RADIATION-SENSITIVE CAMERA SHUTTER AND APERTURE CONTROL SYSTEMS

Original Filed May 28, 1970 3 Sheets-Sheet 1

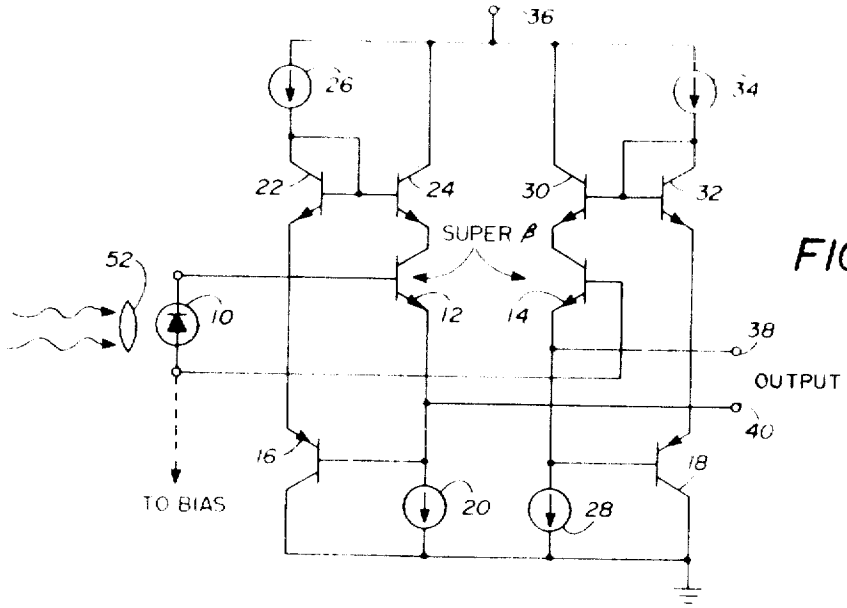


FIG. 1

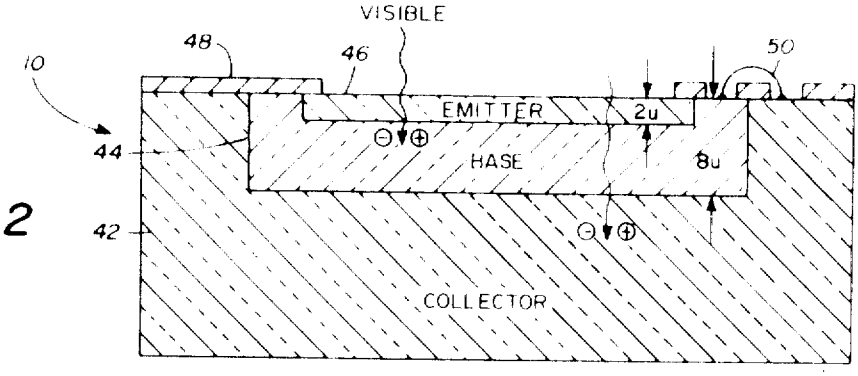


FIG. 2

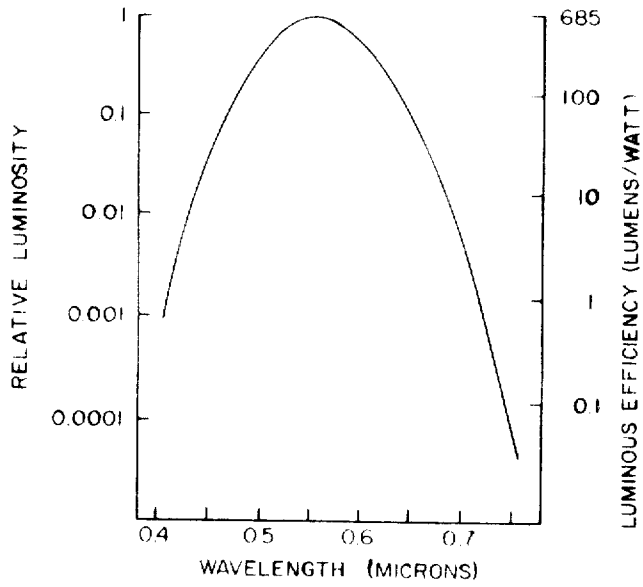
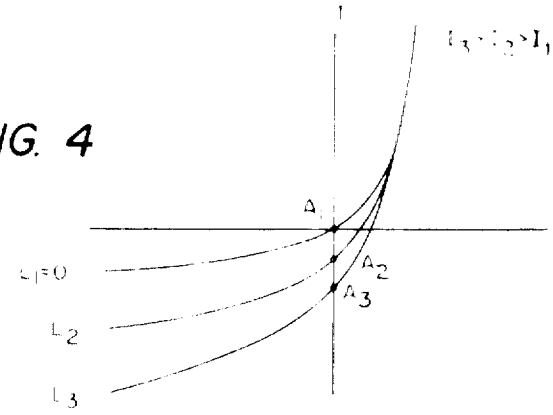


FIG. 3

RADIATION-SENSITIVE CAMERA SHUTTER AND APERTURE CONTROL SYSTEMS

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FIG. 4



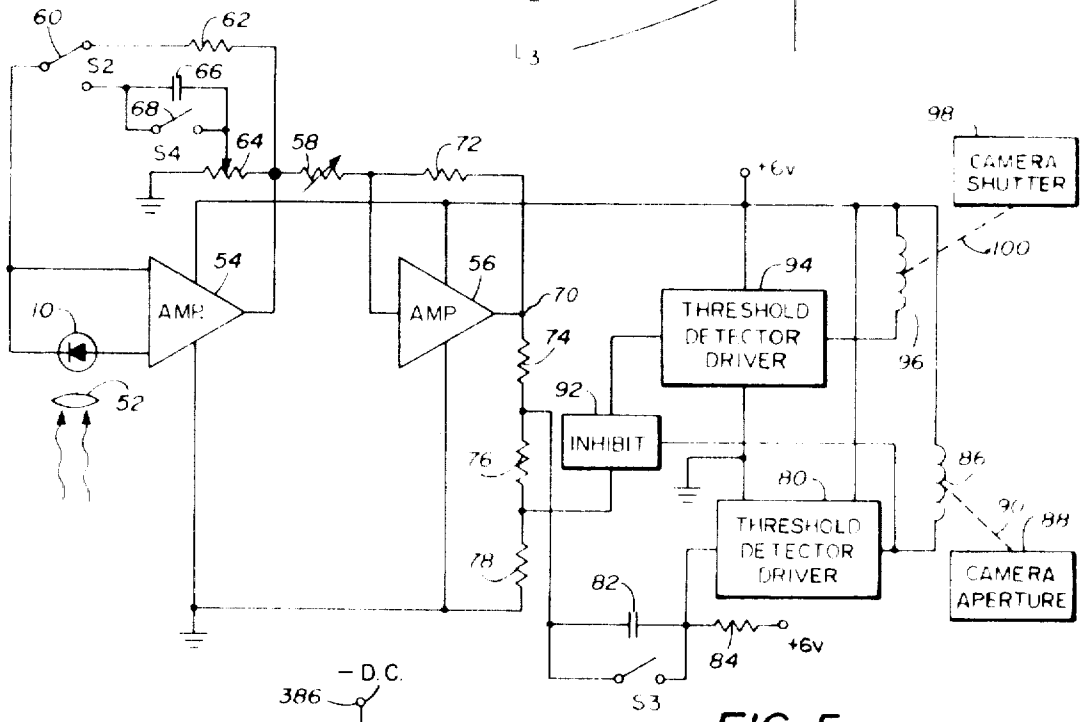


FIG. 5

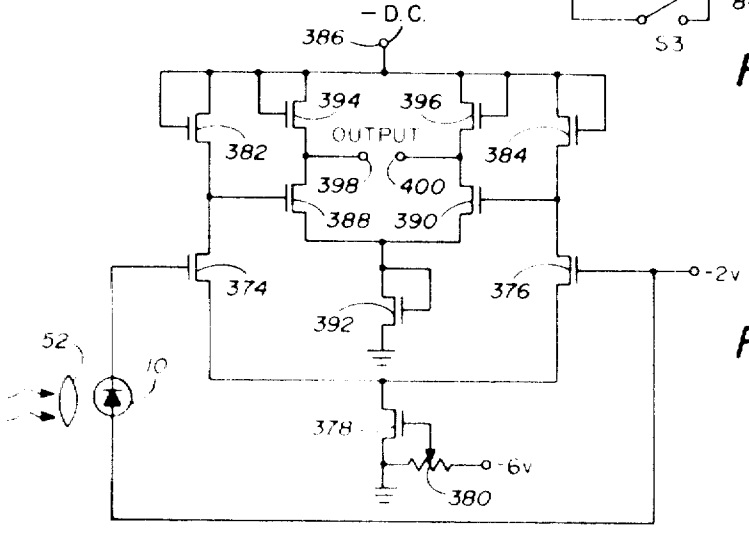


FIG. 7

RADIATION-SENSITIVE CAMERA SHUTTER AND APERTURE CONTROL SYSTEMS

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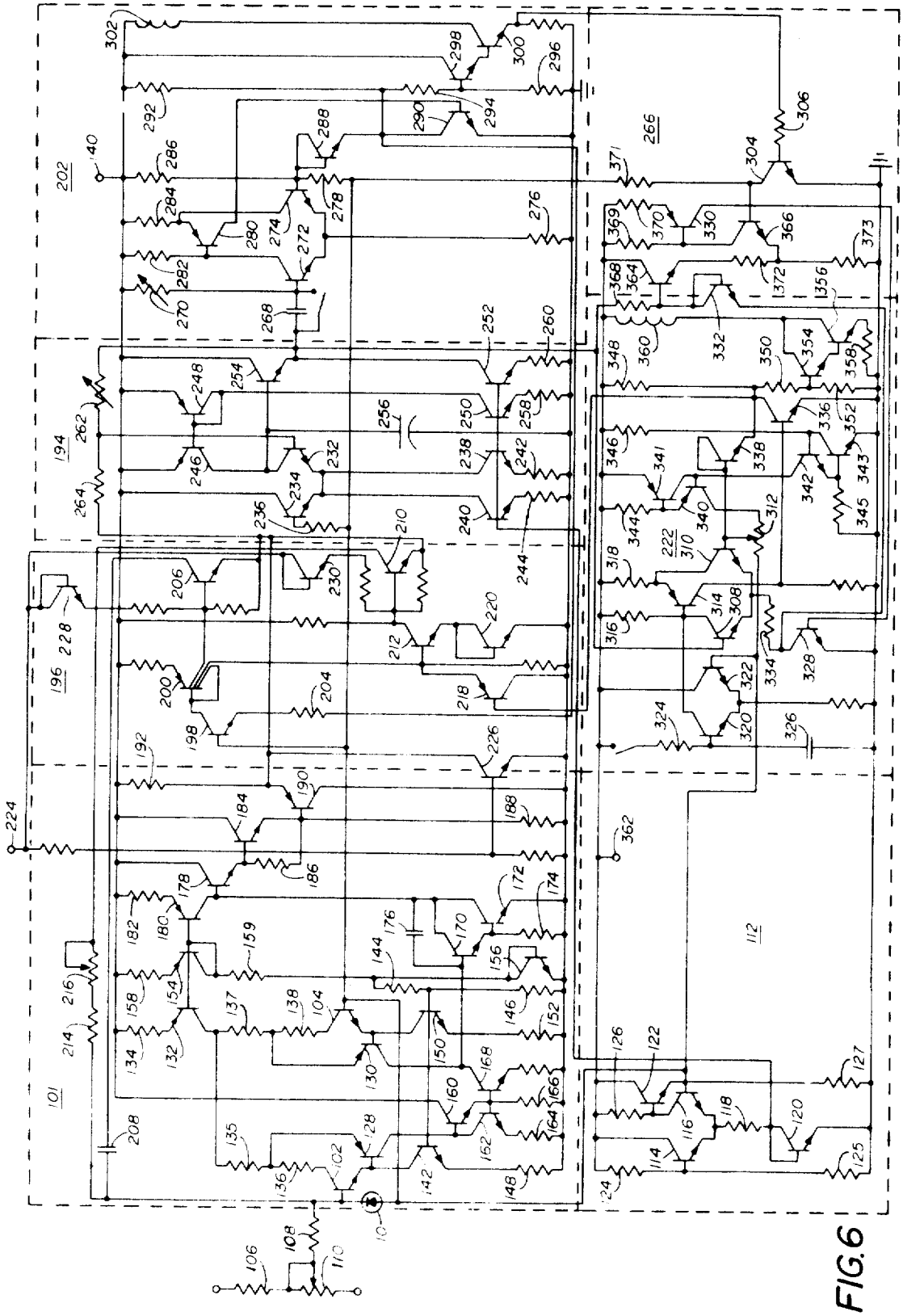


FIG. 6

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27,867

RADIATION-SENSITIVE CAMERA SHUTTER AND APERTURE CONTROL SYSTEMS

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Int. Cl. G01j *1/00*

U.S. Cl. 95—10 C 8 Claims

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

ABSTRACT OF THE DISCLOSURE

A voltage that varies linearly with light intensity variation is generated by an amplifier having a differential input stage connected to a light responsive diode. Two high gain transistors are included in the differential input stage to provide amplification of the signal currents of the light responsive diode. In a camera shutter and aperture control system, the linearly varying light intensity voltage is amplified to control two threshold detector circuits. An inhibiting circuit prevents one of the threshold detector circuits from responding to the light intensity voltage until the first threshold circuit has completed its desired operation.

This invention relates to photosensor control and more particularly to photosensor control circuitry that produces a voltage varying linearly with light intensity.

By far the greatest use of light responsive detectors is in circuitry that produces an on-off signal. When the ambient light in which a photosensor is located reaches a critical level, the detector circuit switches from one steady-state condition to a second steady-state condition. Such circuits usually employ the photosensor in a voltage sensing arrangement. A few circuits are designed to produce an output voltage that varies with light intensity; these circuits also employ the photosensors as a voltage device. Voltage responsive circuits have found limited use with photosensors because most detectors produce a voltage variation that is too small for the conventional amplifier circuit.

An object of the present invention is to provide an amplifier for generating a voltage that varies linearly with light intensity. Another object of this invention is to provide an amplifier including a differential input stage for producing a voltage that varies linearly with light intensity. A further object of this invention is to provide an amplifier including a photosensor in a current responsive configuration. Still another object of this invention is to provide an amplifier having a high gain differential input stage connected to a photosensor. A still further object of this invention is to provide an autofilter photosensor in an amplifier for producing a voltage that varies linearly with light intensity. Yet another object of this invention is to provide a photosensor in a circuit that produces a voltage that varies linearly with light intensity for camera shutter and aperture control.

In accordance with this invention, an amplifier for generating a voltage that varies in accordance with light intensity includes a light responsive diode that produces a current signal that changes with the light intensity incident thereon connected to a different input section. A feedback loop connected from the output of the amplifier and to one side of the light responsive diode establishes the closed loop amplifier gain and relates the output of the amplifier to the signal generated by the diode. In one configuration of a feedback loop, the amplifier output

varies linearly with the light intensity incident on the light responsive diode.

In accordance with a more specific embodiment of this invention, a light responsive diode that generates a current signal that varies with light intensity incident thereon connects to the inputs of a differential amplifier. The differential amplifier includes a first input transistor with a current gain factor in the range of from 1000 to 5000 connected in a differential configuration with a second input transistor also having a current gain factor in the range of from 1000 to 5000. A feedback loop connected from the output of the amplifier to one side of the light responsive diode determines the closed loop amplifier gain and relates the output of the amplifier to the signal generated by the light responsive diode. A biasing source connected to the second input of the differential configuration and to one side of the light responsive diode establishes a reference level for amplifier operation.

A more complete understanding of the invention and its advantages will be apparent from the specification and claims and from the accompanying drawings illustrative of the invention.

Referring to the drawings:

FIG. 1 is a schematic of a bipolar differential amplifier having an output that varies proportionately with the light intensity as measured by a photosensor;

FIG. 2 is a cross section of a near infrared auto-filter p-n junction photosensor;

FIG. 3 is a curve of relative luminosity as a function of wavelength in microns;

FIG. 4 is a plot of photocurrent as a function of voltage for a p-n junction photosensor;

FIG. 5 is a schematic and block diagram of a camera aperture and shutter control system employing the differential amplifier of FIG. 1;

FIG. 6 is a schematic of a bipolar transistorized circuit for a camera aperture and shutter control system; and

FIG. 7 is a schematic of an MOS circuit producing an output that varies proportionately with the light intensity incident on a photosensor.

Referring to FIG. 1, a photosensor **10** in a diode configuration has a cathode electrode connected to the base electrode of a first input transistor **12** and an anode electrode connected to the base electrode of a second input transistor **14**. A bipolar circuit of the type shown exhibits high voltage gain per stage and accurate light level sensing incident on the photosensor **10**. To accommodate the low current levels of the photosensor **10**, the transistors **12** and **14** have a "super-beta" characteristic. A super-beta transistor is defined as one with electrical characteristics of: $\beta=1000$ to 5000 and BV_{CEO} of approximately 2 to 5 volts. The base widths of super-beta transistors are nominally approximately 0.01 mil. Because of the high beta values, the effective input impedance of the bipolar transistor amplifier of FIG. 1 is a factor of 10 above an amplifier using conventional beta transistors at the input stage.

To maintain the 2 to 5 volt BV_{CEO} value for the transistors **12** and **14**, the circuit of FIG. 1 include transistors **16** and **18**. Transistor **16** has a base electrode connected to the emitter of the transistor **12** and a current source **20**. Additional circuitry for maintaining the current and voltage level for the transistor **12** includes a pair of back-to-back transistors **22** and **24** along with a current source **26**. Transistor **18** has a base electrode connected to the emitter of the transistor **14** and a current source **28**. Additional circuitry for maintaining the current and voltage level of the transistor **14** includes a transistor **30** connected in a back-to-back arrangement with a transistor **32** and a current source **34**. Not included in the schematic of FIG. 1 are various resistors for estab-

lishing biasing and current levels. The circuit of FIG. 1 is energized from a D.C. voltage source connected to the terminal **36**.

A differential output from the transistors **12** and **14** appears at the output terminals **38** and **40** and is proportional to the light intensity incident on the photosensor **10**.

With the diode **10** connected as shown, it operates in a current mode; that is, the transistors **12** and **14** respond to current levels generated in the diode. In the current mode of operation, a higher frequency response is achievable from the diode **10** as compared to a voltage mode of operation. This advantage of current mode operation is due to the capacitance associated with the photodiode. In a voltage mode of operation, this capacitance must be charged and discharged. Diode capacitance has little if any affect in the current mode.

In one form, the photosensor **10** is a selenium photovoltaic diode constructed by depositing a layer of selenium on a conductive substrate followed by a layer of cadmium oxide. The N-type CdO forms a junction with the p-type selenium. Photons penetrate the opaque CdO layer and create hole-electron pairs in the selenium. The electrons slide down the p-junction potential barrier into the CdO and a current proportional to the light created hole-electron pairs will flow and be amplified by the transistors **12** and **14**.

In applications where light memory (the retention of the hole-electron pairs in the selenium) is of concern, an all silicon photosensor is preferred to the thin film selenium junction photosensors. Silicon photosensors exhibit improved signal-to-noise ratio over the selenium counterpart and silicon is memory free for response times greater than a few milliseconds.

Referring to FIG. 2, there is shown in cross section a silicon photosensor **10** having a silicon substrate **42** as the collector electrode with a base region **44** and an emitter region **46** that are diffused into the substrate by subsequent diffusion processes through a silicon dioxide layer **48**. Silicon p-n junctions will respond readily to both the visible (0.4 to 0.7 micron) and the near infrared (0.7 to 1.1 microns) wavelengths because of the nature of the silicon photo absorption coefficient.

To render the silicon photosensor insensitive to the near infrared for applications where only visible light is of interest, selective photo response is achieved by arranging the transistor diffusion schedule such that the deeply penetrating near infrared radiation produces ionization in the transistor collector body where the resulting photocurrent is inoculously removed by short circuiting the collector-base junction. This shorting is accomplished by the jumper wire **50**. For the near infrared radiation photons to travel through the emitter and base diffusions into the collector region, the depth of the base region is on the order of 8 microns. Using a 2 micron diffusion for the emitter **46**, and the 8 micron diffusion for the base region **44**, photons in the visible region will penetrate through the emitter region into the base region where they produce photocurrents related to the photo bombardment.

The photosensor **10** of FIG. 2 will be connected into the amplifier of FIG. **1** such that its emitter-base junction is zero or slightly reverse biased. With the photosensor so connected and with the collector-base junction physically short circuited by the jumper wire **50**, little if any transistor action will take place.

By operating the silicon photosensor with the emitter-base junction in a zero or a slightly reverse biased configuration, the dark current leakage characteristic of a p-n junction, which is temperature dependent, may be eliminated. The leakage current for a p-n junction at voltages less than a few tenths volts positive is given by:

$$I_{Dark}=I_s\left(e^{\frac{qV}{nkt}}-1\right)+I_{Surf.}+I_{Gen.\ (dep.\ layer)} \quad (1)$$

Each of the currents in Equation 1 *is* [are] strongly temperature dependent and will introduce an error in the photo generated current of the diode since the total current flow with the diode exposed to illumination (assuming the depletion layer width is zero) will be:

$$I_{Tot.}=I_{Dark}-qR(L_n+L_p) \quad (2)$$

where

R=carrier generation rate per unit volume of incident illumination, and

L_n, L_p=diffusion length of minority carrier electrons and holes, respectively.

With the emitter-base junction operated at a zero or slightly negative bias, Equation 2 reduces to:

$$I_{Tot.}=qR(L_n+L_p) \quad (3)$$

whereby temperature dependent leakage current components have been eliminated. The zero or slightly negative bias mode of operation is graphically illustrated by the curves of FIG. 4 by points A_1, A_2 and A_3 which represent illumination intensity L_1, L_2 and L_3, respectively.

To limit the response of a silicon photosensor [below] *to* the visible region, an optical filter **52** is placed in the path of the radiation incident on the sensor, as illustrated in FIG. 1.

Referring to FIG. 3, there is shown a luminosity curve, that is, the sensitivity of the human eye to radiant energy as a function of radiation wavelengths. By employing a selective diffusion schedule as explained and the optical filter **52**, the response of a silicon photosensor may be limited to the visible region between 0.4 and 0.7 micron.

One application of the circuit of FIG. 1, using either a selenium photovoltaic diode or a silicon photosensor, is in a camera shutter and aperture control as illustrated in FIG. 5. The photosensor **10** generates a current flow in the input stage of an operational amplifier **54** in accordance with light intensity passing through the optical filter **52**. The differential amplifier of FIG. 1 comprises the input stage of the operational amplifier **54**. A voltage output from the amplifier **54** is proportional to the light intensity on the photosensor **10** and is applied to the input of an operational amplifier **56** through an adjustable resistor **58**.

A feedback circuit connected from the output of the amplifier **54** and to the cathode electrode of the photosensor **10** tailors the input of the amplifier **56** to have a desired relationship to the light intensity. This feedback circuit includes two paths selectable by means of a switch **60**. In the position shown, switch **60** connects a resistor **62** in the feedback circuit and the output of the amplifier **54** varies proportionally with the light intensity incident on the photosensor **10**. With the switch **60** in the second position, the feedback circuit includes a variable resistor **64** and a capacitor **66**. This circuit relates the output of the amplifier **54** to the time integral of the current generated by the photosensor **10**. A switch **68** is closed to shunt the capacitor **66** at the completion of one operating cycle of the control system of FIG. 5.

A signal applied to the input of the operational amplifier **56** is amplified therein to an output voltage level appearing at a terminal **70**. A voltage at the terminal **70** is fed back to the input of the amplifier **56** through a feedback resistor **72** and divided in a voltage divider network of resistors **74**, **76** and **78** into two threshold detector input signals. A voltage at the junction of resistors **74** and **76** is applied to an input of a threshold detector driver **80** through a timing circuit consisting of a capacitor of a capacitor **82** and a resistor **84**. An output of the driver **80** connects to a solenoid **86** for controlling the opening of a camera aperture **88** through a mechanical linkage **90**. An output of the driver **80** is also applied to an inhibit circuit **92** that interrupts the circuit between the junction of resistors **76** and **78** and the input terminal of a threshold detector driver **94**.

Initially, the aperture **88** begins to open and at the same time the switch S–3 is opened. This operation continues until a charge on the capacitor **82** reaches a threshold level. At the threshold level, the output voltage at the output of the driver **80** drops to zero, thereby de-energizing the solenoid **86**. This clamps the *aperture* [aperature] **88** at a desired setting. Since the output of the amplifier **56** at terminal **70** is related to the output of the amlifier **54**, which in turn is related to the light intensity incident on the photosensor **10**, the opening the aperture **88** will be determined by the level of light intensity passing through the optical filter **52**.

Upon completion of the operation of the driver **80**, the inhibit circuit **92** completes the circuit between the junction of resistors **76** and **78** and the input of the threshold detector driver **94**. A voltage appearing at the junction of the resistors **76** and **78** is applied to the driver **94** to actuate a solenoid **96** for controlling the operation of a camera shutter **98** through a mechanical linkage **100**. Also, upon completion of the operation of the driver **80**, the switch **60** is changed to a position to connect the capacitor **66** in the feedback circuit of the operational amplifier **54**. The output of the amplifier **54**, and consequently the output of the amplifier **56** at terminal **70**, now varies as the time integral of the light intensity incident upon the photosensor **10**. This signal changes in a manner determined by the resistor **64** and the capacitor **66**. When it reaches a threshold level as determined by circuitry of the detector driver **94**, the output of the driver de-energizes the solenoid **96** to return the shutter **98** to a closed position. Thus, the time that the shutter **98** remains open is deermined by the light intensity incident on the photosensor **10**. Note, that by means of the inhibit circuit **92**, operation of the shutter **98** is prevented until after the aperture **88** has been opened to the desired level.

Many threshold detectors may be used in the system illustrated and may consist of a high gain differential input and a single ended output amplifier. The function of the detector drivers is to compare a signal voltage on one input with a fixed internal reference. When the input exceeds the reference voltage, the output amplifier is switched to a non-conducting state thereby changing the energization state of the respective solenoid.

Referring to FIG. 6, there is shown the complete schematic of a camera and shutter control system including the photosensor **10** coupled to a differential amplifier input stage of super-beta transistors **102** and **104**. The cathode electrode of the photosensor **10** also connects to a biasing circuit comprising resistors **106** and **108** and a variable resistor **110**. A reference voltage, as established at the output of a reference supply **112**, is applied to the anode electrode of the photosensor **10** and the base electrode of the transistor **104**.

The reference supply **112** includes a differential amplifier of transistors **114** and **116** having a comomn emitter connection. Emitter current for the transistor pair is established and controlled by a network consisting of a resistor **118** and a transistor **120**. The reference voltage generated by the supply **112** appears at the emitter terminal of a transistor **122** having a base electrode connected to the collector electrode of the transistor **116**. Resistors **124** through **127** establish the various bias voltage levels and current levels for operation of the transistors of the reference supply **112**.

To protect the super-beta transistors from over-voltage surges, a transistor **128** is shunted across the transistor **102** and a transistor **130** shunts the transistor **104**. Collector current control for the transistors **102** and **104** is provided by a circuit that includes a transistor **132** and resistors **134** through **138**. Transistor **132** is connected to the positive side of a D.C. supply at terminal **140** through the resistor **134**. The emitter circuit for the transistor **102** includes a transistor **142** having a base electrode connected to the junction of resistors **144** and **146** and an emitter electrode connected to ground through a resistor **148**. Similarly, the super-beta transistor **104** includes a transistor **150** in the emitter electrode circuit with the base electrode of the transistor **150** connected to the junction of resistors **144** and **146** and having an emitter electrode connected to ground through a resistor **152**. A voltage developed at the junction of the resistors **144** and **146** is established by transistors **154** and **156** along with resistors **158** and **159** in a circuit connected from the D.C. supply to ground.

The output circuit for the transistor **102** includes transistors **160** and **162** in addition to the transistor **128**. The emitter current of the transistor **162** is controlled by a resistor **164**, and the emitter current of the transistor **160** and the base drive of the transistor **162** *are* [is] controlled by a resistor **166**. This voltage at the emitter electrode of the transistor **160** also drives a transistor **168** in the output circuit for the transistor **104**. A voltage at the collector electrode of the transistor **168** is the output of the differential input pair and is applied to cascaded transistors **170** and **172** that are part of a circuit that contains a base drive resistor **174** and a capacitor **176**.

Connected to the common collector junction of the transistors **170** and **172** is the base electrode of a transistor **178** and the collector electrode of a transistor **180**. Transistor **178** further amplifies the output voltage of the differential input pair. Transistor **180**, which has an emitter electrode connected to the positive terminal of a D.C. supply through a resistor **182**, establishes the base bias level of the transistor **178**. Further amplification of the signal from the differential input pair is provided by the transistor **184** having a base level set by the resistors **186** and **188**. The final amplification stage of the amplifier **101** in the system shown includes a transistor **190** having a base electrode coupled to the emitter electrode of the transistor **184**. In the emitter circuit of the transistor **190** is a resistor **192** connected to the D.C. supply.

By operation of the super-beta transistors **102** and **104** and the various other amplification stages, the voltage at the emitter electrode of the transistor **190** varies in a predetermined relationship with the light intensity incident on the photosensor **10**. This voltage is coupled to the input of an operational amplifier **194** and to one of one of two feedback circuits through an electronic switch **196**. Switch **196** includes transistors **198** and **200** for determining the initial state of the switching circuitry. Transistor **198** is coupled to the reference supply **112** through the base electrode and the output of a threshold detector **202** through a resistor **204** to the emitter electrode. Transistor **200** connects to the base electrode of a switching transistor **206** that connects a capacitor **208** in the feedback loop for the amplifier **101** when in a conducting state. Transistor **200** also controls the switching transistor **210** through an inverting transistor **212**. Transistor [**200**] *210* connects resistors **214** and **216** in a feedback loop for the amplifier **101**. In addition to the transistor **212**, the circuit for controlling the operation of the switching transistor **210** includes transistors **218** and **220**. Transistor **218** is controlled by the output of the threshold detector **222** through a base electrode connection.

During a reset cycle of the camera control, a voltage at terminal **224** controls the conducting state of transistors **226**, **228** and **230** in the electronic switch **196**.

As explained, a voltage at the emitter electrode of the transistor **190** is the input to the amplifier **194**. This voltage is applied to the base electrode of a transistor **232** of a differential pair that includes a transistor **234**. The output of this differential pair is determined by the difference between the voltage at the base electrode of transistor **232** and the base electrode of transistor **234**. A voltage at the base electrode of the transistor **234** is established by the resistor **236** connected to the output of the reference supply **112**.

Emitter curent for the transistors **232** and **234** is controlled by transistors **238** and **240**, respectively. The

base electrode of each of these transistors is connected to the collector electrode of transistor **120** of the reference supply **112**. Resistors .242 and **244** connected to the emitter electrodes of the transistors **238** and **240**, respectively, complete the current emitter control circuitry for the transistors **232** and **234**. Collector current of the transistor **232** is established by a transistor **246** having an emitter electrode connected to the terminal **140** and a base electrode to the base electrode of a transistor **248**. Transistor **248** is connected in the collector electrode circuit of a transistor **250** which along with a transistor **252** controls the base curent of the transistor **246**.

An output transistor **254** of the amplifier **194** has a base electrode tied to the collector electrode of the transistor **232** and to a filtering capacitor **256**. The emitter control circuit for the transistor **254** includes resistor **260**.

The output voltage of the amplifier **194** as appearing at the emitter electrode of the transistor **254** is fed back to the base electrode of the transistor **232** through a feedback resistor **262**. Resistor **262** along with the input resistor **264** establishes the external gain of the amplifier **194**.

The output of the amplifier **194**, which corresponds to the output of the amplifier **56** of FIG. 5, connects to the input of the threshold detector **202** and an inhibit circuit **266**. The threshold detector **202** corresponds to the detector driver **80** of FIG. 5. An output voltage from the amplifier **194** is coupled through a timing network of a capacitor **268** and a variable resistor **270** to the base electrode of a transistor **272**. Transistor **272** is connected in a differential amplifier configuration with a transistor **274**. These two transistors have a common emitter junction connected through a resistor **276** to ground. The output of the differentially connected transistors **272** and **274** is the difference between the voltage connected to the base electrode of the transistor **274** and the voltage at the emitter electrode of the transistor **254**. This output voltage appears at the collector electrode of a transistor **280** having a base electrode tied to the collector of the transistor **272**. Resistors **282** and **284** establish the current levels for the transistors **272** and **280**.

A resistor **286** connected to terminal **140** and resistor **278** which is tied to the output of the source **112** establishes the base drive for the transistor **274** and the base drive for the transistor **288**. Transistor **288** establishes the collector current for a transistor **290** having a base electrode tied to the collector electrode of the transistor **280**. A voltage at the collector of the transistor **290** is applied to the emitter electrode of the transistor **198** of the electronic switch **196** and to a resistor network of resistors **292**, **294** and **296**.

The voltage at the junction of resistors **294** and **296** drives a transistor **298** in an output stage of the threshold detector **202**. Transistor **300** comprises the final output stage of the detector **202** and energizes the aperture solenoid **302** to control the opening of a camera aperture.

Returning to the output of the amplifier **194** as appearing at the emitter electrode of the transistor **254**, this voltage is also applied to the base electrode of a transistor **308** in the threshold detector **222**. Transistor **308** is part of a differential pair that includes a transistor **310** having a base electrode voltage determined by the setting of a variable resistor **312**. An output signal from the differential pair appears at the collector electrode of a transistor **314** having a base electrode connected to the collector electrode of the transistor **308**. Resistors **316** and **318** establish the current levels for the transistors **308** and **314**.

The threshould detector **222** is similar in many respects to the threshold detector **202**. One difference, however, is a "flash control" provision that includes differential transistors **320** and **322**. The base electrode of transistor **322** is driven by the output of the reference supply **112**. The base electrode of the transistor **320** is coupled to a timing circuit of a resistor **324** and a capacitor **326**.

Emitter current for the differential transistors **308** and **310** is controlled by a transistor **328** having a base electrode coupled to the collector electrode of a transistor **330** in the inhibit circuit **266**. The collector electrode of the transistor **328** is tied to the emitter electrode of a transistor **332**, also in the inhibit circuit **266**. Thus, transistor **328** establishes the emitter current for the transistors **308** and **310** through a resistor **334**, and, by the interconnection to the inhibit circuit **266**, controls the operation of the differential transistors **308** and **310**.

When in the inhibit state, the detector **222** is in a hold condition. This continues so long as the aperture solenoid **302** operates to position the camera aperture. After the aperture has been set, as determined by a signal at the base electrode of the transistor **304**, the output voltage on the transistor **314** is applied to the base electrode of a transistor **336**. A collector bias for the transistor **336** is provided by means of a transistor **338** having a base electrode tied to the wiper arm of the variable resistor **312**. The voltage at the variable resistor **312** is established by the output of the reference supply **112** and transistors **340** through **343** and resistors **344** through **346**.

A voltage appearing at the collector electrode of the transistor **336** is applied to a network of resistors **348**, **350** and **352**. At the junction between resistors **350** and **352** there is connected the base electrode of a transistor **354** of the output stage of the threshold detector **222**. A transistor **356** is also included in the output stage and has an emitter electrode coupled to ground through a resistor **358**. In series with the common connection of the collector electrodes of transistors **354** and **356** is a shutter control solenoid **360** that has one terminal tied to the positive side of a D.C. supply at a terminal **362**.

As mentioned, the operation of the threshold detector **222** is inhibited by the inhibit circuit **266**. A voltage at the emitter electrode of the transistor **300** drives a transistor **304** through a resistor **306** in the inhibit circuit. In addition to the other transistors previously defined, the circuit **266** further includes transistors **364** and **366** each having a base connection to the collector electrodes of transistors **332** and **304**, respectively. The remainder of the inhibit circuit **266** includes resistors **368** through **373**. This circuit operates to inhibit the threshold detector **222**, as explained with regard to the system of FIG. 5.

The operation of the circuit of FIG. 6 is similar to the system of FIG. 5. The capacitor **268** and resistor **270** determine the operation of the aperture control solenoid **302** in conjunction with the light incident upon the photosensor **10**. Upon completion of the aperture setting operation, the feedback capacitor **208** is connected in the feedback loop for the amplifier **101** and the inhibit circuit **266** controls the shutter solenoid **360**, leaving the camera shutter open for a time determined by the amount of light incident upon the photosensor **10**.

In addition to bipolar circuitry, the photosensor **10** may be included in the input stage of a P-channel MOSFET differential amplifier as illustrated in FIG. 7. The photosensor **10**, which receives light through the optical filter **52**, connects to the [base] *gate* electrode of field-effect transistors **374** and **376**. These transistors are coupled in a differential amplifier configuration with a common connection through a transistor **378** for [emitter] *source* current control; the [emitter] *source* current being established by the setting of a variable resistor **380**. The [collector] *drain* current for the transistors **374** and **376** is controlled by transistors **382** and **384**, respectively, having one electrode coupled to the negative terminal of a D.C. supply at terminal **386**. An output signal from the transistor **374** is applied to a transistor **388** which comprises part of a differential pair that includes a transistor **390** coupled to the output of the transistor **376**. Transistors **388** and **390** have a common connection to a transistor **392** that controls the current flow through these

transistors. Additional circuitry for the transistors **388** and **390** includes transistors **394** and **396**.

An outuput voltage from the circuit of FIG. 7 appears at the terminals **398** and **400** and is related to the light intensity incident upon the photosensor **10**. The differential amplifier configuration of FIG. 7 is included in a MOS shutter control circuit in a manner similar to that described above with respect to the bipolar circuit of FIG. 1.

While several embodiments of the invention, together with modifications thereof, have been described in detail herein and shown in the accompanying drawings, it will be evident that various further modifications are possible without departing from the scope of the invention.

What is claimed is:

1. In a camera shutter and aperture control system, the combination comprising:

a light-responsive photosensor generating a current signal that varies with light intensity incident thereon,

an amplifier including a differential input section connected to said light-responsive photosensor and having a first feedback loop for relating the amplifier output proportionately to the diode-generated signal and a second feedback loop for relating the amplifier output to the time integral of the photosensor generated signal,

switching means for connecting each of the feedback loops separately to said amplifier output,

a second amplifier having an output that varies with [film speed and] the output of said first amplifier,

a first threshold detector responsive to the output of said second amplifier when said switching means connects the first feedback loop across said first amplifier for controlling the camera aperture setting,

a second threshold detector responsive to the output of said second amplifier when said switching means connects the second feedback loop across said first amplifier for controlling the camera shutter operation, and

means for inhibiting the operation of said second threshold detector until said first threshold detector sets the opening of the camera aperture.

2. In a camera shutter and aperture control system as set forth in claim **1** including timing means connected between the output of said second amplifier and said first threshold detector for controlling the operation of said first detector in accordance with the output of the second amplifier.

3. In a camera shutter and aperture control system as set forth in claim **2** including means for biasing the second input to the differential section of the first amplifier and one side of said light-responsive photosensor at a reference level.

4. In a camera shutter and aperture control system as set forth in claim **3** wherein said light-responsive photosensor is a selenium photovoltaic cell.

5. In a camera shutter and aperture control system as set forth in claim **3** wherein said light-responsive photosensor is a silicon transistor.

6. In a camera shutter and aperture control system as set forth in claim **5** including means for shunting the collector-base junction of said transistor.

7. In a camera shutter and aperture control system as set forth in claim **6** including means for biasing the emitter-base junction of said transistor.

8. In a camera shutter and aperture control system as set forth in claim **7** including an optical filter to limit the response of said transistor to radiant energy in the visible region.

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