Oct. 9, 1951 N. R. GUNDERSON 2,570,665

METHOD AND MEANS FOR CORRECTING SENSITIVITY DRIFT OF AMPLIFIERS

Filed Oct. 18, 1948 3 Sheets-Sheet 1

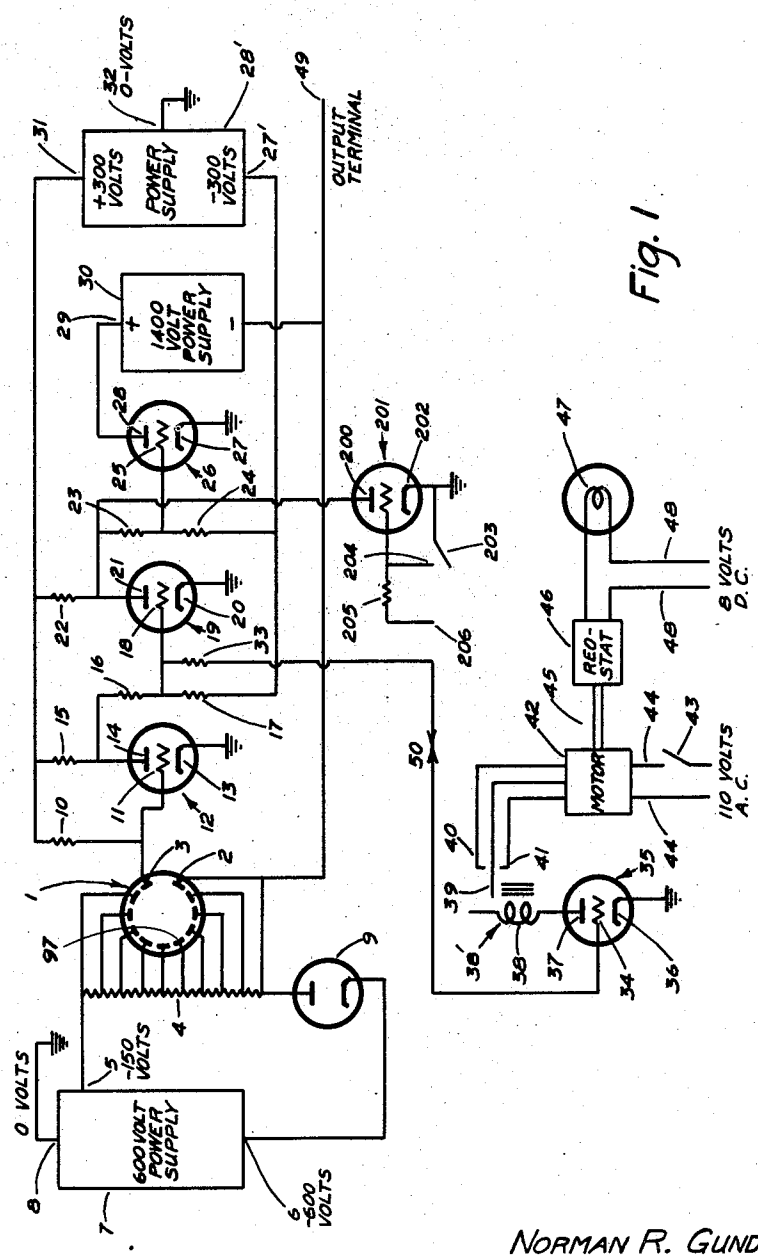


Fig. 1

NORMAN R. GUNDERSON
INVENTOR.

BY

ATTORNEY

Oct. 9, 1951 N. R. GUNDERSON 2,570,665

METHOD AND MEANS FOR CORRECTING SENSITIVITY DRIFT OF AMPLIFIERS

Filed Oct. 18, 1948 3 Sheets-Sheet 2

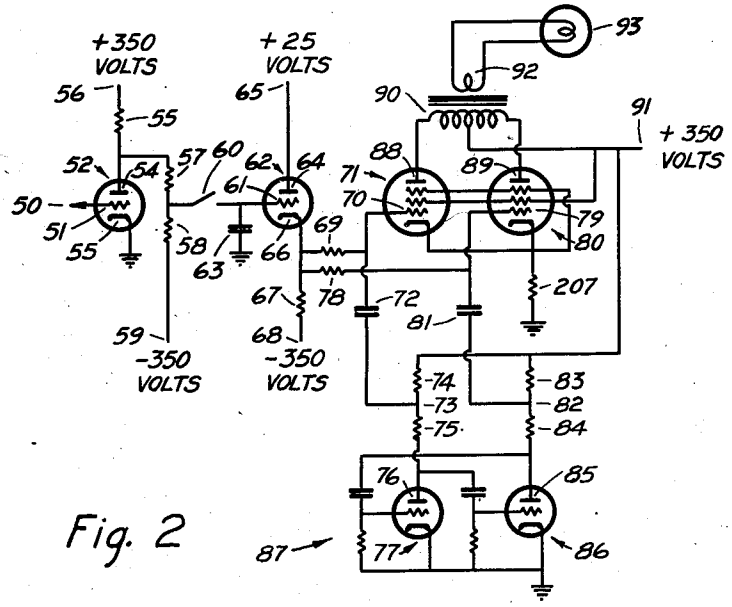


Fig. 2

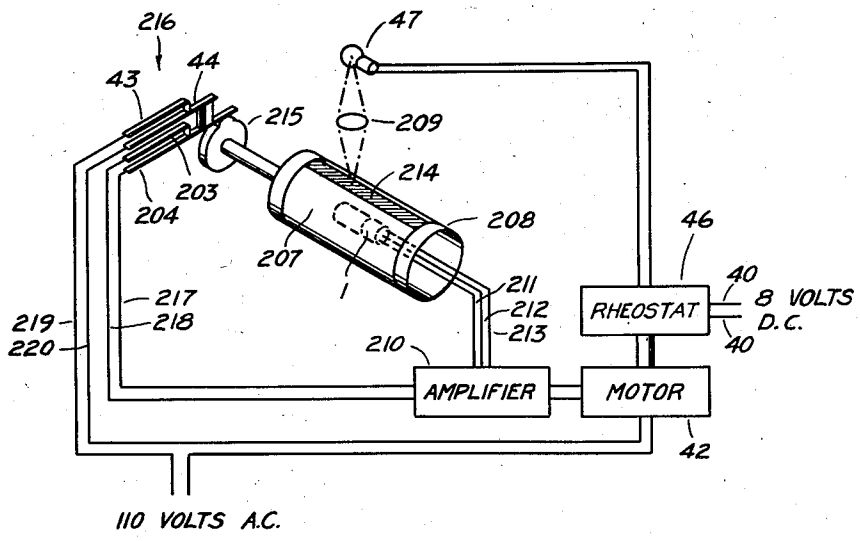


Fig. 4

NORMAN R. GUNDERSON,
INVENTOR.

BY

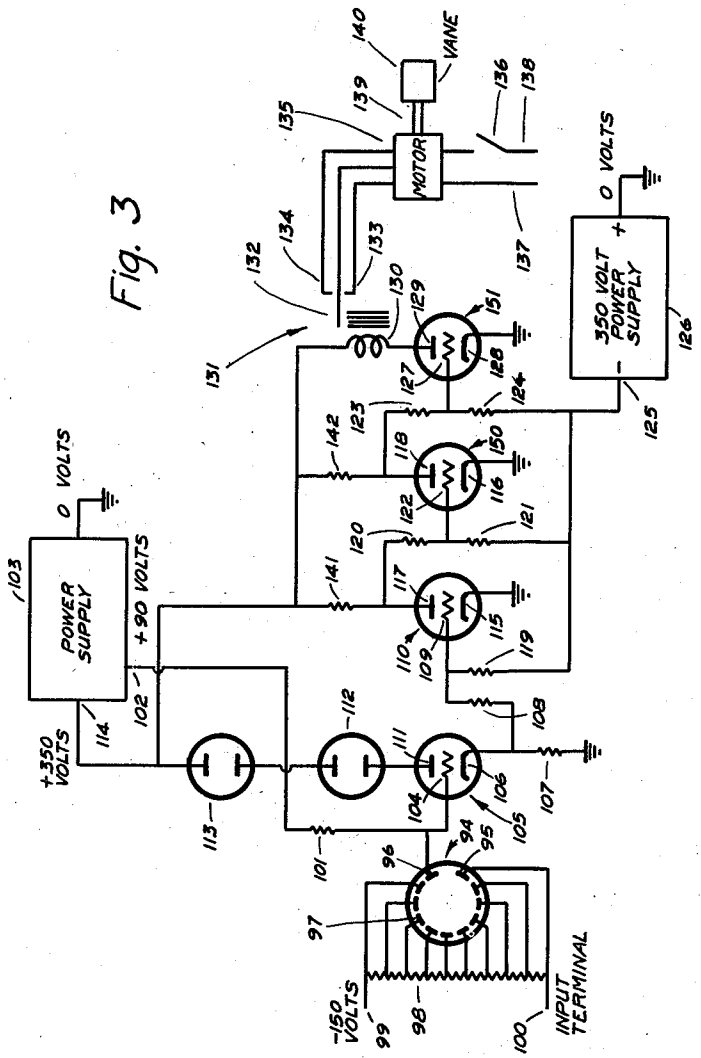
ATTORNEY

Oct. 9, 1951 N. R. GUNDERSON 2,570,665

METHOD AND MEANS FOR CORRECTING SENSITIVITY DRIFT OF AMPLIFIERS

Filed Oct. 18, 1948 3 Sheets-Sheet 3

Fig. 3



NORMAN R. GUNDERSON
INVENTOR.

BY

ATTORNEY

Patented Oct. 9, 1951 2,570,665

UNITED STATES PATENT OFFICE

2,570,665

METHOD AND MEANS FOR CORRECTING SENSITIVITY DRIFT OF AMPLIFIERS

Norman R. Gunderson, Pasadena, Calif.

Application October 18, 1948, Serial No. 55,033

19 Claims. (Cl. 250—205)

1

This invention relates generally to a method and system for compensating for changes in sensitivity in amplifier systems. It relates more particularly to an intermittently effective feedback system connected in an inverse or negative feedback sense, and primarily, though not necessarily, intended for use in correcting or compensating for sensitivity drift in an electron multiplier amplifier with or without a phototube input forming an electro-optical system.

The present invention is primarily, though not necessarily, intended for use in automatically compensating for changes in phototube sensitivity in a scanning process, especially in a process in which photographic negatives, positives or other images are scanned. The present invention is described and illustrated in a form employing electron multiplier phototubes of the electrostatically focused type comprising a photosensitive cathode and output anode and a plurality of electrostatic focusing, secondary emission electrodes (commonly known as dynodes). The R. C. A. 931 electron multiplier is exemplary of such tubes, although the invention is applicable when other various multiplier and even ordinary phototubes are employed.

Electron multiplier phototubes such as the R. C. A. 931 are subject to a very considerable degree of sensitivity drift primarily during continued operation of the tube although there is some sensitivity drift due to aging. The sensitivity drift due to continued operation is probably caused by a number of cooperating factors such as temperature changes occurring in various elements of the phototube during continued operation thereof, such changes being either self caused or caused by variations in ambient temperature, and an inherent instability arising from the mode of operation of such an electron multiplier phototube wherein saturation current flows and relatively little space charge limiting and stabilizing effect is employed.

My invention provides an electron multiplier amplifier capable of operating in a stable manner and virtually free from sensitivity drift, and great advantages flow therefrom because the extreme sensitivity or amplification and minimal space and weight requirements of such multipliers can now be utilized effectively. In spite of the extreme sensitivity and high amplification of electron multiplier phototubes they have not heretofore proved to be satisfactory for use in electro-optical systems intended for use where accuracy is important unless such systems are operative for extremely short periods of time only, in which

2

case the time factor limits the sensitivity drift to a relatively small value. A sensitivity drift compensated electron multiplier phototube amplifier of the type I have invented will find extremely wide application in the art, and indeed will probably replace most ordinary phototubes heretofore used.

Generally speaking, an illustrative preferred form of the present invention comprises an amplifier system including a phototube and an amplifier effectively connected to the output of the phototube, and inverse feedback means responsive to amplified phototube output signal arranged to modify the light input to the phototube in a negative feedback sense in accordance with the value of the amplified phototube output signal whereby sensitivity drift of the system will be minimized. In the preferred form of the present invention means are provided for intermittently, alternately, effectively rendering the inverse feedback adjustment means effectively responsive and nonresponsive to the amplified phototube output signal whereby the light input to the phototube will be intermittently modified in a negative feedback sense in accordance with the amplified phototube output signal during the corresponding intermittent responsive periods. The present invention may also include referencing means for intermittently rendering the modulation of the input to the system (which may be electric input or light input) to be of a selected reference value during the simultaneous, intermittent periods when the inverse feedback means is effectivly responsive to the amplified phototube output signal. The inverse feedback means may be arranged (whenever during a responsive period the amplified phototube output signal differs from a selected standard value) to modify the light input to the phototube in a manner tending to return the amplified phototube output signal to the selected standard value. In one preferred general form of the present invention, the phototube is an electron multiplier phototube amplifier of the type comprising a photosensitive cathode, an anode and a plurality of secondary emission electrodes, and the system input is the light input to the photosensitive cathode. The referencing means may also be arranged to intermittently and frequently apply a short-duration electric signal of a selected reference value across various or all of the secondary emission electrodes of the electron multiplier phototube during the simultaneous, intermittent periods when the inverse feedback means is effectively responsive to deviation of

the amplified phototube output signal from the selected standard value and when the referencing means causes the modulation of the light input to the phototube to be of a selected reference value. In another preferred general form of the present invention, an electron multiplier phototube of the type just described is employed, and the system input is an electric input signal applied to the secondary emission electrodes of the electron multiplier phototube.

The preferred form of the invention standardizes system input conditions momentarily during each intermittent period of adjustment by negative feedback means. During this intermittent period of adjustment the phototube current output regulates phototube light input in an inverse feedback manner until the phototube current output falls within a narrow predetermined reference range. This virtually eliminates any change in effective sensitivity of the photoelectric scanning unit. Thus the present invention provides virtually complete sensitivity drift correction during each intermittent negative feedback period to a degree of accuracy heretofore unattainable even with exceedingly complex, continuous negative feedback amplifiers and servomechanisms.

The difficulty in designing prior art negative feedback amplifiers and servomechanisms where a rapidly varying input signal is employed, is that the more rapidly the signal varies the less faithfully the negative feedback compensates or corrects sensitivity drift in the amplifier. If an exceedingly complex and sensitive negative feedback system is employed it is extremely difficult to avoid the production of oscillation or instability in the system. Most prior art negative feedback amplifiers and servomechanisms intended for use with a rapidly fluctuating input signal are therefore compromises so arranged as to avoid instability and oscillation and yet have the least possible error in sensitivity drift correction compatible with the instability and oscillations avoidance requirements.

Through the use of the present invention, instability and oscillation are avoided and yet during each negative feedback period the sensitivity drift of the amplifier is virtually completely corrected without error in a manner never before attainable.

Since the sensitivity drift in an amplifier, whether of the electron multiplier phototube type or not, is a relatively slow thing, the intermittent correction thereof virtually without error is much more desirable than the continuous relatively inaccurate sensitivity drift correction of an amplifier attainable through prior art systems and methods.

With the above points in mind:

It is an object of the invention to disclose and provide a simple and efficient method of compensating for changes in response characteristics of a phototube, such as an electron multiplier, at frequent intervals during the use of the circuit in which such tube is employed.

It is an object of the present invention to provide an improved negative feedback system for virtually completely correcting sensitivity drift of an amplifier system.

It is a further object of the present invention to provide an improved negative feedback system for use with an amplifier to intermittently apply negative feedback to the input to the amplifier in a manner tending to correct amplifier sensitivity drift intermittently.

It is a further object of the present invention to provide an improved negative feedback system for use with an amplifier to intermittently apply a selected reference input modulation to the amplifier and simultaneously to apply negative feedback to the input to the amplifier in a manner tending to return the amplifier output to a selected standard value having a fixed relationship to the input to the amplifier whereby to intermittently compensate for amplifier sensitivity drift.

Other and allied objects will be apparent to those skilled in the art from a careful study of the illustrations, specification and appended claims.

To facilitate understanding reference will be made to the following drawings in which:

Fig. 1 is a diagrammatic electrical schematic drawing of one illustrative embodiment of the present invention applied to a logarithmic amplifier circuit.

Fig. 2 is a schematic diagram illustrating a modified feedback compensating system which may be used with a logarithmic amplifier system of the character shown in Fig. 1.

Fig. 3 is a diagrammatic electrical schematic drawing of a third form illustrating the application of the method to a system employing an antilogarithmic amplifier.

Fig. 4 is a schematic electrical diagram, together with an isometric view of a scanning drum, showing means for periodically energizing the adjusting system of my invention.

Fig. 1 illustrates one embodiment of the present invention employed in conjunction with a logarithmic amplifier system of the general type more particularly described in my co-pending application, Serial No. 702,172, filed October 9, 1946, now Patent No. 2,454,871, and also described and illustrated in my Patent No. 2,413,706 in conjunction with a mechanically driven scanning drum adapted to carry a photographic negative or positive, or other image to be scanned by the photocathode of the electron multiplier phototube forming part of the logarithmic amplifier.

In the example illustrated in Fig. 1, an electron multiplier amplifier provided with means for introducing an electronic input thereinto and secondary emission controlling means, is shown. The specific form of electron multiplier amplifier shown in Fig. 1 is of the type wherein the electronic input is provided by a photosensitive cathode **2** and wherein the secondary emission controlling means comprises a plurality of secondary electron emission controlling electrodes (commonly known as dynodes) indicated generally at **97**. The electron multiplier phototube **1** also includes an output anode **3**. It should be noted that the plurality of secondary electron emission electrodes **97** are connected at spaced points along a resistor **4** through which a controlled electric current passes, thus applying the proper potential to each of the secondary emission electrodes **97** for controllably producing secondary electron emission from each of said electrodes and electrostatically focusing the emitted electrons upon the succeeding secondary emission electrode. The original source of electrons is the photosensitive cathode which emits electrons in response to light input thereto, which are then electrostatically focused upon the adjacent, succeeding secondary emission electrode, this continuing until the last emission electrode focuses

the electrons emitted therefrom upon the output anode 3.

The resistor 4 is connected in series with a rectifier tube 9 and terminals 5 and 6 of a regulated, constant voltage power supply 7, the purpose of which will be more fully described hereinafter. The photocathode 2 of the electron multiplier tube is also connected to the lower end of the resistor 4 and is also connected to the negative terminal of a power supply 30.

It should be noted that the terminal 5 of the power supply is at a negative potential with respect to ground and that the positive terminal 8 of the power supply 7 is grounded, thus connecting the resistor 4 in series with an electron tube 26 through the cathode 27 which is also grounded. The anode 28 of the tube 26 is connected to the positive terminal 29 of the power supply 30. Since the power supply 30, in the example illustrated, is of 1400 volts potential which is considerably greater than the potential supplied by power supply 7, normally speaking the anode of the rectifier tube 9 is negative with respect to the cathode thereof, thus allowing no current to pass through the circuit comprising rectifier tube 9, the resistor 4 and the power supply 7. The only current which normally flows through the resistor 4 is that which flows from the power supply 30 through the resistor 4 to the terminal 5 of the power supply 7 to the positive terminal 8 thereof, which is grounded, through the cathode 27 of tube 26 to the anode 28 of the tube 26 and back to the positive terminal 29 of the power supply 30. Since this current flows through the tube 26, it can be seen that the current normally flowing through the resistor 4 (and therefore the potentials applied to the secondary emission controlling electrodes 97) is controlled by the bias of the grid 25 of the electron tube 26.

The effective over-all amplification of an electron multiplier tube of the type illustrated at 1 is controlled by the potentials applied to the secondary emission controlling electrodes 97 and therefore the amplification of the electron multiplier phototube 1 is controlled by the bias of the grid 25 of the electron tube 26. Potentials here given are illustrative only and not limiting.

The output anode 3 of the electron multiplier phototube 1 is connected through a resistance 10 to the positive terminal 31 of a power supply 28', which is grounded at 32. The terminal 31 of power supply 28', in the example, is at a 300 volt positive potential with respect to ground. The anode 3 is also connected to the grid 11 of an electron tube 12, the cathode 13 of which is grounded and the anode 14 of which is connected through a resistance 15 to the terminal 31 of the power supply 28'. The anode 14 of electron tube 12 is also connected through a resistance 16 to the grid 18 of an electron tube 19, the cathode 20 of which is grounded and the anode 21 of which is connected through a resistance 22 to the positive terminal 31 of the power supply 28'. The lower end of the resistor 16 and the grid 18 are connected through a resistance 17 to the lower terminal 27' of the power supply 28' which, in the example illustrated, is at a negative potential of 300 volts with respect to ground. The lower end of the resistor 16, the upper end of the resistor 17 and the grid 18 of the electron tube 19 are connected through a resistor 33 and junction 50 to inverse feedback means which will be more particularly described hereafter. The anode 21 of the electron tube 19 is connected through a resistance 23 to the grid 25 of the electron tube 26

and through a resistor 24, to the negative terminal 27' of the power supply 28'. The lower end of resistor 22 is also connected to the anode 200 of an electron tube 201, the cathode 202 of which is grounded and also connected to a switch 203 arranged to selectively make contact with an electric contact 204 connected to the grid of the electron 201. The grid and the contact 204 are also connected through a resistance 205 to a terminal 206 which is connected to the negative terminal of a low voltage power supply (such as —15 volts) sufficient to bias said tube beyond its cut-off point.

From the above description it can be seen that the output of the electron multiplier phototube 1 is resistively coupled to the succeeding amplifier stage including the electron tube 12 which is resistively coupled to the succeeding amplifier stage including tube 19 which is resistively coupled to the succeeding amplifier stage including tube 26, and that the output of tube 26 (which corresponds to the output of the multiplier tube 1), controls the current flow through the resister 4 and consequently the potential across the dynodes of the electron multipler tube 1, thus controlling the amplification constant thereof in an inverse feedback manner and tending to maintain the anode output current of multiplier tube 1 virtually at a constant value, irrespective of light input to the photocathode 2 of the multiplier phototube. The voltage applied across the bleeder resister 4 (which can be picked off at the output terminal 49) has a virtually logarithmic relationship to the light input to the photocathode 2. The operation of this logarithmic amplifier is more fully described in the hereinabove mentioned co-pending allowed patent application Serial No. 702,172, filed October 9, 1946, now Patent No. 2,454,871, and it will not be described in detail herein.

The input to the system in the example illustrated in Fig. 1 is understood to be light modulated by a photographic positive or negative or other image by means of a scanning process. One form of scanning process which may be used for this purpose is illustrated in Fig. 4. As there shown, a photographic positive 207 is mounted on transparent cylinder 208. Light from light source 47 is focused on photographic positive 207 by means of lens 209, and the light which passes through photographic positive 207 and transparent cylinder 208 falls on phototube 1. Phototube 1 is connected to the amplifier 210 by means of conductors 211, 212, and 213.

Only so much of the scanning means has been shown as necessary to the understanding of the invention. The scanning unit consisting of light source 47, lens 209, and phototube 1 is a structural unit which, as is well known in the art, is driven in synchronism with the rotation of cylinder 208 so that the scanning unit slowly moves longitudinally of the cylinder.

A portion of the photographic positive 207 shown on Fig. 4 as shaded portion 214, is of uniform optical density for use in adjusting the system during the intermittent adjusting period. A cam 215 is mounted on the same shaft as transparent cylinder 208 and operates the switch indicated generally at 216. During the intermittent adjusting period when the scanning beam is scanning the area of uniform density 214, cam 215 closes the switch 216. Connection is then made between contacts 43 and 44 and between contacts 203 and 204. Contacts 203 and 204 are connected to the amplifier 210 by means of wires

217 and 218. Contacts 43 and 44 of switch 216 are connected to motor 42 and the 110 volt A. C. power supply by means of wires 219 and 220.

The operation of the system is such that during the intermittent adjusting period the scanning beam scans the area of uniform density 214 and at the same time the two sections of switch 216 are closed. This causes the intensity of light from the light source 47 to be adjusted in an inverse feedback manner by the rheostat 46 which is in turn controlled by motor 42, amplifier 210 and phototube 1 until the anode current of phototube 1 falls within a narrow predetermined range.

Referencing means are provided to intermittently apply a selected reference voltage or signal to the secondary emission electrodes 97. In the example illustrated this includes the electron tube 201 which is connected in parallel with the electron tube 19. The closing of switch 203 removes negative bias from the grid of the tube 201 and allows same to conduct electric current therethrough and causes grid 25 of tube 26 to become extremely negative with respect to ground and to prevent the flow of current through tube 26 and consequently through resister 4. This allows the power supply 7 to take control of the flow of current through resister 4, thus applying a constant pre-selected reference signal to the secondary emission electrodes 97, during the intermittent periods when the switch 203 is closed under the control of the scanning drum 208 carrying the image 207 being scanned.

The scanning drum 208 is also arranged to close the switch 43 simultaneously with the closure of switch 203, and the image 207 carried by the scanning drum or the scanning drum itself, is provided with a strip 214 of constant optical density in a position such as to simultaneously modulate the light originally emitted by lamp 47 by a selected reference density during the period of time when the switches 203 and 43 are closed, whereby the modulation of the light input to the photocathode 2 will be of a selected reference value intermittently at precisely the same instant that a selected fixed reference value potential or signal is applied to the secondary electrodes 97 and at precisely the same instant that the switch 43 is closed to render the inverse feedback means responsive to variations in the amplified phototube output current.

The inverse feedback means used during the intermittent adjusting period includes an electron tube 35, the grid 34 of which is connected through a junction 50 to the output of electron tube 12. In this way the output voltage of tube 12 controls the current through tube 35 and through coil 38 of a relay indicated generally at 38'. The relay coil 38 controls the position of switch arm 39 positioned between two electric contacts 40 and 41. If the current through tube 35 and relay coil 38 is greater than the closing current of the relay, then connection will be made between contacts 39 and 41 and the motor will be caused to rotate in one direction. If the current through tube 35 and relay coil 38 is less than the opening current of the relay then connection will be made between contacts 39 and 40 and the motor will be caused to rotate in the opposite direction. Due to the amplifying action of tubes 35 and 12, a very small voltage change at the grid of tube 12 is sufficient to change the position of the relay armature. During the intermittent adjusting period, the current from anode 3 of phototube 1 is such as to cause a voltage drop in resistor 10 slightly greater than the positive potential above ground of the terminal 31 of power supply 28'. In the example given the voltage of terminal 31 is +300 volts with respect to ground. If the current from anode 3 of phototube 1 decreases by a very small percentage from the mean value for correct adjustment, then the grid of tube 12 will be made more positive than the mean value for correct adjustment. The anode 14 of tube 12 and the grid 34 of tube 35 will in turn be made more negative than their respective mean values. The relay 38' will be de-energized and connection will be made between contacts 39 and 40. This causes the motor 42 to rotate in such a direction that rheostat 46 increases the current to scanning lamp 47. The opposite action takes place if the current from anode 3 of phototube 1 is greater than the normal mean value during the automatic adjusting period. It should be noted that the switch 43 which is closed only during the intermittent checking periods under the control of the mechanically driven scanning drum 208, makes it impossible for the motor 42 to be energized for rotation in either direction except during the intermittent checking periods. The shaft 45 of the motor 42 is arranged to control the position of a variable rheostat 46 connected to the scanning lamp 47 and through leads 48 to a suitable source of potential, in the example illustrated, 8 volts D. C. The motor 42 is connected through leads 44 and switch 43 to a suitable source of potential.

Operation of the above embodiment of the present invention can be summarized as follows. Periodically during the scanning of the image 207 carried by the driven scanning drum 208, the modulation of light from the lamp 47 is momentarily change by a selected fixed reference density, in the example described by means of a constant optical density strip 214 along the edge of the image. At the same time that the light is modified by the constant density optical strip (or by other suitable means), the switches 203 and 43 are momentarily closed. The closure of the switch 203 interrupts the control of the multiplier by the amplifier and a fixed reference value signal is applied to the secondary electron emission controlling means, in this case the dynodes 97, thus standardizing the amplification conditions of the electron multiplier 1. The simultaneous closure of switch 43 places motor 42 in condition for energization in either direction under the control of the relay 38', which acts to energize the motor in either of two directions whenever the anode current of phototube 1 deviates from a selected standard value. The energization of the motor 42 takes place in a direction such as to rotate the variable rheostat 46 in a manner whereby to control the electric current flow through the lamp 47 in a negative feedback sense. Thus the system provides for a standard input modulation during the checking periods, a standard voltage applied to the secondary emission controlling means during the checking period, and provides for modifying the light input to the phototube in a negative feedback sense in response to deviation of the output signal from a standard value during the checking period, until such standard value is reached by the output signal. Thus during each checking period, the sensitivity drift of the electron multiplier amplifier is virtually completely compensated. The checking periods may take place at the end

of every other line of scan, during the scanning operation, or at any other desired timing.

Fig. 2 illustrates a modification of inverse feedback means adapted to be connected to the logarithmic amplifier system shown in Fig. 1 at the junction 50 in lieu of the inverse feedback means of Fig. 1 shown below junction 50. The lead from the junction 50 may be connected to the grid of an electron tube 52, the cathode 53 of which is grounded and the anode 54 of which is connected through a resistance 55 to a terminal 56 adapted to be connected to suitable source of positive potential. The anode 54 of the electron tube 52 is also connected through a resistance 57 to one end of a switch 60 and also through a resistance 58 to a terminal 59 adapted to be connected to a suitable source of negative potential.

The switch 60 is arranged to close a circuit to grid 61 of an electron tube 62, the anode 64 of which is connected to a terminal 65 adapted to be connected to a suitable source of positive potential and the cathode 66 of which is connected through a resistance 67 to a terminal 68 adapted to be connected to a suitable source of negative potential. The grid 61 of the electron tube 62 is also connected through a capacitor 63 to ground. It should be noted that the switch 60 corresponds in function to the switch 43 shown in Fig. 1 and is arranged to be intermittently closed by the scanning drum 208 (or other timing means) in the same manner and at the same time as switch 203. The cathode 66 of the electron tube 62 is connected in parallel through resistances 69 and 78 to grids 70 and 79 of electron tubes 71 and 80, which form the output stage of an oscillator, the cathodes of which are connected through a resister 207 to ground and the anodes 88 and 89 of which are connected to opposite ends of a primary coil 90 of an output transformer, the center tap of which is connected to a terminal 91 adapted to be connected to a suitable source of positive potential. The secondary winding 92 of the output transformer is connected to the scanning lamp 93, which corresponds to the scanning lamp 47 of Fig. 1.

An oscillation generator indicated generally at 87 includes electron tubes 77 and 86 coupled to the tubes 71 and 80 through leads connecting the anodes 76 and 85 through resistances 75 and 84 to points 73 and 82 connected through capacitors 72 and 81 to the grids 70 and 79 of the tubes 71 and 80. The points 73 and 82 are also connected through resistances 74 and 83 to the terminal 91 and the source of positive potential.

Deviation of the phototube output signal is fed through the switch 60 to the grid 61 of electron tube 62 modifying the bias thereof and current therethrough, thus modifying the grids 70 and 79 of tubes 71 and 80 and modifying the output oscillations of the tubes 71 and 80 which are fed by the oscillation generator 87. The transformer secondary winding 92 feeds oscillations to the lamp 93 which have been modified as hereinabove described, and in an inverse feedback sense, so that the phototube output signal is returned to the selected standard value. In the example illustrated the oscillation generator 87 is of the square wave generating type, since square waves minimize undesirable variations in the intensity of the light emitted by the scanning lamp 93. It should be noted the capacitor 63 is of the type having a low leakage current, and that the tube 62 is a cathode follower tube requiring a low positive potential at terminal 65 thus minimizing grid current to the grid 61 and preventing capacitor 63 from becoming charged or discharged between adjusting periods.

The embodiment of the present invention illustrated in Fig. 3 is a modification intended for use with an antilogarithmic amplifier system of the type more specifically described in my co-pending application Serial No. 702,172, now Patent No. 2,454,871. In this modification of the invention, the electron multiplier phototube 94 is provided with a photocathode 95, anode 96, and a plurality of secondary emission electrodes 97, connected across a resistor 98, the upper terminal 99 of which is connected to a source of negative potential and the lower terminal 100 of which is arranged to be connected to receive the system input signal. The anode 96 of multiplier tube 94 is connected through a resistance 101 to terminal 102 of a power supply 103 which, in the example shown, is at approximately 90 volts positive potential with respect to ground. The anode 96 is also connected to grid 104 of an electron tube 105, the cathode 106 of which is connected through a resistance 107 to ground. The anode 111 of tube 105 is connected to lights 112 and 113 which are connected to terminal 114 of the power supply 103, which may be at approximately 350 volts positive potential with respect to ground. Light source 112 (as modulated by vane 140) is directed upon the cathode of tube 94, whereas light source 113 is the scanning light.

Cathode 106 of the output tube 105, is coupled through resistance 108 to the grid 109 of electron tube 110, the cathode 115 of which is grounded and the anode 117 of which is connected through a resistance 141 to the positive terminal 114 of the power supply 103. Grid 109 of tube 110 is connected through a resistance 119 to the negative terminal 125 of a power supply 126. Said negative terminal 125 in the example illustrated, is at approximately 350 volts negative potential with respect to ground. Anode 117 of tube 110 is connected through the resister 120 to grid 122 of an electron tube 150, the cathode 116 of which is grounded and the anode 118 of which is connected through a resistance 142 to the positive terminal 114 of the power supply 103. Grid 122 of tube 150 is also connected through a resistance 121 to the negative terminal 125 of the power supply 126. Anode 118 of tube 150 is also connected through a resistance 123 to the grid 127 of an electron tube 151, the cathode 128 of which is grounded and the anode 129 of which is connected through a relay coil 130 to the positive terminal 114 of the power supply 103. The grid 127 of tube 151 is also connected through a resistance 124 to the negative terminal 125 of the power supply 126.

A control switch having a movable element 132 positioned between opposed electric contacts 133 and 134 is arranged to be actuated by the relay coil 130, thus closing either of two motor circuits of the reversible motor 135 in a manner similar to that previously described in connection with motor 42 in Fig. 1, thus rotating the motor shaft 139 in either of two directions, positioning a vane or light valve 140 of suitable configuration between the light source and the photocathode 95 of multiplier 94. Whenever switch 136 is closed during a checking period, vane 140 will modify the light impinging on the photocathode 95 in a negative feedback sense. Switch 136 may be actuated in any suitable manner and resembles switch 43 in characteristics.

It should be noted, that in this case the input

to the system is an electric input signal applied to the secondary emission controlling means and that the output from the system corresponds to the phototube output signal and can be taken from the system at any suitable point. It may comprise the light emitted from either or both of the light sources 112—113 or it may comprise the current flowing therethrough or the amplified signal corresponding thereto. It will be seen that in this case the relationship of output to input is virtually antilogarithmic, whereas the relationship between system output and system input in the logarithmic circuit employed in conjunction with the apparatus of the present invention and illustrated in Fig. 1, is virtually logarithmic.

While the present invention has been described in connection with an electron multiplier amplifier having a photocathode arranged to provide an electronic input to the secondary emission controlling means in response to light impinging the photocathode, it is to be understood that the invention is not limited to this arrangement, since any type of electronic input to an electron multiplier tube could be substituted for the photoelectric input. For example, the electronic input to the secondary emission controlling means might be of a thermionic type, or various other types of electronic input may be employed with the present invention. While the present invention is described as employing secondary emission electrodes, it is not limited to such an arrangement, since any type of secondary emission controlling means may be employed. For example, magnetic electron focusing and/or secondary emission controlling means may be employed single or in conjunction with electrostatic secondary electron emission controlling and/or focusing means.

The referencing means may also be modified within wide limits without departing from the spirit of the present invention. Any means for providing intermittent fixed reference modulation of system input and simultaneous inverse feedback to the amplifier for causing the modification of the amplifier output to a fixed standard bearing a certain preselected relationship to the fixed selected reference input may be employed. Numerous types of inverse feedback means may be employed. The means for modifying the light input may also be modified within wide limits.

Those skilled in the art will, from the description given, understand that both a constant density strip and a vane may be used in modulating the light supply to the phototube simultaneously, or sequentially.

The inverse feedback may be applied to the secondary emission controlling means rather than to the electronic input to the electron multiplier tube if desired. This is more particularly described, illustrated and claimed in my copending application, Serial No. 55,034, filed concurrently herewith, which is now U. S. Patent No. 2,534,668, granted December 19, 1950.

The examples described and illustrated herein are exemplary only, and are not intended to limit the scope of the present invention, which is to be interpreted in the light of the appended claims only.

I claim:

1. A method of compensating for changes in response characteristics of a multiplier phototube and amplifier controlling said multiplier phototube during a scanning operation, which comprises: periodically interrupting the control of said multiplier phototube by said amplifier and simultaneously subjecting the multiplier phototube both to scanning light modulated by a standard density and to a predetermined potential and adjusting the intensity of the scanning light in accordance with the response of the phototube and amplifier while under the influence of said light and predetermined potential.

2. A method of compensating for changes in response characteristics of a multiplier phototube in an operating circuit of a scanning device which comprises: periodically interrupting a scanning operation and subjecting the multiplier phototube to a predetermined potential and a light modulated by a standard density and adjusting the light in accordance with the response of the phototube while under the influence of the predetermined potential and modulated light; and continuing the scanning operation with the light in its adjusted state.

3. In a method of automatically compensating for changes in response characteristics of an amplifier including a multiplier phototube having a plurality of secondary emission electrodes, the steps of: intermittently and frequently interrupting the operation of an amplifier for a period of short duration and subjecting the multiplier phototube to a predetermined uniform potential and a light of a value expected to produce a selected, fixed response from the phototube; and adjusting the light input to the phototube during said period in a negative feedback manner in accordance with deviation of the phototube response, while under said predetermined potential, from the selected response; and continuing the operation of the amplifier with the light in its adjusted state until the succeeding checking period.

4. In a method of correcting for changes in sensitivity of a scanning system, including a scanning light and an amplifier provided with a phototube, the steps of: periodically and intermittently interrupting the scanning operation and subjecting the phototube to a predetermined, uniform potential and a light of a value expected to produce a selected response from the phototube; adjusting the light input to the photocell in accordance with deviation of the phototube response, while under said predetermined potential, from the selected response; and continuing the scanning operation with the light in its adjusted state.

5. In a scanning system, including a phototube and an amplifier connected to the output thereof: means for supplying light; an inverse feedback means operably connected to the phototube and amplifier, said feedback means being responsive to phototube output to modify the light to the phototube in accordance with the output of the phototube; means for periodically and intermittently restoring the modulation of the system input to a selected, fixed reference value; and means for rendering the inverse feedback means responsive only during said intermittent checking periods, said feedback means being arranged to modify the light input in a direction tending to return the output signal to a selected standard value whenever, during such checking periods, the phototube output differs from a desired value.

6. A system of the character stated in claim 5 wherein the phototube is an electron multiplier phototube amplifier of the type including a photosensitive cathode, an output anode and a

plurality of secondary emission electrodes, and wherein the modulated system input is the light input to the photosensitive cathode of the phototube.

7. A system of the character stated in claim 6 wherein the means for intermittently restoring the system input to a selected value include means for applying an electric signal of a selected fixed reference value across the secondary emission electrodes of the electron multiplier phototube amplifier during the simultaneous periods when the inverse feedback means is responsive to deviation of the amplified phototube output signal from the selected standard value, and when the light input to the phototube is modulated by a selected reference fixed density.

8. A system of the character stated in claim 5 wherein the means for intermittently restoring the modulation of the system input comprises a mechanically driven scanning system arranged to carry an image to be scanned by the phototube, said image being provided with a strip of constant modulating effectiveness arranged to intermittently modify the modulation of the light input to the phototube to a selected fixed reference value during scanning of the image.

9. A scanning system of the character stated in claim 5 wherein the phototube is a multiplier including a photosensitive cathode, an output anode, and a plurality of secondary emission electrodes; and the means for intermittently restoring the modulation of the system input comprise a mechanically driven scanning drum, a strip of constant modulating effectiveness arranged to intermittently modify the modulation of the light input to the phototube and switch means correlated with the scanning drum to intermittently apply an electric signal of desired reference value across the secondary emission electrodes of the phototube simultaneously with the modulation of the light input to the phototube by the strip.

10. A scanning system of the character stated in claim 5 wherein the inverse feedback means include a reversible motor, variable rheostat means operably connected to the motor, a light source under the control of the rheostat, reversing switch means for energizing the motor for rotation in either direction, and relay means responsive to deviation of the amplified phototube output for actuating the reversing switch means.

11. A scanning system of the character stated in claim 5 wherein the inverse feedback means include a reversible motor, variable rheostat means operably connected to the motor, a light source under the control of the rheostat, reversing switch means for energizing the motor for rotation in either direction, and relay means responsive to deviation of the amplified phototube output for actuating the reversing switch means, the means for intermittently rendering the feedback means responsive including switch means arranged to energize and de-energize the motor in timed relation.

12. A scanning system of the character stated in claim 5 wherein the inverse feedback means includes reversible motor means, light valve means operably connected to the motor and arranged to modify light input to the phototube in accordance with the direction of rotation of the motor, reversing switch means for energizing the motor for rotation in either direction, and relay means responsive to deviation of the phototube output for actuating the reversing switch means.

13. A system of the character stated in claim 5 wherein the inverse feedback means comprises electric oscillation generating means; and including modulator means arranged to modulate the output oscillations produced by the electric oscillation generator in accordance with the amplified deviation of phototube output current from a fixed reference value; and scanning lamp means arranged to be effectively energized by the output electric oscillations and to supply light input to the phototube.

14. A system of the character stated in claim 5 wherein the inverse feedback means comprises electric oscillation generating means; and including modulator means arranged to modulate the output oscillations produced by the electric oscillation generator in accordance with the amplified deviation of phototube output current from a fixed reference value; and scanning lamp means arranged to be effectively energized by the output electric oscillations and to supply light input to the phototube, the means for rendering the inverse feedback means responsive to the phototube output including switch means arranged to connect and disconnect the amplified phototube output to the modulator means in the inverse feedback means in timed relation to the scanning of an image and only during checking periods when the modulation of the light input into the phototube is of fixed reference value.

15. A system of the character stated in claim 13 wherein the electric oscillation generating means is of the square wave generating type.

16. In an electron multiplier amplifier system arranged to receive a modulated system input, the provision of: means for supplying electronic input to the electron multiplier amplifier; and inverse feedback means effectively responsive to the electron multiplier output signal arranged to modify the electronic input to the electron multiplier in a negative feedback sense in accordance with the electron multiplier output signal, whereby sensitivity drift of the amplifier will be minimized.

17. A system of the character stated in claim 16 including: means for intermittently, alternately, effectively rendering the inverse feedback means effectively responsive and non-responsive to the electron multiplier output signal, whereby the electronic input to the electron multiplier amplifier will be modified intermittently in a negative feedback sense in accordance with the electron multiplier output signal during the corresponding intermittent responsive periods.

18. In an electro-optical amplifier system arranged to receive a modulated system input and including a phototube and an amplifier connected to the output thereof to produce an amplified phototube output signal, the provision of: means for supplying light input to the phototube; inverse feedback means responsive to the amplified phototube output signal arranged to modify the light input to the phototube in a negative feedback sense in accordance with the amplified phototube output signal; and means for periodically and repetitively rendering the inverse feedback means effectively responsive for a period of short duration to the amplified phototube output signal, whereby the light input to the phototube will be modified periodically during the corresponding intermittent responsive periods and sensitivity drift of the system will be minimized.

19. A system of the character stated in claim 19

including: means for intermittently restoring the modulation of the system input to a selected fixed reference value during the simultaneous, intermittent periods when the inverse feedback means is responsive to the amplified phototube output signal.

NORMAN R. GUNDERSON.

REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
2,012,573	Long	Aug. 27, 1935
2,158,193	Morse	May 16, 1939
2,347,015	Woloschak	Apr. 18, 1944
2,411,440	Le Page	Nov. 19, 1946
2,412,423	Rajchman et al.	Dec. 10, 1946