This invention relates to an electrical circuit employing capacitor-resistance timing of an operating period.

More specifically, the invention relates to a timing circuit which is particularly suited to controlling electronic tubes, comprising a capacitor and a pair of serially connected resistors in parallel therewith.

One object of the present invention is the provision of a timing circuit suitable for controlling the voltage between the control grid and cathode of an electronic tube.

Another object of the present invention is the provision of a timing circuit suitable for very accurately controlling the voltage between the control grid and the cathode of an electronic tube, in which a capacitor is utilized together with a pair of serially connected resistors in parallel with the capacitor, one of the resistors being fixed while the other is variable.

Another object of the present invention is a timing circuit in accordance with the preceding objects in which the value of the fixed resistor is small in comparison with the maximum resistance of the variable resistor, and large with respect to the minimum resistance of the variable resistor.

Another object of the present invention is a timing circuit in accordance with the preceding objects, in which the capacitor discharges through the fixed and variable resistors, the voltage drop across the variable resistor determining the timing period.

Another object of the present invention is the provision of a timing circuit arrangement which utilizes a capacitor and a pair of serially connected resistors in parallel therewith, the circuit components and connections being such that the voltage between the control grid and cathode of the electronic tube is gradually dissipated, while the voltage applied to a second control element effects the actual initiating moment of conduction.

Other objects and features of the invention will be readily apparent to those skilled in the art from the specification and appended drawing illustrating certain preferred embodiments in which:

The figure is a diagrammatic representation of a welding circuit including the timing arrangement of applicant's invention.

In the figure the numerals 1 and 2 represent a pair of main supply lines which are connected to a source of energy which is not illustrated.

Connected across these lines 1 and 2 is a valve 3 solenoid 3 controlled by a normally open contact 4. A transformer 5 having a secondary 6 is connected across the main supply lines 1 and 2, the secondary 8 of the transformer serving to supply voltage to conductors 7 and 9. A half-wave rectifier 11 in circuit with the secondary 6, cooperates with a smoothing capacitor 12 which is connected between the conductors 7 and 6, to provide these conductors with a pulsating D.C. voltage.

Seriesly disposed across the conductors 7 and 8 is a pair of resistors 13 and 14 which are connected by a conductor 15 to a timing circuit comprising a fixed resistor 16, a variable resistor 17 in series therewith, and a capacitor 18 connected in parallel with these two resistors. The resistance of resistor 16 is large with respect to the minimum resistance of the variable resistor 17, but small with respect to the maximum resistance of resistor 17. This timing circuit is connected to the conductor 7 through a normally closed contact 18, and also to the control grid 21 of an electronic tube 22 having a cathode 23 and an anode 24, the cathode 23 being connected to conductor 8, the anode 24 connected to conductor 7 through a normally open contact 20 and resistor 29. Tube 22 has a shield grid 25 which is connected between a capacitor 26 and a resistor 27 serially disposed between the conductors 7 and 8.

Connected to the resistor 29 is a conductor 31 which serves to connect a timing circuit comprising an adjustable resistor 32 and a capacitor 33 in series therewith, to the anode circuit of tube 22. The capacitor 33 is normally shorted out by a contact 34 which is normally closed. A conductor 35 is connected between the adjustable resistor 32 and the capacitor 33 and to a secondary 36 of a transformer 45, the primary of which is connected across lines 1 and 2, the secondary 38 serving to supply heat to the cathode 37 of an electronic tube 38. This tube has an anode 39 and a control grid 41 and the principal electrodes are supplied from a secondary 46 of the transformer 45. A capacitor 42 is connected between the control grid 41 and the cathode 37 of the tube 38, and to a point between a pair of voltage dividing resistors 43 and 44 which are serially disposed between the conductors 7 and 8. A relay cell 47 is disposed between the anode 39 of tube 38 and the transformer secondary 46, the relay cell 47 being parallel by a capacitor 48 and an inductor 49, this parallel circuit being further paralleled by the primary of a transformer 51. The advantages and detailed operation of this relay circuit are particularly pointed

The relay coil 47 controls the closure of a normally open contact 52 connected in a back-to-back circuit comprising ignitrons 53 and 54 conventionally disposed between the main lines 1 and 2 and serving to control the energization of a welding transformer 55 having a secondary 56 for passing current to the work to be welded. The stroke of this relay is designed so that contact 52 closes during the first half cycle following the first conducting half cycle of tube 36, and in the preferred embodiment at a point in that half cycle which approximately corresponds to a normal current zero point for a welding transformer of average power factor. The secondary of transformer 51 is connected through a resistor 58 of an electronic tube 59, the anode of which is connected to the conductor 7, the cathode being connected to a timing circuit comprising a fixed resistor 69, an adjustable resistor 61 in series therewith, and a parallel capacitor 62, a conductor 63 being connected between the fixed and variable resistors to introduce a voltage into the timing circuit from a second circuit comprising a resistor 64 and resistor 65, these latter resistors being serially connected between the conductor 7 and a cathode heating circuit to be subsequently explained. The timing circuit arrangement consisting of capacitor 62 and resistors 65 and 69 is like that described for the arrangement of capacitor 18 and resistors 16 and 17.

The capacitor 62 is connected to a control grid 66 of an electronic tube 67 having an anode 68 and a cathode 69, the anode 68 being connected through a resistor 71 to the conductor 9 while the cathode 69 is connected to the aforementioned cathode heater circuit. The resistor 71 is connected through another resistor to a control grid 72 of an electronic tube 73, the anode of which is connected to the conductor 7, while the cathode is connected to another timing circuit comprising a fixed resistor 74 and a variable resistor 75 in series therewith, the series circuit being parallel to a capacitor 76. The arrangement of this timing circuit is like that previously described. A voltage is introduced into this timing circuit by a conductor 78 from a series circuit comprising a resistor 77 and a resistor 79 these resistors being serially disposed between conductor 7 and the aforementioned cathode heater circuit.

The capacitor 76 is connected to a control grid 78 of an electronic tube 81, having an anode 82 and a cathode 83, these electrodes of tube 81 being connected across one secondary 85 of a transformer 86 through a normally open manual operated switch 86 and a relay coil 87, a capacitor 88 paralleling the relay coil. The primary of transformer 86 is connected across the supply lines 1 and 2. The relay coil controls the operation of a contact 89, which is normally open and which parallels the manually operated switch 86, this relay coil also controlling the operation of contacts 4, 15, 23 and 34. A second secondary 61 of transformer 85 supplies the cathode heaters of tubes 22, 61 and 81. In the description of the circuit, conventional elements such as surge bypass capacitors, fuses, thermal flow switches and other conventional elements have been eliminated although these would be present in an operating circuit. This elimination of conventional parts has been effected for purposes of simplicity, their position and function being well known to those familiar with the art.

Prior to the operation of the manually operated switch 86, the valve solenoid 3 is deenergized as contact 4 is open. Contact 19 is closed, and capacitor 18 is charged to approximately the full voltage between conductors 7 and 8 through control grid rectification of tube 22. Contact 23 is, as illustrated, in an open condition thus disconnecting the anode 54 of tube 22 from the conductor 7. The contact 34 is closed, thereby shorting out capacitor 33 and the contact 85 is open, no path from secondary 84 through the tube 81 therefore existing. These contacts are mechanically arranged so that the normally closed contacts 18 and 24 will open before the normally open contacts 4, 28 and 89.

Upon closure of the manually operated switch 86, tube 81 will begin to conduct as soon as secondary 84 drives the anode 52 positive with respect to the cathode 53, the operation of this tube serving to energize the relay coil 87. During the half cycles in which tube 81 does not conduct, due to improper polarity of the transformer secondary 84, the capacitor 88 serves to maintain the relay coil 87 in an energized condition in the conventional manner. As contact 19 opens, the control grid 21 of tube 22 is swept negative with respect to the cathode 23 of that tube due to the change on capacitor 18. As contact 34 opens, the short across capacitor 33 is eliminated. As the contact 4 then closes, the valve solenoid 3 is energized, and the welding electrode act to apply pressure to the work in the conventional manner to start the "squeeze time" period. Closure of contact 28 completes the anode circuit of tube 24, but this tube cannot begin to conduct due to the charge on capacitor 18. Closure of contact 89 forms a manual-beat holding circuit across the manually operated switch 86.

Tube 22 remains in the quiescent condition aforementioned for a period determined by the timing elements including the capacitor 18 and the resistors in parallel therewith, these elements determining the length of the "squeeze time" period. The discharge of capacitor 18 through the resistors 16 and 17 causes a voltage drop across these resistors which varies with the discharge current. In previous timing systems where short timing periods were desired, the variable resistor would be set to a small value, and the capacitor would discharge through this small value of resistance rapidly. The voltage across the resistor (or resistors) which determined the timing period would therefore rapidly change, and the exact instant at which the timed element, usually an electronic tube, would act at the termination of a timed period would be difficult to control. This is true especially if the timed element is to be actuated at the end of the timed period by a second voltage, for example a voltage supplied to the shield grid of an electronic tube, as illustrated herein. The circuit illustrated in Figure 1 obviates these difficulties by using a resistor 16 having a resistance which is large in comparison with the minimum value of the variable resistance, and by employing as the timing voltage that voltage which is across the resistor 17. As the value of resistance in resistor 17 is decreased, more and more of the voltage across capacitor 18 appears across resistor 17. Therefore the largest voltage across this variable resistance element at a minimum
time setting is relatively small, and as the capacitor 48 discharges current through this element, the actual change in the voltage appearing across it will be relatively small, the greatest part of the voltage of capacitor 48 appearing across resistor 16. The voltage difference between the cathode 23 and control grid 21 of tube 22 will therefore be diminished gradually. The shield grid 35 of tube 23 is synchronously driven positive by the pulsed conduction of rectifier 11 as it acts to charge the smoothing capacitor 12. One of these positive pulsations of the shield grid, therefore, triggers the tube 22 after the voltage between the grid 21 and cathode 23 is sufficiently small. The resistance of resistor 16 is sufficiently small in comparison to the maximum resistance of the variable resistor 17 so as to have negligible effect at that setting.

Prior to the conduction of tube 22, the control grid 41 of the tube 30 is negative with respect to the cathode 37 of that tube. The capacitor 42 is charged with a polarity according to this voltage difference. As tube 22 begins to conduct, the conductor 35 tends to carry the shield grid 35 of the tube 38 as a negative amount due to the voltage drop across the adjustable resistor 32, this drop being due to conduction current of the tube 22. This has a tendency to cause the cathode 37 of tube 38 to become negative with respect to the control grid 41, but the charge on capacitor 42 momentarily prevents this occurrence. Inasmuch as tube 22, as previously mentioned, is rendered conducting by a positive pulse of voltage upon the shield grid 25 thereof, this positive pulse occurring adjacent to the mid point of a half cycle of voltage, if the capacitor 42 were not present tube 38 might begin to conduct during the latter half of a half cycle, thereby causing current to flow through the ignitrons and the welding transformer for only a portion of a half cycle. Capacitor 42 prevents this unfavorable occurrence, the charge on the capacitor 42 being rapidly dissipated, however, through the resistors 43 and 44 so that during the next positive excursions of the grid 38 voltage tube 38 will conduct to energize the relay coil 47, the conduction therefore occurring only during a whole half cycle.

As current passes from the secondary 45 of transformer 45 through the relay coil 47 and the electronic tube 38, the normally open contact 52 is closed at the instant previously described, causing the conventionally disposed ignitrons 53 and 54 to pass current through the welding transformer 55 for as long as the contact 52 remains closed. During the half cycles of non-conduction of tube 38, the capacitor 48 discharges through the relay coil 47 to maintain the relay in an energized condition. Tube 39 will continue to conduct and the coil 47 will remain energized for a period determined by the timing combination comprising the adjustable resistor 32 and the capacitor 35. As conduction current of tube 22 passes through the resistor 32 and the capacitor 33 and subsequently through tube 22, a charge is built up upon the capacitor 33 until this charge is sufficiently large to cause the cathode 37 of the tube 38 to become positive with respect to the control grid 61 thereof. When this condition prevails, tube 38 is cut off and no longer conducts. The time required to build a charge on capacitor 33 therefore determines the "hold time."

During the first half cycle after tube 38 stops conducting, capacitor 48 will act, as before described, to keep the relay coil 47 energized; during the half cycle following this occurrence, the inductor 49, which is in series with the capacitor 48, causes a definite deenergization of the relay coil 47, the contact 52 thereby returning to its normal open condition. This opening will not occur until after the "trail" ignitor has begun to conduct.

During the period in which tube 33 conducts, the primary of transformer 51 is energized, the secondary of the transformer 51 driving the grid 57 of the electronic tube 58 sufficiently positive to cause that tube to conduct. This conduction charges capacitor 62 through control grid 66 conduction of electronic tube 67. These pulses occur during the time when the anode 68 of tube 67 is negative with respect to the cathode 69 thereof, so that the tube 67 is immediately cut off by the charge on capacitor 62 and does not, therefore, conduct during the period in which tube 33 conducts.

The timing arrangement comprising capacitor 62 and resistors 59 and 61 in the grid circuit of electronic tube 67 is that described earlier and acts to permit the voltage at the cathode 57 of tube 67 and grid 57 to very gradually approach a single value. Superimposed upon the gradually decreasing voltage of capacitor 62 is a synchronizing alternating ripple fed into the voltage divider circuit which comprises resistors 64 and 65 from the transformer secondary 51 and, hence, to the control grid 66. This ripple controls the actual moment at which conduction of tube 67 is initiated. Tube 67 will therefore remain non-conductive until capacitor 62 has properly discharged through the circuit in parallel therewith, the actual instant of initiation of conduction being controlled by the positive drive of the synchronizing pulse from the cathode heater circuit. It should be noted that this pulse is applied to the control grid, while the synchronizing pulse applied to trigger tube 22 was applied to the shield grid of that tube.

Throughout the period in which tube 67 is quiescent, the control grid 72 of tube 73 is at approximately the potential of conductor 9 and is intermittently sufficiently positive so that the tube 72 will conduct to charge capacitor 76 through control grid 79 conduction of electronic tube 81. Inasmuch as these current pulses occur during the half cycles in which the anode 82 of the tube 81 is positive with respect to the cathode 83 of that tube, tube 81 is not immediately cut off, as was the case with tube 67. Tube 81 will therefore continue to conduct until the before described timing control voltages of tube 57 are such that that tube 67 will again resume conduction. The elements which determine these timing voltages thereby control the "hold time" of the circuit. The conduction of tube 67 will no longer permit the grid 72 of tube 73 to become sufficiently positive to permit tube 72 to conduct, so the charge on capacitor 76 cuts off tube 81 as soon as tube 76 begins to conduct. The timing circuit controlling conduction of tube 81 is the same as that before described for the control of the tube 67, the voltage between the cathode 83 and control grid 79 being gradually dissipated. As soon as tube 81 is cut off, the relay coil 87 is deenergized and the contacts which it controls are returned to the position indicated in the drawing. Immediately after the circuit controlling the control grid 19 of tube 81 has timed out, the voltage fed into the timing circuit of this tube from the cathode heater secondary 91 triggers the tube 81 which will once again conduct,
provided initiated contact 66 is closed, to initiate another cycle as that herein described.

It will be obvious that the particular circuit arrangement and variable capacitor's invention provides an extremely reliable method of timing which is particularly effective in eliminating undesirable loss of control over the timed element during short control settings, especially where a second voltage is employed to trigger the controlled element.

In the illustrated circuit, the electronic tubes are triggered by a ripple voltage applied at a grid of the tubes employed, and the circuit illustrated clearly shows a plurality of connections to effect this control, the circuit of applicant's invention permitting the grid to effect conduction of the controlled tubes even at minimum time settings.

While certain preferred embodiments of the invention have been specifically disclosed, it is understood that the invention is not limited thereto, as many variations will be readily apparent to those skilled in the art and the invention is to be given its broadest possible interpretation within the terms of the following claims.

What is claimed is:

1. In a timing system, a capacitor, a source of voltage, means for charging said capacitor from said source of voltage, discharging means associated with said capacitor comprising first and second resistors, said first and second resistors being serially connected and in parallel with said capacitor, said first resistor being fixed while said second resistor is variable, the resistance of said first resistor being small in comparison to the maximum resistance of said second resistor and large in comparison to the minimum resistance of said second resistor, timed means, and means electrically impressing upon said timed means substantially only that portion of the voltage across said discharging means which exists across said variable resistor, whereby said timed means is responsive to voltage drop across said variable resistor and determines a timed period as said capacitor discharges through said fixed and variable resistors.

2. In a timing circuit, a source of voltage, a capacitor, said capacitor being charged from said source of voltage, discharging means for said capacitor comprising serially connected fixed and variable resistors in parallel with said capacitor, the resistance of said fixed resistor being large in comparison with the minimum resistance of said variable resistor, an electronic tube connected across said source of voltage and having an anode and cathode and at least an auxiliary electrode, means for impressing substantially only that portion of the voltage across said discharging means which exists across said variable resistor between an auxiliary electrode and the cathode of said electronic tube, means for discharging through said fixed and variable resistors, and means for superimposing an additional triggering voltage between an auxiliary electrode and said cathode to determine the conduction of said electronic tube to effect a control function.

3. In a timing circuit, a source of voltage, a capacitor, said capacitor being charged from said source of voltage, discharging means for said capacitor comprising serially connected fixed and variable resistors in parallel with said capacitor, the resistance of said fixed resistor being large in comparison with the minimum resistance of said variable resistor, an electronic tube connected across said source of voltage having an anode and cathode and at least a control grid and an auxiliary grid, means for impressing substantially only that portion of the voltage across said discharging means which exists across said variable resistor between the control grid and cathode of said electronic tube as said capacitor discharges through said fixed and variable resistors, and means for superimposing an additional triggering voltage between said auxiliary grid and said cathode to determine the conduction of said electronic tube to effect a control function.

4. In a timing circuit, a source of voltage, a capacitor, said capacitor being charged from said source of voltage, discharging means for said capacitor comprising serially connected fixed and variable resistors in parallel with said capacitor, the resistance of said fixed resistor being large in comparison with the minimum resistance of said variable resistor, an electronic tube connected across said source of voltage having an anode and cathode and at least a control grid and a shield grid, means for impressing substantially only that portion of the voltage across said discharging means which exists across said variable resistor between the control grid and cathode of said electronic tube as said capacitor discharges through said fixed and variable resistors, and means for applying a triggering voltage to said shield grid to determine the conduction of said electronic tube to effect a control function.

5. In a timing circuit, a source of voltage, a capacitor, said capacitor being charged from said source of voltage, discharging means for said capacitor comprising serially connected fixed and variable resistors in parallel with said capacitor, the resistance of said fixed resistor being large in comparison with the minimum resistance of said variable resistor, an electronic tube connected across said source of voltage having an anode and cathode and at least an auxiliary electrode, means for impressing substantially only that portion of the voltage across said discharging means which exists across said variable resistor between an auxiliary electrode and the cathode of said electronic tube as said capacitor discharges through said fixed and variable resistors, and means for superimposing an additional triggering voltage between an auxiliary electrode and said cathode to determine the conduction of said electronic tube to effect a control function.

6. In a timing circuit, a source of voltage, a capacitor, said capacitor being charged from said source of voltage, discharging means for said capacitor comprising serially connected fixed and variable resistors in parallel with said capacitor, the resistance of said fixed resistor being large in comparison with the minimum resistance of said variable resistor, an electronic tube connected across said source of voltage having an anode and cathode and at least an auxiliary electrode, means for impressing substantially only that portion of the voltage across said discharging means which exists across said variable resistor between an auxiliary electrode and the cathode of said electronic tube as said capacitor discharges through said fixed and variable resistors, and means for superimposing an additional triggering voltage between an auxiliary electrode and said cathode to determine the conduction of said electronic tube to effect a control function.

7. In a timing circuit, a source of voltage, a capacitor, said capacitor being charged from said source of voltage, discharging means for said capacitor comprising serially connected fixed and variable resistors in parallel with said capacitor, the resistance of said fixed resistor being large in comparison with the minimum resistance of said variable resistor, an electronic tube connected across said source of voltage having an anode and cathode and at least a control grid and an auxiliary grid, means for impressing substantially only that portion of the voltage across said discharging means which exists across said variable resistor between the control grid and cathode of said electronic tube as said capacitor discharges through said fixed and variable resistors, and means for superimposing an additional triggering voltage between said auxiliary grid and said cathode to determine the conduction of said electronic tube to effect a control function.
comparison with the minimum resistance of said variable resistor and small in comparison with the maximum resistance of said variable resistor, an electronic tube connected across said source of voltage having an anode and cathode and at least control and auxiliary grids, means for impressing substantially only that portion of the voltage across said discharging means which exists across said variable resistor between the control grid and cathode of said electronic tube as said capacitor discharges through said fixed and variable resistors, and means for superimposing an additional triggering voltage between said auxiliary grid and said cathode to determine the conduction of said electronic tube to effect a control function.

8. In a timing circuit, a source of voltage, a capacitor, said capacitor being charged from said source of voltage, discharging means for said capacitor comprising fixed and variable resistors in parallel with said capacitor, the resistance of said fixed resistor being large in comparison with the minimum resistance of said variable resistor and small in comparison with the maximum resistance of said variable resistor, an electronic tube connected across said source of voltage and having an anode and cathode and at least an auxiliary electrode, means for impressing substantially only that portion of the voltage across said discharging means which exists across one of said resistors between an auxiliary electrode and the cathode of said electronic tube as said capacitor discharges through said fixed and variable resistors, and means for superimposing an additional triggering voltage between an auxiliary electrode and said cathode to determine the conduction of said electronic tube to effect a control function.

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