Jan. 19, 1943. E. L. HARDER 2,309,066

TIMING RELAY

Filed Dec. 22, 1938

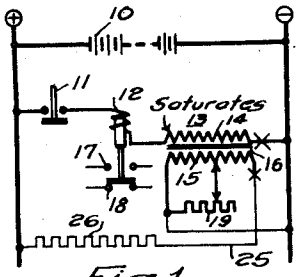


Fig. 1.

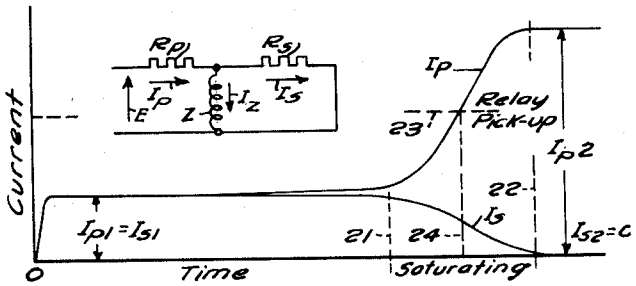


Fig. 2.

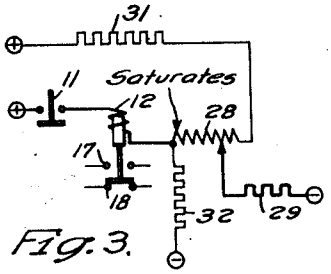


Fig. 3.

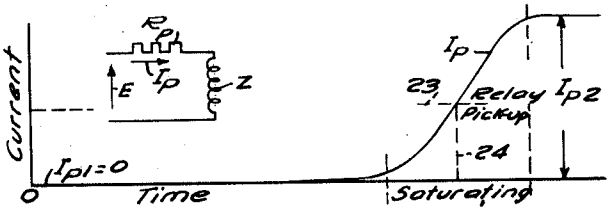


Fig. 4.

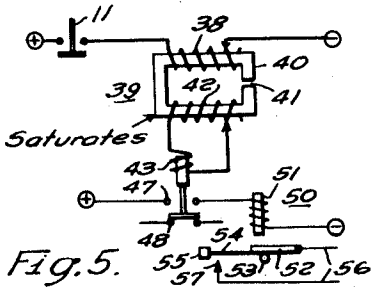


Fig. 5.

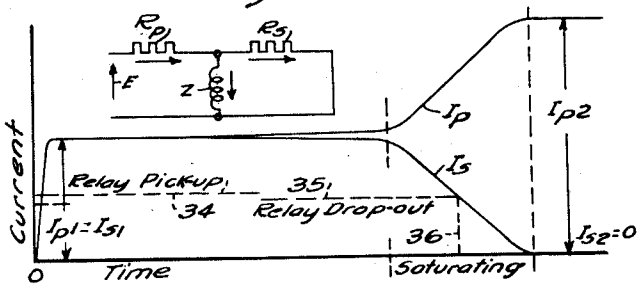


Fig. 6.

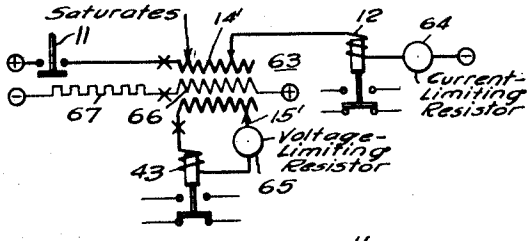


Fig. 7.

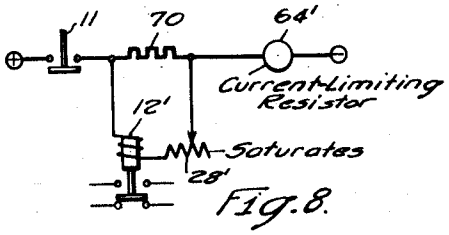


Fig. 8.

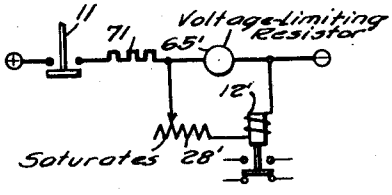


Fig. 9.

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TIMING RELAY

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24 Claims. (Cl. 175—294)

My invention relates to electrical timing relay mechanisms, and it has particular relation to such mechanisms operating on direct-current energizing-circuits, for producing accurate timing for periods ranging from 1/30 of a second to ½ of a second, more or less.

Heretofore time-delays of the shorter values, such as from 1 to 2 cycles on a 60-cycle system, have been attained by interposing an auxiliary relay having a speed of operation approximately equal to the desired time-delay. For time-delays of ½ second or longer, there have been available various motor-driven timing devices which have filled the requirements very nicely. However, for the intermediate timing periods, between about 1 or 2 cycles and something of the order of 10 to 30 cycles, on a 60-cycle basis, timing equipment has heretofore had to rely largely on slow-pick-up direct-current relays, or relays having a short-circuited slug or washer placed on the magnetizable core, for delaying the rate of flux-build-up by reason of the eddy currents in the slug. These slow-pick-up relays have had various disadvantages, usually requiring operation on the drop-out movement of the relay, being somewhat sensitive to changes in the battery-voltage in respect to their pickup times, and in any event operating at a time when the flux is changing slowly, thus causing considerable time-variations with comparatively small changes in the relay armature-travel or gap, and with comparatively small changes in friction or in spring-adjustment.

An object of the invention is to utilize the principle of a saturable inductance device, energized from a direct-current circuit, and having the property of developing a rapid rate of change of current during the period when the inductance device is saturating, that is, during the period between the non-saturated range of flux-densitives and the saturated range of flux-densities.

A further object of my invention is to provide means for utilizing a non-linear current-limiting or voltage-limiting resistor, or both, in connection with my invention, in overcoming the deleterious effect of variable-voltage conditions on the timing.

A further object of my invention is to provide a relaying mechanism which is capable of causing a normally open contact to close at the end of a predetermined time after a circuit-making switching-operation, said predetermined time being within the previously mentioned timing-range.

With the foregoing and other objects in view, my invention consists in the circuits, apparatus, methods and systems hereinafter described and claimed, and illustrated in the accompanying drawing, wherein:

Figure 1 is a diagrammatic view of circuits and apparatus illustrating my invention in one form of embodiment;

Fig. 2 is an approximate curve-diagram with a superimposed diagram of the equivalent circuit, illustrating the nature of the current-changes, with time, obtainable with the apparatus shown in Fig. 1;

Figs. 3 and 4 are views similar to Figs. 1 and 2, respectively, illustrating a modification;

Figs. 5 and 6 are also views similar to Figs. 1 and 2, respectively, illustrating a still further modification; and

Figs. 7, 8 and 9 are diagrammatic views illustrating the application of non-linear resistors in accordance with my invention.

In Fig. 1, my invention is illustrated in connection with a direct-current energizing-circuit indicated by the positive and negative terminals (+) and (—), energized by a storage-battery 10. My relaying mechanism comprises a normally open main controlling or initiating relay-contact 11, an ordinary overcurrent relay 12, and a saturable inductance device 13. In the particular form of invention shown in Fig. 1, the saturable inductance device 13 is a two-winding transformer comprising a primary winding 14 and a secondary winding 15 mounted upon a common saturable ferro-magnetic core 16. The primary winding 14 of the saturable inductance device is connected in series-circuit relation with the operating winding of the overcurrent relay 12 and with the initiating or controlling contact 11, in an electrical circuit which is energized across the battery-terminals (+) and (—). The overcurrent relay 12 may have either a normally open front or "make" contact 17, or a normally closed back or "break" contact 18, or both. A variable portion of the secondary winding 15 of the saturable inductance device 13 may be loaded with a resistance 19 which may be varied from various low values up to infinity or open-circuit condition.

The equivalent circuit for the apparatus thus far described is indicated in the diagram in Fig. 2, wherein the battery-voltage is designated as E, the entire primary-circuit resistance is designated as R_p which includes the equivalent resistances of both the relay 12 and the primary winding 14, the corresponding equivalent secondary-circuit resistance is designated as R_s, the mutual reactance is designated as a purely inductive impedance Z, and the primary, secondary and mag-

netizing currents are designated as I_p, I_s and I_z, respectively.

When such a circuit is first closed, at a moment corresponding to zero time in Fig. 2, the current quickly rises to a steady value of approximately

$$I_{p1}=I_{s1}=\frac{E}{R_p+R_s} \quad \text{(1)}$$

This equation assumes, in accordance with the facts, that the magnetizing current I_z through the reactance Z is negligibly small in comparision with the secondary current I_s.

From the equivalent diagram in Fig. 2, it will be noted that the voltage I_sR_s is impressed upon the reactance of the saturable inductance device. This voltage will cause the magnetizing current I_z to begin to build up in this inductance device at a rate such that the induced voltage, which is induced by the rate of change of the magnetic flux in the inductance device, is just equal and opposite to the impressed voltage I_sR_s.

The inductance device 13 may be visualized as a 100-henry choke-coil, or as a 1000-volt transformer, except that it would be insulated for more like 100 volts rather than 1000 volts, although I am obviously not limited to any particular values. Considering an inductance device which, on 60-cycle excitation, would develop 1000 volts RMS (root-means-square) across its primary winding 14, the ratio between this RMS voltage and the average voltage for a quarter of a cycle would be

$$\frac{1}{4}\sqrt{2\pi}=1.11$$

This average voltage is the voltage which is induced when the magnetic induction is changed from zero to its maximum operating value, which is just under the knee of the saturation-curve, in an ordinary transformer-design. Therefore, such an inductance device would produce an average of 1000/1.11 volts in ¼ of a cycle or $\frac{1}{240}$ second.

If we assumed that we could make use of a flux-change from a negative maximum value of magnetic induction to a positive maximum value of magnetic induction, this average voltage of 1000/1.11 would be maintained for 1/120 second, or a quantity equal to $1/120\times1000/1.11$ or 7.51 volt-seconds.

If we assume a battery-voltage which is normally rated at 125 volts, but which, as a matter of fact, varies between a somewhat higher value and a somewhat lower value, and if we further assume that an average of 35 volts is consumed in the reactance Z, which means that $R_sI_s=35$, then the above-mentioned inductance device would maintain an average of 35 volts for 7.51/35=.215 second or 12.9 cycles. The foregoing discussion covers the time from 0 up to the point 21 in Fig. 2.

During the period when the magnetizable core of the inductance 13 is saturating, the rate of change of the magnetizing current I_z in the inductance device must rapidly increase, in order to induce a given voltage in the inductance device, until finally, when the magnetic circuit is wholly saturated, as indicated at 22 in Fig. 2, practically no voltage is induced in the induction device, no matter how rapidly the magnetizing current I_z increases. Under these fully-saturated conditions, the direct current flows freely through the pure reactance Z in the equivalent diagram shown in Fig. 2, with a practically zero-voltage drop therein, so that the secondary current reaches a value $I_{s2}=0$, while the primary current reaches a value

$$I_{p2}=\frac{E}{R_p} \quad \text{(2)}$$

It will be noted that, during the transition-period, while the induction device is saturating, or in the vicinity of the knee of the saturation-curve, the primary current increases in the ratio

$$\frac{I_{p2}}{I_{p1}}=\frac{R_p+R_s}{R_p}$$

which can be adjusted by the proper choice of the primary and secondary resistances R_p and R_s.

According to my invention, the overcurrent relay 12 is so chosen or designed, that it has a pick-up value intermediate between the non-saturated primary current I_{p1} and the saturated primary current I_{p2}, as indicated by the dotted line 23 in Fig. 2, thus giving a time of operation from 0 to the line 24 in Fig. 2. It will be noted that this time of operation is fixed by the constants of the electrical circuit, depending upon the saturation of the inductance device 13 and depending also upon the pick-up current-value 23 of the relay 12.

Referring, again, to Fig. 1, it will be noted that I have provided means for normally saturating the inductance device 13 in a polarity opposite to the polarity in which it is saturated during operating conditions. The means which are shown for this purpose, in Fig. 1, include an auxiliary circuit 25 which energizes the secondary winding 15 from the battery 10 through a large resistance 26, so as to limit the exciting current to a properly small value. It will be noted that the primary and secondary windings 14 and 15 are provided with polarity marks X to indicate corresponding terminals, and it will be further noted that the pre-polarizing circuit 25 normally energizes the inductance device so that it is saturated with the positive battery terminal (+) connected to the marked secondary terminal, whereas, when the main controlling contact 11 closes, the primary circuit is energized so that the marked primary terminal is connected to the negative battery terminal (−). Thus, when the primary circuit is established, the magnetic flux in the inductance device changes, from its normal maximum saturating value in one polarity, to the maximum saturating value in the opposite polarity, thus taking advantage of the maximum possible flux-change in the inductance device, a flux-change which is fixed and constant, regardless of such considerations as residual magnetism or battery-voltage.

In the foregoing explanation of the conditions shown in Figs. 1 and 2, it will be noted that the secondary resistance R_s might well be infinity, which means that the secondary circuit would be open-circuited. Such a condition is depicted in Fig. 3, wherein the relay 12 is energized, from the battery terminals (+) and (−), in an energizing circuit serially including the initiating contact 11 and an adjustable number of turns of a saturable inductance-device 28, the circuit being completed through a primary resistor 29, which may be of very small value, or may be omitted entirely, if desired. In the apparatus shown in Fig. 3, an auxiliary pre-saturating circuit may be traced through the whole of the induction device 28 and through two large resistors 31 and 32, which normally draw a very small charging-current from the battery terminals (+) and (−).

As shown in Fig. 4, the equivalent circuit for the apparatus of Fig. 3 includes the equivalent primary resistance R_p and the inductance Z, with-

out any secondary circuit at all. The initial non-saturated primary current I_{p1} is substantially zero, being merely the value of the almost negligibly small magnetizing current. When saturating conditions are reached, the primary current I_p rapidly increases in value until, at full saturation, it reaches its steady-state value

$$I_{p2}=\frac{E}{R_p}$$

The relay 12 is set to have a pick-up value 23 somewhere along the slope of I_p during the saturating conditions of the inductance device, giving a pick-up time as determined by the line 24.

It will be noted, from Fig. 2, that during the saturating period, I obtain not only a rapid increase in the primary current I_p, but also a rapid decrease in the secondary current I_s. It is possible, therefore, to utilize a relay, as depicted in Fig. 6, having a pick-up value 34 which is some what below the initial value of the secondary current I_{s1}, and having a relay drop-out value 35 which falls within the range of the rapidly decreasing secondary current I_s during the saturating period of the operation, thus giving a total time to relay drop-out, from O to the line 36 in Fig. 6. Under these conditions, it is obvious that the relay would have to be included in the secondary circuit of the inductance device or, referring to the equivalent circuit, in shunt-circuit relation to the inductance Z of the inductance device.

Fig. 5 shows an example of circuits and apparatus embodying the invention as depicted in Fig. 6. In Fig. 5, the primary energizing-circuit comprises simply the operation-initiating contact 11 in series with the primary winding 38 of a saturable inductance device 39 which is shown as having an iron core 40 provided with a small air-gap 41 therein and provided also with a secondary winding 42. An under-current relay 43 is energized across an adjustable portion of the secondary winding 42. The air-gap 41 is a small gap, perhaps of the order of 10 mils in length, which is very small compared to the size of gap which would be necessary to prevent saturation of the iron core 40 under the operating conditions of the device. The small gap 41 serves the purpose of causing the residual magnetic induction to reduce substantially to zero when the inductance device 39 is deenergized by the opening of the initiating contact 11 after each operation of the timing mechanism. In this embodiment of my invention, I utilize only the flux-change from zero to the maximum saturating value in the operating direction, instead of utilizing the double amount of flux-change which has been explained in connection with Figs. 1 to 4. This avoids the necessity for having a constantly energized, pre-saturating circuit such as the circuit 25—26 in Fig. 1 or the circuit 31—32 in Fig. 3.

One phase of my invention relates to the desirability of obtaining a timing-relay "make" contact which closes in a predetermined short time, such as 13 cycles, or other adjustable time, after the closure of a main operation-initiating contact 11. In Figs. 1 and 3, such a time-delay "make" contact is provided, in the form of the make-contact 17 of the overcurrent relay 12, which does not pick up until the time 24 has been reached, as indicated in Figs. 2 and 4, respectively.

In Fig. 5, the undercurrent relay 43 is shown as being provided with a make-contact 47 and a break-contact 48. The make-contact 47 is closed, however, almost instantly after the closure of the operation-initiating contact 11, and this make-contact 47 remains closed until the relay drop-out time 36 is reached, as depicted in Fig. 6. In order to obtain a contact which is not made until the make-contact 47 of the undercurrent relay 43 drops out, I have shown, in Fig. 5, an auxiliary relay-element 50 comprising an electromagnet 51 and a cooperative pivoted armature 52, which normally rests against a backstop 53, and which carries a spring-member 54 the end of which is weighted with an inertia-mass 55. This auxiliary relay 50 is provided with a controlled circuit 56 including a stationary contact-member 57 which is normally spaced from the resilient spring-part 54 of the movable element of the relay.

In the operation of the auxiliary relay-element 50 of Fig. 5, the closure of the make-contact 47 energizes the auxiliary relay-element 50 and causes the armature 52 to pick up, moving away from its backstop 53. Under these circumstances, the circuit 56 continues to be open-circuited at 57. When the front contact 47 of the under-current relay 43 finally opens, the auxiliary relay-element 50 is deenergized, permitting the movable armature 52 to drop back to its backstop 53, and the inertia of the mass 55 will cause it to continue to move until the spring-part 54 makes contact with the electrical contact-member 57, thus completing the circuit 56 in a time which is controlled by the saturating characteristics of the inductance device 39.

A disadvantage common to all battery-energized timing-relay mechanisms is that any variation in the battery-voltage is quite likely to have a more or less deleterious effect upon the timing period. This deleterious effect is not as large, in my hereinabove-described devices, as in other, or prior-art devices, because of the rapid change in current which I obtain at the operating point of the relay.

In order to still further minimize the deleterious effects of voltage-changes in the direct-current energizing circuit, I preferably make use of a non-linear resistor, as is illustrated in several different forms of embodiments in Figs. 7 to 9. Several such non-linear resistors are known on the market, and they include resistors of the current-limiting, or so-called constant-current, type, having the property of increasing their resistance when the applied voltage is increased, as exemplified in a ballast resistance or a tungsten lamp. Other non-linear resistors on the market are of the voltage-limiting, or so-called constant-voltage, type, having the property of decreasing their resistance as the current increases, as exemplified in so-called voltage-regulating tubes, glow-lamps, the "forward"-circuit characteristics of copper-oxide rectifiers, and certain composite lightning-arrester materials.

Reference to the equivalent-circuit diagram in Fig. 2 will show that the voltage impressed on the equivalent reactance Z of the inductance device is the secondary voltage-drop I_sR_s. The rate at which the magnetizing current Iz builds up is dependent, therefore, upon this secondary-voltage, and this voltage is dependent, in turn, upon the battery-voltage E. It will be obvious that, if the secondary resistance R_s is of a nature tending to hold its voltage-drop I_sR_s constant, or if it even approaches such a characteristic, such a secondary resistance will counteract or minimize the effect of a variable battery-voltage E upon the time required for the inductance device

to reach the knee of its saturation curve as indicated by the line 21 in Fig. 2.

In like manner, also, it will be seen, from the equivalent-circuit diagram of Fig. 2, that if the equivalent primary resistance R_p were of a nature tending to hold the current constant, that is, if it increased its resistance when the battery-voltage E increased, there would be a more nearly constant voltage-difference $(E—I_pR_p)=I_sR_s$, so that the saturation buildup-time would be more nearly constant, by reason of the more nearly constant voltage I_sR_s impressed upon the equivalent reactance Z of the inductance device.

Fig. 7 shows an exemplary form of embodiment of my invention, including the principles just discussed. The primary circuit, as before, is a battery-energized circuit and it includes the normally open operation-initiating contact 11, the primary winding 14' of a saturable inductance device 63, the overcurrent relay 12, and a non-linear current-limiting resistor 64. The saturable inductance device 63 is provided with a secondary winding 15' which energizes the undercurrent relay 43 and a serially connected non-linear voltage-limiting resistor 65. The saturable inductance device 63 is further provided with a tertiary winding 66 which is utilized for giving the inductance device an initial saturating flux in the direction opposite to the direction or polarity at which it saturates when the primary circuit is energized, said tertiary winding 66 being in a battery-energized circuit including a current-limiting resistor 67.

While I have shown, in Figs. 1, 3, 5 and 7, four different arrangements or embodiments of the saturable inductance device, as indicated at 13, 28, 39 and 63, it will be obvious that any one of these inductance devices may be substituted for any of the others, and it will be further obvious that any of the elements of any of the circuits may be omitted, if the functions of said elements are not needed or desired, or if said functions are dispensed with in the interest of obtaining a better performance of the rest of the equipment.

In Figs. 8 and 9, I illustrate two other circuit-arrangements for advantageously counteracting, or partially counteracting, the deleterious effects of variations in the battery-voltage, with the aid of a current-limiting resistor 64' or a voltage-limiting resistor 65', respectively.

In Fig. 8, the current-limiting resistor 64' is included in a primary battery-energized circuit which serially includes the initiating contact 11 and another resistance-element 70, so that the current-regulating properties of the non-linear resistor 64' tends to maintain a fairly constant current in the resistance 70, independently of the battery-voltage, thus resulting in a substantially constant voltage-drop across the resistance 70. This substantially constant voltage-drop is utilized as a source of voltage for energizing a timing relay mechanism of a type in which the time of response depends upon the impressed voltage. A simple form of such timing relay mechanism is illustrated, in Fig. 8, in the shape of an overcurrent relay 12' and a serially connected saturable inductance device 28'.

In Fig. 9, the voltage-limiting resistor 65' is included in a primary battery-energized circuit including the initiating contact 11 and another resistance 71, so that the voltage-regulating properties of the non-linear resistor 65' tends to maintain a substantially constant voltage across its terminals, independently of variations in the battery-voltage. This substantially constant voltage across the voltage-limiting resistor 65' is utilized as a source of energy for a timing relay mechanism such as the mechanism 12'—28' of Fig. 8.

While I have illustrated my invention in a number of different forms of embodiment, I wish it to be understood that the specific forms are intended to be merely illustrative of the principles of the invention, as my invention, in its broader aspects, is obviously not limited to these particular forms, but various substitutions, omissions and additions may be made by those skilled in the art without departing from all of the essential features of the invention. I desire, therefore, that the appended claims shall be accorded the broadest construction consistent with their language and the prior art.

I claim as my invention:

1. A timing relay mechanism comprising, in combination, a direct-current energizing-circuit, a saturable inductance device, a normally open circuit-controlling switching-means for, at times, causing said inductance device to become energized solely from said direct-current energizing-circuit, a direct-current relay-element, and means for causing said relay-element to be so energized as to be responsive to flux and current-changes during the period when said inductance device is saturating, said circuit-controlling switching-means operating to cause said inductance device to be connected to said direct-current energizing circuit prior to the response of said relay-element, and the magnetizing current of said inductance device prior to the saturation thereof being a small fraction of the relay-current at the moment when said relay makes its aforesaid response.

2. A timing relay mechanism comprising, in combination, a direct-current energizing-circuit, an inductance device having a saturable ferromagnetic core having a small air-gap therein, a normally open circuit-controlling switching-means for, at times, causing said inductance device to become energized solely from said direct-current energizing-circuit, a direct-current relay-element, and means for causing said relay-element to be so energized as to be responsive to flux and current-changes during the period when said inductance device is saturating.

3. A timing relay mechanism comprising, in combination, a direct-current energizing-circuit, a saturable inductance device, means for causing said inductance device to be normally saturated in one polarity of magnetic flux, a normally open circuit-controlling switching-means for, at times, causing said inductance device to be connected to said direct-current energizing-circuit in such direction of energization that said inductance device after a time becomes saturated in the opposite polarity of magnetic flux, a direct-current relay-element, and means for causing said relay-element to be so energized as to be responsive to flux and current-changes during the period when said inductance device is saturating in said opposite polarity.

4. A timing relay mechanism comprising, in combination, a direct-current energizing-circuit, a saturable inductance device, circuit-controlling means associated with said direct-current energizing-circuit for normally causing said inductance device to be saturated in one polarity of magnetic flux and for, at times, causing said inductance device to become saturated in the opposite polarity of magnetic flux, a direct-current

relay-element, and means for causing said relay-element to be so energized as to be responsive to flux and current-changes during the period when said inductance device is saturating in said opposite polarity.

5. A timing relay mechanism comprising, in combination, a direct-current energizing-circuit, a saturable inductance device, a direct-current relay-element, and a normally open circuit-controlling switching-means for, at times, causing said inductance device and said relay-element to be connected in series-circuit relation to each other in an electrical circuit which is energized from said direct-current energizing-circuit, said relay-element having a pick-up current-value corresponding to operating conditions obtaining during the period when said inductance device is saturating, said circuit-controlling switching-means operating to cause said inductance device to be connected in its energized circuit prior to the response of said relay-element, and the magnetizing current of said inductance device prior to the saturation thereof being a small fraction of the relay-current at the moment when said relay makes its aforesaid response.

6. A timing relay mechanism comprising, in combination, a direct-current energizing-circuit, an inductance device having a saturable ferromagnetic core having a small air-gap therein, a direct-current relay-element, and a normally open circuit-controlling switching-means for, at times, causing said inductance device to be connected in an electrical circuit which is energized solely from said direct-current energizing-circuit, and means for causing said relay-element to be so energized as to be responsive to flux and current-changes during the period when said inductance device is saturating.

7. A timiug relay mechanism comprising, in combination, a direct-current energizing-circuit, a saturable inductance device, means for causing said inductance device to be normally saturated in one polarity of magnetic flux, a direct-current relay-element, and a normally open circuit-controlling switching-means for, at times, causing said inductance device and said relay-element to be connected in series-circuit relation to each other in an electrical circuit which is energized from said direct-current energizing-circuit in such direction of energization that said inductance device after a time becomes saturated in the opposite polarity of magnetic flux, said relay-element having a pick-up current-value corresponding to operating conditions obtaining during the period when said inductance device is saturating in said opposite polarity.

8. A timing relay mechanism comprising, in combination, a direct-current energizing-circuit, a saturable inductance device, electric-circuit means including current-limiting resistance for causing said inductance device to be normally energized from said direct-current energizing-circuit so as to be normally saturated in one polarity of magnetic flux, a direct-current relay-element, and a normally open circuit-controlling switching-means for, at times, causing said inductance device and said relay-element to be connected in series-circuit relation to each other in an electrical circuit which is energized from said direct-current energizing-circuit in such direction of energization that said inductance device after a time becomes saturated in the opposite polarity of magnetic flux, said relay-element having a pick-up current-value corresponding to operating conditions obtaining during the period when said inductance device is saturating in said opposite polarity.

9. A timing relay mechanism comprising, in combination, a direct-current energizing-circuit, a saturable inductance device, a normally open circuit-controlling switching-means for, at times, causing said inductance device to become energized solely from said direct-current energizing-circuit, a direct-current relay-element, and means for causing said relay-element to be energized in shunt-circuit relation to said inductance device, said relay-element having a drop-out current-value corresponding to operating conditions obtaining during the period when said inductance device is saturating.

10. A timing relay mechanism comprising, in combination, a direct-current energizing-circuit, an inductance device having a saturable ferromagnetic core having a small air-gap therein, a normally open circuit-controlling switching-means for, at times, causing said inductance device to become energized solely from said direct-current energizing-circuit, a direct-current relay-element, and means for causing said relay-element to be energized in shunt-circuit relation to said inductance device, said relay-element having a drop-out current-value corresponding to operating conditions obtaining during the period when said inductance device is saturating.

11. A timing relay mechanism comprising, in combination, a direct-current energizing-circuit, a saturable inductance device, means for causing said inductance device to be normally saturated in one polarity of magnetic flux, a normally open circuit-controlling switching-means for, at times, causing said inductance device to be connected to said direct-current energizing-circuit in such direction of energization that said inductance device after a time becomes saturated in the opposite polarity of magnetic flux, a direct-current relay-element, and means for causing said relay-element to be energized in shunt-circuit relation to said inductance device, said relay-element having a drop-out current-value corresponding to operating conditions obtaining during the period when said inductance device is saturating.

12. A timing relay mechanism comprising, in combination, a direct-current energizing-circuit, a saturable inductance device, electric-circuit means including current-limiting resistance for causing said inductance device to be normally energized from said direct-current energizing-circuit so as to be normally saturated in one polarity of magnetic flux, a normally open circuit-controlling switching-means for, at times, causing said inductance device to be connected to said direct-current energizing-circuit in such direction of energization that said inductance device after a time becomes saturated in the opposite polarity of magnetic flux, a direct-current relay-element, and means for causing said relay-element to be energized in shunt-circuit relation to said inductance device, said relay-element having a drop-out current-value corresponding to operating conditions obtaining during the period when said inductance device is saturating.

13. The invention as defined in claim 1, characterized by means including a non-linear current-limiting resistor for minimizing the effects of voltage-changes in said direct-current energizing-circuit.

14. The invention as defined in claim 5 characterized by a non-linear current-limiting resistor connected in series-circuit relation to said inductance device and said relay-element.

15. The invention as defined in claim 9, characterized by a non-linear current-limiting resistor connected in series-circuit relation to said inductance device.

16. The invention as defined in claim 1, characterized by said direct-current energizing-circuit being tapped off of a relatively constant-voltage element of a primary circuit comprising, in series, a source of variable unidirectional voltage, a relatively fixed-value resistor, and a non-linear resistor which is responsive to an electrical condition of said circuit.

17. The invention as defined in claim 1, characterized by means including a non-linear voltage-limiting resistor for minimizing the effects of voltage-changes in said direct-current energizing-circuit.

18. The invention as defined in claim 5, characterized by a non-linear voltage-limiting resistor connected in shunt-circuit relation to said inductance device.

19. The invention as defined in claim 9, characterized by a non-linear voltage-limiting resistor connected in series-circuit relation to said relay-element.

20. The invention as defined in claim 1, characterized by said direct-current energizing-circuit being tapped off of a non-linear voltage-limiting resistor of a primary circuit comprising, in series, a source of variable unidirectional voltage, said non-linear voltage-limiting resistor, and another resistance-element.

21. A timing relay mechanism comprising, in combination, a primary circuit comprising, in series, a source of variable unidirectional voltage, a non-linear resistor which is responsive to an electrical condition of said circuit, and another resistor of a dissimilar nature; timing-relay means tapped off of a relatively constant-voltage element of said primary circuit, said timing-relay means being of a type which performs a relaying function after a predetermined time-interval following the application of voltage thereto, said time-interval being dependent somewhat upon the voltage; and means for initiating the application of said voltage to said timing-relay means.

22. A timing relay mechanism comprising, in combination, a primary circuit comprising, in series, a source of variable unidirectional voltage, a non-linear voltage-limiting resistor, and another resistance-element; timing-relay means tapped off of said non-linear voltage-limiting resistor, said timing-relay means being of a type which performs a relaying function after a predetermined time-interval following the application of voltage thereto, said time-interval being dependent somewhat upon the voltage; and means for initiating the application of said voltage to said timing-relay means.

23. The invention as defined in claim 9, characterized by said relay-element having a "make" contact; in combination with a second relay-element having a normally open back-contact and having an inertia-mass so carried by its movable element that said second relay-element has the property of closing its normally open back-contact on the back-stroke resulting from the deenergization of the relay-element after having been energized, and means for causing said second relay-element to be energized during the period of closure of said "make" contact of the first-mentioned relay-element.

24. Means for effecting the closure of a normally open contact after a predetermined time-interval following the closure of an electrical circuit, comprising the combination, with said electrical circuit and means for effecting said closure thereof, of relay-means responsive to the closure of said circuit for causing an auxiliary contact to close and to thereafter remain closed for a predetermined time and to open at the expiration of said time, a relay-element having a normally open back-contact and having an inertia-mass so carried by its movable element that said relay-element has the property of closing its normally open back-contact on the back-stroke resulting from the deenergization of the relay-element after having been energized, and means for causing said relay-element to be energized during the period of closure of said auxiliary contact.

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