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ELECTRICAL CONTROL CIRCUIT

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FIG. 1

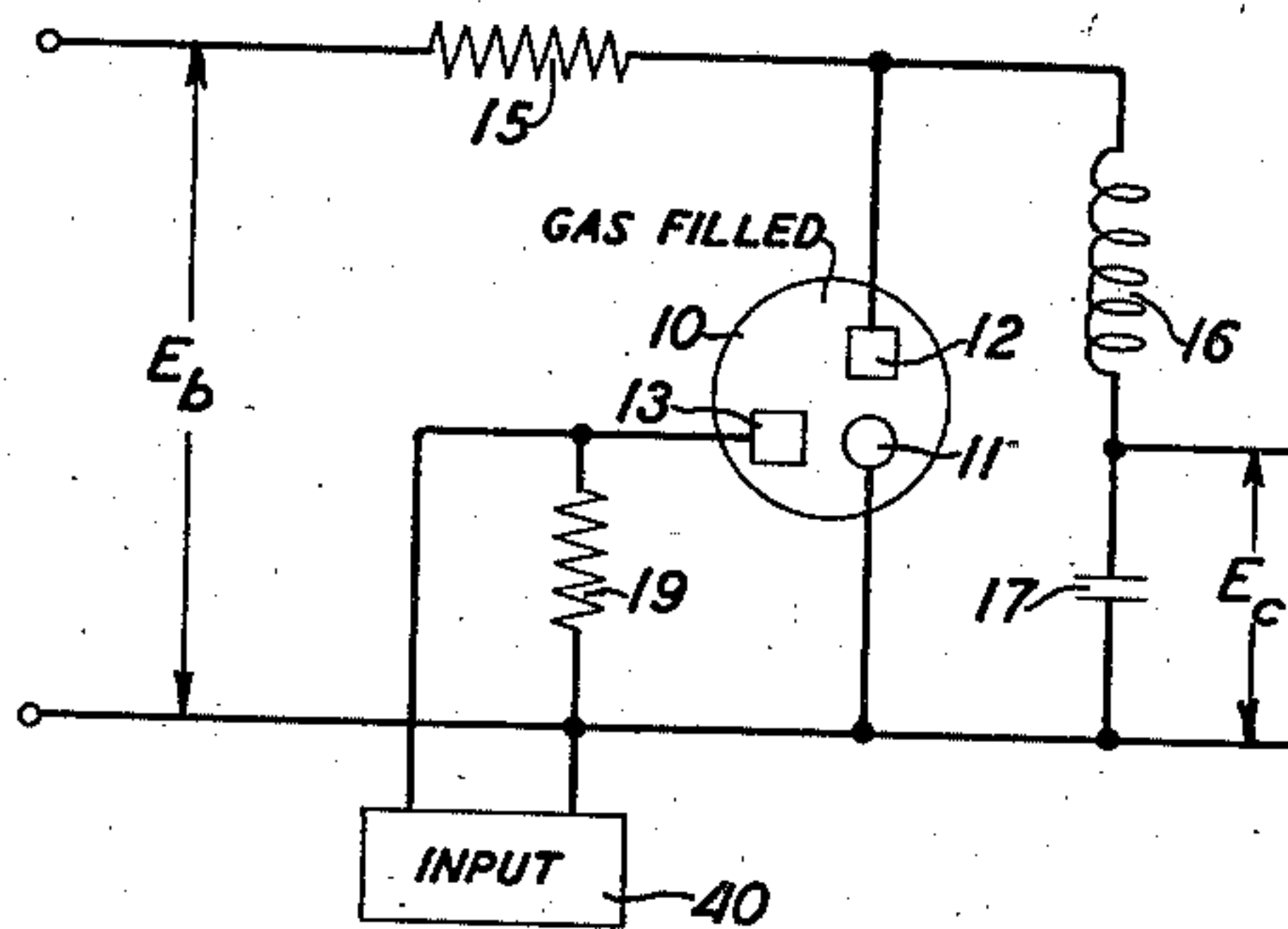
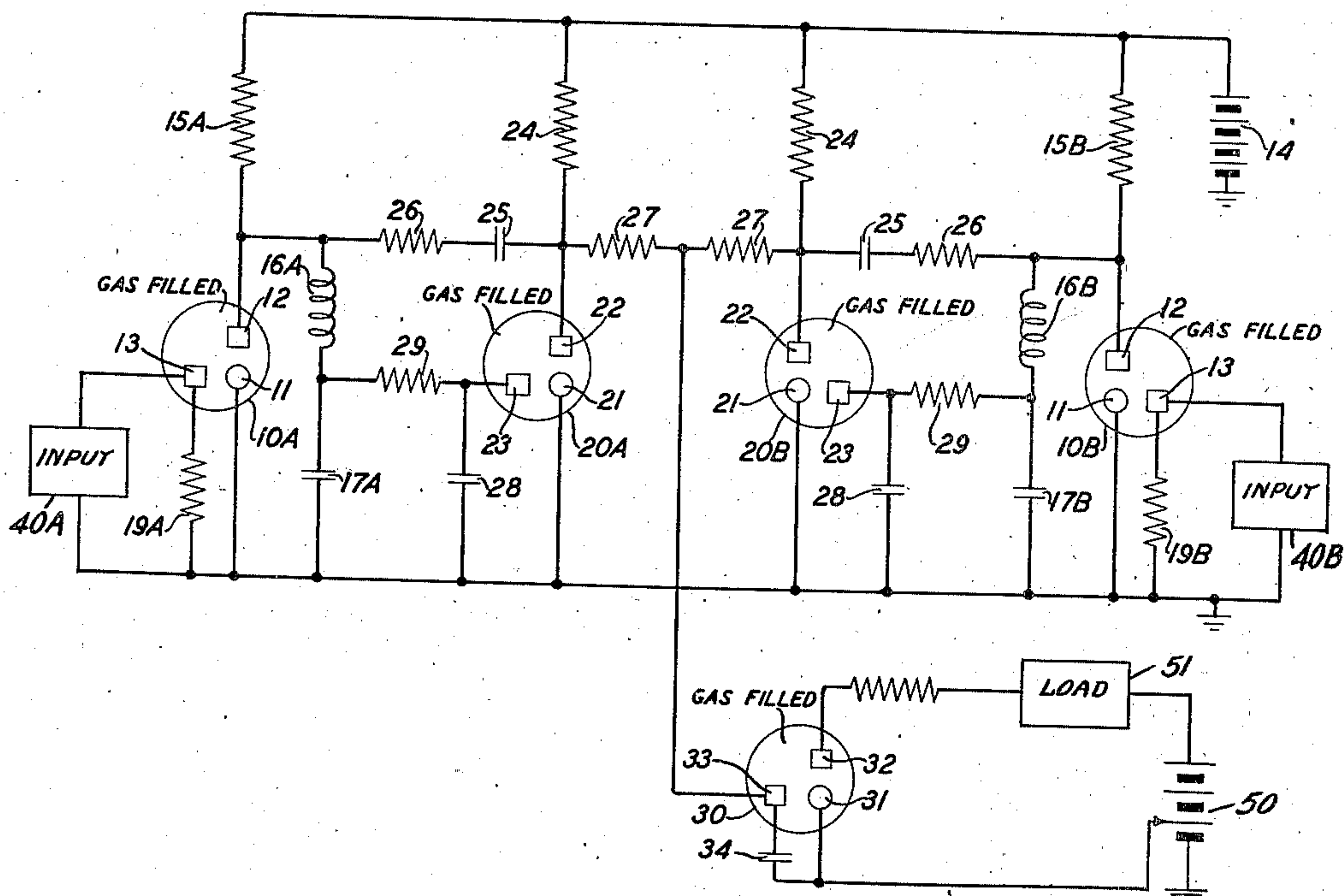


FIG. 2



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ELECTRICAL CONTROL CIRCUIT

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This invention relates to electrical control circuits and more particularly to electrical timer circuits including discharge devices of the gaseous, trigger control type.

One general object of this invention is to produce, in an electrical control circuit, an output voltage pulse of desired amplitude and of prescribed and substantially constant duration.

More specifically, one object of this invention is to obtain, in an electrical circuit including gaseous discharge devices, a voltage pulse of a prescribed duration substantially independent of the voltage of the supply source for the circuit.

Another object of this invention is to produce in such a circuit a voltage which will increase from a minimum to a predetermined amplitude in a substantially constant time after initiation of operation of the circuit.

A further object of this invention is to control an operating, voltage producing element in accordance with such an increasing voltage so that during the interval in which the increasing voltage rises from a minimum to the predetermined amplitude, the element produces a voltage pulse.

In one illustrative embodiment of this invention, an electrical control circuit especially suitable for use in marine mines comprises a pair of gaseous discharge devices each having a cathode, a main or work anode and a control electrode or anode, a load circuit connected to the main anode of one of the devices, an input circuit connected to the control anode of the other device, and a direct current voltage supply source for the two devices.

In accordance with one feature of this invention, the two devices are associated with one another and the source so that normally the one device aforementioned is conducting and the other is non-conducting and when the other device is rendered conducting, as by the application of a suitable signal voltage to the control anode thereof, the one device is extinguished, and means are provided in association with the other device for impressing upon the control anode of the one device, at a substantially fixed interval after firing of the other device, a voltage sufficient to again render the one device conducting. When the one device is extinguished, its main anode potential rises abruptly; when it is again rendered conducting, the main anode potential thereof falls. Thus, during the interval noted, a voltage pulse is supplied to the load circuit.

In accordance with another and specific feature of this invention, the two discharge devices are such that the control gap breakdown voltage of the one device is substantially equal to the

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main gap sustaining voltage of the other device and the means aforementioned comprises a condenser connected across the main gap of the other device through an inductance and connected also across the control gap of the one device by way of a suitable resistance. When the other device fires, the condenser discharges therethrough, its voltage falls to a minimum value and then the condenser begins to charge so that its voltage increases. After a time, determined by the circuit constants and substantially independent of the supply source voltage, the condenser voltage has increased to a value substantially equal to the main gap sustaining voltage of the other device, and hence substantially equal also to control gap breakdown voltage of the one device, so that the one device is again rendered conducting.

In accordance with a further feature of the invention, the load circuit includes a third gaseous discharge device of the trigger type which is normally non-conducting and two pairs of gaseous discharge devices, cooperatively associated in the manner of the one and other device as described hereinabove, are associated with the control anode of the third device in such relation that when one pair of devices operates to produce a voltage pulse the third device is primed and if, during the period of this pulse, the other pair of devices operates to produce a pulse, the third device is rendered conducting.

The invention and the aforementioned and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

Fig. 1 is a diagram showing the general association of a gaseous discharge device and a condenser included in timer circuits illustrative of this invention; and

Fig. 2 is a schematic of a timer circuit illustrative of one embodiment of this invention.

Referring now to the drawing, the combination illustrated in Fig. 1 comprises a gaseous discharge device 10 of the cold cathode trigger type having a cathode 11, a main or work anode 12 defining a main discharge gap with the cathode and an auxiliary or control anode 13 defining a control gap with the cathode. As is known, such a device may be rendered conductive, with the main anode voltage less than the breakdown potential of the main gap but of at least a prescribed magnitude, commonly termed the sustaining voltage, by the application to the control anode of a voltage at least as great as the breakdown potential of the control gap. The cathode 11 and main anode 12 are connected

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across a direct current source, such as a battery, not shown, a resistance 15 being provided in series with the main anode as shown. Connected across the main gap of the device 10 by way of an inductance 16 is a condenser 17. An input resistor 19 is connected between the control anode and cathode and to an input circuit 40, as shown.

Assume that the voltage of the source is somewhat above the sustaining voltage of the main gap of the discharge device 10. In the absence of a voltage upon the control anode 13 sufficient to break down the control gap, the condenser 17 will be charged to the voltage of the direct current source. If, then, a voltage sufficient to effect breakdown of the control gap is applied to the control anode 13, the device 10 will be rendered conductive and the condenser will discharge through the device so that the voltage across the condenser 17 will fall to a certain minimum value. By proper correlation of the parameters of the discharge circuit in ways known in the art, the fall in condenser voltage to the minimum value may be made very abrupt so as to be substantially instantaneous for practical purposes and the minimum value may be below the sustaining voltage of the main gap of the discharge device 10. After the condenser voltage has fallen to the minimum value, below the sustaining voltage of the main gap of the device 10, the condenser becomes charged so that its voltage increases exponentially and, after an interval, determined by circuit constants as pointed out hereinafter, reaches a value equal to the sustaining voltage of the main gap of the device 10.

It can be shown readily that in the general case of a condenser in parallel with a rectifier and charging from a source, at the instant when the condenser current passes through zero, the negative voltage on the condenser is some fraction, determined by the resistance, inductance and capacitance of the circuit, of the maximum charging voltage. In the circuit illustrated in Fig. 1, when the condenser voltage is at its minimum value, the voltage acting to charge the condenser is

$$E_b - E_m = (1 + K)(E_b - E_s) \quad (1)$$

where

E_b = voltage of the source

E_m = minimum voltage of the condenser 17

E_s = sustaining voltage of the main gap of device 10, and

K = a constant, for practical purposes

$$e^{\frac{-R\pi}{4L\sqrt{\frac{1}{LC}}}}$$

e = the Naperian base

L = inductance of the coil 16

R = resistance of the coil 16 and the device 10

C = capacitance of the condenser 17

The condenser voltage, E_c , at any instant is given by the relation

$$E_c = (E_b - E_m) \left(1 - e^{\frac{-t}{RC}} \right) + E_m \quad (2)$$

where t = time.

From Equations 1 and 2, it will be seen that

$$e^{\frac{-t}{RC}} = \frac{E_b - E_c}{(1 + K)(E_b - E_s)} \quad (3)$$

When $E_c = E_s$, it follows from Equation 3 that

$$e^{\frac{-t}{RC}} = \frac{1}{1 + K} = K_1 \quad (4)$$

Thus, as is apparent from Equation 4, the time

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required to charge the condenser 17 from its minimum value, E_m , back to the sustaining voltage, E_s , of the discharge device 10 is independent of the source voltage, E_b , and is determined solely by the circuit constants.

The circuit illustrated in Fig. 2 comprises two combinations identical with that illustrated in Fig. 1 and described hereinabove, the elements of these combinations in Fig. 2 being identified by the same numeral as the corresponding elements of Fig. 1 plus the letter A or B. The circuit comprises also a pair of gaseous discharge devices 20A and 20B of the cold cathode trigger type, each of which includes a cathode 21, a main or work anode 22 and a control anode 23. The main anode 22 of each discharge device 20 is connected to the source 14 through a resistor 24, smaller than the resistances 15, and is connected also to the main anode of the respective discharge device 10 through a condenser 25 and resistance 26 in series. The main anodes of the devices 20 are connected to each other by equal resistances 27.

Each of the control anodes 23 is connected to the respective cathode 21 by a suitable condenser 28 and the control gap of each device 20 is connected across the respective condenser 17 through a high resistance 29. For reasons which will appear presently, the devices 20 are of such construction that the control gap breakdown voltage thereof is equal to the main gap sustaining voltage of the respective device 10.

A load circuit comprises a trigger type gaseous discharge device 30 having a cathode 31, for example of the cold type, a main anode 32 and a control anode 33 connected directly to the midpoint between the resistances 27 and connected to the cathode 31 by a suitable condenser 34 which serves to minimize the effects of transients in the circuit, upon the voltage of the control anode 33. A suitable source 50 in circuit with a load 51, is provided for establishing between the cathode 31 and main anode 32 a direct current potential below the breakdown voltage of the main gap of the device 30 but sufficient to sustain a discharge thereacross.

Normally, that is when no signal voltages are applied to the control anodes 13, both the discharge devices 10 are non-conducting and both the discharge devices 20 are conducting due to the application of suitable potentials to the control anodes 23 from the source 14 by way of the respective resistances 15 and 29 and inductance 16. The condensers 17 are charged to the voltage of the source 14. The discharge device 30 also is non-conducting and no current is supplied to the load. When a signal voltage of sufficient magnitude to break down the control gap of the device 10A is applied to the control anode of this device, the device 10A is rendered conductive. Consequently, the device 20A is extinguished by virtue of its connection to the device 10A by the condenser 25 and resistance 26 associated therewith. When the device 20A extinguishes, the voltage of its main anode 22 rises to substantially the voltage of the source 14 so that a voltage pulse is supplied to the control anode 33 of the device 30, the constants of the circuit being such that this pulse is of insufficient amplitude to render the device 30 conductive.

When the device 10A becomes conductive, the condenser 17A discharges therethrough and the voltage across the condenser 17A increases with time in accordance with Equation 2. After an interval, which is independent of the supply voltage as pointed out hereinabove, the condenser

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voltage becomes equal to the main gap sustaining voltage of the device 10A and inasmuch as, as pointed out heretofore, the control gap breakdown voltage of the device 20A is equal to the main gap sustaining voltage of the device 10A, at the end of this interval the device 20A is rendered conductive. Thus, a voltage pulse of predetermined amplitude and of duration independent of the supply voltage is impressed upon the control anode 33 of the device 30.

If, during this interval, a signal voltage of sufficient magnitude to break down the control gap is impressed upon the control anode 13 of the device 10B, this device will be rendered conductive. Consequently, the device 20B will be extinguished, the potential of the main anode 22 will rise and a voltage pulse, additive with respect to the pulse due to the extinguishing of the device 20A, will be supplied to the control anode of the device 30 so that the device 30 is rendered conductive and current is supplied to the load.

In any particular circuit, certain general relationships should be observed. Of course, the resistance 15 and condenser 17 must be such as to provide the desired time interval. In a specific circuit, a resistance 15 of 15 megohms and a condenser 17 of 15 microfarads have been found satisfactory for producing a pulse of approximately 120 seconds' duration. The inductance 16 should be such as to limit the peak current when the condenser 17 discharges, to a safe value for the device 10. In general, the resistance 29 should be very large in comparison to the resistance 15 so that the condenser 17 may be charged to a voltage substantially equal to the voltage of the source 14. In a specific circuit wherein the resistance 15 was 15 megohms, the voltage upon the control anode 23 was approximately 60 volts when the device 20 is conducting and the source voltage was approximately 175 volts, a resistance 29 of 100 megohms has been found to be satisfactory. The resistance 24 should be sufficiently small so that the associated device 20 does not behave as a relaxation oscillator due to its interelectrode capacitance. The condenser 28 must be large enough to initiate a discharge in the associated device 20 by discharge of the condenser from the control gap breakdown voltage to the control gap sustaining voltage of this device.

It will be understood, of course, that the circuit shown in Fig. 2 will operate similarly if a signal voltage is applied to the control anode of the device 10B before the application of a signal voltage to the control anode of the device 10A. In either case, the firing of one of the devices 10A or 10B primes the device 30 and the firing of the other device 10A or 10B during the interval in which the device 20 associated with the first fired device 10 is extinguished, results in the firing of the device 30. It will be understood also that although in the circuit illustrated in Fig. 2 the two portions, each including the discharge device 10A or 10B, corresponding discharge device 20A or 20B and associated impedances, have been described as identical, these two portions may have different constants so that the duration of the period wherein one portion is operative to apply a pulse to the control anode 33 is longer or shorter than the period wherein the other portion is operative to provide such a pulse.

It will be understood also that although the invention has been described with particular reference to systems including discharge devices of the cold cathode type, it may be practiced also

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in systems including gaseous discharge devices of the heated or incandescable type. A particular advantage of the use of devices of the latter type is the low value of sustaining voltage, E_a , therefore, the low value of the minimum voltage E_m that may be utilized and the corresponding ease with which one device may be extinguished by another.

It is manifest that the invention provides a timer circuit which is utilizable in a variety of applications where a voltage pulse of prescribed duration is desired. As an illustration, and as noted heretofore, the circuit shown in Fig. 2 is especially suitable for use in marine mines. In such case, for example, the device 10A may be fired in response to the application of a signal to the control electrode 13 of this device by a magnetic detector responsive to the approach of a ship into the vicinity of the mine and the device 10B may be fired by a signal applied to its control electrode 13 by a detector when the ship reaches a prescribed position with respect to the mine. The firing of both devices 10A and 10B results in firing of the device 30, which may serve as a detonator control for the explosive charge in the mine.

Further, it will be understood that the specific embodiment of the invention shown and described is but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. An electrical control circuit comprising a gaseous discharge device having a cathode, an anode defining a main gap with said cathode and a control electrode defining a control gap with said cathode, a load circuit connected to said anode, a direct current source connected to said anode and control electrode for applying thereto biasing potentials sufficient to render said device conducting, the potential applied to said anode being below the breakdown potential of said main gap, a normally non-conducting electronic rectifier connected to said source and in circuit with said main gap and effective when conducting to render said device non-conducting, a condenser in parallel with said rectifier, means including a high resistance connecting said condenser in circuit with said control gap, and means for rendering said rectifier conducting.

2. An electrical control circuit in accordance with claim 1 wherein said electronic rectifier is a gaseous discharge device having main and control gaps, and the sustaining voltage of the main gap of said second device is substantially equal to the control gap breakdown voltage of said first device.

3. An electrical control circuit comprising a first gaseous discharge device having a cathode, an anode defining a main gap with the cathode and a control electrode defining a control gap with the cathode, a direct current source connected to said anode to establish across said main gap a potential sufficient to sustain a discharge thereacross but less than the breakdown voltage thereof, means for biasing said control electrode at a potential sufficient to initiate a discharge in said main gap, a load circuit connected to said anode, means for extinguishing said device comprising a second gaseous discharge device having a main gap connected in parallel relation with the main gap of said first device and having also a control gap, and means for refiring said first device at a prescribed time after it is extinguished

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by said extinguishing means comprising a condenser connected across the main gap of said second device through a low resistance path and connected also across the control gap of said first device and a charging circuit for said condenser including said source and a resistance.

4. An electrical circuit in accordance with claim 3 wherein the breakdown voltage of the control gap of said first device is substantially equal to the sustaining voltage of the main gap of said second device.

5. In combination, a gaseous discharge device including a cathode, an anode defining a main gap with said cathode and a control electrode defining a control gap with said cathode, a direct current source for impressing across said main gap a voltage below the breakdown voltage but at least as great as the sustaining voltage thereof, means for impressing upon said control electrode a potential sufficient to break down said control gap, means for producing a voltage pulse increasing from a minimum to a value substantially equal to said sustaining voltage in a prescribed time following breakdown of said control gap, said voltage producing means comprising a condenser, means connecting said condenser in parallel with said main gap, and a circuit including a discharge gap adapted to break down when said voltage pulse reaches said value, connected across said condenser.

6. The combination defined in claim 5 wherein said discharge gap is the control gap of a second gaseous discharge device having its anode and control electrode connected to said source and biased thereby at such potential as to render said second device normally conducting, said second device having its anode connected to the anode of said first device by a resistive-capacitive connection.

7. In combination, a load circuit including an electron discharge device having a control electrode biased at such potential that the device normally is non-conductive, a pair of normally non-conducting gaseous discharge devices, means for rendering one of said pair of devices conducting, means controlled by operation of said one device for impressing a priming voltage pulse of substantially constant amplitude prescribed duration upon said control electrode, means for rendering the other of said pair of devices con-

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ducting, and means controlled by operation of said other device for impressing upon said control electrode a voltage pulse additive with respect to said first pulse to render said electron discharge device conducting.

8. The combination defined in claim 7 wherein each of said controlled means comprises a normally conducting gaseous discharge device having its anode connected to said control electrode, means connecting said anode to the circuit of a corresponding one of said pair of devices so that upon operation of either of said pair of devices the corresponding normally conducting device is extinguished, and means for rendering each normally conducting device again conducting a prescribed interval after it has been extinguished.

9. An electrical control circuit comprising two similar portions each of which comprises a first gaseous discharge device having a cathode, an anode and a control electrode, a second gaseous discharge device having a cathode, an anode and a control electrode, an input circuit connected to the control electrode of the second device, a condenser connected through a high resistance between the cathode and control electrode of the first device and connected also between the cathode and anode of the second device, a resistive-capacitive connection between the anodes of said first and second devices and a direct current source for impressing upon the anodes of said first and second devices a potential below the main gap breakdown potential thereof but at least as great as the main gap sustaining voltage and for biasing the control electrode of said first device at such potential that said first device normally is conducting, a resistive connection between the anodes of the two first devices, and a load circuit connected to said resistance.

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