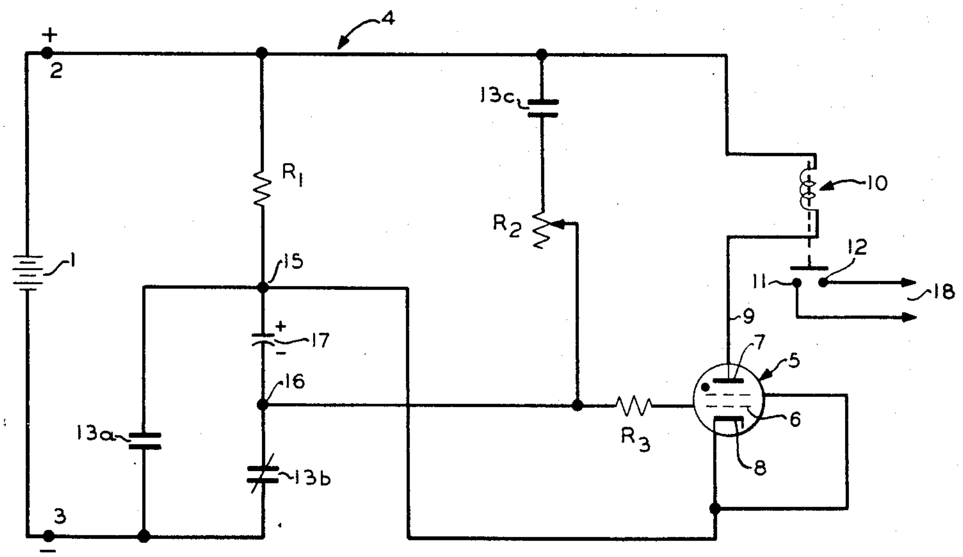
Aug. 23, 1960 R. E. PURKHISER 2,950,422

ELECTRONICALLY CONTROLLED TIME DELAY APPARATUS

Filed May 9, 1957

FIG. 1



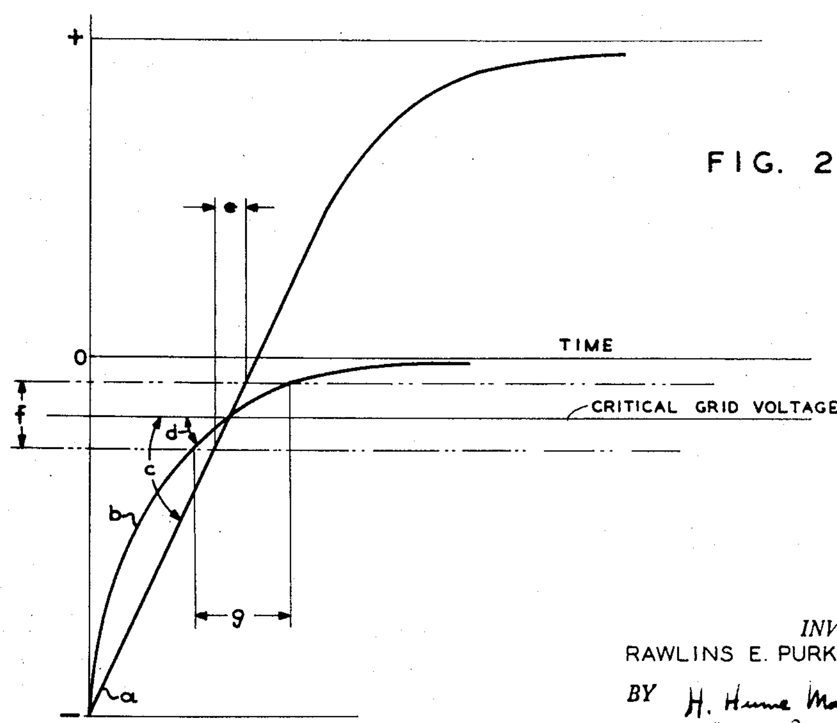


FIG. 2

INVENTOR.
RAWLINS E. PURKHISER

BY H. Hume Mathews
Edmund W. Bopp

ATTORNEY & AGENT

2,950,422
Patented Aug. 23, 1960

2,950,422

ELECTRONICALLY CONTROLLED TIME DELAY APPARATUS

Rawlins Edison Purkhiser, Springfield, N.J., assignor to Air Reduction Company, Incorporated, New York, N.Y., a corporation of New York

Filed May 9, 1957, Ser. No. 658,109

2 Claims. (Cl. 317—142)

This invention relates to electrical control devices and more particularly to electronically controllable time delay apparatus.

Time delay devices find many fields of use in modern day industry where precise timing for controlling various phases of some particular process is necessary. As an example, it is not uncommon in the welding art to make use of such timers to control the length of the welding period as shown in United States Patent No. 2,702,333 issued to Nelson E. Anderson on February 15, 1950.

Time delay devices generally have their timing mechanisms operable by either pneumatic or electrical means. The timing mechanisms, usually called "timers," operate on the dashpot principle in the case of pneumatic timers, and by the charging and discharging of a control capacitor, through a resistor-capacitor (RC) network, in the case of electronic timers. Electrical timers may also be motor driven to control the timing sequence in a controlled operation, but such a system is not under discussion here.

Pneumatic timers have an inherent error of the order of 10 percent in reset accuracy resulting from the variables in the dashpot timing mechanism. Such inaccuracies present definite limitations in the uses to which such timers can be put.

On the other hand electronic timers, as presently constructed and operated, have definite disadvantages and errors resulting therefrom. Electronic timers generally have their timing sequence controlled by a capacitor-resistor (RC) combination. In operation, a control grid of an electron discharge device is biased negatively via a negatively charged capacitor (C), so that the discharge device is inoperable or non-conductive. Upon discharging the negatively charged capacitor, after a given interval of time, through a resistor (R), the control grid is released from its negative biased state and the discharge device subsequently conducts. The rapidity with which the control bias is released is dependent upon the value of the timing resistor (R).

Present day electronic timers employ alternating, 60 cycle current and operate on the half-wave conducting principle, e.g. when the alternating wave is on the positive half of the cycle. Consequently if the alternating wave is on the negative half of the cycle, the discharge device will fail to conduct, producing up to an extra delay of one-half cycle. This resulting delay represents an appreciable error, especially where short cycles of operation in the timing sequence are necessary. To overcome this inherent disadvantage, direct current is employed for operating the electronic timer of this invention.

Another shortcoming in the present commercially available electronic timers is in the method of timing or approaching the critical grid voltage at which voltage the electron device conducts. The timing circuits comprising the RC network permits the capacitor controlling the control grid bias to decay in an exponential manner, the critical control grid or firing voltage being, therefore, approached asymptotically. The resulting discharge curve approaches the critical grid voltage value at a rather small angle of incidence, the angle formed by the discharge exponential curve and the critical grid voltage value. Such a small incidence angle presents a decided limitation in the timing circuit in that any variations in the grid control capacitor voltage or change in the critical or firing grid voltage of the electron discharge device, by virtue of its aging electrode characteristic changes, will result in a timing period different than that originally desired.

To overcome the limitation presented by the low angle of incidence in the timing circuit, the discharging capacitor instead of discharging to a source of reference potential, e.g. ground, is made to reverse its polarity so that the discharge curve approaches the critical grid or firing voltage at a much steeper or greater angle of incidence than heretofore achieved. The capacitor discharges to zero and again charges in the reverse direction, the effect being to increase the angle of incidence and thus to minimize errors.

Present day commercially available electronic timers are limited to approximately a 20 to 1 ratio of maximum to minimum time range because of their inherent design features. However, in the present invention, it is possible to achieve ratios of approximately 50 to 1 and perhaps even higher because of the fact that the safety or limiting circuits of the timer are completely divorced from the timing components and can be selected without regard to the timing ranges employed. This selective advantage is not available in present commercial timers, hence the reason why such present day timers are limited to a 20 to 1 ratio.

Further, present timers have a reset time whose relationship to the minimum time range is fixed, a factor dependent upon the timer electrical components. However, this invention provides components whose reset and minimum time functions are completely divorced from each other and therefore completely independent.

This invention has for its primary object the provision of an electronic timer having greater accuracy than presently available timers.

Another object of this invention is to provide an electronic timer which utilizes a direct current source of potential to minimize timing errors inherent when an alternating current source is used.

Another object of this invention is to provide an electronic timer having a charging and discharging polarity reversing circuit for a grid bias controlling capacitor to produce a high angle of incidence in the grid voltage as it passes the critical grid voltage of the electron discharge device.

A further object of this invention is to provide an electronic timer having a substantially improved ratio of maximum to minimum time range by virtue of the complete separation of the safety or limiting circuits from the timing components.

A still further object of this invention is to provide an electronic timer whose reset time is independent of the minimum time range of the timer by virtue of the independence of the electrical components which effect the reset and minimum time parameters.

An additional object of this invention is to provide a timer of the character indicated that is simple in design, that is compact and sturdy in construction, that is reasonable in manufacturing and maintenance costs and that is capable of performing its intended functions in an efficient and trouble-free manner.

The foregoing objects and other objects, together with the advantages of this invention, will be readily comprehended by persons skilled in the art from the following detailed description and the accompanying drawing which respectively describe and illustrate a preferred embodiment of the invention.

In the drawing:

Fig. 1 is a diagrammatic representation of an electric circuit of an electronically controlled timer according to the invention; and

Fig. 2 shows representative charging and discharging curves for the grid-bias controlling capacitor.

Referring now to Fig. 1 of the drawing, a direct current potential source **1** is connected to the positive and negative supply terminals **2** and **3** of an electronically controlled timer **4**. The timer comprises an electron discharge device **5** having a control grid **6**, an anode **7** and a cathode **8**. Electron discharge device **5** may, for example, be a type 2D21 thyratron tube. In the anode circuit **9** of the electron discharge device **5** there is connected the operating winding of a relay **10** having contacts **11** and **12** which are normally open. This particular circuit controlling means is adapted to operably function in response to anode current flow when the discharge device **5** conducts, the contacts **11** and **12** thereby becoming bridged or connected. There is associated with the timer **4** an initiating relay having three pairs of relay contacts **13***a*, **13***b* and **13***c* and operable by an external initiating switch (not shown). Relay contacts **13***a* are connected across the direct current supply line terminals **2** and **3** through a resistive element R_1 and are normally open. The cathode electrode **8** of discharge device **5** is connected to and interposed between the normally open relay contacts **13***a* and the resistive element R_1 at a terminal point **15** thus connecting the cathode **8** to the positive side of the direct current supply terminals through the resistive element R_1. Another set of relay contacts **13***b* is normally closed and is interposed between the electrode discharge device control grid **6** and the negative terminal **3** of the direct current supply source **1** at a terminal point **16**. The third set of relay contacts **13***c* is normally open and is interposed between the control grid **6**, on the side of the terminal point **16**, and the positive terminal **2** of the direct current supply source through a variable resistive element R_2. Finally, there is interposed between the control grid **6** and the cathode **8** of the electron discharge device **5** a grid-bias control capacitor **17** connected to the terminals **15** and **16**. There is also included in the grid circuit a protective resistor R_3 which prevents excessive grid current when conducting.

In operation the electronically controlled timer has three operable states, namely the initial or reset state, the timing state and the timed out state. The timing state is that period of time for which the timer is set to place in operation some external device. The timed out state is that time period after the external device is set in operation. Finally, the reset state is that period, after the timed out state, for placing the timer in condition for starting a new timing sequence or cycle. Fig. 1 shows the timer circuit in the reset state, and the capacitor **17** charged so that the terminal **15** side of the capacitor is positive and the terminal **16** side is negative. The capacitor **17** is initially charged to a voltage whose magnitude is equal to the D.C. voltage source **1**. The discharge device **5** has both its anode and cathode electrodes connected to the positive terminal of the supply source so that there is essentially no potential gradient from the anode **7** to the cathode **8**. A potential gradient is necessary to cause an electron or current flow through the discharge device and its external circuit.

To set the timer in operation for a given timing period an iintiating switch is actuated by some external means, either automatically or manually, to cause the initiating relay contacts to all function simultaneously. Therefore, when the initiating switch is actuated the timing period begins and the normally open relay contacts **13***a* and **13***c* both close, and simultaneously therewith the normally closed relay contacts **13***b* opens. Terminal

15 is now connected to the negative side of the direct current supply source through the closed contacts **13***a*, and terminal **16** is connected to the positive side of the direct current supply source through the closed contacts **13***c* and the variable resistor R_2. The capacitor **17**, originally charged in a direction such that the terminal **15** side was positive and the terminal **16** side negative, now has its terminals **15** and **16** reversed with respect to the supply source, the terminal **15** now being on the negative supply side and the terminal **16** being on the positive supply side. The reversal in polarity of terminals **15** and **16** provides a discharge path for the initially charged capacitor **17**, the discharge path going from the negative side **3** of the direct current supply through the closed relay contact **13***a* and up through the variable resistor R_2 and finally through the closed relay contacts **13***c* to the positive side of the direct current supply source. The capacitor **17** discharges and goes to zero volts and thereafter recharges in the opposite direction to reverse its polarity. The capacitor in discharging reaches a voltage value which is the critical grid voltage, that voltage at which the electron discharge device starts to conduct, and thereby releases the electron discharge device from its cut-off or non-conductive state. The electron discharge device although in condition for conduction, because of a potential gradient now existing between the positive anode and negative cathode, nevertheless is non-conductive because of the negative grid-bias supplied by the capacitor **17**, this condition prevailing until the capacitor reaches the critical value as previously mentioned. Because the capacitor **17** discharges and recharges across the direct current supply lines through the variable resistor R_2, its time rate of discharge and recharge is dependent upon the magnitude of the variable resistor R_2. Thus the timing period is directly controllable by the variable resistor R_2.

The conduction of the discharge device **5** provides a flow of current in the anode circuit **9** which causes the relay **10** to operate so that the relay contacts **11** and **12** are bridged to complete some controlled utilization circuit **18**. The timer is considered timed-out when the relay **10** functions, although the capacitor continues to discharge and recharge after the stated timed-out period.

To start the timing period or cycle again it is necessary to first reset the timer, that is to say the relay contacts **13***a*, **13***b* and **13***c* must be returned to their initial state and the capacitor must be recharged as initially. This is accomplished by releasing the initiating switch which orginally actuated the relay contacts **13***a*, **13***b* and **13***c*, so that the terminal **15** is disconnected from the negative supply terminal **3** and terminal **16** is returned to the negative supply terminal in its stead. The capacitor, as a result of the terminals now being reversed, will discharge and recharge to the direct current supply source through the resistance R_1 in the opposite direction to that occurring during the timing period. The time duration for discharge and recharge during the reset period is dependent upon the value of the resistive element R_1, this element being in the discharge-charge path across the direct current supply lines during the reset period. During the reset period, the capacitor **17** is recharged to its original polarity and device **5** stops conducting. At this time, relay **10** is cut out due to the relay contacts having returned to their original position.

Fig. 2 illustrates the charge and discharge-charge curve *a* of the capacitor **17** according to the invention and the discharge curve *b* of another capacitor according to previous timing devices. Curve *a* shows the discharge and charge curve of capacitor **17** as it discharges from some fixed negative value through zero and approaches asymptotically a fixed positive value. The discharge-charge curve *a* approaches the critical grid voltage at a large angle *c*, called the angle of incidence. This large angle or incidence *c* provides only a relatively small time differential *e* for a differential change *f* in critical grid voltage. Discharge curve *b*, for the capacitors in the present commercially available timers, shows a relatively small angle of incidence *d* as the curve *b* approaches the critical grid voltage. The time differential *g*, for the same critical grid voltage change *f*, represents a decided increase over that produced by the high angle of incidence. Thus for changes in the critical grid voltage the errors resulting therefrom will be reduced to a minimum by the utilization of a storage device which controls the grid-bias in such a manner as to cause the stated bias to approach the critical point at a high angle of incidence as shown by Fig. 2.

Electron discharge device **5** may consist of any suitable grid controlled electron device, such as a thyratron tube or a vacuum tube. I prefer to use a thyratron tube because of its greater accuracy and, further, because it may be used with a lower supply voltage for a given type of relay coil than a vacuum tube.

From the foregoing it is believed that the construction, operation and advantages of my present invention will be readily comprehended by persons skilled in the art. It is to be clearly understood, however, that various changes in the apparatus set forth above may be made without departing from the scope of the invention, it being intended that all matter contained in the description or shown in the drawing shall be interpreted as illustrative only and not in a limiting sense.

I claim:

1. Time delay control apparatus having positive and negative supply terminals for connection to a direct current source of supply, an electron discharge device having an anode, a cathode and a control grid, circuit controlling means connected in series with the anode-cathode circuit of said electron discharge device across said supply terminals, an initiating device having three pairs of contacts which upon operation of said device simultaneously reverse their settings, one pair of said contacts being normally closed and two pairs thereof being normally open, means for operating said initiating device to reverse simultaneously the settings of its said contact, a capacitor having first and second terminals and having its second terminal connected to said grid of said electron discharge device, a first conductive path for charging said capacitor in a given direction across said supply terminals to render said electron discharge device non-conductive and comprising a resistive element connected between said positive supply terminal and said first terminal of said capacitor in circuit with said pair of normally closed contacts of said initiating device connected between said negative supply terminal and said second terminal of said capacitor, and a second conductive path for discharging and recharging said capacitor in the reverse direction to render said electron discharge device conductive and comprising a variable resistive element connected in series with one pair of said normally open contacts of said initiating device between said positive supply terminal and said second terminal of said capacitor in circuit with the other pair of said normally open contacts of said initiating device connected between said negative supply terminal and said first terminal of said capacitor.

2. Time delay control apparatus having positive and negative supply terminals for connection to a direct current source of supply, an electron discharge device having an anode, a cathode and a control grid, a controlled circuit, a relay having contacts connected in said controlled circuit and an operating winding connected in series with the anode-cathode circuit of said electron discharge device across said supply terminals, an initiating device having three pairs of contacts which upon operation of said device simultaneously reverse their settings, one pair of said contacts being normally closed and two pairs thereof being normally open, means for operating said initiating device to reverse simultaneously the settings of its said contacts, a capacitor having first and second terminals and having its second terminal connected to said grid of said electron discharge device, a first conductive path for charging said capacitor in a given direction across said supply terminals to render said electron discharge device non-conductive and comprising a resistive element connected between said positive supply terminal and said first terminal of said capacitor in circuit with said pair of normally closed contacts of said initiating device connected between said negative supply terminal and said second terminal of said capacitor, and a second conductive path for discharging and recharging said capacitor in the reverse direction to render said electron discharge device conductive and comprising a variable resistive element connected in series with one pair of said normally open contacts of said initiating device between said positive supply terminal and said second terminal of said capacitor in circuit with the other pair of said normally open contacts of said initiating device connected between said negative supply terminal and said first terminal of said capacitor.

References Cited in the file of this patent

UNITED STATES PATENTS

2,444,208	Taylor et al.	June 29, 1948
2,803,814	Bloser	Aug. 20, 1957

OTHER REFERENCES

Publication I, "Precision Interval Timer," Electronics, December 1948, vol. 22, pp. 88 and 89.