United States Patent [19]

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[11] **3,711,720**

[45] **Jan. 16, 1973**

[54] **AUTOMATIC BRIGHTNESS CONTROL FOR IMAGE INTENSIFIER TUBE**

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[22] Filed: **Feb. 12, 1971**

[21] Appl. No.: **114,787**

[52] **U.S. Cl.** .....**250/213 VT**, 307/296, 250/207, 323/79, 313/96

[51] **Int. Cl.**.....**H01j 31/50**

[58] **Field of Search** ..250/207, 213 VT; 313/105, 96; 315/246; 323/79; 307/296

[56] **References Cited**

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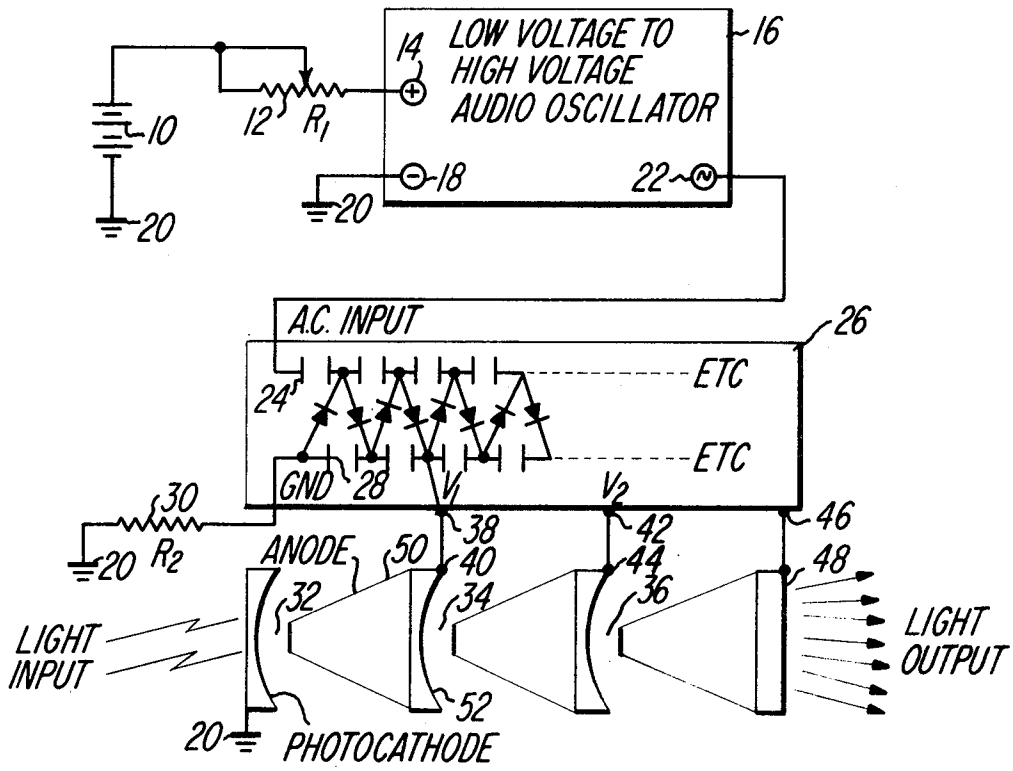
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[57] **ABSTRACT**

A circuit for operating an image intensifier tube wherein the voltages for the individual intensifier stages are supplied by a voltage multiplier arrangement. The invention includes circuitry to compensate for the loading down and cutting off of individual stages of the multiplier at scene illumination levels above 10^{-2} foot candles, enabling operation of the intensifier at scene illumination levels as high as 10^{2} foot candles.

5 Claims, 4 Drawing Figures



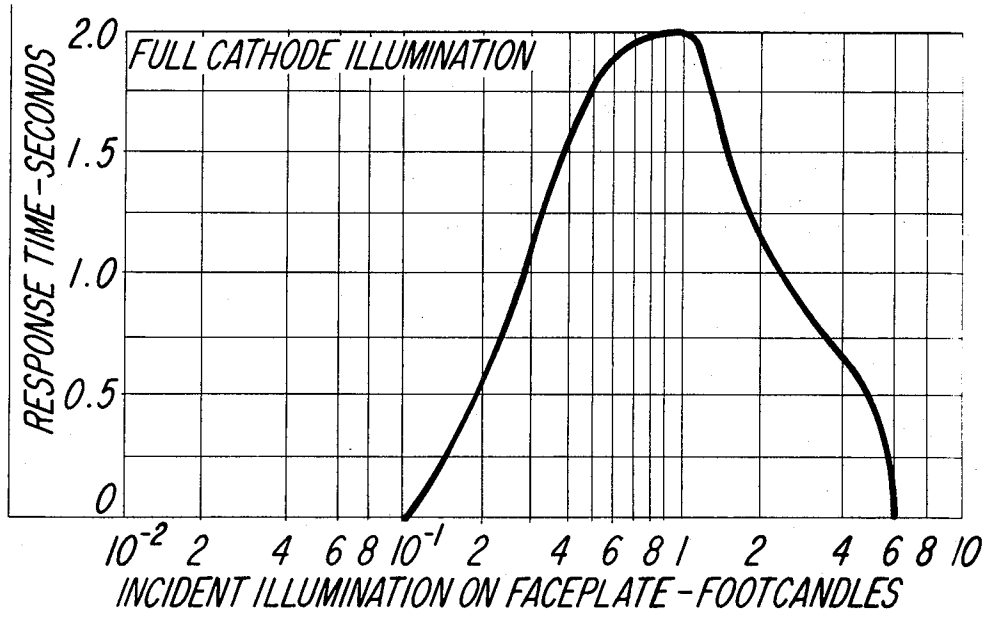


FIG. 1

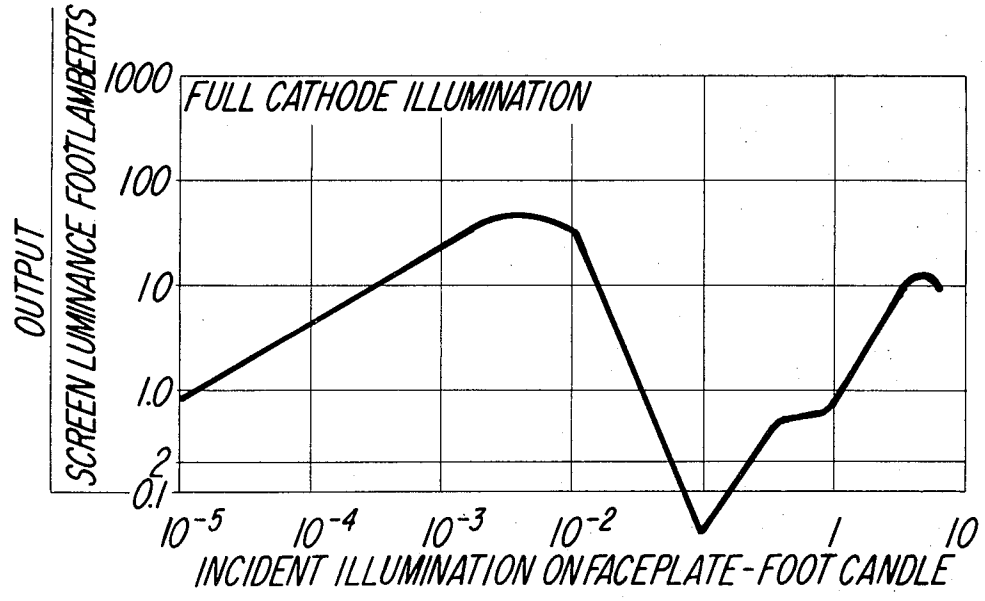


FIG. 2

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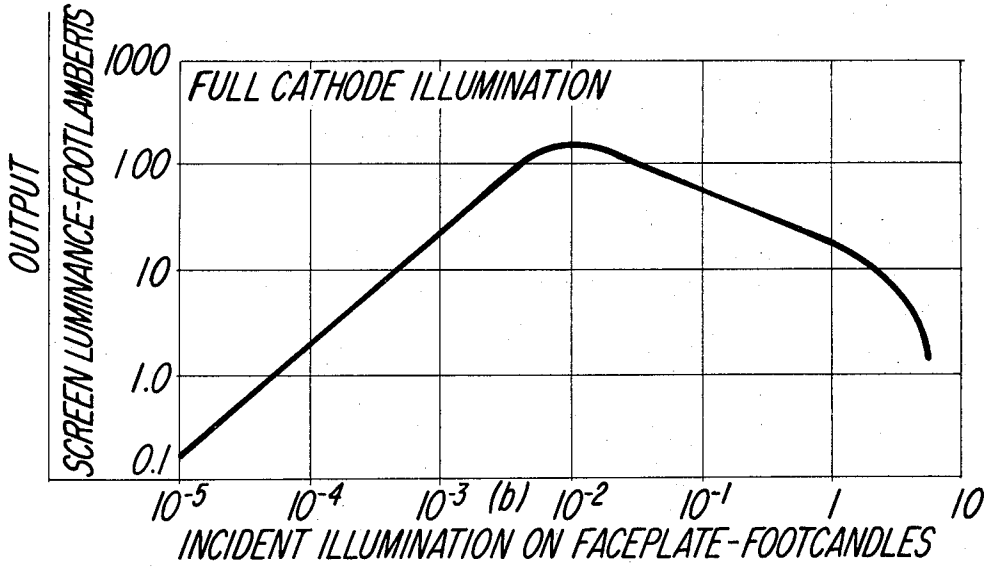


FIG. 4

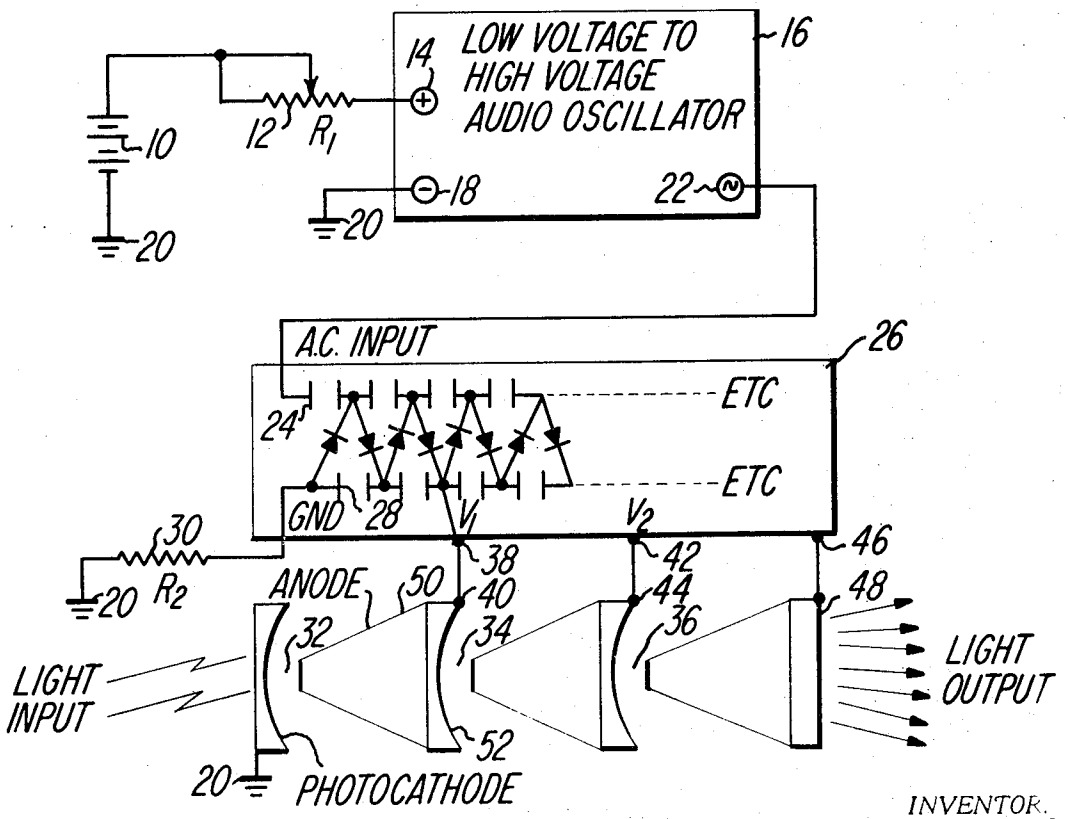


FIG. 3

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AUTOMATIC BRIGHTNESS CONTROL FOR IMAGE INTENSIFIER TUBE

BACKGROUND OF THE INVENTION

This invention relates to circuitry for improving the dynamic response and extending the operating range of an image intensifier.

An image intensifier or image tube is a device in which a visible image is produced in response to radiant energy, such as ultra violet light, visible light or infrared rays. In an image intensifier, the light reflected from a scene is imaged onto the photocathode of the intensifier. The photocathode converts the light image into an electron image and the electron image is focused and accelerated by a voltage on the anode of the intensifier. The electron image bombards a phosphor screen, on which the intensified visible image of the original scene is displayed. The degree of intensification is dependent on the voltage difference between the anode and photocathode at each stage of the intensifier.

A limitation found in many prior art image intensifiers is that the intensifier will become inoperable or cut off, i.e., the voltage on a stage will drop below the value required to accelerate the electron beam, upon a sudden increase in light level and remain inoperable as long as the high light level persists.

Cutoff occurs because the voltage multiplier assembly that supplies voltage to the individual intensifier stages includes cascaded voltage doubler arrangements containing capacitors and diodes. Since the voltage multiplier has poor voltage regulation properties, the capacitors discharge in the presence of high currents, greatly reducing the output voltage of the multiplier, (induced by high levels of light intensity incident on the photocathode surface) and remain discharged as long as the high photocurrents remain. This characteristic of the voltage multiplier assembly limits intensifier operation to scene illumination levels generally below 10^{-2} foot candles.

When the incident light intensity decreases, a substantial amount of time is required for the voltage multiplier capacitors to recharge to their normal operating voltages. Thus the output voltage of the multiplier gradually increases to its value prior to incidence of the high light intensity, over a period of time which may be as long as 10 to 15 seconds. During this time the output voltage of the multiplier is too low to provide significant intensifier output, and the intensifier is said to be "cut off."

An object of the present invention is to provide an image intensifier having an improved response time, generally less than 2 seconds, for sudden increases in light level, and having the capability of continuous operation at scene illumination levels over the range of 10^{-5} foot candles to 50 foot candles.

SUMMARY OF THE INVENTION

The invention herein described covers circuitry for an improved cascaded image intensifier, for operation over the range of scene brightness levels from 10^{-5} foot candles to 10^{2} foot candles.

The circuitry includes an inverter having an input terminal and an output terminal. Means are provided for coupling the input terminal of the inverter to a source of dc voltage. The output terminal of the inverter is coupled to a voltage multiplier assembly having at least two output terminals and a ground terminal. The multiplier assembly is of the cascaded voltage doubler type containing capacitors and diodes. The output terminals of the voltage multiplier assembly are coupled to the individual stages of the cascaded image intensifier. The photocathode of the first stage of the intensifier is coupled to the point of reference potential.

First impedance means, coupled between the input terminal of the inverter and a source of DC voltage, are provided for reducing the output voltage of the inverter-voltage multiplier combination. The value of the first impedance means is determined by the maximum permissible output light level of the cascaded intensifier.

Second impedance means are coupled between the ground terminal of the voltage multiplier assembly and the point of reference potential. The value of the second impedance means is chosen so that at scene brightness levels above 10^{-2} foot candles, the voltage drop across the second impedance means results in a reduction in the voltage applied to the first stage of the intensifier. The reduction in voltage is not sufficient to cause the first stage voltage to fall below the cutoff voltage of the intensifier.

IN THE DRAWINGS

FIG. 1 shows a diagram of the response time for screen luminance (brightness) to adjust to incident illumination for an image intensifier according to an embodiment of the invention.

FIG. 2 shows a plot of the screen luminance (brightness) vs. incident illumination characteristic of a prior art image intensifier.

FIG. 3 shows a circuit for an image intensifier according to an embodiment of the invention.

FIG. 4 shows a plot of the screen luminance (brightness) vs. incident illumination characteristic of an image intensifier according to an embodiment of the invention.

In general, the usefulness of prior art image intensifiers has been limited because they would cut off due to a sudden increase in illumination and remain off for as long as the high light level persisted and for as much as 15 seconds after removal of the high light level. Applicant's invention, which is described in detail below, results in an intensifier having the characteristic shown in FIG. 1. FIG. 1 shows a curve of the time required for the screen luminance to decrease to a minimum value, i.e., cut-off, and then to return to or exceed 15 foot-lamberts when the photocathode illumination is increased from 5×10^{-4} foot-candles to the illumination levels shown on the abscissa. Thus, Applicant's intensifier is inoperable only for the period of time, shown on the ordinate, required to adjust to the new light level.

FIG. 2 shows a curve, plotted on logarithmic scales, of the screen brightness vs. incident illumination characteristic of a typical prior art three stage cascaded image intensifier. It can be seen that for low input light levels, below 10^{-3} foot candles, the curve is a straight line and the gain of the intensifier, calculated by dividing the output luminance by the input luminance, is substantially constant. The output illumination begins to level off at higher input light levels, due to the loading down of the multiplier assembly. The output luminance then decreases very sharply with increasing il-

lumination, since the capacitors in the multiplier assembly have completely discharged, resulting in cut-off of the intensifier at 10^{-1} foot candles. At higher input light levels, the output luminance begins to increase, as the capacitors begin to recharge, but at a non-uniform rate.

It is highly undesirable for an image intensifier to operate in the manner shown in FIG. 2 at high light levels and for this reason the operation of prior art intensifiers was limited to levels below about 10^{-2} foot-candles.

The circuitry shown in FIG. 3 extends the operating range of cascaded image intensifiers to scene light levels as high as 50 foot candles. In addition, Applicant's image intensifier does not produce brightness peaks in output illumination which could result in damage to the vision of surrounding personnel.

As shown in FIG. 3, positive terminal of a DC power source **10** is connected to one terminal of variable resistor **12**. The negative terminal of DC power source **10** is connected to a point of reference potential **20**. The other terminal of variable resistor **12** is connected to a first DC input terminal **14** of audio oscillator **16**. The second DC input terminal **18** of audio oscillator **16** is connected to a point of reference potential **20**. The AC output terminal **22** of audio oscillator **16** is connected to the AC input terminal **24** of voltage multiplier assembly **26**. The combination of DC power source **10**, resistor **12** and audio oscillator **16** comprising an inverter. The ground terminal **28** of voltage multiplier assembly **26** is connected to one terminal of resistor **30**. The other terminal of resistor **30** is connected to the point of reference potential **20**.

Three intensifier stages in cascade **32**, **34**, and **36** are also shown in FIG. 3. Terminal **38**, corresponding to the first stage of voltage multiplier **26**, is connected to the cathode flange **40** of image intensifier stage **34**. Terminal **42**, corresponding to the second stage of voltage multiplier **26**, is connected to cathode flange **44** of image intensifier stage **36**. Terminal **46**, corresponding to the third stage of voltage multiplier **26**, is connected to phosphor screen electrode **48** of the image intensifier assembly.

The gain of the first stage **32** is dependent on the voltage applied to the anode **50** of intensifier stage **32**, i.e. to the output voltage of multiplier stage **38**, which anode **50** is coupled to the photocathode **52** of the second stage **34**. Resistor **30** is inserted between the ground terminal **28** of multiplier **26** and the point of reference potential **20** to control the voltage applied to intensifier stage **32** and thereby control the gain of intensifier stage **32**. The value of resistor **30** is chosen so that at low light levels, below 10^{-3} foot candles where less than a nanoampere of photocurrent is emitted from photocathode **52**, a negligible voltage drop exists across resistor **30**. However, at input light levels above 10^{-2} foot candles, the voltage drop across resistor **30** becomes significant, (for example, if resistor **30** is 500 megohms and assuming a photocurrent of 10 microamperes, there exists a voltage drop of $500 \times 10^6 \times 10 \times 10^{-6} = 5KV$) and since resistor **30** is in series with intensifier stage **32**, this results in a drop in the voltage across first stage intensifier **32**, thereby reducing the first stage gain. Thus, at high input light levels, the gain of the first stage is significantly reduced, thus reducing the photocurrents in subsequent stages. In addition the gain of later stages is reduced to a lesser extent, because of the drop across the first stage resistor.

The improved characteristic curve, shown in FIG. 4, results because the reduction in stage voltages limits the current drawn by the inverter-multiplier combination, so that the capacitors do not discharge excessively.

An additional technique for improving the screen brightness-incident illumination characteristic curve, is to reduce the overall gain of the intensifier. To accomplish this reduction in gain, resistor **12** is inserted between the first DC input terminal **14** of audio oscillator **16** and the positive terminal of DC power source **10**. Insertion of resistor **12** will reduce the voltage applied to oscillator **12**, by the drop in voltage across resistor **16**, which in turn will reduce the voltage at the input of multiplier **26**, thereby reducing the voltage on each stage of the cascaded image intensifiers.

Resistor **12** is a variable resistor so that it can be adjusted for a maximum output level consistent with personnel safety, as directed by the purchaser, for a particular intensifier. Once this peak adjustment is made, the value of resistor **12** is fixed for operation at all input light levels.

FIG. 4 shows a plot of the screen brightness-incident illumination characteristic for an intensifier incorporating resistor **12** in the power supply circuit and resistor **30** between the ground terminal **28** of multiplier **26** and the point of reference potential. It can be seen by comparing FIG. 2 and FIG. 4 that the overall gain of the intensifier at low input levels (below 10^{-3} foot candles) is lower in FIG. 4, which is reasonable since the input voltage for the intensifier of FIG. 4 is lower than the one for FIG. 2. In FIG. 4, the gain decreases with increasing input light levels above 10^{-2} foot candles, which is desirable since, in general, an output level above 10^{-1} foot lamberts is sufficient for clear viewing of most objects. In addition, the curve of FIG. 4 has no discontinuities and the operating range has been extended to a cathode illumination of 5 foot candles.

Applicant's circuit results in a characteristic curve, shown in FIG. 4, having no discontinuities because the combination of resistors **12** and **30** causes a reduction in second and third stage photocurrents in such an amount so that voltage multiplier assembly **26** is loaded down to a minimum extent, consistent with output viewing requirements. For the prior art intensifier, whose characteristic curve is shown in FIG. 2, second and later stage photocurrents become very high, at light levels above 10^{-2} foot candles, causing the capacitors to discharge, and thereby reduce the multiplier output voltage below the cut-off value for the stages.

For a persistent light level above 10^{-2} foot candles, the prior art intensifier will remain in a cut-off condition since the second and third stage capacitors will remain discharged because of the relatively large second and third stage photocurrents produced by the first stage's gain remaining relatively high.

What is claimed is:

1. An automatic image brightness control system for a light imaging device comprising an image intensifier tube, a power supply circuit and means for coupling said power supply to said tube, said tube being adapted for operation over the range of input light illumination levels from 10^{-5} to 10^{-2} foot candles;

wherein said tube includes a plurality of cascaded image intensifier stages each stage including a photocathode electrode and an anode electrode wherein each anode electrode is coupled to the succeeding photocathode electrode, the photocathode electrode of the first of said stages being a photocathode input electrode for emitting electrons in response to the intensity of light applied thereto, and the anode electrode of the last of said stages including a phosphor display screen output electrode providing an image display in accordance with said electrons impinging thereon;

wherein said power supply includes a DC voltage source, an oscillator circuit having an input and output, a first resistive impedance serially coupling said DC voltage source to said input of said oscillator circuit wherein the alternating voltage at said output of said oscillator circuit decreases in proportion to the direct current being supplied to said oscillator circuit, and a diode-capacitor voltage multiplier having an input terminal and a plurality of discrete DC voltage output terminals, said input terminal of said voltage multiplier being coupled to said output of said oscillator circuit; and

wherein said means for coupling said power supply to said tube includes stepped connections respectively coupling output terminals of said voltage multiplier to said stages of said tube, the one of said connections coupling a given one of said output terminals of said voltage multiplier to said photocathode input electrode of said tube including a serially connected second resistive impedance to individually control the voltage applied to the first of said stages in response to the intensity of the light being applied to said photocathode input electrode, said second resistive impedance having a given fixed value which at input light illumination levels substantially below 10^{-2} foot candles results in only a negligible voltage drop existing across said second resistive impedance and at input light illumination levels substantially above 10^{-2} foot candles results in a voltage drop across said second resistive impedance sufficient to substantially reduce the voltage applied to the first of said stages.

2. The system according to claim 1 wherein said second resistive impedance is a resistor having first and second terminals, said first terminal being coupled to said given one of said output terminals of said voltage multiplier and said second terminal being coupled to said photocathode input electrode and a fixed point of reference potential with respect to said DC voltage source.

3. The system according to claim 2 wherein said resistor has a value substantially equal to 500 megohms.

4. The system according to claim 1 wherein the maximum response time for a displayed image output variation from minimum screen brightness to 15 foot-lamberts, while the intensity of the light being applied to said photocathode input electrode varies from 5×10^{-4} to 1 foot-candle, is on the order of 2 seconds.

5. The system according to claim 1 wherein the value of said second resistor is such that said individually controlled voltage is maintained above the level of the cut-off voltage of said first stage over the entire range of input illumination.

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