

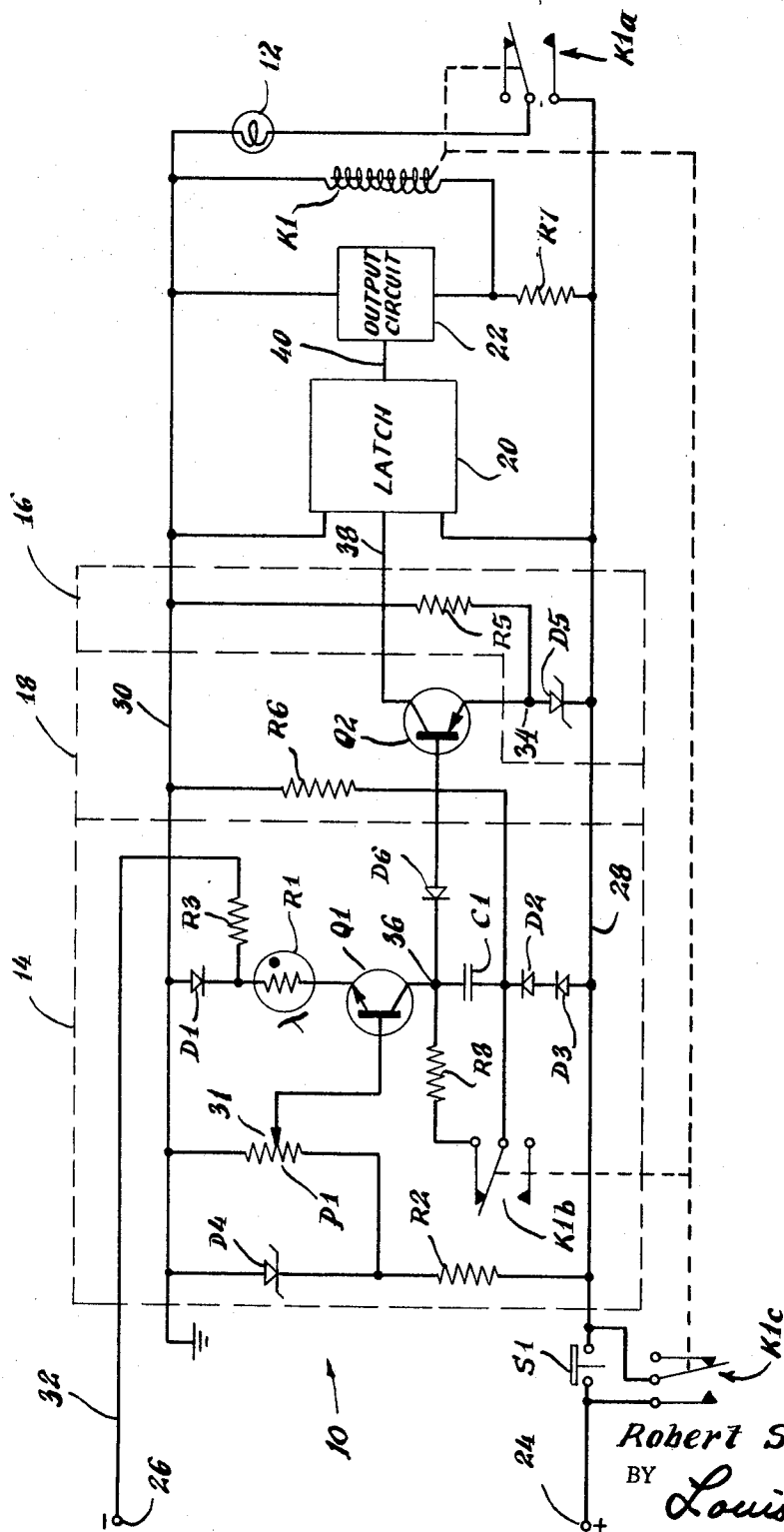
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CONDITION RESPONSIVE PROCESS TIMER

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CONDITION RESPONSIVE PROCESS TIMER

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ABSTRACT OF THE DISCLOSURE

A photoprocess controller having an RC interval timer which utilizes a photosensitive resistor, in the capacitor's charging path, which is optically coupled to a lamp. An adjustable, transistor, constant current source in the charging path maintains the charging current constant. The photosensitive resistor and constant current source respectively compensate for lamp deterioration and line voltage fluctuations thereby maintaining constant the lumen-second light output of the lamp, which output is adjustable by varying the level of charging current. The charging current circuit is one side of a bridge circuit, whose other side includes a Zener diode which provides fixed voltage source. A detector, connected across the bridge sides, is energized when the voltage across the charging capacitor reaches the fixed voltage of the Zener to operate a latching circuit which turns off the lamp to end the timing cycle.

The present invention relates generally to a condition responsive process timer. More specifically, it relates to a condition responsive timer particularly adapted for use as an input controller. The disclosed embodiment of my invention is directed to a lumen-second controller operating to control a light source such that its light output, in lumen-seconds, is held to an adjustably preset value.

In the photocopy and photoprocessing industries there has been a great need for a lumen-second controller that compensates for line voltage fluctuations and lamp deterioration. It will be appreciated that either one of these factors produces variations in the quantity of light emitted by a lamp. Exposure time must therefore be varied in order to properly expose photosensitive papers. Failure to compensate for these two factors gives rise not only to poor quality, but to nonuniformities in exposure.

Similar problems exist in all processing industries where it is desired to supply a given quantity of energy. The circuit described herein uses a light responsive element and is specifically applicable to photography. Those skilled in the processing arts will appreciate that the circuit of the invention may be applied to many other processes by substituting for the light responsive element an element responsive to the form of energy to be supplied.

Accordingly, it is an object of my invention to provide an interval timer.

A further object of the invention is to provide an interval timer of the above character adapted for operation as an input controller.

A further object is to provide a condition responsive timer of the above character for controlling condition producing means.

A still further object is to provide a timer of the above character which responds to the existing level of a condition and modifies its control of the condition producing means accordingly.

A yet further object of the invention is to provide an electronic timer of the above character which compensates for fluctuations in line voltage.

An additional object is to provide a timer of the above character which compensates for variations in the con-

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dition level produced by the condition producing means.

Another object of the present invention is to provide a controller of the above character adapted for use as a lumen-second controller.

Still another object of the present invention is to provide a lumen-second controller of the above character which may be adjustably preset so as to provide a predetermined lumen-second light output.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the features of construction, combination of elements, and arrangement of parts which will be exemplified in the construction hereinafter set forth, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawing, in which the sole figure is a detailed circuit schematic diagram, partially in block form, of a preferred embodiment of my invention adapted as a lumen-second controller.

Broadly stated, my invention is directed to an interval timer of the type described in the copending application of Klaus Wallentowitz, Ser. No. 405,503, filed Oct. 21, 1964, for Electronic Timer Circuit. This copending application is assigned to the same assignee as the present application. Accordingly, in my invention there is provided a bridge circuit consisting of first and second sides connected across a potential source. The bridge sides are connected to a detector circuit which controls the condition of a latch circuit. The latch circuit in turn controls the energization of an output relay having operatively associated relay contacts connecting condition producing means to a source of electrical energy.

One side of the bridge includes a timing capacitor and an impedance element through which charging current flows to the timing capacitor from the potential source. Unlike the timer disclosed in the above-noted copending application, in my invention, this impedance element is a condition responsive device whose impedance value is proportional to the existing level of a condition produced by the condition producing means. The timing capacitor charges at a rate which is a function of the measured condition. When the potential across the timing capacitor reaches a predetermined voltage relative to a fixed reference potential established at the other bridge side, the detector, connected across the two bridge sides, is energized to condition the latch and thereby control the energization condition of the output relay.

The disclosed embodiment of my invention is specifically directed to a timer for use as a lumen-second controller and thus the condition producing means takes the form of a lamp. The condition responsive device is a photosensitive resistor optically coupled to the lamp. In addition to the photosensitive resistor and in further distinction from the timer of the aforesaid copending application, a variable conductance device is included in the charging path for the timing capacitor so as to regulate the charging current according to the setting of a potentiometer which, in and of itself, determines the light output, in lumen-seconds, of the lamp. The controller responds to the existing light output to automatically control the duration of the interval of the lamp's illumination so as to hold the lumen-second light output of the lamp at a set point value established by the setting of the potentiometer.

The timer of my invention is further rendered insensitive to power supply variations. This is achieved in a novel manner by supplying a fixed reference potential to the detector. The potentiometer is energized from a

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second fixed potential such that for a particular setting, a constant fraction of this second fixed potential is supplied to a control terminal of the variable conductance device connected in the charging path for the timing capacitor. Thus, the charging current supplied to the timing capacitor is maintained constant for a particular set point regardless of variations in the power supply for the interval timer. Thus the rate at which the timing capacitor charges to the voltage of the fixed reference potential supplied to the detector is unaffected by power supply variations.

Moreover, since the interval times of my invention monitors only the light output of the lamp, the precise lumen-second output is obtained regardless of variations in the lamp power supply and regardless of lamp deterioration.

Referring now to the sole figure of the drawing, the condition responsive process timer, constructed according to my invention and generally indicated at 10, operates as an interval timer timing the interval during which a lamp 12 is energized. According to the disclosed application of the timer 10, the lamp 12 is utilized in a photocopying process wherein it gives off light for developing photosensitive paper. The particular manner in which the photocopying process is carried out and the specific optical system employed is not material to the invention embodied in the timer 10. The function performed by the timer 10 is to accurately control the lumen-second light output of the lamp 12 so as to properly expose the photosensitive paper on which the copied subject matter is developed.

The timer 10 includes a bridge side 14 and a bridge side 16 which cooperate with a detector circuit 18, a latch circuit 20, and an output circuit 22 in order to control the energization of an output relay K1. Output relay K1 includes operatively associated relay contacts K1a for controlling the energization of the lamp 12.

Referring more specifically to the drawing, a source of positive potential is connected to an input terminal 24 while a source of negative potential is connected to input terminal 26. Terminal 24 is connected through a switch S1 to a positive buss 28. One side of the lamp 12 is connectable to buss 28 through the relay contacts K1a of output relay K1 while the other side of the lamp is connected to a grounded buss 30. It is to be understood that, although the timer 10 and lamp 12 are shown as sharing a common power supply, in practice they may be energized from separate power supplies.

Bridge side 14 comprises the series circuit including a diode D1, a resistor R1, the emitter-collector circuit of a transistor Q1, a timing capacitor C1, a diode D2 and a diode D3 connected between busses 28, 30. According to the disclosed embodiment of my invention as directed to controlling the lumen-second light output of lamp 12, resistor R1 is a photosensitive resistor which is positioned so as to be optically coupled with the lamp 12. A Zener diode D4 and a resistor R2 are connected in series across the busses 28, 30. A potentiometer P1 is connected across the Zener diode D4. The base of transistor Q1 is connected to the adjustable tap 31 of the potentiometer P1 so as to tap off a predetermined fraction of the fixed potential developed across Zener diode D4. Input terminal 26 is connected by a lead 32 and a resistor R3 to the junction between the diode D1 and the photoresistor R1. The negative potential applied to terminal 26 serves to maintain a forward voltage drop across diode D1 which, as will be seen, compensates for the base-emitter junction potential of transistor Q1.

Bridge side 16 is comprised of the series circuit of resistor R5 and Zener diode D5 connected between the busses 28, 30. The emitter of a transistor Q2, included in the detector circuit 18, is connected to a junction 34 between the resistor R5 and Zener diode D5. Thus, the emitter of transistor Q2 is maintained at a fixed voltage, as regulated by Zener diode D5, despite variations in the

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power supply connected to input terminal 24. A junction 36 between the collector of transistor Q1 and the timing capacitor C1 is connected to the base of transistor Q2 through a decoupling diode D6. A resistor R6 connected from the grounded buss 30 to the cathode of diode D2 preserves forward potential drops across diodes D2 and D3. As will be seen later, the forward potential drops across diodes D2 and D3 serve to cancel out the junction potentials of diode D6 and the base-emitter of transistor Q2.

The collector of transistor Q2 in the detector circuit 18 is connected over line 38 to the input of the latch circuit 20. Latch circuit 20, in turn, controls the condition of the output circuit 22 over line 40. The latch circuit 20 and the output circuit 22 are preferably constructed in the manner described in the above-noted Wallentowitz application. The latch 20 is triggered from its "off" state to its "on" state by the detector 18. When the latch 20 is in its "off" state, the output circuit 22 is disabled from otherwise shunting the operating coil of the output relay K1 which is energized by current flow between busses 28, 30 and through a current limiting resistor R7. When the latch 20 is triggered to its "on" state by detector circuit 18, the output circuit 22 is enabled to short out the operating coil with the result that the output relay K1 is de-energized. When output relay K1 is energized, its normally open contacts K1a close to connect the lamp across busses 28, 30.

The output relay K1 includes a second set of relay contacts K1b which are normally closed when the relay is deenergized so as to short out the timing capacitor C1 through a current limiting resistor R8. A third set of relay contacts K1c close when the output relay K1 is energized to short out the switch S1 in order that the switch need only be momentarily closed in order to initiate an exposure time cycle.

Considering the operation of the timer 10, the adjustable tap 31 of the potentiometer P1 is adjustably preset according to the desired lumen-second light output of the lamp 12. The voltage tapped from the potentiometer P1, which is a certain percentage of the fixed potential drop developed across Zener diode D4, serves to establish the level of conduction of transistor Q1. The photosensitive resistor R1 varies the magnitude of the charging current conducted through the emitter-collector circuit of transistor Q1 to the timing capacitor C1 in accordance with the existing light output, in lumens, of the lamp 12.

In order to initiate the timing of an exposure time interval by timer 10, the switch S1 is closed to complete the energization circuit for the operating coil of output relay K1. At this point, the output circuit 22 is disabled by the "off" state of latch circuit 20 so that the operating coil for the output relay K1 is not shunted. The output relay K1 is energized, and its relay contacts K1a close to energize lamp 12. Relay contacts K1c close to electrically by-pass the switch S1, establishing a holding circuit for output relay K1. Consequently, the switch S1 need not be held down after the holding circuit through relay contacts K1c is established. The holding circuit contacts K1c of output relay K1 may be omitted if it is convenient to maintain the switch S1 closed for the entire exposure time interval. Relay contacts K1b open so that the timing capacitor C1 is no longer shorted on itself.

Timing capacitor C1 now begins to charge toward the potential across the busses 28, 30. The rate at which timing capacitor C1 charges is determined by the level of conductance of transistor Q1 and the resistance of the photosensitive resistor R1. After the expiration of an interval of time determined by the charging rate of capacitor C1, the potential at junction 36 falls until it equals the potential at junction 34. At this point, transistor Q2 in the detector circuit 18 is biased on with the result that the latch 20 is triggered to its "on" state. Latch 20, in turn, conditions the output circuit 22 so as to short out the energization circuit for the output relay K1, whereupon

- (a) said resistor is adjustable to provide for adjustment of the duration of said timed interval.
3. The process timer defined in claim 1 wherein
- (a) said means establishing the current conducting level of said device is adjustable to provide for adjustment of the duration of said timed interval.
4. A process timer of the class described, comprising, in combination:
- (A) a timing capacitor connectable to be charged from a potential source;
- (B) a resistor connected in the charging path for said capacitor;
- (C) a transistor having
- (a) an emitter-collector circuit connected in the charging path for said capacitor, and
- (b) a base;
- (D) means connected to the base of said transistor for establishing a current conducting level for said emitter-collector circuit;
- (E) means establishing a first fixed reference potential; and
- (F) detector means connected to said last named means and said capacitor; and,
- (a) operating when said capacitor has charged to a potential having a predetermined relationship to said first fixed reference potential
- (b) whereby to signal the expiration of a time interval.
5. The timer defined in claim 4 wherein:
- (a) said means connected to the base of said transistor includes
- (1) a Zener diode establishing a second fixed potential; and
- (2) a potentiometer connected across said Zener diode for applying an adjustably predetermined fraction of said second fixed potential to the base of said transistor, and
- (b) said means establishing said first fixed reference potential comprising a second Zener diode,
- (1) said first and second Zener diodes having closely matched characteristics.
6. The timer defined in claim 4, and:
- (G) a forward biased diode connected in the base-emitter circuit of said transistor,
- (a) the forward potential drop across said diode being equal and opposite to the base-emitter junction potential of said transistor.
7. The timer defined in claim 6 wherein said detector means comprises:
- (a) a second transistor having
- (1) an emitter connected to said fixed reference potential, and
- (2) a base, and
- (b) a base circuit diode connecting said base to said timing capacitor.
8. The timer defined in claim 7 and
- (H) a pair of forwardly biased diodes connected in circuit with said timing capacitor and said detector means,
- (1) the forward potential drop across said pair of diodes being equal and opposite to the sum of the junction potentials of said base circuit diode and the base-emitter junction of said second transistor in said detector.
9. An interval timer of the class described for controlling the operation of means producing a condition, said timer comprising, in combination:
- (A) an electrical potential source;
- (B) an interval timing circuit connected to said potential source, said timing circuit comprising
- (a) a capacitor charged from said potential source,
- (b) a condition responsive impedance circuit element connected in the charging path for said capacitor to determine the charging rate thereof;
- (1) said element having an impedance value

- proportional to the level of said condition, and
- (c) a detector operating to signal the expiration of a time interval when said capacitor charges to a predetermined potential; and,
- (C) output means responsive to said detector for controlling the operation of said condition producing means.
10. The timer defined in claim 9 wherein said interval timing circuit further comprises:
- (d) adjustably preset means connected in the charging path for said capacitor to establish a desired time integrated condition output,
- (1) said connection producing means being controlled such that the condition output over the interval timer is equal to said desired condition output.
11. The timer defined in claim 10 wherein said adjustably preset means comprises:
- (2) a transistor having an emitter-collector circuit connected in said charging path, and
- (3) means deriving an adjustably preset potential for application to the base of said transistor to control the conductance of said emitter-collector circuit.
12. An interval timer of the class described for providing a selectably predetermined lumen-second output of a lamp irrespective of lamp deterioration and fluctuations in lamp supply voltage, said timer comprising, in combination:
- (A) a capacitor connectable to be charged from a potential source;
- (B) a photosensitive resistor connected in the charge path for said capacitor,
- (a) said photosensitive resistor being optically coupled to said lamp, and
- (b) having a resistance value proportional to the level of light output from said lamp;
- (C) a variable current conducting device connected in the charge path for said capacitor,
- (a) said device having a control input;
- (D) means connected to the control input of said device for establishing a level of current conduction;
- (E) means establishing a fixed reference potential;
- (F) detector means connected to said last named means and said capacitor,
- (a) said detector operating when said capacitor has charged to a potential having a predetermined relationship to said fixed reference potential to signal the expiration of a timed interval measured from when said capacitor was connected to said potential source; and,
- (G) output circuit means connected to said detector and said potential source, said output circuit means
- (a) operating to enable the energization of a lamp upon connection of said capacitor to said voltage source, and
- (b) operating in response to said detector upon the expiration of said timed interval to disable the energization of the lamp.
13. The timer defined in claim 12 wherein said output circuit means comprises:
- (a) an output relay having relay contacts operating in the energization circuit for the lamp, and
- (b) a bistable latch circuit having
- (1) a first stable state effective to enable the energization of said output relay to close said relay contacts, and
- (2) a second stable state to which said latch is triggered by said detector effective to disable the energization of said output relay,
- (3) said latch automatically reverting to its first stable state upon disconnection of said output circuit means from said voltage source.
14. The timer defined in claim 12 wherein:

the output relay is de-energized. Relay contacts K1a open to de-energize the lamp 12. At the same time, relay contacts K1b close to discharge capacitor C1, and relay contacts K1c open to disconnect the positive buss 28 from the power input terminal 24. The moment of de-energization of the output relay K1 signifies the expiration of the exposure time interval during which the desired lumen-second quantity of light has been given off by the lamp 12 as determined by the setting of the potentiometer P1. With the removal of power, the latch circuit automatically reverts to its "off" state in which it remains until again triggered by detector circuit 18. When capacitor C1 is fully discharged through relay contacts K1b, the switch S1 may be closed to initiate the timing of another exposure time interval.

The adjustability of the timer 10 afforded by the selective setting of the potentiometer P1 for different exposures in a photocopying process, as well as the compensation of the controller for power source fluctuations and lamp deterioration, can perhaps best be demonstrated by the following mathematical analysis of the circuit operation. The charging current I_c for timing capacitor C1 is constant when under conditions of equilibrium:

$$kV_{D4} - V_{Q1} - I_c R_1 + V_{D1} = 0$$

where:

k =setting of potentiometer P1;

V_{D4} =fixed potential drop across Zener diode D4;

V_{Q1} =base-emitter junction potential of transistor Q1;

V_{D1} =forward potential drop across diode D1;

R_1 =resistance of photosensitive resistor R1.

By selecting diode D1 such that its junction potential matches that of the base-emitter junction of transistor Q1, the terms V_{Q1} and V_{D1} cancel from the above equation. Therefore:

$$kV_{D4} = I_c R_1$$

Since, at equilibrium, the charging current I_c is constant, the potential V_{C1} across the timing capacitor C1 as a function of time t can be expressed as:

$$V_{C1} = \frac{I_c t}{C_1}$$

where C_1 =capacitance of capacitor C1 in farads. Substituting for I_c in the above equation:

$$V_{C1} = \frac{kV_{D4} t}{R_1 C_1}$$

Inasmuch as diodes D2 and D3 are selected for their ability to cancel out the junction potentials of diode D6 and the base-emitter junction of transistor Q2, this transistor will conduct to signal the expiration of an exposure time interval when $V_{C1} = V_{D5}$ (the fixed voltage drop across Zener diode D5). Consequently the time t_c of an exposure time interval may be expressed as:

$$t_c = \frac{V_{D5} R_1 C_1}{kV_{D4}}$$

It will be observed that if Zener diodes D4 and D5 are fairly closely matched both as to potential drop and temperature coefficients, the exposure time t_c is compensated for temperature variations as far as the terms V_{D4} and V_{D5} are concerned. The effects of temperature on the terms R_1 and C_1 can be compensated for by making the temperature coefficients of the photosensitive resistor R1 and timing capacitor C1 equal and opposite.

It will further be observed that the above expression for t_c is a general expression for an interval timer and is not necessarily limited to an exposure time (lumen-second) controller. The time interval is seen to be directly proportional to the resistance value R_1 and inversely proportional to the setting k of the potentiometer P1. Moreover, since the supply voltage does not enter into the expression, the time interval is independent of supply voltage fluctuations.

Considering the disclosed application where the photo-

sensitive resistor R1 response to the existing light level output of lamp 12, its resistance R_1 may be expressed as:

$$R_1 = \frac{m}{\lambda}$$

where λ =light level of lamp 12 is lumens; and m =constant of proportionality. Substituting for R_1 in the above equation for the exposure time interval and arranging terms, we obtain:

$$\lambda \cdot t_c = \frac{m C_1 V_{D5}}{k V_{D4}}$$

It will thus be observed that the term $\lambda \cdot t_c$ represents lumen-seconds which is solely determined by the adjusted setting k of potentiometer P1; all other terms being constants. The timer 10 automatically adjusts the exposure time so as to compensate for variations in the light output of lamp 12 caused by power source fluctuations and lamp deterioration. Consequently, the lumen-second light output of lamp 12 is held constant for a particular setting of potentiometer P1 in spite of variations in the light output level.

Although the invention has been disclosed in its specific application as a lumen-second controller, it will be observed from the above expression $t_c = V_{D5} R_1 C_1 / k V_{D4}$ that it has applicability as a condition responsive timer in a wide variety of control applications. The interval timer is readily made variable by adjustment of the setting k of potentiometer P1 or by adjustment of a manually variable resistor substituted for photoresistor R1. In addition, the timer can be readily compensated for temperature and is inherently insensitive to power supply variations.

It will be appreciated that the resistance R1 may be constituted by some other form of element responsive to a condition other than light, and the controller implemented to control means producing that particular condition. Thus, the time integrated control function performed by the timer, as in the disclosed application, is rendered independent of spurious variations in the condition level.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above construction without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention which, as a matter of language, might be said to fall therebetween.

Having described my invention, what I claim as new and desire to secure by Letters Patent is:

1. A condition responsive process timer comprising, in combination:

(A) A timing capacitor connectable to be charged from a potential source;

(B) A constant current source connected in the charging path for said timing capacitor, including;

(a) a resistor connected in the charging path for said capacitor,

(b) a variable current conducting device connected in the charging path for said capacitor in series with said resistor, and

(c) means connected to said variable conductance device for establishing the current conducting level thereof;

(C) A detector connected in circuit with said last named means and said timing capacitor;

(a) said detector operating when said capacitor has charged to a predetermined potential relative to said fixed reference potential to signal the expiration of a timed interval.

2. The process timer defined in claim 1 wherein

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(a) said variable conducting device is a transistor having

(1) an emitter-collector circuit connected in said charging path, and

(2) said control input is the base of said transistor. 5

15. The timer defined in claim 14 wherein

(a) said means connected to the base of said transistor includes

(1) a Zener diode establishing a fixed potential, and 10

(2) a potentiometer connected across said Zener diode for applying an adjustably predetermined fraction of said fixed voltage to the base of said transistor, and 15

(b) said means establishing said fixed reference potential comprising a second Zener diode,

(1) said first and second Zener diodes having closely matched characteristics.

16. The timer defined in claim 15 further comprising: 20

(H) a forward biased diode connected in the base-emitter circuit of said transistor,

(a) the forward potential drop across said diode being equal and opposite to the base-emitter junction potential of said transistor.

17. The timer defined in claim 16 wherein said detector means comprises:

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(a) a second transistor having

(1) an emitter connected to said means producing a fixed reference potential, and

(2) a base, and

(b) a diode connecting said base to said timing capacitor.

18. The timer defined in claim 17 further comprises:

(I) a pair of forwardly biased diodes connected in circuit with said timing capacitor and said detector means,

(1) the forward potential drop across said pair of diodes being equal and opposite to the sum of the junction potentials of said diode and the base-emitter junction of said second transistor in said detector means.

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