ABSTRACT: A timer comprising a battery, an impedance connected in circuit with the battery for progressively draining the battery, and a device actuable when the battery has been drained to a sufficiently low level.
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TIMER EMPLOYING CURRENT DRAIN CHARACTERICISTIC OF BATTERY

BACKGROUND OF THE INVENTION

The present invention relates to timers and more particularly to devices capable of effecting an operation after the lapse of a relatively long period of time.

Long term timers of the type which initiate operations after lapse of days, weeks, or months, generally employ clock mechanisms to accomplish the timing function. Timers such as these are quite accurate but suffer from the disadvantages of being expensive, noisy, bulky and heavy. Any one of these disadvantages may render such clock-type mechanisms unsuitable for particular timing applications, especially where precise timing is not of the essence.

Electrical timing circuitry, comprising combinations of interconnected resistors and capacitors, has been employed for timing short intervals, that is from fractions of a second to several minutes. These RC timers, as they are called, are substantially devoid of the disadvantages enumerated above for the clock-type timer, but are unsuitable for timing long time intervals.

SUMMARY OF THE INVENTION

The present invention employs the rundown time of the terminal voltage of an electric battery in a timing mechanism. In one embodiment of the invention the battery is connected across a relay coil which holds a pair of normally open contacts closed. When the terminal voltage of the battery runs down sufficiently, contact bias toward open condition overcomes the holding force of the relay coil and the relay releases, permitting the contacts to close a circuit to a load. Various modifications of this embodiment are disclosed herein; in addition, devices other than relays, such as electronic switching circuits, are disclosed as sensing the battery condition, so that no moving parts need be employed in the timer. For most batteries, the terminal voltage versus time characteristic for given current drains can be made substantially the same for a large sampling of batteries. Therefore, adequately accurate timers form for many purposes can be designed wherein the timing function depends on the rate of current drain from the battery, a predetermined terminal voltage on the terminal voltage versus time characteristic being employed to initiate a triggering action of a mechanical or an electrical device. The timing period can, of course, be varied by varying the current drain from the battery, accomplished by changing the draining impedance connected across the battery terminals.

It is therefore an object of the present invention to provide a long term timing device which is less expensive, more compact, more reliable, and quieter than prior art devices employed for this purpose.

It is another object of the present invention to employ the time required for a battery to discharge to a specified terminal voltage under a predetermined current drain condition to delay the initiation of an operation.

It is still another object of the present invention to provide a timer based on the terminal voltage versus current drain characteristic of a battery, taken as a function of time.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of the timer of the present invention;

FIGS. 2, 3, 4 and 5 are schematic diagrams of modified embodiments of the timer of FIG. 1; and

FIG. 3a is a graphical representation of a family of curves representing the terminal voltage versus time characteristic for a battery under various current drain conditions.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now, specifically to FIG. 1, there is illustrated a timer constructed in accordance with the principles of the present invention. The timer comprises a battery 11 having one terminal connected to a relay coil 13 and having another terminal connected to the movable arm of a single-pole double-throw switch 15. A fixed contact representing the ON position of switch 15 is connected to the opposite end of relay coil 13. When switch 15 is in its ON position, therefore, relay coil 13 is connected directly across battery 11. Relay coil 13 is associated with a core 16 constructed in a U-shape of conventional ferrous material. An armature 17 of magnetizable material is pivotally mounted so as to be disposed across the upstanding legs of U-shaped core 16 in one position and remote from core 15 in a second position. Armature 17 is biased by means of bias spring 19 so as to normally be disposed in the latter position, remote from core 16, in the absence of an energizing current through relay coil 13. An electrical contact 21 is carried by armature 17 and is movable therewith. A fixed electrical contact 23 is positioned so as to be engaged by movable contact 21 when armature 17 is in its deenergized position remote from core 16. A series circuit comprising a battery 25 and a load 27 is connected between respective contacts 23 and 21.

In operation, when switch 15 is placed in the ON position, battery 11 produces a current which flows through relay coil 13. The current through coil 13 induces a magnetic flux in core 16, the density of the flux being proportional to the amplitude of the current. At flux densities in core 16 above a predetermined value, the magnetic force pulling on armature 17 will be sufficient to overcome the counterforce exerted by bias spring 19. For purposes of this embodiment, battery 11, coil 13, and core 16 are chosen so that for a fresh battery 11 having a terminal voltage substantially at its rated terminal voltage, the impedance of coil 13 is sufficient to provide a flux density in core 16 which exerts a large enough force on armature 17 to overcome the effects of bias spring 19. Therefore, electrical contacts 21 and 23 are open and current is not permitted to flow through load 27. As battery 11 drains through relay coil 13 its terminal voltage drops. At some terminal voltage of battery 11 the current in relay coil 13 is insufficient to maintain the flux density in core 16 at a value sufficient to overcome the effects of bias spring 19. At that point spring 19 pulls armature 17 away from the core 16 and closes contacts 21 and 23. The closure of contacts 21 and 23 permits battery 25 to supply current to load 27 and the timing function is completed. Load 27 may be any voltage or current sensitive element which upon energization effects a desired operation.

Referring now to FIG. 2, there is illustrated another embodiment of the timer of this invention. The embodiment of FIG. 2 is similar to the embodiment of FIG. 1, other than that a permanent magnet 29 is provided in place of bias spring 19, a device having a nonlinear voltage versus current characteristic such as diode 31 being in series with relay coil 13, and a second relay coil 13' being connected in parallel across the series combination of diode 31 and relay coil 13. The function of permanent magnet 29 is analogous to that of bias spring 19 in FIG. 1; namely, to bias armature 17 to closed contact position in the absence of a predetermined flux density in core 16. However, the position of magnet 29 can be readily adjusted in order to modify the bias force exerted on armature 17. This position adjustment is preferably accomplished in a plane generally parallel to armature 17 rather than perpendicularly thereof, to provide a latch effect. The function of relay coil 13' and diode 31 is to provide more reliable relay action than is possible with the embodiment of FIG. 1. Specifically, where extremely reliable and sensitive relay action is desired, it is important that the holding power of core 16 relative to armature 17 be very much in excess of the pull of magnet 29 (or bias spring 19). In this regard it may be desirable to provide a small armature mass for armature 17 to prevent opening of the magnetic circuit comprising core 16 and armature 17 when the device is subject to shock and jolt. The ultimate condition however, would be to provide an armature of small mass which is gripped hard while the relay is energized, and to require an opposing but very small force to move the armature away from
through coil 13 is insufficient to induce a sufficiently strong flux density in core 16 to overcome the counterforce of bias spring 19. If resistance 33 is set to a very low resistance value, upon closure of switch 15 to the ON position the terminal voltage of battery 11 will decay relatively rapidly to X volts and armature 17 will be released. Release of armature 17 results in closure of contacts 21 and 23 to complete the circuit for energization for load 27, assuming, of course, that switch 35 is in its ON position. When the value of resistor 33 is such to drain current from battery 11 according to curve A, the time at which the armature is released is represented at $T_r$ in Fig. 3e which is the point on the time scale corresponding to the intersection of X volts and curve A. The intersections of the line representing X volts with curves B, C, and D have corresponding times $T_a$, $T_c$, and $T_d$ indicated in Fig. 3a. These times indicate the times at which load 27 is energized when the resistance of element 33 is set to provide the respective terminal voltage versus time characteristic for battery 11. It is to be understood that curves A, B, C, and D are provided for illustrative purposes only, and that in effect an infinite number of curves are possible depending upon the setting of resistive 33, and the characteristics of the battery employed in the system.

The function of diode 31 in the embodiment of Fig. 3 is to provide substantially zero volts across coil 13 before the terminal voltage of battery 11 reaches zero volts. Specifically, for low values of battery terminal voltage, the impedance of diode 31 becomes quite large relative to the impedance of coil 13, and substantially all of the voltage drop across the series circuit comprising diode 31 and coil 13 appears across diode 13. Of course, diode 31 is not necessary to provide the variable timing feature provided by resistance 33.

The function of switch 35 in the embodiment of Fig. 3 is to prevent activation of load element 27 prior to the beginning of a timing operation. Specifically, and referring now to Fig. 1, with switch 15 in its OFF position prior to initiation of a timing operation, armature 17 is in its OFF position, providing a closure of contacts 21 and 23. As a result, the circuit for battery 25 and load element 27 is completed without a timing operation having been properly initiated. This may be a serious disadvantage where load element 27 is a detonation device for an explosive device, in which case load element 27 would have to be connected in circuit subsequent to the closure of switch 15 to the ON position in order to avoid a premature explosion. Rather than have a situation where load element 27 must be physically wired into the circuit subsequent to closure of switch 15, switch 35 may be provided in series with the load element 27, switch 35 normally remaining in its OFF position to interrupt current flow between battery 25 and load element 27. If switches 15 and 35 are independent, it is important that the operator be made aware of the necessity of closing switch 35 after switch 15 is closed so as to prevent premature activation of load element 27. If switch 35 and switch 15 are ganged, however, premature activation of load element 27 cannot occur so long as the arm of switch 15 makes contact with the ON contact. This may be readily achieved by employing a make-before-break switch for switch 15 and a break-before-make switch for switch 35, both of which are conventional and are therefore not described in detail.

Referring again to Fig. 4, there is illustrated still another embodiment of this invention wherein circuit provisions are included to avoid premature activation of load element 27 without the necessity for switch 35 of Fig. 3. Specifically, the circuit of Fig. 4 comprises battery 11, switch 15 and relay coil 13 connected in closed series circuit. These elements cooperate with core 16 and armature 17 (illustrated in schematic form for convenience) in the manner described above for the embodiment of Fig. 1. A series circuit comprising a diode 37, a resistor 39 and a capacitor 41 is connected across relay coil 13 with diode 37 polarized so as to permit current to flow from battery 11 through the series circuit. A further series circuit comprising a fixed contact 23 and movable contact 21 and load element 27 is connected across capacitor 41.
Prior to initiation of a timing operation, switch 15 is in the OFF position and armature 17 is in its up position, to provide a closure between contacts 21 and 23. When switch 15 is placed in the ON position, capacitor 41 presents a momentary short circuit across the series combination of closed contacts 23 and 21 and load element 27, thereby assuring that premature activation of load element 27 does not occur. The short circuit provided by capacitor 41 remains for a sufficient period of time to permit the current through relay coil 13 to activate armature 17 and open contacts 21 and 23. The charge time of capacitor 41 is, of course, determined by the combined resistance of diode 37 and resistance 39 and by the capacitor of capacitor 41. With the relay actuated, battery 11 begins to decay at a drain rate determined by the impedance of relay coil 13. Of course, a resistor, such as resistor 33 in Fig. 3, may be employed to control the drain rate. In addition, during the early portion of the timing cycle, capacitor 41 charges up to substantially the rated terminal voltage of battery 11 and it is prevented by diode 37 from discharging below said rated voltage as the terminal voltage of a battery 11 decays. When the battery voltage decays to a point beyond which the flux in core 16 can no longer oppose the biasing counterforce (provided by either spring 19 or magnet 29 in Figs. 1-3), armature 17 is released and contacts 21 and 23 close. The rated battery terminal voltage appearing across capacitor 41 then appears directly across load element 27 and is discharged therethrough.

Still another embodiment of the present invention is illustrated in Fig. 5 wherein battery 11 is illustrated as being connected directly in parallel with variable resistor 33. The positive terminal of battery 11 is connected to ground and to the emitter electrode of an NPN transistor 49. The collector electrode of transistor 49 is connected to one end of load element 27, the other end of which is connected to the positive terminal of battery 25. The negative terminal of battery 25 is connected to ground. A voltage divider comprising series connected resistors 51 and 53 is connected across the positive terminal of battery 25 and the negative terminal of battery 11. The junction between resistors 51 and 53 is connected to the base electrode of transistor 49. The values Rb and Rf for resistors 51 and 53 respectively are chosen such that the initial base-to-emitter voltage for transistor 49 (when battery 11 is fresh) is less than is required to cause transistor 49 to conduct. Specifically, if the ratio of Rb and Rf of 53 is greater than the ratio ratio Uf10/Ub1, the base-to-emitter voltage of transistor 49 reverse biases the base-to-emitter junction and transistor 49 is prevented from conducting. Battery 11 is permitted to decay at a rate determined by the setting of variable resistor 33. As the terminal voltage across battery 11 diminishes, there is a corresponding decrease in voltage across the voltage divider comprising resistors 51 and 53, battery 25 becoming dominant as the decrease in voltage at battery 11 continues. The junction between resistors 51 and 53 therefore tends to become more positive as battery 11 decays and, after a predetermined time elapse, reaches a sufficiently positive value relative to the grounded emitter electrode to cause transistor 49 to conduct. When transistor 49 conducts the load element 27 is activated and the timing sequence is completed.

The embodiment of Fig. 5 may provide greater timing accuracy than is possible with the previously described embodiments which employ relays to effect switching. Specifically, the triggering level of a transistor may be more accurately determined than the pullout voltage of a relay. Thus, if the triggering level of transistor 49 can be set accurately with resistors 51 and 53, any point on the terminal voltage versus time characteristic for battery 11 may be employed as the triggering level for transistor 49. By appropriately setting resistors 33, the current drain condition for battery 11 can be chosen such that the transistor triggering voltage occurs after a desired time elapse. Particularly advantageous results may be achieved by employing the embodiment of Fig. 5 to trigger on the relatively flat portion of the terminal voltage versus time characteristic of battery 11 rather than the somewhat less accurately determined sharp fall off portion of the characteristic.

It is to be understood that the embodiment of Fig. 5 may be provided with appropriate ON-OFF switches switches as necessary to prevent premature initiation of the timing sequence. Further, other known electronic switching devices such as vacuum tubes, silicon controlled rectifiers, etc., may be employed in place of transistor 49.

It is further to be understood that several of the features disclosed above have significance independently of the specific embodiment in which they are illustrated. For example, permanent magnet 29 may be employed in the embodiments of Figs. 1, 3 and 4 as well as Fig. 2. Similarly switch 35 may be utilized with any of the embodiments, not only that of Fig. 3, and the safety circuit comprising elements 37, 39 and 41 of Fig. 4 may be employed in conjunction with the embodiments of Figs. 1-3.

Accordingly, while we have disclosed preferred embodiments of our invention, it will be apparent that variations in the specific details of construction which have been described and illustrated may be restored to without departing from the spirit and scope of the invention, as defined in the appended claims.

I claim:
1. A timer for providing a time delay interval, comprising: a battery having a pair of terminals and a terminal voltage versus time characteristic established in terms of rate of current drain from said battery as a function of time; resistive means connected in circuit with said battery for providing a desired rate of current drain from said battery; actuable means having at least two operative states and responsive to attainment of a predetermined battery terminal voltage in the course of said current drain for assuming one of said two operative states, said predetermined battery terminal voltage being less by a predetermined increment than the rated terminal voltage for said battery prior to said current drain; means for initiating said time delay interval by connecting said terminals to said resistive means in such relation that said resistive means drains current from said battery; wherein said actuable means includes a relay circuit comprising a relay coil responsive to the voltage between said pair of terminals and further comprising a pair of normally closed relay contacts, said relay coil being arranged and adapted to maintain said contacts open only while the terminal voltage of said battery is above said predetermined voltage;

wherein said resistive means further comprises a nonlinear resistance element connected in series with said relay coil and said battery, said element having a greater resistance when low voltages are applied thereacross than when high voltages are applied thereacross, whereby the voltage across said relay coils decreases in accordance with the cumulative effects of decreasing battery terminal voltage and increasing resistance of said element; and

wherein said relay circuit includes a second relay coil connected in parallel with a the series combination of said first-mentioned relay coil and said nonlinear resistance element, said second relay coil being arranged to provide an opposing and smaller magnetomotive force than that provided by said first-mentioned relay coil when both coils conduct equal currents, whereby the magnetomotive forces provided by said relay coils are substantially equal and opposite upon attainment of said predetermined terminal voltage at said battery.

2. A timer for providing a time delay interval, comprising: a battery having a pair of terminals and a terminal voltage versus time characteristic established in terms of rate of current drain from said battery as a function of time; resistive means connected in circuit with said battery for providing a desired rate of current drain from said battery;
actuable means having at least two operative states and responsive to attainment of a predetermined battery terminal voltage in the course of said current drain for assuming one of said two operative states, said predetermined battery terminal voltage being less by a predetermined increment than the rated terminal voltage for said battery prior to said current drain; means for initiating said time delay interval by connecting said terminals to said resistive means in such relation that said resistive means drains current from said battery; wherein said actuable means includes a relay circuit comprising a relay coil responsive to the voltage between said pair of terminals and further comprising a pair of normally closed relay contacts, said relay coil being arranged and adapted to maintain said contacts open only while the terminal voltage of said battery is above said predetermined voltage; and further comprising a load device for effecting a specified operation upon conduction of current therethrough, means for connecting said load device in series with said pair of normally closed relay contacts, capacitor means connected in parallel with the series combination of said load device and said pair of normally closed relay contacts for transiently providing a short circuit across said series combination upon initiation of said time delay interval, and a timer circuit for slowly charging said capacitor from said battery whereby said load device is prevented from conducting current until said capacitor is sufficiently charged and said battery attains said predetermined terminal voltage.

3. The timer according to claim 2 wherein said timing circuit is connected in series with said capacitor and wherein the series combination of the timing circuit and the capacitor is connected in parallel with said relay coil, said timing circuit comprising a diode and a resistor connected in series, said diode being poled to conduct current from said battery.

4. A timer for providing a time delay interval comprising: a battery having a pair of terminals and a terminal voltage versus time characteristic established in terms of rate of current drain from said battery as a function of time; resistive means connected in circuit with said battery for providing a desired rate of current drain from said battery; actuable means having at least two operative states and responsive to attainment of a predetermined battery terminal voltage in the course of said current drain for assuming one of said two operative states, said predetermined battery terminal voltage being less by a predetermined increment than the rated terminal voltage for said battery prior to said current drain; means for initiating said time delay interval by connecting said terminals to said resistive means in such relation that said resistive means drains current from said battery; wherein said actuable means comprises a transistor having base, collector and emitter electrodes, and means for biasing said transistor in a nonconducting condition for battery voltages above said predetermined terminal voltage and in conducting condition for battery voltages equal to and less than said predetermined terminal voltage; further comprising a load device connected in series of with the collector-emitter circuit of said transistor, said load device being responsive to current flow therethrough for effecting a specified operation; wherein said means for biasing said transistor comprises: a source of reference potential; a further battery; means for connecting said further battery in series aiding relating with said first mentioned battery; a voltage divider network; means for connecting said voltage divider network in closed series circuit with said series-connected batteries; means for connecting said base electrode to a first circuit point intermediate said voltage divider network; said circuit point being at a potential which is less than said reference potential when said first-mentioned battery is at its rated terminal voltage prior to said drain; means for connecting the series combination of said load device and the collector-emitter circuit of said transistor in shunt with said further battery; and means for connecting said source of reference potential to a second circuit point intermediate said series-connected batteries.