

PATENT SPECIFICATION

(11)

1 374 245

1 374 245

(21) Application No. 39704/71 (22) Filed 24 Aug. 1971

(31) Convention Application Nos.

755 196

(32) Filed 24 Aug. 1970

756 553

23 Sept. 1970

763 925

8 March 1971

765 578

9 April 1971

104 488

11 June 1971 in

(33) Belgium (BE)

(44) Complete Specification published 20 Nov. 1974

(51) International Classification G03B 15/05

(52) Index at acceptance

G2A 401 474 483 497 526 536 603 667 704 711 BJ

(19)



(54) ELECTRONIC PHOTOFLASH

(71) We, PONDER & BEST INC., a corporation organized under the laws of the State of California, United States of America, of 11201 West Pico Boulevard, Los Angeles, California 9004, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed to be particularly described in and by the following statement:

The present invention relates to electronic photoflash devices.

In recent years, electronic photoflash devices incorporating the various types of automatic flash limiting systems have been developed on both an experimental and a commercial level and have enjoyed a constantly growing commercial success. These devices represent a substantial improvement over previous nonautomatic photoflashes in which no control, or only a crude control, of the flash duration, or total light output, was possible. In the recently developed systems, the light reflected from the subject being photographed is sensed and integrated and when the total quantity of light being sensed reaches a predetermined value, a signal is produced to terminate the light flash.

In some systems already proposed, this termination is effected by creating a short circuit across the photoflash tube. When this short circuit is created, the discharge current from an energy storage capacitor supplying the photoflash tube is shunted from the tube, so that the light flash is terminated. The energy storage capacitor then discharges completely through the short circuit and at some time after complete discharge of the capacitor the short circuit is removed and the system is permitted to recycle back to its ready state.

While such systems function reasonably well and offer a generally accurate control of the light produced during a single flash

as a function of the nature and range of the subject being photographed, these systems do offer certain disadvantages.

Firstly as already noted, they cause the energy storage capacitor to be completely discharged after termination of each light flash. This results in a great waste of energy which is not employed for producing light flashes and increases the recycling time of the flash unit, since the capacitor must be recharged from a completely discharged state. It also reduces the total number of light flashes which can be provided by a power source having a given energy content.

Further, in other systems already disclosed in which flash termination is effected by a capacitor turn off method of opening an electronic switch in series with the photoflash tube, the commutation of the quenching circuit has the initial result of increasing the current through the tube so as to temporarily increase the light output from the tube and delay the light termination operation.

In addition, despite various efforts at miniaturization of these devices, they remain relatively large, a considerable amount of space being required within the unit housing, for example, for the induction coil normally disposed in the flash tube-energy storage capacitor circuit.

It is an object of the present invention to provide improved electronic flash devices and specific embodiments thereof which overcome at least some of these drawbacks and difficulties.

According to one aspect of the present invention there is provided an electronic photoflash device including an electronic photoflash tube, an energy supply means for supplying flash-generating electric current to the flash tube through a series-connected switching means, and a flash limiting circuit for terminating a flash by causing cessa-

[Price 25p]

tion of the said current and opening of the said switching means at least for long enough to allow the flash tube to de-ionise, wherein, the energy supply means

5 being such as to supply direct current to the flash tube, the said switching means is an electronic switching means which, when conducting the said current in a forward direction, can be rendered non-conductive by causing a momentary reverse current flow therethrough, and the flash limiting circuit is a capacitor turn-off circuit 4 causing such reverse current flow and comprises at least one capacitor and a second switching means connected in series with the capacitor or one of the capacitors across the series combination of the flash tube and the first-mentioned switching means, the circuit arrangement of the device being such that, with the second switching means open prior to flash terminating operation of the flash limiting circuit, the said capacitor becomes appropriately charged.

25 According to another aspect of the present invention there is provided an electronic photoflash device including an electronic photoflash tube, an energy supply means for supplying flash-generating electric current to the flash tube through a series-connected switching means, and a flash limiting circuit for terminating a flash by causing cessation of the said current and opening of the said switching means at least for long enough to allow the flash tube to de-ionise, wherein the flash limiting circuit comprises a normally open switching means connected in parallel with the flash tube and arranged to short-circuit the flash tube to terminate a flash, and the said series-connected switching means is connected between that parallel combination and the energy supply means and arranged to open upon closing of the parallel-connected switching means.

Thus, with the energy supply means comprising an energy storage capacitor, useless or wasteful discharge of the capacitor is prevented.

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

Figure 1 is a circuit diagram of an automatic flash unit.

55 Figure 2 is a circuit diagram of a modified form of the unit of Figure 1.

Figure 3 is a partial circuit diagram of a photoflash unit.

Figure 4 is a perspective view of an embodiment of an induction coil arrangement.

Figure 5 is a perspective view of another induction coil arrangement.

65 Figure 6 is a block diagram of a further flash unit.

Figure 7 is a diagram illustrating the operation of the circuit of Figure 6, in comparison with the operation of prior art circuits.

Figure 8 is a circuit diagram of a modified form of construction of the unit of Figure 6.

Figure 9 is a circuit diagram of a modified form of one component of the circuit of Figure 6.

Figure 10 is a perspective cross-sectional view of one form of an element of the circuit of Figure 8.

Figure 1 illustrates an automatic electronic flash unit which basically includes a flash limiting circuit composed of a capacitor 8 and a thyristor 10, an auxiliary circuit 432 for controlling the flash limiting circuit, a flash triggering circuit 433 and a resistor 40.

The unit further includes a basic photoflash circuit composed of an energy storage capacitor 1 charged by a voltage applied via line 2, a photoflash tube 3, and a triggering circuit for the tube, the triggering circuit including a trigger transformer 4 having its secondary connected to the control electrode of the tube 3, a trigger capacitor 5, a control thyristor 6 and an induction coil 7.

The capacitor 8 of the flash limiting circuit is charged from a voltage source via a line 9. The auxiliary circuit 432 is composed of a unijunction transistor 201 having one main electrode connected to the gate electrode of thyristor 10, a resistor 202 connected between the gate electrode 51 and the cathode of thyristor 10, a capacitor 203 connected between the gate electrode of transistor 201 and the cathode of thyristor 10, a phototransistor 204 having its emitter connected to the gate electrode of transistor 201 and its collector connected to the other main electrode of transistor 201, a resistor 205 having one end connected to the collector of transistor 204, a Zener diode 206 connected across the series arrangement of capacitor 203 and the collector-emitter path of transistor 204, a transistor 207 having its collector connected to the other end of resistor 205, an electrolytic capacitor 208 connected between the emitter of transistor 207 and the cathode of thyristor 10, a resistor 209 having one end connected to the base of transistor 207, and a diode 210 having its anode connected to the other end of resistor 209 and its cathode connected to the emitter of transistor 207.

The flash triggering circuit for the unit is composed of a camera synchronization contact 301, a resistor 303 having one end connected to one side of contact 301, a capacitor 308 connected between the other end of resistor 303 and the other side of

contact 301, a resistor 305 having one end connected to the junction between elements 303 and 308, and its other end connected to the other side of capacitor 308 and also to one side of inductance 7, a unijunction transistor 307 having its gate electrode connected to the junction between resistors 303 and 305 and one main electrode connected to the one side of contact 301, a resistor 306 having one end connected to the one side of contact 301, a resistor 304 having one end connected to the other main electrode of transistor 307, and also to the gate electrode 50 of thyristor 6, and its other end connected to the other end of resistor 305, and a resistor 302 connected between the other end of resistor 306 and one main electrode of photoflash tube 3.

In addition, triggering capacitor 5 is connected between the other side of contact 301 and the primary of transformer 4, the secondary of transformer 4 is connected between the one main electrode of tube 3 and the trigger electrode of that tube, the one main electrode of tube 3 is connected to the anode of thyristor 6, and the other main electrode of tube 3 is connected to the junction between capacitors 1 and 8. In addition, inductance 7 is connected in series between capacitor 1 and the cathode of thyristor 6. A connection between inductance 7 and the cathodes of thyristors 6 and 10 constitutes the common connection for the circuit, to which other components are also connected, as illustrated.

The operation of the device is as follows: Initially, capacitors 1 and 8 are charged by voltages applied via their respective charging lines 2 and 9. In addition, capacitor 308 will become charged to a certain level by the voltage appearing across resistor 305, this resistor forming a voltage divider, together with resistors 303, 306, 302 and 40, across capacitor 1. For producing a flash, synchronization contact 301, generally located within the camera, is closed. This has the effect of provoking the discharge of capacitor 308 through transistor 307 and to gate 50 of thyristor 6 for triggering the thyristor 6 into its conductive condition. The discharge of capacitor 308 also applies a voltage pulse through capacitor 5 and this voltage pulse is converted by transformer 4 into a flash triggering pulse. Then, capacitor 1 is discharged through the series arrangement of tube 3, thyristor 6 and induction coil 7.

In addition, the voltage applied via line 2 serves to initially charge capacitor 208 to a predetermined value and the subsequent voltage pulse corresponding to the initiation of a light flash renders transistor 207 conductive to produce a predetermined voltage across Zener diode 206.

The light produced by tube 3 is reflected from the subject being photographed to phototransistor 204. The voltage provided by Zener diode 206 produces a current flow through phototransistor 204 which is proportional to the intensity of the light radiation incident thereon. This current charges capacitor 203 and when the resulting voltage across that capacitor, which voltage is applied to the gate of transistor 201, reaches a predetermined value, transistor 201 is rendered conductive to produce a voltage across resistor 202 sufficient to trigger thyristor 10 into conduction. As a result, capacitor 8 discharges through thyristor 10, this discharge producing a current flow in a direction opposite to that of the previous current flow through tube 3 and thyristor 6. This has the result of blocking thyristor 6 and thus terminating the discharge of capacitor 1 through tube 3.

The advantage of the circuit illustrated in Figure 1 is that, whereas in circuits disclosed in our patent specification Ser. No. 1,267,234 the intensity of the light flash increases progressively during the period of the control pulse serving to trigger termination of the flash tube discharge, such an increase in light intensity does not occur in the circuit illustrated in Figure 1 of the present drawings. Thus, for example, in the circuit of Figure 4 of the above-cited patent specification, the discharge current flowing from the flash terminating capacitor is in a direction opposite to the current flowing through the discharge limiting thyristor so as to provoke the turning off of the latter. However, the capacitor discharge current does flow in a direction to temporarily increase the current flowing through the electronic flash tube. As a result, rather than the light flash being terminated immediately upon the occurrence of a flash terminating signal, its intensity increases for a short period until the flash limiting thyristor has become non-conductive.

In contrast, in the circuit of Figure 1 of the present drawings, the discharge current from capacitor 8 is in a direction which is not only opposite to the direction of forward current flow through thyristor 6, but also opposite to the direction of current flow through tube 3. As a result, the initiation of discharge of capacitor 8 serves to immediately interrupt the flow of current through tube 3, even before thyristor 6 has been rendered non-conductive.

In a modification of the circuit of Figure 1, thyristors 6 and 10 could be replaced by gas-filling switching tubes such as those illustrated in Figs. 19, 20, 19A and 20A of our above-cited patent specification, which we call Triastor tubes, and at the same time the control circuitry for these thyristors could be replaced with comparable control

circuits such as those illustrated for the Triastor tubes.

In order to reduce the reactance values and physical sizes of the various circuit components, particularly the capacitors and inductor, thyristor 6 is preferably designed to have the shortest possible turn-off time. Triastor tubes can be given the shortest possible turn-off time if they are filled with a gas having a low atomic weight, preferably hydrogen.

Figure 2 illustrates an improved version of the circuit of Figure 1 which eliminates the need for a second voltage supply, i.e. the voltage supplied via line 9 of Figure 1, and which includes a control lamp for indicating when the unit is ready for use. In Figure 2, elements identical with the circuit of Figure 1 are given the same reference numerals.

The unit illustrated in Figure 2 includes an auxiliary circuit 432 and a flash triggering circuit 433, both identical with the corresponding circuit of Figure 1. In addition to the other elements which the circuit has in common with the circuit of Figure 1, there are provided a resistor 41 connected across circuit 433, a series arrangement of a resistor 11 and a diode 12 connected across the series arrangement of photoflash tube 3 and thyristor 6, resistor 11 being in parallel with capacitor 8, an indicating circuit composed of a potentiometer 13 connected between the junction of tube 3 and thyristor 6 and the junction of resistor 11 and diode 12 and a neon lamp 14 connected between the junction of resistor 11 and diode 12 and the movable tap of potentiometer 13, and a capacitor 19 connected in parallel with the resistor of potentiometer 13. Voltage is applied to the circuit between lines 2 and 2' connected to a suitable voltage source, which may be a battery or a.c.-d.c. rectifying supply. Similar sources may be employed for the circuit of Figure 1.

Resistor 11 and capacitor 19 form, together with capacitor 8 and thyristor 10, the flash limiting circuit.

The operation of the circuit of Figure 2 differs from that of the circuit of Figure 1 in the following respects:

To place the unit in a condition for operation, a d.c. voltage is applied across lines 2 and 2' to charge capacitor 1 to the voltage between lines 2 and 2' and to charge capacitor 8 to the voltage across resistor 11 and capacitor 19 to the voltage across resistor 13, the total voltage being equal to that across resistor 40 of voltage divider 40, 41. Diode 12 serves to prevent capacitor 19 from being charged to an undesirably high voltage when thyristor 6 is turned off.

Neon lamp 14 lights as soon as the

voltage on capacitor 19 reaches a value at which the unit is ready for operation. Even after current ceases to flow through capacitor 8, capacitor 19 can continue to be charged by the current through resistor 11.

When a light flash terminating pulse is applied to the gate electrode of thyristor 10 to render that thyristor conductive, capacitor 8 causes a reverse current to flow through the series arrangement of tube 3 and thyristor 6. At the same time, the discharge current from capacitor 19 flows through thyristor 6, but not tube 3 and thus accelerates the blocking of that thyristor.

Figure 3 is a simplified schematic illustration of the connection between the basic components 1, 2, 2', 3-5 and 7 of the flash unit, a sub-unit 451 (containing the auxiliary circuit, flash triggering circuit and flash limiting circuit), the synchronizing contact 301, disposed in the camera, and the light sensor 101. As in the embodiments illustrated in Figures 1 and 2, capacitor 1 is preferably an electrolytic capacitor charged to have the polarity illustrated. The camera synchronizing contact is connected to the sub-unit 451 by means of connections 102 and 103. Sub-unit 451 also includes a connection 104 connected to the negative plate of capacitor 1, a connection 105 connected to the negative terminal of the flash tube 3, and a connection 106 connected to the positive electrode of tube 3.

Figure 4 illustrates an arrangement wherein the inductance coil 7 is wound around a reflector 601 of the photoflash unit. This arrangement offers the advantage of reducing the current density through the flash tube, and reducing the volume required for housing the flash unit circuitry while utilizing the otherwise wasted space around the reflector. The wire 604 connected to the positive plate of capacitor 1 is wound around reflector 601 to form coil 7 and the other end of the wire is then connected to the positive electrode 603 of tube 3.

In order to further reduce space requirements, or for other fabrication reasons, the induction coil 7 can be wound on one or more other surfaces of the photoflash unit housing and/or on the photoflash unit cover. One such arrangement is illustrated in Figure 5 wherein the wire 604 forming the coil is wound on the inner surface of a casing component 704 of the photoflash unit. One end of wire 604 is connected to the positive terminal 702 of capacitor 1, while the other end of wire 604 is connected to the positive terminal 703 of the photoflash tube.

Circuits described below represent improvements over those already described in that they utilize only the amount of electrical energy necessary to produce the de-

sired light flash, and thus provide a substantial energy saving and substantially reduce the recycling time of the flash unit.

The above-cited patent specification and the preceding portion of the present specification describe essentially two different types of control circuits. One of these is the parallel type in which a light flash is terminated by creating a conductive path in parallel with the photoflash tube. This type of circuit permits the quantity of light emitted during any one flash to be controlled with satisfactory accuracy. Moreover, the required circuits can be relatively small and inexpensive to fabricate. However, on the other hand, it causes the photoflash energy storage capacitor to discharge completely during, and after, each light flash, and this results in a substantial waste of energy. The other type of circuit is a series type which terminates a light flash by opening the circuit between the energy storage capacitor and the flash tube. This type of circuit permits a substantial energy saving but previously disclosed embodiments of circuits of this type do not permit as accurate a control of the flash duration as parallel type circuits due primarily to delays in the circuit opening operation. Moreover, these series type circuits are physically of large size and are relatively expensive to fabricate.

Figure 6 illustrates a further flash unit which represents an improvement over the previously described circuits in that it employs a combination of a parallel type circuit which determines the accuracy of the light control and a series type circuit which performs the actual function of interrupting the discharge of the photoflash energy storage capacitor.

The circuit of Figure 6 includes, in addition to an energy storage capacitor 1 and a flash tube 3, a trigger circuit 33 controlled by the closing of the camera synchronizing contact to trigger a light flash, a parallel type light flash control circuit 81 and a series type control element 82 which functions, and is illustrated, as a normally closed switch. Series type circuit 82 is connected so that the switch which it represents is in series in the line between capacitor 1 and tube 3. Circuit 81 is composed essentially of a light sensor 80, an electronic gate 83 connected to activate the circuit 81 upon the commencement of a light flash, an integrator-comparator circuit 84 and a circuit 85 which functions as a normally open switch connected in parallel with the tube 3. Both switches 85 and 82 are connected to be operated by an output signal from circuit 84.

Circuit 81 could be constituted by any of the previously disclosed parallel circuits, e.g. the circuit 30 of Fig. 3 of the above-

cited patent specification in which case element 85 would be constituted by the element 204 of Fig. 2 of that specification. Similarly circuit 82 could be constituted by an element such as switch 103 illustrated in Figure 1 of that specification, which element could be a gate turn-off thyristor or other equivalent component.

The operation of the system of Figure 6 is as follows: The voltage due to the charge across capacitor 1 is applied across photoflash tube 3 via the normally closed switch 82. When the camera synchronizing contact is closed to initiate a flash, triggering circuit 33 produces a pulse to trigger the production of a light flash by tube 3. The leading edge of the current pulse then passing through tube 3 produces a corresponding current pulse which passes through gate circuit 83 to initiate operation of integrator-comparator circuit 84. The light reflected from the subject being photographed reaches sensor 80 and is converted into a proportional electrical signal which is processed by circuit 84. When the total quantity of light received by sensor 80 reaches a predetermined value, the output signal from circuit 84 reaches a level at which it actuates switches 85 and 82. This actuation closes switch 85 so as to create an effective short circuit across the photoflash tube 3 and thus halt the production of light by that tube. At the same time, the actuation of switch 82 serves to open that switch and thus halt the discharge of capacitor 1.

The switch 82 is so designed that it will reclose only after a delay period which is longer than the period required for de-ionization of tube 3 and the opening of switch 85.

Figure 7 illustrates the operation of the circuit of Figure 6 in comparison with the operation of prior circuits. The A curves represent the intensity of the light produced by tube 3, while the B curves represent the voltage across capacitor 1. A light flash is initiated at the moment T_0 , while the moment at which the predetermined quantity of light has been received by sensor 80 is T_1 . The time required for the circuit 81 to respond by closing switch 85 is ΔT_1 , and the time required for the circuit 81 to open switch 82 is ΔT_2 . The period ΔT_2 is normally longer than ΔT_1 , owing to the nature of components acting as normally closed electronic switches. However, because it is the closing of switch 85, which occurs with a delay of ΔT_1 , that determines the termination of the light flash, the longer delay involved in the closing of switch 82 will not introduce any inaccuracies into the automatic flash limiting operation. However, the utilization of series switch 82 does result in a substantial energy saving in that it

conserves a large portion of the charge initially present on capacitor 1 and thus reduces the amount of energy, and the time, required to restore capacitor 1 to full charge. Curves A₁ and B₁ illustrate the operation of a conventional photoflash unit without any automatic flash limiting control. Curve B₂ illustrates the variation in the voltage across capacitor 1 in an automatic control circuit equipped only with a normally open flash limiting switch. This curve shows that with such a circuit, capacitor 1 is completely discharged after each light flash and must therefore be completely recharged before another light flash can be produced. Finally, curve B illustrates the variation in the voltage across capacitor 1 in the circuit shown in Figure 6, wherein capacitor 1 retains a substantial portion of its initial charge after a light flash has been terminated.

The curves of Figure 7 illustrate, in particular, that the quantity of light produced by the flash, illustrated by area C, is accurately controlled by the operation of switch 85, and that even though switch 82 does not open until after a delay of ΔT_2 , the quantity of the charge remaining on capacitor 1 after the opening of switch 82 is still relatively high. Thus, the device consumes only a small amount of energy in addition to that required for producing the desired light flash.

Figure 8 illustrates a specific embodiment of the circuit illustrated in block form in Figure 6, but modified in that there is no control connection from circuit 84 to switch 82. In Figure 8, the circuit for triggering tube 3 is not illustrated for purposes of simplicity. The parallel type circuit 81 is similar to circuits of the type illustrated in our above-cited patent specification and operates in a manner disclosed in that specification.

The series type circuit 82' comprises a new type of electrodynamic switch which is connected in series between capacitor 1 and tube 3. This switch comprises a pair of contacts 87 which are maintained normally closed by the pressure of two compression springs 86. These springs are in the form of solenoids and serve simultaneously as induction coils. Contacts 87 and springs 86 are preferably disposed on a common axis. A capacitor 88 is connected in parallel with the contacts 87.

The operation of the circuit is as follows: Circuit 81 operates in the manner disclosed above in connection with the corresponding circuit of Figure 6. The series circuit 82' remains closed for as long as the intensity of the discharge current from capacitor 1 is equal to the current required for maintaining tube 3 conductive. As soon as the switch 85 of parallel circuit 81 closes

to place a short circuit across tube 3, the discharge current from capacitor 1 increases, as indicated by the steep portion of curve B of Figure 7, to a value which provokes sufficient electrodynamic forces in coils 86 to separate contacts 87 from one another, thus interrupting the discharge of capacitor 1. Capacitor 88 serves to absorb the arc which would normally appear between contacts 87 upon their opening and to then prolong the passage of current through the series circuit, the total result being a rapid opening of contacts 87 and a sufficiently long delay prior to their reclosing.

Each coil 86 acts as a solenoid and its connected contact 87 acts as a movable relay contact in that the current through coil 86 produces an axial magnetic field which attracts contact 87, the contact being of a magnetic material. Alternatively, the spring and solenoid could be constituted by separate elements.

The nature of circuit 82' is such as to render unnecessary the provision of a control connection between that circuit and circuit 84.

Figure 9 illustrates a circuit 82'' constituting another embodiment of a series type circuit which could be employed in the device of Figure 6 or Figure 8. This embodiment comprises an electromagnetic relay 91 of a fast acting type, for example a reed relay, having a normally closed contact. The circuit further includes a control thyristor 92 and a charging circuit composed of a capacitor 93 and a diode 94. The gate electrode of thyristor 92 is, as illustrated, connected to the output of circuit 84 of Figure 6 or 8. Before operation, capacitor 93 is charged via diode 94 from capacitor 1. When a signal applied to the gate electrode of thyristor 92 renders that thyristor conductive, a current flow is produced through the coil of relay 91, this current coming from capacitor 1. This causes the normally closed contact of relay 91 to open, thus interrupting the current flow between capacitor 1 and photoflash tube 3. Even after the opening of that contact, current continues to flow through the relay coil from capacitor 93, thus assuring a sufficiently long delay before the reclosing of the contact of relay 91.

Turning now to Figure 10, there is shown the physical structure of one form of the switch 82' illustrated in circuit form in Figure 8. The contacts 87 and solenoid-inductance coils 86 are preferably disposed in a hermetically sealed enclosure 123 whose interior 126 is either evacuated or filled with a gas, dielectric liquid, etc. As one alternative of this embodiment, the coil 86 could be made in the form of a printed circuit.

Reference is directed to our copending applications numbers 19919/74 and 20221/74 Serial Nos. 1374246 and 1374249.

5 WHAT WE CLAIM IS:

1. An electronic photoflash device including an electronic photoflash tube, an energy supply means for supplying flash-
10 generating electric current to the flash tube through a series-connected switching means, and a flash limiting circuit for terminating a flash by causing cessation of the said current and opening of the said switching
15 means at least for long enough to allow the flash tube to de-ionise, wherein, the energy supply means being such as to supply direct current to the flash tube, the said switching means is an electronic switching means
20 which, when conducting the said current in a forward direction, can be rendered non-conductive by causing a momentary reverse current flow therethrough, and the flash limiting circuit is a capacitor turn-off circuit for causing such reverse current flow
25 and comprises at least one capacitor and a second switching means connected in series with the capacitor or one of the capacitors across the series combination of the flash tube and the first-mentioned switching means, the circuit arrangement of the device being such that, with the second switching means open prior to flash terminating operation of the flash limiting circuit, the
30 said capacitor becomes appropriately charged.

2. A photoflash device as claimed in claim 1, including a voltage source connected for charging the said capacitor independently of the said energy supply means.
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3. A photoflash device as claimed in claim 1, wherein the said capacitor is connected to derive its charge from voltage dividing means connected across the said energy supply means.
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4. A photoflash device as claimed in claim 3, wherein the capacitor turn-off circuit includes a second capacitor connected between the junction between the flash tube and series-connected switching means and the junction between the second switching means and first-mentioned capacitor, the second capacitor also being connected to derive its charge from the said voltage dividing means.
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5. A photoflash device as claimed in claim 4, further comprising an indicator circuit connected across said second capacitor for providing an indication that said device is ready for use.
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6. A photoflash device as claimed in claim 5, wherein said indicator circuit comprises a potentiometer having its resistance connected across said second capacitor, and an indicator lamp connected be-
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tween one end of the resistance of said potentiometer and the movable tap of said potentiometer.

7. A photoflash device as claimed in any preceding claim, wherein the photoflash tube has two main electrodes and a trigger electrode, a trigger circuit is connected to said trigger electrode for applying a flash initiation pulse thereto, said series-connected switching means is a normally open
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electronic switch, the energy supply means comprises an energy storage capacitor, a flash initiation circuit is connected to said trigger circuit and to said series-connected switching means for causing said trigger circuit to produce a flash initiation pulse and for closing said series-connected switching means when a light flash is to be produced, the device includes a flash limiting trigger circuit for producing a trigger
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signal when a light flash being produced by said tube is to be terminated, and the second switching means is a normally open electronic switch connected to said flash limiting trigger circuit to be closed in response to a trigger signal therefrom.

8. A photoflash device as claimed in claim 7, wherein the flash limiting trigger circuit is responsive to a predetermined amount of light reflected from a subject illuminated by a light flash from said tube for producing a signal when the light flash being produced by said tube is to be terminated.

9. A photoflash device as claimed in claim 7 or 8, wherein each of said switching means is constituted by a thyristor, said flash initiation circuit being connected to the gate electrode of the thyristor constituting said series-connected switching means, and said flash limiting trigger circuit being connected to the gate electrode of the thyristor constituting said second switching means.

10. A photoflash device as claimed in any preceding claim, wherein at least one of said switching means is constituted by a gas-filled switching tube having two main electrodes and a trigger electrode.

11. A photoflash device as claimed in claim 10, wherein said switching tube is filled with gas having low atomic weight.

12. A photoflash device as claimed in claim 11, wherein the gas is hydrogen.

13. A photoflash device as claimed in claim 12, wherein said switching tube is a Triastor tube (as hereinbefore defined).

14. An electronic photoflash device as claimed in any preceding claim, with the photoflash tube in a housing including a reflector and an induction coil connected between the tube and the energy supply means, said coil being wound upon at least one surface of said housing.

15. A photoflash device as claimed in

Reference is directed to our copending applications numbers 19919/74 and 20221/74 Serial Nos. 1374246 and 1374249.

5 WHAT WE CLAIM IS:

1. An electronic photoflash device including an electronic photoflash tube, an energy supply means for supplying flash-generating electric current to the flash tube through a series-connected switching means, and a flash limiting circuit for terminating a flash by causing cessation of the said current and opening of the said switching means at least for long enough to allow the flash tube to de-ionise, wherein, the energy supply means being such as to supply direct current to the flash tube, the said switching means is an electronic switching means which, when conducting the said current in a forward direction, can be rendered non-conductive by causing a momentary reverse current flow therethrough, and the flash limiting circuit is a capacitor turn-off circuit for causing such reverse current flow and comprises at least one capacitor and a second switching means connected in series with the capacitor or one of the capacitors across the series combination of the flash tube and the first-mentioned switching means, the circuit arrangement of the device being such that, with the second switching means open prior to flash terminating operation of the flash limiting circuit, the said capacitor becomes appropriately charged.

2. A photoflash device as claimed in claim 1, including a voltage source connected for charging the said capacitor independently of the said energy supply means.

3. A photoflash device as claimed in claim 1, wherein the said capacitor is connected to derive its charge from voltage dividing means connected across the said energy supply means.

4. A photoflash device as claimed in claim 3, wherein the capacitor turn-off circuit includes a second capacitor connected between the junction between the flash tube and series-connected switching means and the junction between the second switching means and first-mentioned capacitor, the second capacitor also being connected to derive its charge from the said voltage dividing means.

5. A photoflash device as claimed in claim 4, further comprising an indicator circuit connected across said second capacitor for providing an indication that said device is ready for use.

6. A photoflash device as claimed in claim 5, wherein said indicator circuit comprises a potentiometer having its resistance connected across said second capacitor, and an indicator lamp connected be-

tween one end of the resistance of said potentiometer and the movable tap of said potentiometer.

7. A photoflash device as claimed in any preceding claim, wherein the photoflash tube has two main electrodes and a trigger electrode, a trigger circuit is connected to said trigger electrode for applying a flash initiation pulse thereto, said series-connected switching means is a normally open electronic switch, the energy supply means comprises an energy storage capacitor, a flash initiation circuit is connected to said trigger circuit and to said series-connected switching means for causing said trigger circuit to produce a flash initiation pulse and for closing said series-connected switching means when a light flash is to be produced, the device includes a flash limiting trigger circuit for producing a trigger signal when a light flash being produced by said tube is to be terminated, and the second switching means is a normally open electronic switch connected to said flash limiting trigger circuit to be closed in response to a trigger signal therefrom.

8. A photoflash device as claimed in claim 7, wherein the flash limiting trigger circuit is responsive to a predetermined amount of light reflected from a subject illuminated by a light flash from said tube for producing a signal when the light flash being produced by said tube is to be terminated.

9. A photoflash device as claimed in claim 7 or 8, wherein each of said switching means is constituted by a thyristor, said flash initiation circuit being connected to the gate electrode of the thyristor constituting said series-connected switching means, and said flash limiting trigger circuit being connected to the gate electrode of the thyristor constituting said second switching means.

10. A photoflash device as claimed in any preceding claim, wherein at least one of said switching means is constituted by a gas-filled switching tube having two main electrodes and a trigger electrode.

11. A photoflash device as claimed in claim 10, wherein said switching tube is filled with gas having low atomic weight.

12. A photoflash device as claimed in claim 11, wherein the gas is hydrogen.

13. A photoflash device as claimed in claim 12, wherein said switching tube is a Triastor tube (as hereinbefore defined).

14. An electronic photoflash device as claimed in any preceding claim, with the photoflash tube in a housing including a reflector and an induction coil connected between the tube and the energy supply means, said coil being wound upon at least one surface of said housing.

15. A photoflash device as claimed in 130





claim 14, wherein said coil is wound around the outer surface of said housing.

16. A photoflash device as claimed in claim 14, wherein said coil is wound upon a flat inner surface of said housing.

17. An electronic photoflash device including an electronic photoflash tube, an energy supply means for supplying flash-generating electric current to the flash tube through a series-connected switching means, and a flash limiting circuit for terminating a flash by causing cessation of the said current and opening of the said switching means at least for long enough to allow the flash tube to de-ionise, wherein the flash limiting circuit comprises a normally open switching means connected in parallel with the flash tube and arranged to short-circuit the flash tube to terminate a flash, and the said series connected switching means is connected between that parallel combination and the energy supply means and arranged to open upon closing of the parallel-connected switching means.

18. A photoflash device as claimed in claim 17, wherein the energy supply means comprises an energy storage capacitor.

19. A photoflash device as claimed in claim 17 or 18, wherein the series-connected switching means is an electronic switching means arranged to open in response to a signal from a flash limiting trigger circuit which also causes closing of the said parallel-connected switching means.

20. A photoflash device as claimed in claim 17 or 18, wherein the said series-connected switching means comprises a fast-acting relay including a normally closed contact connected as the series-connected switching means, and a coil for causing the opening of the contact, the device including a semiconductor control element connected in series with the coil for opening the relay contact in response to a signal from a flash limiting trigger circuit.

21. A photoflash device as claimed in claim 18, wherein the said series-connected switching means is such as to open in response to the short circuit current created by the closing of the said parallel-connected switching means.

22. A photoflash device as claimed in claim 21, wherein the said series-connected switching means comprises a pair of electrically conductive contacts, and at least one coil of a mechanically resilient, electrically conductive material connected to and supporting one of said contacts and formed as a compression spring normally urging said one of said contacts against the other one of said contacts, said coil and said contacts being connected to conduct the current flowing from the energy storage capacitor, and said coil being formed to act as a solenoid magnetically attracting said one contact

with a force proportional to the current flowing therethrough and to produce a mechanical spring force of a value such that it is overcome by the electromagnetic attraction force produced by the short circuit current occurring when said parallel-connected switching means closes, whereupon said one contact is drawn away from said other contact.

23. A photoflash device as claimed in claim 22, wherein there are two of said coils each connected to and supporting a respective one of said contacts and each arranged to subject its respective contact to an electromagnetic attraction force.

24. A photoflash device as claimed in claim 23, wherein said series-connected switching means further comprises a hermetically sealed casing enclosing said contacts and said coils.

25. A photoflash device as claimed in any of claims 22-24, wherein said series-connected switching means further comprises a capacitor connected between said contacts.

26. A photoflash device as claimed in claim 21, wherein said series-connected switching means comprises a pair of conductive contacts, spring means normally urging said contacts together, and at least one solenoid coil connected in series with said contacts and arranged to conduct the current from the energy storage capacitor and to produce an electromagnetic force attracting its said contact, this force exceeding the force produced by said spring means upon the occurrence of the short circuit current appearing when said parallel-connected switching means closes.

27. A photoflash device as claimed in any of claims 17-26, including means connected to said tube for producing a signal which initiates the production of a light flash, and automatic flash limiting means including a light sensor and arranged to produce a signal for causing the flash limiting circuit to terminate the light flash when a predetermined quantity of light has been received by the sensor.

28. An electronic photoflash device as claimed in claim 1, substantially as described herein with reference to any of Figs. 1-5 of the accompanying drawings.

29. An electronic photoflash device as claimed in claim 17, substantially as described herein with reference to Figs. 6-10 of the accompanying drawings.

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