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Bianchini

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[54] **FAIL-SAFE TIMING CIRCUIT**

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May 30, 1973 Italy 24809/73

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[51] **Int. Cl.** **H01h 47/18**

[58] **Field of Search**............ 317/141 R, 141 S, 146, 317/148.5 R; 307/246, 254, 293, 141, 141.4

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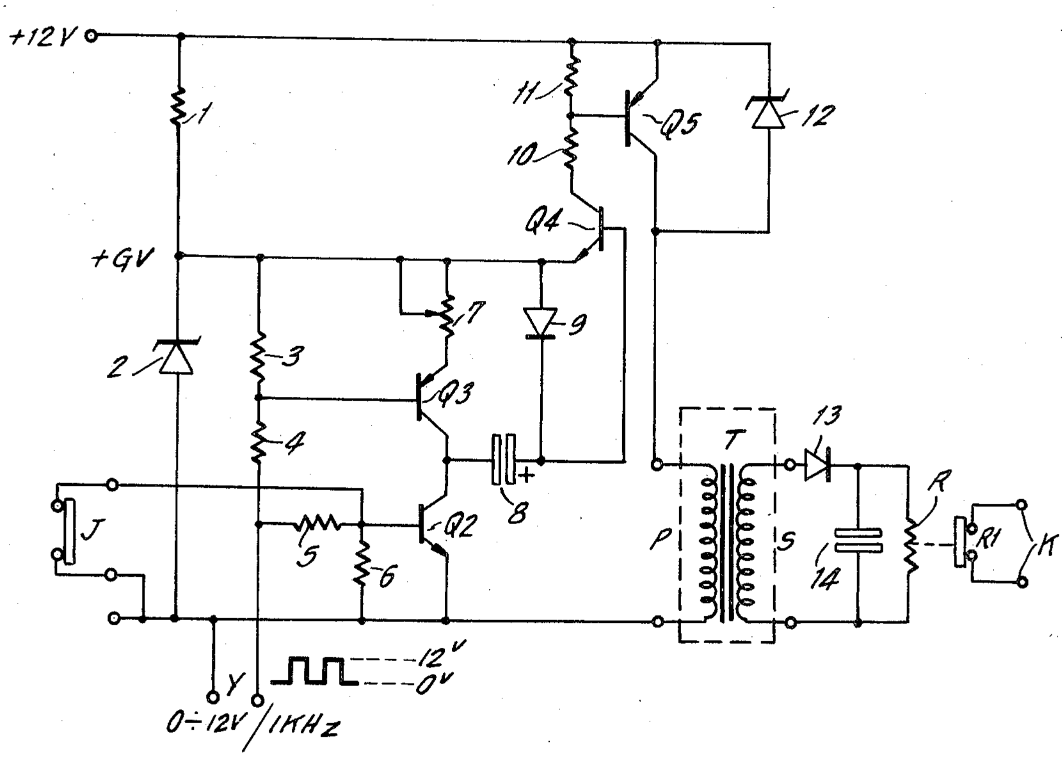
Assistant Examiner—Harry E. Moose, Jr.
Attorney, Agent, or Firm—Ostrolenk, Faber, Gerb & Soffen

[57] **ABSTRACT**

A timing circuit having an energy storage means which normally charges abruptly to a preset value and a circuit for regularly and intermittently discharging the energy storage means through an output circuit of high input impedance to provide an accurate and reliable timing interval of substantial length through the use of simple and yet reliable circuitry.

15 Claims, 7 Drawing Figures



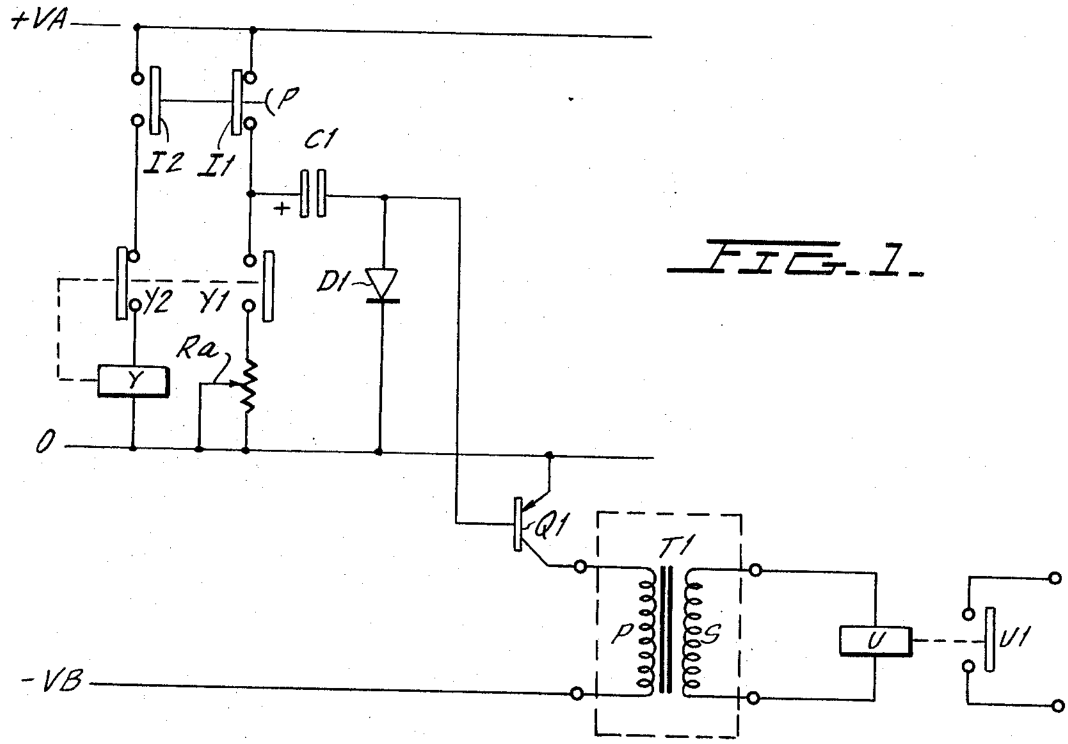

+VA
P
I2
I1
C1
+
D1
Y2
Y1
Y
Ra
0
Q1
T1
P
S
U
U1
-VB

FIG. 1

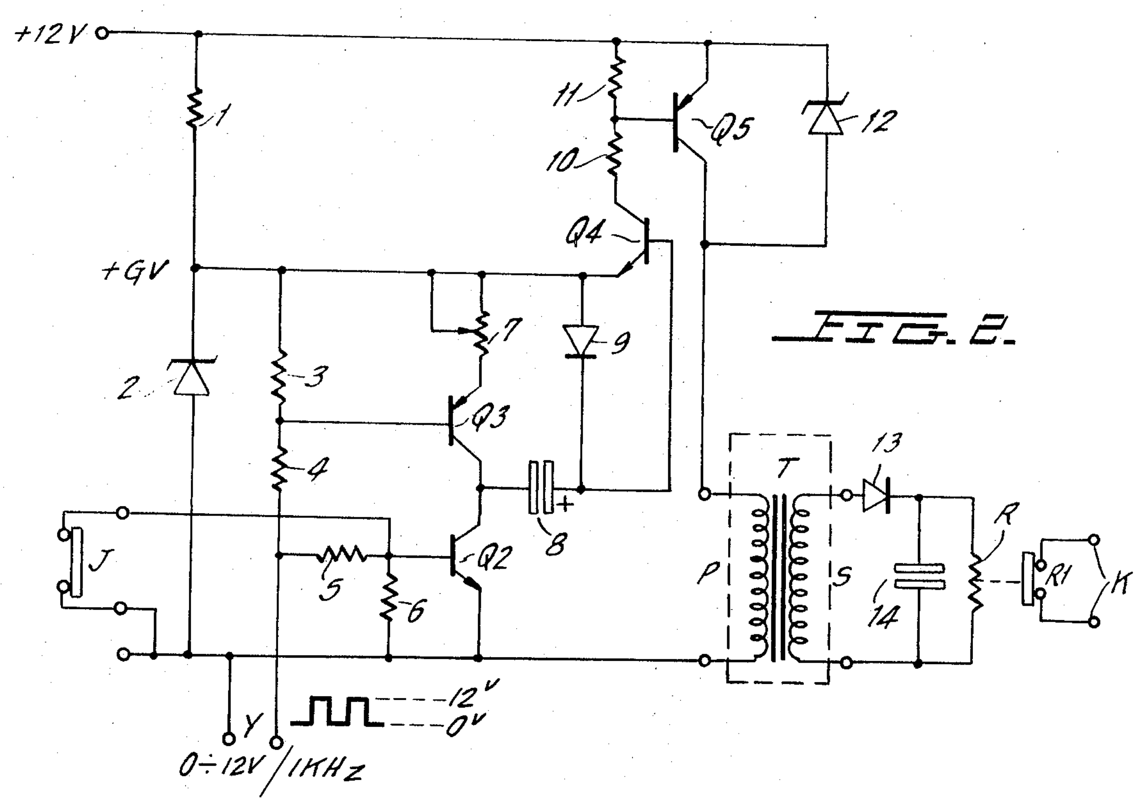

+12V
1
11
10
Q5
12
Q4
+GV
7
9
2
3
Q3
4
8
J
5
6
Q2
T
13
P
S
R
R1
K
14
Y
12v
0v
0÷12V/1KHz

FIG. 2

FIG. 3.

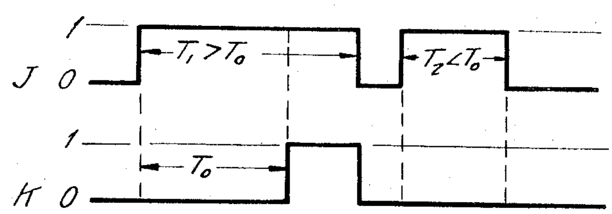
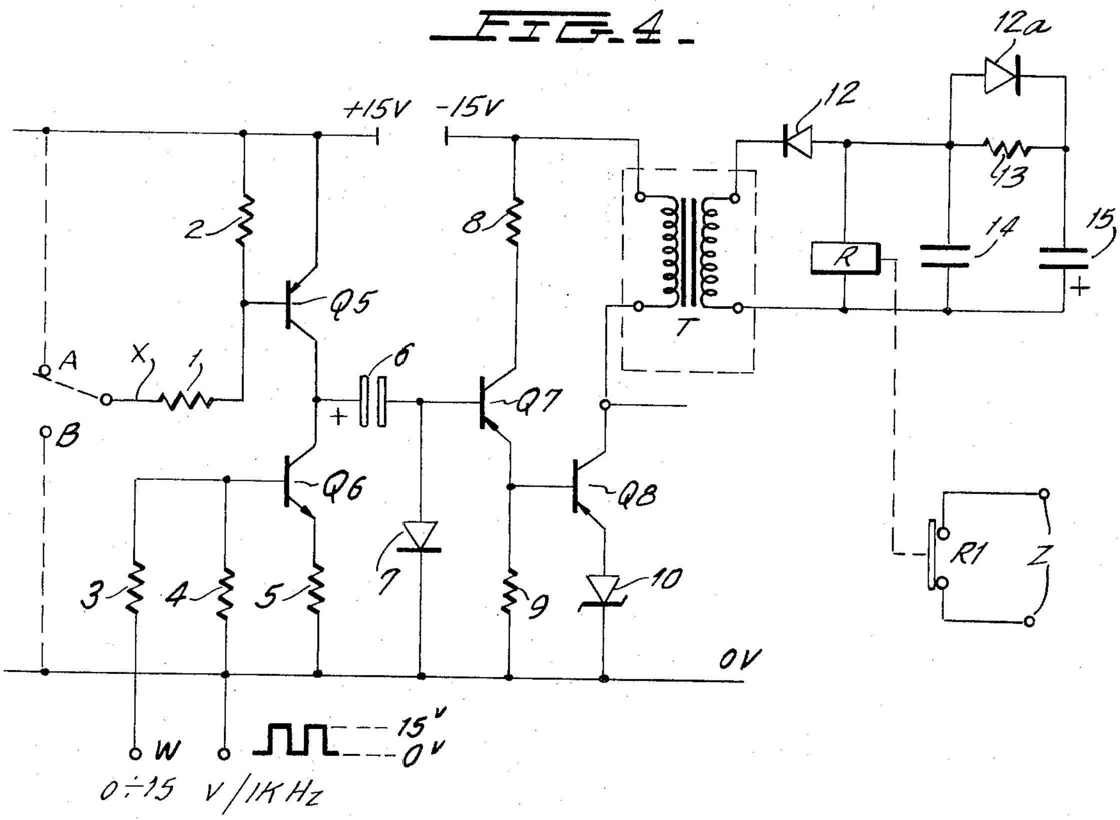

1
J 0
$T_1 > T_0$
$T_2 < T_0$
1
K 0
T_0

FIG. 4.


+15V
-15V
12a
12
13
14
15
+
R
T
2
8
Q5
Q7
Q6
Q8
A
B
X
1
6
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4
5
9
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R1
Z
0V
W
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0v
0÷15 V/1KHz

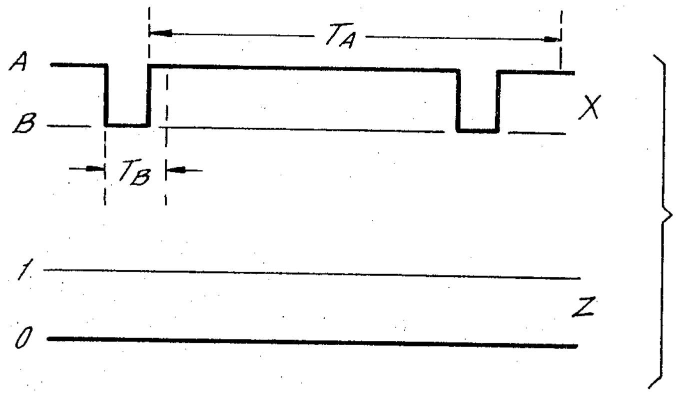

FIG. 5a

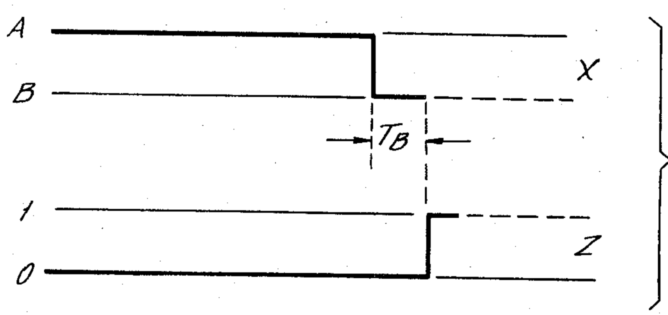

FIG. 5b

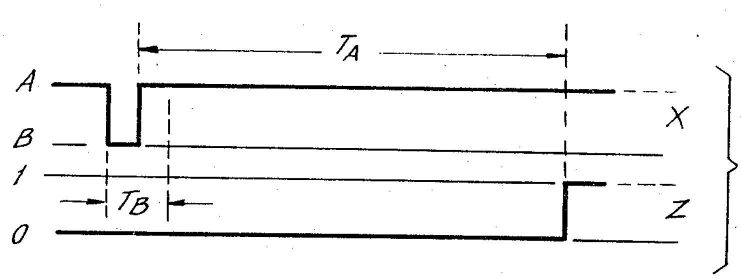

FIG. 5c

FAIL-SAFE TIMING CIRCUIT

The present invention relates to timing devices and more particularly to an electronic timing circuit of a novel type, which is extremely advantageous for use in those industrial control and protection systems in which the interventions of vital importance for safety must normally be delayed for a certain time.

BACKGROUND OF THE INVENTION

In many safety devices and systems it is necessary to generate a protection command or signal whenever certain physical events, or special combinations of physical events which represent a danger situation, occur at the input.

The identification of such danger situations occurs by specific criteria and with specific physical means which vary from case to case, and which lie outside the scope of the present description. However, in general, the identification is attributable to a logic type signal, which may consist, for example, in the closing or opening of an electric contact, or in switching a voltage signal between two pre-established levels. The protection signal or command may, in turn, consist of a manipulation of some kind which, in general, amounts to the closing or opening of an electric contact, for example, as a result of the de-energization (or energization, as the case may be) of a relay.

To ensure the effectiveness-reliability of the protection device or system, the entire process, which correlates the physical events identified at the input with one another, with time, or with other signals of a logic type, must necessarily be realized with extremely dependable circuits.

One of the most delicate circuits, in this respect, is the delay circuit, or timer, which under normal conditions, after the arrival of the input signal, must prevent the output of the protection signal for a certain time, predetermined by calibration, while, as the predetermined time runs out, it must with utmost reliability cause the output of the protection signal, called "end time" signal.

The limiting factor of electronic timing devices normally used in the art is that:

when they are suitable for the control of long times, that is, with simple means and good possibilities of precision and calibration, they are not highly dependable, that is, they are not fail-safe;

when they are highly dependable and in particular fail-safe, they can be used practically only for very short times, of the order of one second, as they require the use of costly and bulky components.

BRIEF DESCRIPTION OF THE INVENTION AND OBJECTS

The present invention is characterized by providing a timing circuit which is well suitable for the control of long times, for example, several minutes, and generates an output signal with extremely high dependability and fail-safe reliability. This means that neither loss of insulation of a capacitor nor other dangerous conditions, especially all those deriving from a possible failure of any electronic component of the circuit, prevent in any way the output of the end time signal, or delay it beyond the pre-established maximum time.

Throughout the present description, that prerogative is defined as "fail-safe reliability."

The problem posed is solved according to the invention by means of a circuit which comprises:

at least one source of energy;

energy storage means (for example, a capacitor);

means for charging a maximum quantity of energy in said storage devices before the time count;

means for discharging, during the time count, the energy stored in said storage devices;

means for modulating the power associated with the energy discharged during the time count (for example, a transistor);

means which amplify the power modulated during the time count (for example, a transistor);

means which receive and filter modulated and amplified power and transferring the thus filtered power to utilization circuitry, only that portion comprising the alternate components produced by the modulation (for example, a transformer);

means which in conditions of rest, that is, without any external action acting on them, assume safely and stably a state unequivocally recognizable as end time signal, and which utilize said filtered power made available during the time count for leaving in a somewhat unstable manner said state of rest (for example, a relay).

It is therefore one object of the present invention to provide a new and improved electronic timing circuit, employable in various ways for controlling time intervals, especially calibratable and/or long time intervals, enduring with fail-safe reliability the output of the end time signal, within the planned maximum time.

Another object of the present invention is to provide a fail-safe electronic circuit adapted to command (control) delayed protections or interventions, especially with long and calibratable delays, useful in all those systems in which it is of capital importance that the intervention to be delayed must in no way be prevented due to failures in the electronic circuit.

BRIEF DESCRIPTION OF THE FIGURES

The above as well as other objects of the invention will now be made apparent from the accompanying description and drawings in which:

FIG. 1 is a schematic diagram of a particularly simple device embodying the principles of the instant invention.

FIG. 2 is a schematic diagram showing a preferred realization of the timer according to the invention.

FIG. 3 shows waveforms which illustrate the operation of the device of FIG. 2.

FIG. 4 is a schematic diagram of another example of a preferred embodiment of the timer according to the invention.

FIGS. 5*a*–5*c* show waveforms which illustrate the operation of the device of FIG. 4.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 shows a particularly simple form of the invention which may be described as follows:

The command at the input, to initiate the time count, is constituted by the actuation of the pushbutton (or release) P, provided with the contacts I1 and I2 The control circuit gives an end time signal by opening the contact U1 of the relay U, a certain time To after it receives said command.

The power supply of the circuit consists of two different sources of direct current, so that two voltage levels are available, one positive $+V_A$ and one negative $-V_B$ referred to a common line taken as reference voltage O.

In the absence of command, contact I1 is normally biased (by means not shown) to remain closed, and through the diode D1 the capacitor C1 is charged and maintained charged with the polarity indicated. When the command arrives (i.e. when pushbutton P is depressed, for example), I1 opens and I2 closes to energize the vibratory relay Y having contacts Y_2 and Y_1. Suitable bias means (not shown for purposes of simplicity) normally maintains contact Y_2 closed and Y_1 open. Energization of relay Y upon closure of contact I_2 causes Y_2 to open and Y_1 to close. The opening of contact Y_2 deenergizes relay Y causing Y_2 to reclose and Y_1 to reopen. This vibratory action continues so long as contact I_2 remains closed. Through the contact Y1 there occurs intermittently the discharge of the capacitor C1 across the base of transistor Q1.

The variable resistor R, having slider arm R_a limits the discharge current to a value sufficient to pilot the transistor Q1, but such as to prolong the discharge time of C1. The transistor Q1 is thus triggered on and off by successive current pulses.

The impulse current amplified by Q1 is supplied through the collector of Q1 to the primary P of the transformer T1 which carries out a dynamic transfer of power to the secondary S. Energization of relay U closes its contact U1.

Under such conditions there occurs the regular time count, during which the contact U1 stays closed.

The relay U remains energized as long as the capacitor C1 is not discharged below a certain value, which depends on the parameters of the components of the circuit.

At the end of the discharge, in fact, the base of Q1 no longer receives sufficient current to allow the current operation of the circuits downstream, and the relay de-energizes reliably, causing the contact U1 to reopen, and hence giving the end time signal.

The time To during which the closing of the contact U1 is delayed can be calibrated by varying the value of R, and the circuit is able to control it with absolute failure-proof reliability. That is, there is no electronic component in the circuit which, by breaking down, could keep the relay U energized beyond the time To. Therefore, the circuit is particularly useful for controlling in a reliable manner the delay time of a protection intervention, causing the protection to be brought about by the opening of the contact U1.

On the other hand, the time To is particularly long, both because the discharge of C1 occurs intermittently, and because the discharge current can be limited to very low values (for example, due to the notoriously low base current drawn by transistors), since it is subsequently amplified by Q1 (i.e. $I_c = \beta I_b$ where I_b= base current; I_c= collector current and, for instance, $40<\beta<80$. Moreover, the controlled time To can be varied, in a manner not shown in FIG. 1, by varying the maximum quantity of energy charged in the capacitor C1, for example, by properly calibrating the value of the voltage +VA.

For the use of the circuit described in the various practical applications it is sufficient to choose in each case the modulation frequency, the forms of actuation of the contacts I1 and Y1, and the gain of the amplifier stage.

In particular the contacts I1 and Y1 stated above can be replaced by electronic switches, that is for example, transistors which alternate between the conducting state and non-conducting state, and the respective command criteria depend on the function demanded of the device.

So, by substituting, for the single components described above for the simplified diagram of FIG. 1, circuit elements which carry out the same basic function with better performance, one obtains a large range of control devices having the desirable characteristics mentioned hereinabove.

One preferred embodiment of the invention, for example, is the device illustrated in FIG. 2, the operation of which is diagrammatically represented by means of the waveforms of FIG. 3 in which "0" denotes the contact "open" position and "1" indicates the contact "closed" position.

The transistors Q2 and Q3 (in place, respectively, of the contacts 11 and Y1 of FIG. 1), are controlled by an external signal Y always present, of rectangular wave shape, of a frequency equal to 1 KHz, whose amplitude lies in the range from 0 to 12V, which transistors act in phase opposition so that one is turned off while the other is conducting and vice versa. Initially the contact J is normally maintained open, corresponding to absent input signal. When Q2 conducts, it charges the capacitor **8** across the diode **9** to the voltage of about 6V. In this phase both transistors Q3 and Q4 are non-conducting.

When Q3 conducts (and Q2 is turned off), Q3 limits the current to a nearly constant value, dependent upon the calibration value of the variable resistor **7**, and upon the voltage present across the terminals of resistor **3**. In this phase the capacitor **8** discharges into the base-emitter circuit of the transistor Q4 with constant (direct) current limited by Q3, so as to obtain a longer and more regular process of discharge.

Thus, Q4 alternates between conduction and non-conduction at the same frequency rate of the external signal Y equal to 1 KHz. Through the amplifier-transistor Q5 the primary P of the coupling transformer T is supplied with pulsating voltage. In the secondary winding S a pulsating voltage is induced also, which is rectified by the diode **13** and filtered by the capacitor **14**, to serve to maintain the relay R energized. In these conditions, that is in the absence of an input signal, the contact R1 is open, and the output signal across terminals K is also absent.

However, when a signal is introduced at the input closing the contact J, transistor Q2 is rendered non-conductive due to short-circuit placed across the base-emitter circuit of Q2 by closure of contact J preventing capacitor **8** from recharging.

Instead the transistor Q3 continues to supply current pulses to the base of Q4 and to the circuits downstream, at the expense of the energy charged in the capacitor **8**. When capacitor **8** is fully discharged, current can no longer flow in the output circuits, and after a time To preestablished by calibration, the relay R is de-energized, closing the contact R1 and supplying at the output the protection signal or command K. What has been described occurs when the signal J remains present at the input for a time $T1 > T_0$ (cf. the left part of FIG. 3). For example, with the use of a capacitor **8** of 300 μF a time interval To equal to three minutes can be obtained. When the signal J disappears (i.e. when J opens), **8** recharges and relay R is energized, causing the signal K to disappear at the output.

If instead the signal J disappears before the lapse of the time To (cf. right-hand part of FIG. **3**) then the capacitor **8** can recharge before it is completely discharged, relay R is not deenergized, and the output signal K cannot appear.

When the signal Y fails because of an external fault, or capacitor **8** breaks down or any electronic component of the circuit breaks down, there occurs in any event the deenergization of R and the output of the signal K, well within the maximum time T*o*, confirming the fact that the circuit is fail-safe.

Another preferred embodiment of the invention, useful, for example, in self-controlled protection systems, is shown in FIG. **4,** the normal operation of which is diagrammatically represented by means of the waveforms of FIGS. **5***a*–**5***c*. In particular closure on contact A represents a high level (+15V) of a logic input signal and closure on contact B represents a low level (OV) thereof, while the 0 is indicated the contact R1 of the output relay R is in open position and by 1 is indicated the same contact in closed position.

The device illustrated in FIG. **4** serves to control that the logic signal X at the input carries out continuously a cycle of alternations between level A and level B.

In order that contact R1, which in closing supplies the output signal Z, will remain open, the signal at X must leave level A for a time not greater than TB and must leave level B for a time not greater than TA (FIG. **5***a*). If the cycle of alternations does not occur regularly respecting the said conditions (FIGS. **5***b–c*) or in case of a fault, the output of the protection signal Z occurs reliably.

In particular the device illustrated is especially useful when TA is much greater than TB.

The circuit according to FIG. **4** is supplied with two continuous voltages, of opposite polarity, that is, +15V and −15V, with one pole in common (OV).

When the logic input signal is at the level B=0V, the transistor Q5 rapidly charges the capacitor **6** across diode **7**, with the indicated polarity. During this time Q7 and Q8 are always non-conducting.

In this stage the output relay R can remain energized across the diode **12***a*, since the capacitor **15** has previously been charged, as will be seen below, and at any rate it discharges, reliably supplying the output signal Z, at the end of the discharge time TB, determined by the capacitance of the capacitor **15** and by the characteristic parameters of the relay R.

In the example given, to obtain a time TB equal to about one second with a relay having a resistance of 500 Ohm a capacitor **15** of about 2,500 μF was employed.

If, before the time TB has lapsed, the input X switches to the level A = 15 V, transistor Q5 is turned off, the transistor Q6, operating alternately as circuit breaker and as current limiter by effect of the rectangular wave signal W of a frequency equal to 1 KHz, which is always present, allows the capacitor **6** to discharge constant current pulses across the base of transistor Q7, which then switches continuously.

The transformer T, supplied with pulsating voltage across transistor Q8, supplies the necessary power to energize the relay R across the diode **11** and further across the resistor **13** progressively charges the capacitor **15,** making it ready for the next discharge phase, as described hereinabove.

The capacitor **14** has much smaller capacitance than capacitor **15,** and serves only to filter the voltage rectified by the diode **11.**

The relay R can remain energized, in this phase, for the maximum time TA.

That time is determined by: the capacitance of the capacitor **6**; the mean discharge current, limited by Q6, and the particular waveform of the signal W.

The possible losses in the dielectric of the capacitor **6** causes a reduction of the time TA, that is, they too act in the sense of safety.

With a rectangular wave signal W and the capacitance of capacitor **6** equal to 200 μF and a maximum discharge current equal to 100 μA a discharge time TA equal to about 30 secs is obtained. It is clear that with the circuit of the present invention one can easily obtain a long timing, with maximum safety and with the use of inexpensive components.

It is further seen at once that any dangerous situation deriving from a possible failure of any electronic component of the circuits illustrated in FIGS. **2** and **4** involves in a pre-established maximum time the deenergization of the output relay, and hence the certain appearance of the protection signal.

Although there have been described preferred embodiments of this novel invention, many variations and modifications will now be apparent to those skilled in the art. Therefore, this invention is to be limited, not by the specific disclosure herein, but only by the appended claims.

What is claimed is:

1. Means responsive to a predetermined input condition for obtaining a delayed output signal only when said input condition persists of over the entire first delay period comprising:
- a source of electrical energy;
- energy storage means;
- output means having first quiescent and second active operating states;
- amplifier means;
- transfer means coupling said amplifier means to said output means;
- charging means normally coupling said energy storage means to said energy source and responsive to said input condition to decouple said energy storage means from said energy source;
- discharge control means responsive to said input condition for coupling said energy storage means to said amplifying means in a repetitive alternating fashion;
- said transfer means comprising means for coupling only said alternating components of the output of said amplifier means to said output means;
- said output means being operated in its active state upon occurrence of said input condition and being moved to its quiescent state only if said input condition persists after said energy storage means is fully discharged.

2. The device of claim **1** wherein said energy storage means is a capacitor.

3. The device of claim **2** wherein said discharge control means comprises a vibratory relay for coupling said capacitor to said amplifier means in pulsating fashion.

4. The device of claim **3** further comprising adjustable current limiting means coupled to said relay for adjustably controlling the discharge rate of said capacitor.

5. The device of claim **1** wherein said transfer means comprises a transformer having input and output windings respectively coupled to said amplifying means and said output means.

6. The device of claim **1** wherein said output means comprises a relay.

7. The device of claim **3** wherein said charging means comprises first switch means for coupling said energy source to said capacitor only during the absence of said input condition and second switch means for coupling said energy source to said vibratory relay only during the presence of said input condition.

8. The device of claim **1** wherein said charging means comprises a first transistor for coupling said energy storage means only when said input condition is absent.

9. The device of claim **1** wherein said discharge control means comprises a transistor coupled to said energy storage means and means coupled to the input of said transistor for operating said transistor in a pulsating fashion between its conductive and non-conductive state to thereby cause the energy stored therein to be discharged into said amplifying means in a pulsating fashion.

10. The device of claim **1** wherein said amplifying means has a high input impedance to cause the energy stored in said energy storage means to be discharged at a low rate.

11. The device of claim **1** further comprising filter means coupled between said transfer means and said output means.

12. Means responsive to a predetermined input condition for obtaining a delayed output signal only when said input condition persists of over the entire first delay period comprising:

a source of electrical energy;

energy storage means;

output means having first quiescent and second active operating states;

transfer means coupling said energy storage means to said output means;

charging means normally coupling said energy storage means to said energy source and responsive to said input condition to decouple said energy storage means from said energy source;

discharge control means responsive to said input condition for coupling said energy storage means to said transfer means in an alternating fashion;

said transfer means comprising means for coupling said alternating components of the output of said amplifier means to said output means;

said output means being operated in its active state upon occurrence of said input condition and being moved to its high input impedance to cause the energy stored in said energy storage means to be discharged at a low rate.

13. An electronic timing device which, in response to an input signal, supplies with failureproof reliability a delayed output signal, utilizable, for example, for interventions of protection, characterized by the fact that it comprises:

at least one source of energy;

an energy storage device (for example, a capacitor **8** in FIG. **2, 6** in FIG. **4**);

means coupled to said source for charging a maximum quantity of energy in said storage device prior to initiation of the time count;

means responsive to the input signal for controlling the discharge rate, during the time count, of the energy stored in said storage devices;

means for modulating said discharge control means;

means for amplifying the power discharged by the energy storage device during the time count;

means for filtering the output of said amplifying means;

means coupling said amplifying means to said filtering means whereby only the alternate components produced by the modulation are coupled to said filtering means;

output means coupled to said filtering means and which, in its rest condition, that is without any external energy supplied thereto, securely assumes a stable state unequivocally recognizable as "end time" signal, and which utilizes said filtered power made available during the time count to maintain said output means in a state opposite said rest state indicating that the end time signal has not yet occurred.

14. The device of claim **1** wherein the time count may be adjusted by varying at least one parameter which characterizes the modulation of power associated to the discharge of the stored energy.

15. The device of claim **1** further comprising second energy storage means coupled across said output means for storing energy transferred thereto by said transfer means to maintain said output means in the active state for a second time period greater than said first delay period whereby said output means will be returned to its quiescent state when said predetermined input condition persists for a time interval greater than said second time period thereby providing a device which generates an output in cases where a cyclically variable input signal deviates from its normal waveslope.

* * * * *