

- [54] SHUTTER OPERATING CIRCUITS FOR PHOTOGRAPHIC CAMERAS
[75] Inventor: Osamu Ichihashi, Machida, Japan
[73] Assignee: Yashica Co., Ltd., Japan
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[52] U.S. Cl. 354/51; 354/60 R
[58] Field of Search 354/24, 29, 50, 51, 354/60

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Primary Examiner—Russell E. Adams
Attorney, Agent, or Firm—Charles W. Helzer

[57] ABSTRACT

In a shutter operating circuit wherein the shutter time is controlled by a photoelectric transducer disposed to receive the light transmitting through the objective lens, there are provided a first amplifier for amplifying the output from the photoelectric transducer, a second amplifier having a high input impedance and operating to generate an output corresponding to the output from the first amplifier, means for feeding back the output from the second amplifier to the input of the first amplifier, a capacitor connected on the input side of the second amplifier for holding the output from the first amplifier in accordance with the opening operation of the shutter of the camera, a first impedance element connected in series with the photoelectric transducer, a second impedance element connected in parallel with the series combination of the first impedance element and the photoelectric transducer, an integrating capacitor for integrating the output from the second amplifier in accordance with the opening operation of the shutter, and a shutter trigger circuit for closing the shutter when the voltage across the integrating capacitor reaches a predetermined [value] value whereby the exposure time is determined by the output current from the second amplifier.

9 Claims, 7 Drawing Figures

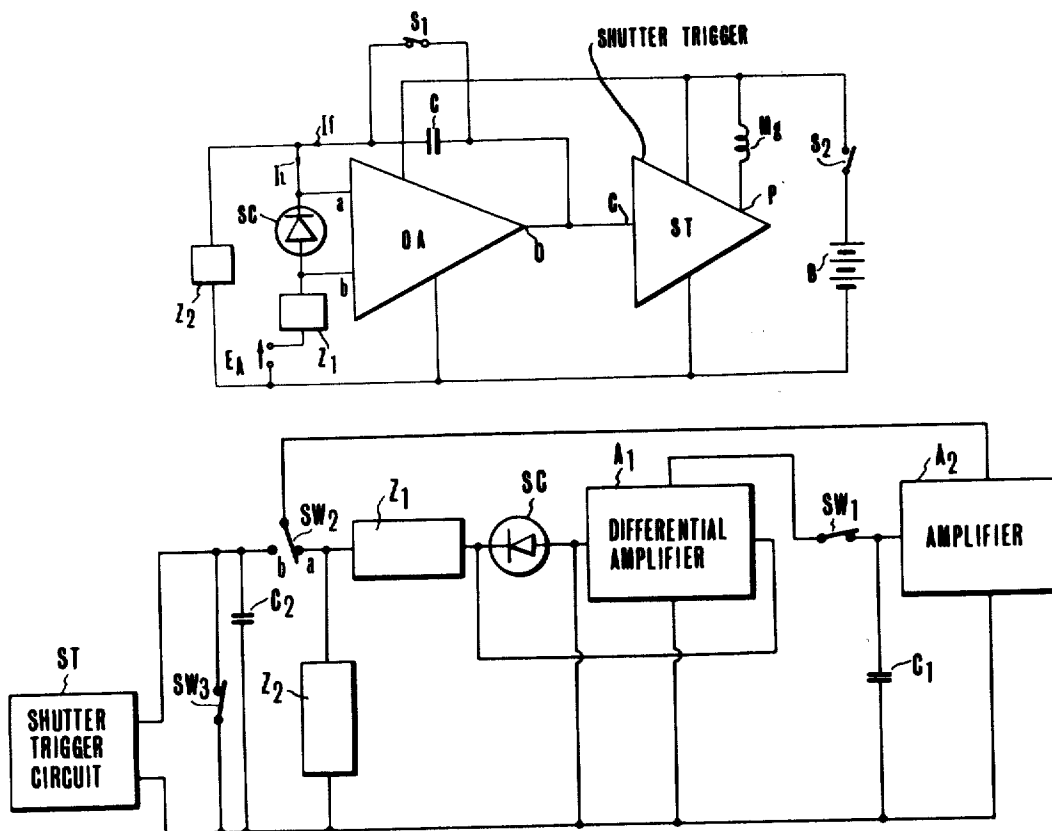


FIG. 1

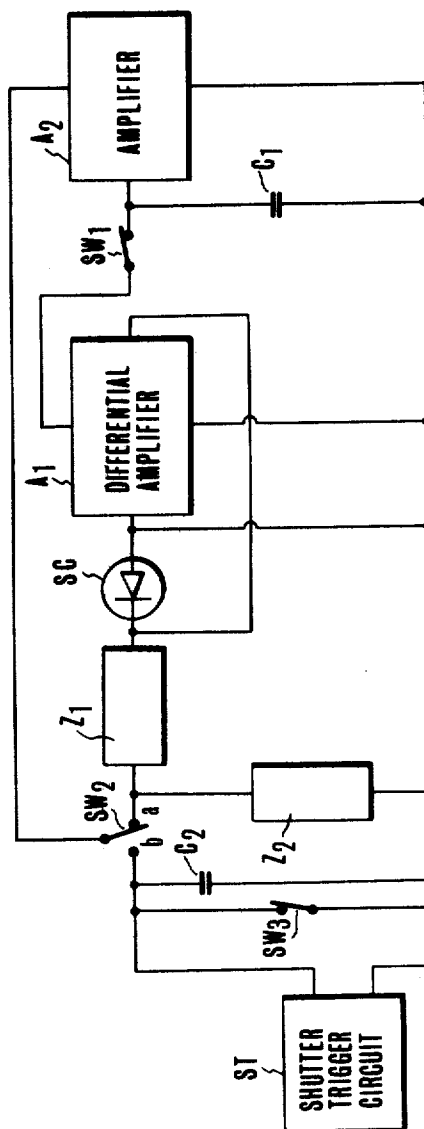


FIG. 2

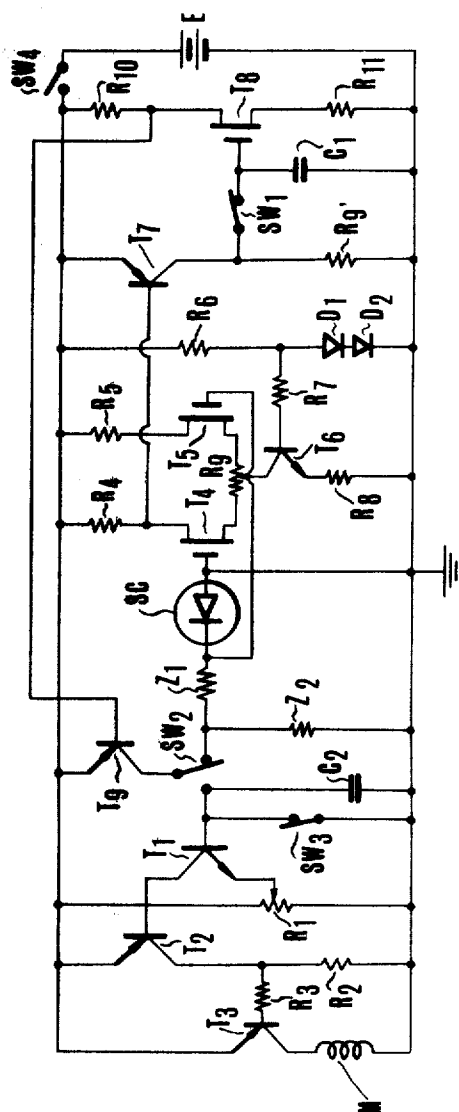


FIG. 3

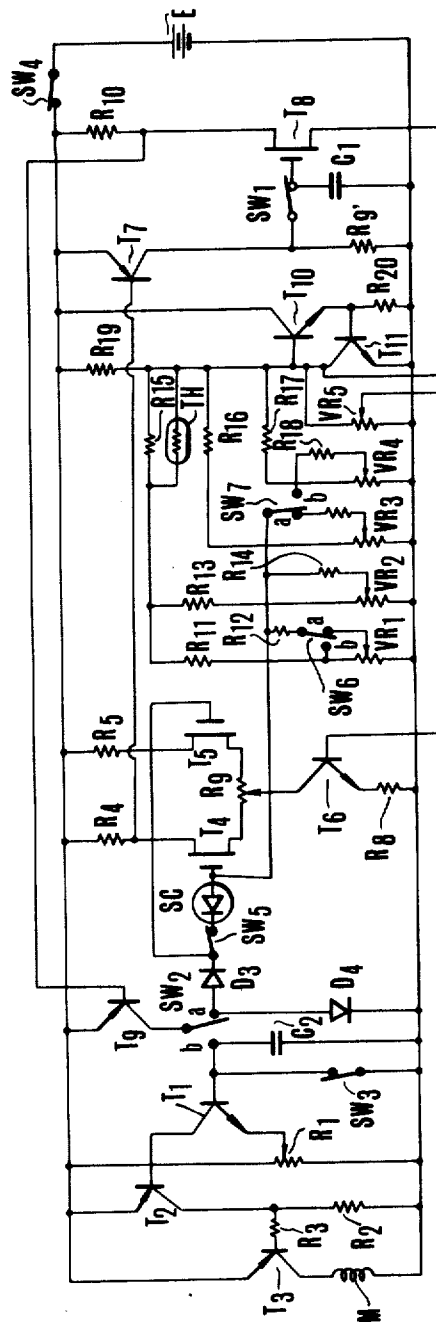


FIG. 4

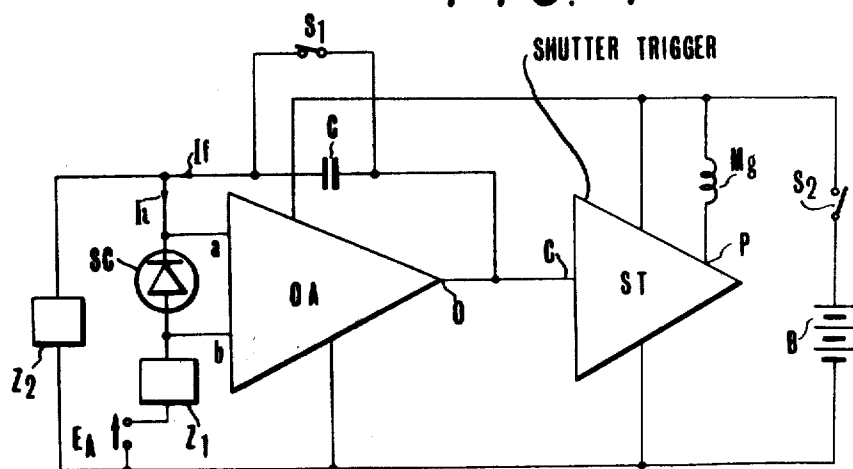


FIG. 7

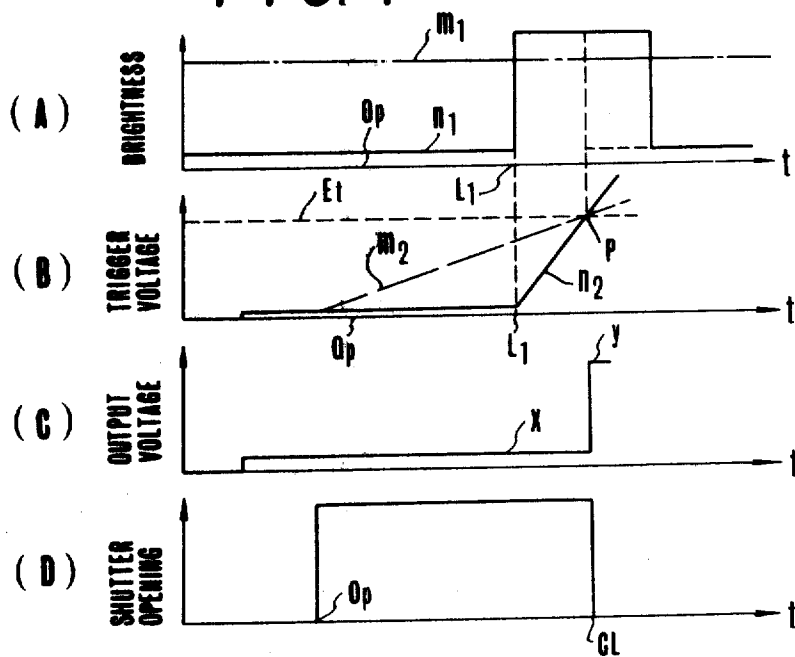


FIG. 5

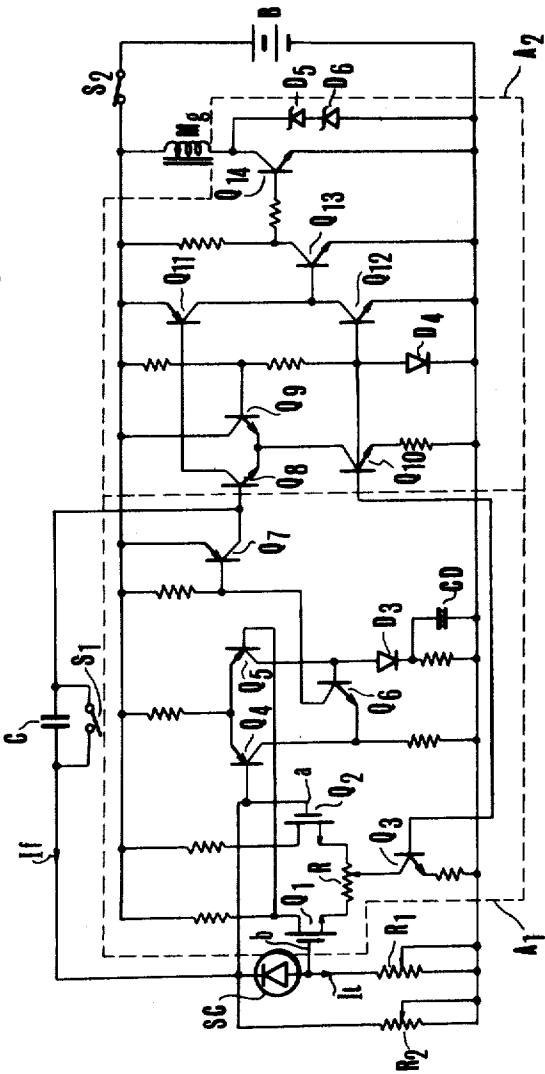
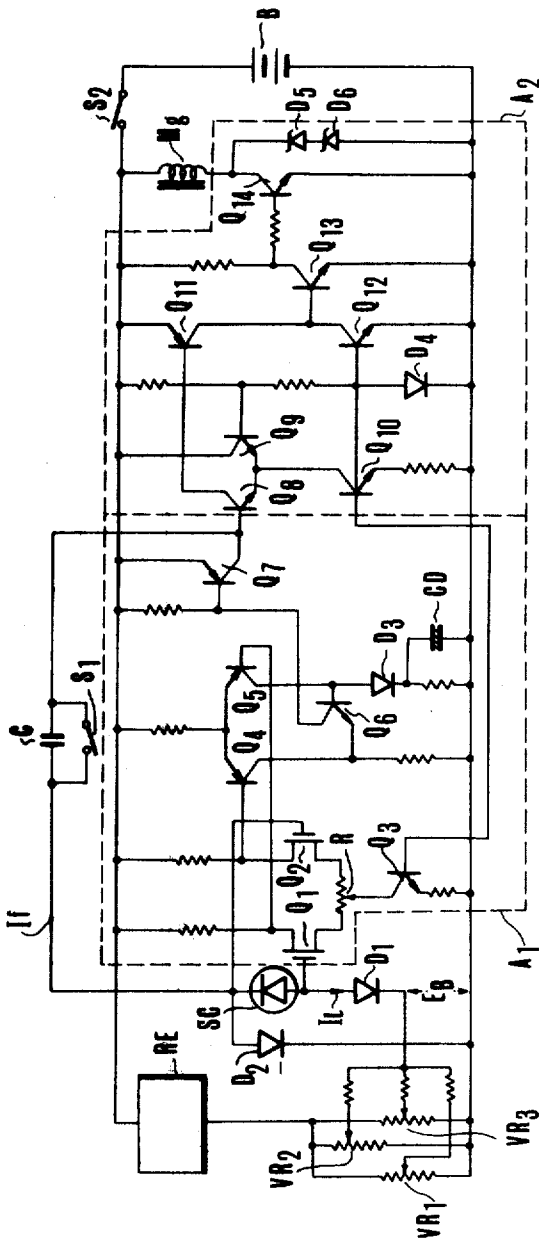


FIG. 6



SHUTTER OPERATING CIRCUITS FOR PHOTOGRAPHIC CAMERAS

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.

BACKGROUND OF THE INVENTION

This invention relates to an electric shutter operating circuit [of] for photographic cameras, more particularly, single lens reflecting cameras.

A shutter operating circuit is used for the purpose of setting a shutter time in accordance with the brightness of an object to be photographed and in a prior art shutter operating circuit a photoelectric element or transducer has been used in most cases as a light receiving element. However, in an shutter operating circuit utilizing a photoelectric element as the light receiving element it is extremely difficult to maintain at a definite value the rate of varying of the resistance value of the element for varying brightness of the object, that is the γ value for the [brightness] *brightness* varying over a wide range. In other words, the contrast of the picture or the quantity of light exposure of the photographic film varies with the brightness of the object. Furthermore, the photoelectric element varies its resistance with a time lag in response to the variation in the quantity of received light so that when the brightness of the object varies rapidly it is difficult to assure proper exposure due to said time lag. For this reason, it has been proposed to obviate this difficulty by providing in front of the photoelectric element an iris diaphragm of complicated shape which varies its opening in accordance with the iris setting or the sensitivity of the photographic film.

When such an iris mechanism is mounted in front of the photoelectric element it is possible to compensate for the γ value but it is necessary to mechanically couple such iris mechanism with an ordinary iris mechanism for a lens or with a ring giving an information regarding the film sensitivity. Accordingly, the mechanism becomes extremely [complicate] *complicated* and expensive. Furthermore, as the response characteristic of the photoelectric element is poor, when a picture is photographed by using a device which [complete] *completes* flashing in a short time, such as a stroboscope, it is impossible to set a proper shutter time by taking into consideration such flashing [of] *for a short time*. Moreover, with the arrangement described above, the quantity of light impinging upon the photoelectric element is reduced in accordance with the opening of the iris diaphragm associated with the lens, the response characteristic of the photoelectric element in dark conditions becomes poor.

SUMMARY OF THE INVENTION

Accordingly, it is an object of this invention to provide an improved shutter operating circuit for a photographic camera wherein the response of the circuit is greatly improved.

A further object of this invention is to provide an improved shutter operating circuit capable of assuring a constant quantity of the light exposure for a wide range of [the] brightness of the object being photographed.

Still a further object of this invention is to provide an improved shutter operating circuit that makes it possible to manufacture the shutter at a low cost.

According to one aspect of this invention there is provided a shutter operating circuit for a photographic camera, comprising a photoelectric transducer disposed to receive the light [transmitting] *transmitted* through the objective lens of the camera, first amplifier means for amplifying the output from the photoelectric transducer, second amplifier means having a high input impedance and operating to generate an output corresponding to the output from the first amplifier means, means for feeding back the output from the second amplifier means to the input of the first amplifier means, a capacitor connected on the input side of the second amplifier means for holding the output from the second amplifier means in accordance with the opening operation of the shutter of the camera, a first impedance element connected in series with the photoelectric transducer, a second impedance element connected in parallel with the series combination of the first impedance element and the photoelectric transducer, an integrating capacitor for integrating the output from the second amplifier means in accordance with the opening operation of the shutter, and a shutter trigger circuit for closing the shutter when the voltage across the integrating capacitor reaches a predetermined value whereby the exposure time is determined by the output current from the second amplifier means which is proportional to the output from the photoelectric transducer and varied by utilizing the impedances of the first and second impedance elements as parameters.

According to another aspect of this invention there is provided a shutter operating circuit for a photographic camera, comprising a photoelectric transducer disposed to receive the light [transmitting] *transmitted* through the objective lens of the camera for producing an output corresponding to the intensity of the light, an operational amplifier having a high input impedance for amplifying said output, a feedback circuit for feeding back the output of the operational amplifier to the input thereof, an integrating capacitor connected in the feedback circuit for integrating the output from the operational amplifier in an interlocked relation with the operation of the shutter of the camera, a first impedance element connected in series with the photoelectric transducer, a second impedance element connected in parallel with the series combination of the photoelectric transducer and the first impedance element, and a shutter trigger circuit connected to the integrating capacitor for closing the shutter when the voltage across the integrating capacitor reaches a predetermined value whereby to determine the exposure time in accordance with the output from the operational amplifier which is proportional to the output of the photoelectric transducer by utilizing the impedances of the first and second impedance elements as the parameters.

BRIEF DESCRIPTION OF THE DRAWINGS

Further objects and advantages of the invention can be more fully understood from the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a block diagram showing the simplest form of the shutter control circuit embodying the invention;

FIG. 2 is a detailed connection diagram of the circuit shown in FIG. 1;

FIG. 3 is a connection diagram of a modified embodiment of this invention;

FIG. 4 is a diagrammatic block diagram of another embodiment of this invention;

FIG. 5 is a detailed connection diagram of the control circuit shown in FIG. 4;

FIG. 6 shows a modification of the embodiment shown in FIG. 5 and

FIGS. 7A through 7D are characteristic curves helpful to explain the operation of the embodiments shown in FIGS. 4 and 5.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1 of the accompanying drawings which shows a block diagram of the simplest form of this invention, the electric shutter operating circuit shown therein comprises a differential amplifier A₁, a silicon photocell SC connected between two input terminals of the differential amplifier, impedance elements Z₁ and Z₂ serially connected between the cathode electrode of the photocell SC and the ground, an amplifier A₂ connected to receive the output of the differential amplifier A₁ via a switch SW₁, a current holding capacitor C₁ connected between the input to the amplifier A₂ and the ground, a shutter trigger circuit ST for the shutter of a photographic camera, not shown, a transfer switch SW₂ for connecting the output from amplifier A₂ to the juncture between impedances Z₁ and Z₂ or to the shutter trigger circuit ST, an integrating capacitor C₂ connected between one stationary contact b of the transfer switch SW₂ and the ground and a switch SW₃ connected across the integrating capacitor C₂.

When the light from an object impinges upon the photocell SC through an objective lens, not shown, the photocell SC will produce an output corresponding to the quantity of the light received thereby. Since the photocell SC is connected between two inputs of the differential amplifier A₁, this amplifier produces an output corresponding to the output of the photocell SC. The output of the differential amplifier A₁ is applied to the input of amplifier A₂ via switch SW₁ and the amplified output from amplifier A₂ is supplied to the juncture between impedance elements Z₁ and Z₂ through transfer switch SW₂. Because the photocell SC produces a photocurrent I_L corresponding to the quantity of the light received thereby it is possible to consider it as a source of constant current. When the output from amplifier A₂ is supplied to the photocell as described above, the differential amplifier A₁ produces an output which is amplified by amplifier A₂ to produce a voltage having a polarity to oppose the terminal voltage of the photocell SC. Thus, the circuit acts as an automatic balancing circuit having a negative feedback circuit. When the input resistance to amplifier A₁ is selected to be sufficiently high a voltage drop expressed by I_L·Z₁ will be produced across the impedance element Z₁. As above described, since the terminal voltage across the photocell SC is set to be substantially zero by said automatic balancing circuit, the voltage across impedance element Z₂ will be equal to the voltage across the impedance element Z₁.

Accordingly, the current I flowing through the impedance element Z₂ is expressed by the following equation.

$$I_L \cdot Z_1 = I \cdot Z_2 \quad (1)$$

-continued

$$I = \frac{Z_1}{Z_2} \cdot I_L$$

In order that the output current I_O from amplifier A₂ can satisfy a relation,

$$I_0 = I + I_L$$

I₀ must be shown by

$$I_0 = I + I_L = \left(\frac{Z_1}{Z_2} + 1 \right) \cdot I_L \quad (2)$$

Since this value is proportional to the photocurrent produced by the photocell SC, the circuit assumes a balanced condition. When switch SW₁ is opened under such balanced condition, because the input impedance of the amplifier A₂ is selected to be extremely high, the charge of the current holding capacitor C₁ will not leak so that the potential established prior to the opening of switch SW₁ can be preserved. Accordingly, amplifier A₂ will not be affected in any way by the opening of switch SW₁ but will continue to produce the output current which has been flowing prior to the opening of the switch SW₁.

When transfer switch SW₂ is transferred from its stationary contact a to its stationary contact b concurrently with the opening of switch SW₁, the output current from amplifier A₂ will charge the integrating capacitor C₂, and the front curtain of a shutter, not shown, will be operated. As the capacitor C₂ is charged gradually until its terminal voltage reaches the threshold level E_{Tr} of the trigger circuit ST at which time the trigger circuit operates to operate the back curtain of the shutter, thereby closing the shutter. With the circuit constructed as above described, the charging time T of the integrating circuit corresponds to the interval during which the shutter is maintained open, that is the shutter time. The charging time has the following relation.

$$E_{Tr} = \frac{I_0 T}{C_2} = \frac{\frac{Z_1}{Z_2} + 1}{C_2} \cdot I_L T \quad (3)$$

As the threshold level E_{Tr} is determined by the shutter trigger circuit itself, the product of the light quantity and time, I_L·T, is always constant.

FIG. 2 shows a connection diagram of one embodiment of the electric shutter operating circuit embodying the invention in which the same or corresponding elements as those shown in FIG. 1 are designated by the same reference characters. The circuit shown in FIG. 2 comprises a source of supply E, a source switch SW₄, a first transistor T₁ with its base electrode connected to one terminal of the integrating capacitor C₂, a variable resistor R₁ connected across the source E via source switch SW₄, the sliding arm of the variable resistor R₁ being connected to the emitter electrode of the first transistor T₁ for adjusting the emitter bias potential, a second transistor T₂ with its emitter and collector electrodes connected across the source E and its base electrode connected with the collector electrode of the first transistor T₁, and a third transistor T₃ also connected across the source E and having its base electrode connected with the collector electrode of the second transistor T₂ via a resistor R₃. An electromagnet M is con-

nected across the source E through the third transistor T₃ for holding the back curtain of the shutter for predetermined time thus delaying its operation. The circuit elements thus far described constitute a shutter trigger circuit ST. There are also provided a field effect type fourth transistor T₄ with its gate electrode connected to the anode electrode of a photocell SC, a field effect type fifth transistor T₅ with its gate electrode connected to the cathode electrode of the photocell SC, resistors R₄ and R₅ respectively connected between the drain electrodes of the fourth and fifth transistors T₄ and T₅ and the positive pole of the source E and diodes D₁ and D₂ which are connected in series with a resistor R₆ across the source E, the diodes D₁ and D₂ providing temperature compensation of a constant current circuit comprising a sixth transistor T₆ which is connected to receive the terminal voltage across serially connected diodes D₁ and D₂ through a resistor R₇. The emitter electrode of transistor T₆ is connected to the ground via resistor R₈. The source electrodes of field effect transistors T₄ and T₅ are interconnected by a variable resistor R₉ having a sliding arm connected to the collector electrode of the sixth transistor T₆ whereby to constitute the differential amplifier A₁. Across the source E is connected a seventh transistor T₇ having a base electrode connected to the drain electrode of the field effect transistor T₄ and a collector electrode connected to the ground through a collector resistor R₉. An eighth transistor T₈ having an extremely high input impedance, preferably of the field effect type, is connected to receive the terminal voltage across the current holding capacitor C₁ as an input, the drain electrode and the source electrodes of transistor T₈ being connected to the positive and negative poles of the source E via resistors R₁₀ and R₁₁, respectively and switch SW₄. A ninth transistor T₉ is provided with its base electrode connected to the drain electrode of the field effect transistor T₈ and the collector electrode connected to the movable contact of the transfer switch SW₂, thus constituting the amplifier A₂ shown in FIG. 1.

When the source switch SW₄ is closed the fourth and fifth transistors T₄ and T₅ constituting the differential amplifier A₁ shown in FIG. 1 are connected across the source E. Under these conditions, when the light from an object is projected upon the photocell SC, the photocell produces an output corresponding to the brightness of the object. Since the photocell is connected across the gate electrodes of the fourth and fifth transistors T₄ and T₅ these transistors produce on their outputs an output voltage corresponding to the output of the photocell SC. After being amplified by transistor T₇, the output from the fourth and fifth transistors T₄ and T₅ is applied to the gate electrode of the field effect transistor T₈ via switch SW₁, now in the closed state. Since current holding capacitor C₁ is connected between the gate electrode of transistor T₈ and the ground, all signals supplied to this transistor via switch SW₁ are stored in capacitor C₁.

The signal supplied to transistor T₈ is amplified by transistors T₈ and T₉ and is then applied to the juncture between impedance elements Z₁ and Z₂. Consequently, the circuit constructed as described above operates as a negative feedback circuit and the circuit will be balanced when the negative feedback signal reaches a value sufficient to cancel the terminal voltage across the photocell SC. As a consequence, under the balanced condition, the output from transistor T₇, that is the negative feedback current assumes a value correspond-

ing to the quantity of the light impinging upon the photocell. When the circuit is balanced at which the terminal voltage across the photocell SC is nearly zero volt, there is no adverse effect caused by the dark current of the photocell.

Substantially concurrently with the operation of the front diaphragm of the shutter, switches SW₁, SW₂ and SW₃ are changed over, that is switches SW₁ and SW₃ are opened and switch SW₂ is thrown to the left hand contact so that the current holding capacitor C₁ continues to hold the condition existed before opening of the switch SW₁ because the input impedance of transistor T₈ is extremely high. As a consequence, the outputs of transistors T₈ and T₉ are maintained substantially at the same values as those provided before opening of the switch SW₁. Since switch SW₃ is now opened, the output of the transistor T₉, that is the feedback current is supplied to the integrating capacitor C₂ to gradually charge the same. When the terminal voltage across integrating capacitor C₂ reaches the threshold level of transistor T₁, this transistor is turned ON. Then transistors T₂ and T₃ connected to receive the output from transistor T₁ are turned ON and OFF, respectively, whereby the rear diaphragm of the shutter which has been held by electromagnet M is operated to close the shutter. The interval between the operations of the front and rear diaphragms of the shutter, that is the charging time of the integrating capacitor C₂, represents the shutter time. As it is possible to adjust the threshold level of transistor T₁ by varying the variable resistor R₁, it is advantageous to vary this resistor R₁ in accordance with the sensitivity of the film used.

In this manner, the disclosed shutter operating circuit provides a correct shutter time corresponding to the quantity of light received by the photoelectric element without any trouble caused by the time lag of the photoelectric element at the time of quick variation of the light and by the dark current of the photoelectric element. Transistor T₆ is effective to stabilize the circuit operation by improving the percentage of removing the in-phase component of the differential amplifier A₁, while diodes D₁ and D₂ function to compensate for the temperature characteristic of transistor T₆ acting as a constant current source and for the voltage variation of the source.

FIG. 3 shows another embodiment of this invention in which the same or corresponding elements to those shown in FIG. 2 are designated by the same reference characters. In the modification shown in FIG. 3, diodes D₃ and D₄ are substituted for the impedance elements Z₁ and Z₂ utilized in the embodiment shown in FIG. 2, and tenth and eleventh transistors T₁₀ and T₁₁ are provided to form a constant voltage circuit. Furthermore, variable resistors VR₁ through [VR₆] VR₅ are provided to set such informations as the ASA sensitivity of the photographic film used, and the iris opening at the time of measuring light. Further, resistors R₁₁ through R₂₀ and switches SW₅, SW₆ and SW₇ are connected as shown.

In operation, when switch SW₅ is closed, photocell SC produces a photocurrent I_L proportional to the quantity of light received, thereby to produce a voltage drop E₁ across diode D₃. When the characteristic of diode D₃ is expressed by an equation $I_d = I_s \exp(qE_1/kT)$ where I_d represents a current flowing through the diode D₃, I_s is the saturation current thereof, q the electric charge of an electron, E the terminal voltage across the diode D₃, K the Boltzman's constant

and T the absolute temperature ($^{\circ}\text{K}$.) since $I_d = I_L$, the photocurrent I_L is expressed by $I_L = I_s \exp(qE_1/rT)$. Accordingly, the voltage drop across diode D_3 is expressed by

$$E_1 = \frac{KT}{q} \ln \frac{I_L}{I_s} \quad (4)$$

A voltage expressed by an equation $E_2 = (KT/q) \ln 2^n$ is impressed upon the cathode electrode of diode D_3 . Since the terminal voltage of the photocell SC is set to be substantially zero volt by the balancing operation of the negative feedback circuit described above, the voltage E_3 impressed across diode D_4 is equal to $(E_1 + E_2)$, namely

$$\begin{aligned} E_3 &= E_1 + E_2 \\ &= \frac{KT}{q} \left(\ln \frac{I_L}{I_s} + \ln 2^n \right) \\ &= \frac{KT}{q} \ln \frac{2^n \cdot I_L}{I_s} \end{aligned} \quad (5)$$

In this example, resistor VR_1 is used to set an information regarding iris opening, resistor VR_2 is used to set [information] information regarding ASA sensitivity and manual shutter, resistor VR_4 is used to automatically adjust the sensitivity of the circuit, and resistor VR_3 to manually adjust the shutter. Resistors VR_1 through VR_5 are of the same type and switches SW_6 and SW_7 are thrown to their stationary contacts a for automatic operation. Accordingly, at the time of automatic operation, $\frac{1}{2}$ of the voltages across resistors VR_1 and VR_2 is impressed upon the cathode electrode of the photocell SC. Under these conditions, in order to [avoid] avoid errors in various informations regarding ASA sensitivity and iris opening, it is necessary to set these resistors at low values.

As [describe] described above, since voltage drop E is created across diode D_4 as has been pointed out herein above, if the characteristics of diodes D_3 and D_4 were identical. The current I_2 flowing through diode D_4 could be expressed as follows:

$$\begin{aligned} I_2 &= I_s \exp \frac{q}{KT} E_3 \\ &= I_s \exp \frac{q}{KT} \left(\frac{KT}{q} \ln \frac{2^n \cdot I_L}{I_s} \right) \\ &= 2^n \cdot I_L \end{aligned} \quad (6)$$

At this time, when a voltage expressed by

$$E_4 = \frac{KT}{q} \ln 2^n = \frac{KT}{q} \ln 2 \cdot n \quad (7)$$

is impressed upon the cathode electrode of the photocell SC, a current 2^n will be produced on the output. Accordingly, even when the sum of three voltages, that is $n = \text{ASA information} + \text{iris opening information} + \text{sensitivity adjustment}$ is impressed, since the resistors impressed with these voltages may be constructed to vary linearly their resistances, it is possible to readily set a large number of informations. Where n is selected such that $2^n > 1$, the collector current I_0 of transistor T_9 is nearly equal to I_2 , so that when switch SW_1 is turned OFF and switch SW_2 is transferred to stationary contact b, the time required by the voltage across the

integrating capacitor C_2 to reach the threshold level of the shutter trigger circuit ST is expressed by the following equation

$$E_T = \frac{I_0 T}{C_2} = \frac{I_0 T}{C_2} = \frac{2^n}{C_2} \cdot I_L \cdot T \quad (8)$$

where C_2 represents the capacitance of capacitor C_2 . Thus, a condition wherein $I_L \cdot T_1$ that is the light quantity, is constant is fulfilled.

In the embodiment shown in FIG. 2, it is also possible to give an information by impressing a voltage $E = A \cdot 2^n$ (where $n = 1, 2, \dots$) upon the cathode electrode of photocell SC. Further, the transistors which constitute the differential amplifier should operate with a base or gate current which is sufficiently smaller than the photocurrent produced by the photocell. Where MOSFETs are used their gate leakage current is smaller than 10 pA so that such gate leakage current is negligible. The type of the amplifiers included in the succeeding stages is determined depending upon the capacitance of the current holding capacitor and the time required for storing. If a high degree of accuracy is desired, MOSFET is preferred.

As described above, the invention provides a novel shutter operating circuit capable of using a photocell as a light receiving element without being adversely effected by the dark current of the photocell thus eliminating the problem of time lag which has been inevitable in the prior art shutter operating circuit when the high quantity varies quickly.

Further, the novel shutter operating circuit of this invention permits ready setting of [information] information regarding ASA sensitivity, iris opening or the like and the resistors utilized to set such [information] information may be resistors which vary their resistances linearly so that it is possible to readily set a large number of informations. As a differential amplifier having an extremely high input impedance is used as the first amplifier, it is possible to make effective use of the characteristic of the photocell and to greatly simplify the circuit construction.

In the following modified embodiments an [operation] operational amplifier is substituted for the first and second amplifiers utilized in the preceding embodiments. FIG. 4 shows a basic block diagram of such a modified embodiment which comprises an operational amplifier OA having a high input resistance and differential input terminals a and b across which is connected a photocell SC with a polarity as shown, the photocell being disposed to receive the light from an object to be photographed through an objective lens of the camera. The differential input terminal a of the operational amplifier OA is connected to an impedance element Z_2 while the differential input terminal b is connected via an impedance element Z_1 to a terminal EA to which is given an information regarding the iris opening or the ASA sensitivity.

An integrating capacitor C is connected between the output terminal O of the operational amplifier OA and input terminal a and a switch S_1 interlocked with the shutter such that the switch is opened when the shutter is opened and is connected across the capacitor C for normally short circuiting the same. The output terminal O of the operational amplifier OA is also connected to the input terminal c of a shutter trigger circuit ST having an output terminal p connected to an electromagnet

Mg for closing the shutter. The electromagnet Mg is constructed such that it is deenergized when the potential impressed upon the input terminal c of the shutter trigger circuit ST exceeds a predetermined value. A source of supply B is connected to the shutter operating circuit ST through a source switch S₂. Instead of providing the first impedance element Z₁ on the anode electrode side of the photocell SC, the impedance can be provided on the cathode electrode side.

When the camera is directed toward the object to project the light from the object upon the photocell SC, the operational amplifier OA begins to operate. When a shutter release button (not shown) of the camera is depressed at this time, switch S₁ interlocked therewith is opened at a point OP shown in FIGS. 7A through 7B. Then, the charging of the integrating capacitor C by a current I_f fed back from the operational amplifier OA is commenced. If the brightness of the object does not vary, the information thereof has a constant value as shown by a dot and dash line m₁ shown in FIG. 7A. As the terminal voltage across capacitor C builds up which is charged by the light from the object, the voltage appearing at the output terminal O of the operational amplifier OA also builds up as shown by dot and dash lines m₂ shown in FIG. 7B. When this voltage reaches at point P the trigger voltage E_t of the shutter trigger circuit ST shown in FIG. 7B, the voltage appearing at the output terminal of the shutter trigger circuit ST varies from a level x to a level y as shown in FIG. 7C. At the level y, electromagnet Mg is deenergized to close the shutter. During an interval OP-CL shown in FIG. 7D the shutter is maintained opened. Solid line curves n₁ and n₂ shown in FIGS. 7A and 7B show an operation wherein the shutter is interlocked with a strobo flash. More particularly, the shutter release button, not shown, is depressed at an instant OP shown in FIGS. 7A and 7B, and at an instant L₁ the strobo flash begins to luminesce. The light caused by this flash is projected upon the photocell SC from the object so that the voltage appearing at the operational amplifier OA begins to build up as shown by a solid line n₂ shown in FIG. 7B. When this voltage reaches the trigger voltage E_t of the shutter trigger circuit ST at point P the output voltage from the shutter trigger circuit ST jumps from x to y as shown in FIG. 7C. Thus, the electromagnet Mg is deenergized thereby completing the shutter control.

FIG. 5 shows a detailed connection of the circuit diagrammatically shown in FIG. 4. In the circuit shown in FIG. 5, variable resistors R₁ and R₂ are used as the impedance elements Z₁ and Z₂ shown in FIG. 4 and it is assumed that the information impressed across terminals EA has a voltage of 0 volt. Elements shown in FIG. 5 which are identical to those shown in FIG. 4 are designated by the same reference characters and Q₁ and Q₂ show MOS type field effect transistors, Q₃ through Q₁₄ bipolar transistors, r a resistor, R a variable resistor, [Q₃] D₃ and [Q₄] D₄ diodes, D₅ and D₆ Zener diodes, and CD an electrolytic capacitor.

In operation, when the shutter release button is depressed after directing the camera toward the object to be photographed, switch S₁ interlocked with the shutter release button is opened. Concurrently therewith the light from the object is received by the photocell SC to produce a photocurrent I_l which is expressed by the following equation

$$I = I_s \left(\exp \frac{qE}{nKT} - 1 \right) - I_l \quad (9)$$

in which I represents the total current flowing through the photocell, I_s the saturation current thereof, q the electric charge of an electron, E the terminal voltage across the photocell SC, n a constant determined by the junction of the photocell, K the Boltzman's constant and T the absolute temperature (°K.).

By the operation of the operational amplifier OA, the terminal voltage across the photocell is made to be zero and since |I_s| < |I_l|, the total current I shown by equation (9) becomes

$$I = -I_l \quad (10)$$

While maintaining the condition shown by equation (10) the light from the object is amplified by the operational amplifier OA and is fed back to the input terminal a of the operational amplifier OA from the collector electrode of transistor Q₇ of the amplifier through capacitor C, the feedback current being designated by I_f, thus gradually charging the capacitor C. At the same time photocurrent I_l flows through variable resistor R₁ thus creating a voltage drop I_lR₁ across the variable resistor R₁ current (I_f - I_l) flows through the variable resistor R₂ so that a voltage drop (I_f - I_l) R₂ is produced across resistor R₂. Since the voltage across the photocell SC is zero, I_l R₁ = (I_f - I_l) R₂. The feedback current I_f is expressed by the following equation

$$I_f = \left(\frac{R_1}{R_2} + 1 \right) I_l \quad (11)$$

As can be noted from this equation, the feedback current is equal to

$$\left(\frac{R_1}{R_2} + 1 \right)$$

times [of] the photocurrent I_l so that it is possible to amplify current I_l by suitably selecting the values of resistors R₁ and R₂. As described above, capacitor C is charged by feedback current I_f and the voltage across the capacitor C and the output voltage from the operational amplifier OA increase proportionally [the]. The interval T₁ required for the capacitor voltage to build up to the trigger voltage E_t of the shutter trigger circuit ST is expressed by the following equation since CE_t = I_fT₁

$$T_1 = \frac{CE_t}{I_f} = \frac{CE_t}{\left(\frac{R_1}{R_2} + 1 \right) I_l} \quad (12)$$

At an instant when this equation is satisfied, transistor Q₁₄ of the shutter trigger circuit ST is turned OFF so that the electromagnet Mg is deenergized to close the shutter.

To assure the operation described above, it is necessary to maintain the quantity of the light arriving at the film of the camera always at a constant value, and the circuit of this invention fulfills this requirements as follows. More particularly, since the quantity of the light is equal to the product of the brightness of the

object and time, that is $\Pi \times T_1$, from equation (12) we obtain

$$\Pi \cdot T_1 = \frac{CE_1}{\frac{R_1}{R_2} + 1} \quad (13)$$

Since the right hand term of this equation is constant the product $\Pi \times T_1$ is also a constant. In other words, with the novel shutter control circuit it is possible to project always a definite quantity of light upon the film surface. Where $R_1 \gg R_2$

$$T_1 \cdot \Pi = \frac{R_2}{R_1} CE_1 \quad (14)$$

In this equation, when the ratio between R_2 and R_1 is varied in accordance with the ASA sensitivity of the film or the iris opening, it is possible to set [these informations] *this information* in the circuit shown in FIG. 5.

For example, assuming ASA sensitivities of 25, 50, 100, 200, 400, 800 and 1600, and iris openings of 1.4, 2, 2.8, 4, 5.6, 8, 11, and 16, these informations may be set in resistors R_2 and R_1 respectively as shown in the following Tables.

ASA sensitivity	25	50	100	200	400	800	1600
R_2	$64r_2$	$32r_2$	$16r_2$	$8r_2$	$4r_2$	$2r_2$	r_2
iris opening	1.4	2	2.8	4	8	11	16
R_1	$128r_1$	$64r_1$	$32r_1$	$16r_1$	$4r_1$	$2r_1$	r_1

In these tables r_2 and r_1 show a resistance value of R_2 corresponding to ASA sensitivity of 1600 and a resistance value of R_1 corresponding to iris opening of 16, respectively. So long as the values of resistors R_2 and R_1 can be set as shown, [informations] *information* set in these resistors may be interchanged. Further, it is also possible to fix either one of these resistors and to vary the other in accordance with the ASA sensitivity or the iris opening. Alternatively, an iris diaphragm may be provided in front of the photocell so as to present [the informations of both of] *information concerning both* the ASA sensitivity and the iris opening as the intensity of light in which case both resistors R_2 and R_1 may be fixed. It is also possible to set [the] information regarding either one of the ASA sensitivity or iris opening as the degree of opening of the iris opening disposed in front of the photocell and to process the other information by either or both of the resistors R_2 and R_1 .

In the embodiment shown in FIG. 6, impedance elements Z_2 and Z_1 shown in FIG. 4 are replaced by diodes D_2 and D_1 and [an] information regarding the ASA sensitivity and or iris opening is inserted into the shutter control circuit from a constant voltage circuit RE through variable resistors VR_1 , VR_2 and VR_3 . Again, circuit elements identical to those shown in FIGS. 4 and 5 are designated by the same reference characters. In FIG. 6, if the impedances of diodes D_2 and D_1 are expressed by Z_2 and Z_1 respectively, the photocurrent Π will produce following voltage [ED₂] ED_1 across diode D_1

$$ED_1 = \frac{nKT}{q} \cdot \ln \frac{\Pi}{I_s} \quad (15)$$

Accordingly, a voltage ED_2 will be created across diode D_2 according to the following equation

$$ED_2 = \frac{nKT}{q} \cdot \ln \frac{I_t - \Pi}{I_s} \quad (16)$$

$$ED_2 = ED_1 + E_a \quad (17)$$

wherein E_a represents an information voltage regarding the ASA sensitivity or iris opening. Since, the terminal voltage across the photocell SC is zero, by putting

$$E_a = \frac{nKT}{q} \ln 2^* \quad (18)$$

From equations (14) through (18)

$$\frac{\Pi}{I_s} \cdot 2^* = \frac{I_t - \Pi}{I_s} \quad (19)$$

Accordingly

$$I_t = \Pi (2^* + 1) \quad (20)$$

If E_a were large, $2^* < 1$, thus

$$I_t = 2^* \Pi \quad (21)$$

The instant at which the shutter trigger circuit ST operates or the shutter time T_1 can be shown as follows:

$$T_1 = \frac{CE_1}{I_t} = \frac{CE_1}{2^* \Pi} \quad (22)$$

and the light quantity $\Pi \cdot T_1$ is shown by

$$\Pi \cdot T_1 = \frac{CE_1}{2^*} \quad (23)$$

Since the right hand term of equation (23) is constant, the light quantity is also constant. The information regarding the ASA sensitivity or the iris opening can be represented by e of 2^e . The information regarding the brightness of the object can be logarithmically compressed by diode D_1 employed in the circuit shown in FIG. 6 and logarithmically expanded by diode D_2 . Consequently, the circuit shown in FIG. 6 can provide a positive control for the shutter.

According to the modified embodiments shown in FIGS. 4 to 6, a photoelectric transducer adapted to receive the light from an object is connected to the input of an operational amplifier, the output of the operational amplifier is fed back to its input through a capacitor so as to commence the charging thereof in an interlocked relation with the opening operation of the shutter of a camera, and to close the shutter when the voltage across the capacitor reaches a predetermined trigger voltage. Accordingly it is possible to greatly improve the response of the circuit to the brightness of the object, and to make always constant the quantity of light exposure of the photographic film over the entire range of the brightness of the object. Furthermore, as it is possible to project the light from the object over the entire surface of the photoelectric transducer, it is possible to simplify the construction of the shutter and re-

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duce its cost. Use of a photocell greatly improves the response thereof to the light from an object of low brightness as well as the response of the control circuit as a whole. Moreover, as the measurement of light and shutter control are performed simultaneously, operation of the control circuit becomes simple. Also satisfactory flash control is possible even when an automatic [storobo] strobo flash is used.

What is claimed is:

1. A shutter operating circuit for a photographic camera, comprising a photoelectric transducer disposed to receive [the] light [transmitting] transmitted through the objective lens of said camera, first amplifier means for amplifying the output from said photoelectric transducer, second amplifier means having a high input impedance and operating to generate an output corresponding to the output from said first amplifier means, means for feeding back the output from said second amplifier means to the input of said first amplifier means, a capacitor connected on the input side of said second amplifier means for holding the output from said second amplifier means in accordance with the opening operation of the shutter of said camera, a first impedance element connected in series with said photoelectric transducer, a second impedance element connected in parallel with said series combination of said first impedance element and said photoelectric transducer, an integrating capacitor for integrating the output from said second amplifier means in accordance with the opening operation of said shutter, and a shutter trigger circuit for closing said shutter [when] upon the voltage across said integrating capacitor [reaches] reaching a predetermined value whereby the exposure time is determined by the output current from said second amplifier means [which] and is proportional to the output from said photoelectric transducer and varied by utilizing the impedances of said first and second impedance elements as parameters.

2. The shutter operating circuit according to claim 1 wherein said first and second impedance elements comprise diodes having substantially the same characteristic.

3. The shutter operating circuit according to claim 1 wherein said first and second impedance elements comprise resistors having substantially the same characteristic.

4. The shutter operating circuit according to claim 2 [wherein] further including means for impressing voltages corresponding to [informations] information regarding the ASA sensitivity of the film utilized, iris opening or the like [are impressed] upon said first and second impedance elements so as to insert various [informations in] additional factors controlling the shutter time.

5. The shutter operating circuit according to claim 1 wherein said first amplifier means comprises a differential amplifier circuit having an extremely high input

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impedance and said second amplifier means has an extremely high input impedance.

6. A shutter operating circuit for a photographic camera, comprising a photoelectric transducer disposed to receive [the] light [transmitting] transmitted through the objective lens of said camera for producing an output corresponding to the intensity of said light, an operational amplifier having a high input impedance and having said photoelectric transducer connected to the input thereof for amplifying said output, a feedback circuit for feeding back the output of said operational amplifier to the input thereof, an integrating capacitor connected in said feedback circuit for integrating the output from said operational amplifier in an interlocked relation with the opening operation of the shutter of said camera, a first impedance element having an impedance Z_1 connected in series with said photoelectric transducer to the input of said operational amplifier, a second impedance element having an impedance Z_2 connected in parallel with the series combination of said photoelectric transducer and said first impedance element said first and second impedance elements being included in and comprising a part of the load on said feedback circuit, and a shutter trigger circuit connected to said integrating capacitor for closing said shutter when the voltage across said integrating capacitor reaches a predetermined value [whereby] thereby to determine the exposure time in accordance with the [output] feedback current from said operational amplifier which is proportional to the output of said photoelectric transducer in accordance with the expression

$$I_f = \left(\frac{Z_1}{Z_2} + 1 \right) I_L$$

where I_f is the feedback current of the operational amplifier and I_L is the photocurrent of the photoelectric transducer and wherein the exposure time is varied dynamically by utilizing the impedances of said first and second impedance elements as [the] parameters [.] in the feedback circuit and the accuracy of setting the exposure time in dark areas is improved.

7. The shutter control circuit according to claim [5] 6 wherein said first and second impedance elements comprise diodes having substantially the same characteristic.

8. The shutter control circuit according to claim [5] 6 wherein said first and second impedance elements comprise resistors having substantially the same characteristic.

9. The shutter control circuit according to claim 6 [wherein] further including means for impressing voltages representing [the informations] information regarding the ASA sensitivity of the film used and the iris opening of the camera [are impressed] upon said first and second impedance elements.

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