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MULTI-STATION VARIABLE TIMING APPARATUS

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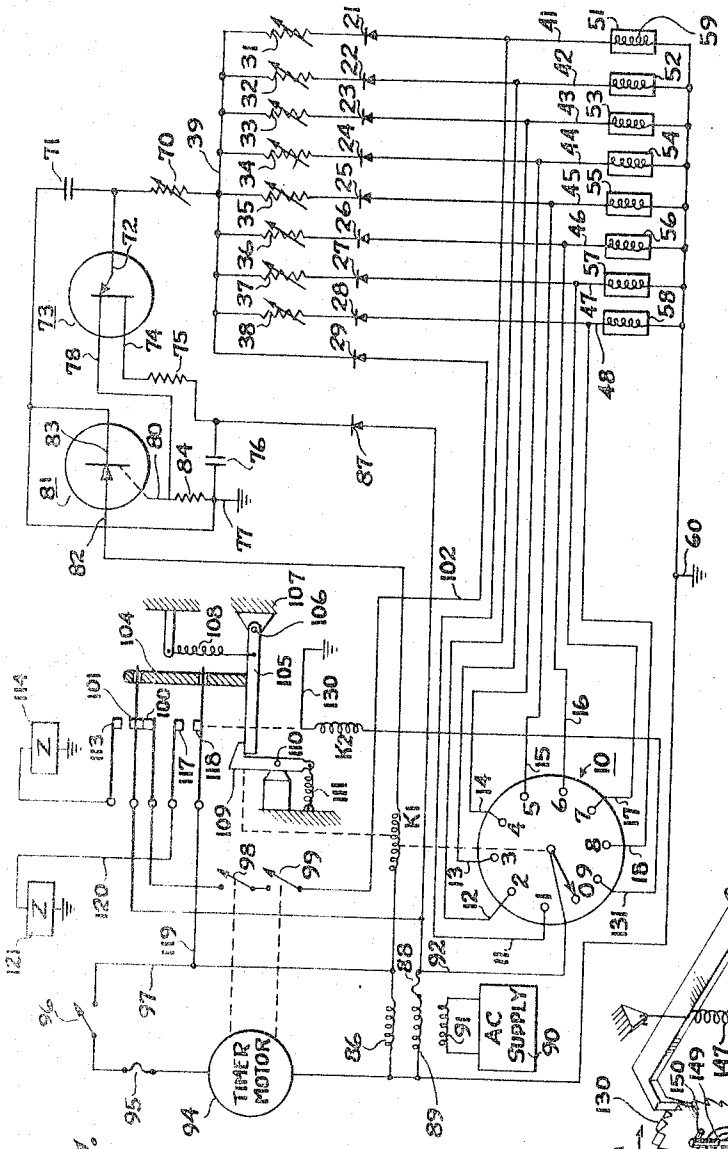


Fig. 1.

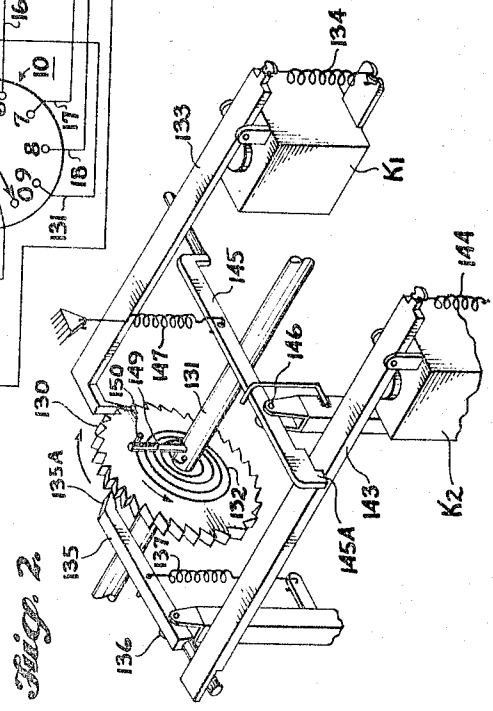


Fig. 2.

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MULTI-STATION VARIABLE TIMING APPARATUS

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The present invention relates to timing devices and systems and more particularly to an improved multi-station variable timing apparatus adapted to provide control of current flow to a number of load elements with the duration of the current applied to individual elements being individually selectively controllable and wherein the sequence of the application of current to the loads is readily variable.

Various devices have been devised in the prior art for providing current to a plurality of devices in sequence, as for example by the use of conventional stepping switches. In those cases where it is desired to have the duration of the current applied to individual devices individually controllable and presettable for a preselected length of time it has been common to use mechanical timing devices such as clocks together with suitable wiper switches to control the duration of the applied current to the devices. While such mechanical arrangements are found to work well in various control arrangements, the cost thereof is relatively high and the physical space occupied by such devices is generally quite large. In addition, such controlling devices normally are sensitive to shock and, therefore, care must be exercised to avoid damage thereto. In applications where a large number of mechanical sliding electrical contacts are utilized, the wear thereof often leads to difficulties and costly replacement of parts as well as creating problems of sensitivity to dirt, moisture, and other conditions which are known to effect the current carrying capability of such contacts.

It is therefore an object of the present invention to provide an improved variable timing apparatus having a plurality of stations.

Another object of the present invention is to provide an improved variable timing apparatus utilizing a minimum of mechanical parts and relying upon rugged electronic circuitry.

A further object of the present invention is to provide an improved variable time control gate utilizing solid-state electronic circuitry components in combination with a minimum of mechanical components.

An additional object of the present invention is to provide improved master control apparatus for selectively providing current to a plurality of devices for individually variable lengths of time and wherein a preselected sequence for the application of current to the individual devices can be readily programmed with assurance that a complete sequence of operation will take place.

Another object of the present invention is to provide an improved master control timing device for controlling the operation of a plurality of devices and wherein the apparatus lends itself readily to use in applications where low voltages and currents are used in the control circuit and yet heavy currents can be utilized for the individual devices which are to be controlled by the apparatus.

In accordance with the teachings of the present invention a current gating device such as an electromechanical stepping switch is connected in series circuit arrangement

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between a plurality of load devices and a source of current in a manner such that when the single moving contact of the stepping switch is at a given position, a selected one of the devices will be provided with operating current. A network including a plurality of timing resistors is also connected to the stepping switch and to a single electronic current control circuit in a manner such that after current has been provided to a given device for a selected length of time the single electronic current control circuit will provide an output signal to the control winding (or solenoid) of the stepping switch to advance the wiper thereof to the next position. The duration of the application of current to any given device is therefore readily controllable by means of control of the individual resistive impedance elements which are part of an RC timing network within the electronic current control circuit. The timing resistors are connected in a manner such that any selected one thereof will be connected in series circuit arrangement with the timing capacitor within the pulse gating network and hence a single timing capacitor and single pulse gating network is selectively connected in circuit arrangement with one of the timing resistors with the stepping switch controlling the sequence of the connection of such timing resistors with the current control network. The circuit is so designed that the stepping switch advances following the application of current to a selected device for a given length of time and therefore the switch returns to a preselected position following the application of current to the last of the devices in the apparatus. The stepping switch is of the return-to-zero type and therefore additional means is rendered operable in said preselected position to cause return of the stepping switch to an initial inactive condition. A set of switches and a pair of current contacts are connected in circuit arrangement with the current control circuit and the stepping switch in a manner such that an initial pulse of current is provided to advance the stepping switch from its inactive position to its first active position. A complete cycle of operation then takes place even though the set of switches is opened. When said preselected position is again reached the condition of said set of switches is sampled and connected in active circuit arrangement to determine whether the cycle of operation is to be repeated. Thus by controlling this set of switches the program can be repeated for a given time duration and yet each cycle of operation will be completed even though the set of switches is opened during the occurrence of a given cycle.

The above and additional objects and advantages of the present invention will be more clearly understood from the following description when read with reference to the accompanying drawings wherein,

FIGURE 1 is a schematic circuit diagram illustrating a preferred embodiment of the variable timing control circuit, and

FIGURE 2 is an orthogonal view illustrating the manner of mechanical intercoupling of the two solenoids which are part of the schematic circuit diagram of FIGURE 1.

Referring now to the drawing and in particular to FIGURE 1 it will be seen that the circuit includes a stepping switch **10** having ten individual positions and associated terminals thereon indicated as **1** through **9** and zero. Suitable conductors **11–18** directly connect each of the terminals **1** through **8** on the stepping switch to a corresponding one of the anodes of diodes **21–28** which preferably (although not necessarily) are of the solid-state

type. The anodes of diodes 21–28 are thus directly connected to corresponding ones of the terminals 1–8 while the cathodes of the diodes are individually connected to corresponding ones of the variable impedance element shown for purpose of illustration as the variable resistors 31–38. The opposite ends of the variable resistors 31–38 are connected to a common lead 39.

The variable resistors 31–38 individually serve at different times as a portion of a timing network for a pulse gating or current control electronic circuit which will be seen to include a resistor 70 which is shown as being variable in magnitude. The resistor 70 is seen to be connected to the lead 49 and to a timing capacitor 71 with a point intermediate the capacitor 71 and the resistor 70 being connected to a voltage sensitive pulse generating device shown as a unijunction transistor 73. The emitter electrode 72 of the unijunction transistor 73 will be seen to be connected to the capacitor 71. A first base 74 of the unijunction transistor 73 is connected via a resistor 75 and a filter capacitor 76 to signal ground at lead 77. A second base electrode 78 is connected directly to the control electrode 80 of a current gating device illustrated as a silicon controlled rectifier 81 having an anode 82 and a cathode 83. The base electrode 78 is also connected through the resistor 84 to signal ground at the lead 77. The base electrode 83 of the current gating device shown as a silicon controlled rectifier 81 is connected to the capacitor 71 and also by lead 85 to signal ground at the lead 77.

The anode 82 of the silicon controlled rectifier 81 is directly connected to one side of the solenoid winding K1 which serves to operate the stepping switch 10 with the winding of the solenoid K1 being further connected to one side of a high voltage winding 86 of a transformer. The base 74 of the transistor 73 is connected through the resistor 75 to the cathode of a diode 87 having its anode connected via a fuse 88 to a low voltage winding 89 of the transformer. Power is supplied to the two windings 89 and 86 by means of an A.C. power supply 90 and a suitable winding 91 thereon in energy exchange relationship with the windings 86 and 89. For purpose of illustration the windings 86 and 89 are illustrated with winding 89 providing a low voltage and winding 86 providing a high voltage. As an example winding 89 may provide 24 volts and winding 86 115 volts.

The control circuit provided in accordance with the teaching of the present invention is advantageously used for controlling the application of current for a selected time to a plurality of individual load elements in a preselected sequence. The individual load elements could be any of a number of different types as, for example, control solenoids usable in electromechanical systems or to control valves as in water sprinkling systems or other applications where the energy of solenoids is utilized to provide mechanical movement and hence control of selected parts. For purpose of illustration the individual devices which are to be controlled are illustrated as the load elements 51–58 which as seen in FIGURE 1 are individually directly connected by leads 41–48 to corresponding ones of the leads 11–18 and hence directly to to the terminals 1–8 on the stepping switch 10. The devices to be controlled 51–58 are also connected to signal ground by a conductor 60 which will be seen to be connected to the common point of windings 86 and 89. For purpose of illustration the device 51 is shown as including a winding or coil 59 of a solenoid and it is to be understood that similar windings could be included within the remaining load elements 52–58. It should also be noted that while the leads 41–48 are shown as being directly connected to leads 11–18 a terminal board and associated sockets could be used to facilitate connection of any load element to any one of the terminals 1–8 and hence provide each change of the sequence of application of current to the loads.

A lead 92 is seen to be connected to the 24 volt winding 89 and also to the central moving contact 93 of the stepping switch 10. The arrangement is such that when the winding 89 is energized the moving contact 93 of the stepping switch 10 will be provided with a low voltage source of power with the home position of the moving contact 93 being the zero position on the stepping switch 10. It will be noted that no external contact is made to the zero contact on the stepping switch and therefore this corresponds to the rest or initial condition of the apparatus.

A timer motor 94 is shown as being connected to the high voltage power source by having one side thereof directly connected to the winding 86 and the other side thereof connected through a second fuse 95, a manually operable switch 96 and the lead 97 to the other side of the winding 86. The timer motor 97 can be any of a number readily available on the market and has appropriate means such as cams to selectively close a pair of switches 98 and 99 at preselected times. The switch 98 is preferably closed at a selected hour and switch 99 at a particular minute, with each being held closed by the timer motor for any desired length of time. It is of course to be understood that the switches 98 and 99 are provided with mechanical means whereby an operator can selectively close the switches to cause operation of the circuit in the manner to be described hereinafter. It will be seen that the switches 98 and 99 are connected through the contacts 100 and 101 to the voltage supply winding 89 and are also connected by lead 102 to the anode of a diode 39 the cathode of which is connected to conductor 39. Thus it will be seen that when switches 98 and 99 are closed with contacts 100 and 101 engaged current will be supplied to the emitter electrode 72 of transistor 73 and hence the solenoid K1 will be energized to initiate a cycle of operation.

The contact 101 is a movable contact and therefore for purpose of illustration is shown as being mechanically connected to an insulating wafer 104 shown in cross section and carried by a metal lever 105 pivoted at 106 on a stationary member 107. A small spring 108 serves to constantly urge the lever 105 in a clockwise direction. However, in the initial condition of the apparatus as illustrated in FIGURE 1 the lever 105 is restrained against movement to its clockwise position by means of a small latching lever 109 pivoted at 110 and urged clockwise into engagement with the left end of the lever 105 by means of a small spring 111. The arrangement of the parts is such that when the latch 109 is in latching engagement with the end of the lever 105 contact 101 will be held in its downwardly position of engagement with the contact 100. As will be described hereinafter, the winding of the solenoid K1 is so arranged with respect to the latch 109 that when K1 is energized the latch 109 is rocked counterclockwise to release the lever 105 and permit upward movement of the contact 101 to break the circuit existing between contacts 100 and 101. Such upward movement of contact 101 brings said contact into engagement with a stationary contact 113 connected in series circuit arrangement with a load element 114 having one side thereof connected to signal ground. The load element 114 can be any of a number which is responsive to and suitable for use with the low voltage provided by the winding 89 and thus it will be seen that when the contacts 101 and 113 are in engagement with each other, the load element 114 will be provided with the low voltage of the winding 89.

A second set of contacts 117 and 118 are normally in an opened condition with the contact 118 being mechanically carried by the insulating element 104 so that when the lever 105 moves clockwise the contacts 117 and 118 are brought into engagement with each other. It will be seen that contact 118 is directly connected via lead 119 to the lead 97 while contact 117 is connected via lead 120 to a load element 121 which is adapted to be opera-

ted by the high voltage provided by winding 86. Thus, it will be seen that when the lever 105 is moved clockwise the two load elements 114 and 121 are respectively provided with the voltages of the windings 89 and 86.

As described in more detail hereinafter, a second solenoid having a winding K2 is connected to signal ground by lead 130 and to the number 9 terminal of the stepping switch 10 by a lead 131. The solenoid K2 is adapted when energized to pull the lever 105 in a counterclockwise direction to be relatched by the latch 109. Also, as described hereinafter, the solenoid K2 is further adapted when energized to cause return of the moving contact 93 of the stepping switch to its initial position of engagement with the zero contact.

The operation of the circuit is as follows. When the switch 96 is closed by an operator the high voltage power is applied to the timer motor 94 and therefore at a preselected time the switches 99 and 98 will be closed. When these two switches are closed power is provided through the contacts 100 and 101 and the lead 102, through the diode 29 and resistor 70 to the emitter of the transistor 73. After a time which is dependent upon the RC time constant of the resistor 70 and capacitor 71 the emitter 72 will be raised to a voltage such that the transistor 73 will be made conductive. Current will then flow through diode 87 and resistor 75 into base 74 and then from base 78 to the control electrode 80 of the silicon controlled rectifier 81. Since the silicon controlled rectifier is connected in series circuit with the stepping switch winding K1 and has the high voltage applied thereacross, the pulse applied to its control electrode thereof will cause conduction to occur and hence the stepping relay will be energized and cause the moving contact 91 to be advanced to the No. 1 position thereof. Such energization of the winding K1 further serves to operate the latch 109 and hence the lever 105 is freed for clockwise movement to cause opening of the contacts 100 and 101 and closing of contacts 101 and 113 as well as contacts 117 and 118 so that power is applied to load elements 114 and 121. This opening of contacts 100 and 101 removes the bias on emitter 72 of transistor 73 and hence conduction of the transistor and the silicon controlled rectifier 81 terminates.

With the movable contact 93 in engagement with the No. 1 contact on the stepping switch it will be seen that power is applied to the load element 51. Current is also provided through the diode 31 to the resistor-capacitor timing network which now includes resistor 41, resistor 70, and the capacitor 71. The time which elapses before transistor 73 is again made conductive is dependent upon the time constant of the variable resistors 41 and 70 and the capacitor 71. The value of these components can of course be selected to provide times of a few seconds up to several minutes or even hours.

When the transistor 73 conducts, the silicon controlled rectifier will again be made conductive and hence energization of the winding K1 will take place to cause advancement of the switch 93 to the contact No. 2 on the stepping switch 10. It will be seen that as soon as the moving contact 93 departs from the contact No. 1 on the stepping switch 10 no further current is provided through the diode 31 and resistor 41 to the emitter 72 and hence the control pulse applied to the control electrode 80 of the silicon controlled rectifier 81 is removed rendering the rectifier 81 nonconductive and terminating current flow through the winding K1.

The above procedure continues as the stepping switch 93 is sequentially moved from contact to contact on the stepping switch 10 until the No. 8 position thereof is reached. It will be seen that when the moving contact 93 is in the No. 8 position of the stepping switch the load element 58 will be provided with energy for a length of time determined by the time constant of resistors 28 and 70 and capacitor 71. When the solenoid K1 receives a pulse of current with the contact 93 in its No. 8 position

it will be seen that the contact 93 will move to its No. 9 position and hence the second solenoid K2 will be energized. When the solenoid K2 is energized the lever 105 is pulled counterclockwise and the various contacts 101, 100, 113, 117, and 118 are returned to their initial conditions. As described herein after, energization of the solenoid K2 further serves to return the contact 93 to its initial zero position and hence the solenoid K2 will be de-energized and the circuit returned to its initial condition as previously described. If the switches 98 and 99 are still closed, it will be seen that winding K1 will again be energized and a second cycle of operation identical to that just described will take place and such operation will continue until 98 and 99 are opened. It should be noted, however, that once a cycle has started, opening of the switches 98 and 99 has no immediate effect on the cycle then taking place.

The stepping switch 10 can be any of a number readily available on the market at the present time and is of the type which is provided with a spring urge on the moving contact such that the contact is spring urged toward its zero position. As described in connection with FIGURE 2, a spring urged detent serves to hold the moving contact 93 against such spring urged movement towards its zero position in response to the individual steps of movement applied thereto by a stepping solenoid including the winding 81. Thus it will be seen that if a program is desired which requires fewer than eight positions the circuit can be so wired that the solenoid K2 will be energized when the moving contact 93 reaches any preselected position and therefore when reaching that preselected position the detent holding the moving contact against return to its zero condition will be released by the solenoid K2 and thereby permit a return to zero of the contact 93. It wil be obvious to those skilled in the art that a stepping switch which is rotatable through more than 360° can be used and also that any of the positions on the stepping switch can be rapidly passed over merely by setting the appropriate resistor 31–38 at zero ohms or by shorting any contact 1–8 to the diode 29. The impedance of the resistor 70 is preferably maintained low so that the starting time base for each position of the stepping switch is in the order of a very few seconds.

Referring now to FIGURE 2 there is illustrated the mechanical arrangement of the various parts controlled by the solenoids K1 and K2. It will be seen in FIGURE 2 that the movable contact 93 is carried by a toothed ratchet wheel 130 supported for rotation on a shaft 131. For purpose of illustration the shaft 131 is stationary and a coiled spring 132 is wrapped thereabout having one end connected to the shaft 131 and the other end connected to the ratchet wheel 130 so that the ratchet wheel 130 is constantly urged in a counterclockwise direction in FIGURE 2. The solenoid K1 is provided with an associated clapper 133, one end of which is adapted upon downward movement of the clapper 133 to engage the teeth of the ratchet wheel 130 and advance said wheel in a clockwise direction by an amount sufficient to cause the movable contact 93 to be advanced from one contact position on the stepper switch to the adjacent contact position. A spring 134 constantly urges the clapper 133 in a clockwise direction so that the clapper is disposed away from the solenoid winding in the solenoid K1, as is common in the art. A detent pawl 135 pivoted at point 136 and urged in a clockwise direction by a spring 137 serves to maintain the detenting point 135A of the pawl 135 normally in engagement with the teeth on the wheel 130 in a manner to prevent counterclockwise movement of the ratchet wheel under the urge of the spring 132. Thus it will be seen that each time the solenoid K1 is energized the ratchet wheel 130 will be advanced in a clockwise direction by one step and will be prevented from backing up in a counterclockwise direction by the detenting pawl 135.

As previously described the solenoid K2 is adapted to selectively permit return of the movable contact 93 to its initial or zero position and therefore it will be seen in FIGURE 2 that the clapper 143 of the solenoid K2 is normally urged in a clockwise direction by a spring 144 and further that the end of the clapper 143 overlies a portion of the detenting pawl 135. The arrangement is such that when the solenoid K2 is energized the detenting pawl 135 will be rocked counterclockwise and hence permit counterclockwise movement of the ratchet wheel 130 carrying the movable contact 93 under the urge of spring 132. A stationary post 149 welded to shaft 131 and in the path of stud 150 on the ratchet wheel serves to limit such counterclockwise movement and define the zero position.

A latching lever 145 having a latching surface 145A overlying the top surface of the clapper 143 is spring urged in a counterclockwise direction about its pivot point 146 by a small spring 147. The right end of the latching lever 145 is seen to underlie the clapper 133 and therefore each time the solenoid K1 is energized the latching lever 145 is rocked clockwise so that its detenting or latching surface 145A moves away from the top of the clapper 143 to permit upward movement of the clapper 143 under the urge of spring 144 when the solenoid K2 is not energized. The arrangement is such that when the solenoid K1 is energized the clapper 143 will be released for upward movement and hence the detenting pawl 135 moves into engagement with the teeth of the ratchet wheel 130 to prevent counterclockwise movement thereof. Once the solenoid K2 is energized the latching lever 145 will be rocked counterclockwise into latching position on top of the clapper 143 to hold clapper 143 downwardly (or counterclockwise) and thus hold the detenting pawl 135 in a disabled condition even though solenoid K2 is de-energized. When the solenoid K1 is energized it serves to release both the clapper 143 and the detenting pawl 135.

In the event it is desired to make use of the teachings of the present invention in an apparatus where higher voltages are to be applied to the load elements 51–58 than the voltages used with the unijunction transistor and silicon controlled rectifier, the load elements 51–58 can be individually wired to a second set of contacts provided on a second insulation wafer and having a movable contact similar to the contact 93 and adapted for movement simultaneously therewith. That is, a second set of contacts 1–8 can be provided coaxially with the contacts 1–8 in FIGURE 1 and a second wiper can be connected mechanically with the moving contact 93 in a manner such that the second set of contacts are sequentially energized with a high voltage simultaneously with energization of the contacts 1–8 in FIGURE 1. It is, of course, obvious that a second stepping switch simultaneously operable in response to the current pulses applied to the solenoid K1 of FIGURE 1 could be provided for causing the sequential energization of the load elements 51–58 connected to such second stepping switch. It should also be noted that a plug board is advantageously placed between the leads 41–48 and 11–18 to facilitate variations in order of application of current to the load elements.

There has thus been disclosed an improved timing apparatus adapted to selectively provide current to a plurality of loads for individually variable lengths of time utilizing low cost components and few mechanical parts. The various alterations are modifications which are apparent to those skilled in the art from the teachings of the present invention are intended to be encompassed by the following claims.

What is claimed is:

1. A current control apparatus comprising in combination; first and second solenoids; current gating means coupled with said first solenoid having a plurality of signal output terminals and responsive to repeated energization of said first solenoid to cause sequential energization of said terminals; a plurality of load means individually connected to different ones of said terminals; a plurality of individually variable resistive impedance elements; means connecting each of said elements to one of said terminals; current control means connected in series circuit with said first solenoid; a timing capacitor; means connecting said capacitor to each of said elements; voltage responsive means connected to said capacitor and to said current control means responsive to a predetermined voltage on said capacitor to render said current control means conductive; first and second switch means connected in series circuit with said capacitor and adapted when closed to apply said predetermined voltage thereto; timing means coupled with said first switch means and adapted to control the time during which said first switch means is closed; means responsive to energization of said second solenoid to close said second switch means; latch means responsive to closing of said second switch means to latch said second switch means in a closed condition, said latch means being further responsive to operation of said first solenoid to release said second switch means; and circuit means connecting said second solenoid to one of said terminals.

2. A control apparatus in accordance with claim 1 and further including means responsive to energization of said second solenoid to place said current gating means in an inactive condition and wherein energization of said first solenoid when said current gating means is in its said inactive position will cause energization of one of said terminals.

3. A control apparatus in accordance with claim 1 wherein said current control means includes a silicon-controlled rectifier having first and second current carrying electrodes connected in series circuit with said first solenoid and wherein said voltage responsive means includes a transistor having a control electrode connected to said capacitor and a signal ouptut electrode connected to said rectifier.

4. A control apparatus in accordance with claim 1 wherein said current gating means includes a stepping switch having *n* terminals and an inactive position between the *n*th and the first terminals thereof, and wherein said stepping switch assumes said inactive position in response to energization of said second solenoid.

5. A control apparatus comprising in combination: current gating means having an inactive condition and a plurality of individually energizable signal output terminals; a plurality of load elements each connected to a different one of said terminals; drive means coupled with said current gating means including a solenoid coupled with said gating means and operable upon energization to advance said gating means to cause de-energization of one of said terminals and energization of another of said terminals, a current control device connected in series circuit with said solenoid, and a semiconductor device; a plurality of resistor-capacitor timing circuits each connected to said drive means and to said current gating means and sequentially activated upon energization of a different one of said terminals to cause operation of said drive means a predetermined time after energization of one of said terminals, said semiconductor device being connected to said current control device and to said timing circuits adapted to periodically render said current control device conductive in response to signals derived from said timing circuits, whereby said load elements are individually energized for said predetermined time; a second solenoid connected to one of said terminals and operative upon energization to cause said current gating means to assume its said inactive condition; first switch means coupled with said second solenoid and adapted to be closed upon energization of said second solenoid; latch means operative to hold said first switch means in a closed condition after movement to a closed condition by said second solenoid and

further coupled with said first solenoid to release said first switch means for movement to an opened condition upon energization of said first solenoid; and second switch means connected in series circuit with said first switch means and said semiconductor device to cause energization of said first solenoid when said first and second switch means are closed.

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