July 31, 1951 B. CHANCE 2,562,660

PULSE GENERATING CIRCUIT

Filed Dec. 4, 1943

FIG. 1

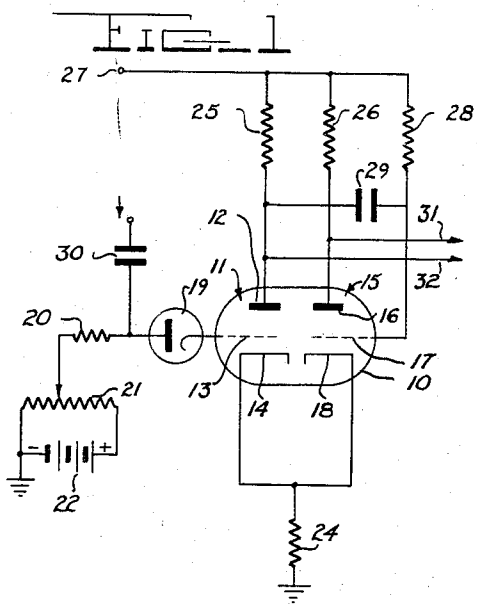


FIG. 3

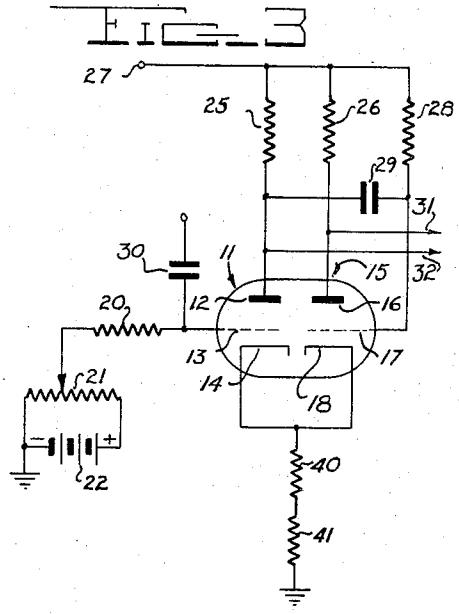


FIG. 2

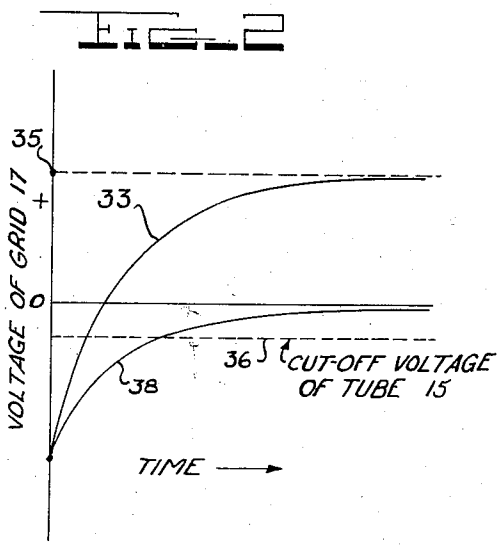
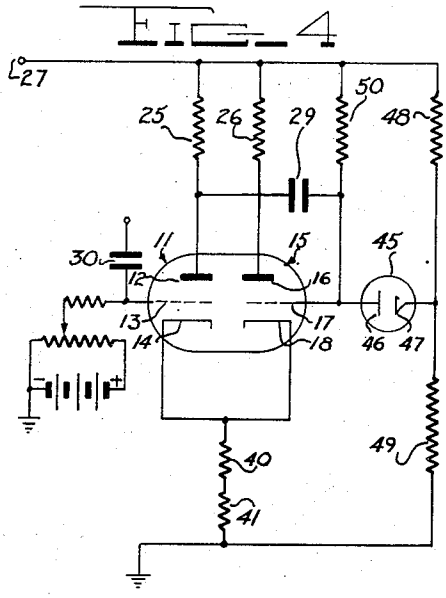


FIG. 4



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PULSE GENERATING CIRCUIT

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4 Claims. (Cl. 250—27)

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This invention relates to pulse-forming devices and particularly to such devices utilizing thermionic tubes.

One of the objects of the invention is to provide a pulse-forming device in which the time duration or width of the pulse produced may be accurately controlled.

Another object of the invention is to provide a pulse-forming device in which the time duration or width of the pulse produced varies linearly with an applied voltage.

Another object of the invention is to provide a pulse-forming device of the delayed multivibrator type in which the time duration or width of the pulse produced varies linearly with the bias voltage on one of the grids.

Another object of the invention is to provide a pulse-forming device of the delay multivibrator type in which variations of temperature do not substantially alter the operation or the accuracy of the device, nor do differences in tube characteristics of replacement tubes.

Other objects and objects relating to the manner of connecting the various components of the circuits will be apparent as the description of the invention proceeds.

The invention has been illustrated in the accompanying drawings in which,

Fig. 1 is a circuit diagram of a pulse-forming device embodying the invention;

Fig. 2 is a diagram showing the grid voltage of one of the tubes plotted against time during a certain portion of the cycle of operation of the circuit;

Fig. 3 is a circuit diagram of a modified form of the circuit which provides compensation for temperature changes; and

Fig. 4 is a circuit diagram of another modified form of the invention with which even greater stability may be obtained.

In carrying out the objects of the invention I may use two thermionic tubes, each having at least a plate, a grid, and a cathode, and these may be incorporated in a single envelope 10, as shown in Fig. 1. The tube 11 within the envelope 10 comprises a plate 12, a control grid 13, and a cathode 14, while the tube 15 comprises a plate 16, a control grid 17, and a cathode 18. The control grid 13 of tube 11 may be given any desired bias potential through a resistor 20 and a potentiometer 21, across which a source of voltage, as, for instance, a battery 22, may be connected.

The cathodes 14 and 18 of tubes 11 and 15 are shown connected together and to ground through a common cathode resistor 24, while the heaters

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for these cathodes together with the energizing circuits have been omitted in the drawing for clearness.

The plates 12 and 16 are connected respectively through resistors 25 and 26 to a source of positive potential, indicated at 27. The grid 17 of the tube 15 is also connected through a resistor 28 to the source of potential 27. This resistor 28 is preferably a great deal larger than the resistors 25 and 26 and is made large to prevent excessive grid current in the tube 15. The plate 12 of the tube 11 is connected to the grid 17 of the tube 15 through a condenser 29. The pulse produced by this device may be obtained by connecting a suitable output circuit to the plate 16 of the tube 15 or to the plate 12 of the tube 11, as indicated respectively by the wires 31 and 32.

An initiating or trigger pulse may be applied to the grid 13 of the tube 11 through a condenser 30 from a source not shown. This trigger pulse must be a sharply peaked positive voltage pulse of very short time duration to insure accurate width or time duration of the pulse to be produced. The values of the condenser 30 and the resistor 20 are so chosen that these components function as a differentiating circuit to aid in producing this type of trigger pulse. Some means, as, for instance, the diode 19, should be provided to prevent negative voltage pulses from being applied to the grid 13 of tube 11 during the time the circuit is operating to produce the desired pulse. Alternatively a negative trigger pulse may be applied to the grid 17 of the tube 15.

In the quiescent condition of the circuit of the invention the tube 15 is conducting, since the grid 17 thereof is held at approximately the potential of the cathode 18 by the grid current through the large resistor 28. The grid 13 of tube 11 on the other hand, has sufficient negative bias potential applied to it normally to prevent this tube 11 from conducting. In this condition the cathodes 14 and 18 are maintained above ground potential by the flow of plate current of the tube 15 through the common cathode resistor 24. This maintains the grid 13 of the tube 11 at a sufficiently lower potential than the cathode 14 to keep this tube shut off. At this time the condenser 29 is charged by the difference in potential between the plate 12 of tube 11, which is at the potential of the source 27, and the grid 17 of tube 15, which is at a lower potential determined by the grid current in the resistor 28.

If now a positive trigger pulse of sufficient am-

plitude is applied to the grid 13 of the tube 11 through the condenser 30 this tube will start to conduct. When this conduction begins, the potential of the plate 12 of the tube 11 will be lowered by an amount equal to the voltage drop across the resistor 25. This drop in potential is applied to the grid 17 of the tube 15 through the condenser 29, and must be sufficient in amplitude to cause the tube 15 to cease conducting. When the tube 15 ceases to conduct the potential of the cathodes 14 and 18 is determined by the plate current of the tube 11 through the cathode resistor 24. The bias potential of the grid 13 must now be sufficiently positive with respect to the cathode 14 to maintain the tube 11 conducting.

A trigger pulse with a steep front is desired to cause the tube 15 to cease conducting and the tube 11 to begin conducting with a minimum time delay after the trigger is applied to the grid 13 of the tube 11. With the proper trigger, this action will take place in a fraction of a microsecond.

During the quiescent state the condenser 29 had been charged by the difference in potential between the plate 12 of the tube 11 and the grid 17 of the tube 15. When the tube 11 starts to conduct, the voltage drop in the resistor 25, caused by the plate current of the tube 11, is also applied to this condenser and is opposite in potential to the charge thereon. The change in voltage of the plate 12, acting through the condenser 29, drives the grid 17 of the tube 15 to a potential with respect to the cathode 18 which is sufficient to cut-off the tube 15, and the discharge path of this condenser 29 is now through the resistors 28 and 25. But the plate current of the tube 11, while this tube is conducting, causes a constant potential drop across the resistor 25. Therefore, during the time that the tube 15 is cut-off, the condenser 29 is effectively in series with a source of constant potential and the resistor 28. Since the grid 17 of the tube 15 is connected by the resistor 28 to the source of voltage at 27, the potential of the grid 17 tends to rise to the voltage at 27 to establish equilibrium conditions in this series circuit consisting of the condenser 29, the resistor 28, and the constant voltage drop across the resistor 25. However, the potential of the grid 17 never reaches that of the source 27, for when the condenser 29 has discharged sufficiently so that the grid 17 of the tube 15 is positive enough with respect to the cathode 18 to allow the tube 15 to begin conducting again, the increase in current through the resistance 24 causes the cathodes 14 and 18 to rise in potential with respect to ground. This causes a reduction of the current in tube 11 and an increase in the voltage of the plate 12. Through the condenser 29, this plate voltage rise causes the potential of the grid 17 to rise further in potential, increasing the current in tube 15 which further raises the potential of the cathodes 14 and 18. Thus, the action is cumulative, the tube 15 rapidly building up to its quiescent conducting state and the tube 11 being cut off. The grid current in the tube 15 then holds the grid 17 at substantially cathode potential, and the condenser 29 starts to charge again.

The tendency of the grid 17 to assume the potential of the source at 27 during the condenser discharge is what makes this circuit capable of producing pulses of very accurate width. The curve 33 of Fig. 2 shows the variation with time of the voltage of the grid 17 during the period that tube 15 is cut-off.

Grid voltage is plotted vertically from the point 34, which represents the most negative potential

of the grid 17, as produced by the operation of the tube 11, to the point 35 which represents the potential of the source 27. As indicated, the cut-off grid voltage of the tube 15 is represented by the dotted line 36. As the potential of the grid 17 rises exponentially with time with the discharge of the condenser 29, the voltage necessary for the tube 15 to begin conducting (which is the cut-off voltage) will be approached during the time that the rate of increase of the voltage of the grid 17 is substantially its maximum. This insures the tube 15 coming on and the tube 11 being cut-off at a very accurate time interval after the initial trigger pulse is applied to the grid 13 of the tube 11.

In the usual arrangement of multivibrator circuits the grids derive their biasing potential from the cathodes through suitable grid resistors. In such a multivibrator when one grid is driven more negative than the cathode through the coupling condenser which is connected to the plate circuit of the other tube, the potential of the grid will tend to rise, as the condenser discharges until it reaches the potential of the cathode. If such a grid were driven sufficiently negative to reach the point 34 in Fig. 2, and then were permitted to rise in potential as the coupling condenser discharged, the rise in potential might follow a curve somewhat similar to the curve 38, shown in Fig. 2. Here, as the condenser discharges the potential of the grid will approach zero or cathode potential. It will be seen that as the voltage of the grid approaches the cut-off potential of the tube the angle it makes with the cut-off potential line 36 at the point of crossing will be so small that any slight change in cut-off potential will cause a relatively large variation in the length of time that the particular tube is non-conducting. With the circuit of the invention, the much steeper intersection of the grid-voltage curve 33 with the line 36 insures a very small time difference for variations in the cut-off voltage and therefore produces a much more accurately timed pulse.

The width or time duration of the pulse produced by the circuit of the invention may be controlled in several ways. It has been pointed out that the width of the pulse produced in the plate circuit of the tube 15 is determined by the time required for the condenser 29 to discharge to the point where the grid 17 is positive enough with respect to the cathode 18 to start the tube 15 conducting. This time is dependent not only on the charge of the condenser 29 but also on the potential of the cathode 18. In the quiescent state the condenser 29 is charged by the difference in potential between the plate 12 and the grid 17. The conduction of the tube 11 also impresses a voltage drop on the condenser 29. The magnitude of this voltage drop in the resistor 25 may be controlled by the bias on the grid 13 of the tube 11, since this bias voltage determines the plate current when the tube 11 is conducting. This bias voltage also determines the potential of the cathodes 14 and 18 during the time the tube 11 is conducting, and therefore governs the amount condenser 29 must discharge before the tube 15 begins conducting.

It will be seen from these statements that the time the tube 15 is non-conducting which time is equal to the pulse width, may be changed by varying either the value of the condenser 29, the value of the resistor 28, the value of the resistor 24, or the bias potential applied to the grid 13. One or more of these values may

be changed to make the desired adjustment, but probably the most convenient method is to adjust the bias on the grid 13 of the tube 11.

An important feature of this invention is that with the correct choice of circuit constants the width or time duration of the pulse produced is a linear function of the bias voltage applied to the grid 13 of the tube 11. This simple relation between the grid voltage and pulse width results from the proper choice of circuit constants, especially resistors 25 and 24, which choice tends to minimize the effect of the variable grid-plate characteristic of the tube 15. It may be proved mathematically that if the resistors 24 and 25 are equal in value, the percent deviation from linearity at the maximum pulse width would be about $\frac{1}{10}$ of one percent. It has been found experimentally, however, that substantially as good results are obtained when the value of the cathode resistor 24 is increased or decreased by as much as 500 ohms. Therefore these values are not critical.

In one instance the circuit of Fig. 1 was used with a double triode tube of the 6SN7 type. The voltage of the source 27 was 250 volts; the resistor 20 was 25000 ohms; the resistor 24 was 3000 ohms; the resistor 25 was 5000 ohms; the resistor 26 was 5000 ohms; and the resistor 28 was 3 megohms. The values of the condensers 30 and 29 were 5 and 300 micro-micro-farads, respectively. These values gave a cathode potential of 42 volts in the quiescent condition. When the tube 11 was conducting and the tube 15 non-conducting, the cathode potential dropped to 25 volts.

By changing the bias voltage on the grid 13 of the tube 11 in this particular example from 19.4 volts to 35.3 volts the pulse width was changed linearly with the bias voltage from 1.832 microseconds to 110 microseconds.

By using resistors and condensers in the circuit of Fig. 1 that are little effected by temperature variations, accurate pulse widths will be obtained over long periods of operation. However, Fig. 3 shows a modified form of the invention in which is incorporated a means for obtaining temperature compensation if such is desired. The circuit is similar to that shown in Fig. 1 except that the common cathode resistor 24 of Fig. 1 has been replaced by two resistors 40 and 41 one of which, as, for instance, the resistor 40, is a resistance having a positive temperature coefficient of resistance, such as a wire wound resistor, and the other, as, for instance the resistor 41, is a resistance having a negative temperature coefficient of resistance, such as a carbon resistance. As far as the pulse-forming operation of the circuit is concerned, the purpose of these two resistors is the same as that of the resistance 24 in Fig. 1.

However, when a proper choice of values for the resistors 40 and 41 is made, so that the proper variation of resistance with temperature changes is obtained, effects of temperature on the circuit may be largely eliminated.

Under certain conditions variation of the pulse width may result because the grid 17 of the tube 15 of the circuit of Fig. 1 draws grid current during the time that the tube 15 is conducting. In order to prevent the flow of grid current, the circuit of Fig. 1 or Fig. 3 may be modified, as shown in Fig. 4. In this figure the tubes 11 and 15 are connected as in Fig. 3, but in addition a thermionic tube 45, having at least a plate 46 and a cathode 47 is connected in the

circuit of the grid 17. The cathode 47 is connected to the source of voltage 27 by a resistor 48 and to ground through a resistor 49. The plate 46 of the tube 45 is connected directly to the grid 17 of the tube 15, and through a resistor 50, which replaces the resistor 28 of Fig. 1, to the source of potential at 27. The potential of the plate 46 of the tube 45 and therefore the potential of the grid 17 of the tube 15 may be fixed by adjusting the resistors 50, 48, and 49. These resistors must be adjusted so that during the time that the tube 15 is conducting, the grid 17 of this tube is slightly negative with respect to the cathode 18. If the plate 46 of the tube 45 is maintained very slightly positive with respect to the cathode 47 a negative voltage pulse applied to the grid 17 of the tube 15 through the condenser 29 will cause the tube 45 to cease conducting. The discharge path of the condenser 29 will then be through the resistors 50 and 25, as previously described, in connection with Fig. 1. The resistor 50 in the circuit of Fig. 4 serves the dual purpose of determining the time required for the condenser 29 to discharge sufficiently for the tube 15 to begin conducting, and also, by means of the resistors 48 and 49, of maintaining the grid 17 at the desired potential to prevent grid current from flowing.

The modification of the circuit of Fig. 1 in this manner eliminates any variation in pulse width that may result because of the tube 15 drawing grid current. With the addition of the means for compensating for temperature variations, already described in connection with Fig. 3, and which, of course, may be omitted, if desired, from the circuit of Fig. 4, the accuracy of the pulse width obtained is greatly increased over that of the circuit of Fig. 1.

It will be seen from the above description that I have provided a circuit utilizing thermionic tubes by means of which a pulse of a given width or time duration may be produced very accurately by adjusting certain components of the circuit, such as a grid bias voltage. In addition, the width or time duration of this pulse may be made to vary linearly with the grid bias potential. If properly constructed, the linearity of the pulse width variation may have an accuracy of one tenth of one percent (0.1%).

Various modifications may be made in the invention without departing from the spirit thereof, and I do not therefore wish to limit myself to what has been shown and described except as such limitations occur in the appended claims.

What I desire to claim and secure by Letters Patent is:

1. A pulse-forming circuit comprising, in combination, a first thermionic tube having at least a plate, a grid, and a cathode, a second thermionic tube having at least a plate, a grid, and a cathode, a common cathode circuit for said tubes, a pair of resistors in said cathode circuit, one having a positive temperature coefficient of resistance and the other having a negative temperature coefficient of resistance, the values of said resistors being so proportioned that temperature changes in said circuit are compensated for, a source of positive potential, a third resistor connected between said source of positive potential and the plate of said first tube, a fourth resistor connected between said source of positive potential and the plate of said second tube, a fifth resistor connected between the grid of said second tube and said source of positive

potential, a condenser connected between the plate of said first tube and the grid of said second tube, a third thermionic tube having at least a plate and a cathode, the plate of said third tube being connected to the grid of said second tube, a sixth resistor connected between the cathode of said third thermionic tube and said source of positive potential, a seventh resistor connected between said cathode of said third thermionic tube and the outer end of said pair of common cathode resistors, the values of said fifth, sixth, and seventh resistors being so chosen that the grid of said second thermionic tube is normally maintained at such a potential with respect to the cathode thereof as to maintain said second tube conductive but to prevent the flow of grid current therein when said tube is conducting and to cause said grid to tend to reach a potential much higher than the cathode of said second tube when said tube stops conducting, means to apply a biasing potential to the grid of said first tube, so as normally to maintain said tube non-conductive when said second tube is conductive, and means to apply a positive initiating pulse to the grid of said first tube to cause said tube to become conductive.

2. A pulse-forming network comprising, first and second electron tubes each having at least an anode, a cathode, and a control grid, a source of anode potential, means including a resistance connecting each of said anodes to said source of anode potential, a common cathode circuit for said tubes, a condenser coupling the anode of said first tube to the control grid of said second tube, means including an adjustable source of potential coupled to the grid of said first tube for controlling the bias thereof, means resistively coupling the grid of said second tube to said source of anode potential for maintaining said grid at a positive potential, and means including a diode coupling the grid of said second tube to a positive potential less than the potential of said source, the anode of said diode being connected to the grid of said second tube.

3. A pulse-forming network comprising, first and second electron tubes each having at least an anode, a cathode and a control grid, a source of anode potential, means including a resistance connecting each of said anodes to said source of anode potential, a common cathode circuit for said tubes, a condenser coupling the anode of said first tube to the control grid of said second tube, means including an adjustable source of potential coupled to the grid of said first tube for controlling the bias thereof, first coupling means resistively connecting the grid of said second tube to said source of anode potential, and second coupling means including a diode and a resistor serially connected between the grid of said second tube and said source of anode potential, the anode of said diode being connected to the grid of said second tube.

4. A pulse-forming network comprising, in combination, first and second electron tubes each having at least an anode, a cathode, and a control grid, a source of anode potential, means including a resistance connecting each of said anodes to said source of anode potential, a common cathode circuit including a resistor for said tubes, means including a resistance connecting the control grid of said second tube to said source of anode potential, a first condenser coupling the anode of said first tube to the control grid of said second tube, a source of biasing potential, a potentiometer connected across said source of biasing potential, means including a resistance and a serially connected diode coupling said potentiometer to the control grid of said first tube, the cathode of said diode being connected to the grid of said first tube, a second condenser connected to the anode of said diode, and means for applying a positive pulse to said second condenser.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
Re. 19,735	Lederer	Oct. 22, 1935
2,102,951	Hackenberg	Dec. 21, 1937
2,185,363	White	Jan. 2, 1940
2,185,367	Blumlein	Jan. 2, 1940
2,207,511	Geiger	July 9, 1940
2,234,690	Depp	Mar. 11, 1941
2,265,996	Blumlein	Dec. 16, 1941
2,356,761	Jones et al.	Aug. 29, 1944
2,405,237	Ruhlig	Aug. 6, 1946
2,428,058	Wise	Sept. 30, 1947