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Elliott

[11] **3,758,817**

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[54] **FLASH APPARATUS WITH AUTOMATIC LIGHT TERMINATION USING A NUMBER OF STORAGE CAPACITORS**

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[52] **U.S. Cl.** ..... **315/151,** 315/84.5, 315/159, 315/240, 315/241 R, 315/241 P

[51] **Int. Cl.** **H05b 37/02**

[58] **Field of Search** ..... 307/221; 315/149, 315/151, 159, 84.5, 240, 241 R, 241 P; 320/1; 328/106

[56] **References Cited**

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3,666,964	5/1972	Flynn	315/241 R X
3,519,879	7/1970	Ogawa	315/151
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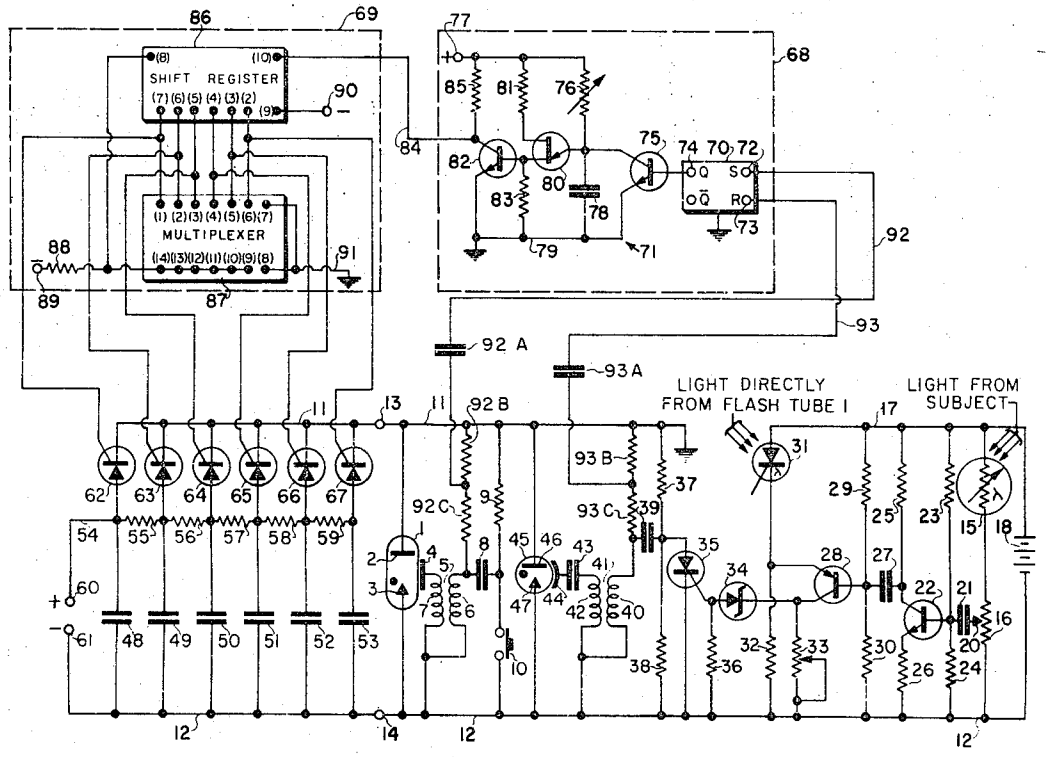
Attorney—Arthur H. Swanson et al.

[57] **ABSTRACT**

A counter and a plurality of SCR's normally connect only one of a plurality of storage capacitors to a flash tube until the latter is fired, at which time a clock is started to advance the counter. The latter then connects the capacitors in discharging relationship to the tube in repeated sequence until a photocell has received a predetermined quantity of light reflected from a subject to be photographed which receives the light emitted by the tube. At that time, the clock and the counter are stopped and a quench tube is fired which effectively short-circuits the flash tube and terminates its production of light. Each capacitor is recharged following its discharge into the flash tube.

2 Claims, 2 Drawing Figures



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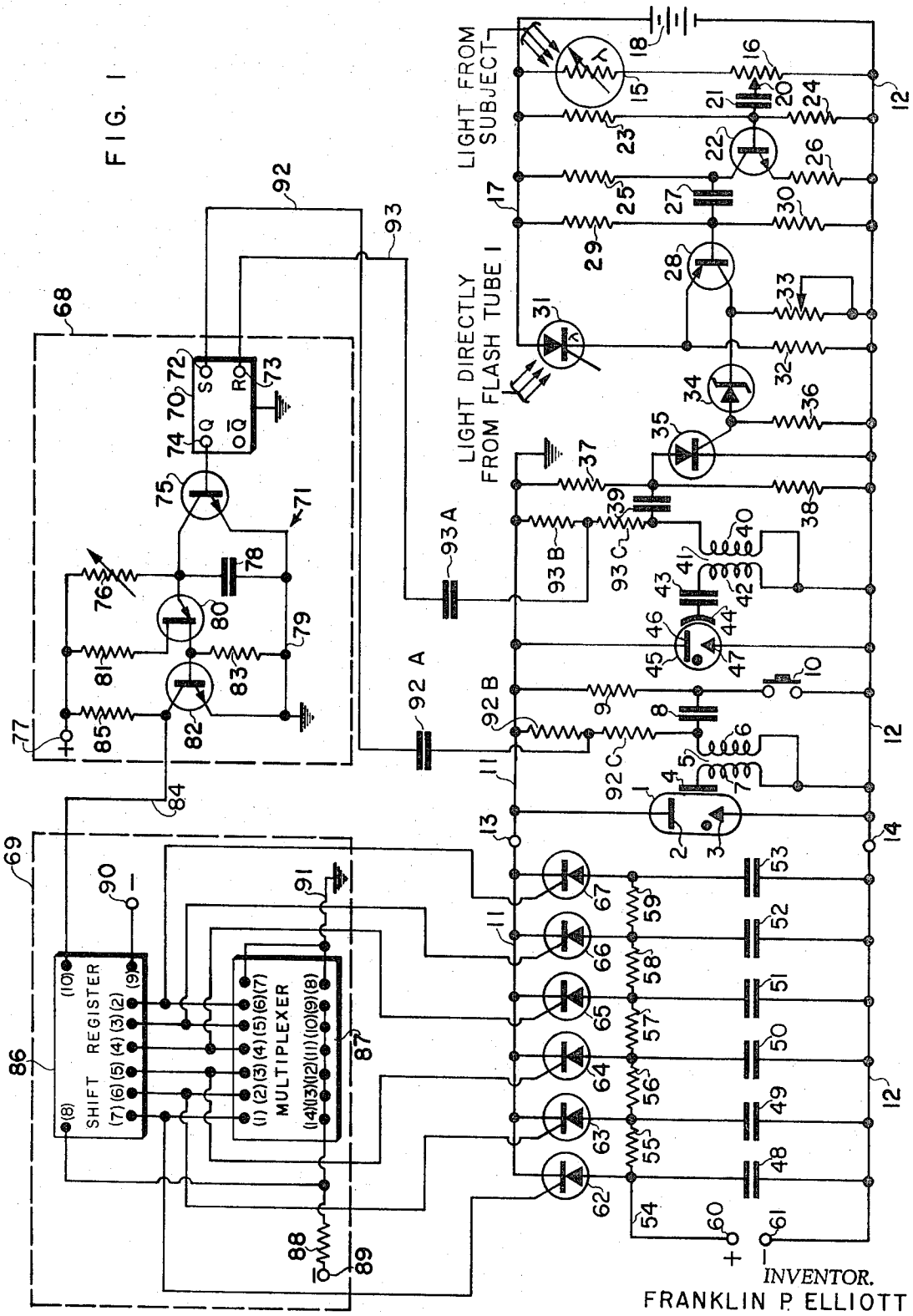
SHEET 1 OF 2

FIG. 1



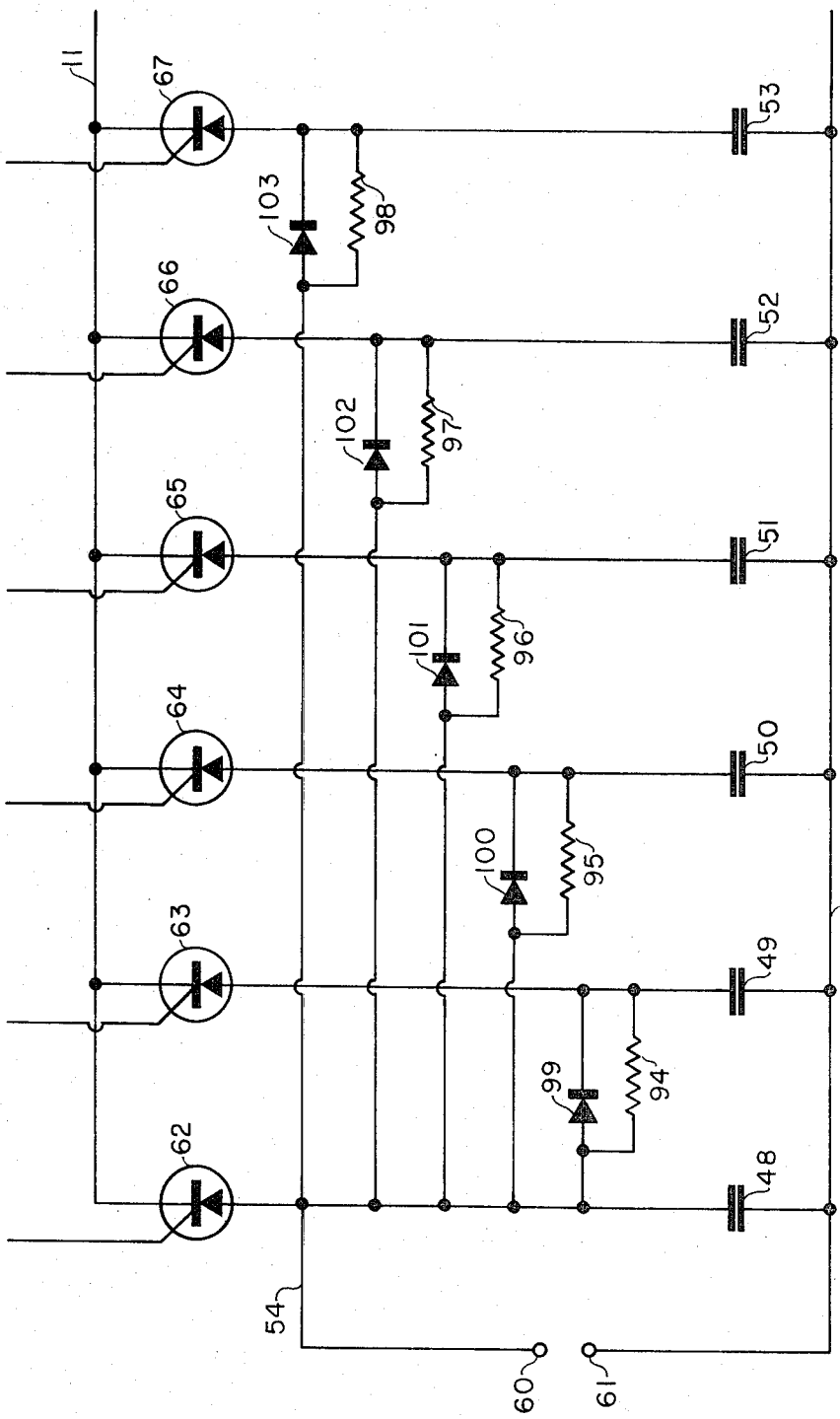


FIG. 2

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FLASH APPARATUS WITH AUTOMATIC LIGHT TERMINATION USING A NUMBER OF STORAGE CAPACITORS

BACKGROUND OF THE INVENTION

The present invention relates generally to electronic flash devices, such as those employed in the field of photography, which produce light by the discharge of a charged storage capacitor into a flash tube. Specifically, the invention relates to devices of this type which automatically control the amount or quantity of light produced by each flashing of the flash tube. Such control makes the quantity of light produced by each flash to be that quantity which provides such illumination of the subject being photographed as to produce the correct exposure of the film in the associated camera under the prevailing conditions.

Devices of the type last mentioned are well known in the art, and are generally referred to as computer flash devices. In one, and probably the most popular, form of such known devices, the quantity of light present in each flash is controlled by causing the flash tube and storage capacitor of the device to be effectively short-circuited at the instant that a desired quantity of light has been produced, according to the invention of U.S. letters Pat. No. 3,033,988 (Edgerton). Such short-circuiting interrupts the flow of current through the flash tube, and hence turns off or quenches the latter, and is effected in said known devices at the instant at which a light-responsive sensor senses a predetermined quantity of light reflected from the subject being photographed. Examples of such devices are those which are disclosed and claimed in U.S. letters Pat. Nos. 3,350,603 (Erickson), 3,517,255 (Hoffer et al.), 3,519,879 (Ogawa), and Re: 26,999 (Elliott).

Although the known computer flash devices of the form just noted have provided reasonably acceptable operation in practice, their employment of the above described short-circuiting or quenching action has caused them to have several practical short-comings, and has thus made them somewhat less than entirely satisfactory. This is so because each of such quenching actions causes practically all of the energy remaining in the storage capacitor, at the instant of the quenching of the flash tube, to be dissipated by the quenching means, and because this dissipation is produced every time that the flash tube is fired, even for those flashes which utilize only a small portion of the capacitor energy to produce the quantity of light which is actually required at the time.

Specifically, the conditions just described cause said known devices to be wasteful of electrical energy. This is particularly objectionable because, in most instances, this energy is supplied by a battery which is carried by or with the device. Also, the fact that the storage capacitor is substantially entirely discharged for each flash results in the recycle time of the device being unnecessarily long following those flashes in which the quenching action is produced early in the flash period and in which, therefore, only a small portion of the capacitor energy is actually used to produce light. Additionally, for flashes of this type, the quenching means is caused to carry relatively high currents and to dissipate large amounts of energy, due to the required size of the storage capacitor. This tends to shorten the life at the quenching means. Also, the accuracy with which the actual quenching is effected timewise is less for the flashes wherein such large amounts of energy must be dissipated than it is for the flashes wherein the quenching action is produced nearer to the end of the flash period.

In order to avoid the need for the above-noted quenching action, and hence to avoid the foregoing shortcomings or deficiencies, several other ways have been suggested in the past for controlling the quantity of light present in each flash in a computer flash device. In one such suggested arrangement, the storage capacitor is given only that amount of energy which is needed to cause the flash tube to emit the required quantity of light when subsequently flashed. Such an arrangement suffers, however, from the disadvantage of requiring a so-called test flash in order to ascertain what the correct charge for the capacitor actually is under the existing conditions, and of being unduly complex and less covenient to use as a result of this requirement. An example of such an arrangement is that disclosed in U.S. letter Pat. No. 3,465,656 (Wick et al.).

In another arrangement which has been suggested for overcoming the above-noted shortcomings, a signal generator connects the storage capacitor of the arrangement to two flash tubes alternately and repeatedly until a desired quantity of light has been produced. Again, the nature of such an arrangement renders it unduly complex. An example of this type of arrangement is that disclosed in U.S. letters Pat. No. 3,438,766 (Biber).

In still another arrangement which has been suggested for overcoming the above-noted shortcomings, the flash tube is quenched by interrupting the path over which current flows to the tube, as distinguished from short-circuiting the tube. Such an arrangement does, however, introduce new problems because of the nature of the currents which must be so interrupted. An example of this type of arrangement is that disclosed in Japanese Published Patent Application No. 30905/69 (Ban).

Therefore, although numerous suggestions have been made for the purpose of providing computer flash devices which are not subject to the above-noted shortcomings, each of the resulting arrangements of which I am aware has, for one or another reason, failed to be entirely satisfactory. Thus, there has continued to be a need for a computer flash device which is not only free from the above-noted shortcomings of the known devices employing the noted quenching technique, but which also does not introduce any of the several other described disadvantages of the noted previously suggested computer flash arrangements.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an improved type of computer flash device or apparatus which is of relatively simple construction, which does not require the above-noted objectionable means and actions of the previously suggested arrangements, but which, for each flash, draws from its storage capacitor means only a minimum and relatively small amount of energy, if any, in excess of that actually required to produce the required quantity of light for that flash.

In accomplishing the foregoing and other desirable objects, the improved apparatus provided in accordance with, and embodying, the present invention includes storage capacitor means having a number (at

least two) of discrete portions. These portions may be separate capacitors, or may be sections of a large capacitor, and are normally maintained in a charged condition. Said improved apparatus also includes switching means which interconnects said capacitor means and a flash tube, and which is actuated at the time that the apparatus is to produce a flash of light. When so actuated, the switching means effectively connects one after another of said capacitor portions temporarily or momentarily to the flash tube in sequence, and continues this sequential connecting of said portions for a period of time following said actuation, so that one after another of said portions is discharged in sequence into said tube, and causes current to flow or pass therethrough, during this period. As a result, said tube emits light during this period. After each capacitor portion has been so discharged into the flash tube, such portion is recharged.

The length of said period during which the switching means of said improved apparatus continues the sequential discharging of the capacitor portions into the flash tube may be determined by the operation of terminating means which includes light responsive means and which terminates said period when the flash tube has emitted a desired quantity of light during said period. This terminating means may also act to quench or stop the tube positively from emitting further light at the time or instant at which the desired quantity of light has been produced by the tube. In this way, only as many of said portions as are needed to produce the desired quantity of light are discharged, one after the other, into the tube, whereby the wasting of energy and the other undesirable actions described above are avoided.

In a preferred form of such apparatus, the switching means may include a switch individual to each capacitor portion and sequencing means which, when started, actuates one after another of said switches to cause one after another of the capaictor portions to discharge into the flash tube, this action, and hence said period, continuing until the sequencing means is stopped by the terminating means. The latter may include a light responsive device which is exposed to, and receives, light reflected from an object which receives the light emitted by the flash tube, the terminating means acting to stop the sequencing means when the responsive device has received a predetermined quantity of light during said period. The terminating means may also positively stop the flash tube from emitting light by short-circuiting the tube, and hence discharging only that one of the capacitor portions which is then connected thereto, at the instant at which said predetermined quantity of light has been received by the light responsive device.

BRIEF DESCRIPTION OF THE DRAWING

A better understanding of the invention may be had from the following detailed description when read in connection with the accompanying drawing, wherein:

FIG. 1 is a circuit diagram of computer flash apparatus embodying the present invention; and

FIG. 2 is a circuit diagram of a modification of a portion of the FIG. 1 apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In brief, the computer flash apparatus embodying the present invention which is illustrated in FIG. 1 is of the preferred form as last described above. This illustrated apparatus, on command, fires its flash tube to produce a flash of light, and then automatically controls the quantity of light present in the flash. The produced light is usually used to illuminate a subject to be photographed by an associated camera, not shown. The quantity of light present in the flash is automatically controlled to be that necessary to cause the quantity of light which reaches the camera film to be that which will produce the correct exposure of the film under the prevailing conditions. The apparatus provides such operation through the use of capacitor storage means having a plurality of discrete portions, hereinafter referred to as capacitors, together with a switching means, including a ring counter, a clock, and individual SCR switches, and a flash terminating portion. Upon the firing of the flash tube, the firing means therefor actuates the clock, counter, and switches, causing one after another of the capacitors to discharge into and pass current through the flash tube sequentially until a light sensor and integrator of the terminating portion signals that a predetermined quantity of light has been received back from the subject being photographed. At that time, said sequential action is terminated, and a quench tube is activated to short-circuit the flash tube and hence positively terminate the flash of light.

FLASH PRODUCING PORTION

In accordance with the foregoing, the FIG. 1 apparatus includes a flash producing portion including a flash tube **1** having main electrodes **2** and **3** and a trigger electrode **4**, a trigger transformer **5** having a primary winding **6** and a secondary winding **7**, a trigger capacitor **8**, a resistor **9**, a normally-open switch **10**, and high voltage supply conductors **11** and **12**. The latter are connected to respective high voltage supply terminals **13** and **14** which, in turn, are connected to an energy-supplying storage capacitor means of the apparatus according to the present invention, to be described hereinafter. As shown, the conductor **11** is a common conductor for the apparatus.

In said flash producing portion, the flash tube electrodes **2** and **3** are connected to the conductors **11** and **12**, respectively. The resistor **9** and the switch **10** are connected in series between the conductors **11** and **12**, and the trigger transformer primary winding **6** and the trigger capacitor **8** are connected in series across the switch **10**. The latter represents the usual camera shutter flash contacts and/or open flash or test switch of flash apparatus. The trigger transformer secondary winding **7** is connected between the flash tube trigger electrode **4** and the conductor **12**. Said storage capacitor means normally maintains a suitably high d.c. voltage between the terminals **13** and **14** as will be described hereinafter, which voltage normally maintains the capacitor **8** charged and energizes the flash tube **1** to cause it to emit light when fired.

In the apparatus just described, the flash tube **1** is fired by closing the switch **10**. Such closure, which is usually momentary, dumps the charge on the capacitor **8** into the winding **6**. This causes a triggering voltage to appear across the winding **6**, and a resulting, higher, triggering voltage to appear across the winding **7** and between the flash tube electrodes **3** and **4**. This latter voltage fires the tube **1**. Such operation need not be elaborated upon further herein, since it is well-known

and is also more fully described in the aforementioned U.S. letters Pat. No. 3,033,988.

FLASH TERMINATING PORTION

The FIG. 1 apparatus also includes a flash terminating means or portion which is generally like the quench control circuit disclosed in the aforementioned U.S. letters Pat. No. Re. 26,999. Thus, this portion includes a photocell **15** which is connected in series with a resistor **16** between a supply conductor **17** and the supply conductor **12**. These conductors are connected across a suitable source of d.c. voltage, shown as a battery **18**.

A slider **20**, which is adjustable along the resistor **16**, is connected through a coupling capacitor **21** to the base of a transistor **22**. This base is also connected to the conductor **17** by a resistor **23**, and to the conductor **12** by a resistor **24**. A resistor **25** connects the collector of the transistor **22** to the conductor **17**, and a resistor **26** connects the emitter of the transistor **22** to the conductor **12**.

The collector of the transistor **22** is also connected by a coupling capacitor **27** to the base of a transistor **28**. This base is also connected to the conductor **17** by a resistor **29**, and to the conductor **12** by a resistor **30**. The emitter of the transistor **28** is connected to the conductor **17** by a light-sensitive silicon controlled rectifier (LASCR) **31**, and to the conductor **12** by a resistor **32**, while the collector of the transistor **28** is connected to the conductor **12** by an adjustable resistor **33**. Accordingly, the transistor **28** is normally biased off and hence disabled.

The collector of the transistor **28** is also connected through a Zener diode **34** to the gate of a silicon controlled rectifier (SCR) **35**. This gate is also connected to the conductor **12** by a resistor **36**. The cathode of the SCR **35** is connected directly to the conductor **12**.

The anode of the SCR **35** is connected to the conductor **11** by a resistor **37**, and to the conductor **12** by a resistor **38**. A quench triggering capacitor **39** and the primary winding **40** of a quench triggering transformer **41** are connected in series across the resistor **38**. The secondary winding **42** of the transformer **41** is connected in series with a capacitor **43** between the trigger electrode **44** of a quench tube **45** and the conductor **12**. The tube **45** also has a main electrode **46** which is connected to the conductor **11**, and has a main electrode **47** which is connected to the conductor **12**.

In the manner explained in the aforementioned U.S. letters Pat. No. Re 26,999, the photocell **15** is of the light integrating type, such as the CdS type, and is exposed to, and receives, light reflected from the subject to be photographed, which subject is illuminated by the light emitted by the flash tube **1**. Therefore, when the tube **1** is fired, the photocell **15** begins to integrate said reflected light which it receives, and produces a light integral signal across the resistor **16** which represents the quantity of light which the photocell has received during the period starting with the firing of the tube **1**.

The LASCR **31** is exposed directly to the light emitted by the tube **1**, and enables the normally disabled transistor **28** when the tube **1** is fired. Accordingly, the said light integral signal is amplified by the circuit including the transistors **22** and **28**. When the resulting signal reaches a predetermined value, which is determined by the adjustments of the slider **20** and the resistor **33**, the SCR **35** is turned on and produces a quench triggering or terminating voltage across the winding **40** which fires the quench tube **45**. Said predetermined value is made to be that which is reached at the instant at which the photocell **15** has received a predetermined quantity of light, the receipt of which quantity indicates that the proper quantity of light for a correct exposure has reached the associated camera film.

When the quench tube **45** is so fired, it effectively short-circuits or shunts the flash tube **1** and stops the latter from emitting any further light. In the apparatus of said U.S. letters Pat. No. Re 26,999, this action of the quench tube also undesirable dissipates or dumps substantially all of the energy remaining in the single large storage capacitor of that apparatus. This undesirable action does not occur in the FIG. 1 apparatus, however, as will be explained hereinafter.

STORAGE CAPACITOR MEANS

As previously noted, the FIG. 1 apparatus includes a storage capacitor means in the form of a plurality of capacitors. Specifically, this storage capacitor means consists of six storage capacitors **48** through **53**. These capacitors are connected between a charging conductor **54** and the conductor **12**, the capacitor **48** being connected directly between these conductors, and each of capacitors **49**, **50**, **51**, **52**, and **53** being connected across its preceeding capacitor in series with a corresponding one of resistors **55**, **56**, **57**, **58**, and **59**. The capacitors **48** through **53** may be separate capacitors, or may be sections of a large capacitor.

The conductor **54** and **12** are provided with respective terminals **60** and **61** for connecting these conductors, and hence the capacitors **48** through **53**, to the usual flash capacitor charging means, not shown. Examples of such means are the device disclosed in U.S. letters Pat. No. 3,310,723 (Schmidt et al.), or a suitable high voltage battery. The connection just described cause each of capacitors **48** through **53** to be maintained in a charge condition until discharged into the flash tube **1**, and causes any such discharged capacitor to be recharged at a suitably rapid rate.

SWITCHING MEANS

As noted hereinbefore, the FIG. 1 apparatus includes switching means for causing one after another of the individual storage capacitors **48** through **53** to discharge into the flash tube **1** sequentially when and while the latter is to emit light. This switching means includes six switches, one for each of the six capacitors **48** through **53**, and a time sequence circuit. The switches are in the form of SCR's **62** through **67**. The time sequence circuit includes a clock **68** and a ring counter **69**, the latter having six outputs or positions, one for each of the six SCR's and capacitors.

The cathodes of all of the SCR's **62** through **67** are connected to the conductor **11**. Also, the anode of each of these SCR's is connected to a respective one of the capacitors **48** through **53** at the terminal thereof which is not connected to the conductor **12**. As a result, when any one of the SCR's **62** through **67** is on, it effectively connects the corresponding one of the capacitors **48** through **53** between the conductors **11** and **12**, and hence across the tubes **1** and **45**.

CLOCK 68

The clock **68** includes a set-reset flip-flop **70** which controls a suitable time, shown as a unijunction transistor timer **71**. The flip-flop **70** has the usual set input ter-

minal 72, reset input terminal 73, and Q output terminal 74. The flip-flop 70 is also energized in the usual manner, not shown, and is provided with a common connection to the conductor 11. In the usual manner, a pulse applied to the terminal 72 switches the terminal 74 to its low or 0 state, while a pulse applied to the terminal 73 switches the terminal 74 to its high or 1 state.

The timer 71 is of conventional form, and includes a transistor 75 having a base connected to the flip-flop terminal 74. The collector of the transistor 75 is connected through an adjustable timing resistor 76 to a positive supply terminal 77, and is connected through a timing capacitor 78 to a common and negative supply conductor 79. As shown, the latter is common to the conductor 11. The emitter of the transistor 75 is also connected to the conductor 79. The collector of the transistor 75 is also connected to the emitter of a unijunction transistor 80, one base connection of which is connected through a resistor 81 to the terminal 77, and the other base connection of which is connected to the base of a transistor 82 and through a resistor 83 to the conductor 79. The emitter of the transistor 82 is connected to the conductor 79, and the collector of the transistor 82 is connected to an output conductor 84 and through a resistor 85 to the terminal 77.

As a result of the construction just described, the flip-flop 70, when in its reset or normal condition, maintains the transistor 75 on, whereby the capacitor 78 is then kept short-circuited, the timer 71 is kept stopped, and no output pulses appear on the conductor 84. The application of a pulse to the set terminal 72, however, turns off the transistor 75 and starts the timer 71 and hence the clock 68, causing it to produce a series or chain of pulses on the conductor 84. The rate at which these pulses are produced is determined by the setting of the resistor 76. The timer 71 continues to produce these pulses until such time as a pulse is applied to the reset terminal 73. At that instant, the transistor 75 is turned on, the timer 71 and hence the clock 68 are stopped, and no further pulses are produced on the conductor 84 until such time as a pulse is again applied to the set terminal 72.

RING COUNTER 69

The ring counter 69 may be of any of the known, conventional forms for such devices, and is illustrated herein as being of the form shown in FIG. 11 on Page 5 of the General Instrument Corporation publication "Microelectronics Application Notes" for December, 1967. Thus, the counter 69 is shown as including a shift register 86 and a multiplexer 87. As noted in the last-mentioned publication, the register 86 may well be of the General Instrument type MEM 3012 SP, and the multiplexer 87 may be of the General Instrument type MEM 2009. It will be assumed for the purposes of the present description and for purposes of illustration that the devices 86 and 87 are of these types. Accordingly, the input terminal [10] of the register 86 is connected to the clock output conductor 84, while the register output terminals [7] through [2] are connected to respective terminals [1] through [6] of the multiplexer 87, and to the gates of SCR's 62 through 67, respectively. The register terminal [8] and the multiplexer terminals [9] through [14] are connected through a resistor 88 to a negative supply terminal 89, and the register terminal [9] is connected to a negative supply terminal 90. The multiplexer terminals [7] and [8] are connected to a positive supply conductor 91 which is common to the conductors 11 and 79.

As a result of the foregoing construction, the counter 69 applies a turn-on signal between the gate and cathode of one of the SCR's 62 through 67 at all times, and advances this turn-on signal from one SCR to the next and back to the first in sequence around a ring as long as the clock 68 produces the aforementioned pulse chain on the conductor 84. In other words, as long as the clock 68 is running, it pulses the counter 69, and one after another of the SCR's 62 through 67, around a ring, is turned on by the counter 69. As a result, as long as the clock 68 is running, one after another of the capacitors 48 through 53, around a ring, is effectively connected between the terminals 13 and 14 to energize the conductors 11 and 12.

In order that the foregoing sequential connection of the capacitors 48 through 53 to the terminals 13 and 14 be started at the time at which the flash tube 1 is fired, the set terminal 72 of the clock flip-flop 70 is connected to the firing circuit of the flash tube 1. Specifically, the set terminal 72 is connected by a conductor 92 and a blocking capacitor 92A to the junction between a pair of voltage dividing resistors 92B and 92C which are connected in series between the upper end terminal of the flash tube trigger transformer primary winding 6 and the conductor 11. As a result, a suitable set or start pulse is applied to the flip-flop 70 at the time at which the triggering voltage which fires the flash tube 1 appears across the winding 6.

Similarly, in order that said sequential capacitor connection be stopped at the time at which the flash tube 1 should be stopped from emitting further light, the reset terminal 73 of the flip-flop 70 is connected to the firing circuit of the quench tube 45. Specifically, the reset terminal 73 is connected by a conductor 93 and a blocking capacitor 93A to the junction between a pair of voltage dividing resistors 93B and 93C which are connected in series between the upper end terminal of the quench tube trigger transformer primary winding 40 and the conductor 11. As a result, a suitable reset or stop pulse is applied to the flip-flop 70 at the time at which the terminating portion determines that the flash tube 1 should be stopped and hence produces the quench tube triggering voltage across the winding 40.

As a result of the presence of the connections just described, the appearance on the winding 6 of the flash tube triggering voltage starts the clock 68, and the subsequent appearance on the winding 40 of the quench tube triggering voltage stops the clock 68. The purpose of the voltage dividing resistors 92B, 92C, 93B, and 93C is to cause the pulses applied to the flip-flop 70 to be of a suitable value notwithstanding the relatively high value of the voltage existing between the conductors 11 and 12, and the purpose of the blocking capacitors 92A and 93A is to prevent the flip-flop 70 from being affected by the voltages which normally exist across the trigger capacitors 8 and 39.

OPERATION OF THE FIG. 1 APPARATUS

At any time at which the FIG. 1 apparatus is ready to fire the flash tube 1, but before any such firing takes place, all of the capacitors 48 through 53 are charged, the clock 68 is stopped, and the counter 69 is thus not being pulsed. The latter is then applying a turn-on signal to one of the SCR's 62 through 67, say the SCR 63, for example. Thus, this SCR is on, and effectively con-

nects the charged capacitor 49 between the conductors 11 and 12 to supply energizing voltage between these conductors. As a result, the trigger capacitors 8 and 39 are charged, but the flash tube 1 and quench tube 45 are not conducting or passing current.

When the flash tube 1 is to be fired, the switch 10 is closed, and the triggering voltage appears across the winding 6. This fires the flash tube 1, causing it to pass current from the capacitor 49 and to emit light as the capacitor 49 discharges into the tube 1. This triggering voltage also starts the clock 68 by way of the connection 92. As a result, the clock 68 starts to pulse the counter 69 over the conductor 84. This first causes the counter 69 to remove the turn-on signal from the SCR 63 and to apply a turn-on signal to the SCR 64. The SCR 63 remains on, however, until the capacitor 49 has discharged a sufficient amount of its energy into the flash tube 1 to cause the SCR 63 to turn off. Before this occurs, however, the turned on SCR 64 effectively connects the charged capacitor 50 between the conductors 11 and 12, causing the capacitor 50 to discharge into the flash tube 1. Subsequently, while the capacitor 50 is so discharging, the SCR 63 turns off, and the capacitor 49 is effectively disconnected from the conductors 11 and 12 and begins to recharge from the energy supplied between the terminals 60 and 61.

While the capacitor 50 is so discharging to cause the flash tube 1 to emit light, the next pulse from the clock 68 causes the counter 69 to remove the turn-on signal from the SCR 64 and to apply a turn-on signal to the SCR 65. This turns on the latte and causes the charged capacitor 51 to start to discharge into the flash tube 1. Subsequently, the SCR 64 turns off and the capacitor 50 stops discharging and starts recharging. The next clock pulse causes the SCR 66 to turn on and the capacitor 52 to start discharging into the flash tube 1, and subsequent pulses turn on the SCR's 67, 62, 63, etc., in sequence. This sequential connection of the capacitors 53, 48, 49, etc., to the conductors 11 and 12 and across the flash tube 1, and the sequential recharging of the discharged capacitors, continues until the clock 68 is subsequently stopped.

The repetition rate for the clock output pulses is made to be such that the flash tube 1 emits light of acceptable intensity throughout the period in which the capacitors 48 through 53 are being seuqentially effectively connected to and discharged into the tube 1. This rate must, of course, be such that any given capacitor is caused to begin discharging before the previous capacitor can allow the tube 1 to become extinguished. Also, in choosing this rate, such factors as the size of the capacitors 48 through 53, the rate at which the flash tube 1 utilizes the capacitor energy. and the rate at which the capacitors 48 through 53 are recharged must be taken into account.

As the flash tube 1 emits light, light is received back by the photocell 15 from the subject being photographed, and the aforementioned light integral signal is produced across the resistor 16. Since the LASCR 31 is on at this time, the amplified resultant of this signal appears across the active portion of the resistor 33. When this latter signal reaches the aforementioned predetermined value, indicating that the flash tube 1 has emitted the quantity of light needed to provide the correct exposure of the associated camera film, the SCR 35 is turned on, producing the terminating voltage across the winding 40. This voltage stops the clock 68 by way of the connection 93. Accordingly, the sequential connection and discharging of the capacitors 48 through 53 is terminated, with the turn-on signal remaining on whichever of the SCR's 62 through 67 it was being applied to at the instant that the clock 68 stopped. Assuming by way of example that this SCR is the SCR 62, and that the clock 68 stopped subsequent to the turn-off of the SCR 67, the stopping of the clock 68 leaves only the capacitor 48 connected to the flash tube 1.

At the instant at which the clock 68 is stopped, however, the voltage on the winding 40 also fires the quench tube 45. The latter then effectively short-circuits the flash tube 1, and positively interrupts its current and stops it from emitting any further light. This action also effectively short-circuits the capacitor 48, but the only energy which is wasted is that remaining in this single capacitor. As soon as this energy is sufficiently dissipated so that the SCR 62 turns-off, the capacitor 48 recharges until it is again fully charged. At some time during this recharging period, the SCR 62 turns on again, and energizes the conductors 11 and 12 to ready the apparatus for the next flash. This reappearance of energizing voltage on the conductors 11 and 12 does not, of course, fire either of the tubes 1 and 45.

Summarizing the foregoing operation, when the flash tube 1 is fired, the switching means is actuated, and the clock 68 is started and pulses the counter 69 until the switching means is subsequently deactuated. Throughout the time period in which the counter 69 is being so pulsed. the latter turns on one after another of the SCR's 62 through 67 so that one after another of the capacitors 48 through 53 is discharging into and passing current through the tube 1 throughout this period, thereby causing the tube 1 to emit light of acceptable intensity throughout this period. When the photocell 15 of the terminating portion has received a predetermined quantity of light, this portion deactuates said switching means by stopping the clock 68, thereby terminating said period, the sequential effective connection of the capacitors 48 through 53 to the tube 1, and the sequential discharge of these capacitors into the tube 1. At the same time, the quench tube 45 is fired to interrupt the flow of current through the tube 1 to stop the tube 1 positively from emitting further light until fired again. Those of the capacitors 48 through 53 which are not effectively connected to the tube 1 at any given time receive charging current and energy from the terminals 60 and 61.

COMMENTS ON THE FIG. 1 APPARATUS

Although the individual capacitor switches have been illustrated in FIG. 1 as being SCR's, it is noted that these switches could be of other forms, and could, for example, be low impedance discharge tubes of the form of the quench tube 45. Also, although the storage capacitor means of the FIG. 1 apparatus has been illustrated by way of example as including six capacitors, it is noted that a larger or smaller number of storage capacitors and corresponding counter outputs or positions may be employed if desired, as dictated by the degree to which it is desired to avoid the wasting of energy. In general, the larger the number of such capacitors, the smaller the amount of energy which is wasted.

It is also noted that, if desired, quenching of the flash tube 1 may be accomplished by the use of means other than the illustrated shunt-connected quench tube 45,

and, for example, may be accomplished by the use of a series device as disclosed in the aforementioned Japanese application. Moreover, if desired, the quench tube **45**, or any other quenching means, may be entirely omitted from the FIG. 1 apparatus, and the stopping of the counter **69** thus used as the sole means for stopping the flash tube **1** from emitting light after the terminating means has signaled that the photocell **15** has received said predetermined quantity of light. The FIG. **1** apparatus without any quenching means can be made to have an accuracy which closely approaches that obtained when a quenching means is employed simply by providing a sufficiently large number of storage capacitors and counter positions. That is, by the use of a sufficient number of storage capacitors, the stopping of the clock **68** and counter **69** alone will provide sufficiently accurate turn-off of the flash tube **1** as to make the use of any quenching means unnecessary.

Further, it is noted that, if desired, the terminating portion may be of a type other than that illustrated, and may, for example, be of the type disclosed in the aforementioned U.S. letter Pat. No. 3,517,255. Also, if it is desired to utilize the FIG. 1 apparatus for the purpose of producing flashes which continue merely for fixed time periods of extended duration, the terminating portion can consist of merely a simple time delay device or timer which provides the reset signal on the conductor **93** when the wanted time period has elapsed in each flash following the firing of the flash tube **1**. SUch an extended flash will, of course, contain the same quantity of light as would be obtained by the use of a single large capacitor having a capacity which is equal to the sum of the capacities of the individual capacitors which are discharged into the flash tube **1** during the flash period. However, the duration of such an extended flash will be desirably stretched out with respect to the conventional flash which would be produced by the use of such a single large capacitor. Such flashes of extended duration are useful, for example, in those instances where a camera having a focal plane shutter is used but where, for one or another reason, it is not desired to employ the computer flash technique for controlling the flash duration. If desired, the light produced by such extended flashes may be evened out and stretched out even further by coating the flash tube **1** with a phosphorescent material, or by providing a lens or filter in front of the tube which is coated with such a meterial.

THE CIRCUIT OF FIG. 2

In FIG. **2** there is shown a different form which the capacitor charging circuit of the FIG. **1** apparatus may take. In the FIG. **2** circuit, the FIG. **1** resistors **55** through **59** are replaced by resistors **94** through **98**, each of which connects a respective one of the capacitors **49** through **53** directly between the charging terminals **60** and **61**. A corresponding one of diodes **99** through **103** is connected in parallel with each of the resistors **94** through **98**. This arrangement causes each of the capacitors **49** through **53** to be supplied with charging current through but a single resistor, instead of through a string of resistors as occurs in the FIG. **1** arrangement. As a result, the recharging or recycle time of the FIG. **2** arrangement is desirably reduced with respect to that of the FIG. **1** arrangement.

SUMMARY

In summary, it is seen that the described apparatus according to the present invention fulfills the objects set forth hereinbefore by being of relatively simple construction, and by providing computer flash operation characterized by minimum electrical energy waste and recycle time, minimum quench tube currents, increased accuracy with which each flash is automatically controlled, and increased quench tube life.

I claim:

1. Flash apparatus comprising

a single flash tube,

a plurality of capacitors,

charging means connected to said capacitors for supplying charging current thereto,

a plurality of switching devices arranged electrically in a ring, each of said devices being connected between said tube and a corresponding one of said capacitors and being operative, only when turned on, to discharge said corresponding capacitor into said tube to cause the latter to emit light,

firing means connected to said tube to fire the latter when it is to emit light,

a pulse generator responsive to the firing of said tube to produce a chain of substantially equal and equally spaced pulses upon the firing of said tube,

a ring counter connected to said generator to receive said pulses, and connected to all of said switching devices to normally supply a turn-on signal to one of said switching devices in the absence of said pulses, and to advance and supply said turn-on signal to the next of said switching devices around said ring upon the production of each of said pulses by said generator, thereby to cause one after the other of said capacitors to discharge into said tube around said ring at substantially equally spaced intervals as long as said generator produces said pulses,

a light responsive integrating device arranged to receive light which is influenced by the light emitted by said tube and to produce a stop signal upon receiving a predetermined quantity of light, and

means connecting said light responsive device to said generating means to stop the latter from producing said pulses upon the production of said stop signal by said light responsive device.

2. Apparatus as specified in claim **1**, including means connected between said tube and said light responsive device to receive said stop signal and to positively stop said tube from emitting further light upon the production of said stop signal by said light responsive device.

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