Dec. 7, 1954 E. R. SCHMID 2,696,572

PULSE GENERATING CIRCUIT

Filed Oct. 31, 1952 2 Sheets-Sheet 1

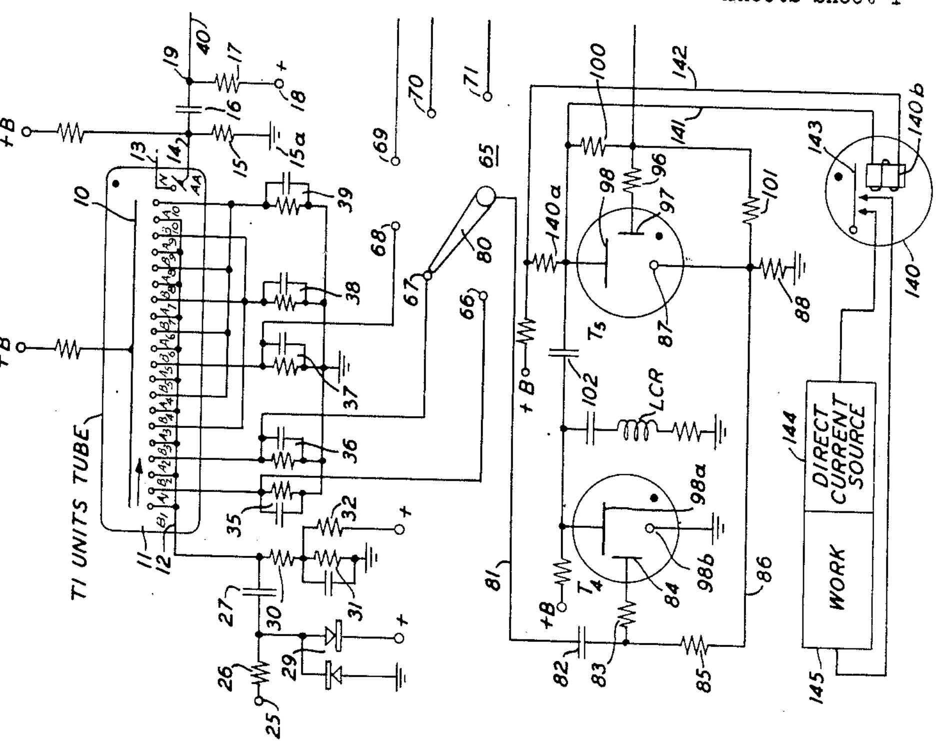

FIG. 1

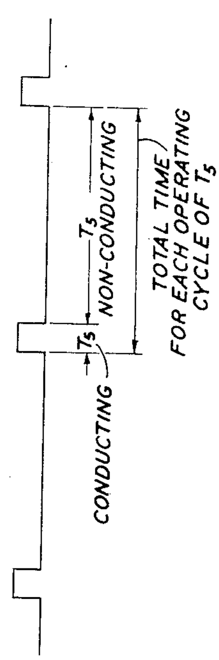

FIG. 3

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2 Sheets-Sheet 2

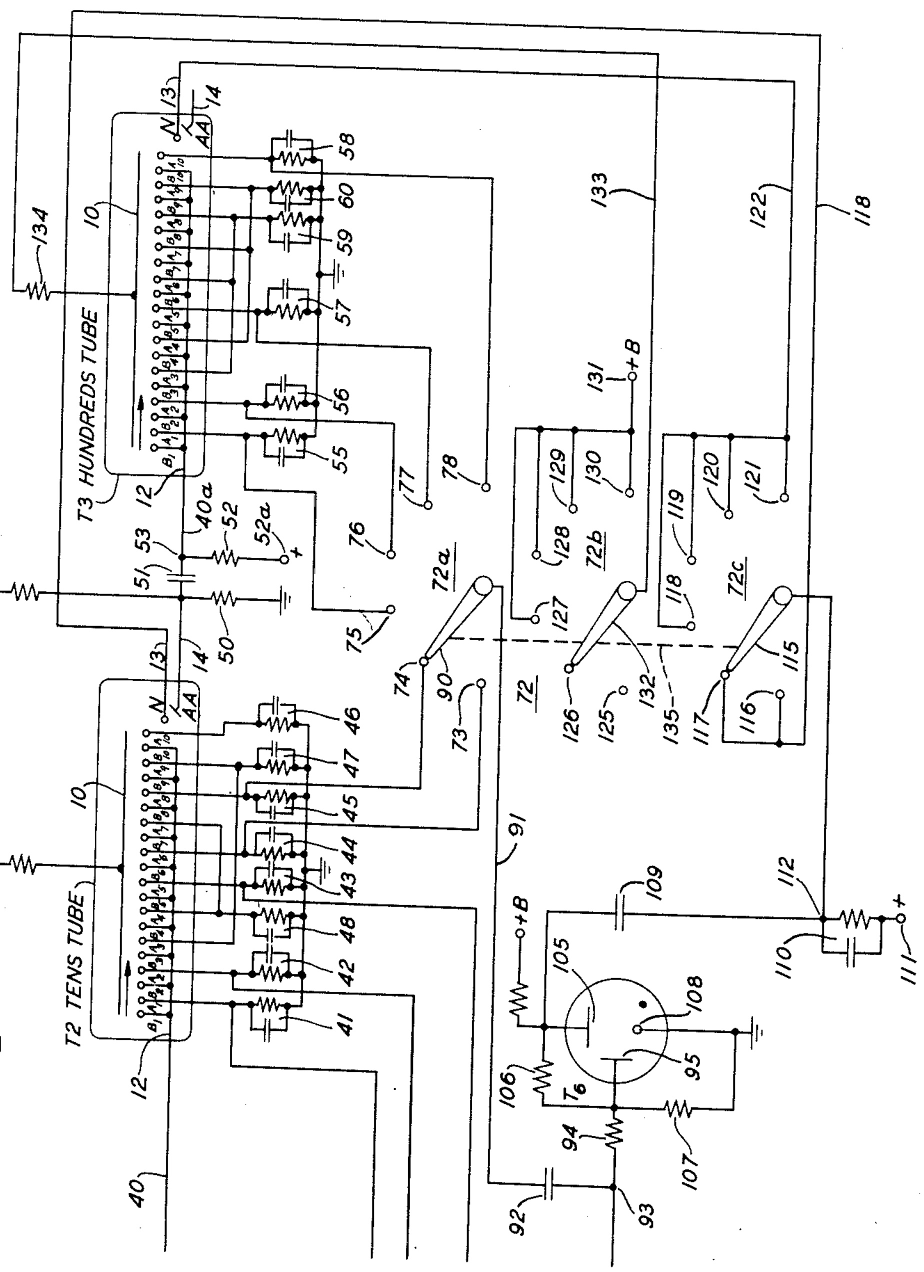

FIG. 2

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PULSE GENERATING CIRCUIT

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Application October 31, 1952, Serial No. 317,859

14 Claims. (Cl. 315—163)

This invention relates to a timing sequence system, and more specifically to such system using a plurality of multiple cold cathode glow discharge tubes arranged in a counting circuit for controlling the time sequence. In a specific aspect, the invention is concerned with a generator of electric current pulses whose time duration and time rate of repetition are variable.

A specific aspect of the invention has been found to be useful as an accurate timing control in aging certain cold cathode gaseous discharge tubes during their manufacture. In the manufacture and prior to the testing, the cold cathode tubes are aged at the factory by applying to them a series of high current pulses having a preselected duration and recurring at predetermined intervals. As the characteristics of the manufactured cold cathode tubes depend to a great extent on the proper aging of them, it is evident that the production of the aging current pulses with a high degree of accuracy as to their length and repetitive rate is important and desirable in the manufacture of those tubes.

It is the main object of the present invention to produce a series of current pulses whose duration and rate of repetition are controllable with a high order of accuracy.

It is another object to provide a series of current pulses whose length and rate of repetition are substantially constant.

It is a further object to provide a series of electric pulses whose length and/or rate of repetition are variable at will to activate a work circuit in a predetermined timing sequence.

It is still another object of the invention to provide a timing circuit having variable intervals for activating a work circuit in corresponding variable time intervals.

A timing control in accordance with the present invention employed with a group of glow discharge stepping tubes arranged in a counting circuit comprises a source of alternating current connected to the input of a first tube in the counting circuit, a source of direct current, a work circuit, and a group of interconnected gaseous discharge devices controlled in regard to conduction and non-conduction therein by the counting circuit for the purpose of connecting the direct current source to the work circuit and disconnecting it therefrom in a predetermined timing sequence. Multi-contact switches interconnect the stepping tubes of the counting circuit and the group of gaseous devices in such manner that the direct current source can be connected to the work circuit for a time interval equal to a preselected number of the alternating current cycles counted by the stepping tube counting circuit; and further in such manner that the time interval can be caused to recur at a time rate of repetition equal to a predetermined number of the alternating current cycles counted by the same counting circuit, the predetermined number of counted cycles being in excess of the preselected number of counted cycles.

As one example of a specific timing control according to the present invention, the direct current source is connected to the work circuit, i. e., to the cold cathode tubes to be aged, for a time interval equal to two cycles of the alternating current cycles counted by the stepping tube counting circuit, and such two-cycle connection is caused to recur at a time rate of repetition equal to each 80 cycles of the alternating current cycles counted by the stepping tube counting circuit. Thus, in effect, a series of current pulses, each having a constant time duration

and a constant time spacing between successive pulses, is produced and applied to the work circuit.

A feature of the invention involves an arrangement whereby the time duration of the respective current pulses and/or the rate of repeating them to constitute a series of current pulses can be changed at will.

Another feature resides in a voltage coincidence circuit insuring that a group of gaseous discharge devices in a timing circuit are changed from conducting condition to non-conducting condition, and vice versa, in a time sequence controlled by a stepping tube counting circuit whereby a voltage of preselected magnitude can be connected to a work circuit and disconnected therefrom for preselected time intervals.

The invention will be readily understood from the following description taken together with the accompanying drawing, in which:

Figs. 1 and 2 constitute a schematic circuit illustrating a specific embodiment of the invention, and

Fig. 3 is a curve illustrating action obtainable in Figs. 1 and 2.

Referring to Figs. 1 and 2, there is shown a plurality of multicathode gaseous discharge stepping tubes **T1**, **T2** and **T3**, each comprising a common anode **10**, ten rest cathodes A_1 through A_{10}, ten transfer cathodes B_1 through B_{10}, an auxiliary anode AA, and a normal cathode N. The transfer cathodes B_1 through B_{10} are connected together internally of a sealed bulb **11** to a bus **12** which projects therethrough. The normal cathode N mounted in proximity of transfer cathode B_1 for initiating a main discharge between the latter cathode and the common anode is connected to a lead **13** which projects through the bulb **11**. The auxiliary anode AA positioned adjacent rest cathode A_{10} is connected to a lead **14** which also extends through the bulb **11**.

A preference mechanism disposed in proximity of the normal section and the adjacent transfer cathode assures stepping of the main discharge from the normal section into the stepping row of cathodes in one direction following the application of the initiating or normalizing voltage pulse to the normal cathode. This preference mechanism may comprise a second portion of low discharge efficiency secured to the transfer cathode and facing the normal cathode.

Bias of a high positive voltage for auxiliary anode AA of units tube **T1** is obtained from a bias and output circuit comprising ground terminal **15*a***, resistor **15**, capacitor **16**, resistor **17** and terminal **18**, to which is connected a source of positive voltage, not shown, such for example as a +55 volt battery. The bias for auxiliary anode AA is obtained via lead **14** connected to a junction point between resistor **15** and capacitor **16**; and output connection **19** for auxiliary anode AA is constituted by a junction point between resistor **16** and capacitor **17**.

As discharge is stepped from rest cathode A_9 through transfer cathode B_{10} and then to rest cathode A_{10}, an auxiliary gap defined by auxiliary anode AA and rest cathode A_{10} breaks down. As a consequence, capacitor **16** discharges through resistor **15** to provide a negative voltage pulse of relatively large amplitude. Now, a voltage applied to transfer cathode B_1 in a manner to be mentioned later herein will cause discharge to transfer from rest cathode A_{10} to transfer cathode B_1 and in due time to rest cathode A_1, as will be pointed out hereinafter. During this time, capacitor **16** will be discharged to such extent that the auxiliary gap will no longer sustain discharge, and will be extinguished.

The voltage across resistor **17** which is included in the output of auxiliary anode AA constitutes the negative output voltage pulse previously mentioned. Such output voltage pulse effected by stepping tube **T1** can be used to step the discharge in tens stepping tube **T2**; and when effected by the latter tube, the voltage pulse can be used to step the discharge in hundreds stepping tube **T3**. Thus, the stepping tubes **T1**, **T2** and **T3** can be connected in sequence in a circuit for the decade counting of alternating current cycles from 1 through 1000 in such manner that the auxiliary anode AA in each tube in the sequence, except the last one, serves to step the discharge to the next succeeding tube. In such decade counting circuit, units tube **T1** will step discharge between its respective cathodes once for each alternating current cycle input thereto; tens tube T2 will step discharge between its respective cathodes once for each ten cycles of the alternating current input to the units tube T1, or once for each complete cycle of operation of the latter tube; and hundreds tube T3 will step discharge between its respective cathodes once for each 100 cycles of the alternating current input to the units tube T1, or once for each 10 input voltage pulses to the tens tube T2.

Further details concerning the structure and operation of the respective stepping tubes T1, T2 and T3 and the structure and operation of the decade counting circuit embodying these tubes may be made by referring to the copending application of M. A. Townsend, Serial No. 271,663, filed February 15, 1952, now Patent No. 2,635,810 issued April 21, 1953, and to the patent of M. A. Townsend, No. 2,575,370, issued November 20, 1951.

A specific embodiment of the present invention including the above-described decade counting circuit constitutes an electronic pulse generator for producing a series of current or voltage pulses whose time duration and rate of repetition are variable at will. In the series, each pulse occurs a certain time interval out of each recurrent predetermined total time interval. As one example of a specific timing circuit, the present invention comprises an electronic pulse generator to provide a series of current pulses for aging the cathodes of cold cathode gas tubes as hereinafter disclosed.

Referring to Figs. 1 and 2, a source of 60 cycle sinusoidal alternating voltage, not shown, is connected to input terminal **25** which in turn is connected through resistor **26** and capacitor **27** to bus **12** of the B transfer cathodes in units tube T1. Connected to a junction point of resistor **26** and capacitor **27** is a clipping and shaping network **29**. This comprises a pair of oppositely poled unidirectional devices, one of which has a positive bias voltage of predetermined magnitude effective thereon and the second of which is unbiased and connected to ground for a purpose that will later appear. The junction of capacitor **27** and bus **12** is connected through serially joined resistor **30** and a parallel RC network **31** to ground; and the junction of the latter resistor and network has a positive voltage of predetermined magnitude applied thereto through resistor **32**. This supplies to B cathode bus **12** a voltage consisting of sharp negative and positive pulses centered about a positive bias established by the resistor **32** and the RC network **31**.

In units tube T1, rest cathodes A_1, A_2 and A_5 are connected to ground through parallel RC networks **35**, **36** and **37**, respectively. Rest cathodes A_3, A_7 and A_9 are connected through parallel RC network **38** to ground; and rest cathodes A_4, A_6, A_8 and A_{10} are connected via parallel RC network **39** to ground. Output terminal **19** of units tube T1 is connected over lead **40** to bus **12** of the B transfer cathodes in tens tube T2. In the latter tube, rest cathodes, A_1, A_2, A_5, A_6, A_8 and A_{10} are connected to ground through parallel RC networks **41**, **42**, **43**, **44**, **45** and **46**, respectively; rest cathodes A_3 and A_9 are connected to ground through parallel RC network **47**; and rest cathodes A_4 and A_7 are connected to ground through parallel RC network **48**. Auxiliary anode AA of tens tube T2 is connected over lead **14** and through bias and output circuitry including resistor **50**, capacitor **51**, resistor **52**, positive voltage terminal **52a**, output terminal **53**, and lead **40a** to bus **12** of the B transfer cathodes in hundreds tube T3. This bias and output circuitry of the tens tube T2 is identical in function with the previously mentioned bias and output circuitry including resistor **15**, capacitor **16**, resistor **17** and output terminal **19** of units tube T1. Positive voltage of a magnitude appropriate to the operation of tens tube T2 is applied to the bus **12** of the B cathodes thereof in a circuit including positive voltage terminal **18**, resistor **17**, terminal **19** and lead **40**.

In hundreds tube T3, rest cathodes A_1, A_2, A_5, and A_{10} are connected through parallel RC networks **55**, **56**, **57** and **58**, respectively, to ground; rest cathodes A_3, A_6, and A_8 are connected through parallel RC network **59** to ground; and rest cathodes A_4, A_7, and A_9 are connected through parallel RC network **60** to ground. Normal cathode N via lead **13** and auxiliary anode AA via lead **14** are open circuited. Positive voltage suitable for the operation of the tube is applied to bus **12** of the B cathodes thereof in a circuit comprising positive voltage terminal **52a**, resistor **52**, terminal **53** and lead **40a**.

In Figs. 1 and 2, multicontact switch **65** has its respective contacts **66**, **67**, and **68** connected to junction points of RC networks **35**, **36**, and **37** and rest cathodes A_1, A_2, and A_5 of units tube T1, and its respective contacts **69**, **70** and **71** connected to junction points of RC networks **41**, **42** and **43** and rest cathodes A_1, A_2, and A_5 of tens tube T2. Multicontact 3-stage switch **72** has its respective contacts **73** and **74** of stage **72a** connected to junction points of RC networks **44** and **45** and rest cathodes A_6 and A_8 of tens tube T2, and its respective contacts **75**, **76**, **77** and **78** of stage **72a** connected to junction points of RC networks **55**, **56**, **57** and **58** and rest cathodes A_1, A_2, A_5, and A_{10} of hundreds tube T3.

Movable arm **80** of switch **65** is connected via lead **87**, capacitor **82** and resistor **83** to starter anode **84** of gas tube T4, referred to hereinafter as the turn-off tube. This starter anode is also connected through resistor **85** to a junction point of cathode **87** of gas tube T5 and cathode resistor **88** through which the cathode **87** is connected to ground. The tube T5 will be called the output tube subsequently herein. Movable arm **90** of switch stage **72a** is connected over lead **91** and capacitor **92** to a junction point **93** which is connected through resistor **94** to starter anode **95** of gas tube T6 and which is also connected through resistor **96** to starter anode **97** of output tube T5. The tube T6 will be identified hereinafter as the reset tube. The junction point **93** is also connected through resistor **100** to anode **98** of output tube T5 and through resistor **101** to the junction point of the cathode **87** and cathode resistor **88** of the latter tube. Anodes **98a** and **98** of turn-off and output tubes T4 and T5, respectively, are joined via capacitor **102**. A series network LCR has one terminal connected to a junction point of the anode **98a** and one side of capacitor **102**, and its opposite terminal connected to ground.

Reset tube T6 has its starter anode **95** connected through resistor **106** to its anode **105**, and through resistor **107** to its cathode **108** which is grounded; and its main anode **105** connected through capacitor **109** and parallel RC network **110** to positive terminal **111** of a suitable source of positive voltage, not shown. A junction point **112** of capacitor **109** and RC network **110** is connected to movable arm **115** of stage **72c** of switch **72**. In switch stage **72c**, contacts **116** and **117** joined together are connected over lead **118** to lead **13** which is joined to normal cathode N in tens tube T2; and joined contacts **118**, **119**, **120** and **121** are connected by lead **122** to normal cathode N of hundreds tube T3.

In stage **72b** of switch **72**, contacts **125** and **126** are not used; and joined contacts **127**, **128**, **129** and **130** are connected to terminal **131** of the +B voltage source, not shown. Movable arm **132** of switch stage **72b** is connected by lead **133** and resistor **134** to anode **10** of hundreds tube T3. The purpose for the particular connections of switch stage **72b** will be stated later.

In switch **72**, stages **72a**, **72b** and **72c** are joined by mechanical linkage **135** whereby the movable arms **90**, **132** and **115**, respectively, are simultaneously actuated and caused to engage corresponding contacts of the respective stages at the same time in the operation of the electronic pulse generator in a manner that will be subsequently mentioned.

Electromagnetic relay **140** of a well-known mercury type has its operating winding **140b** connected via leads **141** and **142** in parallel with resistor **140a**; and the latter parallel circuitry is connected in series in anode-cathode circuit of output tube T5. Armature **143** of relay **140** is operable to connect source **144** of direct current to work **145** and to disconnect it therefrom in a manner that will be subsequently mentioned. In the specific example of the invention disclosed herein, the work **145** comprises one or more cold cathode gas tubes whose cathodes are supplied with a series of direct current from source **144** for the purpose of aging such tube at the factory in a manner which will be presently explained. This aging is performed before the tubes are actually utilized in electrical operating systems so that in such systems the tubes will perform with a voltage characteristic, for example, which closely approaches a predetermined one.

In the circuit shown in Figs. 1 and 2 and described below, it will be understood that the anodes of all tubes are supplied with appropriate +B operating voltages in a conventional manner unless hereinafter noted otherwise.

In the operation of the electronic pulse generating circuit shown in Figs. 1 and 2, it will be initially assumed for the purpose of this explanation that direct current source **144**, normally disconnected from work **145**, is to be connected to work **145**, that is, to the cold cathodes of the gas tubes which are to be aged, for a time interval equal to 2 cycles out of a total time interval equal to 80 cycles of the 60-cycle current available at terminal **25** in the input of units tube **T1**; and the operation of the circuit on this basis will be repeated indefinitely. According to this operation, each such 2-cycle time interval will comprise the first 2 cycles out of each 80-cycle period and will be referred to subsequently as "on-time" interval, whereas each 80-cycle period will be referred to as "total" time interval. Thus, for the assumed operation, work **145** will receive a current pulse of suitable magnitude for an "on-time" time interval equal to the time of 2 cycles repeated at recurrent "total" time intervals, each of which is equal to the time of 80 cycles.

Also, it will be initially assumed for the purpose of the explanation that in the units, tens and hundreds tubes **T1**, **T2**, and **T3**, respectively, discharge is taking place simultaneously in the auxiliary gap comprising rest cathode A_{10} and auxiliary anode AA and in the main gap comprising rest cathode A_{10} and anode **10**. The tubes **T1**, **T2**, and **T3** are thus initially conditioned for the cycle counting action which will be presently explained. Movable arms **90**, **132** and **115** of 3-stage switch **72** are initially adjusted to rest on corresponding contacts **74**, **126** and **117**, respectively, of switch stages **72**, **72***b* and **72***c*. At this point, it should be noted that tubes **T4**, **T5**, and **T6** are in the non-conducting condition; and relay **140** is in the non-operated condition. As hundreds tube **T3** is effectively disconnected from the circuit shown in Figs. 1 and 2 for the purpose of this explanation of the assumed operating condition, this tube will not be mentioned in the subsequent explanation of the circuit operation.

Further, let it be assumed that as a consequence of the next previous operating cycle of the circuit, a positive voltage from RC network **45** connected to rest anode A_8 of tens tube **T2** has been applied simultaneously to the starter anodes **97** and **95** of the output and reset tubes **T5** and **T6**, respectively, in a circuit including contact **74** and movable arm **90** of switch stage **72***a*, lead **91**, capacitor **92**, junction point **93** and resistors **94** and **96**. Since starter anode **95** of reset tube **T6** was provided initially with a predetermined fixed amount of positive bias via a voltage divider including resistor **106** and resistor **107**, and the +B voltage source, the additional positive voltage supplied by tens tube **T2** in the manner just mentioned serves to trigger the starter gap in reset tube **T6** whereby the main gap including anode **105** and cathode **108** of the same tube is also fired. As the starter anode **97** in output tube **T5** was also provided with a predetermined fixed amount of positive bias effective via a voltage divider including resistor **100**, resistor **101** and resistor **88**, and the +B voltage source, the additional positive voltage produced by the tens tube **T2** in the respect just explained also serves to trigger the starter gap in output tube **T5** from which the main gap between cathode **87** and anode **98** in the same tube is also fired. Hence both tubes **T5** and **T6** are caused to conduct at the same time. The effect of cathode resistor **88** in the associated voltage divider circuit is negligible due to the low resistance value of resistor **88** compared to the combined resistance value of resistors **100** and **101**.

As the anode voltage of reset tube **T6** in the conducting condition drops to a sustaining magnitude, a large negative voltage pulse is developed across capacitor **109** and RC network **110**, both of which are included in the anode-cathode circuit of reset tube **T6** which is now functioning effectively as a relaxation oscillator. This large negative voltage is supplied via junction point **112**, movable arm **115** of switch stage **72***c*, contact **117**, lead **118** and lead **13** to normal cathode N of tens tube **T2**. This conditions the tens tube **T2** to commence the cycle counting action in a manner which will be presently explained. Here, it will be evident that since tens tube **T2** is connected in circuit to count a maximum of 80 alternating current cycles during each complete cycle of the counting action of the circuit, the hundreds tube **T3** is effectively disconnected from the counting action of the circuit as above mentioned. Units tube **T1** was also conditioned for the next-mentioned cycle counting action by the operation of the bias circuitry including resistor **15**, capacitor **16** and resistor **17** in response to the receipt of the tenth sharp negative pulse applied to input terminal **25** during the next preceding cycle counting action which was assumed for the purpose of this explanation as above mentioned. At this point, it will be understood that turn-off tube **T4** rests in the non-conducting state. Since reset tube **T6** is functioning effectively as a relaxation oscillator as previously mentioned, this tube will automatically return to the non-conducting condition to await the next activating positive voltage supplied to its starter anode **95** from tens tube **T2**.

The action of the cycle counting operation of the circuit will now commence due to the fact that output tube **T5** was changed to the conducting state simultaneously with reset tube **T6** in the manner just explained. The conducting condition in output tube **T5** establishes a current flow in the operating winding **140***b* of relay **140** whereby the latter is operated. This actuates armature **143** into engagement with the two contacts associated therewith whereby direct current source **144** is connected to work **145**. In the specific example of a timing circuit according to this invention as previously mentioned, source **144** supplies a current pulse of proper magnitude to work **145** which comprises the cathode of one or more cold cathode gas tubes which are to be aged. This marks the beginning of the time interval during which the current pulse is to be applied to the work, i. e., the beginning of the time interval during which output tube **T5** commences to discharge.

At the same time, the first cycle of the sinusoidal 60-cycle current applied to input terminal **25** connected in the input of units tube **T1** is translated by clipping and shaping network **29** into positive and negative sharp pulses having an average d.-c. level which is above that of the output voltage due to the discharge of the respective rest cathodes A_1 through A_{10} in a manner to be hereinafter mentioned. The shaping network **29** prevents the tied-together B-cathodes of units tube **T1** from receiving such amount of positive voltage as to become effectively an anode. The negative pulse serves to transfer the discharge from a particular A-cathode to a particular B-cathode because the latter B-cathode is more negative than the preceding particular A-cathode. The positive pulse ensures a quenching of the discharge at the gap involving the particular B-cathode by driving the effective positive voltage on the latter cathode well above that on the next succeeding A-cathode.

The first sharp negative pulse developed by the clipping and shaping network **29** in response to the first cycle of the alternating current input at terminal **25** is applied through capacitor **27** to bus **12** of the B-transfer cathodes in units tube **T1**. This causes the discharge in the auxiliary gap and in the main gap in units tube **T1**, both of which have been identified hereinbefore, to transfer from rest cathode A_{10} to transfer cathode B_1 and thence to rest cathode A_1 at the cessation of the pulse as explained in the Townsend copending application and patent, supra. Since the rest cathode A_1 and RC network **35** are connected to open contact **66** of switch **65**, no further action in the cycle counting circuit is effected by the first sharp negative pulse applied to the input of units tube **T1**.

The second sharp negative pulse developed by the clipping and shaping network **29** in response to a second cycle of alternating current input at terminal **25** is applied through capacitor **27** to bus **12** whereupon transfer cathode B_2 is caused to discharge, and in due course this extinguishes the discharge of rest cathode A_1 and institutes discharge at rest cathode A_2, at the cessation of the pulse. As rest cathode A_2 and RC network **36** associated therewith are connected to contact **67** upon which movable arm **80** of switch **65** is resting, a positive voltage from RC network **36** is supplied over a circuit including switch contact **67**, movable arm **80**, lead **81**, capacitor **82** and resistor **83** to starter anode **84** of turn-off tube **T4**.

Coincident with this voltage, another voltage developed across cathode resistor **88** of output tube **T5**, which is in the conducting state as above mentioned, is also applied over a circuit including lead **86** and resistors **85** and **83** to the starter anode **84** of turn-off tube **T4** whereby discharge is instituted in the starter gap thereof. In due course, discharge is effected in the main gap including anode 98a and associated cathode 98b in turn-off tube T4. Resistors 83 and 85 tend to limit peak currents in the starter gap of turn-off tube T4. As a consequence, a negative voltage is developed in series network LCR which is slow acting, and applied through capacitor 102 to anode 98 of output tube T5. As turn-off tube T4 functions effectively as a relaxation oscillator, it automatically returns itself to the non-conducting condition. In the LCR network, inductance L causes the voltage appearing across the LCR network to fall below the normal sustaining voltage of the turn-off tube T4. Because of the long time constant of the LCR network, the voltage on the anode of turn-off tube T4 is prevented from returning to the B+ value while the positive voltage due to RC network 36 of units tube T1 and the coincidence voltage on cathode resistor 88 of output tube T5 are still jointly effective on the starter anode of turn-off tube T4. As a consequence, turn-off tube T4 is prevented from discharging a second time in response to the same set of starter-anode voltages. Thus, the LCR network serves to hold turn-off tube T4 in the non-conducting condition until the voltage at RC network 36 of units tube T1 has disappeared. The negative voltage appearing across the LCR network drives the positive voltage effective on anode 98 down to a value which is less than that required to sustain discharge in output tube T5. Accordingly, this tube is caused to return to the non-conducting condition and thereby to remove (1) the current from the operating winding 140b of relay 140 and (2) the coincident voltage from starter anode 84 of turn-off tube T4. This causes relay 140 to return to the unoperated state to disconnect direct current source 144 from work 145. In view of this, it will be apparent that turn-off tube T4 can have conduction instituted and maintained therein only when conduction is effective in output tube T5. This marks the termination of the time interval during which the current pulse is to be applied to its work.

The third sharp negative pulse developed by network 29 in response to the third cycle of alternating current applied to input terminal 25 is supplied through capacitor 27 to bus 12 connected to the B transfer cathodes in units tube T1 whereupon the discharge is stepped to transfer cathode B_3 and in due course the discharge is transferred to rest cathode A_3 at the cessation of the negative pulse. As rest cathode A_3 and the RC network 38 associated therewith are grounded, no further action is effected in the operation of the cycle counting circuit. Similarly, the fourth sharp negative pulse produced in network 29 in response to the fourth cycle of alternating current at input terminal 25 causes the discharge to step to transfer cathode B_4 and rest cathode A_4 in sequence but as the latter cathode and its associated RC network 39 are grounded, no further action is produced in the operation of the cycle counting circuit.

The fifth sharp negative pulse developed by network 29 in response to the fifth cycle of alternating current present at input terminal 25 effects discharge at cathode B_5. At the cessation of the pulse, discharge will transfer to rest cathode A_5 but since the latter cathode and its associated network 37 are connected to open contact 68 of switch 65, no further action takes place in the operation of the cycle counting circuit. In like manner, the 6th, 7th, 8th, 9th and 10th negative pulses developed by network 29 in response to the 6th, 7th, 8th, 9th and 10th cycles of alternating current present at input terminal 25 serve to cause discharge at transfer cathodes B_6, B_7, B_8, B_9 and B_{10} and thence at rest cathodes A_6, A_7, A_8, A_9 and A_{10} in succession at the cessation of the respective negative pulses until discharge is effected in units tube T1 at the auxiliary gap including rest cathode A_{10} and auxiliary anode AA and in the main gap comprising rest cathode A_{10} and anode 10. As normal cathode N connected to lead 13 of units tube T1 is open-circuited, this cathode exerts no influence on the action of the cycle counting circuit. This is explained in the copending Townsend application and the Townsend patent, supra.

Prior to the discharge in the auxiliary gap of units tube T1, it will be understood that the high positive voltage for auxiliary anode AA had a certain value which comprises the voltage on one side of capacitor 16 and the voltages at the output terminal 18 for auxiliary anode AA had another value which comprises the voltage on the opposite side of capacitor 16. When discharge took place in the auxiliary gap, the biasing and output voltages effective on the opposite sides of capacitor 16 decreased in magnitude to an equal amount; and capacitor 16 discharged and together with resistor 15 served to produce the large negative output signal at output terminal 18, as explained in the Townsend copending application, supra.

This sharp negative pulse applied via output terminal 19 and lead 40 to B-cathode bus 12 in tens tube T2 effects discharge between cathode B_1 and anode 10 in this tube, and upon the cessation of the pulse the discharge is transferred to rest cathode A_1 and anode 10. As the latter cathode and associated RC network 41 are connected to open terminal 69 of switch 65, no further action in the operation of the cycle counting circuit takes place in response to the first negative pulse generated by units tube T1 and transmitted to tens tube T2. Thus, the first ten cycles of the alternating current applied to input terminal 25 at units tube T1 are effectively counted in tens tube T2.

On the eleventh cycle of the sinusoidal current applied to the input terminal 25 and the eleventh sharp negative pulse derived therefrom and applied to bus 12 of the B cathodes of units tube T1, the auxiliary discharge and the main discharge are transferred from rest cathode A_{10} to transfer cathode B_1 and the main discharge to rest cathode A_1, as hereinbefore explained. In response to the twelfth through twentieth cycles of the sinusoidal current applied to input terminal 25, the discharge in units tube T1 is stepped from transfer cathodes B_2 through B_{10} and rest cathodes A_2 through A_{10} in sequence as hereinbefore explained until discharge is effected again in the auxiliary gap including rest cathode A_{10} and auxiliary anode AA and in the main gap comprising rest cathode A_{10} and anode 10. In response to such discharge, the bias and output circuitry including resistor 15, capacitor 16, resistor 17 and output terminal 19 produce and apply a second large negative output voltage pulse at the output terminal 18 and thereby at bus 12 of the B cathodes in tens tube T2.

Referring for the moment to the operation of the circuit involved in the counting of the second group of ten cycles of sinusoidal current at input terminal 25, it will be recalled that turn-off tube T4, output tube T5, and reset tube T6 are now resting in the non-conducting condition. As a consequence, the positive voltage produced by rest cathode A_2 in the discharge state and associated RC network 36 in units tube T1 and applied via contact 67 and arm 80 of switch 65, lead 81, capacitor 82 and resistor 83 to the starter anode 84 of turn-off tube T4 will be ineffective to institute discharge therein. This is occasioned by the fact that the coincidence voltage required for the starter anode 84 and effected by cathode resistor 88 in the cathode circuit of output tube T5 is not present since the latter tube is resting in the non-conducting state.

In regard to the second negative voltage pulse applied to bus 12 of the B cathodes in the tens tube T2 in response to the counting of the second group of ten cycles of sinusoidal current by units tube T1, the discharge in tens tube T2 will be stepped by such negative voltage from the A_1 cathode to the B_2 cathode and upon the cessation of the pulse the discharge will be transferred to the A_2 cathode. As the latter cathode and its associated RC network 42 are connected to open terminal 70 of switch 65, no further action in the operation of the cycle counting circuit takes place.

In response to the counting of the third group of ten cycles of sinusoidal current present at input terminal 25 by the units tube T1 and the application of the third large negative voltage pulse to the input of the tens tube T2, the discharge in tens tube T2 is stepped from the A_2 cathode to the B_3 cathode, and upon the cessation of the pulse is transferred to the A_3 cathode. As the latter cathode and its associated RC network 47 are merely grounded no further action in the operation of the cycle counting circuit is effected. In response to the counting of the fourth group of ten cycles of sinusoidal current at input terminal 25 by units tube T1 and the transmittal of the fourth large negative voltage pulse to tens tube T2, the discharge in the latter tube is stepped from the A_3 cathode to the B_4 cathode, and upon the cessation of the pulse is transferred to the A_4 cathode. Since this cathode and its associated RC network 48 are merely grounded, no further action in the operation of the cycle counting circuit is achieved.

When the fifth group of ten cycles of sinusoidal current present at input terminal **25** is counted in units tube **T1** and the fifth negative voltage pulse is sent thereby to tens tube **T2**, the discharge in the latter tube is stepped from the A_4 cathode to the B_5 cathode, and upon the cessation of the pulse is transferred to the A_5 cathode. This cathode and its associated RC network **43** produce and supply a positive voltage to open contact **71** of switch **65**. This voltage therefore fails to institute further action in the operation of the cycle counting circuit.

In response to the counting of the sixth group of ten cycles of sinusoidal current at input terminal **25** by units tube **T1** and the transmittal thereby of the sixth large negative voltage pulse to the tens tube **T2**, the discharge in the latter tube is stepped from the A_5 cathode to the B_6 cathode, and upon cessation of the pulse the discharge is transferred to the A_6 cathode. As this cathode and its associated RC network **44** are connected to open contact **73** of stage **72*a*** of switch **72**, the action of the operation of the cycle counting circuit is arrested at that switch contact. When the seventh group of ten cycles of the sinusoidal current at input terminal **25** is counted by units tube **T1** and the seventh negative voltage pulse is sent thereby to tens tube **T2**, the discharge in the latter tube is stepped from the A_6 cathode to the B_7 cathode, and upon the cessation of the pulse is transferred to the A_7 cathode. Since this cathode and its associated RC network **48** are merely grounded, no additional action in the operation of the cycle counting circuit is achieved.

In response to the counting of the eighth group of ten cycles of sinusoidal current present at input terminal **25** by units tube **T1** and the transmittal thereby of the eighth negative pulse to the tens tube **T2**, the discharge in the latter tube is stepped from the A_7 cathode to the B_8 cathode, and upon the cessation of the pulse is transferred to the A_8 cathode. This cathode and its associated RC network **45** supply the positive voltage pulse to starter anodes **97** and **95** of the output and reset tubes **T5** and **T6**, respectively, in the circuit previously traced. As a consequence, conduction is simultaneously established in the starter gaps of output tube **T5** and reset tube **T6**, and thence in the main gap including the main anode and the cathode of the respective tubes.

As a result of the establishment of conduction in the main gap including anode **105** and cathode **108** of reset tube **T6**, this tube and its associated capacitor **109** and RC network **110** serve to supply the large negative voltage pulse to the normal cathode N of tens tube **T2** over the circuit previously traced in order to condition tens tube **T2** for the next succeeding cycle in the counting operation of the circuit. This also determines the total time of the operating cycle of the pulse counting action of the circuit. Thereafter, reset tube **T6** still in the conducting condition and functioning as a relaxation oscillator as above mentional automatically returns itself to the non-conducting condition. The institution of conduction in output tube **T5** commences the cycle of the pulse counting action, and the operation of the circuit including turn-off tube **T4**, output tube **T5** and reset tube **T6** have been explained in detail hereinbefore.

Thus, the conditioning of the tens tube **T2** under control of reset tube **T6** at the count of 80 cycles of the sinusoidal voltage applied to input terminal **25** establishes the total time of one complete cycle of operating of the counting circuit. From the such complete cycle, it will be seen that the current source **144** was connected to the work **145** during the time equal to the first 2 cycles of the total time of 80 cycles, and further was disconnected from the work **145** for the time equal to the final 78 cycles of the total time of 80 cycles. This can be readily comprehended from an inspection of the curve in Fig. 3 which illustrates graphically, for each complete operating cycle of the circuit, the "on-time" interval, i. e., the time interval during which the output tube **T5** is in the conduction condition and relay **140** is operated; the time interval during which the output tube **T5** is in the non-conducting condition and the relay **140** is in the non-operated condition; and the "total-time" interval during which the output tube **T5** is in both the conducting and non-conducting conditions and the relay **140** is in both the operated and non-operated conditions. As the above operation recurs on an automatic basis, it will be evident that the cathodes of the gas tubes to be aged can have applied thereto a spurt of current lasting a predetermined time interval out of each recurrent preselected total time interval.

The total time of each complete operating cycle involving the tubes **T1** through **T6** can be varied by (1) appropriately connecting the rest cathodes A_1 through A_{10} and associated RC networks of the tens tube **T2** and hundreds tube **T3** to the respective contacts of switch stage **72*a*** and/or (*a*) by selectively positioning the movable arm **90** thereof to engage the proper contacts of the latter switch stage. In the circuit shown herein for the purpose of the instant explanation, it would appear to be obvious that the total time can be extended to embrace a time interval equal to 1000 cycles of the sinusoidal alternating current supplied to input terminal **25**. For the latter purpose, the negative voltage pulses to step discharge in hundreds tube **T3** are supplied thereto from tens tube **T2** in a manner identical with the supplying of the negative voltage pulses from units tube **T1** to tens tube **T2** to step the discharge therein. The total time interval can be expeditiously extended to count beyond 1000 cycles by including further stages in sequence with the hundreds tube **T3** whereby the total time can be increased by a factor of 10. In regard to the total time, this is achieved in the circuit shown in the drawing by appropriate connections from the respective contacts and movable arm **115** of switch stage **72*c*** to reset tube **T6** and to the normal cathode N of the proper counting tube connected effectively in the counting circuit. The switch stage **72*b*** disconnects the source of +B voltage from the hundreds tube **T3** when such voltage is not required for a particular circuit adjustment. As shown in the drawing, the +B source is disconnected from the hundreds tube **T3** for total time intervals equal to less than that of 100 cycles of sinusoidal current supplied to input terminal **25**.

The institution of conduction in turn-off tube **T4** under control of output tube **T5** terminates the "on-time" interval for one complete cycle of the circuit. Such on-time interval comprises the time during which output tube **T5** is conducting to connect current source **144** to work **145**. As previously indicated, the on-time interval for the circuit adjustment shown in the drawing includes the time interval equal to the first 2 cycles out of each recurrent total time interval of 80 cycles. That is to say, a current pulse equivalent in time to 2 cycles of the alternating current voltage applied to input terminal **25** is available to energize suitable work out of each recurrent total time interval equivalent to 80 cycles of the same voltage. The on-time interval can be changed by (1) appropriately connecting the rest cathodes A_1 through A_{10} and associated RC networks of the units and tens tubes **T1** and **T2**, respectively, to the several contacts of the switch **65**, and (2) by selectively positioning movable arm **80** thereof to engage the proper switch contacts. In the circuit shown in the drawing, it is apparent that the on-time interval can be extended to comprise a time interval equal to 50 cycles of the sinusoidal current applied to input terminal **25**.

In accordance with the circuit shown in the drawing, one of six different on-time intervals is available by actuating movable arm **80** of switch **65** to one of the respective contacts **66** through **71**; and one of six different total time intervals is possible by adjusting movable arm **90** of switch stage **72*a*** to one of contacts **73** through **78**; and the respective time intervals are determined by a timing sequence controlled by the stepping tubes **T1**, **T2** and **T3** connected in circuit to count the cycles of the sinusoidal alternating current present at input terminal **25** in steps of 1, 10 and 100, respectively. In regard to the determination of the on-time interval and the total time interval, it is possible to obtain 1-cycle steps from 1 to 1000 cycles in each of the steps via suitable coincidence triggering circuits, not shown.

It is to be understood that instead of utilizing output tube **T5** to operate the mercury relay **140** as illustrated in the drawing of the disclosed embodiment of the invention, it would be readily evident to those skilled in the art that the embodiment may be expeditiously adapted to perform other timing sequences. For example, a different load could be substituted in the anode cathode circuit of output tube **T5** for the operating winding **140*b*** of the mercury relay **140**; or a voltage signal could be taken off cathode resistor **88** in the anode-cathode circuit of output tube **T5**.

While the principle of the invention has been disclosed in regard to a specific example, it is to be further understood that such disclosure is made for the purpose of illustrating the invention and not in any sense as a limitation of the scope thereof. In particular, it should be mentioned that while for the specific embodiment of the invention disclosed herein a particular type of electronic stepping or counting tube has been employed, it would readily occur to one skilled in the art that other cycle counting or pulse stepping devices could be utilized equally as well. For example, an electromechanical stepping switch of a type used in automatic telephone switching systems is contemplated for use as a pulse stepping device. In view of the foregoing, numerous additional specific applications of the invention will occur to those skilled in the art.

What is claimed is:

1. In a circuit for timing the rate of repetition of a series of voltage pulses and the duration of each pulse in the series, a source of alternating current, a plurality of stepping devices for counting the cycles of said source current, each of said devices including a plurality of output terminals at each of which a voltage is produced to represent the number of cycles of the source current counted thereat, means connected to one terminal of said devices and responsive to the voltage produced thereat to commence the production of one of said voltage pulses, said means simultaneously producing a second voltage, and means connected to another terminal of said devices and responsive to the voltage produced thereat and to said second voltage for causing said first-mentioned means to terminate the production of said one voltage pulse, the time interval occurring between the voltage produced at one said terminal and the next succeeding voltage produced at said other terminal being equivalent to that represented by the numerical value of the cycles of said source current counted between the voltages produced at said last-mentioned one and other terminals, said time interval constituting the duration of each voltage pulse produced by said first-mentioned means, the time interval occurring between two successive voltages produced at said one terminal being equivalent to that represented by the numerical value of the cycles of said source current counted between said two successive voltages produced at said last-mentioned one terminal, said last-mentioned time interval constituting the rate of repetition of the voltage pulses produced by said first-mentioned means.

2. In a circuit for timing the rate of repetition of a series of voltage pulses and the duration of each pulse in the series, a source of alternating current, a plurality of stepping tubes arranged to count the cycles of said source current, each of said tubes including at least one input terminal at which a voltage is produced to represent the number of cycles of said source current counted thereat, means connected to said terminal of one of said tubes and responsive to the voltage produced thereat to commence the production of one of said voltage pulses, said means simultaneously producing another voltage, and means connected to said terminal of another of said tubes and responsive to the voltage produced thereat and to said other voltage for causing said first-mentioned means to terminate the production of said one voltage pulse, the time interval occurring between the voltage produced at said terminal of said one tube and the next succeeding voltage produced at said terminal of said other tube being equivalent to that represented by the numerical value of the cycles of said source current counted between the voltages produced at said last-mentioned tube terminals, said time interval constituting the duration of each voltage pulse produced by said first-mentioned means, the time interval occurring between two successive voltages produced at said terminal on said one tube being equivalent to that represented by the numerical value of the cycles of said source current counted between two successive voltages produced at said last-mentioned terminals, said last-mentioned time interval constituting the rate of repetition of the voltage pulses produced by said first-mentioned means.

3. A timing circuit in accordance with claim 2 in which each of said tubes includes a plurality of output terminals at each of which the produced voltages represent different numerical values of the cycles of said source current counted circuit, and said first-mentioned means includes means for varying the rate of repetition of said voltage pulses, said varying means comprising means for selecting one of said plurality of output terminals of said one tube for varying the time interval occurring between the two successive voltages produced at said last-mentioned selected terminal in accordance with the varying numbers of cycles of said source current counted between the last-mentioned two voltages.

4. A timing circuit in accordance with claim 2 in which each of said tubes includes a plurality of output terminals representing different numerical values of the cycles of said source current counted by said counting circuit, and said second-mentioned means includes means for varying the duration of each of said voltage pulses, said varying means comprising means for selecting one of said plurality of output terminals of said other tube for varying the time interval between the voltage produced at said one terminal of said one tube and the next succeeding voltage produced at said selected terminal of said other tubes in accordance with the varying number of cycles of said source current counted between said last-mentioned two voltages.

5. A timing circuit in accordance with claim 2 in which each of said tubes includes a plurality of output terminals representing different numerical values of the cycles of said source current counted by said counting circuit, said first-mentioned means includes means for varying the rate of repetition of said voltage pulses, said varying means comprising means for selecting one of said plurality of output terminals of said one tube for varying the time interval occurring between the two successive voltages produced at the selected terminal of said one tube in accordance with the varying numbers of cycles of said source current counted between said last-mentioned two voltages, and said second-mentioned means includes means for varying the duration of each of said voltage pulses, said last-mentioned varying means comprising means for selecting one of said plurality of output terminals of said other tube for varying the time interval occurring between the voltage produced at said one terminal of said one tube and the next succeeding voltage produced at said selected terminal of said other tube in accordance with the varying number of cycles of said source current counted between said last-mentioned two voltages.

6. In a circuit for timing the production of a series of voltage pulses, a source of stepping voltages, a plurality of stepping tubes arranged in a counting circuit to count the stepping voltages, each of said tubes having at least one output terminal at which a voltage is produced to represent the number of stepping voltages counted thereat, a plurality of gaseous discharge devices in a nonconduction condition, each having a starter anode, a cathode, and a main anode, means for applying the voltage of one of said stepping tube output terminals to the starter anodes of two of said devices thereby to establish conduction in both thereof at the same time, one of said two conducting devices supplying a voltage to terminate one cycle of the operation of said counting circuit and simultaneously therewith to condition the latter circuit for the commencement of the operation of the next succeeding counting cycle, a second of said two conducting devices commencing the production of one of said voltage pulses, means responsive to conduction in said second device for applying a coincidence voltage to the starter anode of a third of said devices, and means for applying the voltage of another of said stepping tube output terminals to the starter anode of said third device to cooperate with said coincidence voltage applied thereto for establishing conduction in said third device, said third conducting device supplying a voltage to said second conducting device to quench conduction therein thereby to terminate the production of said one voltage pulse, the time interval occurring between the production of the stepping tube output voltage establishing conduction in said two devices and the production of the next succeeding stepping tube output voltage establishing conduction in said third device determining the duration of each pulse produced in the series of pulses, and the time interval occurring between the production of two successive stepping tube output voltages establishing the simultaneous conduction in said two devices on two successive occasions fixing the rate of repetition of the pulses in the produced series of pulses.

7. In a circuit for timing the production of a series of voltage pulses, a source of alternating current, a counting circuit including a plurality of stepping tubes arranged to count the cycles of said source current, each of said tubes including a plurality of output networks for producing voltages to represent the number of cycles of the source current counted thereat, a plurality of gaseous discharge devices, each having a starter anode, a main anode and a cold cathode, means including multicontact switches having arms engageable with the respective contacts thereof for connecting certain of said networks to the starter anodes of said devices, said switch arms being positioned on preselected switch contacts for applying two discrete voltages from two of said networks to the starter anodes of said devices during each complete cycle of operation of said counting circuit, the first of said last-mentioned two network voltages representing a predetermined number of cycles counted by said counting circuit and establishing the conducting condition in two of said devices, the first of said devices in the conducting condition commencing the production of one of said voltage pulses, a second of devices in the conducting condition applying at the same time a voltage to said counting circuit to condition the latter circuit in such manner that one complete cycle of operation of said counting circuit is terminated and the next succeeding cycle of operation of the counting circuit is commenced, and means connected between the starter anode of a third of said devices and the cathode of said first device and responsive to the conducting condition in said first device for applying a coincidence voltage to said last-mentioned starter anode, a second one of said last-mentioned two network voltages representing a preselected number of cycles counted by said counting circuit and cooperating with said coincidence voltage to establish the conducting condition in a third of said devices, said third device in the conducting condition producing a voltage which causes said first device to return to the non-conducting condition thereby to terminate the production of said one voltage pulse, the time interval between two successive conductions in said first device constituting substantially the rate of repetition of the produced voltage pulses, and the time interval between the conduction of said first device and second device constituting substantially the time duration of each of the produced voltage pulses.

8. In a voltage pulse generator, a counting circuit including a plurality of stepping tubes, each tube having a plurality of output terminals and a preselected electrode, each of said terminals having a voltage effective thereon to represent a predetermined number of pulses counted by said circuit, and means for applying stepping pulses to said counting circuit, a plurality of gaseous discharge devices in the non-conducting condition, each including a starter anode, a main anode and a cold cathode, selective means for applying the voltages of certain output terminals of at least two of said tubes to the starter anodes of said devices, the voltage at one terminal selected by said selective means establishing conduction simultaneously in two of said devices, means for applying a voltage due to conduction in the cathode and main anode circuit of one of said last-mentioned two devices to said preselected electrode of a predetermined one of said tubes to condition said counting circuit for a new cycle of counting action, means for applying to the starter anode of a third one of said devices a coincidence voltage due to conduction in the cathode and main anode circuit of a second one of said two conducting devices, means responsive to conduction in the cathode and main anode circuit of said second device to commence the production of a voltage pulse, the simultaneous voltages on the starter anode of said third device due to the tube terminal voltage selected by said selective means and to the coincidence voltage cooperating to establish conduction in the cathode and main anode circuit of said third device and means activated by the conduction in said third device to produce a voltage for quenching the conduction in said second device thereby terminating the production of the voltage by said second device.

9. A pulse generator in accordance with claim 8 in which said activating means comprises an inductor, a resistor and a capacitor.

10. A pulse generator in accordance with claim 8 in which said voltage coincidence means includes a resistor connecting the cathode of said second device to ground, and means connecting the starter anode of said third device to a junction point of said last-mentioned cathode and resistor.

11. A pulse generator in accordance with claim 8 in which said means for applying the voltage from said one conducting device to said preselected electrode of said predetermined tube includes a resistor and capacitor network.

12. A pulse generator in accordance with claim 8 in which said means for applying the voltage from said one conducting device to said preselected electrode of said predetermined tube includes in series a capacitor and a parallel resistor and capacitor network.

13. In an electrical control system, a counting circuit including a plurality of stepping tubes, each of said tubes having a plurality of transfer and rest cathodes, a normal cathode, an auxiliary anode, means for connecting said auxiliary anode of each of said tubes to said transfer cathodes of the next succeeding tube, and a source of stepping pulses connected to the transfer cathodes of a first one of said tubes, a plurality of electronic devices, each including a starter anode, a main anode and a cold cathode, selective means for connecting a certain rest cathode of a preselected one of said tubes to the starter anode of a first one of said devices, further selective means for connecting a preselected rest cathode of another of said tubes to the starter anodes of a second and third of said devices, means for connecting the cathode and main anode circuit of said second device to said normal cathode of a preselected one of said tubes, resistance means for connecting the cathode of said third device to the starter anode of said first device, and means connected to the cathode and main anode circuit of said third device and operatively controlled thereby.

14. In a generator of a series of voltage pulses, a counting circuit including a plurality of stepping tubes, each having a plurality of output terminals, a common anode, a preselected cathode and means for applying stepping pulses to one of said tubes, a plurality of gaseous discharge devices in the non-conducting condition, each including a starter anode, a main anode and a cold cathode, a multicontact switch having preselected contacts connected to certain output terminals of two of said tubes and having an arm engageable with the respective contacts thereof, said arm being connected to the starter anode of a first one of said devices, a three-stage multicontact switch, each stage having an arm engageable with the respective contacts thereof, said arms being mechanically connected together and thereby caused to engage corresponding contacts of the respective stages, a first of said switch stages having its contacts connected to output terminals of two of said tubes, said arm of said first switch stage being connected to the starter anodes of a second and third of said devices, means including a capacitor, an RC network and a second stage of said three-stage switch for connecting the cathode and main anode circuit of said second device to said preselected cathode of a predetermined one of said tubes, means including a third stage of said three-stage switch for connecting a source of +B voltage to said common anode of one of said tubes, means including a network comprising an inductor, a resistor and a capacitor for connecting the main anodes of said first and third devices, means including a resistor for connecting the cathode of said third device to the starter anode of said first device, and work connected to the cathode and main anode circuit of said third device, said arms of said switches being positioned on preselected contacts thereof to apply the voltages of predetermined output terminals of said tubes to the starter anodes of said devices to establish the conducting and non-conducting conditions therein in accordance with a preselected number of stepping pulses counted by said counting circuit, the conducting condition in the cathode and main anode circuit of said second device conditioning said counting circuit for the commencement of each counting cycle, the conducting condition in the cathode and main anode circuit of said third device introducing a voltage pulse in said work and at the same time producing a coincidence voltage in said resistance means for application to the starter anode of said first device, said first device being changed to the conducting condition in its cathode and main anode circuit in response to the simultaneous application of said two voltages to the starter anode thereof, said first device in the conducting condition causing the application of a voltage to said main anode of said

third conducting device through said network connecting the main anodes of said last-mentioned two devices in order to quench the conducting condition therein whereby the voltage pulse introduced into said work is terminated, each such establishment of the conducting and non-conducting conditions in said third device serving to introduce one voltage pulse into said work.

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