

June 1, 1948.

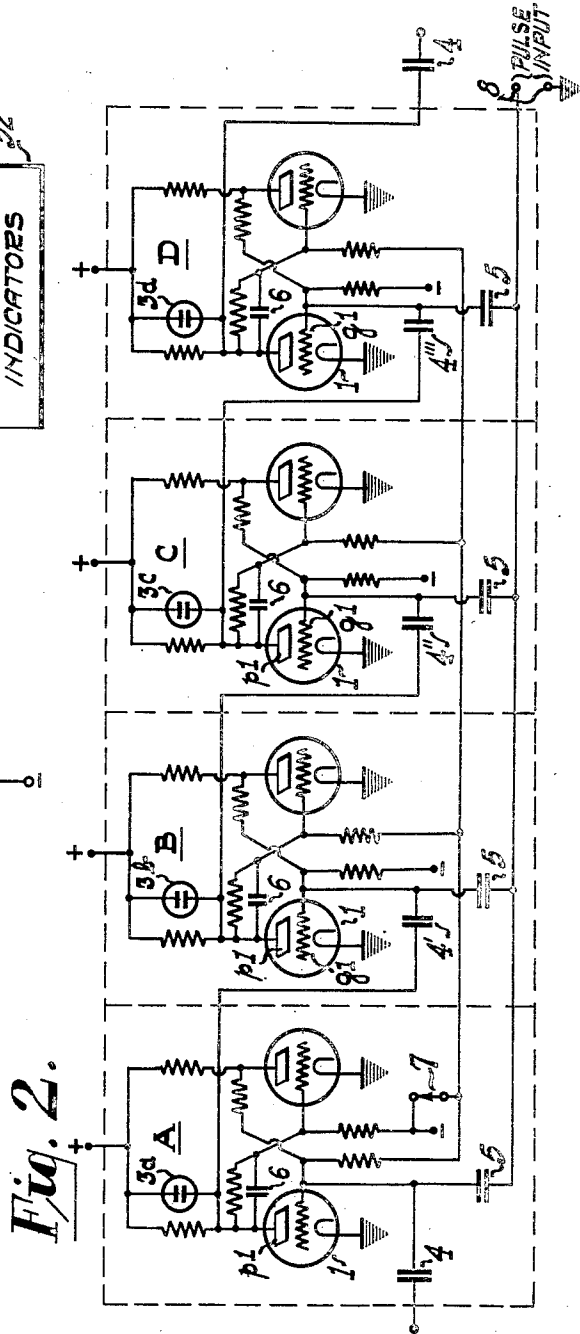
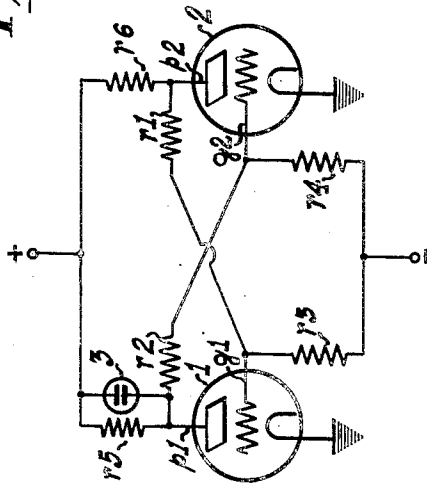
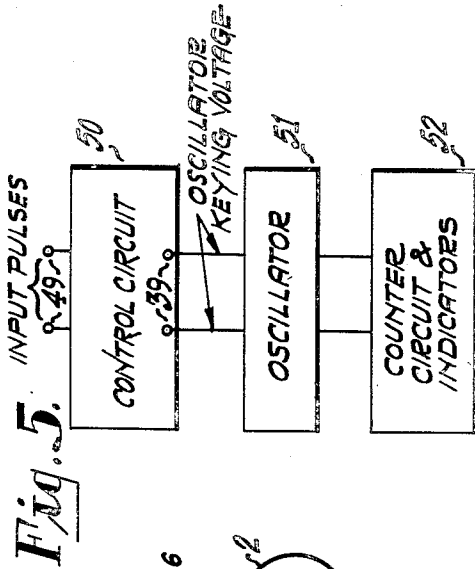
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2,442,403

ELECTRONIC SWITCHING AND COMPUTING DEVICES

Filed Sept. 23, 1942

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

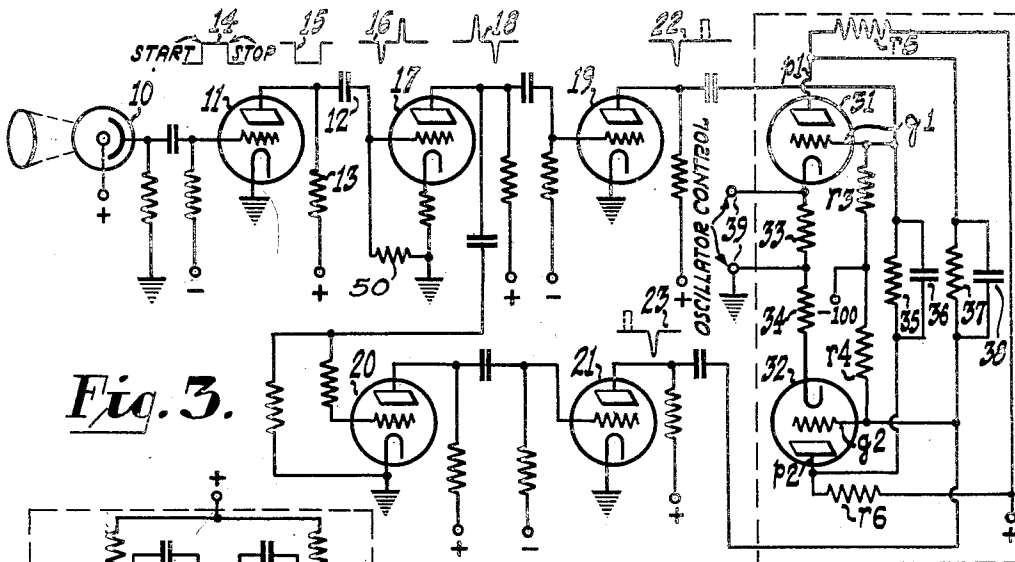


Fig. 3.

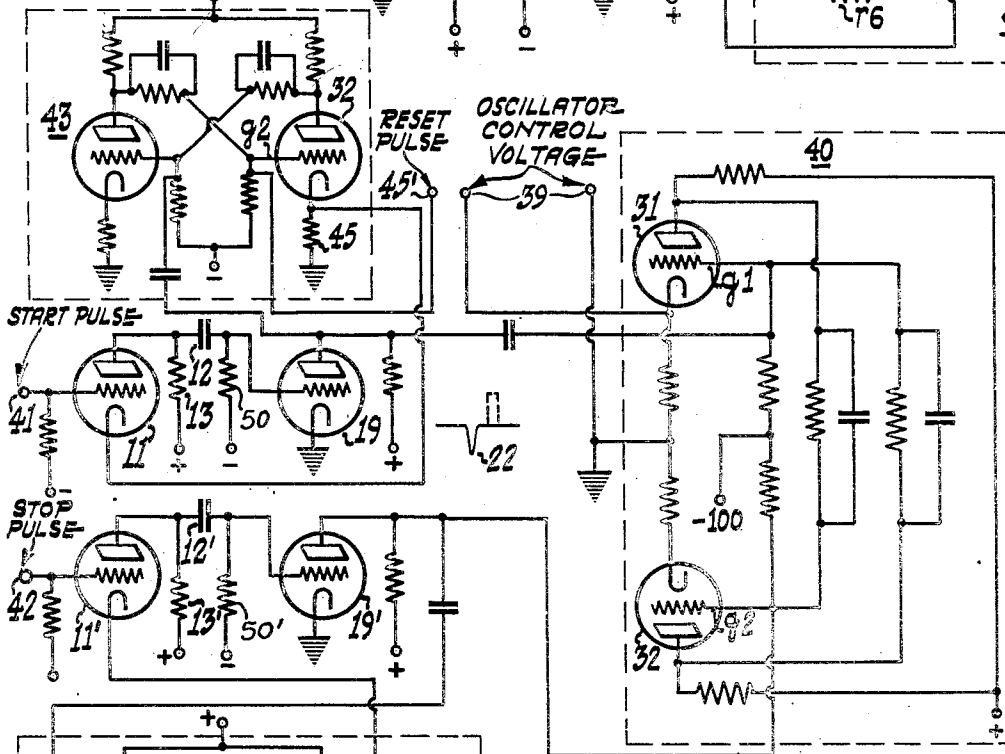


Fig. 4.

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ELECTRONIC SWITCHING AND COMPUTING
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This invention relates generally to electronic computers and particularly to electronic apparatus for counting or timing voltage pulses.

The basic circuit utilized in adapting the invention herein to the various circuits to be described is the well known "trigger" circuit of the general type described in "Theory and Application of Vacuum Tubes," by Herbert J. Reich. In its simplest form, this trigger circuit includes two triodes in which the grid of the first triode is coupled to the anode of the second triode through a coupling resistor, and the grid of the second triode is coupled to the anode of the first triode through a similar coupling resistor. The cathodes of both triodes are grounded. Grid and anode potentials are applied to the respective electrodes through separate resistors. If desired, a gaseous discharge tube may be connected across one of the anode resistors to indicate circuit operation.

In operation, if a negative voltage is applied to the grid of the first triode, the anode current of the triode will be reduced and the anode potential will become more positive. Due to the connection through the coupling resistor, the grid potential of the second triode will become more positive, causing an increase in the anode current of the second triode, with a resultant decrease in the second triode anode potential. This decrease in anode potential will in turn cause the grid potential of the first triode to become more negative. This action will continue until the anode current of the first triode is cut off. The first triode will remain cut off, and the second triode will remain conducting, until a positive potential is applied to the grid of the first triode, or a negative potential is applied to the grid of the second triode. In either instance, the tube operating conditions will be reversed, and the first triode will become conducting and the anode current of the second triode will be cut off.

One of the features of the instant invention is the utilization of such trigger circuits in cascade arrangement, whereby a predetermined change in polarization of one triode of the trigger circuit will generate a pulse to trigger or activate, a corresponding triode in a succeeding trigger circuit. As many trigger circuits as desired may be connected in cascade. A convenient arrangement comprises ten trigger circuits connected in cascade, with a connection from the tenth to the first, and an additional connection to the first of a succeeding bank of cascaded trigger circuits. Such an arrangement provides a convenient counter in the scale of ten. Such a counter cir-

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cuit may also be readily adapted to a scale having any other radix, or base of the counting system.

Another feature of the invention is the use of the trigger circuit for controlling the operation of a constant frequency source such as an oscillator. The output of the oscillator is applied to a counter circuit of the type described. The number of oscillations occurring during the controlled interval are a measure of the length of the interval.

Among the objects of the invention are to provide a new and improved means for counting voltage pulses. Another object of the invention is to provide an improved means for utilizing conventional trigger circuits in cascade arrangement for counting voltage pulses. Still another object is to provide an improved means for connecting conventional trigger circuits in cascade arrangement to provide a continuous counter. A further object is to provide improved means for clearing the counter after each operation thereof, for conditioning the circuit for counting succeeding applied pulses. Another object is to provide a new and improved means for controlling the interval of oscillation of a constant frequency source. Still another object is to provide a new and improved means for controlling the interval of operation of a constant frequency source in combination with electronic means for counting the oscillations during the controlled interval. A further object is to provide a new and improved means for preventing the triggering of the oscillator operating interval by other than predetermined starting and stopping voltage pulses.

The invention will be described by reference to the accompanying drawings of which Figure 1 is a schematic circuit diagram of a trigger circuit representative of the prior art; Figure 2 is a schematic circuit diagram of a counter circuit comprising one embodiment of the invention; Figure 3 is a schematic circuit diagram of a second embodiment of the invention; Figure 4 is a schematic circuit diagram of a third embodiment of the invention; and Figure 5 is a block diagram of a preferred combination of the circuits described in Figures 2, 3 and 4. Similar reference numerals are applied to similar elements throughout the drawings.

Referring to the drawings, Fig. 1 comprises a trigger circuit of the type described heretofore. The grid *g1* of a first triode 1 is connected to the anode *p2* of a second triode 2 through a coupling resistor *r1*. The anode *p1* of the first triode 1 is connected to the grid *g2* of the second triode 2 through a second coupling resistor *r2*. The

cathodes of the first and second triodes 1 and 2 are grounded. A source of negative bias potential is connected to the grid $g1$ of the tube 1 through a grid resistor $r3$ and to the grid $g2$ of the second triode 2 through a grid resistor $r4$. Anode potential is applied to the anode $p1$ of the first tube 1 through an anode coupling resistor $r5$ and to the anode $p2$ of the second tube 2 through a second anode coupling resistor $r6$. A gaseous indicator tube 3, which may be a conventional neon tube, is connected across the first anode resistor $r5$ to indicate when the anode potential exceeds a predetermined value characteristic of the anode current cut-off condition of the first tube 1.

In Fig. 2 a plurality of trigger circuits, which may be of the general type described in Fig. 1, are connected in cascade arrangement by connecting the anode $p1$ of the first tube of the first trigger circuit A to the grid $g1$ of the first tube of the second trigger circuit B through a first coupling capacitor 4'. Similarly the anode $p1$ of the first tube of the second trigger circuit B is connected to the grid of the first tube of a third trigger circuit C through a similar coupling capacitor 4''. Likewise the anode $p1$ of the first tube of the third trigger circuit C is connected to the grid $g1$ of the first tube of a fourth trigger circuit D through a similar coupling capacitor 4'''. As many trigger circuits as desired may be connected in this cascade arrangement. As explained heretofore, the counter may be made continuous, by connecting the last trigger circuit of any bank to the input of the first trigger circuit. Pulses to be counted are applied to the first grid $g1$ of the first tube 1 of each of the trigger circuits through separate second coupling capacitors 5. The second capacitors 5 should preferably be of lower capacity than the first coupling capacitors 4, in order that control potentials due to the cascading of the trigger circuits may over-ride pulses applied through the capacitors 5. In order to compensate for the additional loading of the anode circuit of the first trigger tube in each trigger circuit due to the coupling to the next succeeding trigger circuit, capacitors 6 are connected in parallel with each of the coupling resistors which connect the anode of each first tube to the grid of each second tube. If desired, compensation may be provided by applying different bias voltages to the grids of the first and second tubes of each trigger circuit.

In operation, if it is assumed that trigger circuits A, C and D are polarized so that the anode currents of the first tubes 1 of each of the trigger circuits are cut off, and the second tubes 2 are conducting, while in trigger circuit B the first tube 1 is conducting and the anode current of the second tube 2 is cut off, the neon tube 3b will be illuminated, indicating the different condition of the trigger circuit B. If a negative pulse is applied to the pulse input terminals 8, which are connected to the capacitors 5 and ground, it will not affect the trigger circuits A, C, and D since the first tube of each of these circuits is already cut off. However, the negative pulse will cut off the anode current of the first tube of the trigger circuit B which was previously conducting. The resultant increase in the anode potential of this tube will apply a positive pulse to the grid circuit of the first tube 1 of the trigger circuit C. When this occurs the indicator lamp 3b will be extinguished, and the indicator lamp 3c will be illuminated, indicating the conducting condition of the first tube 1 of the trigger

circuit C. Subsequent negative pulses applied to the terminals 8 will sequentially trigger succeeding trigger circuits in the same manner. The particular illuminated indicator lamp will indicate the total pulses applied. To clear the counter after each operation, a switch 7 is opened. This removes the negative bias from the second tubes of trigger circuits B, C and D, and the first tube of trigger circuit A, thereby tripping all trigger circuits except A into the same polarization, and causing the indicator tube 3a to be illuminated.

Fig. 3 is a counter circuit energized by pulses generated by a light responsive device 10, or other device to be timed, which produces a voltage of approximately square wave form. This voltage is amplified and phase inverted in a first amplifier tube 11, and applied to a differentiating circuit comprising a capacitor 12 and a resistor 50. The square wave voltages are illustrated by the graphs 14 and 15, while the voltage output of the differentiating circuit is illustrated by the graph 16. The differentiated voltage 16, is applied to a second amplifier tube 17, the output of which is phase inverted, as indicated by the graph 18. The thus amplified voltages are next applied to the input of a clipping amplifier or rectifier 19 which passes only the negative half-cycle of each voltage pulse, as indicated by the graph 22. This pulse corresponds to the start of pulse 14. The pulses 18 are also applied to a phase inverter tube 20 and rectified by a second rectifier tube 21 which passes similar negative half-cycles of the pulses 18, as indicated by the graph 23, which correspond to the end of pulse 14.

The negative pulses 22, derived from the first rectifier tube 19, are applied to key the grid $g1$ of a first tube 31 of a trigger circuit which includes the tube 31 and a second tube 32. The negative half cycles derived from the second rectifier tube 21 are applied to the grid $g2$ of the second trigger tube 32. The plate resistors $r5$ and $r6$ and the grid resistors $r3$ and $r4$ are connected as shown in the previously described Fig. 1. The cathodes of the tubes 31 and 32 are connected to ground through the cathode resistors 33 and 34 respectively. A coupling circuit, comprising the parallel connected resistor 35 and capacitor 36, is connected between the grid $g1$ of the first trigger tube 31 and the anode $p2$ of the second trigger tube 32. A second coupling circuit, comprising the parallel connected resistor 37 and capacitor 38, is connected between the anode $p1$ of the first trigger tube 31 and the grid $g2$ of the second trigger tube 32.

The operation is as follows: A negative pulse 22, derived from the energization of the light sensitive device 10, tends to cut off the anode current of the first trigger tube 31, which is normally biased by means of its cathode resistor 33 to be conducting. At the same time, a positive pulse from the anode of the first tube 31 is applied to the grid $g2$ of the second trigger tube 32, which causes it to conduct and apply an additional negative potential to the grid $g1$ of the first trigger tube 31, to cut off its anode current. When the first trigger tube 31 is cut off, the potential across the cathode resistor 33, which is connected to the terminals 39, is reduced. A control potential is derived from the terminals 39, and is utilized to control the interval of oscillation of a constant frequency source, to be described hereinafter. When the light sensitive device 10 is de-energized, the negative pulse 23 is applied to cut off the anode

current of the trigger tube 32, thereby reversing the polarization of the trigger tubes. Since the negative bias potential derived from the anode of the tube 32 is removed, the trigger tube 31 is restored to a conducting condition and the voltage across the cathode resistor 33 applied to the terminals 39 is increased.

Fig. 4 is similar to Fig. 3 with the exception that separate starting and stopping pulses are provided, and additional trigger circuits or multivibrators are included for deconditioning, or locking, the oscillator control trigger circuit after each change in its polarization. In addition, selective means are provided for reconditioning the circuit for succeeding starting and stopping pulses. The circuit includes an amplifier 11, a differentiating circuit comprising the capacitor 12 and the resistor 50, and a rectifier 19, for deriving a negative pulse 22 as described in connection with Fig. 3. An additional amplifier tube, a differentiating circuit comprising a capacitor 12' and a resistor 50'; and an additional rectifier tube 19' is also provided for deriving a second group of negative pulses of similar type. A trigger circuit 40, which is similar to the trigger circuit described in Fig. 3, is connected so that the negative pulses 22 derived in the first rectifier 19 are applied to the grid *g*1 of the first tube 31, while negative pulses derived from the second rectifier 19' are applied to the grid *g*2 of the second trigger tube 32.

A starting pulse, applied to the terminal 41, causes the first trigger tube 31 to be cut off. A stopping pulse, applied to the terminal 42, causes the second tube 32 to be cut off and the first trigger tube 31 to conduct. In order to prevent succeeding pulses applied to the terminals 41 and 42 affecting the operation of the trigger circuit 40, a second trigger circuit, or multivibrator, 43 is connected to the output of the first rectifier 19 and a third trigger circuit, or multivibrator, 44 is connected to the output of the second rectifier 19'. When a pulse is applied to the terminal 41, the trigger circuit 43 generates a positive potential across the cathode resistor 45. This positive potential is applied to the cathode of the amplifier tube 11 to bias off the tube anode current, thereby preventing any succeeding pulses from affecting the operation of the circuit. The operation of the third trigger circuit 44 produces controlling potentials similar to those described for the second trigger circuit 43; the controlling potentials from the third trigger circuit are applied to the cathode of the amplifier 11. A "start" pulse applied to the terminal 41 will provide a control potential across the terminals 39 which will be unaffected by any other applied pulses, until such time as the stop pulse is applied to the terminal 42. Pre-set pulses may be derived in any suitable manner and applied to the terminals 45' and 46, respectively, of the second and third trigger circuits 43, 44, to recondition the circuits for operation by succeeding "start" or "stop" pulses. The third trigger circuit 44 is normally in the state of polarization which prevents transmission of "stop" pulse. An activating pulse either from the "start" circuit, or a delay circuit, not shown, reverses the polarization of the trigger circuit 44, so that a "stop" pulse on 42 will reverse the polarization of the control trigger circuit 40.

Fig. 5 is a block diagram of a typical arrangement for utilizing the circuits described in Figs. 2, 3 and 4. A control circuit 50, which, for example, may be of either of the types described in Figs. 3 and 4, provides a control potential at its

terminal 39 in response to pulses applied to the input terminals 49. This potential is applied to a constant frequency source 51, such as a crystal controlled oscillator, to control the interval of oscillation thereof, for example, by blocking and unblocking the circuit. The output of the oscillator 51 is applied to the input of an electronic counter circuit 52, which may be of the type described in Fig. 2. The indicators of the counter circuit may also be of the type described in Fig. 2 wherein neon discharge tubes indicate the number of pulses applied to the input of the counter circuit. The duration of the control voltage derived from the terminals 39 of the timing circuit 50 will determine the interval of oscillation of the oscillator 51. Since the oscillator output is of constant frequency, the oscillations counted by the counter circuit 52 will be a direct indication of the time interval provided by the timing circuit 50.

Thus the invention described comprises an electronic counter circuit utilizing trigger circuits or multivibrators in cascade arrangement, and means for utilizing additional trigger circuits for generating control potentials for controlling the oscillation interval of a constant frequency source. The oscillation interval is measured by counting pulses derived from the constant frequency source which are applied to the input of the electronic counting circuit.

We claim as our invention:

1. A timing circuit including a source of timing pulses, means for shaping said pulses, a trigger circuit including at least two thermionic tubes each including at least an anode, a cathode, and a control electrode, means interconnecting the anodes of each of said tubes to the control electrode of another of said tubes, means for applying said shaped pulses to one of said interconnected tube circuits of said trigger circuit and to vary the relative polarization of said tubes, means for deriving control potentials from said trigger circuit characteristic of the polarization of said tubes of said trigger circuit, a source of oscillations, an oscillation counter, means responsive to said control potentials for controlling the duration of said oscillations, a second trigger circuit, means for applying said pulses to said second trigger circuit to trigger said second trigger circuit, means for deriving a control voltage from said second trigger circuit, and means for applying said voltage to said timing pulse source to bias-off succeeding applied pulses.

2. Apparatus of the type described in claim 1 including means connected to said second trigger circuit for suppressing said control voltage.

3. The combination of a source of oscillations, an oscillation counter, means for applying a timing pulse of a substantially square wave shape, timing pulse shaping means for producing a control pulse in response to the beginning of said timing pulse, a trigger circuit of the type wherein a pair of triodes each have operating potential applied through separate anode and cathode resistors and each triode has its grid coupled to the anode of the other triode through a capacitor shunted by a resistor, and means responsive to said control pulse for applying said control pulse to one of said grids so that current conduction is shifted from one to another of said triodes and there is applied from one of said cathode resistors to said source of oscillations a potential whereby the supply of said oscillations to said counter is initiated.

4. The combination of a source of oscillations,

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an oscillation counter, means for applying timing pulses of a substantially square wave shape, timing pulse shaping means for producing separate control pulses at the beginning and at the end of said timing pulse, a trigger circuit of the type wherein a pair of triodes each have operating potential applied through separate cathode resistors and each triode has its grid coupled to the anode of the other triode through a capacitor shunted by a resistor, means for applying one of said control pulses to one of said grids, means for reversing the polarity of the other of said control pulses and applying said reversed control pulse to the other of said grids, and means responsive to the voltage of one of said cathode resistors for starting and stopping the supply of said oscillations to said counter.

5. A timing circuit including a source of timing pulses, means responsive to said timing pulses for producing control pulses of the same polarity at the beginning and at the end of said timing pulses, a trigger circuit including at least two thermionic tubes each including at least an anode, a cathode and a control electrode, means interconnecting the anode of each of said tubes to the control electrode of the other of said tubes, means for applying a first one of said control pulses to one of said interconnected tube circuits of said trigger circuit and the next succeeding one of said control pulses to the other of said interconnected tube circuits of said trigger circuit to vary the relative polarization of said tubes of said trigger circuit, means for deriving control potentials from said trigger circuit characteristic of the polarization of said tubes of said trigger

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circuit, a source of oscillations, an oscillation counter connected to the output of said source, and means responsive to one of said control potentials for starting the supply oscillations from said source to said counter and to the other of said control potentials for stopping said supply of oscillations.

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