Aug. 2, 1960 J. B. HORODYSKI 2,947,884

HIGH VOLTAGE PULSE GENERATOR

Filed April 3, 1959

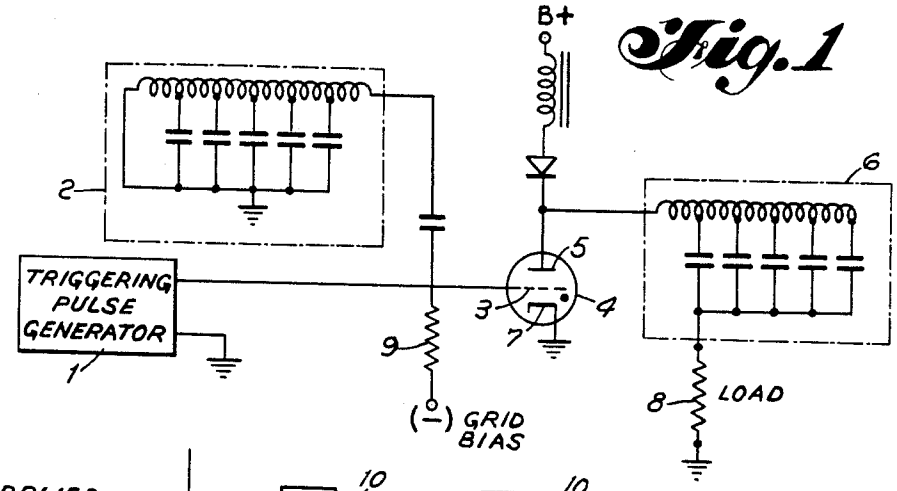

Fig. 1

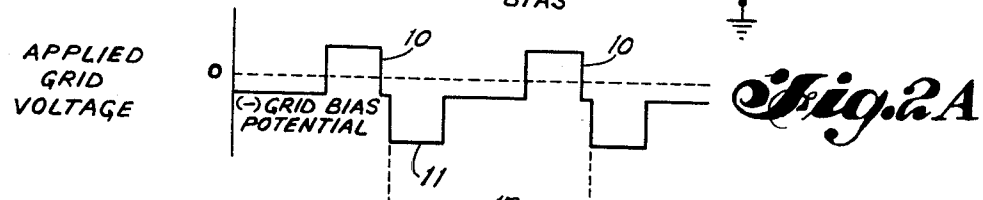

Fig. 2A

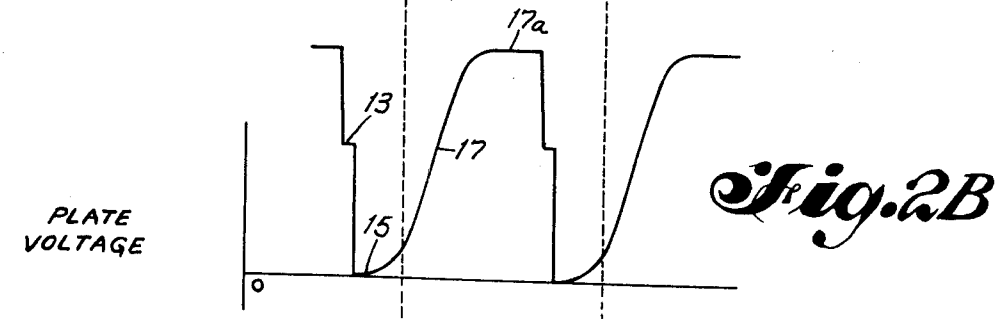

Fig. 2B

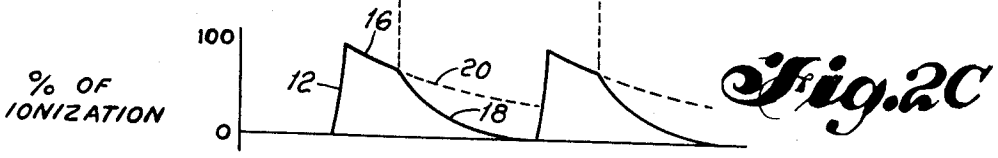

Fig. 2C

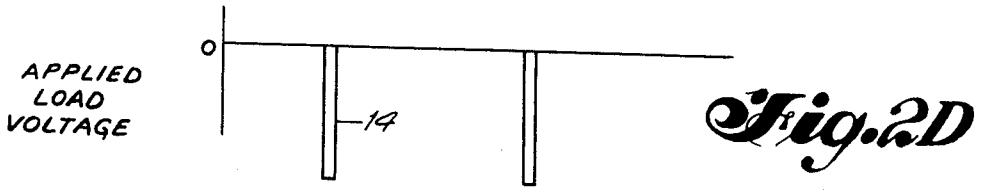

Fig. 2D

INVENTOR.
JOSEPH B. HORODYSKI
BY Lucy P. Lamb
ATTORNEY

United States Patent Office 2,947,884
Patented Aug. 2, 1960

2,947,884

HIGH VOLTAGE PULSE GENERATOR

Joseph B. Horodyski, Rutherford, N.J., assignor to International Telephone and Telegraph Corporation, Nutley, N.J., a corporation of Maryland

Filed Apr. 3, 1959, Ser. No. 803,947

4 Claims. (Cl. 307—106)

This invention relates to high voltage pulse generator circuits, and more particularly to circuits for the rapid deionization of gas tubes. This is a continuation-in-part of my application Serial No. 726,247, filed April 3, 1958, now abandoned.

In certain types of transmitting systems, for example, beacon transmitters and microwave transmitters, pulse generators capable of producing pulses of very short duration, yet having a high voltage and power level are needed. The function of these generators is to apply a voltage pulse to an oscillator, for example, a magnetron, and thereby provide short bursts of high frequency energy which can be radiated by an antenna. Two general categories of pulse generators are used, hard-tube pulsers and line-type pulsers. The present invention is related to line-type pulsers and more specifically to a pulser circuit employing a gas tube known as a "soft-tube pulser."

The function of the gas tube is similar to that of a relay wherein a small control current is used to switch another circuit which is capable of carrying large power loads. In many instances it is desirable to make this switching rate as rapid as possible. In gas tubes the switching rate is determined by the amount of time required to deionize the tube after it has been activated. The most widely used method to deionize these tubes is to interrupt the anode potential in some manner. This method, however, lacks a rapid deionization rate. In order to decrease the deionization time it has been the usual practice to apply a constant negative bias to the grid of the gas tube employed. Deionization time is approximately proportional to the magnitude of the negative bias applied; hence the faster the deionization required the larger the negative bias used. This method necessitates that the triggering of the firing pulse also be increased as the negative bias is increased so that the triggering pulse is able to override the negative bias to fire the tube. Therefore, an inherent disadvantage of this system is the limitation of the practical size and power output of the trigger source.

Another widely used method to decrease deionization time has been to employ an open circuited artificial transmission line in the plate circuit of the tube. This line is used as a pulse forming network. If the pulse forming network is mismatched in impedance with the impedance of the load being driven, a reflection of part of the output energy of the network will occur. This reflection is inverted by the pulse forming network and reapplied to the anode as a negative voltage of short duration. The negative voltage acts in a similar manner to the negative grid bias discussed above to further decrease the deionization time of the tube, however, maximum efficiency cannot be derived from the pulse forming network in this manner, for it is well known that in order to realize a maximum electrical power transfer it is desirable to match the impedance of the load and the load feeding network.

It is an object of the present invention to provide an

improved control circuit for gas tubes which provides for more rapid deionization thereof.

Another object is to provide rapid deionization of gas tubes directly after ionization has been effected by the trigger pulse.

A further object is to provide a high voltage gas tube pulse generating network which can be operated at improved efficiency without loss of a rapid switching rate.

A feature of the present invention is the coupling of the shorted delay line to the control element of the gas tube to be energized by the positive triggering pulse and apply an inverted mode of the triggering pulse to the control element at a predetermined time to aid in the deionization of the tube.

In the embodiment of the invention herein illustrated a gas tube is employed with a pulse forming network and a source of operating potential coupled to its anode. A positive triggering signal is applied simultaneously to the control element and a shorted delay line in the grid circuit of the tube by a triggering pulse generator. This signal performs the dual purpose of ionizing the tube and charging the shorted delay line. Upon ionization of the tube, the pulse forming network discharges through the tube and thus through the load element which is coupled to the cathode circuit of the tube. After the discharge has taken place the anode of the tube will be at essentially ground potential and thus allow the tube to deionize. The rate of deionization of the tube is aided by a negative bias supplied to the grid to the tube. It should be understood, however, that the circuitry is capable of operation without the aid of such a negative bias. After the tube begins its deionization cycle the shorted delay line, having been charged by the triggering pulse, then applies a negative spike approximately equal in magnitude to the triggering pulse to the control element of the tube. This negative spike will then rapidly quench the tube. For purposes of illustration the pulse forming network and the inverting device have been shown as artificial transmission lines. It is to be understood, however, that any other delay or storage devices of this general character could be used.

The novel features that are considered characteristic of this invention are set forth with particularly in the appended claims. The invention itself, however, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawing, in which:

Fig. 1 is a schematic diagram of an embodiment of the invention;

Fig. 2A is a graphic representation of the applied grid voltage;

Fig. 2B is a graphic representation of the plate voltage throughout the operating cycle;

Fig. 2C is a graph showing the percent of ionization in an idealized gas tube during its operating cycle; and

Fig. 2D is a graphic representation of the applied load voltage from the pulse forming network.

In order to institute the generation of a voltage pulse by igniting the tube **4**, a positive trigger pulse is applied to the tube grid **3** from the triggering pulse generator **1**. This triggering pulse charges the shorted delay line **2** and also causes the control element **3** to become positive with respect to ground. The positive charge on the grid **3** will initiate ionization of the tube **4**, and the voltage at the anode **5** will show a sharp decline in amplitude in the pulse forming network **6** discharges through the tube to ground. At the same time, the positive triggering pulse will appear across the shorted delay line **2** wherein the pulse will be delayed, inverted, and reflected. The parameters of the delay line **2** are chosen such that the pulse will be delayed until the time when recovery is

desired. During the conduction of tube 4 the load element 8, coupled by ground to cathohde 7, will experience an abrupt potential variation of one sense. This potential variation will be of high magnitude, but opposite in polarity to the B+ supply. The output waveform from the pulse forming network 6 assumes essentially a square shape, but is, of course, dependent upon the parameters selected for the network. Since no backward reflection from the load element 8 to the pulse forming network 6 is needed to help quench the tube 4, the load element 8 shown as a resistive impedance is preferrably matched in impedance to the pulse forming network 6. Thus, maximum power transfer from the pulse forming network to the load can be experienced with a minimum of reflected energy. When the pulse forming network 6 is fully discharged it momentarily gives the appearance of a direct short to the B+ supply as the network begins to recharge for the next cycle. The anode 5 is thus left at ground potential for a short time and the tube 4 begins its deionization cycle. The deionization of the tube 4, having been initiated by the loss of anode potential, is accelerated by the negative grid bias applied to the control element 3 via resistive element 9. At this time, however, a negative spike reflected from the shorted delay line 2 appears at the control element 3. This negative spike drives the control element 3 to a negative potential essentially equal but opposite in magnitude to the positive pulse emitted from the triggering pulse generator 1 and thus cause the tube 4 to deionize very rapidly.

To facilitate a comprehensive understanding of the exact operation of the circuit of Fig. 1 during a cycle of operation reference is now had to the waveforms shown in Fig. 2. The waveforms shown in Figs. 2A, 2B, 2C and 2D are drawn so that the respective ordinates, each representing time elapsed, measure similar lengths of time for similar distances.

Referring to Fig. 2A, there is illustrated a graph of the triggering pulse 10 and the reflected deionizing pulse 11 after the triggering pulse 10 has been inverted and delayed by the delay line 2 of Fig. 1. For simplicity, the ordinate of this curve has been selected at the value of the negative grid bias of Fig. 1.

When the triggering pulse 10 reaches the control element 3 it ionizes the tube 4 causing a rapid increase in the percent of ionization from near 0% to almost 100% as shown at 12 in Fig. 2C. At the same time, the voltage 13 at the anode 5 drops very rapidly. The waveform 13 is caused by the discharge of the pulse forming network 6 as it discharges through the tube to the grounded cathode 7. While the tube 4 is in a conducting state it forms a conducting path from the pulse forming network 6 to the load element 8 which is coupled to the tube by the common ground connection shown. The load 8 thus experiences the negative pulse 14 shown in Fig. 2D. After the pulse forming network 6 finishes its discharge cycle the voltage at the anode will fall to ground potential, as shown at 15. This lack of anode potential will now allow the tube 4 to deionize in conjunction with the negative grid bias of Fig. 1, in the manner shown at 16. As the tube deionizes the pulse forming network 6 will begin to recharge from the B+ supply and apply an increasing potential 17 to the anode of the tube 4. This potential, however, will not be sufficient to fire the tube until it reaches a critical value which is near the horizontal portion 17*a* of Fig. 2B. Before this critical potential can be reached, however, the reflected voltage 11 from the shorted delay line 2 appears at the grid 3 and causes the rapid deionization shown at 18 of Fig. 2C. Thus, with the use of only a small grid bias, or with the complete elimination of this bias, the tube 4 can be efficiently deionized and is ready to begin its switching cycle upon the reception of another triggering pulse 10.

The dashed curve 20 of Fig. 2C represents the rate of deionization of a circuit of the same type yet having no shorted delay line in the grid circuit. Compared with the solid deionization curve, the decrease of the deionization time is easily evident.

While I have described above the principles of my invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of my invention as set forth in the objects thereof and in the accompanying claims.

I claim:

1. In a circuit of the type described, a gas tube having a control grid, means coupled to said element to apply a positive triggering signal thereto and thereby effect ionization of said tube, means coupled to the anode of said tube to normally supply positive operating potential thereto, means coupled to said anode and responsive to ionization of said tube to interrupt said operating potential and thereby initiate deionization of said tube, a voltage inverting device and means directly coupling said voltage inverting device to said control grid whereby a portion of said triggering signal is inverted and delayed by said inverting device and applied to said control element to accelerate deionization of said tube.

2. A circuit according to claim 1, further including means coupled to said control element to maintain a negative bias on said control element whereby said negative bias in conjunction with the interruption of said anode potential and said inverted and delayed triggering signal further accelerates deionization of said tube.

3. A gas tube pulse generator, comprising a gas tube having an anode, cathode, and at least one control element, a source of positive triggering pulses coupled to said control element, a source of negative bias coupled to said control element, a shorted delay line coupled to said control electrode whereby each triggering pulse applied to ionize said tube is also applied to said shorted delay line which inverts a portion of the energy of said triggering pulse and applies a negative pulse after a delay interval to said control element to aid in deionization of said tube, an open circuited artificial transmission line coupled to said anode to apply an electrical discharge to said anode upon ionization of said tube, and means coupled to said anode and said transmission line to recharge said transmission line during deionization of said tube.

4. A circuit according to claim 3, further including a load circuit of essentially the characteristic impedance of said open circuited transmission line, coupled between said transmission line and said cathode to receive abrupt potential variations of one sense in response to said charging and discharging of said transmission line.

References Cited in the file of this patent

UNITED STATES PATENTS

2,054,496 Craig ..... Sept. 15, 1936
2,429,471 Lord ..... Oct. 21, 1947