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R. C. MOORE  
PULSE DELAY SYSTEM  
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FIG. 1.

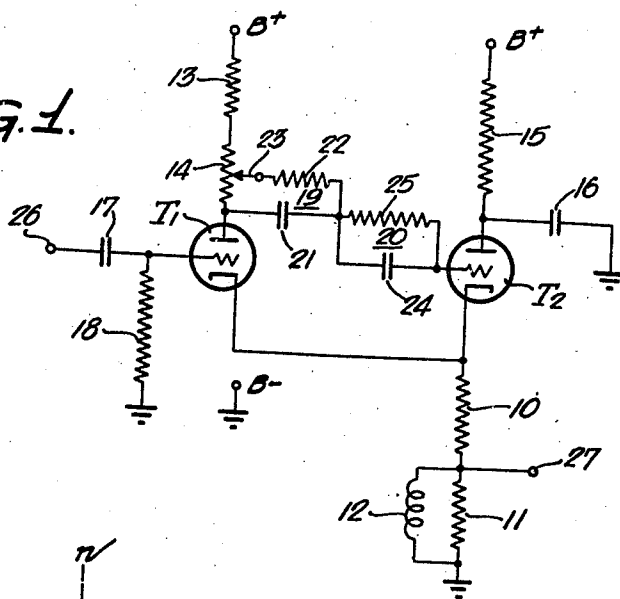


FIG. 2.

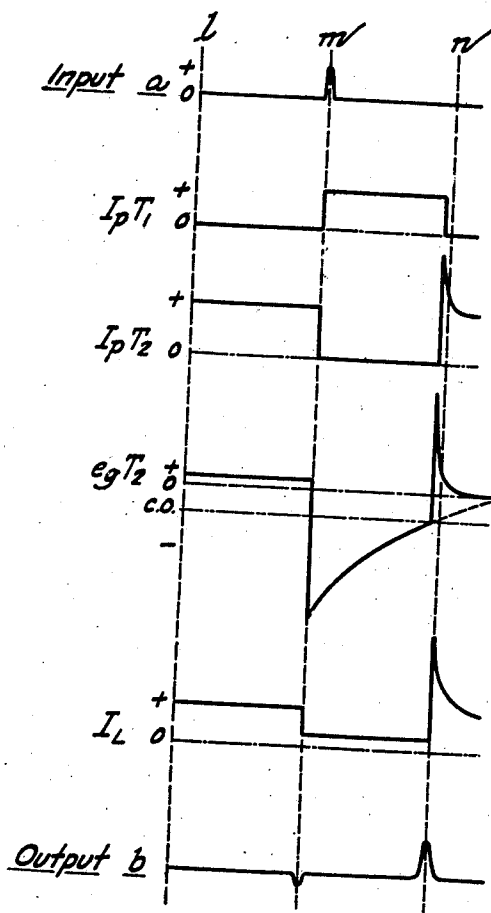
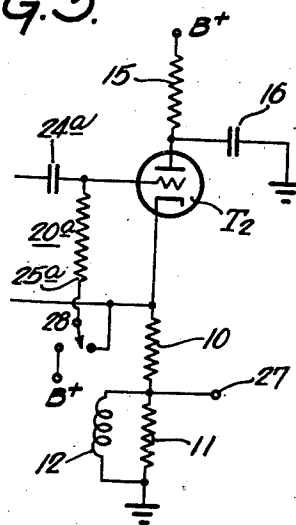


FIG. 3.



Inventor:  
Robert C. Moore  
by his Attorneys  
Houson & Houson

## UNITED STATES PATENT OFFICE

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## PULSE DELAY SYSTEM

Robert C. Moore, Philadelphia, Pa., assignor, by  
mesne assignments, to Philco Corporation,  
Philadelphia, Pa., a corporation of Pennsylvania

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1

This invention relates to pulse delay systems and particularly to pulse delay systems in which the interval between the applied pulse and the output pulse is adjustable.

There are numerous occasions in the art of electronics when it is desired to utilize the effect of a pulse at some predetermined time after the occurrence of the pulse. Furthermore, it is often desirable that the interval between the initial pulse and the delayed pulse be adjustable over a wide range.

It is therefore an object of the present invention to provide by means of a novel circuit, a system in which the interval between the applied pulse and the output pulse may be easily and effectively varied over a wide range.

This and other objects and features of the invention will be understood from the following description and the accompanying drawings, in which:

Fig. 1 illustrates schematically the preferred embodiment of the circuit of the present invention;

Fig. 2 is an explanatory diagram showing the wave forms of current and voltage at various points of the system for a cycle of operation; and

Fig. 3 shows an alternative embodiment of a portion of the circuit of Fig. 1.

Referring now to Fig. 1, there is shown schematically the preferred circuit arrangement of this invention. This circuit may be considered as a modified form of a conventional cathode-loaded multivibrator in which  $T_1$  and  $T_2$  represent the two electron discharge devices. While  $T_1$  and  $T_2$  are shown as separate vacuum tubes, and as triodes, it is evident that both sets of electrodes may be enclosed in a single envelope, and that multi-electrode tubes other than triodes may be used in the circuit with the conventional circuit modifications. The cathodes of tubes  $T_1$  and  $T_2$  are connected together and grounded through the common cathode resistors 10 and 11, resistor 11 being shunted by an inductance 12 to form a differentiating circuit whose function will be described hereinafter. The anode potential for tube  $T_1$  is obtained from a suitable direct current source  $B+$  and is applied through resistor 13 and the resistance of potentiometer 14. Resistor 13 may be a separate element as shown, or it may be included in potentiometer 14, depending upon the desired operating conditions. Vacuum tube  $T_2$  derives its anode potential from the source  $B+$  through the current limiting resistance 15. A by-pass condenser 16 is connected

2

between the anode of tube  $T_2$  and ground. To the grid of tube  $T_1$  there is connected a conventional input circuit, comprising coupling condenser 17 and grid resistor 18. The grid of vacuum tube  $T_2$  is coupled to the plate of tube  $T_1$  through two serially connected resistance-capacitance networks 19 and 20. Network 19 is composed of a condenser 21 shunted by the total resistance of a resistor 22 in series with that portion of potentiometer resistance 14 between the movable contact arm 23 and the plate of tube  $T_1$ . The resistance-capacitance network 20 comprises a condenser 24 in shunt with resistor 25. The input and output terminals of the system are shown at 26 and 27 respectively.

The multivibrator utilized for the present invention differs from the more conventional multivibrator oscillators in that it is constructed and arranged to produce only one cycle of oscillation in response to a given input pulse. Such single-cycle operation is not new, per se, but this mode of operation is utilized in the practice of the present invention.

The operation of the system will now be described with particular reference to Fig. 1, and to the voltage and current wave forms shown in Fig. 2.

In the absence of an input signal tube  $T_2$  is conducting, since a small positive potential is applied to its control grid from the plate circuit of tube  $T_1$  through resistors 22 and 25. These two resistors are of sufficiently high value to develop a large voltage drop across them due to the slight amount of grid current flowing in tube  $T_2$ . The space current of tube  $T_2$  flowing through the common cathode load 10—11—12 develops sufficient voltage across resistor 10 to bias the grid of tube  $T_1$  below its plate-current cut-off value, the bias voltage being applied through grid resistor 18. With no signal input, tube  $T_1$  is then not conducting.

The voltages and currents at various parts of the circuit for no signal input are shown in Fig. 2 for an interval of time represented between the vertical lines  $l$  and  $m$ . Referring to Fig. 2, we have then for zero signal input (see curve  $a$ ), zero plate current in tube  $T_1$  as indicated by curve  $I_{pT_1}$ , a steady current in the plate circuit of tube  $T_2$  shown at  $I_{pT_2}$ , a small positive potential on the grid of tube  $T_2$  as indicated by curve  $e_{gT_2}$ , a steady current through inductance 12 represented by  $I_L$ , and zero output as indicated by the output curve  $b$ .

During this period of no input signal the condensers 21 and 24 of Fig. 1 are charged to the

3  
voltages impressed on their terminals by the voltage drops developed across resistors 22 and 25 respectively. The total voltage across the two resistance-capacitance networks is then approximately equal to the anode supply voltage  $B+$ , since the voltage across the common cathode load circuit is just sufficient to bias tube  $T_1$  to cut-off.

Now when a positive pulse (see curve *a*, Fig. 2) is applied to the input terminal 26, tube  $T_1$  conducts and the potential on the plate of tube  $T_1$  quickly drops by an amount equal to the voltage drop developed across the plate load resistance comprising resistor 13 and potentiometer 14. This fall of potential is applied to the grid of tube  $T_2$  through condensers 21 and 24 thereby biasing the tube  $T_2$  to a potential well below its plate-current cut-off value. At this point then tube  $T_1$  is conducting and tube  $T_2$  is not conducting.

The potential on the grid of tube  $T_2$  remains below the plate-current cut-off value until the condensers 21 and 24 have sufficiently discharged through their respective shunting resistances 22 and 25 to bring the potential on the grid of tube  $T_2$  up to its cut-off value.

The length of time that the grid of tube  $T_2$  remains below its cut-off value is determined by the time constants of the  $R-C$  networks 19 and 20 and by the setting of contact arm 23 of potentiometer 14, the position of arm 23 determining the effective time constant of the coupling networks. The adjustment of the time interval will be described later.

When the grid of tube  $T_2$  reaches its cut-off value (indicated in curve  $e_g T_2$  by the dashed line "c. o.") the system regenerates; that is, tube  $T_2$  becomes conducting and tube  $T_1$  is again cut-off by the large negative bias developed across the cathode circuit resistance by the space current of tube  $T_2$ . When the plate current of tube  $T_1$  is cut off its plate potential immediately rises to substantially that of the supply potential  $B+$ . This increase in potential is also applied to the grid of tube  $T_2$  through the coupling network condensers 21 and 24 causing a sudden increase in the plate current of tube  $T_2$ . This high positive potential on the grid of  $T_2$  soon falls to the original small positive potential by virtue of the grid current of tube  $T_2$ .

However, during the instant the plate current of tube  $T_2$  suddenly increases from zero to the large value due to the high positive potential on its grid there is generated in the differentiating circuit 11-12 a high voltage of short duration. The magnitude of this voltage is, of course, proportional to the rate of change of space current in  $T_2$ . This voltage developed across inductance 12 at this particular instant appears as a positive pulse at output terminal 27. There is then generated in inductance 12 a voltage at the time the conduction changes from one tube to the other; however when the conduction changes from tube  $T_2$  to tube  $T_1$  there is only a relatively small change in current through inductor 12 and consequently only a very small negative pulse is then developed at the output terminal 27.

The voltage and current conditions in the various parts of the circuit from the time of the applied pulse at the input terminal 26 to the time when the circuit returns to its steady no-signal-input state are given in Fig. 2 between the vertical lines *m* and *n*. In this portion of Fig. 2, the position of the input pulse is shown on curve *a* and the changes that occur in those parts of the circuit, previously described for the interval *l* to *m*, are shown from the time of application of

the pulse until the grid of tube  $T_2$  returns to its steady small positive potential.

Curve  $e_g T_2$  clearly illustrates the drop of potential on the grid of tube  $T_2$  at the instant the positive pulse occurs. The resultant change in conduction of tubes  $T_1$  and  $T_2$  is given at  $I_p T_1$  and  $I_p T_2$  respectively, while at  $I_L$  the change in current through inductance 12 is indicated, the very small negative pulse resulting from the decrease in current in coil 12 being shown in curve *b*. During the interval represented between lines *m* and *n* of Fig. 2, the gradual rise of the grid potential of tube  $T_2$  from the large negative potential to the cut-off value "c. o." (due to the discharge of condensers 21 and 24 of Fig. 1) is illustrated at  $e_g T_2$ . This curve also shows the sudden rise in grid potential at the instant the grid of tube  $T_2$  reaches the plate-current cut-off value. The resulting rise in plate current of tube  $T_2$  is given by curve  $I_p T_2$ . Curve  $I_L$  shows the sudden increase of current through inductance 12, and the position of the positive output pulse is given in curve *b* at the instant *n*.

It is apparent then from Fig. 2 that the time taken for the grid of tube  $T_2$  to rise from its highly negative value to its cut-off value determines the time interval between the applied pulse and the output pulse of the circuit of the present invention. As previously stated, the time that the grid of tube  $T_2$  remains below its cut-off value is determined by the time constants of the coupling networks 19 and 20, and by the position of adjustable contact arm 23 of potentiometer 14. The variation of the time interval between application of a pulse to the input terminal 26 and the generation of the output pulse at terminal 27 is accomplished by means of the arrangement of the resistance-capacitance networks 19 and 20. In the preferred arrangement of these networks the time constant of network 19 is much less than that of network 20. In addition, resistor 22 is much smaller than resistor 25. Thus when potentiometer arm 23 is at the plate end of potentiometer 14, no voltage is applied to network 19 from the potentiometer and the time constant of network 20 predominates, for the network 19 has little effect upon the rate of voltage built-up on the grid of tube  $T_2$  since the voltage across condenser 21 is small relative to that across condenser 24. When the contact arm 23 is at the opposite end of potentiometer 14, the voltage across the potentiometer resistance is applied to network 19, and consequently the voltage across condenser 21 is large and the time constant of network 19 practically controls the interval between the applied pulse and the output pulse. Intermediate positions of arm 23 will then vary the duration of the interval between a shorter delay time governed primarily by the network 19, and a longer delay time when the time constant of network 20 prevails.

By the proper selection of the time constants of networks 19 and 20 and a suitable ratio of potentiometer 14 resistance to the total resistance of the plate circuit of tube  $T_1$  the interval between the applied pulse and the delayed output pulse may be easily adjusted by a single control over a wide range.

While the invention has been described for one particular embodiment according to Fig. 1, it will be apparent to those skilled in the art that modifications of the circuit may be made without departing from the general principles of the invention. For instance Fig. 3, which illustrates an alternative arrangement of a portion of the circuit of

Fig. 1, shows an arrangement of the resistance-capacitance network 20 which will give substantially the same operating characteristics. In Fig. 3 the long time constant network 20a replaces the network 20 of Fig. 1. The other elements of Fig. 3 are identical to those of Fig. 1, and hence they bear the same reference numerals. The grid of tube T<sub>2</sub> in Fig. 3 may be returned to cathode, through resistor 25a, either directly (switch 28 in right-hand position) or through a suitable potential source (switch 28 in left-hand position).

In practicing this invention in accordance with the embodiment illustrated in Fig. 1, a pulse delay system comprising the following circuit constants, provided a range of delay intervals extending from approximately 4 to 400 microseconds. The values of the circuit elements were approximately as follows:

|                                                                     |         |
|---------------------------------------------------------------------|---------|
| T <sub>1</sub> and T <sub>2</sub> each a section of a type 7N7 tube |         |
| Anode supply voltage B+-----volts--                                 | 200     |
| Resistor 10-----ohms--                                              | 3,300   |
| Resistor 11-----do-----                                             | 10,000  |
| Inductance 12-----millihenrys--                                     | 2       |
| Resistor 13-----ohms--                                              | 6,800   |
| Potentiometer 14-----do-----                                        | 50,000  |
| Resistor 15-----do-----                                             | 33,000  |
| Capacitor 16-----microfarad--                                       | 0.1     |
| Capacitor 17-----micro-microfarads--                                | 500     |
| Resistor 18-----ohms--                                              | 100,000 |
| Capacitor 21-----micro-microfarads--                                | 100     |
| Resistor 22-----ohms--                                              | 22,000  |
| Capacitor 24-----micro-microfarads--                                | 600     |
| Resistor 25-----megohms--                                           | 2.2     |

Although this invention has been described with particular reference to the embodiments of the drawings, it is to be understood that the invention is capable of various forms of physical expression, and is not to be limited to the specific disclosure but only by the scope of the appended claims.

I claim:

1. A pulse delay system, comprising a multi-vibrator circuit of the type employing a pair of vacuum tubes having at least triode elements, said tubes being regeneratively intercoupled to produce a single cycle of oscillation in response to an input pulse, means included in the anode-cathode circuit of at least one of said tubes for producing an output pulse in response to a change in magnitude of the anode current of said tube, a pair of condensers serially connected between the anode of one of said tubes and the grid of the other of said tubes, a variable resistance device connected in shunt with one of said condensers, and a high resistance direct current path connected between the grid and cathode electrodes of said other tube.

2. A pulse delay system, comprising a multi-vibrator circuit employing first and second tubes having triode elements regeneratively intercoupled, means for applying an input pulse to the first of said tubes, means in the anode-cathode circuit of the second of said tubes for deriving an output pulse, and a pair of shunt-connected resistance-capacitance networks serially connected between the anode of said first tube and the grid of said second tube, the first of said networks comprising fixed resistance and fixed capacitance, the second of said networks comprising a condenser and an adjustable resistor.

3. A pulse delay system, comprising a single-cycle multivibrator of the type employing a pair of inter-coupled vacuum tubes having at least

triode elements, means for applying an input pulse to the input circuit of one tube, means responsive to the resultant space current of said tube for producing a delayed rapid change in magnitude of the space current of the other tube, said last-named means including a pair of series-connected time delay circuits interconnected between the anode of said one tube and the control grid of said other tube, the first of said circuits having a relatively small time constant and the second having a relatively large time constant, means for applying a voltage to the first circuit to vary the time interval between the input pulse and the production of said rapid space current change, and means responsive to said rapid space current change for producing an output pulse.

4. A pulse delay system, comprising a multi-vibrator circuit employing first and second tubes having triode elements regeneratively intercoupled, means for applying an input pulse to the first of said tubes, means in the anode-cathode circuit of the second of said tubes for deriving an output pulse, means for effecting a delay between said input pulse and said output pulse, said delay-effecting means comprising a pair of resistance-capacitance time-delay networks having different time constants connected between the output of the first tube and the input of the second tube, the capacitors of said delay networks being serially connected between the anode of the first tube and the grid of the second tube, and means for applying a voltage of variable magnitude to one of said networks so as to provide a substantial range of adjustment of the time interval between said pulses.

5. A pulse delay system, comprising a multi-vibrator circuit employing first and second tubes having triode elements regeneratively intercoupled, means for applying an input pulse to the first of said tubes, said input pulse effecting a change in the anode voltage of said first tube, means in the anode-cathode circuit of the second of said tubes for deriving an output pulse, means for effecting a delay between said input pulse and said output pulse, said delay-effecting means comprising a first time delay network having a relatively small time constant and a second time delay network having a relatively large time constant, said networks being serially connected between the anode of said first tube and the grid of said second tube, and means for applying a variable portion of the anode voltage change of said first tube to said first network, whereby the time interval between said pulses is adjustable through a substantial range.

6. A pulse delay system, comprising a multi-vibrator circuit of the type employing a first and a second tube regeneratively intercoupled to produce a single cycle of oscillation in response to an input pulse, said tubes having at least triode elements, said input pulse effecting a change in the anode voltage of said first tube, means included in the anode-cathode circuit of said second tube for producing a voltage pulse in response to a change in magnitude of the anode current of said tube, a first time delay network connected to the anode circuit of said first tube, said network comprising resistance and capacitance elements and having a relatively small time constant, a second time delay network connected in series with said first network between said first network and the grid circuit of said second tube, said second network comprising resistance and capacitance elements and having a relatively large time constant, and means for applying a

variable portion of the anode voltage change of said first tube to said first network so as to vary the relative effectiveness of said networks and thus vary the time delay between said input pulse and said voltage pulse.

7. In a system of the type described, a first electron tube having at least triode elements, a source of anode voltage, a resistor connected between the anode of said tube and said source, a second electron tube having at least triode elements, a pair of condensers serially connected between the anode of said first tube and the grid of said second tube, a resistor connected between the junction of said condensers and an adjustable tap on said first-mentioned resistor so as to provide a first delay network, the values of said elements of said network being such as to impart to said network a relatively small time constant, and a resistor connected in shunt with the second condenser so as to provide a second time delay network, the values of the latter elements being such as to impart to said second network a relatively large time constant.

ROBERT C. MOORE.

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