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M. E. KROM
ELECTRIC DELAY SYSTEM
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FIG. 1

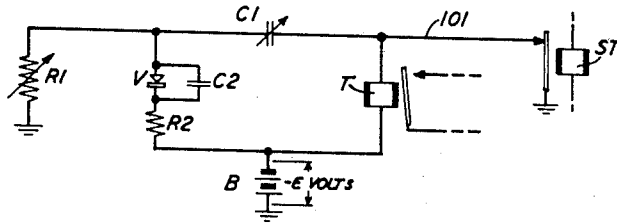


FIG. 2

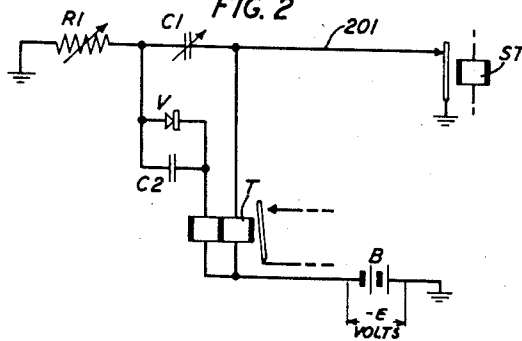


FIG. 3

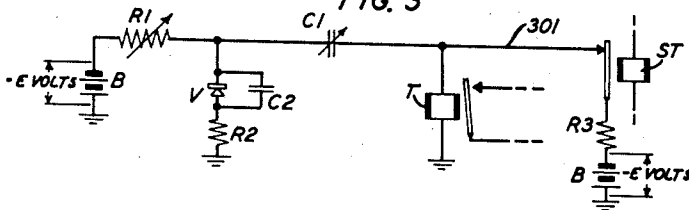
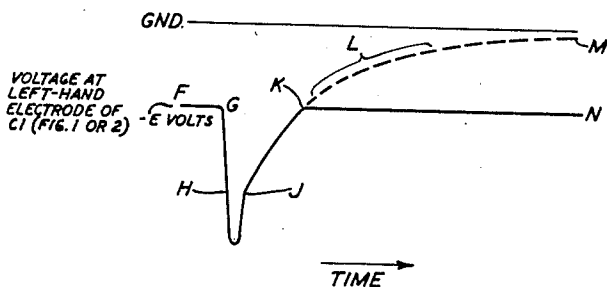


FIG. 4



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ELECTRIC DELAY SYSTEM

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5 Claims. (Cl. 175—320)

1

This invention relates to electrical systems and more particularly to a system for delaying the release time of electromagnetic apparatus.

It is frequently desirable to provide a delay interval between the occurrence of a control function and the release of an electromagnet in response thereto. This is conventionally accomplished either by modifying the electromagnetic structure per se or by associating a capacitor or a resistance-capacitance network with the winding of the electromagnet. It is well known that inaccuracies of timing are inherent in pragmatic utilizations of such devices. These inaccuracies accrue from the fact that the point to which the energizing current must be reduced to permit the release of conventional electromagnets varies over a relatively wide range on successive operations of the electromagnet, and from the fact that with capacitors of practical size, the slope of the charging-current-versus-time curve for the capacitor is small at the delay intervals normally required.

An object of this invention, therefore, is to improve the accuracy of time delay in a system for delaying the release of an electromagnet.

Another object of this invention is to render the time delay of a system for delaying the release of an electromagnet substantially independent of supply voltage variations.

A feature of this invention is the use of a unidirectional current conducting device sharply to cut off the charging current of a capacitor at a predetermined point of charge.

Another feature of this invention is the utilizing of the more nearly linear portion of the charging-current-versus-time curve of a capacitor to control the time delay of release of an electromagnet.

The manner in which the objects are attained, and the above and other features of the invention may be more fully understood from the following description of preferred embodiments thereof when read with reference to the accompanying drawings in which:

Fig. 1 is a representation of a preferred embodiment of the invention;

Fig. 2 represents a modified form of Fig. 1 showing the use of a double-wound relay to increase the accuracy of timing;

Fig. 3 represents another modified form of Fig. 1 showing the use of a different combination of sources of potential; and

Fig. 4 is a voltage-versus-time curve applicable to the circuits disclosed in Figs. 1 and 2.

In the several figures of the drawings, the correlative parts are given identical designations. Where numerical reference characters are employed, the hundreds digit thereof is modified in accordance with the figure number.

Referring now to Fig. 1 of the drawings, relay T is provided with contacts which control an external load circuit. This relay is normally operated, the energizing path therefor being trace-

2

able from ground at the back contact of normally unoperated "start" relay ST, conductor 101, winding of relay T and to the negative pole of the battery B, the positive pole of which is grounded.

Since ground is connected to conductor 101, the right-hand electrode of capacitor C1 is at ground potential. The left-hand electrode of capacitor C1 is connected to ground through resistor R1 and is connected to battery B through the unidirectional current conducting device V and through resistor R2. Device V may be a dry rectifier, a crystal rectifier, a vacuum tube or any other suitable type of unidirectional current conducting device having a low forward resistance and a high inverse resistance. In accordance with the customary symbolism, the device V presents a low impedance to conventional current flow in the direction of the arrow, and presents a high impedance to conventional current flow in the opposite direction. Preferably the inverse resistance of the device V should be several times greater than the resistance of resistor R1.

Although the circuit comprising resistor R1, device V and resistor R2 will serve as a voltage divider since the potentials are applied in the proper direction for device V to be conductive, the value of resistor R1 is preferably very much greater than the combinational value of resistor R2 and the forward resistance of device V and therefore the potential applied to the left-hand electrode of capacitor C1 is substantially at, and for purposes of description may be considered to be at, the potential of battery B. As a result of the application of these potentials to capacitor C1 during the period while relay ST is unoperated, capacitor C1 will attain a charge of negative E volts (the potential of negative battery B), with the left-hand electrode of capacitor C1 being at a potential negative relative to the potential at the right-hand electrode thereof. The condition of the left-hand electrode of capacitor C1 during this period is represented by the line from F to G on the graph of Fig. 4.

When it is desired to initiate the timed release of relay T, relay ST is operated. Relay ST, in operating, disrupts the previously traced energizing path for relay T and also removes the ground potential from the right-hand electrode of capacitor C1. Therefore (ignoring the inductive effects of the winding of relay T) the potential at the right-hand electrode of capacitor C1 momentarily becomes equal to the potential of battery B, i. e., a potential of negative E volts. Since capacitor C1 is charged to a potential of negative E volts and since the charge on a capacitor cannot instantly be changed, the left-hand electrode of capacitor C1 will immediately and momentarily change to a potential of negative 2E volts with respect to ground. This change in condition on the left-hand electrode of capacitor C1 is represented by the line from G to H on the graph of Fig. 4.

Therefore, at this instant, there is a potential of negative $2E$ volts in series with the winding of relay T and resistor $R1$, comprising the charge of negative E volts on capacitor $C1$ in series with the negative E volt potential of battery B . In consequence thereof, capacitor $C1$ will, in effect, charge over a path from the right-hand electrode of capacitor $C1$, winding of relay T , battery B , ground, resistor $R1$, to the left-hand electrode of capacitor $C1$. This current flow is in the same direction through the winding of relay T as was the original energizing current so relay T is held operated. It will be observed that when the left-hand electrode of capacitor $C1$ attains a potential of negative $2E$ volts, the unidirectional current conducting device will be biased in the non-conducting direction so the circuit comprising device V and resistor $R2$ will have no appreciable effect on the charging of capacitor $C1$ over the above-traced path through the winding of relay T .

Since capacitor $C1$ is initially charged to a value of negative E volts, with the left-hand electrode thereof negative relative to the right-hand electrode and since the conditions subsequent to the operation of relay ST are such that ground is connected to the left-hand electrode of capacitor $C1$ through resistor $R1$ and negative battery is connected to the right-hand electrode of capacitor $C1$ through the winding of relay T , capacitor $C1$ will tend to charge to a potential of negative E volts in the opposite direction, viz., with the right-hand electrode thereof negative relative to the left-hand electrode. Ignoring for the present the effect of device V on the operation of the apparatus, the change of condition of the left-hand electrode of capacitor $C1$ during this charging period is represented by the line from H to M on the graph of Fig. 4. Except for the inductive discharge of the winding of relay T , which modifies the curve during the portion H to J , this charge will be exponential, with the rate of charge being controlled essentially by the value of resistor $R1$ and capacitor $C1$, either or both of which may be varied to select the desired delay interval.

Continuing to ignore for the present the effect of the device V on the operation of the apparatus, let it be assumed that the current through the winding of relay T will reach a sufficiently low value to permit the release of relay T somewhere during the range of times and potentials designated L on the graph of Fig. 4. Since the value of the current at which a conventional relay will release is not precise, but varies appreciably with variations in adjustment, voltage and ambient temperature, the time variation during the range marked L will be relatively large due to the reduced slope of the current-versus-time or voltage-versus-time curve during this period. Therefore, inaccuracies in timing result.

In accordance with the principles of the present invention, means are provided for sharply cutting off the charging current for capacitor $C1$, and therefore for sharply cutting off the holding current through the winding of relay T , at a point where the current-versus-time or voltage-versus-time curve has a relatively large slope. The parameters of the circuit are preferably selected so that the value of current at which the said means acts to terminate that current flow is equal to or slightly greater than the determined "hold" current value for the particular relay, i. e., the minimum value of current at which the relay must hold operated. On the

voltage-versus-time graph of Fig. 4, this point is designated K .

The means for performing this sharp cut-off of the holding current flow through the winding of relay T by sharply cutting off the charging current for capacitor $C1$ is the unidirectional current conducting device V . As was noted hereinbefore, when the left-hand electrode of capacitor $C1$ attains a potential of negative $2E$ volts, the device V is rendered non-conductive since its lower electrode is at a potential of a negative E volts. This condition of non-conductivity will continue as long as the upper electrode of device V continues to be at a more negative potential than the lower electrode of device V , i. e., as long as the left-hand electrode of capacitor $C1$ is more negative than a negative E volts. When the left-hand electrode of capacitor $C1$ reaches a potential of a negative E volts, device V becomes conductive and the charging current for capacitor $C1$ is immediately cut off. Since the winding of relay T is in the charging circuit for capacitor $C1$, the holding current for relay T will also be (ignoring the reactive effects of the winding of relay T) immediately terminated and relay T will release. As may be seen in the graph of Fig. 4, the left-hand electrode of capacitor $C1$ reaches a potential of a negative E volts at point K , and therefore the potential at that electrode is held at that potential as is represented by the line from K to N .

It will be noted that capacitor $C1$ has an effective charge of E volts in one direction at point H on the curve of Fig. 4, that capacitor $C1$ has substantially no charge at point K , and that capacitor $C1$, if device V were not effective to prevent it, would approach a charge of E volts in the opposite direction beyond point M on the curve of Fig. 4. The entire change in potential difference across capacitor $C1$ from point H to point M on the curve may be considered to be a "charging" of that capacitor, or, if desired, this change may be considered to be a discharge from point H to point K and a charge from point K to point M .

It will be noted that a single source of potential B controls the initial charge on capacitor $C1$ and the point at which device V subsequently again becomes conductive. Therefore, even though the supply voltage varies within reasonable limits between successive utilizations of the apparatus, the delay interval will remain constant.

When relay ST is operated, a high frequency negative pulse will or may be generated as a result of the inductive characteristics of the winding of relay T . This pulse will or may pass capacitor $C1$ and be applied to the device V . With certain types of unidirectional current conducting devices such as selenium oxide rectifiers, this voltage surge may not cause a breakdown of the device. However, with other types of rectifying device, such as germanium rectifiers, this voltage surge may possibly cause the device to break down in the inverse direction. Capacitor $C2$ may be placed in parallel with the device V to obviate the possibility of such malfunctioning occurring.

When relay ST is released preparatory to the initiation of another cycle of operation of the apparatus, relay T will again operate and capacitor $C1$ will again become charged. It will be noted that the operate time of relay T is not increased by the presence of the other circuit elements.

The circuit of Fig. 2 is identical to the circuit

of Fig. 1 except that resistor R2 is replaced by an opposing secondary or "release" winding of relay T. The circuit of Fig. 2 functions identically to the circuit of Fig. 1 up to the point where device V is rendered conductive. At that time, current will flow from ground, resistor R1, device V, secondary winding of relay T and to grounded battery B. As a result, a negative flux is induced in relay T causing the relay rapidly to release. This provides a substantial reduction of any errors which may arise from variations of the physical release time of the relay per se.

The potentials applied to the circuit may be of either polarity and of any suitable value. One of the plural possible variations of the basic circuit of Fig. 1 is shown in Fig. 3. The circuit of Fig. 3 is identical to the circuit of Fig. 1 except that battery B and ground have been interchanged in each case, except that a current limiting resistor R3 has been added as a safety measure, and except that the polarity of the rectifying device V has been reversed. Taking these modifications into consideration, the modus operandi of the circuit of Fig. 3 is as that above described in relation to Fig. 1. Capacitor C1 in Fig. 3 is initially charged to substantially E volts, with the right-hand electrode thereof being negative with respect to the left-hand electrode; upon the operation of relay ST, the effective potential at each electrode of capacitor C1 is raised by E volts whereby the left-hand electrode of capacitor C1 momentarily assumes the potential of substantially a positive E volts whereby rectifier V is biased to a non-conducting state; capacitor C1 charges towards an ultimate condition wherein its left-hand electrode would be at a potential of negative E volts, and E volts negative relative to the right-hand electrode thereof; but at the time during that charging period at which the left-hand electrode of capacitor C1 assumes an effective potential of ground, device V is rendered conductive to terminate the charging of capacitor C1 and to cause the release of relay T. In a manner similar to that in which the variation of potential at the left-hand electrode of capacitor C1 of Fig. 1 was represented in Fig. 4, so the variation of potential at the left-hand electrode of capacitor C1 in Fig. 3 may be represented by inverting the representation of Fig. 4, labeling point F thereon "ground," labeling point H thereon "positive E volts" and by utilizing a line at "negative E volts" as the asymptote of the curve K-M.

It is to be understood that the above-described arrangements are but illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. In a timing apparatus, a relay, a switch, a capacitor connected to the winding of said relay, means including said switch for establishing an initial potential condition on said capacitor, means operative under the control of said switch for changing the potential condition of said capacitor and for causing current to flow in a circuit including said capacitor and the winding of said relay, and a unidirectional current conducting device connected to said capacitor and operative when said capacitor attains a preselected potential condition for abruptly terminating the flow of current through said relay.

2. In a timing apparatus, a relay, a normally

effective operating circuit for said relay, a capacitor connected to said operating circuit, means for establishing an initial potential condition on said capacitor, a potential-condition changing circuit for said capacitor including the winding of said relay, a switch for simultaneously interrupting said operating circuit and for enabling said potential-condition changing circuit, and a unidirectional current conducting device connected to said capacitor and operative when said capacitor attains a preselected potential-condition for abruptly disabling said potential-condition changing circuit.

3. In a timing apparatus, a relay, a normally effective operating circuit for said relay, a capacitor having one electrode connected to said operating circuit, a unidirectional current conducting device connected to the other electrode of said capacitor, means including said device for establishing an initial potential condition on said capacitor, a potential-condition changing circuit for said capacitor including the winding of said relay, a switch for simultaneously interrupting said operating circuit and for enabling said potential-condition changing circuit, and means including said device effective when said capacitor attains a preselected potential condition for abruptly disabling said potential-condition changing circuit.

4. In a timing apparatus, a relay having an operating winding and an opposing winding; a first series circuit comprising a source of potential, a resistor, a unidirectional current conducting device and the opposing winding of said relay; a second series circuit comprising a source of potential, a switch and the operating winding of said relay; a capacitor having two electrodes; a connection between one electrode of said capacitor and a point in said first series circuit intermediate said resistor and said device; and a connection between the other electrode of said capacitor and a point in said second series circuit intermediate said switch and the operating winding of said relay.

5. In a timing apparatus, a relay, a switch, a capacitor, a normally effective operating circuit for said relay including said switch, means including said switch and a unidirectional current conducting device for establishing an initial potential condition on said capacitor, a normally ineffective potential-condition changing circuit for said capacitor for holding said relay operated including said capacitor, the winding of said relay and a resistor, said switch being effective simultaneously to disable said operating circuit and to enable said potential-condition changing circuit, and means comprising said device effective when said capacitor attains a preselected potential condition for abruptly disabling said potential-condition changing circuit.

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