

Sept. 14, 1965

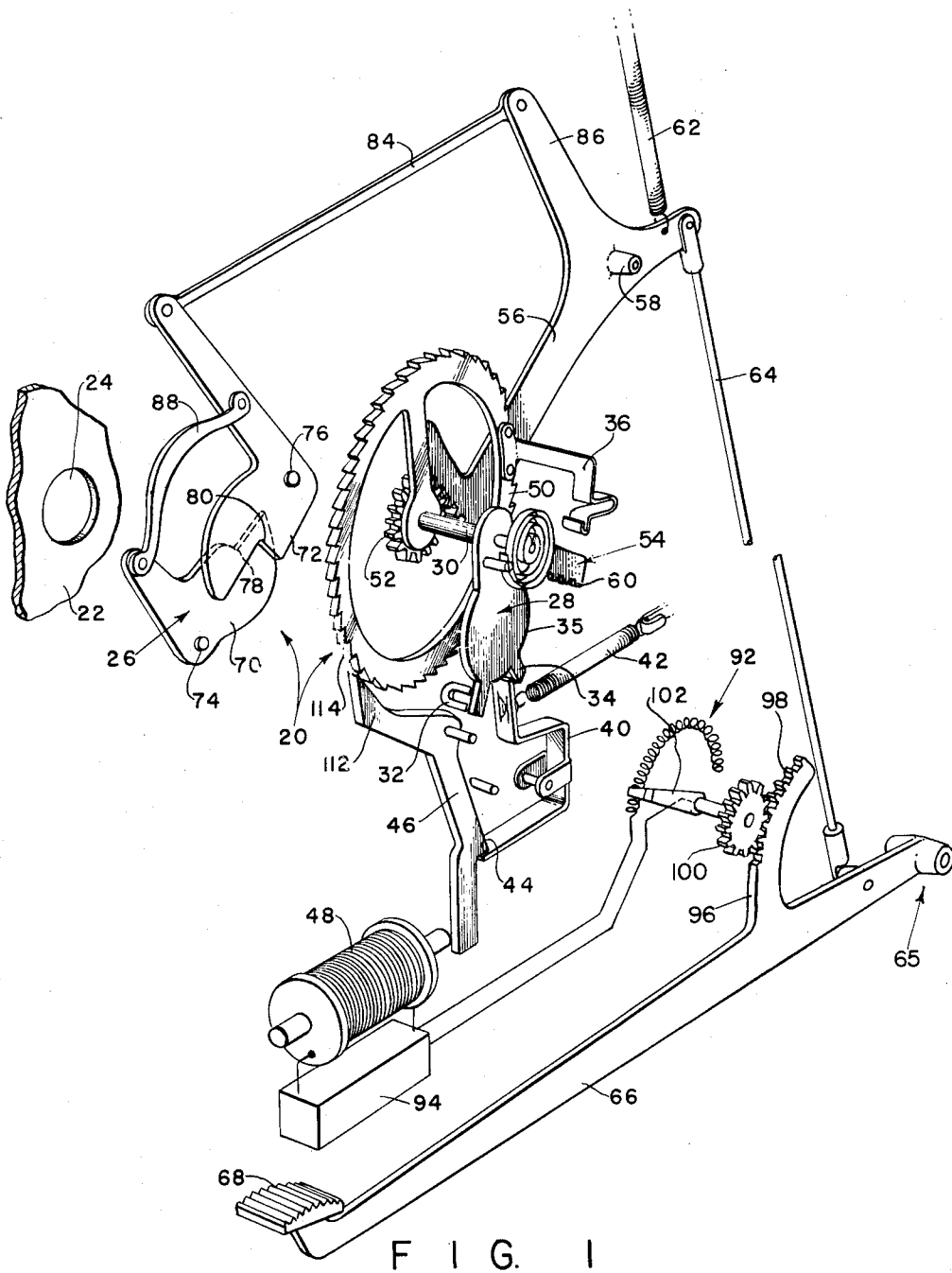
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3,205,795

AUTOMATIC EXPOSURE CONTROL DEVICE

Filed Nov. 6, 1961

9 Sheets-Sheet 1



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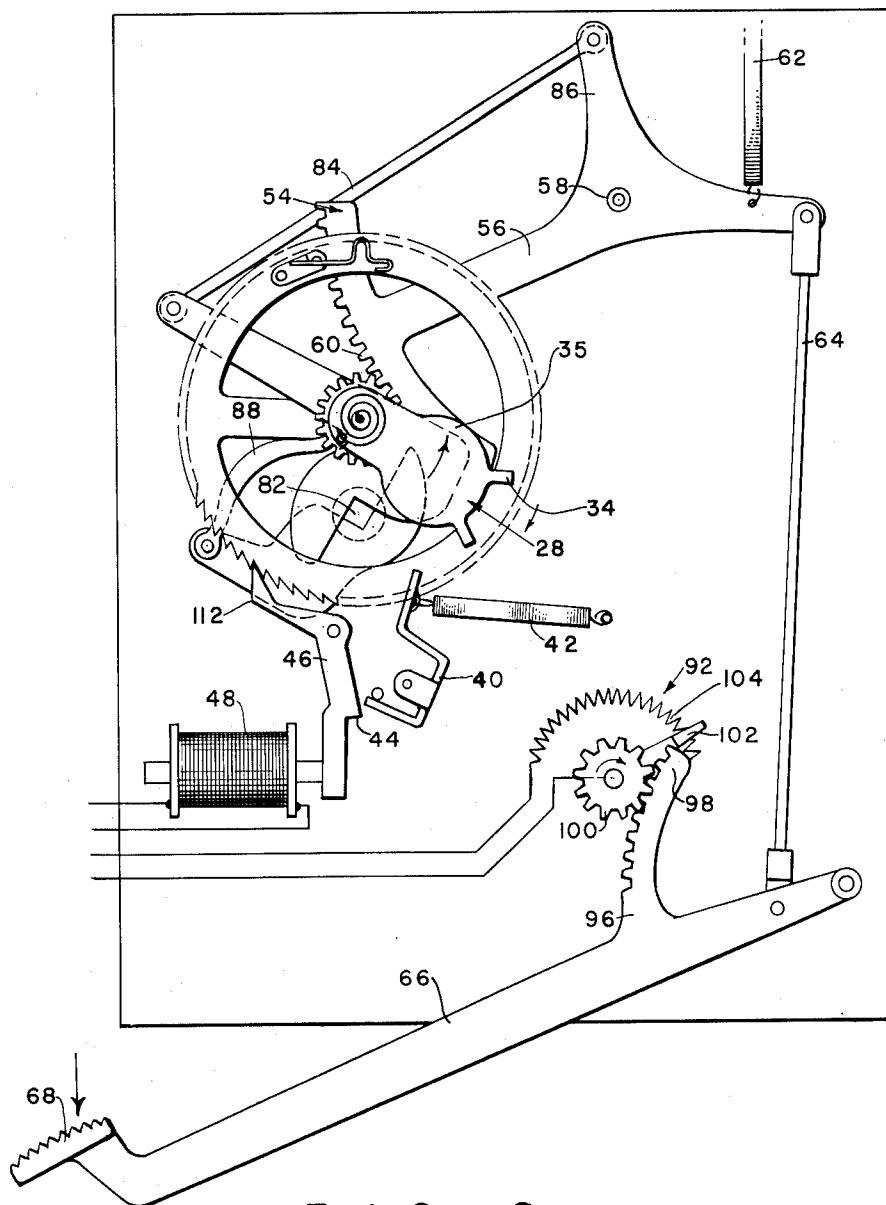
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AUTOMATIC EXPOSURE CONTROL DEVICE

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9 Sheets-Sheet 2



F I G. 2

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AUTOMATIC EXPOSURE CONTROL DEVICE

Filed Nov. 6, 1961

9 Sheets-Sheet 3

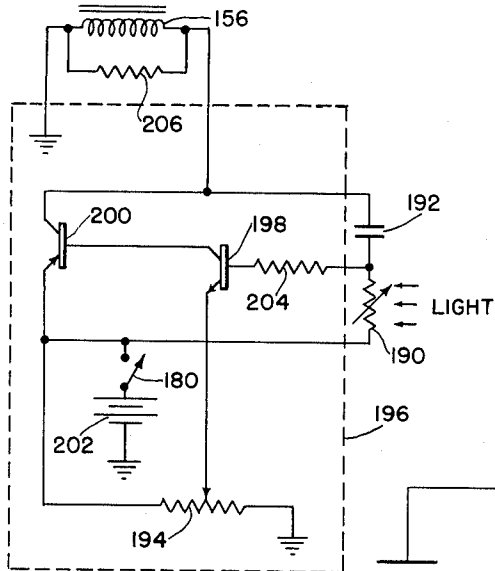


FIG. 7

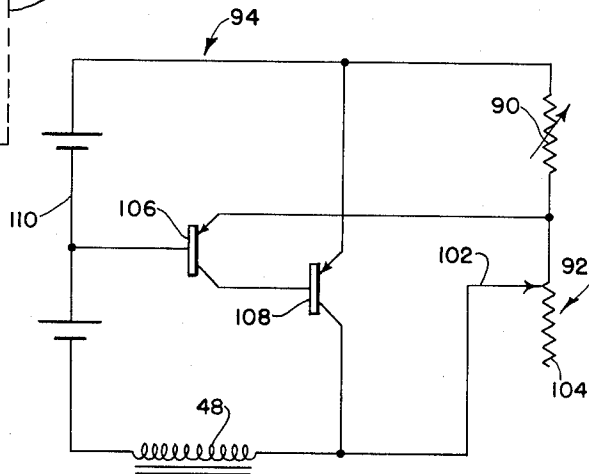


FIG. 3

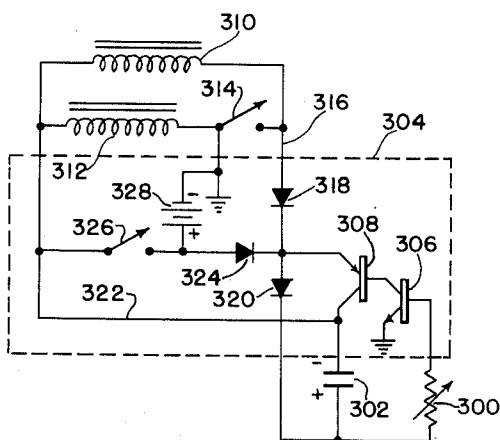


FIG. 10

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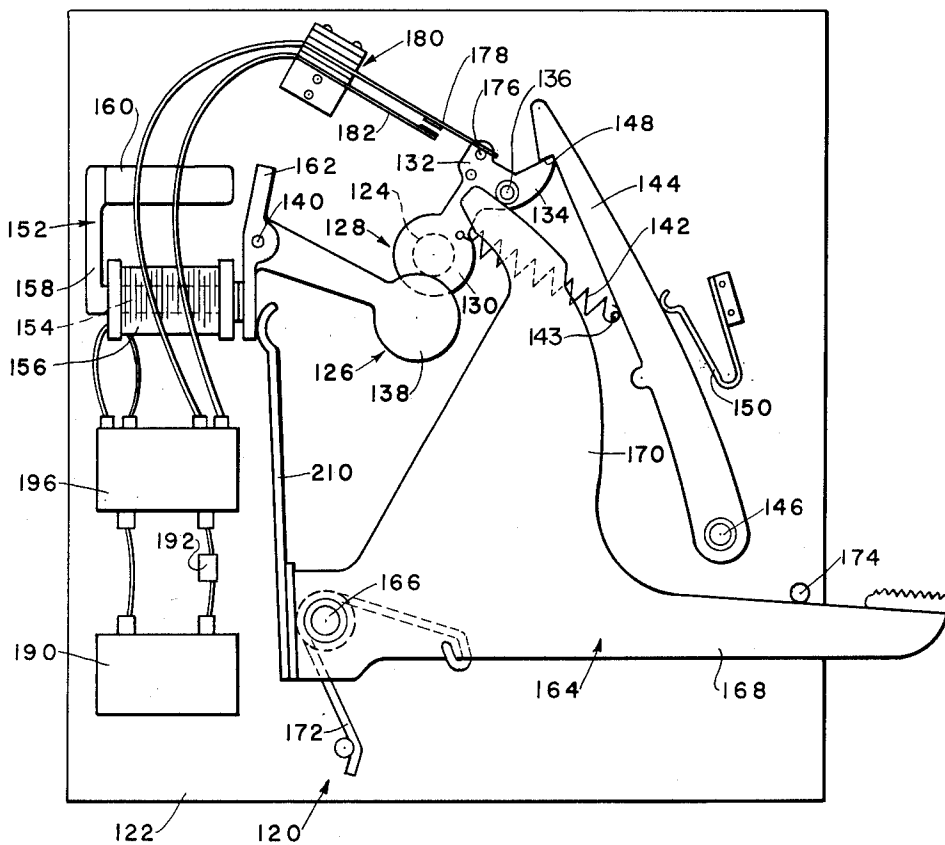
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9 Sheets-Sheet 4



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9 Sheets-Sheet 5

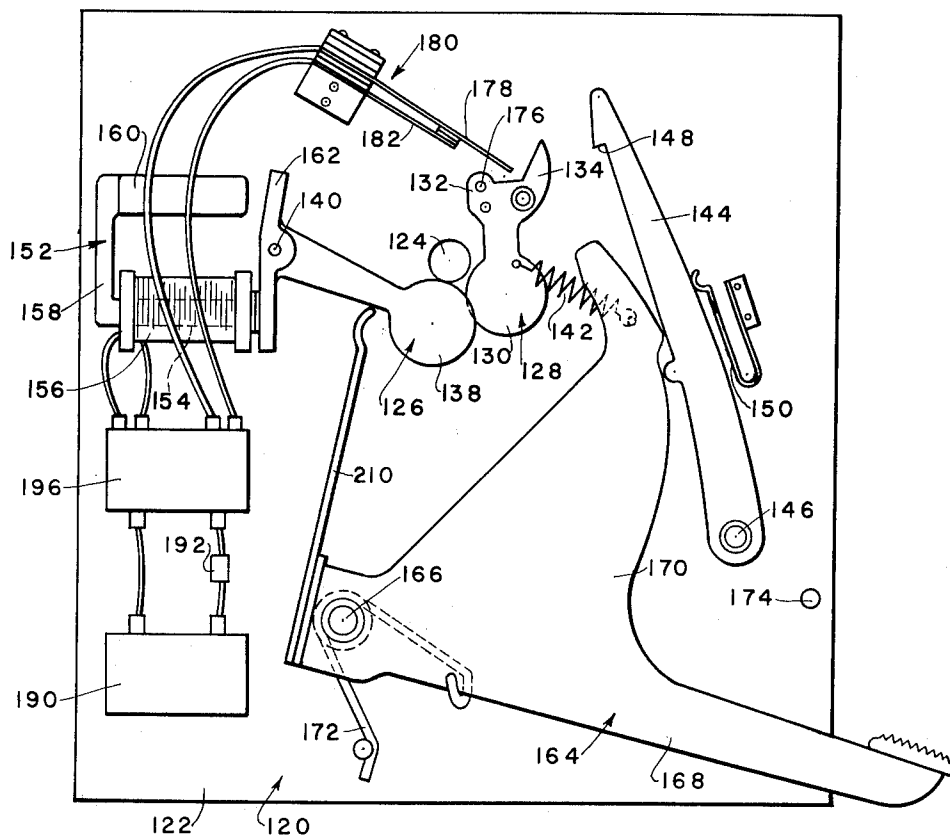


FIG. 5

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AUTOMATIC EXPOSURE CONTROL DEVICE

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9 Sheets-Sheet 6

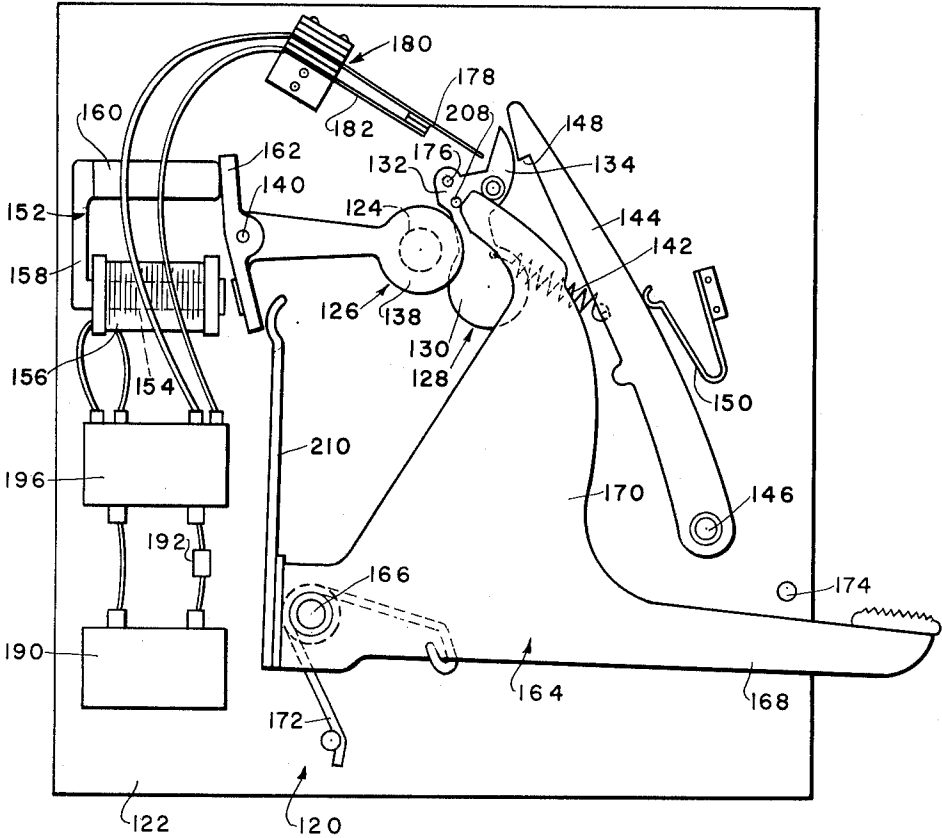


FIG. 6

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9 Sheets-Sheet 7

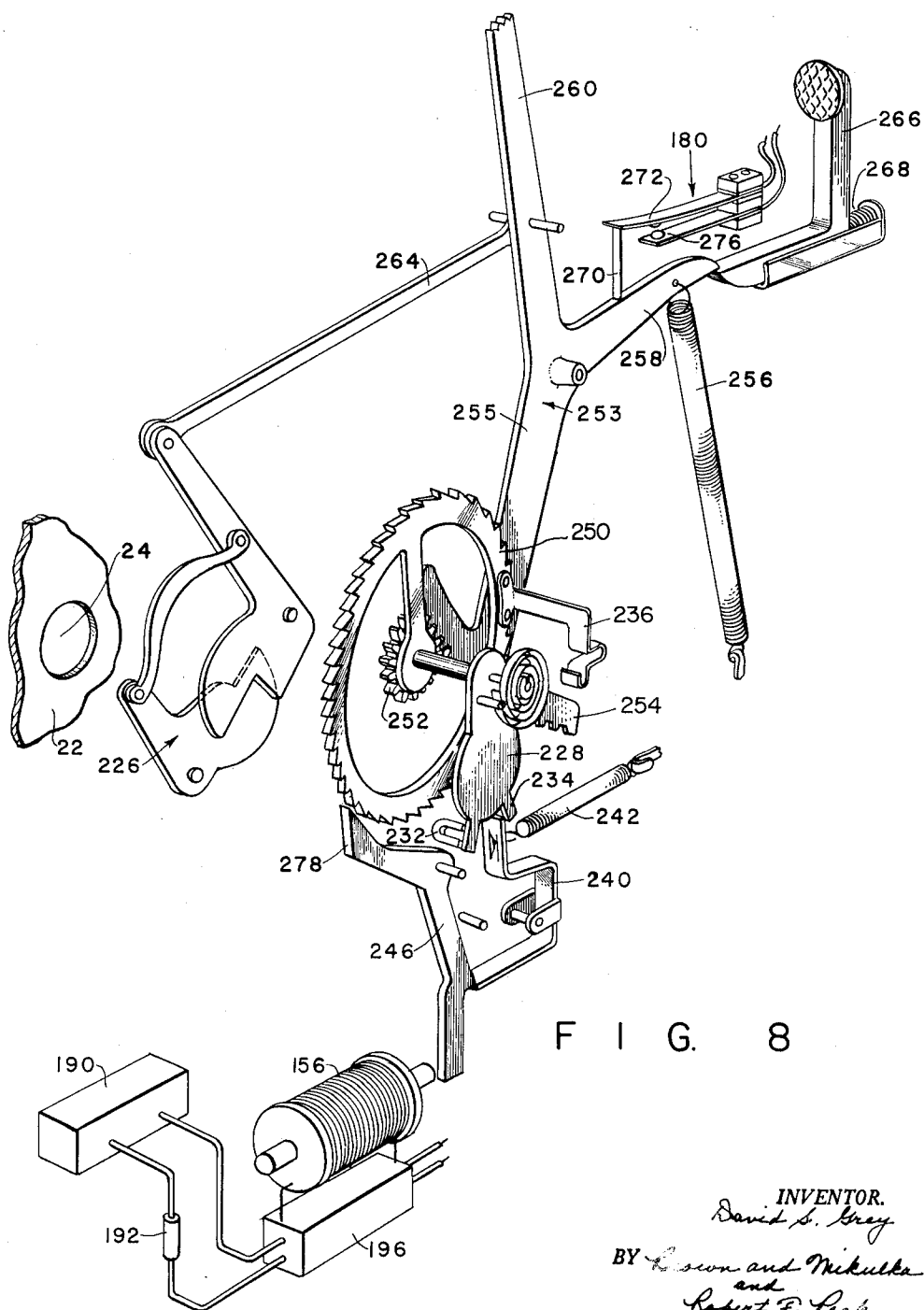


FIG. 8

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AUTOMATIC EXPOSURE CONTROL DEVICE

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9 Sheets-Sheet 8

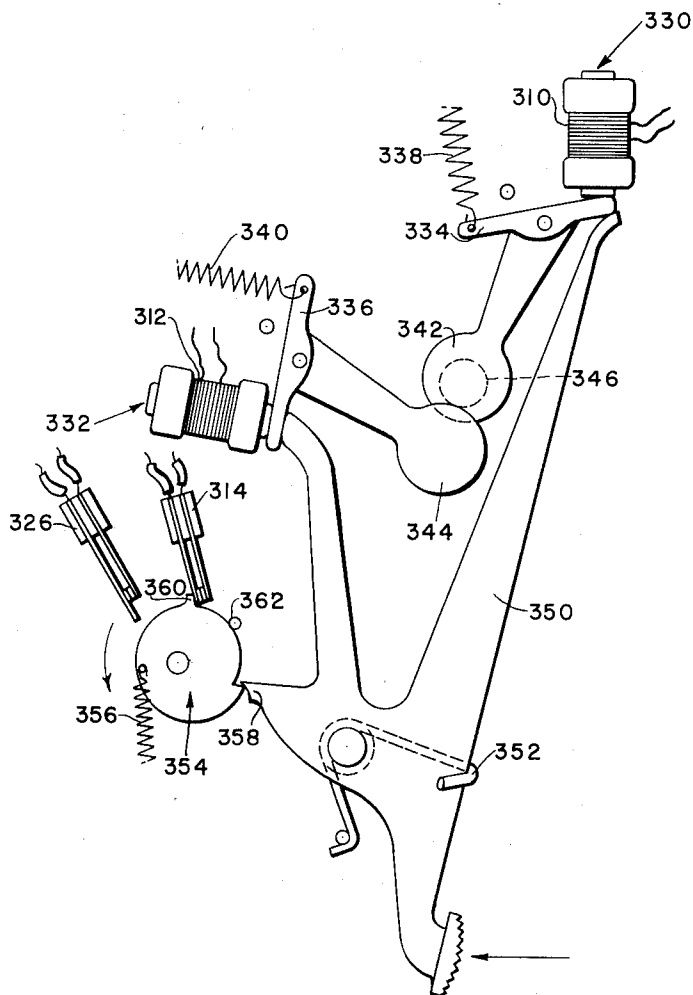


FIG. 9

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9 Sheets-Sheet 9

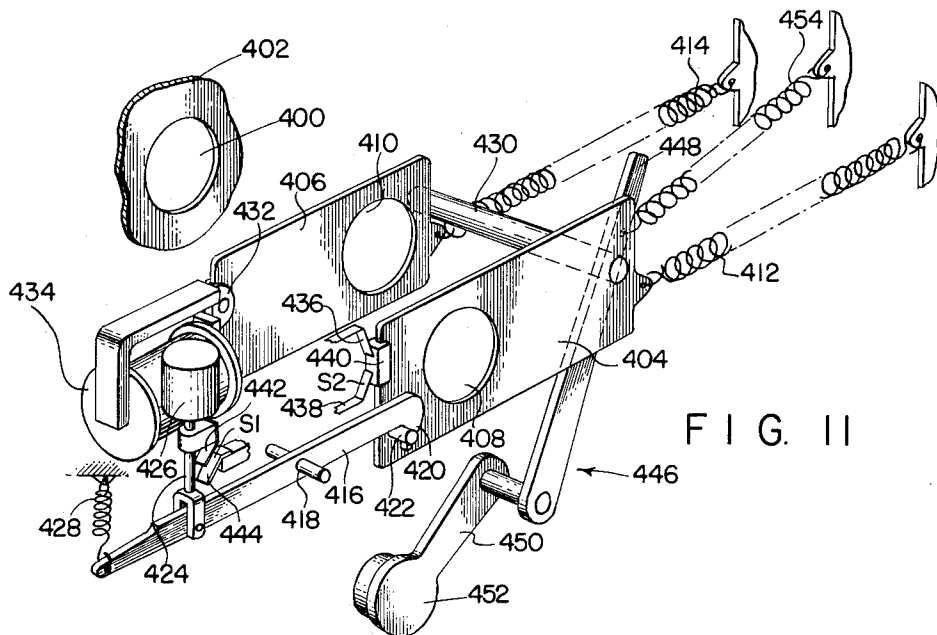


FIG. 11

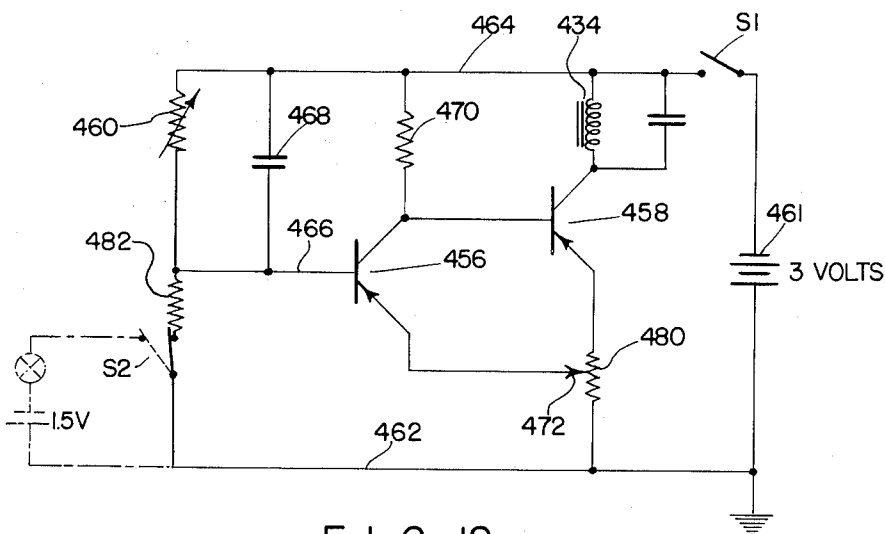


FIG. 12

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AUTOMATIC EXPOSURE CONTROL DEVICE

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Filed Nov. 6, 1961, Ser. No. 150,228

24 Claims. (Cl. 95—10)

This invention relates to photography and more particularly to photoelectrically responsive exposure control mechanisms.

Since the advent of the photoelectric cell, a substantial body of art has arisen concerning applications of photoelectric devices to the automatic or semi-automatic control of exposure values in optical devices, particularly those useful in photography. Until recently only meager power has been available from photoelectric elements incorporated in a readily portable apparatus; this is especially true in the application of photocells in the field of hand-held or portable cameras. In order to convert the small photocurrents available to mechanical displacements, by an electromagnetic transducer, the art has been largely limited to the use of galvanometers. Because of the inherently delicate mechanical construction and the gentle care required in their employment, these galvanometers have been primarily used as mechanical amplifiers and not as motors per se. While many of the resulting devices have functioned satisfactorily, mechanical amplification introduces problems of inertia, frictional effect, time delays due to back-lash, wear and the like and other effects which may seriously impair the accuracy with which exposure value can be determined.

Moreover, since galvanometers, heretofore used in automatic exposure control mechanisms, are usually relatively slow moving devices, i.e., they do not instantaneously respond to changes in ambient illumination, most practical automatic exposure control mechanisms have included various arrangements for immobilizing or clamping the galvanometer just prior to exposure. Such immobilizing or clamping arrangements are obviously unsuited for any type of exposure wherein the ambient light changes substantially during exposure; for example, when taking indoor flash pictures with a camera held fairly near (about 3 to 15 feet) the subject being photographed.

Heretofore, there have been some attempts made to replace the galvanometers used in exposure control mechanisms by the employment of electrical or electronic circuit arrangements, but in general the employment of such circuits has materially added to the cost, size and complexity of the exposure control mechanisms, the result being that such attempts have yielded no practical advantages over prior arrangements employing galvanometers.

Therefore, it is a primary object of the present invention to provide a new and novel photoelectrically responsive exposure control mechanism that employs electronic circuit arrangements in place of galvanometers and utilizes such circuits to maximum advantage in order to provide automatic exposure control with extreme precision and reliability under either fixed or varying ambient illumination, simplicity, and compactness of structure, and economy and ease of manufacture.

Another object of the invention is to provide a photoelectrically responsive exposure control mechanism in which proper exposure is determined by the action of solenoid devices which in turn are responsive to the action of an electronic trigger circuit.

Yet another object of the invention is to provide a photoelectrically responsive exposure control mechanism which dynamically responds to any variations in ambient illumination following opening of the exposure aperture to provide accurate and reliable exposure settings.

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Other objects of the invention will in part be obvious and will in part appear hereinafter.

The present invention therefore contemplates a photoelectrically responsive exposure control mechanism in which galvanometers have been replaced by electronic trigger circuits and associated solenoid devices which not only provide extremely fast shutter action when required, but also perform a timing function during exposure so that the exposure control device will accurately respond to changes in ambient illumination when the camera shutter is open.

The invention accordingly comprises the apparatus possessing the construction, combination of elements and arrangement of parts which are exemplified in the following detailed disclosure, and the scope of the application of which will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings wherein:

FIGURE 1 is an exploded, perspective, partly fragmentary view of one embodiment of the invention showing the parts thereof in rest position;

FIG. 2 is a schematic, front-elevational view of the embodiment of FIGURE 1 showing the parts thereof during exposure operation of the invention;

FIG. 3 is a schematic of one embodiment of an electrical circuit employed for controlling exposure values of the mechanism of FIG. 1;

FIG. 4 is a schematic, front-elevational view of another embodiment of the invention showing the parts thereof in rest position;

FIG 5 is a front-elevational, schematic view of the embodiment of FIG. 4 showing the parts thereof during exposure;

FIG. 6 is a front-elevational, schematic view of the embodiment of FIG. 4 showing the parts thereof immediately after termination of exposure and before the parts are reset;

FIG. 7 is a schematic diagram of an electronic circuit for controlling the exposure values of the device of FIG. 4;

FIG. 8 is an exploded, perspective, partly fragmentary view of yet another embodiment of the invention showing the parts thereof in rest position;

FIG. 9 is another embodiment of the invention showing the exposure-control mechanism with the parts thereof in rest or unactuated position;

FIG. 10 is a circuit schematic of an electronic device for controlling the exposure values of the embodiment of FIG. 9;

FIG. 11 is an exploded, perspective, substantially schematic view of still another embodiment of the invention showing the parts thereof in the rest position; and

FIG. 12 is a schematic diagram of an electronic circuit for controlling the exposure intervals of the arrangement shown in FIG. 11.

In the form of the invention shown in FIGURE 1, novel exposure control means are provided for determining both exposure time interval and effective exposure aperture responsive to the ambient light intensity. The novel control means comprises a photoelectric cell which establishes one electrical parameter, a means for establishing a second electrical parameter, and a means for comparing the two parameters against one another. One of the electrical parameters is relatively fixed, the other being variable so that it can be compared in a predetermined manner against the relatively fixed parameter. A simple electronic trigger circuit may be employed for comparing the two parameters, the circuit being characterized in having substantially no electrical output until the parameters are brought to the predeter-

mined relation or balance at which time the circuit is triggered to initiate control action. The novel control means also includes an electromechanical transducer such as a relay, solenoid etc., which is actuated by the amplified photocurrent to control movement of a shutter element.

In one form, the novel control means is employed to actuate a modification of a shutter mechanism of the essentially free-moving type such as is described in U.S. Patent No. 2,752,834 issued July 3, 1956, to M. N. Fairbank. In the preferred form of the assembly, there is included a shutter blade normally mounted upon a housing in a covering relation to an exposure aperture. As a means for imparting an aperture-uncovering movement to the blade, there is provided an impulse member or "kicker." The kicker is normally held by a latch means in a stationary position against the biasing action of resilient means used for moving the kicker when desired. A tripping means, such as a lever, is disposed for releasing the latch means whereby the kicker is allowed to move under the bias of the resilient means to strike a portion of the shutter blade. The tripping means also includes an electromechanical transducer forming a part of the novel control means heretofore described. The shutter blade, under the striking impetus of the kicker, is thus moved, at a substantially constant speed determined primarily by its inertia and by the impetus imparted thereto, from its aperture-covering position to an aperture-uncovering position.

As a means for limiting the total extent of travel of the blade, there is preferably provided reversing means adapted to momentarily engage the shutter blade at an aperture-uncovering position during movement of the blade from aperture-covering position, and for reversing the movement and returning the blade to the latter position. A preferred embodiment of the reversing means comprises one resilient element, such as a bounce spring, which is disposed for intercepting and reversing the shutter blade at a predetermined point in its arcuate travel. The exposure time interval afforded by the uncovering movement of the blade is a function of the degree of rotation of the blade as determined by the location of the intercepting bounce spring, and may be varied by changing this location. Therefore, in the preferred form of the present invention, means are provided for moving the location or position of the bounce spring along the path of the blade so as to vary the total travel of the latter.

In this embodiment of the present invention, means are provided for variably determining an effective exposure aperture, the latter being defined herein as the total cross-sectional area through which incident light may be admitted by a combination of a diaphragm means and an exposure aperture. Such a diaphragm means is mounted for cooperation with an exposure aperture so as to provide a variable effective exposure aperture, and in one form comprises a multiple-leaved element of known type in which the leaves are movable oppositely to one another for framing an opening determined by the magnitude of displacement of such opposite movement. In this embodiment, the positioning of the diaphragm means for establishing an effective exposure aperture and the positioning of the bounce spring for determining an exposure time interval are effected in fixed relation to one another so that the positioning of the one is accomplished by the positioning of the other whereby a continuum of exposure values is obtained. Movable means are provided for positioning the diaphragm means and the bounce spring such that the exposure value is a function of the displacement of the movable means.

In this embodiment, the variable electrical parameter of the novel control means is provided by an electrically resistive element, such as a potentiometer coupled to the movable means for positioning the diaphragm means and bounce spring. Therefore, the relatively fixed electrical

parameter against which the variable resistance of the potentiometer is to be compared, preferably comprises a photoelectric cell whose resistance is substantially predetermined by the intensity of light incident thereon. The trigger circuit is a bistable, regenerative electronic amplifier which functions to compare the voltage across the potentiometer to the voltage across the photoelectric cell and abruptly delivers an amplified electrical signal when the two resistances are brought to a predetermined relation by adjustment of the movable means. The electrical signal actuates an electromechanical transducer, such as a solenoid, which trips the shutter mechanism to effect an exposure accordingly.

The versatility of the present invention is exhibited in another or alternative embodiment wherein the novel control means is employed with a two bladed shutter mechanism. In this embodiment, the shutter mechanism includes a pair of shutter blades, one of which is normally mounted in covering position relative to an exposure aperture while the other is normally mounted in uncovering position relative to the aperture. Both blades are biased for sequential movement out of their respective normal positions such that the one blade normally in covering position is movable to uncovering position to initiate an exposure, and after a predetermined time interval, the other blade is movable to covering position to terminate the exposure.

In this embodiment the control means includes a switch actuated by release of the one blade at initiation of exposure. The switch actuation for instance, closure, completes a network which includes the variable electrical parameter of the control means. In this embodiment, the variable electrical parameter is an electrical charge which varies with time, as contrasted with the variable electrical parameter of the other embodiment heretofore described which was a resistance which varied with a mechanical displacement. The variable electrical parameter of this alternative embodiment is determined by the value of a capacitor and the resistance of a photoelectric cell coupled to the latter, such that the change in charge with time is a function of RC where R is the value of the photoelectric cell resistance and C is the capacitance of the condenser. This variable electrical parameter is compared by an appropriate circuit against a fixed voltage provided, for instance, by a voltage-dividing network. When the fixed and variable electrical parameters reach a predetermined relation to one another, the positive feedback of the trigger circuit insures that the circuit abruptly delivers an amplified electrical signal which actuates an electromechanical transducer, such as a solenoid, the latter in turn initiating movement of the other shutter blade to terminate exposure. It will be apparent that the time interval between initiation and termination of exposure will, therefore, be a function of the time interval required to charge the condenser and the exposure time interval is therefore controlled in accordance with the intensity of light incident on the photocell.

Referring now to the various drawings wherein like numerals denote like parts, the preferred constructional features of the present invention will be readily apparent. Referring particularly to FIGURES 1 through 3, the embodiment first described above is shown therein and comprises a shutter-and-diaphragm assembly indicated generally by the reference numeral 20. Assembly 20 includes a housing portion 22 shown in fragment only for supporting the various elements of the embodiment. Suitably disposed in the housing portion is a conventional camera lens system represented in cross-section by exposure aperture 24. Disposed for movement across the optical axis of the lens system and mounted upon housing portion 22 is a diaphragm means 26 and a movable shutter member such as shutter blade 28.

Shutter blade 28 is rotatably mounted upon suitable bearing means indicated at 30, the bearing means having a minimal amount of friction. For normally retaining

the shutter blade in a position of rest wherein the shutter blade covers or occludes aperture 24, there is provided a releasable retaining means which comprises, in the preferred form, magnet 32. Consequently, at least a portion of the shutter blade should be formed of a magnetizable substance, such as iron or the like, to allow magnet 32 to act upon the shutter blade and retain same. Shutter blade 28, in the form shown, preferably comprises a sector-shaped, substantially planar blade having a projecting portion or lug 34 extending radially therefrom beyond the outer periphery 35 of the arcuate portion of the sector, the blade being mounted at the portion thereof opposite to periphery 35. As may be seen in the drawing, there is provided a reversing means, such as bounce spring 36 which is positionable in the path of travel of lug 34, which path is defined by the rotation of the shutter blade about a pivotal axis provided by bearing means 30. As a means for initiating rotation of the shutter blade about the bearing means, there is provided impact means, such as kicker 40, which comprises an L-shaped lever mounted for rotation intermediate its ends and which is biased for movement in a clockwise direction by resilient means, for example kicker spring 42. Kicker 40 is releasably restrained from movement in the clockwise direction and held in a restrained position, as shown in FIGURE 1, by latch means such as serration or lip 44 on lever 46. Lever 46 is mounted for rotation intermediate its ends and is normally in a position wherein lip 44 is in engagement with a portion of kicker 40 for holding the latter in its restrained position. Means are provided for releasing lip 44 from kicker 40 and thereby allowing the kicker to rotate in a clockwise direction under the bias of spring 42; such a means is provided as an electromechanical transducer such as solenoid 48. Because solenoid 48 is intended to cause an electrical signal fed thereto to effect a rotation of lever 46, it is necessary to provide lever 46, at least in part, as a magnetizable element.

To effect an exposure, an electrical signal is introduced into solenoid 48 creating a magnetic field which rotates lever 46 in a clockwise direction so that lip 44 disengages kicker 40. This permits the kicker to rotate rapidly in a clockwise direction under the bias of spring 42. Kicker 40 is so disposed relative to lug 34 that the clockwise rotation of the kicker is transmitted by impact against the lug, overcoming the retaining force of magnet 32, and causing shutter blade 28 to rotate rapidly in a counter-clockwise direction about bearing means 30. This rotation of the shutter blade uncovers aperture 24 allowing light from the lens system to pass through the shutter-and-diaphragm assembly and initiate an exposure as shown in FIG. 2. The rotation of the shutter blade in the counter-clockwise direction continues until lug 34 strikes bounce spring 36. Upon impact of lug 34 with spring 36, the direction of rotation of the blade is reversed and the blade is rapidly returned to its rest position at which magnet 32 reengages and retains the blade, the exposure aperture being thus again covered by the blade and exposure, therefore, being terminated. Devices having shutter blades adapted for incorporation in the present invention may be seen by way of example, but are not necessarily limited thereto, in the aforementioned U.S. Patent No. 2,752,834; in U.S. Patent No. 2,531,936, issued November 28, 1950, to M. N. Fairbank; and many others.

In the preferred form of the present invention, bounce spring 36 comprises at least a resilient portion positioned to engage lug 34 of the shutter blade during rotation of the latter, and is therefore adapted to absorb energy from the shutter blade upon engagement therewith and to transmit a substantial portion of the absorbed energy back to the blade for providing the impetus which returns the blade to its rest position. Spring 36 is therefore preferably formed of a resilient substance such as Phosphor bronze or spring steel. Means are provided

for mounting the bounce spring for movement along the path of rotation of lug 34 so as to vary the travel of the blade and, therefore, vary the exposure time interval afforded by movement of the latter. Such a means is provided by a substantially circular element, such as wheel 50, upon a peripheral portion of which spring 36 is fixedly mounted. Wheel 50 is mounted for rotation about a pivotal axis which is substantially colinear to the axis of rotation of the shutter blade, and the plane of rotation of the wheel is therefore substantially parallel to the plane of movement of the shutter blade.

As a means for rotating wheel 50, there is, in the preferred form, a circular gear 52 mounted for rotation integrally with and having a common pivotal axis with wheel 50. A gear segment 54 is mounted adjacent one end of a lever 56, the lever being mounted intermediate its ends on housing portion 22 for pivotal movement about suitable bearing means 58 and with gear teeth 60 of segment 54 in meshing engagement with gear 52. Gear segment 54 is preferably pivotally movable in a plane approximately parallel with the plane of movement of wheel 50 and is urged in a counterclockwise direction by resilient means such as spring 62 such that wheel 50 is biased for movement toward a position wherein spring 36 is at its minimum angular displacement from the rest position of the shutter blade.

For rotating lever 56 and, therefore, gear segment 54 against the bias of spring 62 there is provided linkage means which includes elongated link 64. One extremity of link 64 is pivotally mounted adjacent the opposite extremity of lever 56, the other extremity of link 64 being pivotally mounted adjacent one extremity of elongated lever 66, the latter constituting a manually operable actuating element. Lever 66 is pivotally mounted at one extremity thereof, as at 65, upon housing portion 22, the opposite extremity of lever 66 being provided with a manually engageable portion 68 extending beyond the confines of housing portion 22 so as to be readily grasped by an operator of the device.

It will therefore be seen that pressure exerted by an operator of the device against manually engageable portion 68 in the proper direction will rotate lever 66 in a counterclockwise direction, and this rotation is transmitted through link 64, causing lever 56 to rotate against the bias of spring 62, and ultimately rotating bounce spring 36 from its position of minimum angular displacement. This results in progressively increasing the exposure time interval provided by movement of the shutter blade. In the preferred embodiment, the progressive increase in the angular displacement of the bounce spring which sets increasing exposure time intervals is accompanied by a similar progressive increase in the magnitude of the effective exposure aperture defined by diaphragm means 26.

Hence, there is provided diaphragm means 26 which comprises a multiple-leaved element, which in the form shown, includes at least two thin, substantially planar, radiation-opaque leaves 70 and 72 which are pivotally mounted at respective extremities thereof upon housing portion 22 by respective bearing means such as studs 74 and 76. As a means for defining an effective exposure aperture, leaf 70 is provided in a portion thereof which normally overlies exposure aperture 24 with a notch 78 which preferably has a V-shape such as a right angle; leaf 72 is provided with a similar notch 80. The two leaves are so disposed that the notches may be combined to provide a substantially square opening 82 disposed symmetrically about the optic axis through exposure aperture 24. It is understood that the notches may assume other configurations so that the shape of opening 82 is other than square. Means are included for varying the size of opening 82 and for providing a plurality of effective exposure apertures of different magnitude by the combination of opening 82 with exposure aperture 24. This means is provided as a simple linkage for moving the diaphragm leaves, for instance,

in rotation about studs 74 and 76 respectively, oppositely to one another in closely adjacent and approximately parallel planes symmetrically about the optic axis of the exposure aperture. In the form shown, the linkage comprises an elongated connecting rod or link 84 which is pivotally mounted adjacent its extremities respectively upon a portion of leaf 72 and upon arm 86, the latter constituting a member which is rigidly connected to and projects from lever 56 intermediate its extremities. Thus, motion of lever 56 is transmitted through link 84 for rotating leaf 72 about stud 76. By coupling leaf 72 to leaf 70 through another elongated connecting rod 88 pivotally mounted adjacent its extremities respectively upon portions of each of the leaves, the rotation of leaf 72 is accompanied by a similar rotation of leaf 70 in an opposite direction.

In operation, rotation of actuating lever 66 in a counterclockwise direction moves the bounce spring and the diaphragm through a plurality of respective positions wherein the position of the bounce spring (and therefore the exposure time interval determined thereby) and the magnitude of opening 82 in the diaphragm are established as a function of the angular rotation of wheel 50 from its initial position of rest. The latter position, of course, is established by the bias of spring 62 which forces lever 66 in a clockwise direction until the latter is arrested by engagement with a predeterminedly positioned portion of housing portion 22.

The invention includes means for controlling or determining the exposure value of the mechanism by arresting the setting movement of the elements heretofore described after a predetermined rotation of the actuating lever from its rest position has occurred. In this embodiment, the means for controlling the exposure value comprises an electrical circuit shown schematically in FIG. 1 and in detail in FIG. 3. This circuit includes means, such as photoelectric cell 90, for establishing a relatively fixed electrical parameter, means such as variable resistor or potentiometer 92 for establishing a relatively variable electrical parameter, and comparator means, indicated generally at 94, for comparing the two parameters and for actuating solenoid 48 by an amplified photocurrent only when the two parameters have reached or exceeded a predetermined relation. In this embodiment, the electrical parameter established by potentiometer 92 is intended to vary as a function of a mechanical displacement, i.e., the angular displacement of lever 56 or lever 66 which angular displacement also determines the values of the effective exposure aperture and the exposure time interval and, therefore, the exposure value. Consequently, lever 56, or some element movable in fixed relation thereto, can be employed for varying the potentiometer setting. In the form shown in FIG. 1 actuating lever 66 is adapted to perform this function by inclusion therewith of arm 96, extending radially outward from the axis of rotation of and forming an integral part of the actuating lever. Arm 96 bears at its outermost extremity a gear segment 98 movable with lever 66 substantially along the plane of rotation of lever 66 and being in meshing engagement with circular gear 100 fixedly mounted to movable element 102 of the potentiometer. It is apparent then that any rotation of lever 66 which is accompanied by variations in the position of the bounce spring and the size of opening 80 is also accompanied by a rotation of movable element 102 of potentiometer 92 which varies the effective value of a resistance such as winding 104 of the potentiometer in known manner.

As shown in FIG. 3, the electronic trigger circuit 94 includes photoelectric cell 90, potentiometer 92, a pair of transistors 106, 108, a suitable source of electrical energy 110, and the winding of solenoid 48. The transistors 106, 108 are either PNP or NPN types depending upon the polarity of the energy source.

The circuit could also include a switch (not shown) which could be arranged to close upon initial actuation of lever 66 and to open upon return of lever 66 to the rest position. In any event, with the circuit energized, the photoelectric cell 90 will assume a value of resistance corresponding to the quantity of light impinging thereon and the potentiometer 92 will assume a progressively increasing value of resistance during movement of lever 66. Until such time as the magnitude of resistance assumed by the potentiometer bears a predetermined relation to the magnitude of resistance of photoelectric cell 90, the transistors 106, 108 will be essentially non-conducting; that is, they will be in the "off" state. In this state, no significant amount of current will flow through winding 48, and the solenoid will be effectively deenergized.

However, as soon as the resistance of the photoelectric cell and the potentiometer bear the predetermined relationship to one another, the circuit will abruptly switch to the "on" state with both transistors conducting and with a substantial amplification occurring so that a substantial current will flow through winding 48. When this occurs, the solenoid will move the lever 46 to engage kicker 40 and allow the kicker to move the shutter blade 28 to initiate exposure.

As the lever 46 moves, one extremity thereof in the form of a pawl 112 will engage one of the teeth 114 formed on the periphery of wheel 50 and thus positively stop wheel 50 from further rotation. When this occurs, the bounce spring 36 will be locked against further movement, and the variable diaphragm 26 will also be locked against further movement so that both aperture setting and exposure interval will be determined in accordance with the operation of the trigger circuit.

Suitable clutch means may be incorporated in the driving mechanism to allow slippage after the wheel 50 is locked by pawl 112.

By relating various values of resistance of the photoelectric cell 90 to various combinations of exposure aperture and exposure interval, a wide range in exposure values can be automatically achieved with the invention.

It will be noted that the potentiometer 92 sweeps from a minimum to a maximum resistance as the exposure aperture and exposure interval change from minimum to maximum openings and times, respectively. This action corresponds to the response of the photoelectric cell 90, which has its maximum value of resistance at the low levels of ambient illumination, at which condition the exposure aperture and exposure interval must be at their maximum settings. With appropriate changes in circuitry and mode of operation, the potentiometer 92 could be arranged to sweep from a maximum to a minimum resistance. Such action would eliminate the possibility of any "false" exposure initiation that may occur with the arrangement shown in FIGURE 1 should the potentiometer 92 have any "open" spots which momentarily increase its effective resistance to infinity.

Referring now to FIGS. 4 through 7 an alternative embodiment of the invention is shown therein and comprises a shutter assembly indicated generally by the reference numeral 120. Assembly 120 includes a housing portion 122 for supporting the various elements of this embodiment. Housing portion 122 includes therein an exposure aperture or opening 124 through which it is intended to selectively pass actinic radiation to effect exposure when the invention is employed in conjunction with a photosensitive material such as a silver halide emulsion film thermographic plate, photopolymerizable sheet or the like. Mounted upon housing portion 122 adjacent opening 124 are means for establishing time intervals of exposure through the opening, which means, in the form shown, comprises first shutter blade 126 and second shutter blade 128. For the sake of clarity in the drawing, diaphragm means for varying the effective magnitude of exposure

aperture 124 have been omitted, but it is understood that a diaphragm may be employed with this embodiment either in coupled or uncoupled relation to the other elements thereof.

Each shutter blade is formed of a thin, sheetlike material which is substantially opaque to the radiation with which the invention is intended to be employed, it being understood that housing portion 122 is similarly opaque. As shown, blade 128 is a substantially planar, elongated member, one extremity of which comprises covering portion 130. Covering portion 130 is dimensioned so that when aligned with opening 124, the covering portion fully covers the opening to occlude radiation there-through. The opposite extremity of blade 128 is bifurcated to provide first arm 132 and second arm 134 disposed at an angle to one another. Means, such as pivot 136, are provided for mounting the blade so that the latter is movable, in this instance, in rotation about pivot 136. Blade 128 is mounted upon pivot 136 approximately intermediate covering portion 130 and arms 132 and 134 so that the arms and the covering portion all extend approximately radially from pivot 136. Blade 128 is normally mounted so that covering portion 130 is in alignment with opening 124, being therefore in a first or covering position. The blade is rotatable between its covering position and in uncovering position wherein it is disposed wholly to one side of opening 124.

Blade 126 is provided with a similarly dimensioned covering portion 138 at one extremity thereof and is mounted for movement, as by rotation about pivot 140, adjacent its opposite end. Blade 126 is movable about pivot 140 from an uncovering position wherein portion 138 is wholly to one side of opening 124 to a closed position wherein covering portion 138 is aligned with and occludes opening 124. Both blades are mounted so that the covering portions are movable in their own planes closely adjacent and parallel to one another thereby minimizing light leakage between the blades.

Resilient means, such as spring 142, are provided for moving blade 128 from its covering to its uncovering position, spring 142 being, in the form shown, an elongated spring having one extremity mounted on blade 128 intermediate pivot 136 and covering portion 130, and at its other extremity secured to a pin 143 mounted upon housing portion 122. When blade 128 is in its covering position, spring 142 is under stress and tends to bias the blade toward its uncovering position. As a means for releasably retaining blade 128 in its covering position against the bias of spring 142 there is included a shutter latch shown as elongated element 144 which is pivoted, as at 146, adjacent one of its ends upon housing portion 122. The other end of element 144 includes a latch portion or notch 148 which is normally in engagement with the extremity of second arm 134 when blade 128 is in its covering position. Resilient means, such as spring 150 mounted on housing 122, are provided in engagement with element 144 for rotating the latter about its pivot point so that notch 148 is retained in engagement with arm 134.

Means are provided for moving blade 126 between its covering and uncovering positions and for releasably retaining the blade in either of the positions. In this embodiment of the invention, such a means is provided as a polarized electromechanical transducer, one form of which is shown for instance in FIG. 4. It will be seen that the electromechanical transducer is formed as a U-shaped device 152. One arm 154 and one base 158 of device 152 are formed of a magnetically soft substance, such as soft transformer iron or the like, and has wound about it a coil or solenoid 156. The other arm 160 of device 152 is formed of magnetically hard material such as a permanent magnet of Alnico or similar substances. Arm 154, base 158 and other arm 160 are all preferably formed as a single unit to provide a continuous flux path

throughout the device. It will therefore be apparent that arm 154 is normally somewhat magnetized due to its proximity to arm 160.

Blade 126 includes, adjacent pivot 140, a V-shaped lever or rocker 162 firmly affixed to the blade and movable therewith, the apex of the V-shape being approximately located at pivot 140. Rocker 162 is so shaped and disposed relative to blade 126 that when covering portion 138 of the latter is in its uncovering position, one arm of the rocker is retained in contact with arm 154 of device 152. Rocker 162 is formed of a magnetizable material such as iron which is subject to attraction by magnetic force. The other arm of rocker 162 is adapted to contact and be retained by the larger field of other arm 160 of device 152 when blade 126 is in its covering position relative to opening 124.

Means such as actuating element or bell crank 164 are provided for initiating operation of the shutter mechanism. Bell crank 164 comprises an element mounted for rotation about appropriate bearing means such as pivot 166 disposed on housing portion 122, and includes a first arm 168 extending radially from pivot 166 outwardly of the confines of housing portion 122 so that the radial extremity of arm 168 may be grasped by an operator of the device for rotating the bell crank. Bell crank 164 also includes a second arm 170 which also extends radially from pivot 166 and at an angle to arm 168, both arms lying substantially in the plane of rotation of the bell crank. Arm 170 is so dimensioned that the path of movement of the radial extremity thereof intersects the position of shutter latch 144, the radial extremity of arm 170 being therefore engageable with the shutter latch. Resilient means such as spring 172 are provided for biasing the bell crank for rotation such that the radial extremity of arm 170 is biased away from engagement with shutter latch 144. Means such as pin 174 mounted upon housing portion 122 are provided in the path of movement of arm 168 for limiting the rotation of the bell crank under the bias of spring 172.

In operation, the radial extremity of arm 168 is grasped by an operator and pressure is exerted thereagainst to rotate bell crank 164 against the bias of spring 172. The rotation of the bell crank in the clockwise direction against the bias of spring 172 causes the radial extremity of arm 170 to engage shutter latch 144 and rotate the latter about its pivotal axis at 146 and against the bias of spring 150. The rotation of the shutter latch causes notch 148 to disengage second arm 134 of shutter blade 128; this frees the latter for movement from its covering position to an uncovering position under the impetus provided by spring 142, thereby initiating exposure through opening 124 as shown in FIG. 5.

Shutter blade 128 is provided on first arm 132 with an abutment or pin 176. When shutter blade 128 is in its covering position, pin 176 is in engagement with spring contact 178 of switch 180, for retaining the spring contact out of engagement with relatively fixed contact 182 of the switch. As blade 128 moves toward its uncovering position, pin 178 is rotated and permits spring contact 178 to close under its own resiliency and engage fixed contact 182, thereby closing a circuit substantially simultaneously with the initiation of exposure.

This embodiment of the invention includes means for controlling or determining the exposure value, particularly the exposure time interval, of the mechanism, and comprises an electrical circuit such as shown in detail in FIG. 7, being shown schematically in FIGS. 4-6. This circuit includes means such as photoelectric cell 190 and capacitor 192 for establishing a relatively variable electrical parameter, which in this embodiment, is a voltage. Means such as voltage divider 194 are also included for establishing a relatively fixed or constant electrical parameter or voltage. The circuit includes another form of electronic trigger circuit indicated generally at 196 for comparing the two voltages and for actuating solenoid

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156 only when the two voltages have attained a predetermined relationship to one another. Voltage divider 194 is preferably in the form of an electrically resistive winding having a variable tap intermediate its extremities. It will be seen that the electrical parameter established by the series combination of cell 190 and capacitor 192 is intended to vary as a function of time and is determined by the product of the value R of the cell and the value C of the capacitor, the product RC being the well-known "time constant" of charging. It is apparent that the product RC varies in accordance with the intensity of light incident upon cell 190 which determines the resistive value of the latter when, as in this embodiment, the cell employed is a photoconductive element. The intermediate tap of voltage divider 194 can be predeterminedly set to establish a desired voltage drop.

Comparator means 196 which acts as an electronic switch, as shown in FIG. 7, comprises a pair of transistors 198 and 200. In the form shown, transistor 198 is an NPN transistor while transistor 200 is a PNP transistor. The circuit includes solenoid 156, one end of which is grounded and the opposite end of which is connected to both the collector of transistor 200 and one side of capacitor 192. The base of transistor 200 is connected to the collector of transistor 198. One terminal of cell 190 is coupled in series to the other side of capacitor 192 and the base of transistor 198 is connected to a point between the capacitor and the cell. The emitter of transistor 200 is electrically connected to the other terminal of cell 190, to one contact of switch 180 and also led to ground through the total resistance of voltage divider 194. The emitter of transistor 198 is connected to the intermediate tap of the voltage divider and thence to ground through at least a portion of the latter. A power supply in the form of battery 202 is provided, the negative terminal of the battery being grounded and the positive terminal being connected to the other contact of switch 180.

In one embodiment of the circuit of FIG. 7 the values of the elements are substantially as follows:

Battery 202, 2.68 volts; capacitor 192, 1 mf.; photocell 190 is a photoconductive cell having an effective resistance of approximately 4K Ω to 100K Ω , such as the photoconductive cell CL407S supplied by the Clairex Corporation; the internal resistance of solenoid 156 is 10 Ω and the solenoid has approximately 800 turns of No. 35 copper wire; and transistors 200 and 198 are respectively transistors sold under the identifying numbers 2N404 and 2N1605 by the Raytheon Company. Voltage divider 194 has a total resistance of 100 Ω .

As pin 176 rotates with the movement of blade 128 toward the uncovering position of the latter, closure of switch 180 is effected. When the switch is closed, the base of transistor 198 is first negatively biased and will not conduct, hence transistor 200 is open circuited and also will not conduct. As a charge builds up in condenser 192 at a rate dependent upon the value of the resistance of the cell in accordance with the illumination level thereon, the voltage at the base of transistor 198 increases until it reaches a point at which it is more positive than the emitter of the transistor. The value of potential at the emitter of transistor 198 is determined by the preset position of the tap of voltage divider 194 with respect to ground. When the voltage at the base of transistor 198 reaches a level which is more positive than the emitter potential, the transistor will conduct drawing a small current and driving the base of transistor 200 negative with respect to its emitter, causing initiation of electronic flow through the collector of transistor 200 to its emitter.

As transistor 198 becomes conductive, capacitor 192 then discharges through the base to a voltage somewhat below its peak level thereby increasing the flow of current through the base of transistor 198 and causing more collector current to flow. The increase in collec-

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tor current in transistor 198 drops the voltage at the base of transistor 200 causing an abrupt increase in the conduction of transistor 200 to a maximum to thereby energize solenoid 156. In order to prevent the charge on capacitor 192 from discharging into the base of transistor 198 too rapidly, it is preferred that the circuit include, in series between the base and capacitor, limiting resistor 204, for use with the circuit values heretofore disclosed, of about 30K Ω . As in the circuit shown in FIG. 7, the present embodiment also preferably includes a shunt resistor 206 across the solenoid to prevent circuit oscillation following closure of the switch 180. In order to vary the circuit response to adjust for variations in film speed, or to trim as desired, manual means may be provided for adjusting the position of the intermediate tap of voltage divider 194.

The trigger circuit thus compares the value of the charge on capacitor 192 with the potential across the desired portion of the resistance of voltage divider 194, and after a predetermined time required to charge the capacitor to obtain the desired relationship, abruptly switches to actuate solenoid 156. The flow of current in the solenoid is then in a direction which gives rise to a magnetic field opposed to the field induced in arm 154 by the permanent magnet of arm 160. The magnetic force acting on the one arm of rocker 162 then decreases to a point at which it is no longer capable of retaining the one arm of the rocker in contact with arm 154 of device 152 against the magnetic attraction of arm 160 of device 152 for the other arm of the rocker. Hence the rocker rapidly rotates until the other arm thereof engages with and is retained by arm 160 of device 152. The rotation of the rocker is, of course, accompanied by the rotation of blade 126, thus resulting in closure of opening 124 and termination of exposure as shown in FIG. 6. The exposure time interval therefore established respectively by the sequence of uncovering movement of blade 128 and the closing movement of blade 126 is determined by the "time constant" of comparator means 196, the latter in turn being a function of the intensity of illumination incident upon photocell 190.

Following termination of exposure, release of pressure by the operator on arm 168 allows the latter to move under the bias imposed by spring 172 toward the rest position of bell crank 164 wherein first arm 168 is in engagement with pin 174. Shutter blade 128 is provided on first arm 132 with an engagement portion or pin 208 displaced from pivot 136 and at an intermediate position between pin 176 and covering portion 130. Pin 208 is thus so positioned and second arm 170 of the bell crank is so dimensioned that the radial extremity of the latter engages pin 208 during the return movement of the bell crank to its rest position. As the bell crank therefore rotates toward its rest position, the engagement of arm 170 with pin 208 pivots shutter blade 128 from its uncovering position back toward its covering position. Just before the bell crank arrives at its rest position, the radial extremity of arm 170 thereof slidably disengages pin 208 inasmuch as their arcs of movement no longer intercept. However, elongated element 144 is also released by the return movement of the bell crank, and under the bias imposed by spring 150 returns to a position wherein notch 148 re-engages second arm 134, locking shutter blade 128 in its covering position despite the disengagement of arm 170 from pin 208.

Bell crank 164 has mounted thereon an elongated, resilient lever 210. One end of lever 210 is preferably affixed to the bell crank adjacent pin 156, the other end of lever 210 preferably extending into the path of movement of the one arm of rocker 162 for engagement therewith. Thus, as the bell crank moves towards its rest position following release thereof, lever 210 engages the one arm of rocker 162 rotating the rocker so that the other rocker arm disengages arm 160 of device 152 and the one arm of the rocker is driven into re-engagement with arm 154 of device 152. The one arm of the rocker is

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then returned in contact with arm 154 regardless of the magnetic state of the latter by the resiliency of lever 210. The motion of the rocker as driven by lever 210 also rotates shutter blade 126 from its position of closure to its uncovering position with respect to opening 124. Lastly, as shutter blade 128 is rotated toward its covering position by the engagement of second arm 170 with pin 208, pin 176 re-engages spring contact 178 and moves the latter out of contact with fixed contact 182, thereby opening the circuit of the comparator means 195. With the opening of the circuit, the transistors are returned to their non-conductive state and current no longer flows in solenoid 156. Thus the entire shutter mechanism is reset as shown in FIG. 4 for the next exposure sequence.

For yet a third modification of the present invention, the circuit shown in FIG. 7 may be employed in conjunction with a unitary blade shutter and diaphragm mechanism similar to that illustrated in FIG. 1. The third modification is shown particularly in FIG. 8 and comprises shutter blade 228 formed, mounted, and retained similarly to shutter blade 28 theretofore described. The third embodiment also includes diaphragm means indicated generally at 226 comprising a multiple leaved element substantially similar to diaphragm means 26 hereinbefore described.

As may be seen in FIG. 8, means are provided for variably limiting the travel of shutter blade 228 from its covering position wherein it is retained by magnet 232. In the preferred embodiment the means for limiting the blade travel comprises a reversing means such as bounce spring 236 which is positionable in the path of travel of lug 234, the latter forming a portion of the shutter blade. As a means for initiating rotation of the shutter blade, there is provided impact means such as kicker 240 shaped, positioned, mounted and resiliently biased as by kicker spring 242 in a manner similar to that described in connection with kicker 40. Latch means 246 are provided for releasably restraining the kicker from movement, latch means 246 being also similar in shape and construction to lever 46.

Bounce spring 236 is mounted for movement along the path of rotation of lug 234 so as to vary the travel of the blade, the means for mounting the bounce spring being provided by a substantially circular element such as wheel 250, upon a peripheral portion of which the bounce spring is fixedly mounted. Wheel 250 is mounted and constructed similarly to wheel 50 heretofore described, and has mounted for rotation coaxially and fixedly therewith circular gear 252. A Y-shaped element 253 is provided rotatably mounted approximately centrally thereof and having a gear segment 254 mounted adjacent the extremity of a first one 255 of its arms. Element 253 is so mounted that the gear teeth of segment 254 are in meshing engagement with gear 252 so that rotation of the element rotates wheel 250 thereby changing the position of the bounce spring relative to the position of closure of shutter blade 228. For rotating element 253 there is provided resilient means such as elongated driving spring 256, one end of which is anchored adjacent the radial extremity of second arm 258 of element 253, and the other end of which is anchored upon the support (not shown) for the elements of the shutter mechanism. Spring 256 is preferably disposed for urging element 253 in a rotational direction which, when transmitted to wheel 250, tends to move bounce spring 236 away from the covering position of blade 228, thereby increasing the total arcuate travel of the latter.

Third arm 260 of element 253 is in the form of elongated lever, the radial end of which is adapted to project outwardly of the shutter support so as to be readily grasped by an operator of the mechanism. The shutter includes elongated link 264, one end of which is pivotally mounted at an intermediate position upon third arm 260, the other extremity of link 264 being pivotally coupled with diaphragm means 226 in a manner similar to the coupling provided by link 84 of FIG. 1, so that rotation of element

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253 under the bias of spring 256 moves the diaphragm means 226 to provide an increase in the aperture size defined by the diaphragm means as the position of the bounce spring is moved to increase the total arcuate travel of the shutter blade.

For initiating operation of this embodiment of the invention, there is provided a manually operable latch means such as slidably mounted L-shaped element 266. One limb of element 266 preferably projects beyond the shutter support so as to be available for the exertion of pressure thereagainst by an operator of the device. Element 266 is so located that the other limb thereof is normally in engagement with a portion of second arm 258, such as the radial extremity thereof, when spring 256 is stressed, bounce spring 236 is correspondingly in a position closely adjacent lug 234, and the shutter blade, of course, is in its covering position. Element 266 is preferably resiliently urged, as by spring 268, into its position of releasable engagement with arm 258.

Arm 258 is provided thereon with a raised portion or pin 270. When arm 258 is releasably engaged by element 266, pin 270 is in engagement with spring contact 272 of switch 180 for retaining the spring contact out of engagement with relatively fixed contact 276 of the switch.

In operation, pressure exerted by an operator of this embodiment against the manually engageable portion of element 266 forces the latter against spring 268 releasing element 266 from engagement with second arm 258, thereby freeing the latter for rotation in a clockwise direction under the impetus provided by spring 256. Element 253 then rotates, turning gear 252, wheel 250 and bounce spring 236, rotating the latter in a counterclockwise direction at a rate of speed determined largely by the force exerted by spring 256. Simultaneously, the rotation of element 253 is transmitted through link 264 to diaphragm means 226, causing the latter to move from a position preferably of complete closure with respect to an exposure aperture and expanding the effective exposure opening defined by the diaphragm means at a time rate of opening corresponding to the speed of movement of the bounce spring.

Also, the beginning of rotation of arm 258 in a clockwise direction releases pin 270 from engagement with spring contact 272 of switch 180, allowing the spring contact to move under its own resiliency into engagement with fixed contact 272 of the switch, thereby closing a circuit.

The circuit closed by switch 180 and employed with this embodiment of the invention is substantially the same circuit shown and described heretofore in connection with FIG. 7 and comprising a photoelectric cell 190, capacitor 192, an electromechanical transducer or solenoid 156 and trigger circuit 196, these elements being shown only diagrammatically in FIG. 8. The operation of the circuit is also substantially the same as the operation heretofore described regarding the circuit of FIG. 7 and results in actuation of solenoid 156. In this embodiment, the actuation of the solenoid then causes, after a time interval predetermined by the value of the resistance of the photoelectric cell and the value of the capacitor, latch means 246 to rotate in a clockwise direction. This rotation of the latch means releases kicker 240, the latter striking lug 234 of shutter blade 228 and causing it to rotate out of its covering position, thereby initiating exposure. As with the first embodiment, latch means 246 includes latching element or pawl 278 movable therewith. Because wheel 250 is provided about its external periphery with a continuous plurality of teeth, the rotation of latch means 246 in a clockwise direction moves pawl 278 into engagement with the teeth, thereby locking both the bounce spring and diaphragm in fixed positions almost immediately as exposure is initiated. This provides for the shutter mechanism an exposure value determined by both the distance the bounce spring has moved and the extent that the diaphragm means has opened during the time interval between release of element 253 (and the closure of switch 180) and the

actuation of latch means 245 by the solenoid. Because this time interval is a function of the light intensity upon photoelectric cell 190, it will be apparent that the exposure value is then determined according to ambient illumination as detected by the cell.

The bounce spring is returned to its initial position adjacent lug 234 and the diaphragm means is correspondingly returned to a position wherein it provides a minimum or no opening, as the case may be, simply by rotation by the operator of third arm 260 in a counterclockwise direction. The rotation of arm 260 continues until pin 270 reengages spring contact 272 and moves the latter out of engagement with the fixed contact thereby opening the switch. Simultaneously the spring loading on element 266 causes the latter to reengage the extremity of second arm 258 locking the latter in position. The rotation of element 253 in the counterclockwise direction, of course, stresses spring 256. Known means (not shown for the sake of simplicity) are preferably provided also for releasing pawl 278 from engagement with wheel 250 and rotating kicker 240 into engagement with latch means 246. Thus, this embodiment of the invention is reset for the next sequence of operations resulting in exposure.

In all of the embodiments of the invention heretofore described, the solenoid operated actuated mechanisms function when passage of current through the solenoids is initiated. These embodiments can also, with appropriate mechanical modifications, be actuated or made to operate on the basis of solenoid operated actuated mechanisms which function when passage of current through the solenoids is terminated. For instance, in the embodiment of FIG. 7, simply by interchanging the position of the capacitor and the photoelectric cell in the circuit, reverse action occurs.

Yet another embodiment of the present invention operates basically upon the principle of solenoid operation by turning off the current therethrough and is illustrated in the circuit of FIG. 10. This circuit is particularly well adapted for use with a two-bladed shutter mechanism, such as that shown in FIG. 9, wherein the sequential release of the blades determines the exposure time interval. Each blade is preferably solenoid actuated and the circuit uses the inductive "kick" derived from the opening of one solenoid in order to provide a large voltage for charging a capacitor. The discharge rate of the capacitor in terms of RC, where R is a photoelectric cell resistance and C the capacitance of the capacitor, determines the desired exposure time interval. In this particular embodiment, the provision of charging by induction allows the device to employ comparatively smaller capacitors than those circuits wherein the capacitor is charged directly from a battery. Another advantage with this type of circuit is the availability of higher voltages without the use of excessively large batteries and capacitors; such higher voltages will permit operation of the trigger circuit at higher current levels, and thus minimize the effects of leakage currents in the transistors.

Referring now specifically to the embodiment of the invention comprising the circuit of FIG. 10, there is shown means such as photoelectric cell 300 for establishing a relatively fixed or constant electrical parameter or voltage dependent upon the intensities of radiation incident thereon, and capacitor 302 for establishing a relatively variable electrical parameter. The circuit also includes another form of electronic trigger circuit 304, characterized in having positive feedback, and provided for comparing, in a sense, the electrical parameters provided respectively by the photoelectric cell and capacitor.

The circuit comprises a pair of transistors 306 and 308 which, in the form shown, are respectively of the NPN and PNP types. The transistors are connected so that the collector of transistor 306 is coupled to the base of transistor 308, the emitter of transistor 306 being grounded. One side of cell 300 is in series with the base of transistor 306, while the other side of the cell is con-

nected in series through capacitor 302 to the collector of transistor 308.

The embodiment of the invention shown in FIG. 10 also includes a pair of solenoid operated actuated mechanisms shown respectively and schematically as solenoids 310 and 312. The two solenoids are connected to one another in parallel through a switching means, such as switch 314. An electrically conductive lead 316 is tapped to a point intermediate solenoid 310 and switch 314, and couples the latter to a point intermediate capacitor 302 and cell 300 through a pair of electrical valves or diodes 318 and 320 in series with one another, diode 318 being the one closest to switch 314. Another electrically conducting lead 322 is provided for connecting a point intermediate the solenoids on the side of solenoid 312 opposite switch 314 to a point in the collector circuit of the transistor 308 intermediate the latter and capacitor 302. The emitter of transistor 308 is connected to a point intermediate diodes 318 and 320, means being provided for connecting the latter point to lead 322, and therefore to the collector circuit of transistor 308, through respectively another electrical valve, or diode 324, and a switch means, such as switch 326, in series with one another. A point intermediate diode 324 and switch 326 is connected to one terminal, such as the positive side of a D.C. power source, or battery 328, the other side of the battery being grounded. A point intermediate switch 314 and solenoid 312 is also tapped to ground. Diode 324 is placed in the circuit in known manner so that current can only flow therethrough into the emitter of transistor 308 while diodes 318 and 320 respectively are placed in the circuit so that current can only flow in the same direction through both and away from switch 314.

There will be seen in FIG. 9 a schematic showing of a shutter mechanism useful with the circuit of FIG. 10 and comprising a pair of solenoid operated electromagnetic transducers such as relays 330 and 332, respectively, comprising soft iron (such as transformer iron) cores wrapped in solenoids 310 and 312. Each of relay 330 and 332 includes as a portion thereof a pivotally mounted armature, shown respectively as rocker elements 334 and 336, similar to rocker 162 shown and described in connection with FIG. 4. However, rocker elements 334 and 336 have respectively connected thereto means, such as springs 338 and 340, for moving them in predetermined directions of rotation; rocker elements 334 and 336 having respectively attached thereto and movable therewith substantially planar shutter blades 342 and 344 which are made and disposed similarly to the shutter blades of FIG. 4. Rocker element 336 is normally disposed so that blade 344 is in uncovering position to exposure aperture 346, while rocker element 334 is normally disposed such that blade 342 is in covering position with respect to the exposure aperture, both springs 338 and 340 exerting biases tending to move the rocker elements out of normal disposition. Both rocker elements are formed of a magnetizable metal, such as soft iron. The electromagnetic transducers of this embodiment differ primarily from those shown in FIG. 4 in that the rocker elements of the former, when in their normal position, are in contact with the soft iron cores of the solenoids.

Means such as actuating element 350 are provided for initiating operation of the shutter mechanism. Element 350 is formed as a Y-shaped structure mounted pivotally adjacent the juncture of its three arms and being urged by resilient means such as spring 352 such that each of two of its arms are respectively in engagement with and releasably retain portions of the rocker elements against the relay cores so that the blades are in their normal position. The third arm of element 350 is manually engageable so that an operator of the device can rotate element 350 against the bias of spring 352 thereby moving the other two arms out of engagement respectively with the other two rocker elements.

The embodiment of FIG. 9 also includes a timing de-

vice comprising a fly-wheel 354 biased for rotation by spring 356 and held in a predetermined position against the bias of spring 356 by engagement of a portion of the fly-wheel with portion 358 of element 350 when the latter is in engagement with the rocker elements. Switches 314 and 326 are respectively operable in sequence following the release of fly-wheel 354 inasmuch as switch 314 comprises a pair of switch contacts, at least one of which is normally held in contact with the other (to provide a closed circuit) by engagement with portion 360 of the fly-wheel when the latter is in its predetermined position; the one contact is preferably resiliently biased to open switch 314 when released from engagement with the fly-wheel. Switch 316 in turn comprises a pair of contacts normally in contact with one another, and at least one of which is in the path of movement of portion 360 of fly-wheel 354 such that the switch contacts are forced out of engagement with one another when the one contact is engaged by portion 360 during its movement. The one contact of switch 326 is preferably biased to close the switch when released from engagement with the fly-wheel.

Means, well known in the art, for resetting fly-wheel 354 following displacement thereof from its predetermined position may be provided, but have been omitted for the sake of clarity. Stop means, such as pin 362, are provided in the path of movement of portion 358 of the fly-wheel in order to limit its rotation under the bias of spring 356.

In operation, pressure is exerted by an operator against the manually engageable portion of element 350, rotating the latter in a clockwise direction against the bias of spring 352 and disengaging the other two arms of element 350 from rocker elements 334 and 336. Substantially simultaneously, the clockwise rotation of element 350 disengages the latter from portion 358 of fly-wheel 354, permitting the fly-wheel to rotate in a counterclockwise direction under the impetus provided by spring 356. The rotation of the fly-wheel first allows switch 314 to open, then portion 360 of the fly-wheel engages one contact of switch 326 and opens the latter in sequence. In the preferred embodiment, the factors, such as rotational inertia, spring tension, etc., which control the rate of counterclockwise rotation of the fly-wheel are chosen so that the time interval between the sequential opening of the two switches is in the nature of one millisecond.

When switch 314 and 326 are initially closed, solenoids 310 and 312 are energized and there is no charge on capacitor 302. When switch 314 is opened, the current from battery 328 passing through solenoid 310 is cut off, causing a collapse of the magnetic field of the solenoid. The magnetic force holding rocker 334 decreases, until the bias imposed by spring 338 is sufficient to cause rotation of the rocker in a clockwise direction. This latter rotation moves blade 342 out of its covering position thereby initiating exposure through aperture 346. The rapid clockwise rotation of rocker 334 through the collapsing magnetic field of solenoid 310 induces a current surge or inductive "kick" in the solenoid, having the same polarity as the battery. The inductive "kick" charges capacitor 302 to a much higher voltage than that of the battery. For instance, in one embodiment of the invention wherein battery 328 is a 1.5 volt D.C. power source, capacitor 302 is a 0.2 mfd. condenser and solenoid 310 is a 1,000 turn, No. 30 wire, 10 ohm solenoid with a transformer iron core, the capacitor can be charged to approximately 40 to 50 volts from the inductive "kick." The charge on the capacitor is a function of the resistance of photoelectric cell 300 inasmuch as the capacitor is shunted by transistor 308. As long as switch 326 remains closed, transistors 306 and 308 will conduct, the base current of transistor 308 being controlled by the collector current of transistor 306, which in turn is controlled by its base current according to the value of the resistance of cell 300.

The capacitor starts discharging approximately as soon as it is charged up. The charging time is quite short and

fly-wheel 354 is adapted to open switch 326 substantially at the same time as the charge on the capacitor reaches peak value. The discharge rate of capacitor 302 is linearly proportional to the resistance of cell 300, i.e., the discharge current is equal to the product of capacitor voltage times cell conductance ($E_c P$). When $E_c P$ falls below a value predetermined by the trigger circuit, transistors 306 and 308 are no longer in saturation. The transistors are considered in saturation when current through the photocell is sufficient such that the battery current through solenoid 312 is limited by the resistance of the latter. Now as the current through solenoid 312 drops, there is a tendency due to the inductance of the solenoid to keep the current flowing and the solenoid is no longer capable of drawing current directly from the battery, being cut off from the latter by the opening of switch 326. Since transistor 308 is now cutting off and limiting the current therethrough, the inductive effect of solenoid 312 pulls current from capacitor 302, accelerating its discharge. This latter constitutes a positive feedback loop which renders the transistors abruptly nonconductive and providing high speed collapse of the magnetic field of solenoid 312. When the magnetic field of the latter collapses, it is no longer capable of retaining rocker element 336 in its normal position against the bias of spring 40 and the latter causes blade 344 to rotate into a position of closure with respect to the exposure aperture, thereby abruptly terminating exposure. It will be seen that the time interval between initiation and termination of exposure is a function of the time constant of the capacitor and photocell relationship. In the preferred operation, the sequence of operation of switches 314 and 326 should occupy an interval of not more than the shortest time delay expected from the time constant of the circuit. It will be seen in the operation of the circuit of FIG. 10 that diode 320 provides means for preventing the capacitor from discharging back through solenoid 310. Similarly, diode 324 provides means which prevents the inductive "kick" from solenoid 310 from traversing battery 328. Diode 318 is provided in the circuit in order to prevent a short circuit of battery 328 when switch 314 is in its closed position. It should be noted that when switch 326 is opened, the battery bias upon the base of transistor 306 is reduced, but due to the charge on capacitor 302 the base of the transistor remains biased until the capacitor discharge drops the base current below its critical value.

Still another form of the invention is shown in FIGS. 11 and 12 wherein the exposure control mechanism is in the form of a so-called "guillotine" shutter in which a pair of juxtaposed shutter blades are slidably mounted and moved in sequence to effect exposures. Again, a solenoid is utilized to control the exposure interval by releasing one of the blades to effect termination of exposure. As with several of the previous arrangements, the exposure control mechanism includes a fixed exposure aperture 400 formed in the shutter housing, a part of which is shown at 402. Cooperating with the exposure aperture to effect exposure therethrough are a pair of slidably mounted opaque shutter blades 404, 406, each of which has an opening therein at 408, 410, respectively. The openings are formed in opposite ends of the shutter blades so that when the blades are in the rest position shown in FIG. 11, an opaque portion of each blade overlies the opening in the other blade so that the two blades together cover the exposure aperture.

The blades are held in the rest position against the biasing action of a pair of springs 412, 414 connected, respectively, to corresponding extremities of blades 404, 406. To hold the blades against the biasing action of the springs, there is provided a latch in the form of an elongated lever 416 pivotally mounted in the shutter housing at 418 and having a latching portion 420 at one extremity thereof which cooperates with a suitable pin 422 affixed to shutter blade 404. At the other extremity of

lever 416 there is affixed one end of a shaft 424 to the outer end of which has secured thereto a suitable shutter release button 426. Spring 423 is also connected to this portion of lever 416, and the spring is biased such that it tends to rotate the lever in a clockwise direction to hold the latch portion 420 securely against pin 422.

To hold the blade 406 at the rest position, blade 404 has a shaft 430 extending from one end thereof beyond the corresponding end of blade 406.

Affixed to the other end of blade 406 is a magnetic keeper element 432 located adjacent to solenoid 434 and held thereby when the solenoid is energized.

A switch S2 having a pair of resilient conducting members 436, 438 is normally closed when the parts are in the rest position by means of a conducting member 440 affixed to the end of blade 404, insulated therefrom, and arranged to bridge the members 436, 438 when proximate thereto.

A second switch S1 has a pair of resilient members 442, 444 which are normally open when the parts are in the rest position but arranged to close when the release button 426 is depressed. In one form of switch S1, resilient member 444 is mounted in a fixed position and element 442 is mounted on the shaft 424, suitably insulated therefrom, such that movement of the shaft causes the elements to come together and close the switch. The switch will remain closed so long as the button is held by the camera operator.

In order to cock the shutter mechanism, a suitable cocking member in the form of a pivotally mounted bell-crank 446 is arranged in the shutter housing having arms 448, 450. Arm 448 is normally adjacent the ends of the blades 404, 406 following completion of exposure and arm 450 is arranged to project from the shutter housing and has affixed to its outer end a cocking button 452 which may be manipulated by the camera operator to move the cocking member in a counterclockwise direction to effect return of the shutter blades to the rest position.

With the above arrangement of parts in mind, it is apparent that depression of button 426 will lift latch portion 420 from pin 422 to allow shutter blade 404 to move under the biasing action of spring 412. This motion will bring the shutter blade 404 to its exposure position at which its aperture 408 will be aligned with aperture 410 to effect exposure through the exposure aperture 400. At the proper interval following initiation of exposure, solenoid 434 (which has been energized coincident with depression of button 426) will be deenergized by operation of the electronic trigger circuit, thus allowing blade 406 to be moved by its spring 414. This moves aperture 410 away from exposure aperture 400 and allows the opaque portion of blade 406 to cover the exposure aperture and terminate exposure.

To cock the shutter for the next exposure, the cocking button 452 will be moved in a counterclockwise direction, and this will cause arm 448 to engage rod 430 and move the two shutter blades back together to the rest position at which the latch portion 420 will ride up over pin 422 and then drop down behind it to hold the parts at the rest position. A spring 454 affixed to arm 448 allows the cocking button to return to its normal position.

Looking now at the schematic diagram of FIG. 12, there is shown a pair of transistors 456, 458 coupled together and to solenoid 434 and a photoelectric cell 460. Cell 460 is a suitable photoconductive member whose resistance varies inversely as a function of changes in ambient light. The transistors, 456, 458 may be either PNP or NPN depending upon the polarity of the source. There is provided a suitable source of electric energy in the form of battery 461, one terminal of which is grounded and connected by means of lead 462 to one side of photoelectric cell 460 through switch S2, the other terminal of which is connected by means of lead 464 to the other side of photoelectric cell 460 through switch S1. The base of

transistor 456 is connected between cell 460 and switch S2 by means of lead 466 and the base of transistor 458 is connected to the collector electrode of transistor 456. A capacitor 468 is connected across cell 460 between leads 464 and 466. A resistor 470 is connected from lead 464 to the collector of transistor 456. Solenoid 434 is connected to the collector of transistor 458 from lead 464. A capacitor is connected across the solenoid to protect the transistors against "fly-back" surges during collapse of the solenoid's magnetic field; the capacitor also minimizes the release time of the solenoid and holds this time within tolerable limits from unit to unit. The emitter of transistor 456 is connected by means of a tap 472 to a resistor 480 connected between lead 462 and the emitter of transistor 458. A compensating resistor 482 is connected between switch S2 and lead 466.

In operation of the above circuit, when the shutter is in the rest position, switch S2 is closed, and upon actuation of shutter release button 426, switch S1 is closed. When switch S1 closes, capacitor 468 immediately becomes charged to almost the potential of battery 461 and the circuit parameters are selected so that transistor 458 is "on," or conducting, and transistor 456 is "off," or non-conducting. This allows solenoid 434 to be energized and hold the blade 406 in the rest position.

Shortly after switch S1 is closed, continued movement of the release button 426 will raise the latch portion 420 from pin 422 and allow shutter blade 404 to move and thus open switch S2. When switch S2 opens, capacitor 468 discharges across the cell 460, and its rate of discharge will be determined by the magnitude of resistance assumed by the cell at that particular instant. When the capacitor voltage reaches a level at which the base of transistor 456 is properly biased, it will be switched "on" and thus become conducting, which will have the effect of switching "off" transistor 458 and cause it to be non-conducting, which in turn deenergizes solenoid 434. When this happens, shutter blade 406 is released and is moved by its spring to terminate exposure.

The two transistors operate as a conventional trigger circuit and provide instantaneous switching when required to terminate exposure in accordance with the proper exposure interval, as determined by the magnitude of resistance of photoelectric cell 460 and the capacity of capacitor 468.

It has been found that a suitable photoelectric cell for inclusion in the circuit of FIG. 12 will vary in resistance from 100,000 ohms to 100 ohms as the light level varies between very low and very high levels. The capacitor 468 may have a value of capacitance ranging from 1 microfarad to 50 microfarads, the exact value selected being dependent upon the range in the ASA rating of the speed of film intended to be used with this exposure-control mechanism. In practice, a plurality of capacitors could be provided covering a range in capacitance corresponding to a range in film speed, with suitable switching arrangements also provided to select the particular capacitor that corresponds to the particular film being used in the camera at any particular time.

It is also possible to accommodate films of widely differing speeds with a single capacitor; but in this event, the exposure aperture 400 could be varied through an appropriate range, or a filter could be placed in front of the photoelectric cell, to have the circuit function properly through the range of film speeds used. In the arrangement shown, the aperture 400 may be f8.8 to provide suitable exposure for a range in film speeds between ASA 50 and ASA 3000. For this range, two selectively usable capacitors may be provided.

The resistor 482 is a compensating resistor having a low value of resistance, and this is used because the photoelectric cell does not have a truly linear characteristic, particularly at high light levels, when its resistance becomes too low for proper action in the circuit arrangement of FIG. 12. The value of resistance of resistor 482 is selected

to compensate for the action of the photoelectric cell at high light levels; that is, at such high light levels, the voltage drop across resistor 482 during charging of capacitor 468 is a significant amount compared to the voltage drop across cell 460 and has the effect of reducing the charge on the capacitor. The effect is to "speed up" the action of the capacitor at high light levels, for its voltage has been reduced prior to initiation of discharge, thus permitting it to reach the desired "trigger" value within the proper control interval. At the lower light levels, the resistance of cell 460 is so much higher than that of resistor 482 that the latter has no significant effect on the level of voltage to which the capacitor is charged.

In practice, the various components of the circuit of FIG. 12 will have slight variations in value within specified tolerances; and in order to compensate for such variations and calibrate the circuit for proper triggering action, the tap 472 and associated resistor 480 are provided.

In the shutter mechanism of FIG. 11 the blades have been designed to come to rest after release in a period of 2 milliseconds. The capacitor 468 is charged in less than 1 millisecond and is ready to discharge substantially coincident with release of blade 404. For exposure intervals on the order of 1 millisecond, the two blades will be moving together during exposure; that is, approximately 1 millisecond after release of blade 404, blade 406 will be released and the apertures 408, 410 will be moving together somewhat like a curtain shutter with respect to exposure aperture 400.

For extremely low levels of light, the shutter mechanism has been designed to provide an exposure interval up to 30 second in duration.

For flash operation, suitable flash synchronizing contacts may be added to the shutter mechanism and arranged to close coincident with full shutter opening after release of the blade 404. The dotted construction in FIG. 12 shows one arrangement for providing flash synchronizing contacts by the addition of another fixed contact to switch S2, which closes the flash-lamp circuit when switch S2 opens. Since all commercially available flash bulbs presently in use have a time delay on the order of 3 or more milliseconds for attaining significant levels of illumination, the shutter mechanism will open fully and remain open until the light reflected from the subject reaches a sufficient level to cause the photoelectric cell to change its resistance to initiate trigger action. Photoelectric cell 460 responds very rapidly to changes in ambient light (about 1-5 milliseconds time delay between high and low levels of light), and this dynamic response enables the shutter mechanism to respond dynamically to changing light levels and still function properly to automatically control exposure. With a cell having a maximum time delay of 5 milliseconds upon an abrupt change in ambient illumination from 10 to 30 lumens, and with a flash lamp having a slow rise-time after energization to reach peak brilliance, i.e., on the order of 25-40 milliseconds, the exposure control mechanism of FIGS. 11 and 12 will function to automatically control exposures for flash photography when the object being photographed is between 3-4 feet and 10-15 feet from the camera. Such exposures will be of short enough duration to allow the camera to be hand-held during exposure.

The exposure control mechanism of FIGS. 11 and 12, with its transistorized trigger circuit and closely-spaced sliding shutter blades, can be arranged very compactly when assembled as part of a camera: viz.; in one arrangement, the exposure control mechanism and associated objective, lens system may be readily contained within a substantially flat, rectangular housing measuring 1½" wide x 3" long x ¾"-½" thick.

Since certain changes may be made in the above apparatus without departing from the scope of the invention herein involved, it is intended that all matter contained in the above description or shown in the accompanying draw-

ings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. Automatic photographic exposure control means adapted to establish an exposure parameter in accordance with the intensity of light from a scene being photographed, said exposure control means comprising, in combination:

- (a) at least two elements mounted for movement from initial to terminal positions, and so constructed and arranged that the time period between initiation and termination of movement of said elements is determinative of said exposure parameter;
- (b) means for releasably retaining said elements in said initial positions;
- (c) first operator means selectively movable to permit movement of at least one of said elements away from its initial position and toward its terminal position;
- (d) an electronic trigger circuit adapted to establish a time interval beginning with actuation of said circuit and ending with triggering thereof;
- (e) photoelectric means arranged to receive light from said scene and having an electrical property which varies functionally with variations in intensity of said light;
- (f) said photoelectric means being so arranged in said circuit that said time interval is functionally related to the value of said electrical property, and thereby to the intensity of scene light;
- (g) actuator means for actuating said circuit in response to movement of said first operator means, thereby synchronizing commencement of said time interval with initial movement of at least said one of said elements;
- (h) second operator means actuatable to effect termination of movement of said elements; and
- (i) means for actuating said second operator means in response to triggering of said circuit, whereby said time period from initiation to termination of movement of said elements is synchronized with and established by said time interval between actuation and triggering of said circuit.

2. The invention according to claim 1 wherein said elements comprise a pair of shutter blades movable in sequence to uncover and cover an exposure aperture, said time period running from initiation of movement of the first of said blades to uncover said aperture to termination of movement of the second of said blades to cover said aperture.

3. The combination, with means defining an exposure aperture adapted to pass incident light from a scene for exposing film or the like, of automatic exposure means comprising:

- (a) a pair of movable shutter blades having a blocking position covering said aperture and an unblocking position uncovering said aperture for controlling the passage of incident light therethrough;
- (b) first shutter operator means selectively operable to permit movement of said blades to said unblocking position, thereby initiating an exposure;
- (c) second shutter operator means operable to permit movement of said blades to said blocking position, thereby terminating said exposure;
- (d) a voltage sensitive trigger circuit for operating said second shutter operator means; and
- (e) a timing network, including a photoconductor exposed to light from said scene and having a resistance which varies functionally with variations in the level of scene brightness;
- (f) said voltage sensitive trigger circuit being responsive to the resistance of said photoconductor for operating said second shutter operator means and terminating exposure;
- (g) said timing network being constructed and ar-

ranged so that the resistance of said photoconductor during the exposure interval between initiation and termination of exposure is a parameter which determines such interval.

4. An automatic exposure control device comprising, in combination:

- (a) means defining an exposure aperture;
- (b) first and second shutter blades positioned proximate to said exposure aperture for covering the latter when said blades are in an initial position;
- (c) means for moving said first blade to uncover said aperture, thereby initiating an exposure there-through;
- (d) a solenoid holding mechanism adapted to hold said second blade in its initial position when said mechanism is energized;
- (e) an electronic trigger circuit adapted to establish a time interval beginning with actuation of said circuit and ending with trigger thereof;
- (f) photoelectric means arranged to receive light from the scene being photographed and having an electrical property which varies functionally with variations in intensity of said light;
- (g) said photoelectric means being so arranged in said circuit that said time interval is functionally related to the value of said electrical property, and thereby to the intensity of scene light;
- (h) means for energizing said solenoid holding mechanism prior to movement of said first blade;
- (i) means for de-energizing said solenoid holding mechanism in response to triggering of said circuit; and
- (j) means for moving said second blade, in response to de-energization of said solenoid holding mechanism, to cover said exposure aperture, thereby terminating exposure therethrough.

5. An automatic exposure device in accordance with claim 4 in which said photoelectric means comprises a photoconductive element whose electrical resistance varies inversely in accordance with variations in ambient illumination and said trigger circuit includes a capacitor, said exposure intervals being a function of the product of the value of resistance times the value of capacitance of said photoconductive element and said capacitor, respectively.

6. An automatic exposure device in accordance with claim 5 in which said trigger circuit includes a resistor having a fixed value of resistance which is of the same order of magnitude as the value of resistance assumed by said photoconductive element at relatively high levels of ambient illumination whereby said exposure intervals are primarily a function of the product of said fixed value of resistance and said value of capacitance at said relatively high levels of ambient illumination.

7. An automatic exposure control device comprising, in combination:

- (a) means defining an exposure aperture;
- (b) first and second shutter blades positioned proximate to said exposure aperture and sequentially movable between covering and uncovering positions with respect thereto;
- (c) means for moving said first blade to uncover said aperture, thereby initiating an exposure there-through;
- (d) a solenoid holding mechanism adapted to hold said second blade in uncovering relation to said exposure aperture when said mechanism is energized;
- (e) means for energizing said solenoid holding mechanism;
- (f) an electronic trigger circuit operable upon triggering to de-energize said solenoid holding mechanism;
- (g) said trigger circuit including photoconductive means arranged to receive light from the scene being photographed and having an electrical resistance functionally related to the intensity of said light, a

capacitor and a switch movable between open and closed positions;

- (h) means adapted initially to retain said switch in said closed position;
- (i) means for charging said capacitor to a first predetermined value of voltage when said switch is in said closed position;
- (j) means for moving said switch to said open position in response to movement of said first shutter blade to initiate exposure;
- (k) means for discharging said capacitor, in response to movement of said switch to said open position, from said first predetermined value of voltage to a second predetermined value of voltage, the rate of discharge of said capacitor being a function of the product of the value of resistance of said photoconductive means and the value of capacitance of said capacitor;
- (l) said trigger circuit acting in response to said second predetermined value of voltage to de-energize said solenoid holding mechanism; and
- (m) means for moving said second blade in response to de-energization of said solenoid holding mechanism to cover said exposure aperture, thereby terminating said exposure.

8. An automatic exposure control device as defined in claim 7 wherein said trigger circuit includes a second normally open switch, and said device includes an actuator for closing said second switch prior to movement of said first blade.

9. An automatic exposure control device as defined in claim 8 wherein said photoconductive means has a maximum time delay of about 5 milliseconds in responding to abrupt changes in ambient light between 10 and 30 lumens.

10. The combination, with means defining an exposure aperture adapted to pass incident light from a scene for exposing film or the like, of automatic exposure control means comprising:

- (a) a pair of movable shutter blades having a blocking position covering said aperture and an unblocking position uncovering said aperture for controlling the passage of incident light therethrough;
- (b) first shutter operator means selectively operable to permit movement of said blades to said unblocking position, thereby initiating an exposure;
- (c) second shutter operator means operable to permit movement of said blades to said blocking position, thereby terminating said exposure;
- (d) a voltage sensitive trigger circuit for operating said second shutter operator means; and
- (e) a timing network, including a photoconductor exposed to light from said scene and having a resistance which varies functionally with variations in the level of scene brightness, for generating a time variable voltage in response to initiation of exposure by said shutter blades;
- (f) said voltage sensitive trigger circuit being responsive to said time variable voltage for operating said second shutter operator means when the voltage reaches a predetermined level and terminating exposure;
- (g) said timing network being constructed and arranged so that the resistance of said photoconductor during the exposure interval between initiation and termination of exposure is a parameter which determines such interval.

11. Apparatus in accordance with claim 10 wherein:

- (a) the resistance of said photoconductor bears a substantially linear relationship to brightness over a range of relatively low levels of steady-state brightness for causing said exposure interval to bear a substantially linear relationship to brightness over said low levels of steady-state brightness;
- (b) the resistance of said photoconductor bears a

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- nonlinear relationship to brightness over a range of relatively higher levels of steady-state brightness; and
- (c) means to compensate said timing network so that said exposure interval bears a substantially linear relationship to brightness over said higher levels of steady-state brightness.
12. Apparatus in accordance with claim 10 wherein:
- (a) said timing network is an R-C integrating circuit having an input and an output, the latter being connected to said voltage sensitive trigger circuit;
- (b) means are provided for applying a step function to said input in response to initiation of exposure;
- (c) said photoconductor constitutes the resistance of said integrating circuit;
- (d) the capacitance of said integrating circuit is constituted by a capacitor;
- (e) means are provided for causing said capacitor to have an initial voltage thereacross when said step function is applied to said input, the magnitude of said initial voltage being inversely related to the level of scene brightness when exposure is initiated.
13. The combination, with means defining an exposure aperture adapted to pass incident light from a scene for exposing film or the like, of automatic exposure control means comprising:
- (a) movable opening and closing shutter blades, each having a blocking position overlying said aperture and an unblocking position uncovering said aperture for controlling the passage of incident light there-through;
- (b) first coupling means releasably engaged with said opening blade when the latter is in blocking position for releasably maintaining the opening blade in blocking position;
- (c) means to disengage said first coupling means from said opening blade;
- (d) means made effective upon disengagement of said first coupling means to move said opening blade from blocking to unblocking position;
- (e) closing blade operator means responsive to the disengagement of said first coupling means for releasably maintaining said closing blade in unblocking position whereby incident light passes through said aperture to initiate exposure;
- (f) said operator means being constructed and arranged so that it is operable to release said closing blade;
- (g) means made effective upon release of said closing blade to move the latter to blocking position whereby incident light is prevented from passing through said aperture to terminate exposure; and
- (h) means responsive to the level of scene brightness for automatically operating said operator means after a preselected amount of light has passed through said aperture.
14. Apparatus in accordance with claim 13 wherein said last-named means comprises:
- (a) a timing network, including a photoconductor exposed to light from said scene and having a resistance which varies functionally with variations in the level of scene brightness for generating a time variable voltage in response to disengagement of said first coupling means from said opening blade; and
- (b) a voltage sensitive trigger circuit responsive to the time variable voltage generated by said timing network for operating said operator means when the voltage reaches a predetermined level;
- (c) said timing network being constructed and arranged so that the resistance of said photoconductor during the exposure interval between initiation and termination of exposure is a parameter which determines such interval.
15. Apparatus in accordance with claim 14 wherein:
- (a) said timing network is an R-C integrating circuit
- having an input and an output, the latter being connected to said voltage sensitive trigger circuit;
- (b) means are provided for applying a step function to said input in response to initiation of exposure;
- (c) said photoconductor constitutes the resistance of said integrating circuit;
- (d) the capacitance of said integrating circuit is constituted by a capacitor;
- (e) means are provided for causing said capacitor to have an initial voltage thereacross when said step function is applied to said input, the magnitude of said initial voltage being inversely related to the level of scene brightness when exposure is initiated.
16. Apparatus in accordance with claim 14 wherein:
- (a) the resistance of said photoconductor bears a substantially linear relationship to brightness over a range of relatively low levels of steady-state brightness for causing said exposure interval to bear a substantially linear relationship to brightness over said low levels of a steady-state brightness;
- (b) the resistance of said photoconductor bears a nonlinear relationship to brightness over a range of relatively higher levels of steady-state brightness; and
- (c) means to compensate said timing network so that said exposure interval bears a substantially linear relationship to brightness over said higher levels of steady-state brightness.
17. Apparatus in accordance with claim 17 wherein said closing blade operator means includes:
- (a) an electromagnet energizable in response to the disengagement of said first coupling means to magnetically maintain said closing blade in unblocking position; and
- (b) means for causing said electromagnet to be deenergized when the time variable voltage generated by said timing circuit reaches said predetermined level to effect release of said closing blade.
18. Apparatus in accordance with claim 14 wherein said closing blade operator means includes an electromagnet energizable to magnetically maintain said closing blade in unblocking position and deenergizable to effect release of said closing blade, and said voltage sensitive trigger circuit comprises:
- (a) a first transistor stage constructed and arranged to conduct when a source of bias is applied for energizing said electromagnet;
- (b) a source of bias;
- (c) means responsive to the disengagement of said first coupling means for applying said source to said first stage whereby said electromagnet is energized and exposure is initiated;
- (d) a second transistor stage regeneratively coupled to said first stage for rapidly cutting off the latter when said second stage begins to conduct;
- (e) said second stage being responsive to the time variable voltage generated by said timing network for remaining nonconducting until said voltage reaches said predetermined level whereby said electromagnet is deenergized and exposure is terminated.
19. The combination, with means defining an exposure aperture adapted to pass incident light from a scene for exposing film or the like, of automatic exposure control means comprising:
- (a) movable opening and closing shutter blades, each having a blocking position overlying said aperture and an unblocking position uncovering said aperture for controlling the passage of incident light there-through;
- (b) first coupling means releasably engaged with said opening blade when the latter is in blocking position for releasably maintaining the opening blade in blocking position;
- (c) means to disengage said first coupling means from said opening blade;

- (d) means made effective upon disengagement of said first coupling means to move said opening blade from blocking to unblocking position;
 - (e) electromagnetic means cooperable with said closing blade when the latter is in unblocking position and energizable to maintain said closing blade in unblocking position; 5
 - (f) power means for energizing said electromagnetic means;
 - (g) means responsive to the disengagement of said first coupling means to connect said power means to said electromagnetic means to energize the latter substantially simultaneously with said disengagement for maintaining said closing blade in unblocking position whereby incident light passes through said aperture to initiate exposure; 10 15
 - (h) a timing circuit including a photocell which is exposed to light from said scene and which has an electrical property whose magnitude is functionally related to the brightness of said scene; 20
 - (i) said timing circuit having an input terminal to which said power means is applicable to make the circuit operative, and an output terminal at which the voltage changes from an initial value when the power means is applied to a preselected value after a period of time functionally dependent upon the magnitude of said physical property; 25
 - (j) means responsive to the disengagement of said first coupling means to connect said power means to the input terminal of said timing circuit to render the latter operative; 30
 - (k) means responsive to the voltage at the output of said timing circuit to deactuate said electromagnetic means when the voltage reaches said preselected value; and 35
 - (l) means made effective upon deenergization of said electromagnetic means to move said closing blade to blocking position whereby incident light is then prevented from passing said aperture to terminate exposure. 40
20. The combination, with means defining an exposure aperture adapted to pass incident light from a scene for exposing film or the like, of automatic exposure control means comprising:
- (a) movable opening and closing shutter blades, each having a blocking position overlying said aperture and an unblocking position uncovering said aperture for controlling the passage of incident light there-through; 45
 - (b) first coupling means releasably engaged with said opening blade when the latter is in blocking position for releasably maintaining the opening blade in blocking position; 50
 - (c) means to disengage said first coupling means from said opening blade; 55
 - (d) means made effective upon disengagement of said first coupling means to move said opening blade from blocking to unblocking position;
 - (e) second coupling means cooperable with said closing blade when the latter is in unblocking position and actuatable to maintain said closing blade in unblocking position; 60
 - (f) means responsive to the disengagement of said first coupling means to actuate said second coupling means substantially simultaneously with said disengagement for maintaining said closing blade in unblocking position as said opening blade moves to unblocking position whereby incident light passes through said aperture to initiate exposure; 65
 - (g) an R-C timing circuit including a photocell exposed to light from said subject wherein the internal resistance of said photocell constitutes the resistance of the R-C circuit and bears a substantially linear relationship to the scene brightness over a range of relatively low levels of brightness and a non-linear 70 75

- relationship to the scene brightness over a range of relatively high levels of brightness;
 - (h) said timing circuit having a time-variable voltage output which changes from an initial value when the circuit is made operative to a preselected value after a period of time functionally dependent upon the magnitude of said resistance;
 - (i) means responsive to the disengagement of said first coupling means to make said timing circuit operative;
 - (j) means responsive to the voltage at the output terminal of said timing circuit to deactuate said second coupling means when said voltage reaches said preselected value;
 - (k) means made effective upon deactuation of said second coupling means to move said closing blade to blocking position whereby incident light is then prevented from passing said aperture to terminate exposure; and
 - (l) means to cause the initial value of the voltage output to be closer to said preselected value when the scene brightness is in the relatively high range than when the scene brightness is in the relatively low range.
21. The combination, with means defining an exposure aperture adapted to pass incident light from a scene for exposing film or the like, of automatic exposure control means comprising:
- (a) movable opening and closing shutter blades, each having a blocking position overlying said aperture and an unblocking position uncovering said aperture for controlling the passage of incident light there-through;
 - (b) reset means on said opening blade engageable with said closing blade for moving the latter to unblocking position when the opening blade is moved to blocking position, but being constructed and arranged so that independent movement of said opening blade to unblocking position can occur without directly imparting movement to said closing blade;
 - (c) first coupling means releasably engaged with said opening blade when the latter is in blocking position for releasably maintaining the opening blade in blocking position;
 - (d) said reset means being effective to maintain said closing blade in unblocking position during engagement of said first coupling means with said opening blade;
 - (e) means to disengage said first coupling means from said opening blade;
 - (f) means made effective upon disengagement of said first coupling means to move said opening blade from blocking to unblocking position;
 - (g) second coupling means cooperable with said closing blade when the latter is in unblocking position and actuatable to maintain said closing blade in unblocking position;
 - (h) means responsive to the disengagement of said first coupling means to actuate said second coupling means substantially simultaneously with said disengagement for maintaining said closing blade in unblocking position as said opening blade moves to unblocking position whereby incident light passes through said aperture to initiate exposure;
 - (i) means responsive to the level of scene brightness to deactuate said second coupling means after a preselected amount of light has passed through said aperture; and
 - (j) means made effective upon deactuation of said second coupling means to move said closing blade to blocking position whereby incident light is then prevented from passing said aperture to terminate exposure.
22. The combination, with means defining an exposure aperture adapted to pass incident light from a scene for

exposing film or the like, of automatic exposure control means comprising:

- (a) movable opening and closing shutter blades, each having a blocking position overlying said aperture and an unblocking position uncovering said aperture for controlling the passage of incident light there-through; 5
- (b) first coupling means releasably engaged with said opening blade when the latter is in blocking position for releasably maintaining the opening blade in blocking position; 10
- (c) means to disengage said first coupling means from said opening blade;
- (d) means made effective upon disengagement of said first coupling means to move said opening blade from blocking to unblocking position; 15
- (e) second coupling means cooperable with said closing blade when the latter is in unblocking position and actuatable to maintain said closing blade in unblocking position; 20
- (f) means responsive to the disengagement of said first coupling means to actuate said second coupling means substantially simultaneously with said disengagement for maintaining said second blade in unblocking position as said first blade moves to unblocking position whereby incident light passes through said aperture to initiate exposure; 25
- (g) a timing circuit including a fast acting photocell which is exposed to light from said scene after said first blade moves to unblocking position and whose internal resistance varies inversely with variations in the scene brightness; 30
- (h) said timing circuit having a time variable voltage output which, after said circuit is made operative, has a value which depends upon the variation of said resistance subsequent to when the circuit is made operative; 35
- (i) means responsive to the disengagement of said first coupling means to make said timing circuit operative;
- (j) means responsive to said voltage to deactuate said second coupling means when said voltage reaches said preselected value; and 40
- (k) means made effective upon deactuation of said second coupling means to move said second blade to blocking position whereby incident light is then prevented from passing said aperture to terminate exposure. 45

23. The combination, with means defining an exposure aperture adapted to pass incident light from a scene for exposing film or the like, of automatic exposure control means comprising: 50

- (a) movable opening and closing shutter blades, each having a blocking position overlying said aperture and an unblocking position uncovering said aperture for controlling the passage of incident light there-through; 55
- (b) first coupling means releasably engaged with said opening blade when the latter is in blocking position for releasably maintaining the opening blade in blocking position;
- (c) means to disengage said first coupling means from said opening blade; 60
- (d) means made effective upon disengagement of said first coupling means to move said opening blade from blocking to unblocking position;
- (e) second coupling means cooperable with said closing blade when the latter is in unblocking position and actuatable to maintain said closing blade in unblocking position; 65
- (f) means responsive to the disengagement of said first coupling means to actuate said second coupling means substantially simultaneously with said disengagement for maintaining said closing blade in unblocking position as said opening blade moves to unblocking position whereby incident light passes through said aperture to initiate exposure; 70

- (g) a timing circuit including a fast acting photocell exposed to light from said subject and being responsive to variations in scene brightness after said opening blade moves to unblocking position for producing a time-variable voltage whose value, at any instant after the circuit is made operative, is a measure of the value, at that instant, of the time-integral of the variation of the scene brightness after the circuit was made operative whereby said voltage is a measure of the amount of light passing through the aperture after the circuit is made operative;
- (h) said voltage reaching a preselected value when the amount of light passing through the aperture reaches a preselected value;
- (i) means responsive to the disengagement of said first coupling means to make said timing circuit operative;
- (j) means responsive to the voltage at the output terminal of said timing circuit to deactuate said second coupling means when said voltage reaches said preselected value; and
- (k) means made effective upon deactuation of said second coupling means to move said closing blade to blocking position whereby incident light is then prevented from passing said aperture to terminate exposure. 75

24. The combination, with means defining an exposure aperture adapted to pass incident light from a scene for exposing film or the like, of automatic exposure control means comprising:

- (a) movable opening and closing shutter blades, each having a blocking position overlying said aperture and an unblocking position uncovering said aperture for controlling the passage of incident light there-through;
- (b) first coupling means releasably engaged with said opening blade when the latter is in blocking position for releasably maintaining the opening blade in blocking position;
- (c) means to disengage said first coupling means from said opening blade;
- (d) means made effective upon disengagement of said first coupling means to move said opening blade from blocking to unblocking position;
- (e) second coupling means cooperable with said closing blade when the latter is in unblocking position and actuatable to maintain said closing blade in unblocking position;
- (f) means to actuate said second coupling means no later than when said opening blade starts to move from blocking to unblocking position for maintaining said closing blade in unblocking position whereby incident light passes through said aperture to initiate exposure;
- (g) a fast acting photocell exposed to light from said subject after said opening blade has moved from its blocking position and whose internal resistance varies inversely with variations in scene brightness;
- (h) a capacitor shunting said photocell;
- (i) means to charge said capacitor;
- (j) means responsive to movement of said opening blade from blocking position to cause said capacitor to discharge through said photocell so that the voltage on the capacitor changes from an initial value when the capacitor starts to discharge to a preselected value after a period of time dependent upon the scene brightness during such period;
- (k) means responsive to the voltage on said capacitor to deactuate said second coupling means when the voltage reaches said preselected value;
- (l) means made effective upon deactuation of said second coupling means to move said closing blade to blocking position whereby incident light is then prevented from passing said aperture to terminate exposure.

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Examiners.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,205,795

September 14, 1965

David S. Grey

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 3, line 14, for "aperature" read -- aperture --;
column 14, line 15, for "corespondingly" read -- correspondingly --;
column 19, line 63, for "schemtic" read -- schematic --;
column 21, line 32, for "second" read -- seconds --; column 23, line 19, for "trigger" read -- triggering --; column 24, line 22, for "is" read -- in --; column 26, line 28, for "17" read -- 14 --; column 28, line 45, for "reset" read -- reset --; column 29, line 32, for "brightness:" read -- brightness; --.

Signed and sealed this 7th day of November 1967.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents