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CONTROL CIRCUIT

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Fig. 1.

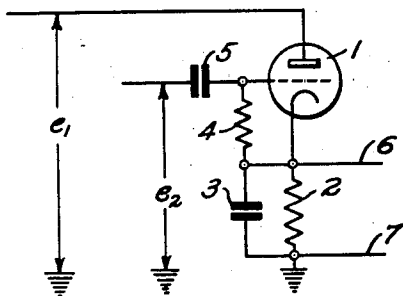


Fig. 2.

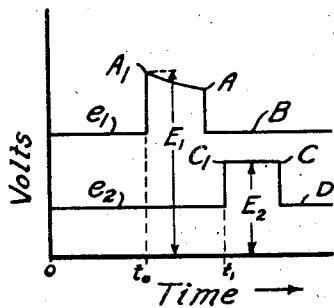
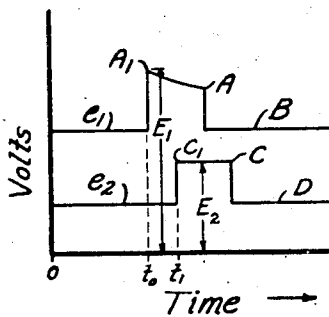


Fig. 3.



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CONTROL CIRCUIT

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My invention relates to electrical control circuits and, in particular, relates to electrical timing circuits.

One object of my invention is to obtain a direct-current output voltage having an amplitude which is a predetermined function of the time interval separating two voltage pulses impressed on its input terminals.

Another object of my invention is to provide a circuit in which the output voltage is substantially an exponential function of the time interval between the input pulses.

Another object of my invention is to provide a circuit in which the output voltage is substantially a linear function of the time interval between the input pulses.

Other objects of my invention will become apparent upon reading the following description taken in connection with the drawings, in which:

Figure 1 is a schematic diagram of a circuit for carrying out the principles of my invention;

Fig. 2 is a graph of curves showing a wave form and timing of voltage pulses impressed on the input terminals of the circuit of Fig. 1 under one condition of operation of that circuit; and

Fig. 3 is a similar graph of the relationship between similar voltage pulses impressed on such input terminals under another condition of operation of my invention.

Referring in particular to Fig. 1, I provide an electrical discharge tube having a cathode and two cooperating electrodes and which is preferably of the high vacuum hot-cathode type well known in the electronic art. A tube having an anode and a control electrode is a well-known example of such a tube. The cathode of the tube 1 is preferably grounded through a cathode resistor 2, shunted by a capacitor 3 and is likewise connected to one electrode of the tube 1 through a suitable resistor 4. A voltage pulse e_2 , having the wave form shown by the lower curve in Figs. 2 and 3, is impressed through a capacitor 5 between ground and this electrode of the tube 1. A voltage pulse e_1 , preferably having the wave form of the upper curves shown in Figs. 2 and 3, is impressed between ground and the other electrode of the tube 1. A pair of output terminals 6, 7 are respectively connected across the cathode resistor 2.

As is known in the art, electron discharge tubes change from a relatively non-conductive to a relatively conductive condition when the voltages impressed between their cathodes and other electrodes are properly related. As a first approximation they are conductive when $e_1 + me_2 > K$

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where m and K are tube parameters. The voltages e_1 and e_2 are so adjusted to the constants of the tube 1 that even the maximum value E_2 of the voltage pulse e_2 will be unable to cause current flow through the tube 1 while e_1 has its trough or low value B ; and also that even the maximum value E_1 of the pulse e_1 will be unable to cause current flow when the voltage pulse e_2 has its trough or low value D . In other words $B + mE_2 < K$ and $E_1 + mD < K$. But the value of E_2 is made such that $e_1 + mE_2 \geq K$ whenever e_1 exceeds its trough value B . Curves connecting plate voltage and control electrode voltage for electron tubes are well known in the art and will enable those skilled in the art to select proper values for the voltage magnitudes E_1 , B , E_2 and D just mentioned, to effect the purposes just described.

A moment's consideration will show that under the conditions illustrated in Fig. 2, i. e. when the voltage pulses in curves e_1 and e_2 are never simultaneously impressed on the tube 1, the latter will never be in condition to conduct substantial current from its anode to its cathode. On the other hand, under the conditions of operation illustrated in Fig. 3, wherein the voltage e_2 attains the value E_2 before the voltage e_1 falls to the trough value B , current will be conducted between the anode and cathode of the tube 1, thereby producing a voltage drop in the cathode resistor 2 and charging the capacitor 3. It is obvious that the tube 1 will begin to conduct at the time t_1 , corresponding to the position of the left-hand edge of the voltage pulse e_2 , since this is the first time when the voltage e_2 has a value at least equal to E_2 and the voltage e_1 has a value greater than B .

When the tube 1 has any substantial conductivity its anode-to-cathode resistance will, in effect, constitute a resistor through which the capacitor 3 is being charged by the voltage e_1 . The value of the anode-to-cathode resistance of tube 1 obviously depends on the magnitude of the voltages e_1 and e_2 at the time t_1 , and by proper design obvious to those skilled in the art, this anode-to-cathode resistance can be made small enough so that the capacitor 3 will charge up almost instantly to the voltage of the source e_1 at time t_1 . Thus, under the conditions illustrated in Fig. 3, the voltage to which the capacitor 3 charges will depend upon the value of the time t_1 and upon the wave shape shown for e_1 in that figure. The voltage to which capacitor 3 charges will increase as the value of the time t_1 decreases.

Once the capacitor 3 has charged up to the value of the voltage e_1 , current flow through the tube 1 will cease because, after the time t_1 , the

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voltage e_1 is smaller than that to which the capacitor 3 has just been charged and e_1 can no longer produce flow of charging current through the unilateral conductance of tube 1.

If the top portion A— A_1 of the voltage pulse e_1 is made linear, it is obvious that the voltage to which the capacitor 3 charges will be proportional to the time interval t_1 — t_0 . In other words, the capacitor 3 is charged to a voltage which is a linear function of the time interval t_1 — t_0 just mentioned.

On the other hand, if the top portion A— A_1 of the voltage pulse e_1 is an exponential curve, the voltage to which the capacitor 3 charges will be an exponential function of the above-mentioned time interval. Similarly, by altering the wave form of the voltage pulse e_1 between the value A and A_1 to any other desired curve, the voltage to which capacitor 3 charges can be made any corresponding desired function of the above-mentioned time interval.

If the curves e_1 and e_2 are non-periodic, i. e. non-repetitive, the capacitor 3 will stay charged to the above-described voltage until it is discharged either by a load impressed across the terminals 6, 7 or by leakage through the resistor 2. The higher the value of the resistor 2, the more slowly the capacitor 3 will discharge under the last-mentioned conditions; and, in particular, by omitting the resistor 2, the capacitor 3 may be kept charged to the value described in the preceding paragraph until it is discharged through the load attached to the terminals 6, 7.

On the other hand, it may be desired to make the voltage pulses e_1 and e_2 of a repetitive character; that is to say, to give them the form of a series of periodic pulses. In such a case the value of the resistor 2 must be so proportioned to the value of the capacitor 3 as to discharge the latter in a time much greater than the period of repetition.

It will be obvious that the pulse-portions of curve E_1 and E_2 may have various forms so long as they conform to the criterion $e_1 + me_2 > K$ throughout a pulse width corresponding to the desired maximum value of t_1 — t_0 and also that the portions other than the pulses in those curves may depart from the constant values B, C and D so long as $e_1 + me_2$ is always $< K$. However, by giving the pulses substantially vertical leading (left) edges and making the values B, C and D constants, the difficulty of fulfilling the inequalities just mentioned are greatly decreased. It should be noted that my arrangement would still be operative if the voltage of wave shape e_1 were impressed on the grid electrode and e_2 on the anode, but the behavior of the tube would then be more sensitive to unwanted variations of either e_1 or e_2 .

It will be noted that in the system so far described the pulse e_2 , having the flat top, is the later in time than e_1 . If it is desired to obtain an output voltage on the terminals 6, 7 which decreases instead of increasing with the time intervals t_1 — t_0 , the top of the pulse having a non-horizontal wave-top may be sloped upward to the right while the width of the other pulse is made substantially narrower than the former.

The capacitor 5 and resistor 4 develop a negative bias in a way well known in the art, which insures that discharge will not start in tube 1 until the positive pulse e_2 is impressed.

I claim as my invention:

1. In combination with a grid controlled electrical discharge tube a capacitor connected to be

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charged by current flow through said tube, means for impressing on the anode of said tube and said capacitor a first voltage pulse, means for impressing on the control electrode of said tube and said capacitor a second voltage pulse, said capacitor being intended to be charged in an amount dependent upon the overlap in time of said pulses, one of said voltage pulses having a substantially horizontal crest, and an output circuit connected to derive voltage from said capacitor.

2. In combination with a grid controlled electrical discharge tube a capacitor connected to be charged by current flow through said tube, means for impressing on the anode of said tube and said capacitor a first voltage pulse, means for impressing on the control electrode of said tube and said capacitor a second voltage pulse, said capacitor being intended to be charged in an amount dependent upon the overlap in time of said pulses, both of said voltage pulses having at least one substantially vertical edge, one of said voltage pulses having a substantially horizontal crest, and an output circuit connected to derive voltage from said capacitor.

3. In combination with a grid controlled electrical discharge tube a capacitor connected to be charged by current flow through said tube, means for impressing on the anode of said tube and said capacitor a first voltage pulse, means for impressing on the control electrode of said tube and said capacitor a second voltage pulse, said capacitor being intended to be charged in an amount dependent upon the overlap in time of said pulses, both said voltage pulses having substantially vertical edges, one of said voltage pulses having a substantially horizontal crest, and an output circuit connected to derive voltage from said capacitor.

4. In combination with a grid controlled electrical discharge tube a capacitor connected to be charged by current flow through said tube, means for impressing on the anode of said tube and said capacitor a first voltage pulse, means for impressing on the control electrode of said tube and said capacitor a second voltage pulse, said capacitor being intended to be charged in an amount dependent upon the overlap in time of said pulses, both of said voltage pulses having substantially vertical edges, one of said voltage pulses having a substantially horizontal crest, the other said voltage pulse having a substantially rectilinear form between its said vertical edges, and an output circuit connected to derive voltage from said capacitor.

5. In combination with a grid controlled electrical discharge tube a capacitor connected to be charged by current flow through said tube, means for impressing on the anode of said tube and said capacitor a first voltage pulse, means for impressing on the control electrode of said tube and said capacitor a second voltage pulse, said capacitor being intended to be charged in an amount dependent upon the overlap in time of said pulses, both said voltage pulses having substantially vertical edges, one of said voltage pulses having a substantially horizontal crest, the other said pulse having a substantially exponential portion between its said vertical edges, and an output circuit connected to derive voltage from said capacitor.

6. In combination with a load circuit on which it is desired to produce a voltage which varies as a predetermined function of a time interval, a capacitor connected across said circuit, an electrical discharge tube having a cathode and two

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cooperating electrodes in series with said capacitor; and means for impressing on said respective cooperating electrodes two charging voltages for said capacitor, said charging voltages comprising voltage pulses, means for causing said voltage pulses to be impressed simultaneously for a time equal to said time interval, each of said voltage pulses having a substantially vertical edge portion, one of said voltage pulses having a substantially horizontal crest during said overlap and the other said voltage pulse having a form during said overlap which varies in accordance with said function.

7. The method of deriving a voltage pulse which is a predetermined function of a time interval which comprises charging a capacitor through a tube having at least three cooperating electrodes, impressing between one pair of said electrodes a voltage in the form of a pulse having a substantially horizontal crest, impressing between another pair of said electrodes a voltage pulse having a pair of substantially vertical edges connected by a time curve which corresponds to said predetermined function, said capacitor being intended to be charged in an amount dependent upon the overlap in time of said pulses, and causing said voltage pulses to overlap in time by an amount corresponding to said time interval.

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8. In combination a capacitor, an electron tube having two electrodes cooperating with a cathode which is connected to one terminal of said capacitor, and means for impressing between one of said electrodes and the other terminal of said capacitor a voltage pulse having a substantially vertical edge and a horizontal crest, means for impressing between the other said electrode and said other terminal of said capacitor a voltage pulse having a substantially vertical edge adjoining a rectilinear top, said capacitor being intended to be charged in an amount dependent upon the overlap in time of said pulses, and means for causing an overlap in time predetermined at will between said voltage pulses.

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