terminal, for example, shown schematically and indicated by reference characters 52 and 53, respectively.

A considerable degree of control of the developed D. C. voltage E_0 may be obtained by varying the voltage on the signal grid 51 of the tube 28. Throughout a considerable portion of the characteristic, the control curve is linear and is suitable for gain control in apparatus employing a photosensitive device such as an electron multiplier phototube. In applicant's copending application above referred to identified by Serial No. 718,375 a system is disclosed and claimed in which the effective gain in a facsimile system is controlled upon scanning of the white background of subject copy in a facsimile scanner. The present invention is directed to the use of the power supply of Fig. 1 which, as stated above, is disclosed and claimed in the application just mentioned, in combination with a system in which the average amount of light is nominally constant to obtain gain control in a novel manner.

Fig. 2 of the drawings is illustrative by way of example only of the electrical features of such a system embodying the present invention. Fig. 4 is a schematic showing of a typical optical arrangement which may be used to excite a phototube 59 which is or may be a part of any well known optical sound reproducing device or "sound head", as it is called. A more or less detailed description of a system suitable for theatre use is described in the RCA Review for January, 1937, published by the RCA Institutes Technical Press, 75 Varick Street, New York, beginning on page 65 of that publication. Fig. 3 of the drawings shows a fragment of a motion picture film 61, or the like, which is printed with a sound track 62. The invention is, as previously stated, useful where there is an average light output in the optical system which is impinged on a phototube. If the sound track 62 is of the "class A" type, and does not have the ground noise reduction feature, described in the publication presently referred to, the average light output of the optical system including the film is constant. The transparent part 63 of the sound track is not reduced in area during periods of silence when the ground noise reduction feature is omitted. This type of sound track as well as other types which do and do not have the ground noise reduction feature are shown in the RCA Review, published by the RCA Institutes Technical Press, 75 Varick Street, New York, for October, 1936 on page 14 thereof. It will be understood that the film, which is fragmentarily shown in Fig. 3, may have any desired form and, in fact, the sound track may be printed upon a narrow transparent strip for use as a phonograph record or it may be printed on an opaque material for use with a reflective optical system.

The phototube 59 generates electrical signals in a known manner which are used after amplification to operate a loud speaker (not shown). A sound system of this type is shown more in detail in Fig. 4 of U. S. Patent #1,888,724, granted to C. R. Hanna on November 22, 1932. The film 61 is moved at constant speed by any suitable means (not shown) and light from an appropriate source such as an exciter lamp 64 after passing through a narrow slit (not shown separately) is focused on the sound track 62 of the film 61 by an optical device 66 including suitable lenses. A collector lens 68 directs light received from the sound track of the film onto the cathode 71 of the phototube 59. The phototube 59 is preferably of the electron multiplier type and may, for example, be the commercially available type 931—A multiplier phototube which is of the electrostatically focused type. The photo-cathode 71 of the phototube 59 (shown schematically in Fig. 2) is connected, for the purposes of this aspect of the invention, to the negative terminal of the high voltage supply of Fig. 1 which is at the negative end of the load resistor 38. For the type of phototube mentioned by way of example, the voltage across the terminals of the power supply source is to be approximately 700 volts.

Automatic gain control in accordance with the invention is accomplished by varying the total voltage supply to the dynodes 72 of the phototube 59. The gain of an electron multiplier can be varied through a wide range in this manner. The

dynodes **72** are connected to spaced points along a voltage divider **70** made up of the resistors **73**. The anode **74** of the phototube is connected through an A. C. load resistor **77** to the grid **51** of the tube **28** through the terminal **53**. A resistor **78** shunted by a capacitance **79** provides a slow-timed load which responds only to slow variations in the average anode current. The resistor **78** is included in the connection from the anode **74** to the positive terminal of the load resistor **38** of the power supply of Fig. 1. A D. C. source **81**, shown for the sake of convenience as a battery, provides a positive voltage E_1 which is to be opposed by the drop in the resistor **78** so that it is almost "bucked out" by this drop. The output from the phototube is taken from the anode **74** through a suitable coupling condenser **83** to the reproducing system (not shown). The output terminal is indicated schematically at **86**.

When the sound reproducing arrangement of Fig. 2 is in operation, and the light intensity the exciter lamp **64**, for example, increases, the control voltage E_3 would go slightly more negative than before and since this voltage is applied to the control grid **51** of the control tube **28**, the high voltage output appearing across the load resistor **38** will be reduced. This reduction of voltage of the high voltage supply and the consequent reduction in gain will continue until an equilibrium point is reached.

The resistor **77** may be made relatively small so that frequency response is as good as required. The resistor **78** may be considerably larger so that a suitably large control voltage E_3 may be obtained. For example, assuming that 50 microamperes is a suitable average current and that 20 volts appearing across the resistor **78** is suitable, the resistor **78** should be about 400,000 ohms. For suitable frequency response, the resistor **77** might be, perhaps, 100,000 ohms. The voltage E_1 would then be set at about +21 volts.

Having now described the invention, what is claimed and desired to be secured by Letters Patent is the following:

1. A signal reproducing system comprising means for generating signal currents in response to an incident modulated light beam, said means including an electron multiplier phototube, an output circuit for said phototube comprising a pair of resistors in series, means for obtaining a control voltage from the junction point of said resistors, means for utilizing said control voltage to control said phototube means for obtaining a signal output across said resistors, the resistor which is situated electrically more remotely from said phototube being shunted by a capacitor whereby to provide a time constant circuit, and a source of voltage which is substantially unaffected by signalling currents generated by said phototube being connected to said time constant circuit at its terminal opposite said control voltage deriving point.

2. A signal reproducing system comprising means for generating signal currents in response to an incident modulated light beam, said means including an electron multiplier phototube, an output circuit for said phototube comprising a resistor, means for obtaining a control voltage from a point on said resistor between its ends, means for utilizing said control voltage to control said phototube means for obtaining a signal output across said resistor, a portion of said resistor being shunted by a capacitor whereby to provide a time constant circuit, and a source of voltage which is substantially unaffected by signalling currents generated by said phototube being connected to said time constant circuit at its terminal opposite said control voltage deriving point.

3. Signal reproducing apparatus comprising an electron multiplier phototube, said phototube having a plurality of electron multiplying dynodes, a voltage divider for said dynodes comprising a plurality of series connected resistors, said dynodes being connected to the junction points of said series combination of resistors, means for applying a voltage from a direct current source across said resistors, a cathode and anode for said phototube, said cathode being connected to the negative terminal of said direct current source, a connection from said anode to the positive terminal of said direct current source including two resistors connected in series, an output connection from said anode, a control voltage connection between said resistors, a connection from said control voltage connection to said means for applying a voltage, a capacitance shunting said resistor which is connected to the positive terminal of said power supply, said resistor and said capacitance providing a slow-timed R. C. load which responds only to slow variations in the anode current, a source of positive substantially constant voltage connected to said time constant circuit at the end thereof which is more remote from said anode, said substantially constant voltage being of a value that it is nearly equal to the voltage drop in said load resistor.

4. Signal reproducing apparatus comprising an electron multiplier phototube, said phototube having electron multiplying means, means for applying a voltage from a direct current source to said electron multiplying means, a cathode and anode for said phototube, said cathode being connected to the negative terminal of said direct current source, a connection from said anode to the positive terminal of said direct current source including a resistor, an output connection from said anode, a control voltage connection at a point on said resistor between its ends, a connection from said control voltage connection to said means for applying a voltage, a capacitance shunting a portion of said resistor, said resistor portion and said capacitance providing a slow-timed R. C. load which responds only to slow variations in the anode current, a source of positive substantially constant voltage connected to said time constant circuit at the end thereof which is most remote from said anode, said voltage being of a value that it is nearly equal to the voltage drop in the output portion of said resistor.

5. An automatic gain setting system comprising a generator of signalling currents having a sensitivity characteristic which varies with applied voltage, a power supply for said signalling current generator comprising a high frequency oscillation generator and energy transfer means coupled to said generator, means to supply an operating voltage from said energy transfer means to said signalling current generator, and means responsive to the average value of the output of said signalling current generator for varying the output voltage of said high frequency oscillation generator.

6. An automatic gain setting system comprising a generator of signalling currents having a sensitivity characteristic which varies with applied voltage, a direct current power supply source for said signalling current generator comprising a high frequency oscillation generator, said oscil-

lation generator comprising a tube provided with at least a cathode, a control electrode, and an anode, a control electrode circuit connected to said control electrode and said cathode, an anode circuit including a variable impedance connected to said anode and said cathode, means providing mutual coupling between said circuits, energy transfer means coupled to at least one of said previously named coupled circuits to apply a voltage to said generator of signalling currents, and means for varying said variable impedance in response to the average output of said signalling current generator for varying the voltage applied thereto.

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REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
1,888,724	Hanna	Nov. 22, 1932
2,158,193	Morse	May 16, 1939
2,290,775	Snyder, Jr.	July 21, 1942
2,363,361	Reiskind	Nov. 21, 1944