

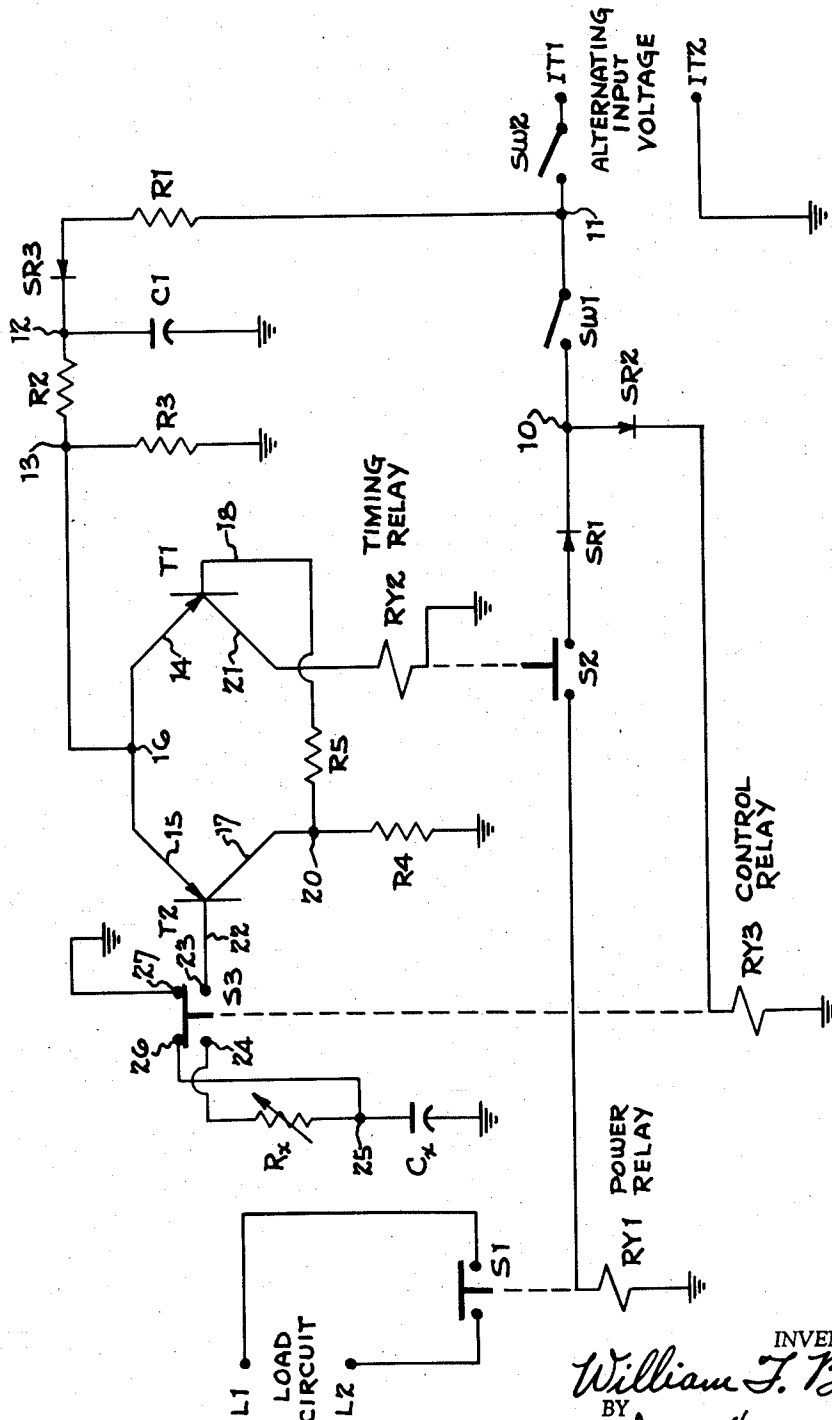
Dec. 6, 1960

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2,963,596

ELECTRONIC X-RAY TIMER

Filed Jan. 19, 1960



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1

2,963,596

ELECTRONIC X-RAY TIMER

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Filed Jan. 19, 1960, Ser. No. 3,358

10 Claims. (Cl. 307—141.4)

This invention relates to X-ray timers and in particular relates to an electronic interval timing device for an X-ray machine which accurately fixes the points on the input voltage cycle at which the X-ray tube is energized and deenergized.

As is well known, an X-ray tube having an anode and a cathode radiates energy only when the cathode is negative with respect to the anode. The conventional source of electric energy for an X-ray tube comprises an alternating voltage supply which is usually of a frequency of about 60 cycles per second. When used with an alternating voltage supply, the tube will conduct only during that half of the supply cycle when the cathode is negative with respect to the anode. The tube thus in effect operates for only half of each cycle, the potential between the tube elements varying during the half cycle that the tube conducts in sinusoidal form from zero to a maximum amplitude and back to zero. Such a tube is said to be self-rectifying. In some installations a full-wave rectifying circuit is included, so that the tube conducts during both halves of the input voltage cycle.

It is important when using alternating voltage supplies of both the half-wave and full-wave rectified types that the tube be energized to begin an X-ray exposure at a time at which the alternating input voltage is zero. The plate voltage then regularly increases in accordance with the sine wave shape of the cycle, so that power is gradually applied. If the timing interval is initiated at a time corresponding, for example, to the peak amplitude of voltage, a heavy surge of power might cause damage to the step-up transformer or the tube itself. Similarly, it is also important that the timing interval cease at a moment when the voltage is again zero, to prevent a very high transient voltage due to rapid collapse of flux in the transformer. These requirements can be otherwise stated as a condition that the X-ray tube be energized at a zero point on the voltage cycle, and be deenergized an integral number of cycles thereafter.

In modern radiological practice, it is common to use high intensity X-rays so that the exposure may be as short as possible. The reason for this is that the cumulative effect in the human body of a short, high-powered exposure is considerably less than the effect of a longer exposure of less intense rays. To generate the high intensity of radiation required for short exposures, X-ray tube voltages as high as 150 kilovolts are required and current in the primary of the transformer may be as high as 300 amperes. When dealing with currents and voltages of this magnitude, it is most important that the timing interval begin and end when the voltage crosses the zero axis, else very severe transients will be set up, causing injury to the system. Furthermore, transients of this type may induce a burst of high current in the X-ray tube circuit which of itself will cause the photographic film to be overexposed. Errors in the timing interval are in this way compounded if the interval does not begin when the voltage is zero. Therefore, one objective of the present invention is to provide

2

a timer which consistently initiates the exposure when the voltage is zero, and which completes the exposure at a like subsequent moment.

When high intensity X-rays are employed to expose the photographic film, the exposure time must be commensurately short. In some instances, exposures of only $\frac{1}{80}$ of a second, or one voltage cycle, are found sufficient. Another object of this invention is to provide a timer capable of energizing the X-ray tube for intervals as short as $\frac{1}{80}$ of a second.

It will be appreciated that, when the exposure is only of one or two cycles duration, an error in timing of, for example, $\frac{1}{2}$ of a cycle, is undesirably large and may impair the quality of the radiograph. As noted, timing errors may be compounded with overloading of the tube to magnify the variation from the desired exposure in terms of voltage and seconds. A further objective of the invention is the provision of a timer which operates with negligible error over timing intervals of a small number of cycles.

Generally speaking, the energization of an X-ray tube is usually governed by the closure of power relay contacts in the primary circuit, the coil of the relay being included in the timing circuit. This completes a circuit winding of a step-up transformer, the secondary of which provides the high voltage required to energize the X-ray tube. The timer of this invention is effective to close the relay contacts at the desired points on the primary voltage cycle.

In practice, the power factor characteristics of the transformer employed to provide a stepped up voltage for the X-ray tube may make it desirable that the power relay contacts be closed and opened at a time slightly lagging the precise moment when the transformer primary voltage is zero. For instance, it may be desirable to energize the tube when current is zero in the primary, or at a point between zero voltage and zero current. This invention is adapted to consistently start and end the timing interval at any point on the voltage cycle, as will be explained more fully hereinafter. For simplicity of explanation, however, the timer is disclosed as adapted to initiate and terminate the timing interval at points of zero voltage. It should be understood, therefore, that this is not intended as a limitation of the invention.

The closure time of power relay contacts is usually appreciable in comparison with one voltage cycle and due allowance for this is made in the invention, whereby the relay is energized at such a time that the primary circuit will be completed by closure of the relay contacts at precisely the moment when the voltage is zero, or at such other time as is desired.

In its fundamental aspects, the invention comprises a conventional time interval-determining device to establish generally the duration of the timed interval, together with a unique arrangement of half-wave rectifiers and relays whereby the moment at which the timed interval begins is precisely fixed with respect to the phase of an alternating voltage which energizes the device being timed. Thus, the invention does not reside in any particular circuit or means for generally establishing the duration of the timed interval, but rather is directed to a means for determining precisely when, with respect to the reference alternating voltage, the timed interval begins. The invention is also directed to a means of adjusting the precise moment at which the timed interval, as established by the general limits of accuracy of the interval-determining circuit, ends with respect to the alternating voltage. The invention thus refines the accuracy of the interval-determining circuit so that a device such as an X-ray tube is energized for a precise number of voltage cycles.

In a preferred embodiment of the invention, the timer

3

comprises two circuits connected to an alternating source. The first circuit includes a half-wave rectifier, a power relay coil (the contacts of the relay completing the primary circuit of the X-ray system when the relay is energized) and the contacts of a timing relay. The second circuit includes a rectifier reversed in polarity with respect to that included in the first circuit, the coil of the timing relay, and a standard time interval-determining device, which may be of the type employing a resistance-capacitance circuit and a multivibrator.

In this embodiment, the duration of the timed interval is generally established by the time constant of a condenser which is charged through a variable resistor. By the system of relays and half wave rectifiers, charging of the condenser, and initiation of the timed interval, is triggered at a preselected point on the alternating voltage cycle. At this moment the power relay energizes the timed device, such as an X-ray system. When the condenser is charged, the multivibrator actuates a relay which causes the load device to be deenergized at a moment which is likewise fixed with respect to the voltage cycle.

It has already been noted that while the invention is primarily described herein as adapted to energize a circuit at zero points on a voltage cycle, the invention may readily be adapted to energize circuits at other points of voltage if desired. This can be effected, for example, by regulating the pull-in time of the various relays, or by adding a phase shifting circuit.

It should be also noted that the timer need not operate only through a power relay, but may, if the voltages are not high, control a load circuit directly. Thus, in the general description given above, if the power relay be omitted from the first circuit across the supply voltage, and if the load circuit be included in its place, the timing relay then will control the load circuit directly.

The figure of the drawing is a circuit diagram of a timer typifying the improvement of this invention.

The circuit shown in the drawing has as its fundamental objective the energization of a load circuit (shown at the left hand side of the drawing) for a predetermined interval of time. This is effected by the closure of relay contacts S1, which completes the load circuit. The terminals L1 and L2 to the load circuit may be connected to an X-ray transformer primary circuit so that upon the closing of S1, the primary circuit is energized.

The timing circuit is energized from an alternating current supply applied through input terminals IT1 and IT2 shown at the right hand side of the figure, one terminal (IT2) being grounded. The other terminal, IT1, is connected in series with an exposure switch SW1, an off-on switch SW2, a half-wave rectifier SR1, across relay contacts S2, to the coils RY1 of a power relay. The other side of relay coil RY1 is grounded. As is indicated by the dashed line connecting RY1 and contacts S1, upon the energization of RY1, S1 is closed so that the load circuit is completed and the timing cycle is initiated. Contacts S1 are normally open; when no current flows in RY1, no current flows in the load circuit. As will be more fully explained hereinafter, S1 is closed only at the precise instant when the alternating voltage in the load circuit passes through zero, and is opened only at a later like moment.

The source of power which is applied at IT1 and IT2 is a 50 or 60 cycle alternating current supply of 105 to 135 volts. By means of a network to be described, the timer of this invention is operable with a high degree of accuracy over a relatively wider range of input voltages.

At 10, between SW1 and SR1, is connected a half-wave rectifier SR2. This rectifier is arranged with respect to SR1 so that it conducts during an opposite half of the voltage cycle from that during which SR1 conducts. The other side of SR2 is connected to the coil RY3 of a control relay, the other side of the coil being grounded. The control relay is of the single pole, double throw type, its contacts being designated by S3. The armature of

4

the relay is spring-biased in the position shown, in which it connects 26 and 27. It will be seen that when switch SW1 is closed, RY3 can respond only to one half of the input voltage cycle because of the inclusion of SR2 in series with it.

At 11, between SW1 and SW2 is connected a line including in series a resistor R1 and a half-wave rectifier SR3. The polarity of rectifier SR3 is the same as that of SR2, and is opposite to that of SR1. Thus both SR2 and SR3 will conduct during the same half of the voltage cycle. Resistor R1 is a limiting resistor to reduce the current in the circuit to an acceptable amount. At 12, on one side of SR3, are connected, in parallel, a filter capacitor C1, the other side of which is grounded, and an isolating resistor R2. A second shunt resistor R3 is connected to ground on the other side of R2 at 13.

The resistors R2 and R3, together with capacitor C1, form an isolating and filtering network whereby the transistor timer elements are isolated from the input, and further whereby the pulsating D.C. passed by SR3 is somewhat smoothed. By the inclusion of this network in the input circuit of the multivibrator to be described, the multivibrator is enabled to operate relatively independently of voltage fluctuation or variations in the source, resistors R2 and R3 acting as a voltage divider to reduce the magnitude of the source voltage variations.

In the preferred embodiment illustrated, that particular portion of the circuit which establishes the timing interval comprises a two-transistor multivibrator. Transistors T1 and T2 having their respective emitters 14 and 15 connected at 16 are connected to junction 13. The collector 17 of transistor T2 is grounded through a series resistor R4. The base 18 of transistor T1 is connected through a limiting resistor R5 to the collector 17 of transistor T2 at 20, ahead of R4. The collector 21 of transistor T1 is connected to the coil RY2 of a timing relay, the other side of the coil being grounded. This relay controls closure of contacts S2 in the power relay circuit. The base 22 of transistor T2 is connected to contact 23 of S3, which is operated by RY3.

The duration of the timed interval is fixed by a series R-C circuit comprised of a variable resistor R_x and a capacitor C_x , one side of R_x being connected to contact 24 of S3 and the far side of C_x being grounded. Thus, when relay coil RY3 is energized, the R-C circuit is connected into the base circuit of T2. At 25, between R_x and C_x , a line is connected to contact 26 of S3, the opposite contact 27 being grounded. Thus, when RY3 is not energized, contact S3 is moved by its biasing spring to the "upper" position shown, so that both sides of condenser C_x are grounded.

The operation of the invention is as follows:

Prior to the beginning of the timing cycle, both switches SW1 and SW2 are open. The power relay is biased so that contacts S1 are open, the timing relay is biased so that contacts S2 are closed, while the control relay is biased so that contacts 26 and 27 are connected. The off-on switch SW2 is now closed. Half-wave rectifier SR3 permits current to flow only during the positive half of the voltage cycle. This current is limited by R1 and R2, is slightly filtered by C1, and is divided by R2 and R3. The multivibrator circuit, under these circumstances, is in a stable condition in which transistor T1 conducts, T2 being non-conductive. The emitter-to-collector current in T1 energizes timing relay coil RY2 to close contacts S2. (The effect of the filter circuit enables RY2 to hold S2 closed during negative half-cycles.) Since switch SW1 is open, no current can flow either through relay coils RY1 or RY3. The circuit is now prepared for the initiation of the timing cycle. This is accomplished by the closure of switch SW1. The duration of the timing cycle, as will be understood by those skilled in the art, is controlled by the values of R_x and C_x . When SW1 is closed, current will flow in the next positive half of the input voltage cycle through

coil RY3; this is because of the presence of half-wave rectifier SR2 in series with RY3.

To establish closure of S1 at zero voltage, the drop-out time of S3 is adjusted or selected so as to be equal to the time of one or some integral number of voltage cycles; in consequence of this, these contacts remain closed on negative half cycles even though current flows in RY3 only during positive half cycles. As noted, because of the filter network in the input circuit of RY2, the timing relay is essentially operating on D.C., and both its pull-in and drop-out times should preferably be as short as possible.

It can be seen that if switch SW1 is closed during one of the positive cycles, RY3 will be energized immediately, and if SW1 is closed during a negative cycle, because of rectifier SR2 RY3 will be energized at the initiation of the succeeding positive half cycle.

Just as with drop-out, the closure of contacts S3 associated with RY3 occurs an integral number of cycles after RY3 has been energized. Therefore, since RY3 can be energized only during a positive half cycle, S3 pulls in only during some later positive half cycle.

When S3 has pulled in, connecting 23 and 24, the R_x and C_x circuit is connected in series with the base 22 of transistor T2. Instantly T2 begins to conduct. The emitter-to-collector current of T2 flows through resistor R4 and quickly raises the potential at junction 20 to a value sufficient to cut off the collector current of transistor T1. RY2 is thereby deenergized and its contacts S2 close, completing the circuit to RY1. Closure time of S2 should be very small, which it can be since the timing relay does not handle large currents or high voltages. This event necessarily occurs during a positive half cycle, since S3 can close to connect poles 23 and 24 only during positive half cycles. During positive half cycles rectifier SR1 is non-conducting, its polarity being opposite to that of SR2.

Current is passed by SR1 at the beginning of the next following negative half cycle. Thus RY1 is energized at the initiation of a negative half cycle. As with S3, to establish closure at zero voltage, the closure time of contacts S1 is also chosen to be equal to an integral multiple of the period of the cycle, in consequence of which current can begin to flow in the load circuit only at the time when the load voltage is passing through zero.

Although current is passed by SR1 only during negative half cycles, contacts S1 remain closed during positive half cycles because of the self inductance of RY1.

The circuit remains in this state until the base current of transistor T2, as limited by R_x , charges C_x . During this time the base current of T2 is diminishing exponentially as C_x charges. As the base current diminishes, the collector current also diminishes so that the potential drop across R4 becomes smaller. Finally, the potential at point 20 decreases to a value which again allows T1 to conduct. Because of the inclusion of rectifier SR3 in its circuit, T1 can begin to conduct only during a positive half cycle. RY2 is energized at the same time. Contacts S2 close within negligible time thereafter. RY1 is now in open circuit. Since the drop-out time of S1 has been specified to be equal to an integral number of cycles, S1 drops out at the same relative point on the voltage cycle as when RY1 was last energized; by the inclusion of SR1 in its circuit, this necessarily occurs at the beginning of a negative half cycle, when the voltage is zero. Thus, the contacts at S1 are both opened and closed at that point on the cycle when the load voltage is zero. After the load circuit has been opened, SW1 is opened manually, and the circuit is then ready to begin another timing sequence.

Representative values for the resistors and capacitors of the circuit are as follows:

R1, 750 ohms; R2, 4,000 ohms; R3, 1,000 ohms; R4, 14,000 ohms; R5, 2,200 ohms. C1 may be 20 micro-

farads. The values of R_x and C_x will, of course, depend upon the range of timing intervals over which the invention is intended to operate.

The circuit shown may be employed without the power relay where the power requirements of the timed circuit are not large, as may be the case when used in applications other than X-ray tube control. In that event, the timed circuit would simply be connected between the left terminal of S2 and ground.

While I have described the preferred embodiment of the invention, the invention is not limited to that embodiment alone but includes other circuits following its overall principles.

Having described my invention, I claim:

1. A timer for a load circuit, said timer comprising a capacitor, means for charging said capacitor at an adjustably variable rate, said means including a mono-stable multivibrator having a pair of transistors, the base of one transistor being in partial circuit connection to said capacitor, switch means to complete the connection of said base to said capacitor, said switch means including a first rectifier and a control relay effective to connect said base and said capacitor when said control relay is energized to commence the charging of said capacitor, a timing relay, the collector of the other transistor being connected to the coil of said timing relay, and a series circuit including a second rectifier oppositely oriented with respect to said first rectifier, the contacts of said timing relay and a power relay, the contacts of which are included in the load circuit.

2. A timer comprising a capacitor, means for charging said capacitor at an adjustably variable rate, said means including a mono-stable multivibrator, said multivibrator comprising a pair of transistors, each transistor having an emitter, base and collector, the base of the first transistor being in partial circuit connection to said capacitor, switch means to complete the connection of said base to said capacitor, said switch means including a first rectifier and a control relay effective to connect said base and said capacitor when said control relay is energized to commence the charging of said capacitor, the emitters of both transistors being connectible to a voltage source, the base of the second transistor being connected through potential-limiting means to the collector of the first transistor, whereby the collector potential of said first transistor determines the state of conduction of the second transistor, a timing relay, the collector of the second transistor being connected to the coil of said timing relay, and a series circuit including a second rectifier oppositely oriented with respect to said first rectifier, the contacts of said timing relay and a power relay.

3. The timer of claim 2, wherein a third rectifier is included in series with said transistor emitters, said third rectifier being oriented similarly to the orientation of said first rectifier.

4. A timer comprising a variable resistor, a capacitor in connection with said resistor, a mono-stable multivibrator including a pair of transistors, the base of one transistor being in partial circuit connection to said capacitor, switch means to complete the connection of said base to said capacitor, said switch means including a first rectifier and a control relay effective to connect said base and said capacitor when said control relay is energized to commence the charging of said capacitor, a timing relay, the collector of the other transistor being connected to the coil of said timing relay, and a series circuit including a second rectifier oppositely oriented with respect to said first rectifier, contacts associated with the armature of said timing relay, and a connection for a load device.

5. A timer for use with a load circuit which includes a source of alternating voltage, said timer being effective to energize said load circuit for a predetermined number of voltage cycles, said timer comprising, a pair of input leads for connection to said voltage source, a first and a second circuit in parallel across said input leads, the first circuit

7

including a half-wave rectifier, a power relay the contacts of which complete said load circuit when said relay is energized, and means to complete and open said first circuit, said second circuit including a half-wave rectifier oppositely oriented with respect to said first rectifier, means to actuate said circuit-completing means of said first circuit, and timing-interval circuit effective to permit current to pass for a predetermined interval of time through said actuating means.

6. A timer for energizing a load circuit for a predetermined interval, said timer comprising, a pair of input leads for connection to a source of alternating voltage, two circuits across said input leads, the first circuit including a half-wave rectifier, the load device to be energized for the prescribed interval and the contacts of a timing relay which relay completes said first circuit for the timing interval, said second circuit including a half-wave rectifier oppositely oriented with respect to said first rectifier, the coil of said timing relay, and a timing-interval circuit including a capacitor and being effective to energize said timing relay for the predetermined interval.

7. A timer for use with a load circuit which includes a source of alternating voltage, said timer being effective to energize said load circuit for a predetermined interval beginning at a time when said voltage is at a zero point of its cycle and ending at a like time, said timer comprising, a pair of input leads for connection to said voltage source, a switch in one of said leads, two circuits across said input leads, the first circuit including in series connection a half-wave rectifier, the coil of a power relay the contacts of which complete said load circuit when said coil is energized and the contacts of a timing relay which completes said first circuit when said timing relay is energized, said second circuit including a half-wave rectifier oppositely oriented with respect to said first rectifier, the coil of said timing relay, and a timing-interval circuit effective to permit current to flow in the coil of said timing relay for a predetermined interval of time, said timing relay having a negligible pull-in time and said power relay having a pull-in time equal to an integral number of voltage cycles.

8. A timer for energizing for a predetermined interval a load circuit operated from a source of alternating voltage, said timer comprising, a power relay having contacts actuable to complete said load circuit, the circuit of said relay including in series connection said voltage supply, a half-wave rectifier, the contacts of a timing relay, said timing relay contacts being effective to complete and break said power relay circuit, and a time-interval deter-

8

mining circuit for actuating said timing relay to complete said power relay circuit at a time when said rectifier is non-conducting and for deenergizing said timing relay to break said power relay circuit at a time when said rectifier is non-conducting, said time-interval determining circuit comprising a multivibrator, a variable resistor and a timing capacitor, said multivibrator in one state energizing the coil of the timing relay and in another state deenergizing said timing relay, said resistor and capacitor driving said multivibrator from said first state to said second state when said capacitor is charged.

9. A timer for use with a load circuit which includes a source of alternating voltage, said timer being effective to energize said load circuit for a predetermined interval beginning at a time when said voltage is at a zero point of its cycle and ending at a like time, said timer comprising, a pair of input leads for connection to said voltage source, a switch in one of said leads, two circuits across said input leads, the first circuit including in series a half-wave rectifier, a power relay the contacts of which complete said load circuit when said relay is energized, and the contacts of a timing relay which complete said first circuit when said timing relay is energized, said second circuit including a half-wave rectifier oppositely oriented with respect to said first rectifier, the coil of said timing relay, and a timing-interval circuit effective to pass current for a predetermined interval of time, said timing relay having a negligible pull-in time, said power relay having a pull-in time equal to an integral number of voltage cycles, said timing-interval circuit including a multivibrator and a capacitor and being effective first to energize said timing relay to complete said first circuit, and second to deenergize said timing relay to open said first circuit.

10. A timer according to claim 9 in which said multivibrator comprises a first and a second transistor each having its emitter connected to said voltage source, the base circuit of the first transistor including said capacitor, the collector of the second transistor being connected to the coil of said timing relay, the second transistor being normally conducting when said switch is closed but being cut off during said timing interval when said first transistor conducts.

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