March 16, 1943. K. R. WENDT 2,313,906

ELECTRICAL DELAY CIRCUIT

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FIG. 1.

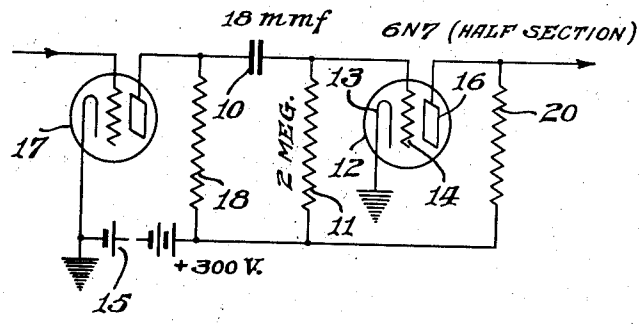


FIG. 2.

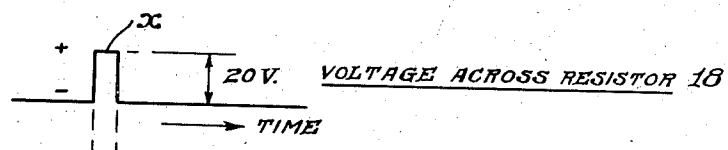


FIG. 2a.

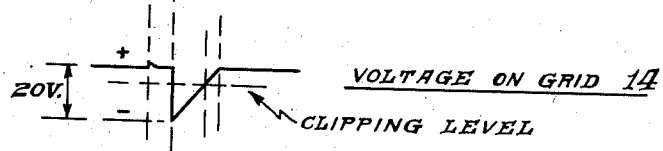


FIG. 2b.

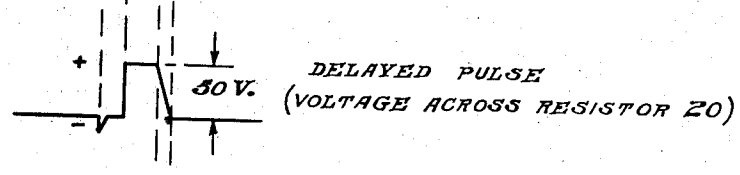
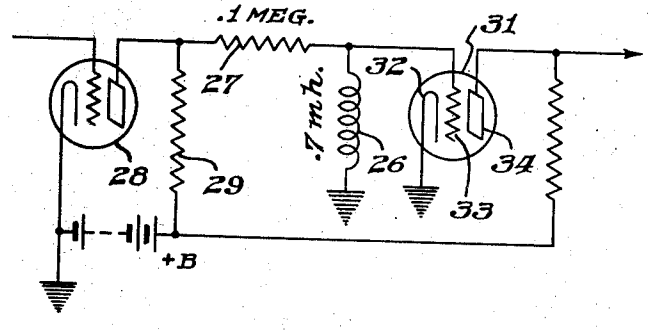


FIG. 3.



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FIG. 4.

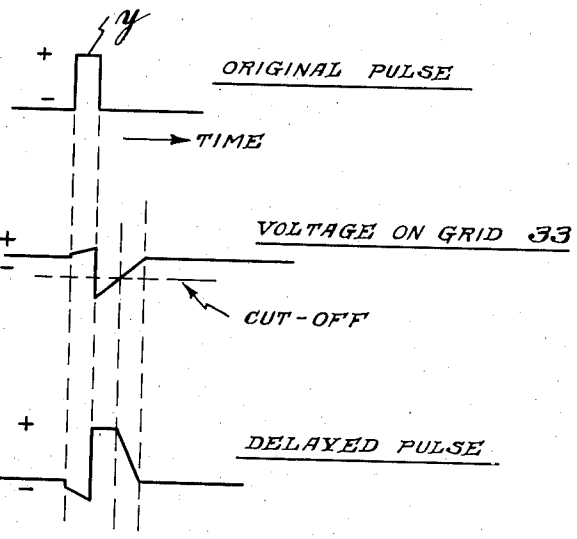
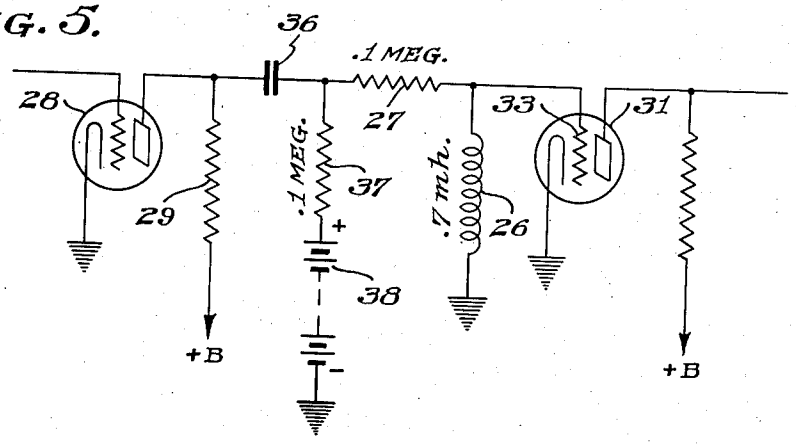


FIG. 4a.

FIG. 4b.

FIG. 5.



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UNITED STATES PATENT OFFICE

2,313,906.

ELECTRICAL DELAY CIRCUIT

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Application May 25, 1940, Serial No. 337,158

6 Claims. (Cl. 178—44)

My invention relates to a method and apparatus for delaying and/or shaping electrical waves, and particularly to a method and apparatus for delaying an electrical pulse or a series of recurring electrical pulses.

In the television art, especially, it is frequently found desirable to delay recurring pulses which are rectangular in wave form. An example of this is described in Patent No. 2,132,655, issued October 11, 1938, to J. P. Smith and assigned to the Radio Corporation of America, this patent describing an electrical generator in which electrical pulses are properly delayed, shaped and combined to produce the desired synchronizing signal. Another example is the case where it is desired to "key" a circuit at the end of an impulse, the "keying" or switching to be done by an impulse which starts as soon as the original impulse ends. Such a "keying" pulse may, of course, be looked upon as the original pulse which has been delayed by an amount equal to the duration of the original pulse.

An object of my invention is to provide an improved means for and method of delaying electrical pulses.

Another object of my invention is to provide an improved and simplified circuit for delaying and shaping electrical pulses.

Still another object of my invention is to provide an improved means for and method of delaying an electrical pulse by an amount equal to the duration of the said pulse.

In practicing my invention, I employ what may be described as a non-linear differentiating circuit, the "non-linear" feature residing in the fact that a vacuum tube which is associated with the differentiating circuit presents a difference impedance thereto during one part of the differentiating action than during a different part.

One of the preferred embodiments of my invention comprises a capacitor-resistor circuit located in the input circuit of a vacuum tube which has a positive bias voltage applied to its grid. When a positive rectangular pulse is applied to the differentiating circuit, the vacuum tube input impedance is so low that there is very little voltage on the grid of the tube for the duration of the pulse. At the termination of the pulse, however, the voltage which results from the differentiation causes the grid to become negative whereby the tube input impedance becomes high, and there is produced a voltage pulse of substantial amplitude which is delayed. If the amplitude of this delayed pulse is made large enough, it drives the tube beyond cut-off and there appears in the output circuit of the tube a substantially rectangular pulse with the desired delay.

The invention will be better understood from the following description taken in connection with the accompanying drawings in which

Figure 1 is a circuit diagram of one preferred embodiment of my invention,

Figures 2, 2*a* and 2*b* are voltage curves which are referred to in explaining the operation of the circuit shown in Fig. 1,

Figure 3 is a circuit diagram of another embodiment of my invention,

Figures 4, 4*a* and 4*b* are voltage curves which are referred to in explaining the operation of the circuit of Fig. 3, and

Figure 5 is a modification of the circuit shown in Fig. 3.

Referring to Fig. 1, the differentiating circuit comprises a condenser 10 of comparatively small capacity connected in series with a resistor 11 which, in the example illustrated, functions also as the grid leak resistor for a vacuum tube 12.

The tube 12 may be a triode having a cathode 13, a control grid 14 and a plate 16. In accordance with one feature of my invention, the grid 14 has a positive bias applied thereto by means of a suitable biasing source. In the example illustrated, this bias is obtained from the B battery 15 to which the grid leak resistor 11 is connected.

The electrical pulse which is to be delayed is applied to the differentiating circuit through an amplifier tube 17 having the usual plate resistor 18.

Considering now the operation of the above-described circuit, it will be assumed that it is desired to delay a rectangular voltage pulse x which appears across the plate resistor 18 with positive polarity as shown in Fig. 2. The voltage appearing on the grid 14 will then be as shown in Fig. 2*a* for the following reasons:

Before the start of pulse x, the tube 12 is operating at a slightly positive bias and the grid is drawing current due to the positive voltage applied to resistor 11. The leading edge of pulse x tends to drive grid 14 more positive which, of course, tends to decrease the already low grid-cathode impedance of tube 12. The leading edge of pulse x is therefore so sharply and rapidly differentiated that condenser 10 is charged almost immediately, and very little of the voltage due to the leading edge of the pulse x appears on the grid of tube 12, as shown by Fig. 2*a*.

At the end of the pulse x, however, the grid 14 is driven negative by the edge of the pulse.

This opens up the low impedance imposed by the grid 14, and the full voltage of the pulse is applied to grid 14. Preferably, this voltage is sufficient to drive tube 12 well beyond plate current cut-off. Condenser 10 immediately starts discharging through resistor 11, aided by the positive voltage applied to this resistor. The condenser 10 discharges comparatively slowly toward +300 in the example shown, and in the interval up to zero, or cathode voltage, the discharge is essentially linear as shown in Fig. 2*a*. Thus the back edge of the pulse *x* is differentiated at a comparatively slow rate. At zero voltage the grid 14 again shorts out the high resistance 11, and the condenser discharge ceases. Due to clipping action, this grid voltage wave is converted to a substantially rectangular pulse of plate current which gives the delayed output pulse voltage as shown in Fig. 2*b*. It is thus seen that the back edge of pulse *x* has been differentiated very differently from the manner in which the front edge was differentiated. It will be noted that this delay circuit does not reverse the polarity of the voltage pulse. In some apparatus this feature saves the cost of a tube for reversing polarity.

Referring now to Fig. 3, there is illustrated a non-linear differentiating circuit in which an inductance coil 26 and a resistor 27 are connected in series to differentiate the applied voltage pulse. The voltage pulse which is to be delayed may be applied to the differentiating circuit through an amplifier tube 28. This pulse appears as a positive pulse, such as the rectangular pulse *y* shown in Fig. 4, across the plate resistor 29 of the tube 28.

The input electrodes of a vacuum tube 31 are connected across the coil 26. This tube may be a triode having a cathode 32, a grid 33 and an anode 34. In the specific circuit illustrated in Fig. 3, the desired positive bias on the grid 33 is obtained from the plate voltage for the tube 28 by utilizing a direct current coupling between the tubes 28 and 31.

The voltage shown in Fig. 4*a* appears on the grid 33 as a result of the following action: Before the voltage pulse *y* is applied to the circuit, the grid 33 is drawing a small amount of grid current just as in the case of the circuit shown in Fig. 1. Thus the input impedance of the tube 31 is low and it remains low while the positive pulse *y* is being applied. For the duration of the pulse *y*, there is a current flow through the coil 26 whereby lines of flux build up in the coil. Thus, the grid voltage increases gradually during this period as shown in Fig. 4*a*, but the corresponding output voltage is low as shown in Fig. 4*b*.

At the end of the pulse *y*, the flux in the coil 26 collapses to produce a negative voltage which drives the grid 33 negative whereby the input impedance of the tube 31 is high. As a result, there is a voltage pulse of substantial amplitude appearing in the output circuit of the tube 31, and, since the tube 31 is driven beyond cut-off, as indicated in Fig. 4*a*, the said voltage pulse is substantially rectangular in wave shape as shown in Fig. 4*b*. It will be apparent that this pulse, like the pulse shown in Fig. 2*b*, has been delayed in time by an amount equal to the duration of the original pulse.

In Fig. 5 there is shown a circuit which operates substantially the same as the circuit shown in Fig. 3, the difference in the two circuits being that an alternating current connection rather than a direct current connection is employed in Fig. 5 between the vacuum tubes. In the two figures, like parts are indicated by the same reference numerals.

Because of the coupling condenser 36 employed in Fig. 5, in this embodiment of the invention, the positive bias is applied to the grid 33 through a grid resistor 37 and the resistor 27 by means of a suitable biasing source such as a battery 38. A delayed pulse is obtained in the output circuit of the tube 31 as previously described.

In certain figures, merely by way of example, the values of certain circuit elements have been indicated in megohms, micromicrofarads, and millihenries. Also, a suitable tube type and suitable voltages have been indicated by way of example.

It will be apparent from the foregoing that various modifications may be made in my invention without departing from the spirit and scope thereof.

I claim as my invention:

1. The method of utilizing a differentiating circuit for delaying an electrical pulse which comprises differentiating said pulse in said circuit and simultaneously presenting a low impedance to said circuit the entire time that the differentiated signal is of one polarity, and presenting a high impedance to said circuit while the differentiated signal is of the opposite polarity.

2. The method of utilizing a differentiating circuit which is connected to impress the differentiated signal upon the input electrodes of an electric discharge tube, said method comprising the step of impressing a voltage pulse of such large amplitude upon said differentiating circuit that the input impedance of said tube is low the entire time the differentiated signal is of one polarity and is high while the differentiated signal is of the opposite polarity.

3. The method of delaying a positive voltage pulse which comprises differentiating the front edge of said pulse to produce a narrow differentiated voltage pulse of small amplitude and differentiating the back edge of said positive pulse differently to produce a pulse of comparatively large amplitude.

4. The method of delaying a positive voltage pulse which comprises differentiating the front edge of said pulse to produce a narrow differentiated voltage pulse of small amplitude and differentiating the back edge of said positive pulse differently to produce a comparatively wide voltage pulse of comparatively large amplitude.

5. The method of delaying a positive voltage pulse which comprises differentiating the front edge of said pulse at a rapid rate and differentiating the back edge of said pulse at a comparatively slow rate.

6. The method of utilizing a differentiating circuit and a vacuum tube having a cathode and a positively biased control grid connected to said differentiating circuit which method comprises impressing a voltage pulse of such large amplitude upon said differentiating circuit that said grid is driven further positive while the differentiated signal is of one polarity and is driven so negative while the differentiated signal is of the opposite polarity that said tube is driven beyond plate current cut-off.

KARL R. WENDT.