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(71) Applicant *(for all designated States except US)*: **MAG INSTRUMENT, INC.** [US/US]; 2001 South Hellman Avenue, Ontario, CA 91761 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **MAGLICA, Anthony** [US/US]; 2001 South Hellman Avenue, Ontario, CA 91761 (US). **WEST, Stacey, H.** [US/US]; 40419 Amesbury Lane, Temecula, CA 92591 (US).

(74) Agent: **WEISS, Robert, C.**; Jones Day, 555 South Flower Street, Fiftieth Floor, Los Angeles, CA 90071 (US).

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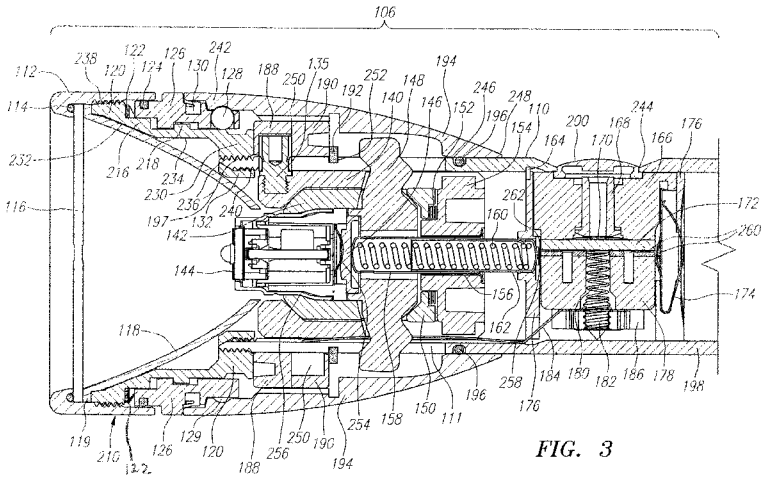

FIG. 3

(57) Abstract: A flashlight having a locking mechanism for securing a head skirt to a head assembly is disclosed. A circuit for temporarily storing the mode of operation of the flashlight is also disclosed.

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PORTABLE LIGHTING DEVICES

Field of the Invention

The present invention relates to portable lighting devices, including for example, flashlights and headlamps, and their circuitry.

Background

Various hand held or portable lighting devices, including flashlights, are known in the art. Such lighting devices typically include one or more dry cell batteries having positive and negative electrodes. The batteries are arranged electrically in series or parallel in a battery compartment or a housing that can be used to hold the flashlights. An electrical circuit is frequently established from a battery electrode through conductive means which are electrically coupled with an electrode of a light source, such as a lamp bulb or a light emitting diode ("LED"). After passing through the light source, the electric circuit continues through a second electrode of the light source in electrical contact with conductive means, which in turn are in electrical contact with the other electrode of a battery. Typically, the circuit includes a switch to open or close the circuit. Actuation of the switch to close the electrical circuit enables current to pass through the lamp bulb, LED, or other light source—and through the filament, in the case of an incandescent lamp bulb—thereby generating light.

Conventional flashlights also frequently include a head assembly, which typically includes a head, a lens, a face cap, and a reflector. The face cap in such flashlights is typically attached to the head to hold the lens and reflector relative to the head. Head assemblies of this type are often threadably mounted to the forward end of the body or barrel of the flashlight via the head. Such head assemblies are not conducive, however, to accessing a light source alignment device, such as the light source alignment devices included in the flashlights described in U.S. Patent No. 7,264,372 B2 ("the '372 patent) or U.S. Patent Publication 2007/0064354 A1 ("the '354 publication"), both of which are assigned to MAG Instrument, Inc.

The '372 patent, teaches a head assembly including a face cap, lens, a sleeve or skirt, and a sealing O-ring that are configured and arranged so that the face cap and sleeve define a clearance envelope surrounding the flange of a reflector module to solve this problem. As a result, the head assembly may be rotated about the axis of the flashlight

relative to reflector module so as to cause the light source to translate along the axis of the reflector and vary the dispersion of light produced by the flashlight. Further, the user may disengage the sleeve or skirt from the face cap and then slide it rearward to gain access to the light source alignment device and thereby move the light source in one or more directions lateral to the axis of the reflector to align the substantial point source of light with the axis of the reflector. The disadvantage of this construction is that when the sleeve or skirt is disengaged from the face cap, the face cap, and hence the lens, are no longer connected to the reflector module or any other portion of the flashlight, and hence they are liable to be dropped and/or damaged.

The flashlight described in the '354 publication solves this problem through the use of a support structure to which the face cap and skirt (which is referred to as the head in the '354 publication) are separately attached. The face cap is threadably attached to the support structure of the flashlight and retains the lens and reflector relative to the support structure. Thus, when the skirt is detached from the support structure to gain access to the light source alignment device included in the flashlight of the '354 publication, the face cap and associated optics remain attached to the flashlight, thereby minimizing the potential for damage to the same. However, the skirt of the '354 patent publication is attached to the support structure via a compressible retaining ring. More particularly, the internal surface of the skirt is configured to mate with the outer surface of the support structure of the flashlight at select locations to properly position the skirt relative to the face cap and the support structure. The compressible retaining ring is then provided in a channel extending around the outer surface of the support structure to create an interference fit with a feature provided on the internal surface of the skirt. Because the skirt must be removable in order for the user to access the light source alignment device included in the flashlight described in the '354 publication, however, the compressible retaining ring may not provide a permanent type interference fit. Indeed, to permit the average user to remove the skirt without undue effort, the interference fit must be relatively weak. As a result, the skirt of this flashlight is subject to being unintentionally disconnected from the support structure if the flashlight is dropped on its tail or otherwise receives a jolt to the tail of the flashlight. The unintentional detachment of the skirt from the support structure in this manner is undesirable.

Although the '372 patent and '354 publication indicate that the light source employed in the flashlights described in each of the patent documents may be an LED, these patent documents do not teach a configuration that suitably addresses the thermal management issues created by high power, high brightness LEDs.

Some advanced portable lighting devices provide multiple functions for different needs. For example, a power saving mode and/or an SOS mode may be implemented in a flashlight or other portable lighting devices in addition to the normal "full power" mode. In such portable lighting devices, the user typically elects the desired mode of operation by manipulation of the main power switch. For example, when the flashlight is in the normal mode or the power save mode of operation, the flashlight may be transitioned to another mode of operation, such as an SOS mode by manipulating the main power switch to momentarily turn off and then turn back on the flashlight.

Typically the functionality of multi-mode portable lighting devices of this sort is provided by a microcontroller, which remains powered by the batteries at all times. As a result, the volatile memory of the microcontroller may be used to store the current mode of the flashlight, and thus determine which mode to transition into in the event that a user enters the proper command signal. However, if the portable lighting device—particularly in the case of larger flashlights—is accidentally hit against, or dropped on, a hard surface, the inertia of the battery or batteries may cause the battery or batteries to disconnect from one of the battery contacts for a short period of time. This disconnection will also cause a power loss to the microcontroller, thereby causing the microcontroller to lose track of the mode the flashlight or other lighting device was in prior to the power loss. As a result, the microcontroller will reset the flashlight or other lighting device to its default mode, which is typically off, rather than automatically returning to the prior mode of operation. Resetting under such circumstances is undesirable and potentially hazardous.

Portable lighting devices that include advanced functionality typically include a printed circuit board with a microcontroller or microprocessor to provide the desired functionality. A need exists, however, for a push button switch assembly that includes an integral circuit board that may be readily employed in a variety of portable lighting devices to provide multiple levels of functionality to the same.

In view of the foregoing, a need exists for an improved technique of attaching a flashlight skirt to the flashlight while also providing a user friendly operation when detaching the skirt. A separate need also exists for an improved portable lighting device that addresses or at least ameliorates one or more of the problems discussed above.

Summary of Invention

It is an object of the present invention to address or at least ameliorate one or more of the problems associated with flashlights and/or portable lighting devices noted above.

Accordingly, in a first aspect of the invention, a flashlight with a detachable head skirt that may be selectively locked to and unlocked from the flashlight via a locking mechanism is provided.

In one embodiment, the locking mechanism comprises a skirt lock ring that is at least partially interposed between an internally disposed head member and an externally disposed head skirt. The skirt lock ring, the interior surface of the skirt head, and the exterior surface of the head member are preferably configured so that the skirt lock ring may be rotated between a first position in which the head skirt is at least axially locked to the head member and a second position in which the head skirt is axially unlocked from the head member and may be removed from the flashlight.

In another embodiment, the head and switch assembly have a hollow head and a skirt locking ring. The outer surface of the head can have a front section, an aft section, and a cylindrical midsection. The cylindrical midsection can have a plurality of protuberances. Each of the protuberances can have a cut facing to the front section. Each of the protuberances can have a lock member formed by an under cut. The inner surface of the skirt lock ring has a front end, an aft end and a middle portion. The middle portion can have a plurality of first indexing bumps and the aft end can have a plurality of second indexing bumps. Each of the first indexing bumps can be aligned to one of the second indexing bumps to form a plurality of channels. Each of the first indexing bumps and the second indexing bumps can be constructed by two high plateau regions that are separated by a low plateau region. The skirt lock ring can be locked to the head when each of the protuberances is aligned with a low plateau region.

In yet another embodiment, a head assembly may comprise a head skirt having an inner surface. The aft section of the head can have an annular groove sized to receive a portion of a ball. At least one of the high plateau regions of the second indexing bumps can have a hole sized to receive the ball. The inner surface of the head skirt has a front end. The inner surface of the head skirt has an annular groove near the front end. The head skirt may be locked to the head when the ball extends into the annular groove of the head skirt. On the other hand, the head skirt is not locked to the head by the ball when the ball does not extend into the annular groove.

In yet another embodiment, the number of protuberances can be the same as the number of channels. In one embodiment, the number of protuberances can be six. In one embodiment, the width of a plurality of protuberances can be smaller than the width of a plurality of channels. In one embodiment, three of the high plateau regions of the second

indexing bumps has a hole sized to receive the balls, the three holes are placed and separate from each other with equal distance. In one embodiment, the head assembly may comprise a wave spring for pushing the skirt lock ring to a lock position.

In a second aspect of the invention, a method for mounting a head skirt to a skirt lock ring of a flashlight is provided. In one embodiment, the method comprises the steps of rotating the skirt lock ring until the skirt lock ring is aligned in a moving position with a head, pushing the skirt lock ring from a moving position to a rotating position, rotating the skirt lock ring from a rotating position to a locking position, and releasing the skirt lock ring to the locking position.

In one embodiment, the head skirt can be locked by the skirt lock ring when the skirt lock ring is in the rotating position and the locking position.

In a third aspect of the invention, a portable lighting device with multiple modes of operation is provided. The device has a main power source, a user interface, a microcontroller having an internal memory, and a plurality of temporary mode memory devices not residing in the microcontroller. The user interface can have an off position, a momentary position, and a latch position. The microcontroller can have a plurality of bidirectional input/output ports. The plurality of temporary mode memory devices can be coupled to the plurality of bidirectional input/output ports of the microcontroller. When the user interface remains in the latch position for a period of time, the microcontroller can read the previous mode information from the internal memory, increment the mode value by one to obtain a current mode information, and write the current mode information into the mode memory devices. In one embodiment, the temporary mode memory devices can be constructed by RC circuits.

In a forth aspect of the invention, a portable lighting device having a reverse polarity protection circuit is provided. The device has a main power source, a controller, and a power control circuit. The controller can have an input and an output. The power control circuit can be electrically coupled to the main power source and the output of the controller. The power control circuit can provide a voltage output to the controller substantially the same as the main power source when the battery count is below a predetermined value. The power control circuit can also provide a voltage output to the controller substantially lower than the main power source when the battery count is above or equal to the predetermined value. In one embodiment, the controller is a microcontroller. In one embodiment, the predetermined value can be four.

In a fifth aspect of the invention, a portable lighting device having a power profile information stored in its memory is provided. The device has a main power source, a lamp, a lamp driving circuit for providing power to the lamp, and a microcontroller. The main power source has a limited life cycle including a high voltage period, a voltage depletion period and a low voltage period. The microcontroller has an internal memory for storing battery count data information. The microcontroller has a lamp drive output pin. The lamp drive output pin can be coupled to the lamp driving circuit. When the main power source is in the high voltage period, the microcontroller can provide a high duty cycle signal to the lamp drive output pin for the lamp driving circuit to provide a high duty cycle power supply to the lamp. When the main power source is in the voltage depletion period, the microcontroller can gradually decline the duty cycle signal to the lamp drive output pin for the lamp driving circuit to provide a gradually declined power supply to the lamp. When the main power source is in the low voltage period, the microcontroller can provide a low duty cycle signal to the lamp drive output pin for the lamp driving circuit to provide a low duty cycle power supply to the lamp.

In one embodiment, a power profile can be calculated real-time based on a cell count variable stored in a non-volatile memory of the microcontroller. The microcontroller may store power profile information for the main power source in the internal memory. The microcontroller can use the power profile information as an indicator of the current state of the main power source. In one embodiment, the microcontroller can also store information about a second power profile for a second main power source that can replace the main power source. In one embodiment, the high duty cycle is 100%. In one embodiment, the low duty cycle is 10%. In other embodiments, the low duty cycle is greater than 10%, but less than 90%.

Further aspects, objects, and desirable features, and advantages of the invention will be better understood from the following description considered in connection with the accompanying drawings in which various embodiments of the disclosed invention are illustrated by way of example. It is to be expressly understood, however, that the drawings are for the purpose of illustration only and are not intended as a definition of the limits of the invention.

Description of the Figures

FIG. 1 is a top view of a portable lighting device comprising a flashlight according to one embodiment of the present invention.

FIG. 2 is a cross-sectional view of the flashlight of FIG. 1 taken along the plane indicated by 102-102.

FIG. 3 is an enlarged cross-sectional view of the forward section of the flashlight of FIG. 1 taken through the plane indicated by 102-102.

FIG. 4 is an exploded perspective view of the flashlight of FIG. 1.

FIG. 5A is an enlarged exploded perspective view of a portion of the head assembly of the flashlight of FIG. 1. FIG. 5B is an enlarged exploded perspective view of the adjustable ball assembly portion of the flashlight of FIG. 1. FIG. 5C is an enlarged exploded perspective view of the switch assembly portion of the flashlight of FIG. 1.

FIGS. 6A through 6C are different cross-sectional views illustrating one relative position between the skirt lock ring and head. FIGS. 6D through 6F are different cross-sectional views illustrating a second relative position between the skirt lock ring and head. FIGS. 6G through 6I are different cross-sectional views illustrating a third relative position between the skirt lock ring and head.

FIG. 7 is a cross-sectional view of a flashlight according to another embodiment of the present invention.

FIG. 8 is an exploded perspective view of the adjustable ball assembly portion of the flashlight of FIG. 7.

FIG. 9 is a circuit diagram illustrating the relationship of the electronic circuitry according to one embodiment of the invention.

FIGS. 10A-E are schematic circuit diagrams of different components of the circuit shown in FIG. 9.

FIGS. 11A-C are diagrams of the power profile for different types of batteries.

Detailed Description of the Preferred Embodiment

Embodiments of the invention will now be described with reference to the drawings. To facilitate the description, any reference numeral representing an element in one figure will represent the same element in any other figure. Further, in the description that is to follow, upper, front, forward or forward facing side of a component shall generally mean the orientation or the side of the component facing the direction toward the

front end of the portable lighting device or flashlight. Similarly, lower, aft, back, rearward or rearward facing side of a component shall generally mean the orientation or the side of the component facing the direction toward the rear of the portable lighting device (e.g., where the tail cap is located in the case of a flashlight).

Flashlights 100, 300 according to different embodiments of the present invention are described in connection with FIGS. 1-11C below. Each of the flashlights 100, 300 incorporate a number of distinct aspects of the present invention. While these distinct aspects have all been incorporated into the flashlights 100, 300 in various combinations, it is to be expressly understood that the present invention is not restricted to flashlights 100, 300 described herein. Rather, the present invention is directed to each of the inventive features of the flashlights 100, 300 described below, both individually as well as collectively. Further, as will become apparent to those skilled in the art after reviewing the present disclosure, one or more aspects of the present invention may also be incorporated into other portable lighting devices, including, for example, head lamps.

Referring to FIGS. 1-2, flashlight 100 includes a barrel 198 enclosed at a rearward end by a tail cap 206 and at a forward end by a head assembly 210.

Barrel 198 is preferably made out of aluminum. As is known in the art, barrel 198 may be provided with a textured surface 104 along a portion of its axial extent, preferably in the form of machined knurling. A portion of forward end 110 of barrel 198 extends beneath a head skirt 194. A hollow space 199 is formed within barrel 198 for housing a portable power source, such as one or more batteries in series, or a battery pack with cells arranged in series or parallel. Further, the employed batteries or battery pack may be rechargeable.

Tail cap 206 is also preferably made out of aluminum and is configured to engage mating threads provided on the interior of barrel 198 as is conventional in the art. However, other suitable means may also be employed for attaching tail cap 206 to barrel 198. A one-way valve 204, such as a lip seal, may be provided at the interface between tail cap 206 and barrel 198 to provide a watertight seal while simultaneously allowing overpressure within the flashlight to expel or vent to atmosphere. However, as those skilled in the art will appreciate, other forms of sealing elements, such as an O-ring, may be used instead of one-way valve 204 to form a watertight seal. The design and use of one-way valves in flashlights is more fully described in U.S. Patent No. 5,113,326 to Anthony Maglica, which is hereby incorporated by reference.

If made out of aluminum, the surfaces of barrel 198 and tail cap 206 are preferably anodized with the exception of those surfaces used to make electrical contact with another metal surface for purposes of forming the electrical circuit of the flashlight. In the present embodiment, an electrical path is formed between barrel 198 and the case electrode of the batteries or battery pack installed in the compartment 199 by spring 202 and tail cap 206. In addition to forming part of the electrical path between the barrel and case electrode, spring 202 also urges batteries or a battery pack installed in the compartment 199 forward so that the center electrode of the front-most battery or battery pack is urged into one end of spring contact 174.

Referring to FIGS. 1-4, the present embodiment includes a head 120 to which a number of other components may be mounted, including, for example, skirt lock ring 126, wave spring 122, head skirt 194, face cap 112, lens 116, and reflector 118 to form a head assembly 210. Head 120, skirt lock ring 126, head skirt 194 and face cap 112 are preferably made from anodized aluminum. On the other hand, reflector 118 is preferably made out of injection molded plastic. The interior surface of reflector 118 is preferably metallized to enhance its reflectivity to a suitable level.

In the present embodiment, head 120 is a hollow support structure comprising a front section 216, a midsection 218 and an aft section 230. Head 120 is internally disposed in the present embodiment in that head 120 is covered by face cap 112, skirt lock ring 126, and head skirt 194 when the flashlight 100 is fully assembled. In other words, in the present embodiment, head 120 does not comprise an external portion of the flashlight 100. The front section 216 comprises a generally cup-shaped receiving area 232 for receiving reflector 118. The midsection 218, which extends rearward from the front section 216, includes a generally cylindrical inner surface 234. And, the aft section 230, which extends rearward from the midsection 218, includes internal threads 236 which are configured to mate with external threads 197 on the forward end of barrel 198. Head 120 is locked to the barrel 198 with a retainer 132. Retainer 132 is externally threaded with threads 240 on its aft end and is outwardly tapered on its forward end. Retainer 132 is configured so that external threads 240 mate with internal threads 195 provided on the forward end of barrel 198. Because the forward end 110 of barrel 198 includes opposing slots 111, when retainer 132 is threaded into threads 125 of barrel 198, barrel 198 is expanded as the tapered portion of retainer 132 contacts barrel 198 and is then screwed further into the barrel 198. When retainer 132 is fully seated in barrel 198, head 120 is locked to the barrel 198.

The face cap 112 retains lens 116 and reflector 118 relative to the head 120 and reflector 118. In the present embodiment, face cap 112 is configured to thread onto external threads 238 provided on the front section 216 of the head 120. In other implementations, however, other forms of attachment may be adopted. An O-ring 114 is provided at the interface between face cap 112 and lens 116 to provide a watertight seal. As best seen in FIG. 3, reflector 118 is positioned within the cup-shaped receiving area 232 of head 120 so that it is disposed forward of the head 120 and retainer 132. The internal surface of the cup-shaped receiving area 232 together with the outer surface of reflector 118 and reflector flange 119 ensure the proper alignment of the principal axis of reflector 118 with the central axis of the barrel 198. The face cap 112 in turn clamps O-ring 114, lens 116, and reflector 118 via reflector flange 119 to head 120.

Head skirt 194 has a diameter greater than that of the barrel 198. Head skirt 194 is also adapted to pass externally over the exterior of the barrel 198. The forward end 242 of head skirt 194 is configured to mate with the outer surface of a skirt lock ring 126 at select locations to properly position head skirt 194 relative to face cap 112 and head 120.

The locking mechanism of the head skirt 194 will now be described. FIG. 5A shows an exploded view of a portion of head assembly 210. The outer surface of head 120 has a nominally smooth surface 266 with an annular groove 267 on the outer surface of aft section 230 and a plurality of protuberances 268 equally spaced from each other around the outer circumference of the midsection 218 of head 120.

FIGS. 6A through 6I are cross-sectional views illustrating different relative positions between the head 120 and skirt lock ring 126. The dimensions of the head 120 and skirt lock ring 126 in FIGS. 6A through 6I are not to scale. Nevertheless, FIGS. 6A-6I are helpful for the purpose of illustrating how the locking mechanism of head skirt 194 works in the illustrated embodiment.

As best seen in FIGS. 6C, 6F, and 6I, a gap 231 is formed between each protuberance 268 and the front section 216 of head 120. In the present embodiment, six protuberances 268 are used. Each of the protuberances 268 has a relief cut 269 on the front end such that each of the protuberances 268 have a reversed L-shaped cross-section in the longitudinal direction of flashlight 100 as seen in FIG. 6C, for example. At the toe of the reversed L-shaped protuberances 268 is a lock member 270. In the present embodiment, the number of protuberances 268 is six. In other embodiments, the number of protuberances 268 may be different. However, the number of protuberances 268 should be an integer number greater than or equal to three.

As best seen in FIG. 5A, the inner surface of skirt lock ring 126 has a front end 281, an aft end 282 and a middle portion 283 in between. The inner surface of skirt lock ring 126 comprises a plurality of longitudinal channels 271 formed by a plurality of first indexing bumps 272 and second indexing bumps 275. In the present embodiment, six first indexing bumps 272 are formed near the middle portion 283 of the inner surface of the skirt lock ring 126 and six second indexing bumps 275 are formed near the aft end 282 of the inner surface of the skirt lock ring 126. Each of the first indexing bumps 272 comprises two high plateau regions 274 separated by a low plateau region 273. Similarly, each of the second indexing bumps 275 comprises two high plateau regions 277 separated by a low plateau region 276. In the present embodiment, some of the high plateau regions 277 of the second indexing bumps 275 have a hole 278 sized to receive a ball 128. In the present embodiment, three holes 278 are equally spaced from each other around the inner circumference of skirt lock ring 126. In the present embodiment, the number of first indexing bumps 272 is the same as the number of second indexing bumps 275. In an alternate embodiment, the number of first indexing bumps 272 may be an integer multiple of the number of second indexing bumps 275. In another embodiment, the number of first indexing bumps 272 is an integer factor of the number of second indexing bumps 275. In the present embodiment, the number of second indexing bumps 275 is the same as the number of protuberances 268. In other embodiments, the number of second indexing bumps 275 may be an integer multiple of the number of protuberances 268.

FIGS. 6A-C show different cross-sectional views through the head 120 and skirt lock ring 126 when the skirt lock ring 126 has been rotated to a position which unlocks the head skirt 126 axially from the head 120. FIGS. 6A-6C also show skirt lock ring 126 in a position (position A) relative to head 120 where their aft ends are aligned. Balls 128 now sits in annular groove 267 and the top end 279 of ball 128 is lower than the top surface 280 near the aft end of skirt lock ring 126. Accordingly, head skirt 194 can be freely mounted to or dismounted from skirt lock ring 126 at this position. When every protuberance 268 of head 120 is aligned with a channel 271 of skirt lock ring 126 (as shown in FIG. 6C) by rotating skirt lock ring 126 to a suitable position, then the first indexing bumps 272 and the second indexing bumps 275 are aligned with the smooth surface 266 of skirt lock ring 126 (as shown in FIGS. 6A-6B). In this position, skirt lock ring 126 may be freely moved axially forward or rearward over head 120. FIG. 6A more particularly shows where low plateau regions 273, 276 of skirt lock ring 126 are aligned with the smooth surface 266 of head 120, and FIG. 6B more particularly shows where high plateau regions 274, 277 of skirt lock ring 126 are aligned with the smooth surface 266 of head 120. When the skirt lock ring 126 is indexed to this position, it is in a position in which it may be moved

forward or rearward relative to head 120 by an operative amount. However, skirt lock ring 126 cannot be rotated relatively to head 120 because protuberances 268 and high plateau regions 274 are next to each other so that high plateau regions 274 extend too far out from skirt locking ring 126 to pass over protuberances 268.

When skirt lock ring 126 and head 120 are aligned as illustrated in FIGS. 6A-6C, skirt lock ring 126 may be pushed forward to position B against the spring force of wave spring 122, as shown in FIGS. 6D-6F. When skirt lock ring 126 is pushed forward in this manner protuberances 268 and high plateau regions 274 are no longer next to each other. As a result, skirt lock ring 126 can now be rotated relative to head 120 because high plateau regions will now pass through gap 231 between protuberance 268 and the front section 216 of head 120 as skirt lock ring 126 is rotated. Balls 128, however, no longer sit in annual groove 267, but instead are disposed on the smooth surface 266. As a result, the top end 279 of ball 128 is now higher than the top surface 280 near the aft end of skirt lock ring 126. If the head skirt 194 is mounted to the skirt lock ring 126, the ball 128 will extend into annular groove 129 formed in the interior surface of head skirt 194. However, because protuberances 268 remain aligned with channels 271, the skirt lock ring 126 remains subject to being moved rearward to position A shown in FIGS. 6A-6C and thus the head skirt 194 is not axially locked to the head 120 at this point.

When skirt lock ring 126 and head 120 are aligned as described in FIGS. 6D-6F, skirt lock ring 126 can be rotated relatively to head 120. If a user rotates skirt lock ring 126 30° in either direction and then releases the skirt lock ring 126 wave spring 122 will bias the skirt lock ring 126 rearward, and the relationship between skirt lock ring 126 and head 120 will be the position (position C) as shown in FIGS. 6G-6I. Now, protuberances 268 are aligned with low plateau regions 273 (as shown in FIG. 6I). Further, the spring force of wave spring 122 pushes skirt lock ring 126 rearward until a corner of each low plateau region 273 fits into a space formed by relief cut 269 of an opposing protuberance 268 and lock members 270 are positioned under the low plateau regions 273. In this manner, skirt lock ring 126 cannot be rotated relative to head 120 because each side of lock member 270 of protuberances 268 is now next to a high plateau region 274. In addition, balls 128 are still disposed on the smooth surface 266, and, as a result, the top end 279 of ball 128 is still higher than the top surface 280 near the aft end of skirt lock ring 126. Thus, if head skirt 194 is mounted, it will be axially locked by ball 128 to head 120 and cannot be dismounted (as shown in FIGS. 2-3).

When head skirt 194 is locked (as shown in FIGS. 2-3), the skirt lock ring 126 and head 120 are aligned as illustrated in FIGS. 6G-6I. To access adjusting ring 148 to adjust the alignment of the beam direction of the substantial point source of light, namely LED 145 of LED module 144 in the present embodiment, with the principal axis of the reflector, head skirt 194 must be unlocked and slid rearward over barrel 198 at least far enough for the user to gain access to adjustment ring 148. The procedure for accomplishing this is described below.

First, when head skirt 194 is axially locked to the head 120 by the skirt locking ring 126, the skirt lock ring 126 and head 120 are aligned as illustrated in FIGS. 6G-6I. Further, skirt lock ring 126 cannot be rotated relative to head 120. However, the head skirt 194 is free to rotate about the skirt locking ring 126 and barrel 198 to axially translate the light source along the axis of the reflector as discussed more fully below. Further, the skirt lock ring 126 together with the head skirt 194 may be pushed forward against wave spring 122 to unlock skirt lock ring 126 from head 120. By rotating the skirt lock ring 126 30° in either direction, the skirt lock ring 126 and head 120 are aligned as illustrated in FIGS. 6D-6F, and, as a result, the head skirt 194 is axially unlocked from the head member 194 and thus may be removed from the flashlight 100. This is because skirt lock ring 126 is now free to move from position B to position A, and once skirt lock ring 126 and head 120 are aligned in position A, as shown in FIGS. 6A-6C, balls 128 will fall into annular groove 267 and the top end 279 of balls 128 will no longer be higher than the top surface 280 near the aft end of skirt lock ring 126. Accordingly, head skirt 194 may continue to be moved rearward and dismounted and no longer locked by ball 128 and head skirt 194 can now be dismounted. However, cam 188 will block skirt lock ring 126 from moving rearward beyond its position in position A.

If it is desired to mount head skirt 194 back to have a complete flashlight assembly, the following procedure can be used. First, head skirt 194 is slid forward over the flashlight barrel 198 until it abuts skirt lock ring 126. Once head skirt 194 abuts skirt lock ring 126, head skirt 194 together with skirt lock ring 126 may be pushed forward to position B against the spring force of wave spring 122, as shown in FIGS. 6D-6F. Balls 128 are now disposed on the smooth surface 266 and the top end 279 of ball 128 is higher than the top surface 280 near the aft end of skirt lock ring 126 so as to extend into annular groove 129 in head skirt 194.

Once in position B, skirt lock ring 126 may be rotated 30° in either direction and then released. Wave spring 122 will bias the skirt lock ring 126 rearward so that the skirt

lock ring 126 and head 120 are placed in position C as shown in FIGS. 6G-6I. At this point, skirt lock ring 126 can no longer be rotated because lock members 270 of protuberances 268 are now locked by high plateau regions 274. Because balls 128 are now disposed on the smooth surface 266, as shown in FIG. 6H and skirt lock ring 126 cannot be rotated, head skirt 194 is axially locked to the head 120 and cannot be dismounted (as shown in FIGS. 2-3).

Referring back to FIGS. 1-4, an O-ring 124 is provided at the interface between face cap 112 and skirt lock ring 126 to provide a watertight seal.

A one-way valve 130, such as a lip seal, may be provided at the interface between the head skirt 194 and skirt lock ring 126 to provide a watertight seal and to prevent moisture and dirt from entering head and switch assembly 106 between skirt lock ring 126 and the forward end 242 of head skirt 194.

As noted above, a portion of the forward end 110 of barrel 198 is disposed under head skirt 194 when it is mounted to the flashlight 100. The forward most portion of the forward end 110 is interposed between, and threadably attached to, the aft section 230 of the head 120 and retainer 132 as explained above. As a result of the foregoing construction, with the exception of the external surface formed by switch cover 200, all of the external surfaces of the flashlight 100 according to the present embodiment may be made out of metal, and more preferably aluminum.

The forward end 110 of barrel 198 is provided with a hole 244 through which a seal or switch cover 200 extends. The outer surface of forward end 110 of barrel 198 surrounding switch cover 200 may be beveled to facilitate tactile operation of flashlight 100. Forward end 110 of barrel 198 may also be provided with a groove 246 about its circumference at a location forward of the trailing edge 248 of head skirt 194 for positioning a sealing element 196, such as an O-ring, to form a watertight seal between the head skirt 194 and barrel 198. Similarly, switch cover 200 is preferably made from molded rubber. As best illustrated in FIG. 3, switch cover 200 is preferably configured to prevent moisture and dirt from entering the head and switch assembly 106 through hole 244.

Referring to FIG. 5B, the components of an adjustable ball assembly 212 according to the present embodiment are illustrated. In the present embodiment, a lamp or other light source, such as LED 145 of LED module 144, is mounted within head and switch assembly 106 so as to extend into reflector 118 through a central hole provided

therein. In particular, LED module 144 is mounted on adjustable ball assembly 212, which in turn is slideably mounted within the forward end 110 of barrel 198. The adjustable ball assembly 212 is prevented from sliding out of the forward end 110 of barrel 198 by retainer 132, head 120, and cam assembly 188, 190 and cam follower assembly 135. In the present embodiment, cam follower assembly 135 includes a cam follower screw 134, a cam follower roller 136, and a cam follower bushing 138.

An LED module that may be used for LED module 144 is described in co-pending U.S. Patent Application Serial No. 12/188,201, filed August 7, 2008, by Anthony Maglica et al., the contents of which is hereby incorporated by reference.

Referring to FIGS. 3 and 4, when adjustable ball assembly is positioned inside the front end 110 of barrel 198 and the cam follower assembly 135 is positioned in one of the axial slots 111 the radial arms of adjusting ring 148 will extend through the opposing slots 110 on the front end 110 of barrel 198. Further, the reflector 118 is sized so that the LED module 144 held by the adjustable ball assembly 212 is positioned adjacent the central opening in the aft end of reflector 118.

Still referring to FIG. 3, the moveable cam assembly 188, 190 is sized to fit around the outer diameter of the barrel 198. Front cam half 188 and rear cam half 190 form the cam assembly 188, 190 which is generally a barrel cam with a curved cam channel 250 that extends around the inner circumference of the cam assembly 188, 190. The cam assembly 188, 190 is also sized such that when installed, the cam follower roller 136 of the cam follower assembly 135 engages with cam channel 250. Accordingly, the cam channel 250 is able to define the axial rise, fall, and dwell of the adjustable ball assembly 212. This is because the cam follower assembly 135 is able to slide in the curved cam channel 250 of the cam assembly 188, 190 when cam assembly 188, 190 is rotated.

The cam assembly is held longitudinally in place between the aft end of head 120 and snap ring 192. Because the curved cam channel 250 is disposed transverse to the axis of the flashlight 100, when cam assembly 188, 190 is rotated, ball housing 140 (along with LED module 144) will move forwards and backwards along the longitudinal direction of flashlight 100, changing the dispersion of light created by the flashlight from spot to flood and then from flood to spot.

In the present embodiment, forward end 110 of barrel 198 preferably includes a groove 252 about its circumference for positioning external snap ring 192 to keep the cam

assembly 188, 190 from moving toward the rear direction of the flashlight 100.

Cam assembly 188, 190 is preferably a two piece construction so that the separate halves may be fitted over the outer diameter of the flashlight barrel 198 and the cam follower assembly 135. The tow pieces of the moveable cam assembly 188, 190 may be secured together by any suitable method. Preferably, the respective cam halves are formed to snap together.

Referring to FIG. 4, longitudinal locking ribs are provided on the outer diameter of the cam assembly 188, 190. Preferably the locking ribs are equally spaced around the outer circumference of the cam assembly. Corresponding longitudinal locking slots are provided on the interior surface of the head skirt 194. As a result, when head skirt 194 is mounted on the flashlight 100 and it is rotated about the axis of the barrel 198, cam assembly 188, 190 will also be caused to rotate about the barrel 198. Rotation of the cam assembly 188, 190 in turn will cause the adjustable ball assembly 212 to axially displace along the inside of reflector 118. In this way, the LED module 144 or other light source may be caused to translate along the reflector axis.

One of the electrode contacts, the positive electrode 254 in the present embodiment, of LED module 144 extends into contact with a contact disc 146 where they are preferably physically engaged. Another electrode contact, the negative electrode 256 in the present embodiment, is configured to make electrical connection with the inner surface of ball 142, which is preferably made out of metal. As previously described, the ball 142 is slideably mounted via ball housing 140, which is also preferably made out of metal, within the front end 110 of barrel 198.

Contact disc 146 is in electrical communication with an outer contact sleeve 158. Outer contact sleeve 158 is slideably engaged with an inner contact sleeve 162. A spring 160 is installed within the outer contact sleeve 158 and the inner contact sleeve 162 to allow relative movement between the outer contact sleeve 158 and the inner contact sleeve 162 while maintaining electrical communication between contact disc 146 and the aft end of inner contact sleeve 162. In the present embodiment, the outer contact sleeve 158, inner contact sleeve 162, and spring 160 are preferably made out of metal.

Outer contact sleeve 158 is further slideably held by a non crush sleeve 156, which in turn is held within a retainer 154. Retainer 154 is in turn held by ball housing 140. In

the present embodiment, non crush sleeve 156 is preferably made out of metal while retainer 154 is preferably made out of non-conductive material, such as plastic.

An adjusting ring 148 is located between retainer 154 and contact disk 146 to slightly adjust the axial direction of LED module 144, and hence LED 145. Adjusting ring 148 is supported by a push cup 150. Push cup 150 is located between the adjusting ring 148 and retainer 154. In the present embodiment, a wave spring 152 is further inserted between the push cup 150 and retainer 154 to bias the push cup forward into the rear of ball 142 and adjusting ring 148.

Inner contact sleeve 162 is frictionally held by main switch housing 176 so that the aft end of inner contact sleeve 162 is in electrical communication with an assembled circuit board 172 at via 258.

Referring to FIGS. 3, 4 and 5C the components of a switch assembly 214 will now be described. Switch assembly 214 preferably includes a main switch housing 176 and a user interface, which is a switch cover 200 in the present embodiment. Main switch housing 176 encloses an upper switch housing 166, an actuator 168, a snap dome 170, an assembled circuit board 172, a snap in contact 174, a lower switch housing 178, a switch spring 180, a set screw 182, a ground contact 184, and a hex nut 186. In the present embodiment, snap in contact 174, switch spring 180, set screw 182, ground contact 184, and hex nut 186 are preferably made out of metal while main switch housing 176, upper switch housing 166, actuator 168, and lower switch housing 178 are preferably made out of non-conductive material, such as plastic.

Referring to FIG. 5C, in the present embodiment, the snap dome 170 has four legs with one leg 282 shorter than other three legs 283, 284, 285. The legs 283, 284, 285 are used to contact to ground pads 286, 287, 288 on assembled circuit board 172 while the short leg 282 is used to contact with a momentary pad 289 on assembled circuit board 172. A ring-shaped latch pad 290 is placed in the middle of the assembled circuit board 172. In the present embodiment, the momentary pad 289 is closer to the center of assembled circuit board 172 than other three pads.

When switch cover 200 is not depressed, short leg 282 is not in contact with any portions on assembled circuit board 172. In this situation, both latch pad 290 and momentary pad 289 on assembled circuit board 172 are not in contact with ground pads 286, 287, 288 on assembled circuit board 172.

When switch cover 200 is depressed half way down, actuator 168 pushes snap dome 170 toward assembled circuit board 172. In this situation, short leg 282 makes contact with momentary pad 289 even though the central body of snap dome 170 remains out of contact with latch pad 290 of assembled circuit board 172. Because the whole snap dome 170 is made of metal, the momentary pad 289 is now connected to ground, while the latch pad 290 is not.

When switch cover 200 is further depressed, actuator 168 pushes snap dome 170 further down until snap dome 170 collapse such that the body of snap dome 170 is in contact with latch pad 290. Now, not only momentary pad 289 is connecting to ground, latch pad 290 is also connecting to ground.

When momentary pad 289 or latch pad 290 are connected to ground are received as signals to the assembled circuit board 172, which in turn passes or disrupts the energy flow from the batteries in the compartment 199 to the aft end of inner contact sleeve 162. In this way, head and switch assembly 106 can turn the flashlight 100 on or off. The assembled circuit board 172 may additionally include circuitry suitable for providing functions to the flashlight 100 which will be described in more detail later.

Snap in contact 174 is configured to include curved springs or biasing elements such that the assembled circuit board 172 is protected by the spring force generated by snap in contact 174 from, for example, batteries shifting and pressing on the main switch housing 176. In this way, an effective electrical connection can be maintained by the biasing elements while protecting sensitive components, such as the assembled circuit board 172.

Lower switch housing 178 includes two L-shaped contacts 260, 262. L-shaped contact 260 is used to form an electrical connection with a positive contact of the assembled circuit board 172 while also electrically contacting one of the biasing elements of snap in contact 174. L-shaped contact 262 is used to electrically contact with another positive contact of the assembled circuit board 172 while also electrically contacting with the aft end of inner contact sleeve 162. In the present embodiment, once batteries are inserted into the battery compartment 199, the center electrode of the forward-most battery (not shown) is electrically coupled to the snap in contact 174, which is electrically coupled to the assembled circuit board 172, which in turn is electrically coupled to the aft end of inner contact sleeve 162.

Ground contact 184 is secured by hex nut 186 so that it is in electrical communication with set screw 182, which in turn is electrically coupled to switch spring 180, which in turn is electrically coupled to a ground contact of the assembled circuit board 172.

When batteries (not shown) are installed into the battery compartment 199, in the present embodiment, an electrical current can flow from the center electrode of the forward-most battery to snap in contact 174, L-shaped contact 260, assembled circuit board 172, switch spring 180, set screw 182, barrel 198, tail cap 206, spring 202, and back to the case electrode of batteries. This electrical path provides electrical power to the components mounted on the assembled circuit board 172.

Electrical current can also flow from the center electrode of the forward-most battery to snap in contact 174, L-shaped contact 260, assembled circuit board 172, L-shaped contact 262, inner contact sleeve 162, spring 160, outer contact sleeve 158, contact disc 146, LED module 144, ball 142, ball housing 140, ground contact 184, set screw 182, barrel 198, tail cap 206, spring 202, and back to the case electrode of batteries. This electrical path provides electrical power to the LED 145 of LED module 144.

Referring to FIG. 7, flashlight 300 has similar construction as that of flashlight 100. The major difference is that, in flashlight 300, incandescent lamp is preferred. Also, a spare lamp holder 208 for holding a spare lamp 209 is inserted in tail cap 206.

FIG. 8 is a partially exploded view of the flashlight of FIG. 7 showing an adjustable ball assembly portion 361 which is corresponding to the adjustable ball assembly portion 212 of flashlight 100 shown in FIG. 5B. According to the embodiment of FIG. 8, flashlight 300 has a ball 342 which can hold a contact holder 344. The front end of contact holder 344 can receive two conductive pins from a lamp 341. In the present embodiment, lamp 341 is a incandescent lamp. On the aft end of contact holder 344 is a lamp contact 346 which is integrally molded into contact holder 344 to form an assembly. The contact 346 serves the same function as the contact disc 146 of flashlight 100 that lamp contact 346 also forms a portion of an electric path between batteries (not shown) and lamp 341. Other components of the ball assembly portion 361 are similar to that in flashlight 100 and would not be described further.

Assembled circuit board 172 will now be described in connection with FIGS. 9-10E. For the purpose of simplification, assembled circuit board 172 is described in connection with flashlight 100. However, it is to be understood that assembled circuit

board 172 as well as switch assembly can also be used in other flashlights or portable lighting devices, such as flashlight 300. FIG. 9 is a block diagram illustrating the relationship of the electronic circuitry of assembled circuit board 172. In the embodiment of FIG. 9, assembled circuit board 172 includes a microcontroller circuit 808, a reverse battery protection circuit 802, a linear regulator circuit 804,a first mode memory device 810, a second mode memory device 812, a third mode memory device 814, a bypass switch 806, a MOSFET driver 820, an electric load switch 822, a momentary pad 289, a latch pad 288, and a cell count test point 824.

Detailed electrical circuit schematics of assembled circuit board 172 are shown in FIGS. 10A-E.

FIG. 10A shows a preferred circuit schematic diagram of reverse battery protection circuit 802. In the present embodiment, the reverse battery protection circuit 802 takes the voltage 702 from the positive electrode of a battery or a battery pack and electrically connects it to an electronic load switch, such as a p-channel metal-oxide-semiconductor field-effect transistor (PMOS) 712. The gate of PMOS 712 is connected to ground 714 while the drain of PMOS 712 is connected to an internal voltage supply 704 for assembled circuit board 172. With this reverse battery protection circuit 802, when the battery or battery pack is installed in reverse order, no current will flow through current paths of the flashlight.

Referring to FIG. 10B, microcontroller circuit 808 includes a microcontroller 720 and connections. Microcontroller 720 receives input signals through signal lines ADC_MODE_CAP1 722, ADC_MODE_CAP2 724, ADC_MODE_CAP3 726, MISO 730, MOMENTARY_SWITCH 736, MAIN_SWITCH 738, and RESET 742. Microcontroller 720 also delivers output signals through signal lines ADC_MODE_CAP1 722, ADC_MODE_CAP2 724, ADC_MODE_CAP3 726, BYPASS_LDO 734, and LAMP_DRIVE 740. Accordingly, signal lines ADC_MODE_CAP2 722, ADC_MODE_CAP1 724, ADC_MODE_CAP3 726 are bi-directional. In one embodiment, the microcontroller 720 is a commercial microcontroller having embedded memory, such as, for example, ATtiny24 which is an 8-bit microcontroller manufactured by Atmel Corporation of San Jose, California. In another embodiment, the microcontroller 720 can be a microprocessor. Yet in other embodiments, the microcontroller 720 can be discrete circuits.

Microcontroller 720 has a power supply source 708 to provide a voltage input. Typically, microcontroller 720 cannot accept a power supply having a voltage higher than

a predefined value, for example, 5.5 volts. However, flashlights 100 and 300 can be adjusted to contain two, three or four batteries (depending on the length of barrel) that the battery voltage source 702 (and also 704) range from 3.0 volts to 6.0 volts. If a flashlight is designed to be used with four batteries, voltage from the battery voltage source 702 cannot be used to supply the microcontroller 708 directly.

FIG. 10C shows a circuit schematic diagram of one embodiment of a linear regulator circuit 804. The illustrated linear regulator circuit 804 takes the internal voltage supply 704 from reverse battery protection circuit 802 as an input voltage and converts it into digital voltage output source 708 for supplying the microcontroller 708 through two different paths. The first path is through a low drop-out (LDO) linear voltage regulator 716 and the second path is to bypass the LDO linear voltage regulator 716 and pass through a PMOS 750.

When a flashlight is designed for receiving four or more batteries or cells electrically connected in series, internal voltage supply 704 cannot be used to supply microcontroller 720 directly. Accordingly, signal line BYPASS_LDO 734 would be turned low by microcontroller 708. Thus, bipolar transistor 806 with built-in resistors will not conduct. As a result, PMOS 750 also will not conduct, therefore, resulting in internal voltage supply 704 being converted to digital voltage output source 708 through LDO linear voltage regulator 716, which will provide an output voltage source that is lower than the input voltage supply. In an embodiment in which four batteries or cells are connected electrically in series, the LDO linear voltage regulator 716 is preferably configured to drop the input voltage by about 1.0 volt.

If a flashlight 100 or 300 is designed for receiving two or three batteries in series, or if flashlight is powered by battery pack, internal voltage supply 704 may be used to supply microcontroller 720 directly. In this situation, signal line BYPASS_LDO 734 would be turned high by microcontroller 708. In this situation, bipolar transistor 806 with built-in resistors would be closed so as to conduct, and, therefore, PMOS 750 would also be closed and thereby conduct. Internal voltage supply 704 would therefore, be converted to digital voltage output source 708 through PMOS 750, and bypass the LDO linear voltage regulator 716.

In the embodiment of FIG. 10C, internal voltage supply 704 may be coupled to digital voltage source 708 first through a resistor 744 before passing through the LDO linear voltage regulator 716 or the PMOS 750. Resistor 744 and capacitor 746 constitute an RC filter that filters out noises, for example, noise due to the switching of PMOS 780

(see FIG. 10D). This RC filter helps reduce errors when microcontroller 720 is making analog-to-digital conversions. In the present embodiment, resistor 744 may be set at 18 Ohms, for example, while capacitor 746 may be set at 1.0 micro Farad, for example.

Microcontroller 720 can be programmed during manufacturing of a flashlight or other portable lighting devices to input the number of battery cell information, such as battery cell count, through cell count test point 824 (shown in FIG. 9) to decide whether to turn signal line BYPASS_LDO 734 high or low. This battery cell count information is also stored in an embedded non-volatile memory, such as EEPROM, of microcontroller 720 for determining an appropriate power profile which will be described in more detail below.

FIG. 10D shows a circuit schematic diagram of MOSFET driver circuit 820 and an electronic load switch 822. In the embodiment of FIG. 10D, electronic load switch 822 comprises PMOS 780. The source of PMOS 780 is coupled to internal voltage supply 704 while the drain of PMOS 780 is coupled to voltage output pin 710. Voltage output pin 710 may be coupled to the positive electrode of the LED 145 of flashlight 100. The gate of PMOS 780 is coupled to a MOSFET driver 820, which is implemented by a bipolar transistor 782. The gate of PMOS 780 is also pulled-up to internal voltage supply 704 by a resistor 778. Accordingly, when the base of bipolar transistor 782 is driven high by signal LAMP_DRIVE 740, bipolar transistor 782 is closed and begins to conduct, which in turn causes PMOS 780 to close and conduct. Therefore, electric power can flow from internal voltage supply 704 to voltage output pin 710 thereby completing the circuit to power LED 145.

In the present embodiments, as long as the batteries or battery pack is installed and the connecting parts are working, the assembled circuit board 172 will be supported by power from the batteries or battery pack regardless whether the flashlight 100 is turned "on" or turned "off." By default, microcontroller 720 by default is in a very low power stand-by mode to minimize drain on the batteries. When momentary pad 289 is grounded by snap dome 170, microcontroller 720 wakes up from the low power stand-by mode and turns on to close the load switch 780, which in turn powers turns on the LED 145 of the flashlight 100. As long as momentary pad 289 is grounded, the LED 145 will be in full power. Once the switch button 200 is released and momentary pad 289 is no longer grounded, microcontroller 720 will turn "off" load switch 780 and power to LED 145 will be cut off. Microcontroller 720 will then go back to low power stand-by mode.

If switch button 200 is pressed sufficiently hard to cause both momentary pad 289 and latch pad 288 to be grounded, the LED 145 will remain powered until another full press is detected.

Referring to FIG. 10E, the three mode memory devices 810, 812, 814 will now be described together. The first mode memory device 810 has an input/output signal line ADC_MODE_CAP1 724 which is coupled to microcontroller 720. Signal line ADC_MODE_CAP1 724 is also coupled to one end of a charge resistor 754. The other end of resistor 754 is coupled to an RC circuit comprising a bleed off resistor 756 connected in parallel with a capacitor 758. The other end of the RC circuit is coupled to ground. This first mode memory device 810 may be used to store information in a temporary manner. Microcontroller 720 may be used to store information in mode memory device 810 by setting signal line ADC_MODE_CAP1 724 to a high or a low signal. The high signal would be stored in the first mode memory device 810 for a short period of time, for example, 2 seconds, before it is decayed sufficiently that it is no longer recognized as a high signal. Microcontroller 720 can execute a read operation from signal line ADC_MODE_CAP1 724 to retrieve data stored in the first mode memory device 810. In one embodiment, the resistance of resistor 756 is 1.0 Mega Ohms while the capacitance of capacitor 758 is 1.0 micro Farad. Similarly, the second mode memory device 812 and the third mode memory device 814 can have the same configuration as that of the first mode memory device 810.

Flashlight 100 may be provided with a variety of modes of operation. In the present embodiment, controller 808 is configured to implement eight separate modes of operations. Accordingly, when the flashlight is switched on, microcontroller 720 reads mode information from an internal memory, for example, an embedded SRAM built in the microcontroller 720. Microcontroller 720 increments the mode information by one to obtain a current mode information and then stores the current mode information to the external mode memory devices 810, 812, 814. Flashlight 100 also changes to the new mode of operation accordingly.

For example, when switch button 200 is hard pressed sufficiently to cause snap dome 170 to deflect into the latch position while flashlight 100 is in the off mode, microcontroller 720 reads the previous mode information from the embedded SRAM. If the previous mode information is 0,0,0, microcontroller 720 increments it by one to obtain the current mode information, which is 0,0,1. In the present embodiment, a 0,0,1 mode information represent a full power mode. In accordance, flashlight 100 enters the full

power mode. Microcontroller 720 then writes the current mode information into the three mode memory devices 810, 812, 814 by pulling signal lines ADC_MODE_CAP3 726 and ADC_MODE_CAP2 722 to low and pulling signal line ADC_MODE_CAP1 724 to high.

If the switch 200 is pressed sufficiently hard to cause switch assembly to enter into the latch position (both momentary pad 289 and latch pad 288 are grounded), while the flashlight 100 is in an operation mode other than off mode, and then held for a period of time, for example, two seconds, in the present embodiment, microcontroller 720 interprets the received input as a command to change modes of operation. Microcontroller 720 reads the previous mode information from the embedded SRAM and increments it by one to obtain the new current mode information. If the previous mode information is 0,0,1, for example, then the new current mode information would be 0,1,0. Microcontroller 720 then writes the new current mode information into the three mode memory devices 810, 812, 814 by pulling signal lines ADC_MODE_CAP3 726 and ADC_MODE_CAP1 724 to low and pulling signal line ADC_MODE_CAP2 722 to high. In the present embodiment, this 0,1,0 combination represents a 50% power save mode.

In the present embodiment, an 0,1,1 combination stored in the three mode memory devices 810, 812, 814 represents that the current mode is a 25% Power Save mode. The rest of the operational modes for flashlight 100 are shown in Table 1.

Table 1: Operation Modes and Code

Mode Name	Current mode	Next mode
Off	0,0,0	0,0,1
Full Power	0,0,1	0,1,0
50% Power Save	0,1,0	0,1,1
25% Power Save	0,1,1	1,0,0
10% Power Save	1,0,0	1,0,1
Blink	1,0,1	1,1,0
Beacon	1,1,0	1,1,1
SOS	1,1,1	1,1,1

As long as the user continues to hold the switch 200 in the latch position, the flashlight 100 will transition through the lists of modes above. Every time a predetermined period of time, for example, two seconds, passes, the mode count will be incremented.

Flashlight 100 may face a power interruption while the flashlight 100 is turned on or turned off. For example, when there is a need for battery replacement, flashlight 100 (and also the microcontroller 720) could experience a relatively long period of power interruption. When the flashlight is accidentally dropped on the ground or hit to a hard surface from one end of its ends, the inertia of the batteries or battery pack could cause the batteries or battery pack to disconnect from one of the battery contacts for a short period of time and that causes a short period of power interruption to the controller 808.

In the present embodiment, after flashlight 100 has experienced a power interruption, no matter if it is a relatively long period or a short period, when the power turned back on, microcontroller 720 runs a power up routine, which includes reading from

the voltages stored on the three mode memory devices 810, 812, 814 through signal lines ADC_MODE_CAP3 726, ADC_MODE_CAP2 722, ADC_MODE_CAP1 724. Accordingly, flashlight 100 enters the mode indicated by the mode memory devices 810, 812, 814.

For example, after a battery replacement, the mode information indicated by the mode memory devices 810, 812, 814 should be 0,0,0 since the charge stored on each of capacitors 758, 764, 770 should have decayed by the time microcontroller 720 is again powered. Microcontroller 720 then reads from the three mode memory devices 810, 812, 814 and obtains 0,0,0 as the previous mode information. Accordingly, flashlight 100 enters the off mode.

On the other hand, if the flashlight is accidentally dropped on the ground or is hit against a hard surface from one of its ends, the inertia of the batteries or battery pack could cause the batteries or battery pack which is sufficient to disconnect from one of the battery contacts for a short period of time, which is sufficient to cause a short period of power interruption of typically shorter than 0.5 seconds to the controller 808. If the mode of operation right before the power interruption was, for example, the SOS mode, the charge, after the short power interruption, stored on each of capacitors 758, 764, 770 would continue to be retained until sufficiently after power is restored that microcontroller 720 will read 1,1,1 when it reads from the three mode memory devices 810, 812, 814. Accordingly, flashlight 100 will enter the SOS mode, which was the operating mode before the power interruption. In other words, the flashlight 100 has immunity from such temporary power interruptions, due to accidental droppings of the flashlight or otherwise.

The power immunity from interruption of flashlight 100 also applies to the condition when the flashlight 100 is in the off mode. When the flashlight 100 is switched off, microcontroller 720 writes 0,0,0 to the three mode memory devices 810, 812, 814, and microcontroller 720 enters a low power stand-by mode. Therefore, regardless of whether a short power interruption or a long power interruption is experienced, after the power connection is restored, microcontroller 720 will read from the three mode memory devices 810, 812, 814 and obtain 0,0,0 as the previous mode information. Accordingly, flashlight 100 will enter the off mode.

The electronic switch supplies power to LED 145 at different duty cycles to maximize battery life. Microcontroller 720 includes an internal memory for storing data battery count information and the power profile information for a variety of batteries that can be installed in flashlight 100. For most of the battery life, electronic switch 822

provides full power (100% duty cycle) to LED 145. As the batteries are depleted, however, battery voltage 702 will drop which is monitored by microcontroller 720. Microcontroller 720 uses the power profile for each battery to determine when to reduce the duty cycle and when to keep.

Each battery has limited life cycle including a high voltage period, a voltage depletion period and a low voltage period. When battery voltage 702 is in the high voltage period, microcontroller 720 provides a high duty cycle signal to the lamp drive output pin 740 for MOSFET driver 820 to provide a high duty cycle power supply 710 to LED 145. When battery voltage 702 is in the voltage depletion period, the microcontroller 720 gradually declines the duty cycle signal to the lamp drive output pin 740 for MOSFET driver 820 to provide a gradually declined power supply 710 to LED 145. When battery voltage 702 is in the low voltage period, microcontroller 720 provides a low duty cycle signal to the lamp drive output pin 740 for MOSFET driver 820 to provide a low duty cycle power supply 710 to LED 145. FIG. 11A is a power profile for two cell batteries. FIG. 11B is a power profile for three cell batteries. FIG. 11C is a power profile for four cell batteries. By reducing the duty cycle towards the end of batteries' life, the usable time of batteries can be significantly extended.

While various embodiments of an improved flashlight and its respective components have been presented in the foregoing disclosure, numerous modifications, alterations, alternate embodiments, and alternate materials may be contemplated by those skilled in the art and may be utilized in accomplishing the various aspects of the present invention. For example, the power control circuit and short protection circuit described herein may be employed together in a flashlight or may be separately employed. Further, the short protection circuit may be used in rechargeable electronic devices other than flashlights. Thus, it is to be clearly understood that this description is made only by way of example and not as a limitation on the scope of the invention as claimed below.

What Is Claimed Is:

1. A head and switch assembly for a flashlight comprising:

a hollow head having an outer surface, the outer surface of the head has a front section, an aft section, and a midsection, the midsection has a plurality of protuberances, each of the protuberances has a cut facing to the front section, each of the protuberances has a lock member forms under the cut; and

a skirt lock ring having an inner surface, the inner surface of the skirt lock ring has a front end, an aft end and a middle portion, the middle portion has a plurality of first indexing bumps and the aft end has a plurality of second indexing bumps, each of the first indexing bumps is aligned to one of the second indexing bumps to form an aligned indexing bumps, a plurality of channels are formed between adjacent aligned indexing bumps, wherein each of the first indexing bumps and the second indexing bumps is constructed by two high plateau regions that separate by a low plateau;

wherein the skirt lock ring is locked by the head when each of the protuberances is aligned with one of the low plateau.

2. A head and switch assembly for a flashlight of claim 1 further comprising a head skirt having an inner surface, wherein the aft section of the head has an outer annular groove sized to receive a portion of a ball, wherein at least one of the high plateau regions of the second indexing bumps of the skirt lock ring has a hole sized to receive the ball, wherein the inner surface of the head skirt has a front end, the inner surface of the head skirt has an inner annular groove near the front end, wherein the head skirt is not locked by the ball when the ball is partially fall in the outer annular groove of the head.

3. A head and switch assembly for a flashlight of claim 1, wherein the number of protuberances is the same as the number of channels.

4. A head and switch assembly for a flashlight of claim 3, wherein the number of protuberances is six.

5. A head and switch assembly for a flashlight of claim 1, wherein the width of a plurality of protuberances is smaller than the width of a plurality of channels.

6. A head and switch assembly for a flashlight of claim 2, wherein three of the high plateau regions of the second indexing bumps has a hole sized to receive the balls, the three holes are placed and separate from each other with equal distance.

7. A head and switch assembly for a flashlight of claim 1 further comprising a wave spring for pushing the skirt lock ring to a lock position.

8. A method for mounting a head skirt to a skirt lock ring of a flashlight comprising:

rotating a skirt lock ring until the skirt lock ring is aligned in a moving position with a head;

pushing the skirt locking ring toward the head to move the skirt lock ring from a moving position to a rotating position;

rotating the skirt lock ring from a rotating position to a locking position; and

releasing the head skirt to lock the head skirt.

9. The method of claim 8, wherein the head skirt is locked by the skirt lock ring when the skirt lock ring is in the rotating position and the locking position.

10. A flashlight comprising:

a main power source;

an user interface having an off position, a momentary position, and a latch position;

a microcontroller including a plurality of bidirectional input/output ports having an internal memory; and

a plurality of temporary mode memory devices not reside in the microcontroller, the plurality of temporary mode memory devices coupled to the plurality of bidirectional input/output ports of the microcontroller, wherein when the user interface is staying in the latch position for a period of time, the microcontroller read the previous mode information from the internal memory, increment the mode value by one to obtain a current mode information, and write the current mode information into the mode memory devices.

11. A flashlight of claim 10, wherein the microcontroller reads the current mode information from the mode memory devices after a power interruption from the main power source.

12. A flashlight of claim 10, wherein the temporary mode memory devices are constructed by RC circuits.

13. A flashlight comprising:

a main power source;

a controller having an input and an output; and

a power control circuit electrically coupled to the main power source and the output of the controller;

wherein the power control circuit provide a voltage output to the controller substantially the same as the main power source when the battery count is below a predetermined value, and the power control circuit provide a voltage output to the controller substantially lower than the main power source when the battery count is above or equal to the predetermined value.

14. A flashlight of claim 13, wherein the predetermined value is four.

15. A flashlight comprising:

a lamp;

a main power source having a limited life cycle, the main power source provides power supply in a high voltage range, a middle voltage range, and a low voltage range during the life cycle, the intersection between the high voltage range and the middle voltage range is a first checking voltage, the intersection between the middle voltage range and the low voltage range is a second checking voltage;

a lamp driving circuit for transferring power source from the main power source to the lamp; and

a microcontroller including an internal memory, the microcontroller has an output coupled to the lamp driving circuit, wherein when the voltage of the main power source is higher than the first checking voltage, the microcontroller provides a high duty cycle signal to the lamp driving circuit to provide a high duty cycle power supply to the lamp, wherein when the voltage of the main power source is lower than the first checking

voltage and higher than the second checking voltage, the microcontroller gradually declines the duty cycle signal to the lamp driving circuit to provide gradually declined power supply to the lamp, wherein when the voltage of the main power source is lower than the second checking point, the microcontroller provides a low duty cycle signal to the lamp driving circuit to provide a low duty cycle power supply to the lamp.

16. A flashlight of claim 15, wherein the microcontroller provides different duty cycle signal to the lamp driving circuit to provide a different duty cycle power supply to the lamp is based on a calculation of a power profile.

17. A flashlight of claim 16, wherein the calculation of a power profile is based on a programmable cell count value set during the manufacturing of the flashlight.

18. A flashlight of claim 15, wherein the high duty cycle is 100%.

19. A flashlight of claim 15, wherein the low duty cycle is 10%.

20. A flashlight of claim 15, wherein the gradually declined duty cycle is between 10% and 90%.

21. A flashlight comprising:

a power source;

a light source;

a first switch housing;

a second switch housing; and

a circuit board located between the first switch housing and the second switch housing having a first side facing the first switch housing, a second side facing the second switch housing, a first contact located on the second side, and a second contact located on the second side,

wherein the second switch housing comprises a first L-shaped contact electrically coupled to the first contact of the circuit board while maintaining electrically communication with the power source, wherein the second switch housing comprises a second L-shaped contact electrically coupled to the second contact of the circuit board while maintaining electrically communication with the light source.

22. A flashlight of claim 21, wherein the first L-shaped contact and the second L-shaped contact are electrically coupled.

23. A flashlight comprising:

a barrel for housing a portable power source;

a lamp; and

a reverse battery protection circuit electrically coupled to the portable power source and the lamp; wherein when the portable power source is installed in reverse order in the barrel, no electric current will be flowed through the lamp.

24. A flashlight of claim 23, wherein the reverse battery protection circuit further comprises a p-channel metal-oxide-semiconductor field-effect transistor, wherein the gate of p-channel metal-oxide-semiconductor field-effect transistor is electrically coupled to ground.

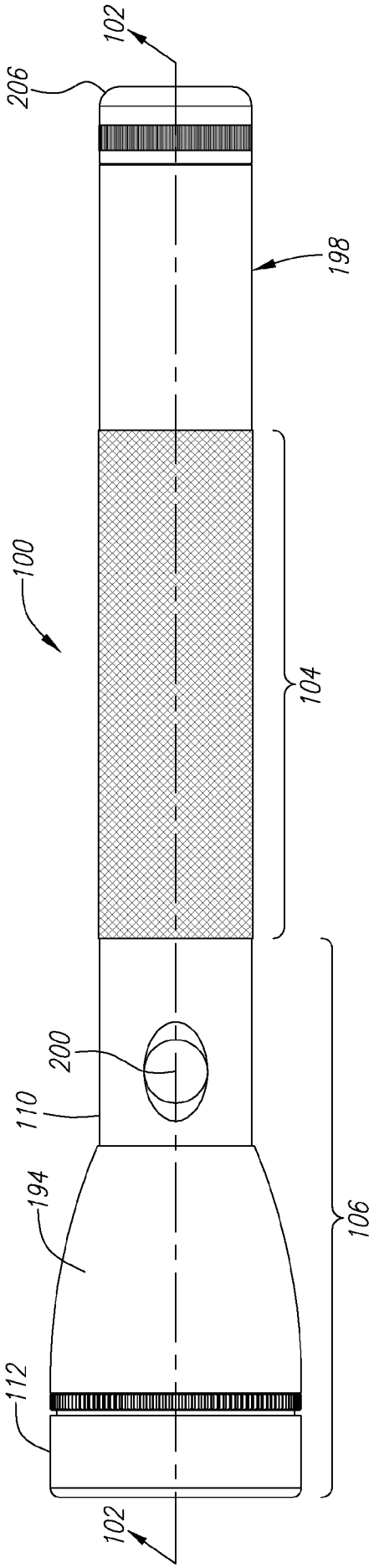
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FIG. 1

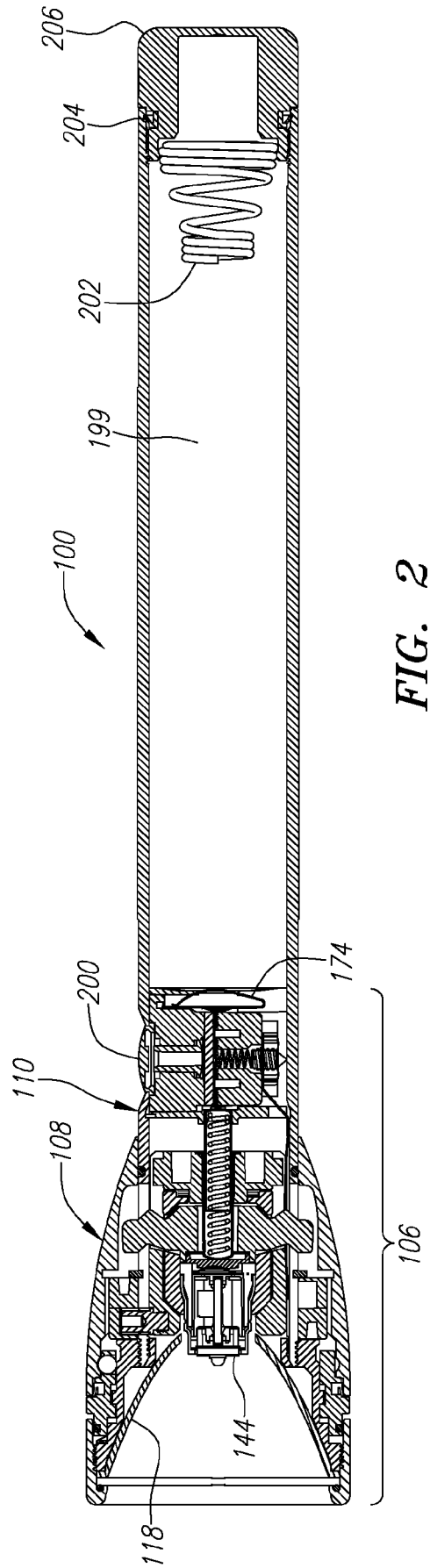
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FIG. 2

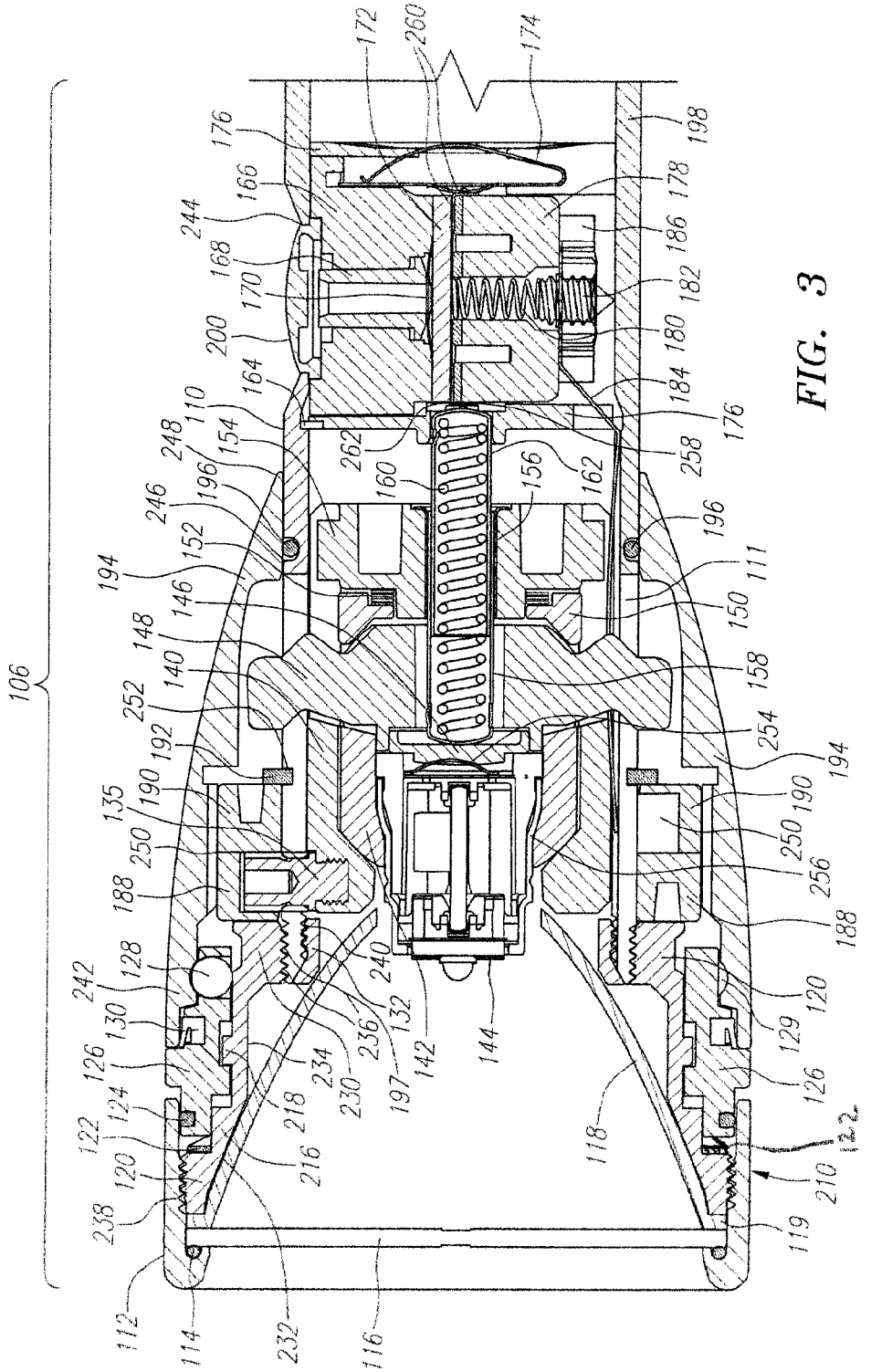
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FIG. 3

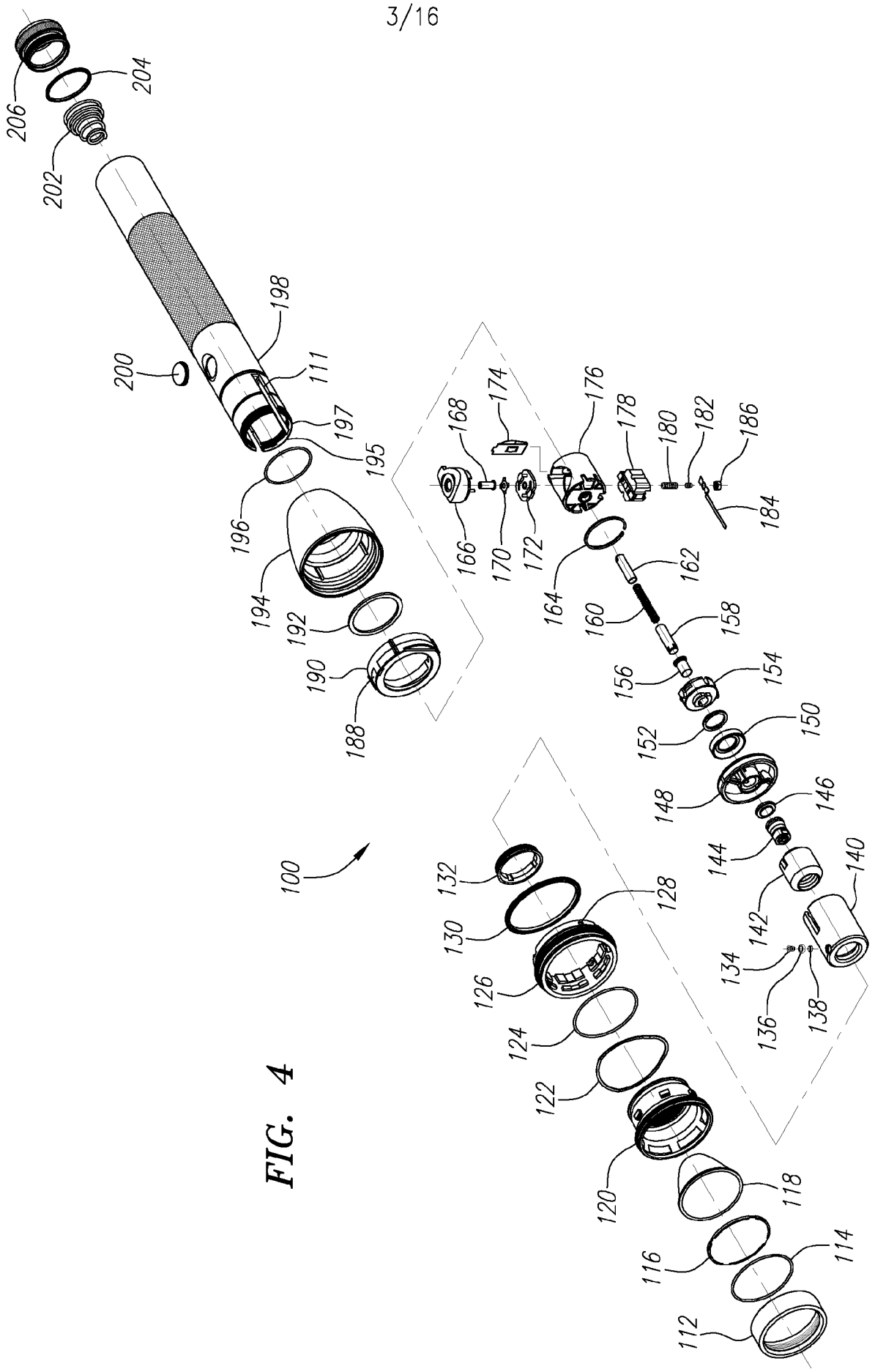
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FIG. 4

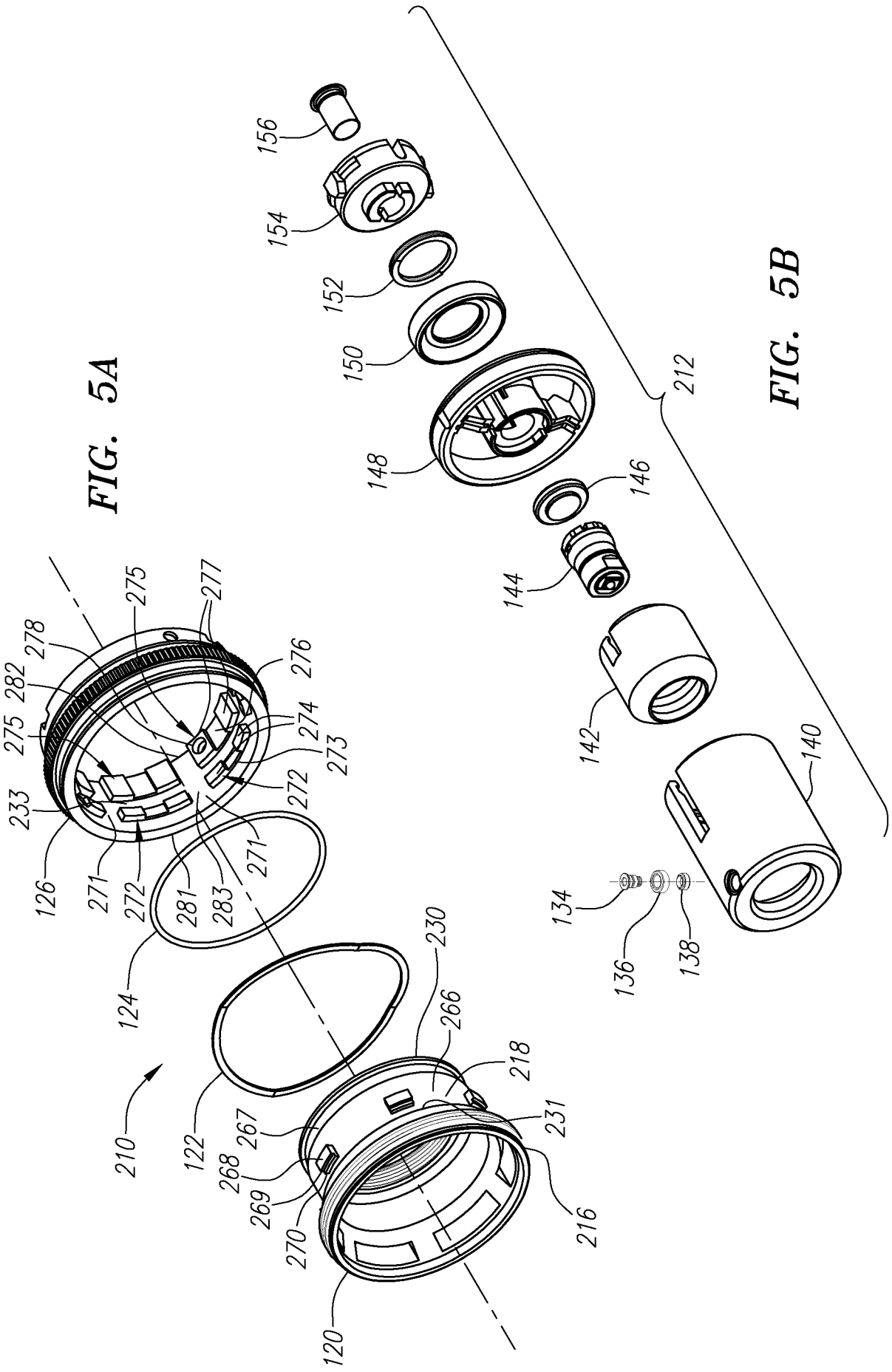
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FIG. 5A

FIG. 5B

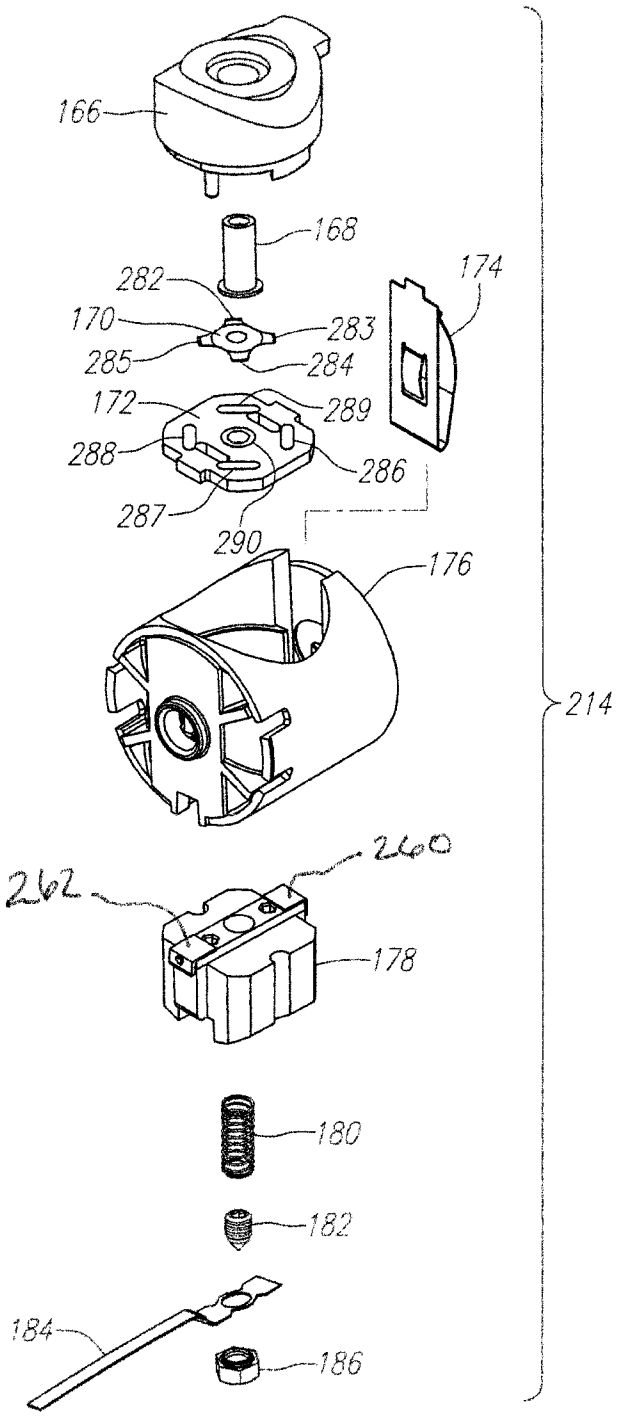
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FIG. 5C

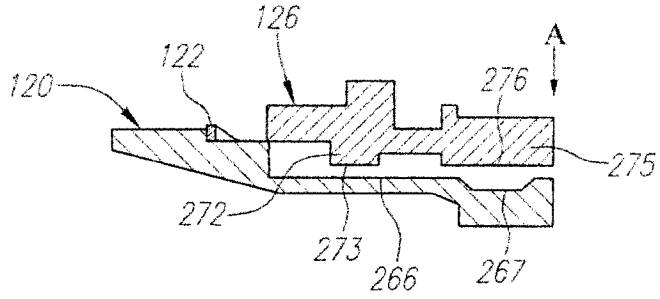

FIG. 6A

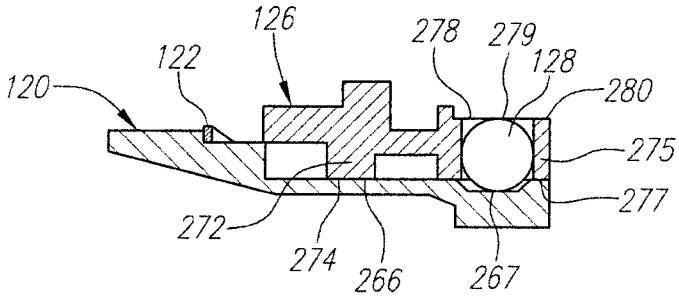

FIG. 6B

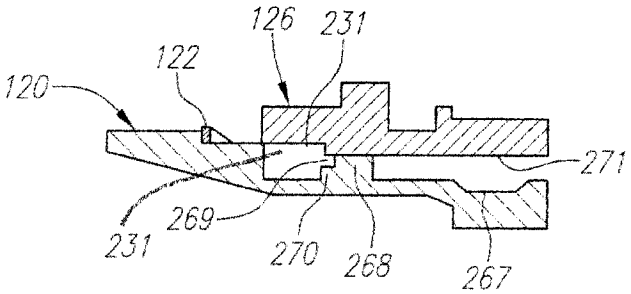

FIG. 6C

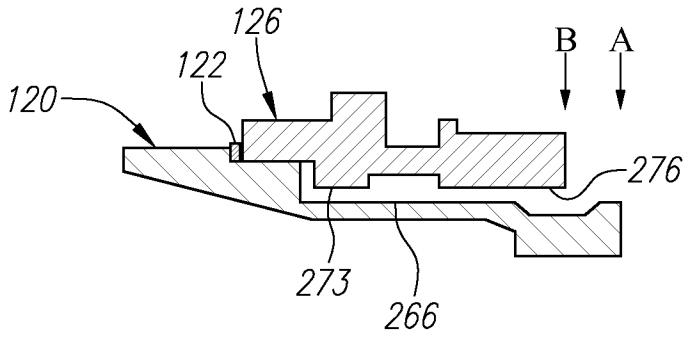

FIG. 6D

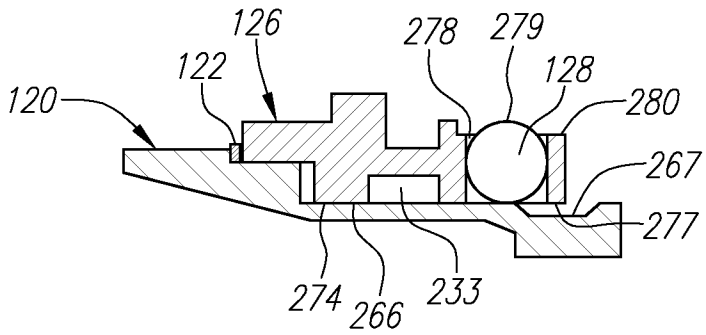

FIG. 6E

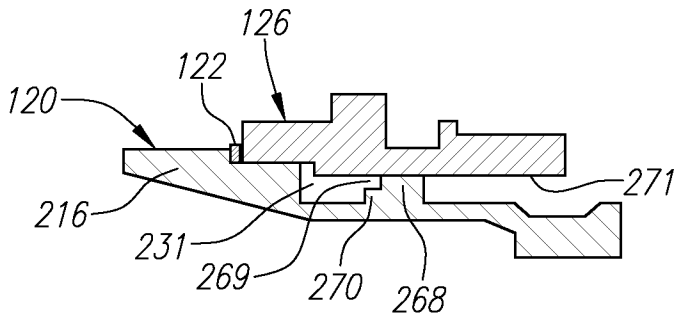

FIG. 6F

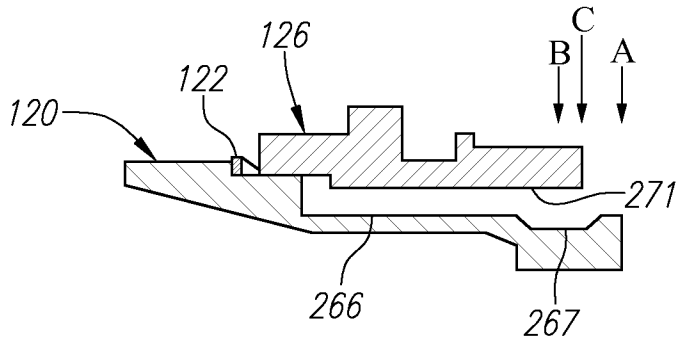

FIG. 6G

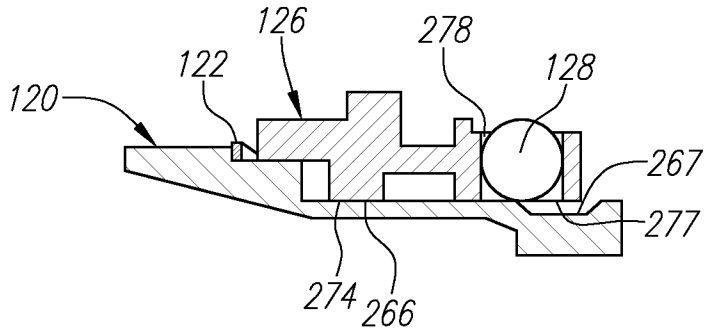

FIG. 6H

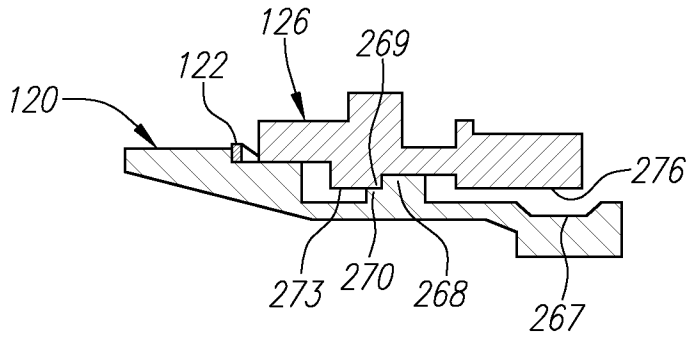

FIG. 6I

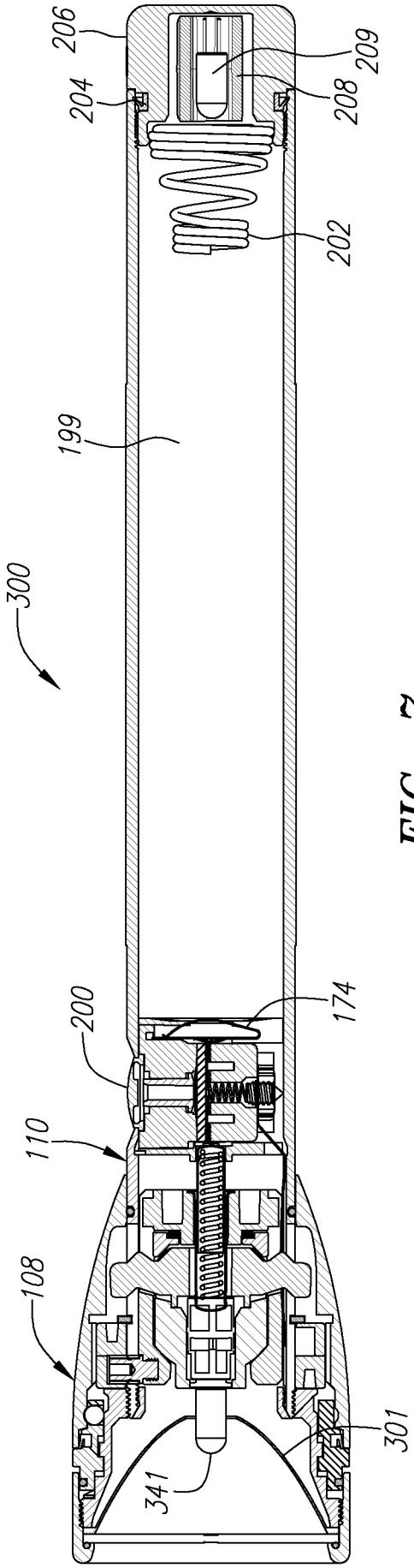

FIG. 7

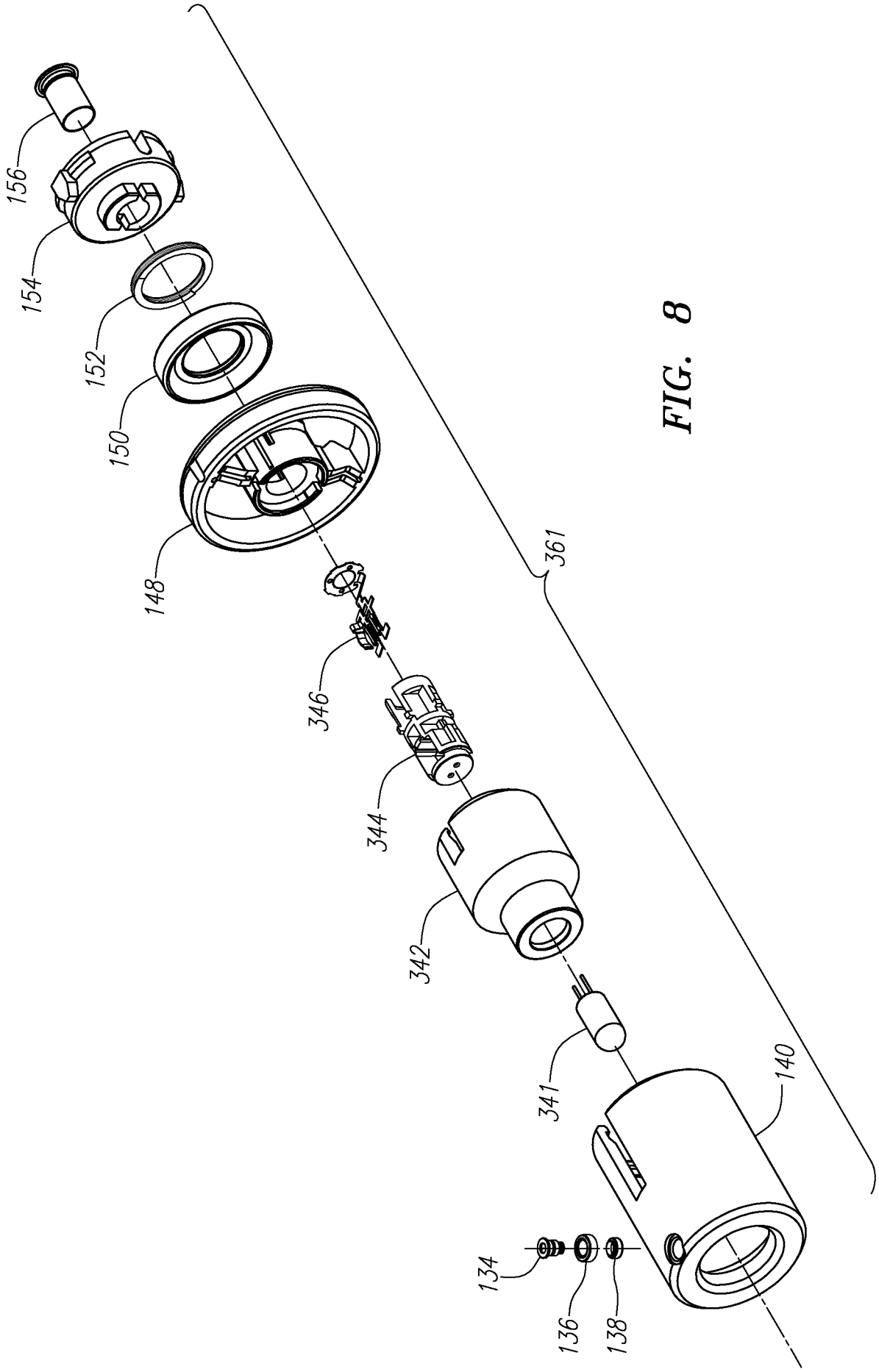

FIG. 8

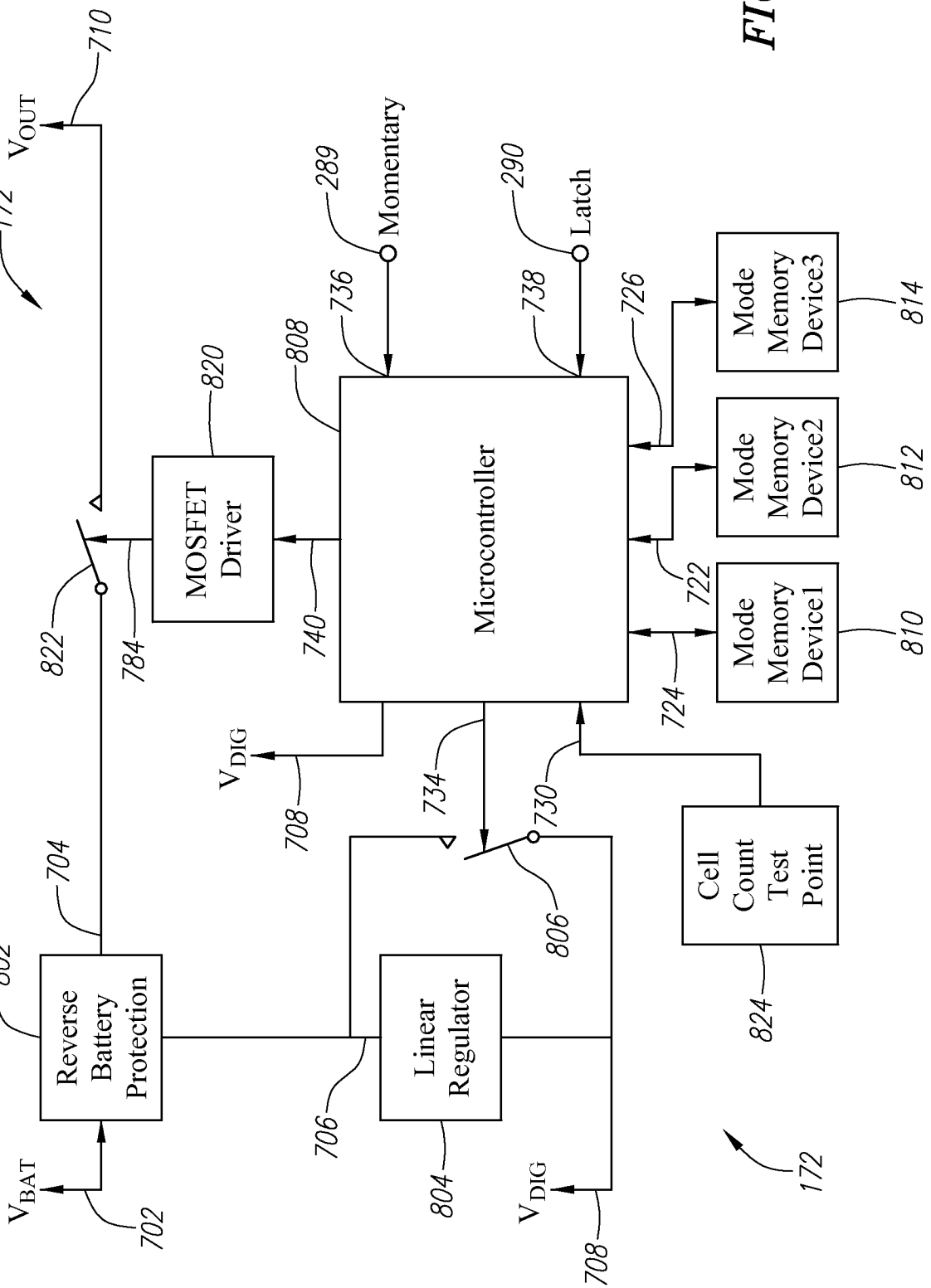
172
710
V_{OUT}
289
Momentary
290
Latch
736
738
726
808
820
MOSFET Driver
Microcontroller
Mode Memory Device3
814
Mode Memory Device2
812
Mode Memory Device1
810
822
784
740
722
724
V_{DIG}
708
734
730
704
802
Reverse Battery Protection
Linear Regulator
806
Cell Count Test Point
824
706
804
V_{BAT}
702
V_{DIG}
708
172

FIG. 9

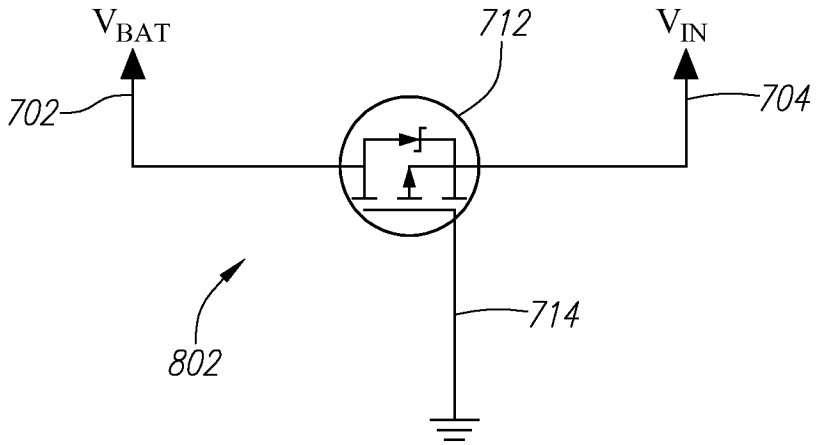

FIG. 10A

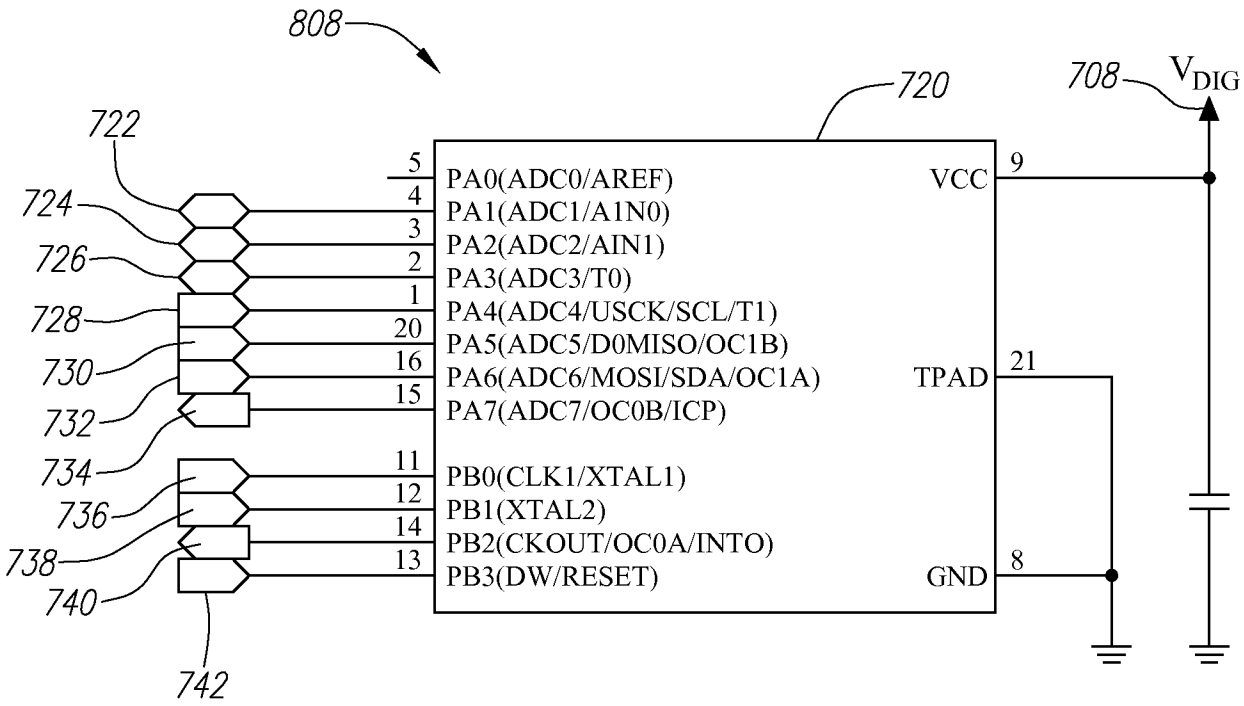

FIG. 10B

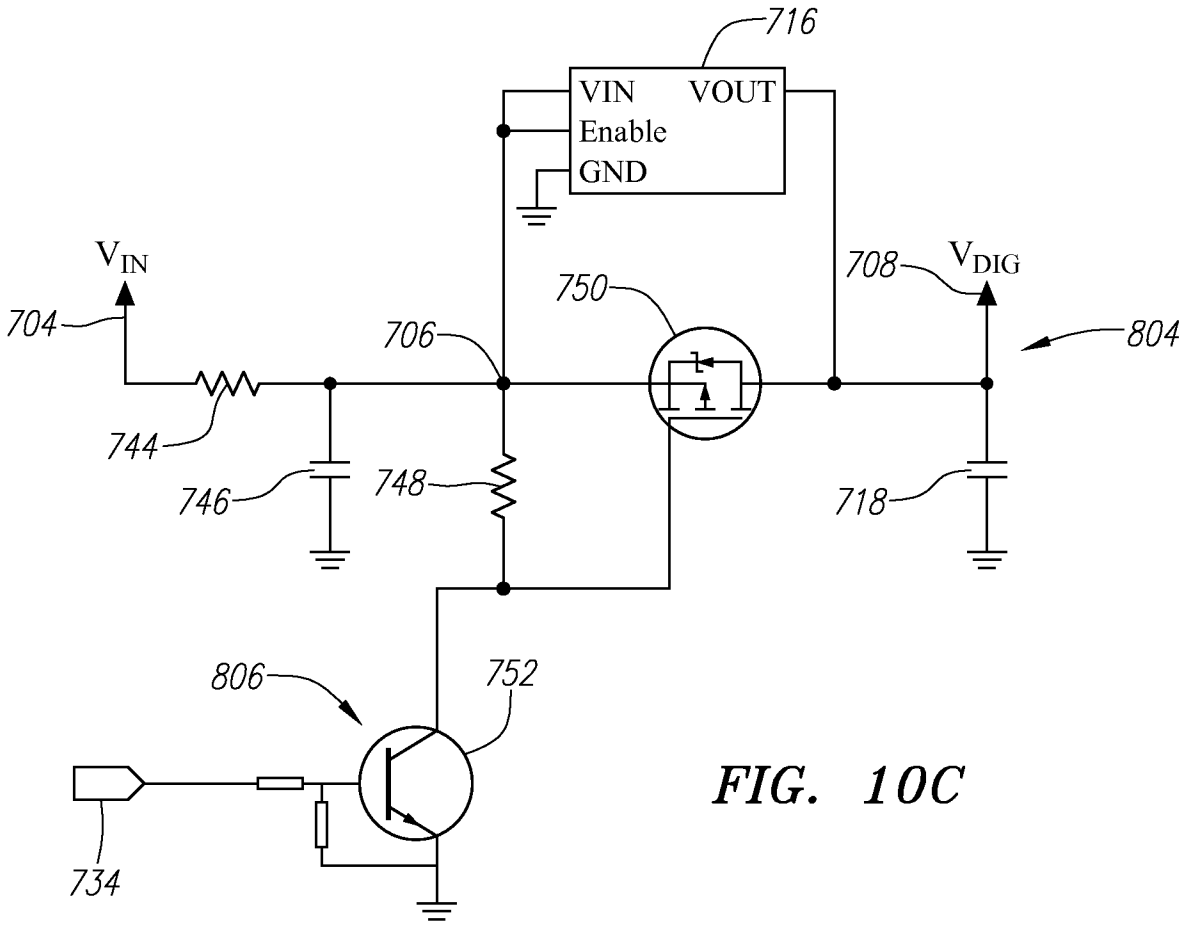

FIG. 10C

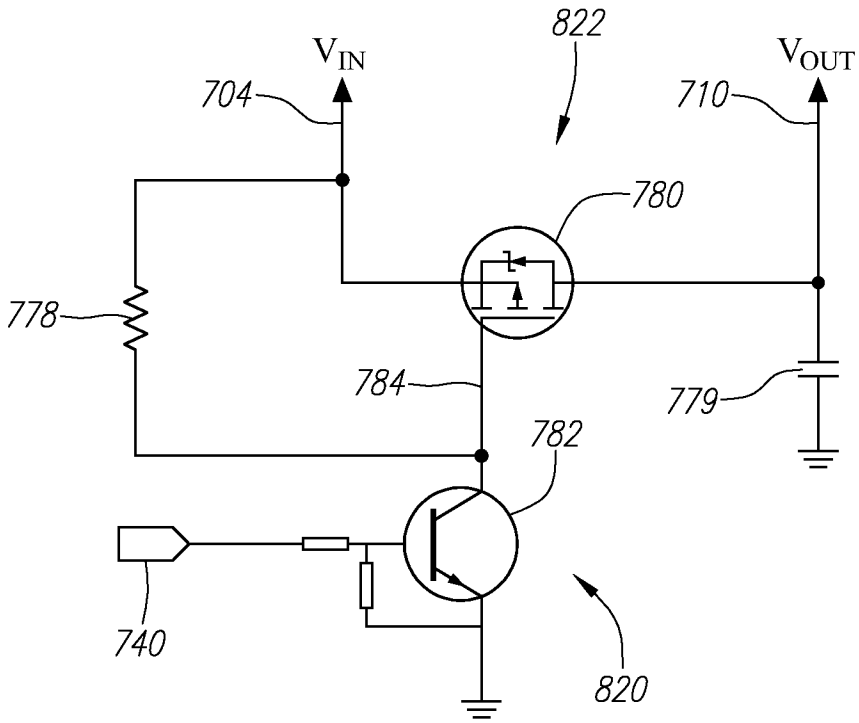

FIG. 10D

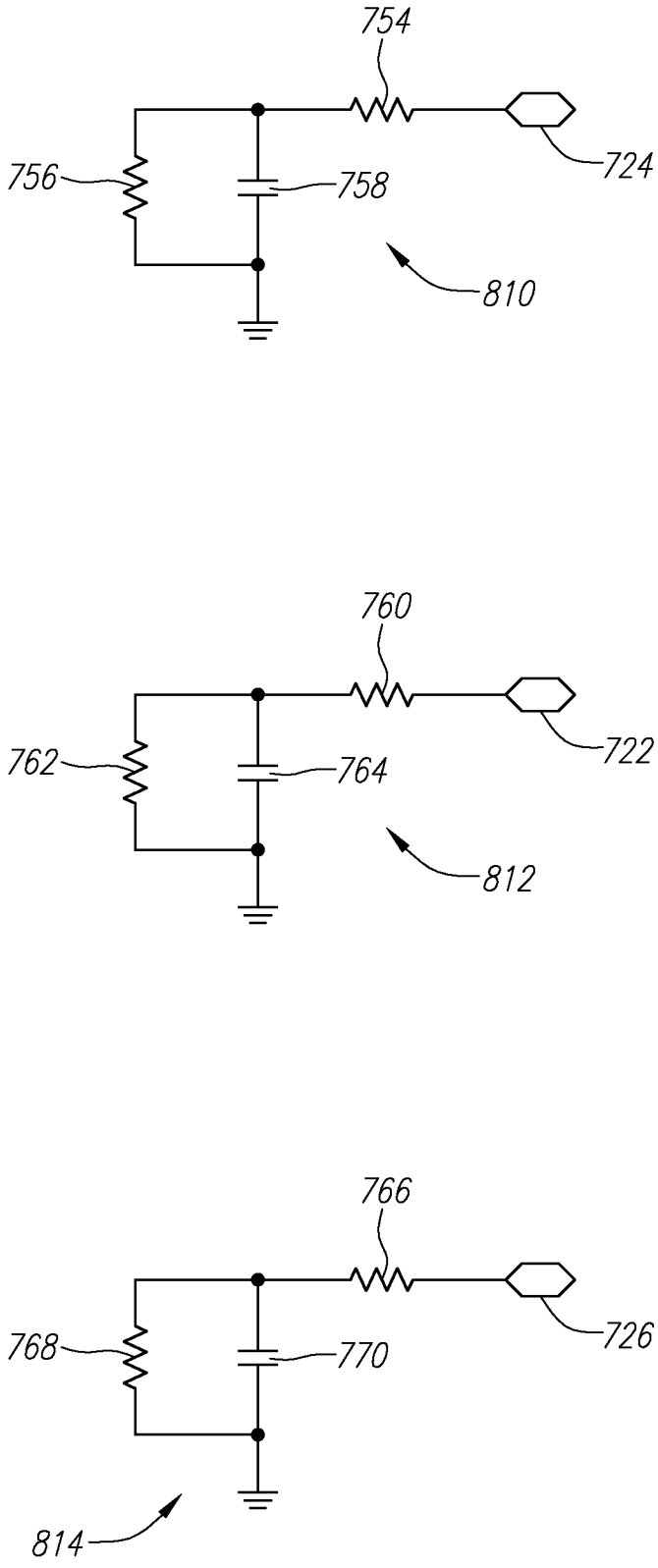

FIG. 10E

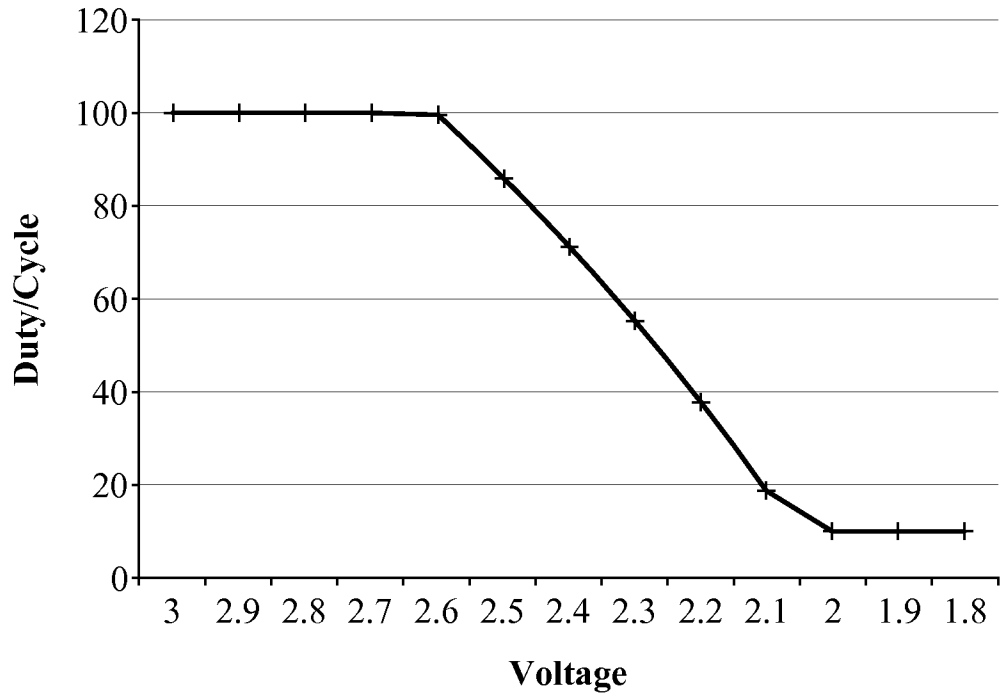

FIG. 11A

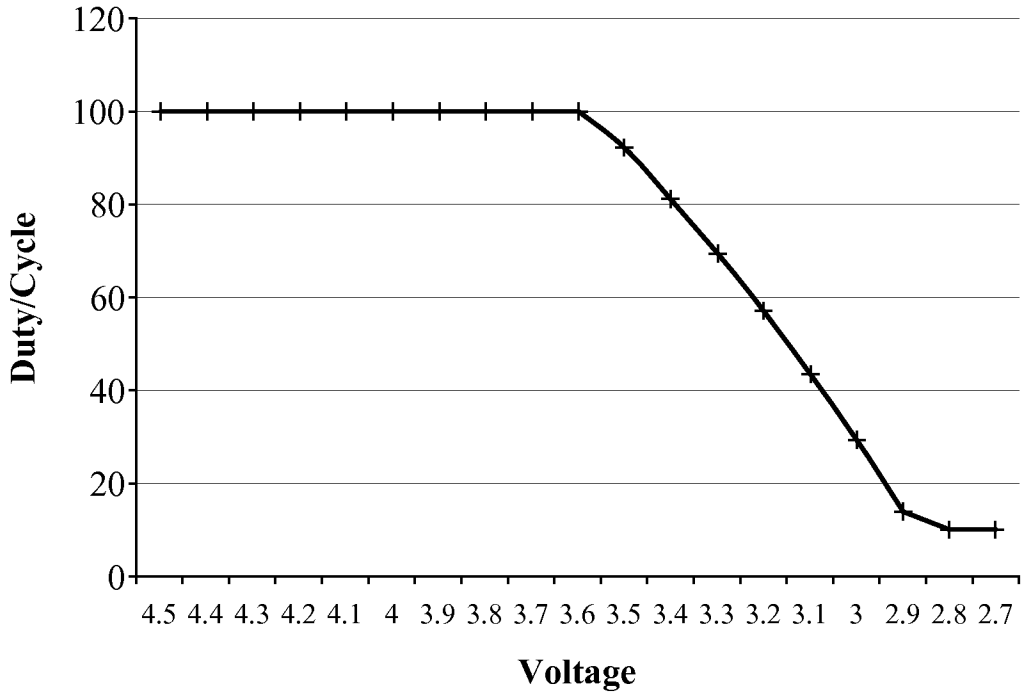

FIG. 11B

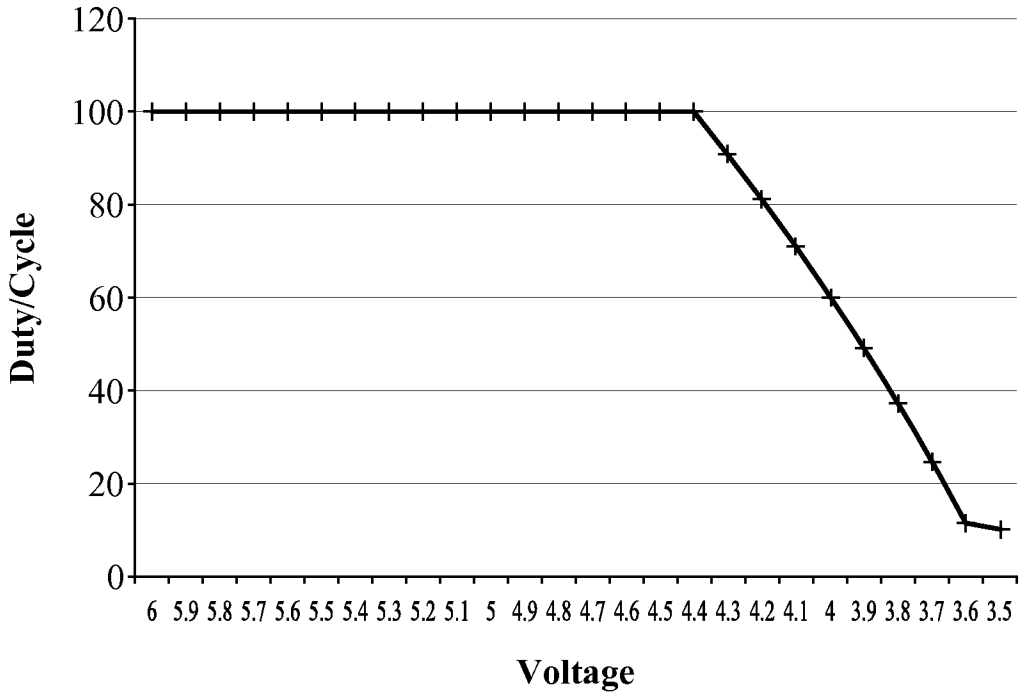
120
100
80
60
40
20
0
Duty/Cycle
6 5.9 5.8 5.7 5.6 5.5 5.4 5.3 5.2 5.1 5 4.9 4.8 4.7 4.6 4.5 4.4 4.3 4.2 4.1 4 3.9 3.8 3.7 3.6 3.5
Voltage

FIG. 11C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2009/053239

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - F21L 4/00 (2009.01)
USPC - 362/157
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - F21L 4/00 (2009.01)
USPC - 362/157

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
USPTO EAST System (US, USPG-PUB, EPO, DERWENT)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 3,738,523 A (LINKLETTER) 12 June 1973 (12.06.1973) entire document	1-9
Y	US 7,140,747 B2 (YANG) 28 November 2006 (28.11.2006) entire document	1-9
Y	US 5,586,819 A (BAMBER et al) 24 December 1996 (24.12.1996) entire document	3-4
A	US 5,716,121 A (DUBOIS) 10 February 1998 (10.02.1998) entire document	1-9
A	US 7,344,269 B2 (MAGLICA) 18 March 2008 (18.03.2008) entire document	1-9
A	US 3,896,644 A (NAGY et al) 29 July 1975 (29.07.1975) entire document	1-9
A	US 4,918,896 A (WIESE) 24 April 1990 (24.04.1990) entire document	1-9
A	US 7,265,494 B2 (BRUWER) 04 September 2007 (04.09.2007) figure 12; column 4, lines 7-23	1-9

☒ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 November 2009	03 DEC 2009
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2009/053239

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See extra sheet.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-9

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2009/053239

Continuation of Box III.

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I, claims 1-9, drawn to a flashlight and method for mounting having a hollow head and a skirt lock ring having indexing bumps, wherein each of first and second indexing bumps is constructed by two high plateau regions separated by a low plateau, wherein the skirt lock ring is locked by the head when each of the protuberances is aligned with one of low plateaus.
Group II, claims 10-12, drawn to a flashlight comprising a microcontroller having a plurality of temporary mode memory devices, wherein the microcontroller reads mode information from the internal memory, increments the mode value by one, and writes the information into the mode memory devices.
Group III, claims 13-20, 23-24 drawn to a flashlight comprising a power control circuit and a controller, wherein the power control circuit supplies a voltage output to the controller which depends upon a battery count being above or below a predetermined value.
Group IV, claims 21-22, drawn to a flashlight having first and second L-shaped contacts.

The inventions listed as Groups I, II, III or IV do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: the special technical feature of the Group I invention: a hollow head and a skirt lock ring having indexing bumps, wherein each of first and second indexing bumps is constructed by two high plateau regions separated by a low plateau, wherein the skirt lock ring is locked by the head when each of the protuberances is aligned with one of low plateaus as claimed therein is not present in the invention of Groups II, III or IV. The special technical feature of the Group II invention: a microcontroller having a plurality of temporary mode memory devices, wherein the microcontroller reads mode information from the internal memory, increments the mode value by one, and writes the information into the mode memory devices as claimed therein is not present in the invention of Groups I, III or IV. The special technical feature of the Group III invention: the power control circuit supplying a voltage output to the controller which depends upon a battery count being above or below a predetermined value as claimed therein is not present in the invention of Groups I, II or IV. The special technical feature of the Group IV invention: first and second L-shaped contacts as claimed therein is not present in the invention of Groups I, II or III.

Groups II, II, III and IV lack unity of invention because even though the inventions of these groups require the technical feature of flashlight having control circuitry and a user interface, this technical feature is not a special technical feature as it does not make a contribution over the prior art in view of US 7,265,494 B2 (BRUWER) 04 September 2007, figure 12; column 4, lines 7-23.

Since none of the special technical features of the Group I, II, III or IV inventions are found in more than one of the inventions, unity of invention is lacking.