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DELAYED ACTION PULSE REPEATER

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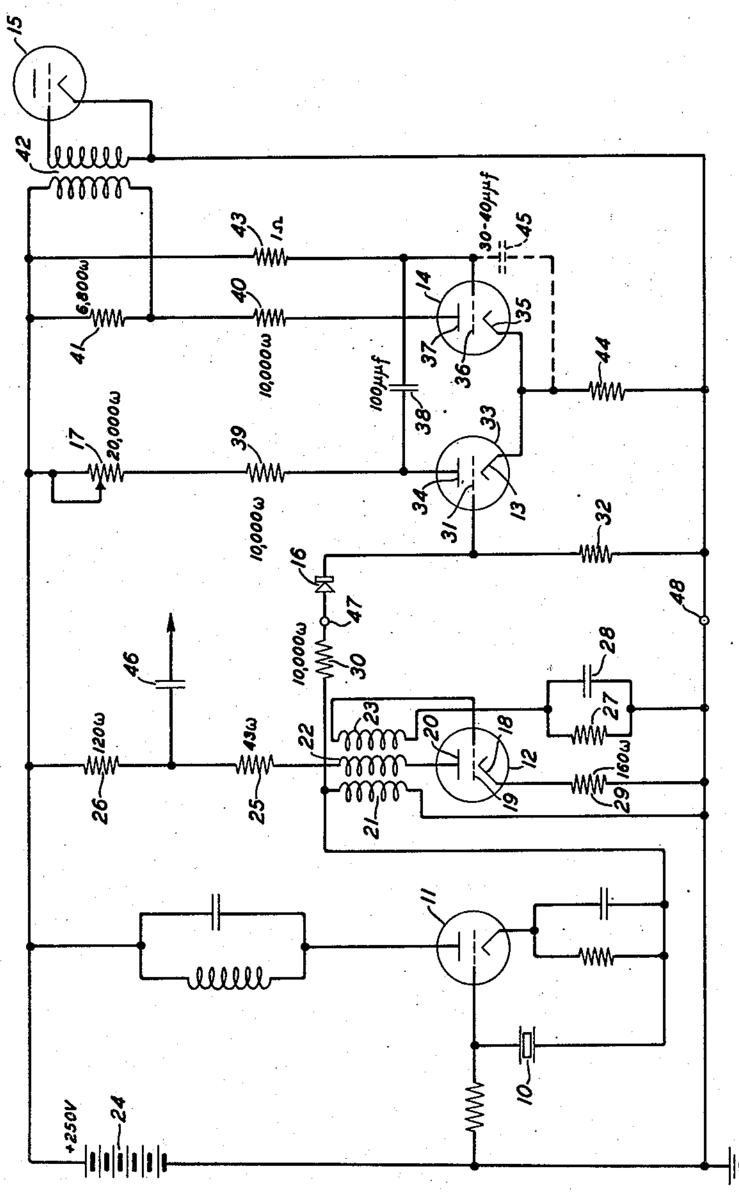

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DELAYED-ACTION PULSE REPEATER

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4 Claims. (Cl. 250—27)

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This invention relates to a repeating device for electrical pulses and more particularly to a delayed action repeater, that is, one in which an impressed input pulse gives rise to an output pulse after a predetermined delay interval.

An object of the invention is to make the length of the delay interval substantially independent of the repetition rate of the pulses to be repeated, even at repetition rates as high as 80,000 or more per second.

Another object is to make the length of the delay interval readily adjustable over a range of values from a quarter of the repetition period to three-quarters of that period, more or less.

A further object of the invention is to improve the operation of a multivibrator as a delayed action pulse repeater.

A feature of the invention is the use of a rectifying element in the grid circuit of one section of a multivibrator.

Another feature is the use of a variable anode load resistor in a delay multivibrator to vary the amount of the delay.

These and other objects and features of the invention are explained in more detail in the following description and illustrated in the accompanying drawing, the single figure of which is a schematic representation of a pulse generating and repeating system embodying the invention.

The drawing shows a system comprising a piezoelectric crystal unit 10 and a plurality of vacuum tubes 11 to 15, inclusive. The vacuum tubes are all shown as triodes but more elaborate tubes having additional electrodes may be substituted for the triodes if desired.

The unit 10 comprises a conventional combination of a piezoelectric crystal, supporting means therefor, and a pair of electrodes between which the crystal is supported. The vacuum tube 11 together with the unit 10 and interconnections constitute a conventional type of piezoelectrically controlled oscillation generator. The tube 12 with associated circuit elements constitutes a pulse generator of the type commonly known as a blocking oscillator and is arranged to be controlled in conventional manner, that is, synchronized, by the output of the tube 11. The tubes 13 and 14 with their associated circuits constitute a delay multivibrator which while to some extent conventional in circuit continuity, has a unique mode of operation as will be described in detail hereinafter. The multivibrator is controlled by the blocking oscillator through a rectifying element 16 in accordance with this invention and the delay interval of the multi-

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vibrator is controlled by means of a variable resistor 17 in the anode circuit of the tube 13, also in accordance with this invention. The output of the multivibrator is impressed upon the grid circuit of the tube 15, which tube is intended to be representative of any suitable utilization circuit for the delayed pulses from the multivibrator.

The blocking oscillator tube 12 has a cathode 18, a control grid 19 and an anode 20. A transformer is provided having three windings, winding 21 of which is connected between ground and the output or cathode circuit of the oscillator tube 11. The second winding 22 is connected between the high potential terminal of a supply source 24, represented as a battery, through a pair of anode circuit load resistors 25 and 26. The negative terminal of the battery 24 is grounded. The remaining winding 23 has one terminal connected to the grid 19 and the other terminal connected to ground through a parallel combination of a resistor 27 and a capacitor 28. The cathode 18 is connected to ground through a cathode resistor 29.

Coupling is provided between the blocking oscillator 12 and the grid of the tube 13 in the multivibrator through the rectifying element 16 and a resistor 30. The grid of the tube 13, designated 31, is connected to ground through a resistor 32. The tube 13 has a cathode 33 and an anode 34. The tube 14 has a cathode 35, a grid 36 and an anode 37.

The internal connections of the multivibrator include a capacitor 38 connected between the anode 34 of the tube 13 and the grid 36 of the tube 14. The anode 34 is connected to the positive terminal of the battery 24 through the variable resistor 17 and a fixed resistor 39. The anode 37 of the tube 14 is connected to the positive terminal of the battery 24 through a pair of fixed resistors 40 and 41 across the resistor 41 of which there is connected the primary winding of an output transformer 42, the secondary winding of which is connected between the grid and cathode of the tube 15. The grid 36 of the tube 14 is connected to the positive terminal of the battery 24 through a resistor 43 of relatively large resistance value. The cathodes 33 and 35 are connected together and jointly grounded through a cathode resistor 44. A capacitance 45 is shown in dotted lines connecting the grid 36 and cathode 35 of the tube 14. The capacitance 45 represents the effective interelectrode capacitance of the grid-cathode circuit of the tube 14 under operating conditions.

A coupling condenser 46 is shown connected to the junction point of the resistors 25 and 26 in the anode circuit of the blocking oscillator 12 for the purpose of taking off a supplementary output from the blocking oscillator for utilization elsewhere.

The multivibrator is represented as having a pair of input terminals 47 and 48, the former having the rectifying element 16 connected in series therewith and the latter being grounded.

In the operation of the system illustrated, the tube 11 is energized by the battery 24 to produce oscillations which energize the crystal 10 which in turn exerts a control over the oscillations of the tube 11 and tends to stabilize the frequency of the oscillations in known manner. The oscillations are fed through the winding 21 and are effective therein to synchronize the operation of the blocking oscillator 12 with the oscillator 11 and crystal unit 10, also in known manner. The pulses generated by the blocking oscillator 12 appear in the winding 21 and are transmitted through the resistor 30, the input terminal 47, the rectifying element 16 and the resistor 32 to ground. The potential drop produced in the resistor 32 by the current of the pulse from the blocking oscillator is effective to apply a positive pulse to the grid 31 of the tube 13 thereby triggering the multivibrator.

In the absence of a triggering pulse, the multivibrator comprising the tubes 13 and 14 assumes a stable condition consistent with the connection of the grid 36 of the tube 14 to the positive terminal of the battery 24 through the resistor 43. This connection places a high initial positive potential upon the grid 36, making the tube 14 normally highly conductive, passing anode and grid currents through the common cathode resistor 44. The voltage drop in the resistor 44 impresses a large negative potential upon the grid 31 of the tube 13 thereby rendering the tube 13 normally non-conductive. While this stable condition of the circuit is being established, the capacitor 38 is charged through the resistors 17, 39 and 44 to a potential substantially equal to the full battery potential less the potential drop maintained in the resistor 44 by the combined anode and grid currents of the tube 14, the negative side of the capacitor 38 being at the grid 36.

When a sufficient positive potential is superposed upon the grid 31, as by means of a pulse through the resistor 32, the tube 13 is rendered conductive, thereby lowering the potential of the anode 34 and with it the potential of the grid 36 due to the charge on the capacitor 38. The lowering of the potential of the grid 36 reduces or preferably cuts off the current through the tube 14. This action in turn reduces the potential drop across the resistor 44 and enables the tube 13 to continue in the conductive condition even after the cessation of the positive pulse in the resistor 32. The circuit remains in this new condition with the tube 13 conductive and the tube 14 non-conductive, until the charge on the capacitor 38 has been reduced sufficiently to enable the tube 14 to become conductive once more. When conduction begins again in the tube 14 a potential difference is generated across the resistor 41 which is transmitted through the transformer 42 to the tube 15 as a delayed pulse.

During the portion of the cycle when the tube 13 is conductive, the capacitor 38 is effectively connected between the battery terminals in series with the resistor 43, the anode-cathode path of the tube 13, and the resistor 44. The polarity of this connection is such that the capacitor 38 tends to discharge and then to recharge in the opposite direction toward the full battery potential. However, the cut-off potential of the tube 14 is reached upon the grid 36 at about the same time as the initial discharge is completed. The time constant of the circuit, for the values given, namely 100 micromicrofarads in capacitor 38 and one megohm in resistor 43, neglecting resistor 44, is 100 microseconds. The discharge time until the cut-off potential is reached is only a fraction of 100 microseconds and depends upon the initial potential at the grid 36. The initial grid potential in turn depends upon a number of factors. Certain of the latter arise from the fact that in practice the tube 13 does not constitute a perfect short-circuit from its anode to its cathode when in the conductive condition. Accordingly, the anode 34 does not drop to the potential of the cathode 33. The value to which the anode potential falls depends upon the relative resistance values of the resistors 17, 39, 44 and the anode-cathode path of the tube 13 in the operating condition. The value of the anode potential together with the potential difference between the anode 34 and cathode 33 determines the initial value of the potential of the grid 36 relative to the cathode 35, as it will be evident that the grid-cathode potential difference in the tube 14 is the algebraic summation of the anode-cathode potential difference in the tube 13 and the potential difference between the terminals of the capacitor 38.

Another factor affecting the initial grid potential is the sharing of charge between the capacitor 38 and the interelectrode capacitance 45. During the portion of the cycle in which the capacitor 38 is being charged through the resistors 17, 39 and 44, the interelectrode capacitance 45 is substantially short-circuited by the grid-cathode path of the tube 14. However, when the triggering pulse is impressed upon the grid 31 of the tube 13 and the tube 14 is consequently rendered non-conductive, the charge on the capacitor 38 is shared with the capacitance 45 by means of current flowing through the anode-cathode path of the tube 13. The resultant grid-cathode potential is less than the initial potential difference in the capacitor 38 and its amount is further lessened by the presence of the anode-cathode potential difference in the tube 13. In an embodiment which was built and successfully operated, the capacitance 45 amounted effectively to 30 to 40 micromicrofarads. The time required for the grid 36 to reach cut-off was found to range from a minimum of about 3 microseconds to a maximum of about 8 microseconds, depending upon the setting of the variable resistor 17 in the anode circuit of the tube 13. By means of the variable resistor 17 the initial potential of the grid 36 was adjustable over a range from 90 to 150 volts, more or less. The system was found to be operable at pulse repetition rates as high as 80,000 cycles per second, which rate corresponds to a cyclic period of 12½ microseconds. Each impressed input pulse gives rise to an output pulse after an interval which may be adjusted, as for example, within the limits from 3 to 8 microseconds, more or less. Other repetition rates may of course be employed as desired and the time delay interval may be adjusted to a desired portion of the cyclic time, at least within wide limits.

Many conventional multivibrators have a coupling condenser or other coupling impedance element with one terminal connected to the anode of the first tube and other terminal to the grid of the second tube and have another coupling condenser or coupling impedance element similarly connected between the anode of the second tube and the grid of the first tube. It has been customary in impressing a triggering pulse upon a multivibrator of this type to insert a unidirectional conductor or rectifier between the triggering source and the grid of one tube in the multivibrator. The rectifier was arranged to conduct only in the direction required to pass the triggering pulse. The presence of the rectifier served to reduce or prevent reaction of the multivibrator upon the triggering source.

In the type of multivibrator circuit disclosed herein, the coupling between the anode **37** and the grid **31** is accomplished by means of the cathode resistor **44**. Accordingly, a change in anode current in the tube **14**, while it affects the potential difference between the grid **31** and the cathode **33** by producing a potential drop in the resistor **44**, does not affect the potential difference between the grid **31** and ground. Hence it would seem feasible to connect a triggering source between the grid **31** and ground, with or without a rectifier, as desired, and without incurring a reaction of the multivibrator upon the triggering source. In other words, the triggering source is decoupled with respect to the coupling means which couples the anode **37** to the grid **31**. Experience with multivibrators of this type at moderate repetition rates has confirmed this conclusion.

At the frequencies and repetition rates here contemplated, namely 80,000 cycles per second or more, however, the circuit was found not to work satisfactorily without a rectifier between the triggering source and the grid **31**. Applicant discovered that an unexpected improvement in operation was obtainable by the use of the rectifier as specified.

The element **16** between the input terminal **47** and the grid **31** is thought to function to prevent the relatively low direct current resistance of the winding **21** and resistor **30** from forming a shunt across the grid resistor **32**. The element **16** is poled in the proper direction to admit the desired input pulse and to prevent a reverse current from being established. The effect of such reverse current is not well understood but it is thought that such current tends to discharge the grid prematurely after the input pulse is terminated. In effect, the rectifying element seems to act to give a higher impedance looking back toward the input from the grid of the tube **13**. It has been found that with the rectifying element in the circuit as shown, the range of delay variation which may be obtained is greater than otherwise could be secured. It has been found also that the delay time is less influenced by the amplitude of the input pulses and also less influenced by the repetition rate of the pulses when the rectifying element is employed.

What is claimed is:

1. A multivibrator comprising two spaced discharge devices each having an anode, a cathode and a grid, a first coupling means coupling the anode of the first space discharge device to the grid of the second, a second coupling means coupling the anode of the second space discharge device to the grid of the first, a circuit decoupled with respect to said second coupling means for impressing a unidirectional control impulse upon the grid of the first space discharge device, a direct-current path including a transformer winding of relatively low direct-current resistance between the grid and cathode of said first space discharge device constituting a grid leak path of excessively low impedance, and a substantially unidirectional conductor in series connection in series with said excessively low impedance grid leak path and having its direction of conductivity in the direction of flow of the impressed control impulse, thereby blocking reverse current grid leakage through said path of excessively low impedance.

2. A multivibrator comprising two space discharge devices each having an anode, a cathode and a grid, said cathodes being connected to a common cathode terminal, a capacitor connected between the anode of the first said space discharge device and the grid of the second said space discharge device, a feedback resistor connected in a circuit between said common cathode terminal and the grid of the first space discharge device, a grid leak resistor serially connected between the grid of the first space discharge device and the said feedback resistor, a source of unidirectional control impulses, connections from said source to the respective terminals of said grid leak resistor, said last-mentioned connections together with said control impulse source being of relatively low impedance compared with said grid leak resistor, and a substantially unidirectional conductor in series connection with said control impulse source and having its conductive direction in the direction of flow of said unidirectional control impulses.

3. A multivibrator comprising two space discharge devices each having an anode, a cathode and a grid, said cathodes being connected to a common cathode terminal, a source of current supply for said space discharge devices, a feedback resistor connected between said common cathode terminal and the negative side of said source of current supply, a capacitor connected between the anode of the first said space discharge device and the grid of the second said space discharge device, a fixed resistor connected between the grid of the second space discharge device and the positive side of said source of current supply, a primary winding of a load transformer connected between the positive side of the source of current supply and the anode of the second space discharge device, and an adjustable timing resistor connected between the positive side of the source of current supply and the anode of the first space discharge device.

4. A multivibrator comprising two space discharge devices each having an anode, a cathode and a grid, a first coupling means coupling the anode of the first space discharge device to the grid of the second, a second coupling means coupling the anode of the second space discharge device to the grid of the first, a grid leak resistor in circuit between the grid and cathode of the first space discharge device and having substantially no coupling with said second coupling means, a control impulse supply path of relatively low impedance compared to said grid leak resistor, said control impulse supply path being in parallel connection with said grid leak resistor, and with the grid cathode path of said first space discharge device and including in series connection a transformer winding of relatively low direct-current resistance, and a substantially unidirectional conductor serially connected with said transformer winding in said control impulse supply path and having its direction of conductivity in the direction of flow of the impressed trans-

former winding thereby blocking grid leakage current through said control while permitting free flow of the control impulses.

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