

ELECTRONIC FLASH APPARATUS

This invention relates to electronic flash apparatus of the type having a control circuit which produces a flash terminating signal upon receipt by a sensor of a specific amount of light.

Automatic electronic flash apparatus has a light responsive control circuit which generates a flash terminating signal when enough reflected flash light has been received by a sensor to indicate that the film will be correctly exposed at a given aperture. With such apparatus, the camera shutter is fixed at an easily synchronized speed, for example, at 1/60th of a second and the camera aperture is set to correspond with settings on the flash apparatus.

Such apparatus can be used in high ambient light conditions as a fill-in flash. However, without special adjustment to the camera, the combined flash and ambient illumination will overexpose the film at 1/60th of a second. At shutter speeds approaching correct exposure, for example, at 1/500th of a second, exposure will be heavily dominated by the flash.

Skilled photographers solve this problem by setting the aperture on the camera one or two stops narrower than the aperture for which the flash is set. The flash output then terminates at a point at which substantially less light than the film requires has been received, and

the rest of the exposure is by ambient light. If an electronic shutter is used, the ambient-to-flash ratio will be constant without regard to subject distance, subject reflectivity or level of ambient light. Unfortunately, 5 this approach is not automatic and requires a camera having a variable aperture.

U.S. 4,192,587 describes a camera-flash combination which senses the level of ambient illumination and, using a diaphragm-shutter fires the flash at a narrower aperture 10 in high ambient light than it does in low ambient light. This automatically gives somewhat the same effect as the manual aperture control. However, it requires a camera with a variable aperture, and the control electronics are complicated and must be built into the camera.

15 It is the object of the invention to provide an electronic flash apparatus having a control circuit of the type which produces a flash terminating signal upon receipt of a specific amount of ambient plus flash light, but which will make an automatic adjustment for exposure 20 requiring fill-in flash in high ambient light conditions without the need for an adjustable diaphragm or extremely complicated camera circuitry.

This object is accomplished by the provision of electronic flash apparatus having a control circuit for 25 producing a flash terminating signal, an ambient light level sensing circuit for measuring the average light re-

flected from a scene and for providing a binary output in
 dependence upon whether the ambient light level is below
 or above a predetermined level, the control circuit includ-
 ing photoresponsive means and a two state integrating
 5 circuit for integrating a signal indicative of the
 amplitude of light incident on the photoresponsive
 means having been reflected from the scene during a
 flash exposure, the integrating circuit operating in
 its first state when the binary output of the ambient
 10 light level sensing circuit indicates that the
 ambient light level is below the predetermined level
 and producing a flash terminating signal when the
 integrated signal corresponds to that appropriate for
 terminating a full flash exposure, and operating in
 15 the second state when the binary output of the
 ambient light level sensing circuit indicates that
 the ambient light level is above the predetermined
 level and producing a flash terminating signal when
 the integrated signal corresponds to a predetermined
 20 fraction of that appropriate for terminating a full
 flash exposure.

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The present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figs. 1-6 are schematics of circuits or portions
5 of circuits for an electronic flash apparatus according to various embodiments of the invention.

Because electronic flash apparatus is well known, the present description will be directed in particular to elements forming part of, or cooperating
10 more directly with, apparatus in accordance with the invention. It is to be understood that electronic flash apparatus and camera elements not specifically shown or described may take various forms well known to those skilled in the art.

15 According to Fig. 1, an electronic flash apparatus 10 includes a light-responsive control circuit for producing a flash terminating signal upon receipt of a specific amount of light. The control circuit

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includes a light-level sensing circuit 12, an integrating circuit 15 and a threshold-setting circuit 30. The light-level sensing circuit 12 includes a photoresponsive element 14 arranged to receive light reflected from a photographic scene. The circuit 12 produces a logic 0 (low level) output signal if the ambient light intensity is low or below a predetermined level, and a logic 1 (high level) output signal if the ambient light intensity is above the predetermined level. Light-level sensing circuits of this type are well known in the photographic art and are disclosed in a variety of patents including the aforementioned U.S. Patent No. 4,192,587, and U.S. Patents Nos. 3,860,936 and 3,924,263. Photo-responsive element 14 should either have a slow response, or include a low-pass filter, to prevent its output being significantly affected by the light emitted by an electronic flashtube 18 referred to below.

Integrating circuit 15 includes a high-speed phototransistor 16, and a timing capacitor 17. Light emitted by the flashtube 18 and reflected from a scene is incident upon the phototransistor 16, and produces a current, which is proportional to the intensity of the light impinging upon it. The phototransistor's current charges the capacitor 17, so that the voltage across the capacitor corresponds to the cumulative amount of light sensed by the phototransistor 16 while the capacitor 17 is charging.

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A normally closed switch S_1 , in parallel with capacitor 17, and a normally open switch S_2 , associated with a flash trigger circuit 19, are arranged to respectively open and close in response to opening movement of a shutter 20 in the camera. When the switch S_2 is closed, the circuit 19 triggers the flashtube 18 by means well known in the electronic flash art. In response to the triggering of the flashtube 18, a flash-firing capacitor 21, which is charged by a suitable DC to DC converter (not shown), discharges through the flashtube 18 thereby producing a high-intensity light pulse.

When switch S_1 is open, the current produced by the phototransistor 16 charges the capacitor 17. When the voltage across the capacitor 17 equals the voltage across a resistor 22, a comparator 23 produces a logic 1 level output signal, i.e., a flash terminating signal.

In response to the comparator's logic 1 level output signal, an SCR 24 is caused to conduct, which causes a circuit 26 to fire a quench tube 28. As is well known in the art, the tube 28 diverts flashtube firing current from the capacitor 21 away from the flashtube 18, thereby interrupting its light emission.

The threshold-setting circuit 30, which includes the resistor 22, a resistor 32 and a PNP transistor 34, is arranged to vary the amount of light required to be sensed by the light-responsive circuit for producing the flash terminating signal. The resistor 22 and the

resistor 32 form a voltage divider. The voltage across the resistor 22, V_{R22} , equals a regulated voltage, V_{REF} , less the voltage across the resistor 32, V_{R32} .

When the ambient light is bright and is therefore
5 above the aforementioned predetermined level, the logic 1 signal produced by the light-level sensing circuit 12 causes the PNP transistor 34 to be non-conductive. In this case, the voltage V_{R32} equals:

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$$V_{REF} \times \frac{R_{32}}{R_{22} + R_{32}}$$

where R_{22} and R_{32} are respectively the values of the resistances of the resistors 22 and 32.

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When the ambient light is low, the logic 0 level signal produced by the light-level sensing circuit 12 causes the transistor 34 to be driven into saturation. In this case, V_{R32} equals the collector-emitter saturation voltage of the transistor 34.

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The resistances of the resistors 22 and 32, and the transistor 34, are selected so that the voltage across the resistor 22 in bright ambient light is about one-fourth the voltage across the resistor 22 in low ambient light. Therefore, the light-responsive circuit is required to
25 sense about one-fourth the light when the ambient light is bright than when the ambient light is low, before producing the flash-terminating signal. Accordingly, for

normal range subjects, the flashtube 18 produces one-fourth the light in bright ambient light, for fill-in flash, that it produces in low light, for full flash.

An alternative embodiment is shown in Fig. 2, where elements similar to the elements of Fig. 1 are identified by like numerals. Electronic flash apparatus 36 includes an integrating circuit 15' and a light-level sensing circuit 40. Elements of the threshold setting circuit are included in the integrating circuit 15'. The light-level sensing circuit 40 produces a logic 1 output signal if the ambient light intensity is below a predetermined level, and a logic 0 output signal if the ambient light intensity is above the predetermined level. The threshold-setting circuit includes an auxiliary timing capacitor 41, connected in series with the phototransistor 16, and an NPN transistor 42. The base of the transistor 42 is connected to the output of the level-sensing circuit 40, and its collector and emitter are connected respectively to the capacitor 41 and ground.

When ambient light is low, the circuit 40 causes the transistor 42 to conduct. In this case, the current produced by the phototransistor 16 is divided. One portion of the current charges the capacitor 41 and a second portion charges the capacitor 17.

In bright ambient light, the transistor 42 is non-conductive. In this case, the current produced by the phototransistor 16 is blocked from charging the capacitor

41, and charges only the capacitor 17.

In low ambient light, the rate of integration of the integrating circuit 15' is thus inversely proportional to the sum of both the capacitance of the capacitor 17 and the capacitance of the capacitor 41. In bright ambient light, the rate of integration of the integrating circuit is inversely proportional to only the capacitance of the capacitor 17. As an example, the ratio $\frac{C_{17} + C_{41}}{C_{17}}$

is made approximately four to one. In this instance, when the ambient light is low, the cumulative light required to be sensed by the integrating circuit 15' to charge the capacitor 17 to a voltage for producing a flash-terminating signal for quenching the flashtube 18 is four times the cumulative light required to be sensed when the ambient light is bright. The operation of the apparatus of Fig. 2 is similar to that of Fig. 1 in that for subjects within the normal range of the flash, the flashtube 18 produces fill-in flash, in bright ambient light, that is one-fourth the amount of the full flash produced in low ambient light.

The phototransistor 16 senses light reflected from a scene which light normally includes ambient light. Because the ambient light intensity is normally much lower than the intensity of the electronic flash, and because the duration of the electronic flash is normally no

greater than about 1 millisecond, the ambient light would generally have little influence in the regulation of the electronic flash.

However, the flash can be controlled independently of the ambient light by separating the current produced by the phototransistor 16 into two components, i.e., one due to ambient light and the other due to electronic flash. The component corresponding to the ambient would be substantially DC, indicating the intensity of slowly changing ambient, and the component relating to the electronic flash would be AC, indicating the rapidly changing flash. A suitable highpass filter can be employed to remove the DC component from the phototransistor's current so that the flash is regulated independently of the ambient light.

In a modification of the Fig. 2 embodiment the capacitors 17 and 41 are connected in series, and the transistor 42 is connected in parallel with capacitor 41, with suitable polarities.

Figs. 3 and 4 show other embodiments of the invention which have the advantage that the same photo-responsive element is used in the integrating circuit as is used in the light-level sensing circuit.

According to Fig. 3 a phototransistor 116 charges an integrating capacitor 17 as in the first two embodiments. When the voltage across the capacitor 17 reaches a specific amount, a thyristor 115 becomes conductive and produces a flash terminating signal. The voltage of capacitor 17 at

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the point at which thyristor 115 conducts is equal to the voltage across a resistor 32 of a voltage divider comprising resistors 22 and 32 plus the gate-cathode voltage of the thyristor 115.

In high ambient light conditions, the light falling on the phototransistor 116 exceeds a predetermined value and a transistor 121 becomes conductive, permitting a capacitor 118 to be charged via a diode 117. A transistor 120 coupled to the capacitor 118 then conducts thereby bridging the resistor 32 to reduce the value at which thyristor 115 becomes conductive. Capacitor 118 keeps the base voltage of transistor 120 constant during the flash period.

As in Figs. 1 and 2, the switches S_1 , S_2 are open and closed respectively while the shutter is open.

The embodiment shown in Fig. 4 is essentially the same as the Fig. 3 embodiment, except that switches S_1 and S_2 are replaced by semiconductor switches in the form of transistors 140 and 141 which are switched to the on-state by coupling capacitors 139 and 138 connected to the base thereof when flash capacitor 21 is discharged through the flashtube 18.

The embodiment shown in Fig. 5 is generally similar to the embodiments shown in Figs. 1 and 2 though containing features shown in the Fig. 3 and 4 embodiment except that the light-level sensing circuit is physically part of the camera. This has the disadvantage that the

flash apparatus itself cannot then be employed with a camera not specially built for it. However, it has the advantage that it utilizes circuitry already employed for other purposes in the camera. For example, a light-level sensing circuit 100 used for low light signalling in the camera can supply the appropriate signal to the flash apparatus to control the point at which the flash terminating signal is produced.

The embodiment shown in Fig. 6 is similar to the embodiment shown in Fig. 4 except that, like the Figs 1 and 2 embodiments, separate photoresponsive elements are used in the integrating circuit and in the light-level sensing circuit. This makes the transistor 141 in the Fig. 4 embodiment unnecessary.

The present invention achieves its most remarkable results when used with a camera having an electronic shutter, that is, a shutter which closes in response to a signal from a light integrating circuit. When so used, a fixed flash to ambient ratio of light will expose the film in the fill-in flash mode regardless of the level of ambient light, distance of the subject (within the maximum range of the flash) or brightness of the subject. However, electronic flash apparatus according to the present invention can be used with cameras not having an electronic shutter. With cameras without an electronic shutter but having an automatic aperture control or no exposure control, there is some chance of overexposure, depending upon the ambient light level and

the exposure latitude of the film. However, this chance is greatly reduced with the present invention, as compared to using full flash in high ambient light conditions.

An advantage of the present invention is that it can be incorporated in a detachable flash apparatus and is then usable with known cameras without the special camera circuitry shown in the prior art. However, as is well known in the art, nearly all flash control circuitry can be incorporated in the camera if the flash is designed especially for that camera. Thus, if use with other cameras is not important to a specific application, the present invention can be used in a camera-flash combination in which some or all of the disclosed circuitry is physically located in the camera. Fig. 5 is an embodiment which uses this approach to save electronic components.

The circuitry of the present invention may also be used in conjunction with a flash permanently built into a camera and, as mentioned above, would give its best results if that camera utilized an electronic shutter.



CLAIMS

1. Electronic flash apparatus having a control circuit for producing a flash terminating signal, an ambient light level sensing circuit for
5 measuring the average light reflected from a scene and for providing a binary output in dependence upon whether the ambient light level is below or above a predetermined level, the control circuit including photoresponsive means and a two state integrating
10 circuit for integrating a signal indicative of the amplitude of light incident on the photoresponsive means having been reflected from the scene during a flash exposure, the integrating circuit operating in its first state when the binary output of the ambient
15 light level sensing circuit indicates that the ambient light level is below the predetermined level and producing a flash terminating signal when the integrated signal corresponds to that appropriate for terminating a full flash exposure, and operating in
20 the second state when the binary output of the ambient light level sensing circuit indicates that the ambient light level is above the predetermined level and producing a flash terminating signal when the integrated signal corresponds to a predetermined
25 fraction of that appropriate for terminating a full flash exposure.

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2. Electronic flash apparatus according to claim 1, wherein the control circuit includes means for connecting or disconnecting one of two integrating capacitors in the integrating circuit in response to level of the binary output.
3. Electronic flash apparatus according to claim 1 or 2, wherein the light-level sensing circuit and the integrating circuit are controlled by the same photo-responsive element.
4. Electronic flash apparatus according to any of claims 1 to 3, wherein the electronic flash apparatus is incorporated into a camera having an electronic shutter.
5. Electronic flash apparatus substantially as hereinbefore described, with reference to and as illustrated in Figs. 1 or 2 of the accompanying drawings.
6. Electronic flash apparatus substantially as hereinbefore described, with reference to and as illustrated in Fig. 3, 4, 5 or 6 of the accompanying drawings.

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