

Aug. 24, 1943.

A. L. HOPPER

2,327,791

TIME DELAY APPARATUS

Filed Aug. 19, 1941

FIG. 1

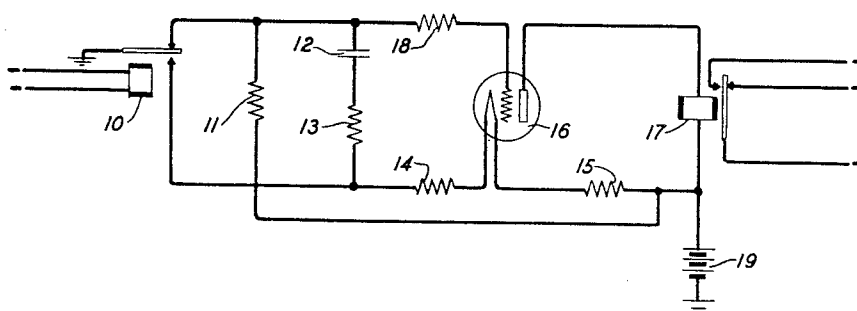
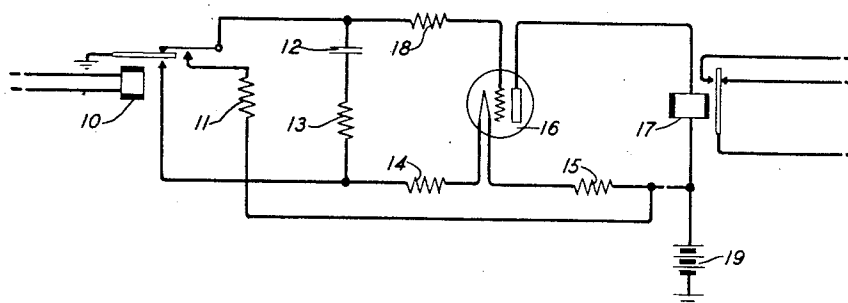


FIG. 2



INVENTOR
A. L. HOPPER
BY *William F. Simpson*
ATTORNEY

UNITED STATES PATENT OFFICE

2,327,791

TIME DELAY APPARATUS

Andrew L. Hopper, River Edge, N. J., assignor to
Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

Application August 19, 1941, Serial No. 407,410

6 Claims. (Cl. 250—27)

This invention relates to an improved timing device for securing greater accuracy, a longer interval of time from a timing circuit having a given set of constants and potentials applied thereto, or for securing the same interval of time with a smaller timing condenser and/or charging resistance.

As set forth in United States patent to Lea 1,552,321, granted September 1, 1925, a time delay may be secured by the time of discharging and charging the condenser connected to the control elements of an electron discharge device. The charge of the condenser is changed through a high resistance. The value of this resistance and the condenser determine the time required for the potential across the condenser and thus the potential of the control element of the electron discharge device to reach the value required to initiate a discharge through it and operate a relay or other device as desired. The arrangement shown in this Lea patent, however, requires the use of two batteries, one for initially charging the condenser and the other for discharging the condenser and operating the electron discharge device.

In accordance with the present invention the charging and discharging circuits of the condenser are rearranged so that the condensers are first charged in the opposite direction and discharged and again charged to the value required to initiate a discharge through the electron discharging device from a single battery or source of potential. Thus, in accordance with this invention substantially all of the advantages of the timing arrangement shown in the patent to Lea is obtained with a single battery.

In accordance with another usual arrangement the condenser is normally discharged. Then when it is desired to initiate the operation of the timing circuit a potential is applied to the condenser through a high resistance.

In accordance with the present invention by charging the condenser in the reverse direction then discharging it and charging it in the direction required to initiate a discharge through the electron discharge device through a high resistance a considerably greater time delay is secured with the same size condenser charging resistance and charging battery or potential.

A further feature of this invention relates to arranging the circuit so that the filament or heater circuit of the electron discharge device is supplied from the same source of potential and its circuit completed by the same contacts as initiate the operation of the timing circuit, that is, in-

itiate first the discharge and then the charge of the condenser.

A further feature of this invention relates to a slight modification of the circuit in which no current is taken from the battery or other source of potential during the idle or normal condition of the circuit.

The foregoing objects and features of this invention, the novel features of which are specifically pointed out in the claims appended thereto, may be more readily and fully understood by reference to the attached drawings in which:

Fig. 1 illustrates a typical embodiment of this invention;

Fig. 2 is a modification of Fig. 1 in which no current is taken from the source of potential during the normal or idle condition of the circuit.

Referring now to Fig. 1, 16 represents an electron discharge device of any suitable type. Device 16 has been shown as a three-element device. It is to be understood, however, it may include more elements if desired. Device 16 may be either a high vacuum tube discharge device in which the grid or control element maintains control of the discharge or anode current at all times or it may be a so-called gas discharge device in which the control element will prevent a discharge from occurring but loses control when the discharge has been initiated through the device. The essential requirement of the device 16 is that in the potential of a control element having a very high input impedance should continuously or at least initially control the discharge or anode current of the device. The output relay 17 is connected in the anode circuit of tube 16 so that it will be operated when sufficient anode current flows through device 16, i. e., when a discharge is initiated through the tube. Relay 17 is shown provided with a single set of transfer contacts. These are shown merely for purposes of illustration and as is well understood by those skilled in the art, other contacts may be added to relay 17. Also, various stepping and switching devices may be operated by magnet 17 as is well understood.

Condenser 12 is connected in series with resistances 13, 14 and 18 between the control element and cathode of tube 16. The purpose of these various resistances will be explained hereinafter. Normally, ground is connected to the upper terminal of condenser 12 through the upper break contacts of relay 10. As shown in Fig. 1, this ground short circuits the high resistance 11 and causes a small current to flow through this resistance at all times. However, the potential of

the upper terminal potential 12 as well as the upper terminal of resistance 11 will be maintained in ground potential at this time. The lower terminal of condenser 12 is charged to positive battery potential from battery through resistance 15, filament or heater of tube 16, resistances 14 and 13 to the lower terminal of condenser 12. The values of resistances 13, 14 and 15 are such that it requires only a very short time for condenser 12 to be charged to the potential of battery 19.

When it is desired to initiate the operation of the timing circuit shown in Fig. 1 relay 10 will be operated in any suitable manner in any suitable circuit. Relay 10 is provided with a single transfer code combination, i. e., a single pole double throw switch. As will be readily understood by persons skilled in the art relay 10 may be provided with other contacts for other purposes. However, so far as initiating the operation of the timing circuit is concerned only a single transfer combination is required, that is, a switch member which has two positions and makes contact with another member in one position and with a third member in the other position.

The operation of relay 10 removes ground from the upper terminal of resistance 11 and condenser 12. The operation of relay 10 also connects ground to the common terminal of resistances 13 and 14. By connecting ground to resistance 14 the filament circuit of tube 16 is completed. By connecting ground to the lower terminal of resistance 13 ground is also connected to the lower terminal of condenser 12. Now the lower terminal of condenser 12 had previously been charged to the potential of battery 19 above ground. In other words, the upper terminal of condenser 12 was charged to a potential lower than the lower terminal condenser 12 by the amount of potential source 19. Thus, when the lower terminal of condenser 12 is connected to ground the upper terminal of condenser 12 will assume a potential substantially equal to the potential of source 19 but in the reverse direction that is below ground potential.

Thereafter condenser 12 will start to discharge through high resistance 11 to battery 19.

After condenser 12 has become fully discharged, that is, its upper terminal reaches ground potential, the upper terminal will start to charge to a positive potential through high resistance 11. After an interval of time the upper terminal of condenser 12 will reach the potential required to initiate the discharge through tube 16.

The potential required to initiate a discharge through tube 16 will be determined by the constants of tube 16 and in addition the value of the source of potential 19 and also the relative magnitude of resistances 14 and 15. Resistance 14 is provided to apply negative bias to tube 16. The left-hand terminal of resistance 14 is at ground potential while the right terminal of resistance 14 is at a positive potential which potential is dependent upon the voltage drop across resistance 14. Since the right-hand terminal of resistance 14 is connected to the cathode of tube 16 the cathode will be at a positive potential above ground. Hence so long as the control element or grid of tube 16 is connected to ground it will be negative with respect to the cathode and thus a negative bias will be applied to the tube.

When the discharge is initiated through the tube 16 relay 17 will be operated at the desired

time delay interval after the operation of relay 10. When relay 10 is released it will remove ground from the common junction of resistances 13 and 14 and interrupt the filament circuit of tube 16. It will also connect ground to the upper terminal of condenser 12. When ground is connected to the upper terminal 12 the charge on condenser 12 will be reversed through resistances 13, 14, 15 and the filament of tube 16. Resistance 13 is included in this path so that the discharge current of condenser 12 will not be sufficient to injure the heater or filament of tube 16.

The modification shown in Fig. 2 operates in a manner similar to that shown in Fig. 1 except that upon the release of relay 10 the circuit through the high resistance 11 is interrupted; consequently no current will flow through this resistance during the normal or idle condition of the circuit.

The equations for the charging of a condenser through a resistance are developed in section 122 "Charging a condenser through a resistance" of Principles of Electrical Engineering by Timbie and Bush and published by John Wiley and Sons, Inc. in 1923.

From Equation 40 on page 452 and the relation $e = q/C$ the voltage e on the condenser at any time t after the closure of the charging circuit of a completely discharged condenser, i. e., a condenser having a zero voltage or charge between its plates, is

$$e_1 = E \left(1 - e^{-\frac{t_1}{RC_1}} \right)$$

where E is equal to the applied voltage, R is equal to the total resistance of the charging circuit, and C the capacity of the condenser.

In case the condenser is initially charged to the voltage of the source E in the reverse direction the voltage across the condenser at any time t after the discharging and charging circuit closed is

$$e_2 = E \left(1 - 2e^{-\frac{t_2}{RC_2}} \right)$$

The rate of change of the voltage e with time determines accuracy or variation of the time required to reach any given potential.

If it is assumed that the same capacity and resistance are used in both circuits and that it is desired to have the same value of e or the same rate of change of e with respect to time, then $t_2 = .693 RC + t_1$. This relationship may be developed as follows:

For charging from zero For discharging and charging from E

$$e_1 = E \left(1 - e^{-\frac{t_1}{RC_1}} \right)$$

$$e_2 = E \left(1 - 2e^{-\frac{t_2}{RC_2}} \right)$$

$$\frac{de}{dt} = \frac{1}{RC_1} e^{-\frac{t_1}{RC_1}}$$

$$\frac{de}{dt} = \frac{2}{RC_2} e^{-\frac{t_2}{RC_2}}$$

$$\frac{1}{RC_1} e^{-\frac{t_1}{RC_1}} = \frac{2}{RC_2} e^{-\frac{t_2}{RC_2}}$$

If $RC_1 = RC_2 = RC$

$$e^{-\frac{1}{RC}(t_2 - t_1)} = 2$$

Then

$$t_2 - t_1 = RC \log 2 = .693 RC$$

$$t_2 = t_1 + .693 RC$$

Thus the increase in time due to initially charging the condenser in the reverse direction is .693 RC . The following table shows the percentage increase in time for different values of t_1 in terms of RC :

t_1	t_2	Per cent increase
2 RC	2.69 RC	34
$\frac{3}{2}$ RC	2.19 RC	46
RC	1.69 RC	69
$\frac{3}{4}$ RC	1.44 RC	91
$\frac{1}{2}$ RC	1.14 RC	138

This improved arrangement thus gives a greater time delay with a given size condenser and resistance. If it is desired the same delay may be secured by a smaller RC product. The size of the condenser may be reduced or the value of the resistance reduced.

The value of the resistance used is usually fixed by the value of or changes in the value of the leakage resistance of the condenser, input circuit of the tube and related wiring. By means of this invention the value of the charging resistance may be reduced without reducing the time delay of the circuit. Such a reduction of the charging resistance will reduce the variation of the effective charging resistance and thus reduce the variation in the time delay of the circuit.

It is to be understood that the foregoing description of a specific embodiment of the invention is by way of example and that various equivalent devices and apparatus may be substituted for the specific equipment shown as will be well understood by those skilled in the art.

What is claimed is:

1. A time delay device comprising a thermionic discharge device, a responsive device connected in the output circuit thereof, a condenser connected to the control circuit of said discharge device, a single battery for supplying anode potential, filament current, and bias potential for said device, circuits for initially charging the condenser to said battery potential, a single pole double throw switch arrangement for completing the filament circuit of said device and for changing the connections to said condenser for first discharging the condenser, and then charging the condenser through a high impedance to the value required to initiate a discharge through said thermionic discharge device to actuate said responsive device.

2. Time delay apparatus comprising a potential operated device responsive to a predetermined potential, a condenser connected across said device for controlling the potential applied to said device in accordance with the potential across said condenser, a source of potential and circuits for applying a reverse charge to said condenser, a single pole double throw switch for changing the connections to said condenser to first discharge the reverse charge on said condenser through a high impedance and then charge said condenser from said same source of potential to said predetermined potential through a high impedance.

3. Time delay apparatus comprising an electron discharging device having a control element for initiating discharges therethrough when a predetermined potential is applied between said element and another element of said device, a condenser connected across said elements for controlling the potential difference between said elements, apparatus for initially charging said condenser in a reverse direction, a single source of potential for supplying all the potential and energy for said device and for charging said condenser, a high resistance, a single transfer switch

combination for changing the connections to said condenser for discharging it through said high resistance and then charging it to the potential required to initiate a discharge through said device.

4. Time delay apparatus comprising an electron discharge device having a control member for initiating discharges therethrough when a predetermined potential is applied to said member, a condenser for controlling the potential of said member, apparatus for initially charging said condenser in a reverse direction, a single source of electrical energy for supplying all the potentials and energy for said device and for charging said condenser, a high resistance, a single pole double throw switch arrangement for changing the connections to said condenser for discharging it through said high resistance and then charging it to the potential required to initiate a discharge through said device, and an auxiliary switch controlled by said single pole double throw switch for interrupting the circuit through said high resistance.

5. A time delay device comprising an electron discharge device having a cathode, an anode, and a control element, a responsive device connected in a circuit extending between said anode and the cathode, a condenser connected between said cathode and said control element for controlling the relative potentials of said elements, a single source of electrical energy for supplying all the potentials supplied to said electron discharge device, circuits for initially charging said condenser to said battery potential, a single transfer switch combination for changing the connections to said condenser for first discharging said condenser through a high impedance and then charging said condenser in a reverse direction through said high impedance to the value required to initiate a discharge through said electron discharge device for actuating said responsive device.

6. A timing device comprising a single transfer switch combination the operation of which initiates the operation of said timing device, a responsive device operative a predetermined time interval after the operation of said transfer device including a thermionic discharge device having a cathode, an anode, and a control electrode, a single source of potential for supplying energy to said thermionic device, circuit connections between said cathode, anode, responsive device, and the source of potential for supplying anode potential to said discharge device, a condenser connected between said control element and said cathode for controlling the relative potentials of said elements, circuit connections between said source of potential, said transfer device and said condenser for charging said condenser to said battery potential when said transfer device is not actuated, circuit connections between said discharge device and said condenser and said source of potential for energizing the cathode of said thermionic discharge device and changing the connections to said condenser through a high impedance upon the actuation of said transfer switch for causing the charge of said condenser to be first discharged through said high impedance and then charged in a reverse direction also through said high impedance to the potential required to initiate a discharge through said thermionic discharge device and actuate said responsive device at the end of said predetermined interval of time.

ANDREW L. HOPPER.