July 30, 1946. L. TONKS ET AL 2,405,070

SQUARE WAVE PULSE GENERATING SYSTEM

Filed Feb. 23, 1942

Fig. 1.

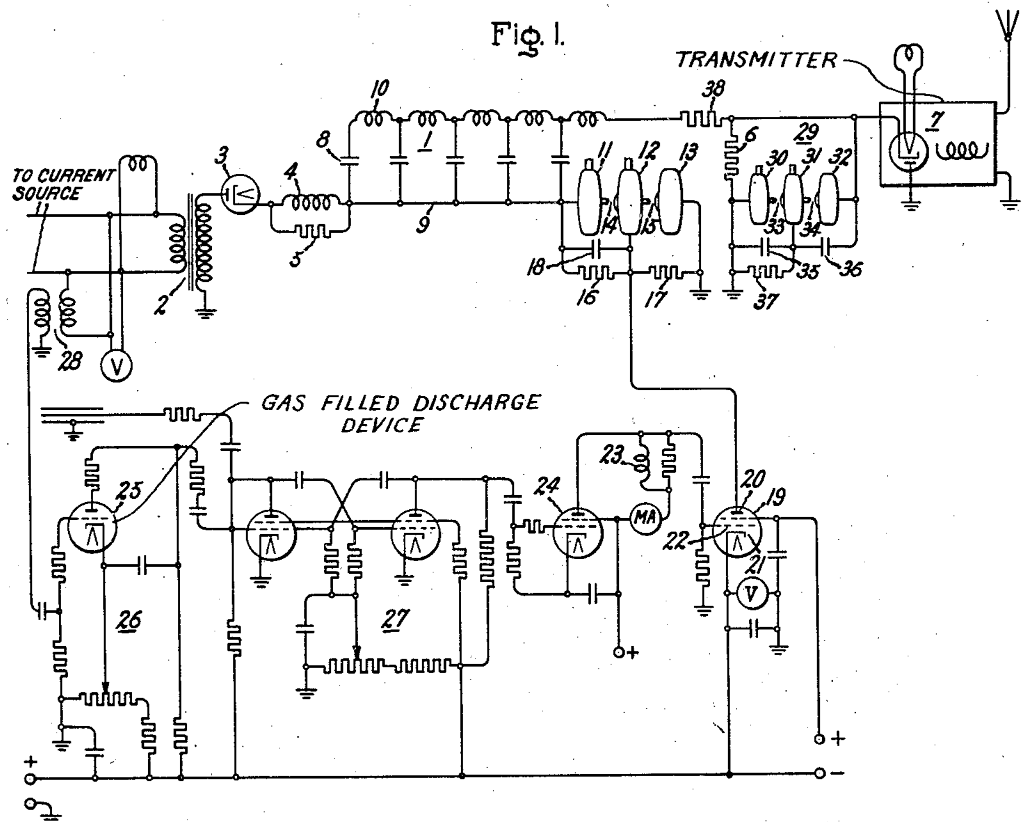
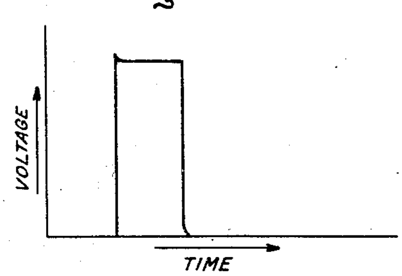


Fig. 2.



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SQUARE WAVE PULSE GENERATING SYSTEM

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5 Claims. (Cl. 250—37)

Our invention relates to pulse generating systems, particularly to such systems employing spark gaps as switching mechanism, and the general object of the invention is to provide improved systems of this character which produce pulses at a relatively high rate and operate at a high charging voltage, and which supply a large value of instantaneous power with a high order of precision of sparking of the switch means proper.

In pulse generating systems for supplying instantaneous high power at a rapid rate which have been proposed and used heretofore in an extended range of applications, difficulties have been encountered in obtaining pulses of the required power and repetition rate and at the same time with the desired timing accuracy.

In a copending application S. N. 432,009, filed February 23, 1942, and assigned to the same assignee as the present application, a pulse generating system is described wherein these disadvantages are overcome by the provision of a pulse generating apparatus in which a charged capacitive storage element is connected to a load by a spark gap assembly providing two spark gaps in series, and in which a predetermined initial apportionment of the voltages across the two gaps is changed or disturbed at the desired triggering instant thereby to cause breakdown of the spark gaps and to initiate the discharge, through the load, of a pulse from the storage element.

An alternating current source is arranged to charge the storage element at each cycle through a rectifier, and during the interval at each cycle when the voltage of the alternating current source is reversed the spark gap switch means is triggered thereby initiating the discharge of the storage element through the load. The capacitive storage element is of such character as to produce a discharge pulse approaching a rectangular wave form and for this purpose is constituted by a section of a suitable transmission line. The initial apportionment of the voltages is disturbed or changed to initiate the discharge by reducing, close to zero, the potential initially impressed on one of the conductive electrode members which provide the two spark gaps. The reducing of the potential close to zero is accomplished by pulsing positive the control electrode of a space discharge device normally in cut-off condition connected to the electrode member, the conduction periods of the space discharge device being synchronized, through timing means which may comprise a multivibrator, with the frequency of the alternating current source which charges the storage element.

In certain uses of the pulse generating system above described it has been found to be highly desirable that the pulse discharge through the load from the capacitive storage means be of a more nearly perfectly rectangular wave form than the pulse provided by the latter system. In accordance with our present invention this object is attained by the provision, in a system such as disclosed in the above-mentioned application, of an auxiliary spark gap switching means so arranged as to terminate the transmission-line-formed pulse abruptly a predetermined relatively short interval of time after the initiation of the pulse by the main spark gap switching means.

The novel features which are considered to be characteristic of our invention are set forth with particularity in the appended claims. Our invention itself, however, both as to its organization and method of operation together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawing wherein Fig. 1 is a diagrammatic representation of a pulse generating system in which our invention has been embodied, and Fig. 2 illustrates a voltage pulse produced in accordance with our invention.

In Fig. 1 the numeral **1** designates a capacitive element adapted to be charged periodically from an alternating current source through a transformer **2**, a rectifier **3** and an inductance **4** shunted by a resistor **5**, and to be discharged during the reverse period of the current source through a load element such as a resistor **6**, across which may be connected a desired output or utilization circuit **7**. For example, the pulses from the resistor **6** may be supplied to radio apparatus or the like employed to transmit high-power signals, rapidly repeated and accurately timed and of short duration. For illustrative purposes the utilization circuit is shown herein as including a magnetron upon the anode-cathode circuit of which the pulses from resistor **6** are impressed and which is connected to an antenna to transmit therefrom rapidly-repeated and short-duration pulses of intense microwave radiation utilized, for example, in the detection of distant objects.

The capacitive storage element **1** is constituted by a section of transmission line of such character that the discharge therefrom approximates a rectangular wave form. The transmission line section comprises a plurality of condensers **8**, preferably at least five in number, connected in parallel, with one side of each connected to a common lead **9** and with the other sides of adjacent condensers connected by inductances **10**.

To discharge the storage element **1** through the load **6** a main switching means is provided comprising three spark gap members or conductive electrode members **11**, **12**, and **13** providing two spark gaps **14** and **15** in series with the storage element **1** and the load **6**. The voltages initially impressed across the spark gaps **14** and **15** are preferably equally apportioned as by resistors

16 and 17 connected respectively between member 11 connected to the capacitor element 1 and the intermediate member 12, and between the intermediate member 12 and member 13 connected to the load 6. A capacitor 18 for balancing the distributed capacity of member 12 is connected between members 11 and 12.

The numeral 19 designates a space discharge device, normally in cutoff condition, the anode 20 of which is connected to the intermediate spark gap member 12, and the cathode 21 of which is connected to ground. To cause space discharge device 19 to become periodically conducting, thereby to reduce periodically close to zero the potential of spark gap member 12, a means is provided to impress a positive pulse upon the control electrode 22 of the latter space discharge device. For this purpose an inductance 23 included in the anode circuit of a space discharge device 24 is provided which is connected to the control electrode 22 of discharge device 19 to supply the positive pulse thereto.

To initiate the supplying of the pulse from inductance 23 to the control electrode 22 of device 19 and to synchronize this pulse with the frequency of the above-mentioned alternating current source, a space discharge device 25 of the gas filled type arranged to operate in a usual sweep circuit 26 is employed in connection with a multivibrator 27. Potentials are supplied to the control electrode of discharge device 25 from the alternating current source through a transformer 28 to initiate periodic operation of this discharge device and thereby to cause negative potentials in synchronism with the frequency of the alternating current source to be impressed upon an input electrode of the multivibrator.

The pulse rate of the multivibrator is thus synchronized, by connection to circuit 26, with the predetermined frequency. The output circuit of the multivibrator is in turn connected to the control electrode of space discharge device 24 to impress short pulses at this frequency upon the latter electrode. Danger of overloading of the anode circuit of device 24, which is liable to occur unless the current-passing interval, or interval during which current is traversing inductance 23, is maintained at a small fraction of the total time period of each pulse, is avoided since current-passing intervals of the required short duration in device 24 are obtained corresponding to the short pulses readily obtainable from the multivibrator and impressed upon the control electrode of the device 24.

In accordance with our present invention an auxiliary switching means, indicated generally by the numeral 29, is provided to cooperate with the above-described main switching means and its associated charging and timing elements in producing a pulse of improved wave form. The switching means 29 comprises three auxiliary spark gap members or conductive electrode members 30, 31 and 32 similar respectively to the members 11, 12 and 13 which are disclosed and described in the above mentioned application, S. N. 432,009. The members 30 to 32 provide auxiliary spark gaps 33 and 34 in shunt with the load resistor 6. The auxiliary spark gap members may be of smaller diameter than that of the main spark gap members 11 to 13 and the length of the gaps 33 and 34 may be less than that of the main gaps 14 and 15. The gaps 33 and 34 are preferably equal in length and are shunted respectively by equal impedances constituted by capacitances 35 and 36 for apportioning the initial voltages of the gaps. To assist in determining the instant of breakdown of the gaps 33 and 34 a resistance 37 is connected in shunt with one of the gaps. The length of the gaps is such that with resistance 37 disconnected, breakdown of the gaps does not occur. To suppress undesired oscillations during the sparking period which tend to occur in the circuit comprising the transmission line 1 and the spark gaps 14, 15, 33 and 34, a resistance 38 is connected in series in the latter circuit.

In operation of the system illustrated in Fig. 1, the transformer 2 charges the transmission line section 1 once per cycle through rectifier 3 and inductance 4. After charging is complete and during the interval when the voltage of transformer 2 is reversed, the switching means constituted by the spark gap members or spark electrode members 11 to 13 is triggered, thus applying to the load 6 one-half of the voltage of the charged transmission line 1.

In the absence of the auxiliary switch means 29 the pulse voltage after persisting for a predetermined period at substantially its maximum value and then decreasing, would not then drop from its maximum to its minimum value instantly but during a definite, even though relatively short, time interval. The terminating or lagging edge of the pulse wave form would therefore be slightly sloped and the resulting wave would thus approach but not attain a square wave form. However, with the auxiliary switch members 30 to 32 connected into the system to provide the spark gaps 33 and 34 in shunt with the load 6, the drop in pulse voltage occurs suddenly and the slight slope of the lagging or terminating edge of the pulse wave form is therefore avoided.

The auxiliary switching means 29 functions in the following manner. The gaps 33 and 34 are of such length that they do not break down in the absence of means to change or disturb the initial apportionment of the voltage impressed thereacross by the charged line 1. But when a suitable impedance, resistance 37, is connected in shunt with one of the latter gaps a progressive unbalance of voltages thereacross occurs which causes the gap to break down or fire during the pulse interval itself and at a predetermined short time interval after the initiation thereof. The sudden breakdown of the gaps 33 and 34 causes the pulse voltage to drop abruptly from its maximum to its minimum value. The pulse being thus terminated abruptly, the lagging edge of the wave form is effectively clipped, and the resulting voltage pulse is of the substantially exactly rectangular wave form illustrated by the curve of Fig. 2.

The resistance 38 serves to damp out the oscillation which tends to be set up, in the circuit comprising storage element 1 and the spark gaps 14, 15, 33 and 34, as a result of the short-circuiting of load 6. The energy still stored in element 1 when the gaps 33 and 34 fire must be dissipated in some manner and if no element such as resistance 38 is provided for this purpose a large part of the energy goes into the spark, and the intense oscillation in the storage element and spark circuit above mentioned interferes with the functioning of the circuits of the multivibrator 27 included in the triggering or spark initiation portion of the system. The damping resistance 38 effectively prevents this interference.

In a practical application of our present invention the charging circuit was powered from a 400 cycle alternating current source. A pulse of 125 amperes at 32 kilovolts which had a duration of approximately one microsecond repeated 400 times per second, and of a substantially improved wave form as shown in Fig. 2, closely approximating the desired square wave form, was applied to the load **6**. The value of resistance **38** ranged from 12.5 to 50 ohms. The value of load resistance **6** was 250 ohms; capacitors **35** and **36** were of approximately 15 micromicrofarads each; the value of resistance **37** was 25,000 ohms; the spark gap members **30** to **32** were one inch in diameter and were provided, as in the main spark members **11** to **13**, with airblast means (not shown) to remove ionization products from the gaps after firing.

It was found, as the charging voltage was first applied at a relatively low value and then increased, that the spark gaps **14** and **15** of the main switching means first fired alone giving, across load **6**, the usual pulse having a wave form the terminating or lagging edge of which was slightly sloped. As a particular charging voltage was passed, however, the spark gaps **33** and **34** of the auxiliary switching means began to fire irregularly in a transition range and then regularly, clipping the lagging edge of the pulse to give the desired substantially rectangular form illustrated in Fig. 2. Further increase of charging voltage shortened the pulse duration until the limit of the main gaps **14** and **15** was reached. The voltage at which clipping began, as well as the pulse duration at a given voltage, was controllable by suitable variation of resistance **37** and capacitances **35** and **36**, and variation of the length of gaps **33** and **34**.

The system illustrated in Fig. 1 embodying our invention has been described as powered from an alternating current source. However, instead of the alternating current source a direct current source may be employed to charge the capacitive storage element **1** as described in the above-mentioned copending application, S. N. 432,009, and in this case the multivibrator **27**, together with any initial or primary timing device connected thereto, may be utilized as a timing means to control the positive pulsing of the control electrode of the space discharge device **24**. Further, instead of changing the initial apportionment of the voltages across the main spark gaps **14** and **15** by reducing close to zero the initial potential on spark gap member **12**, the change may be accomplished, as described in the above-mentioned copending application, by impressing a voltage pulse on member **12** from the inductance **23**, arranged to be traversed periodically by current from the space discharge device **24** having a pulse timing means associated therewith which may include the multivibrator **27** together with any primary or initial timing device associated therewith.

Our invention has been described herein in a particular embodiment for purposes of illustration. It is to be understood, however, that the invention is susceptible of various changes and modifications and that by the appended claims we intend to cover any such modifications as fall within the true spirit and scope of our invention.

What we claim as new and desire to secure by Letters Patent of the United States, is:

1. The combination with means to produce across a load a voltage pulse approaching rectangular wave form, the voltage of said pulse dropping from its maximum to its minimum value during a relatively short time interval, of spark gap switching means to short circuit said load a predetermined time interval after the initiation

of said pulse to cause said voltage to drop abruptly from said maximum to said minimum value whereby said voltage pulse becomes of substantially exactly rectangular wave form.

2. The combination with means to produce a voltage pulse across a load, the voltage of said pulse at the initiation thereof rising abruptly from its minimum to its maximum value, then remaining at maximum for a short time interval, and thereafter dropping to its minimum value during a relatively short time interval, of means to cause said voltage to drop to said minimum value abruptly a predetermined time interval after said initiation whereby said voltage pulse becomes of substantially exactly rectangular wave spark gap members providing two spark gaps in series, the pair being in shunt with said load and means to change the apportionment of the voltages between said gaps.

3. The combination with means to produce a voltage pulse across a load, the value of said voltage at the termination of said pulse dropping from its maximum to its minimum during a short time interval, of means to terminate said pulse abruptly comprising three spark gap members providing two spark gaps in series, the pair being in shunt with said load, and means to change the apportionment of the voltages between said gaps comprising a resistance in shunt with one of said gaps.

4. The combination with a capacitive device adapted to produce a voltage pulse approaching a rectangular wave form, a load, switch means adapted to connect said device to said load providing two spark gaps in series with said device and said load, and means to change suddenly the apportionment of the voltages between said spark gaps to initiate the discharge of said pulse through said load, of means to short circuit said load a predetermined short interval of time after said initiation of said pulse discharge to cause abrupt termination of said pulse thereby to produce a pulse approaching substantially closer than said first-named pulse to an exactly rectangular wave form, said last-named means comprising auxiliary switch means providing two spark gaps in series, the pair being in shunt with said load, two capacitances connected respectively in shunt with said last named spark gaps, and means including a resistance in shunt with one of said last-named spark gaps to change progressively the apportionment of the voltages therebetween.

5. In combination, a capacitive device adapted to produce a voltage pulse approaching a rectangular wave form, a load, switch means adapted to connect said device to said load providing two main spark gaps in series with said device and said load, means to change suddenly the apportionment of the voltages between said gaps to initiate the discharge of said pulse through said load, means to short circuit said load a short interval after said initiation comprising auxiliary switch means providing two auxiliary spark gaps in series, the pair being in shunt with said load, means to change the apportionment of the voltages between said auxiliary spark gaps, an oscillator circuit comprising said capacitive device and said main and auxiliary spark gaps, and a resistance connected in series in said circuit to damp oscillation therein tending to occur upon sparking in said gaps.

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