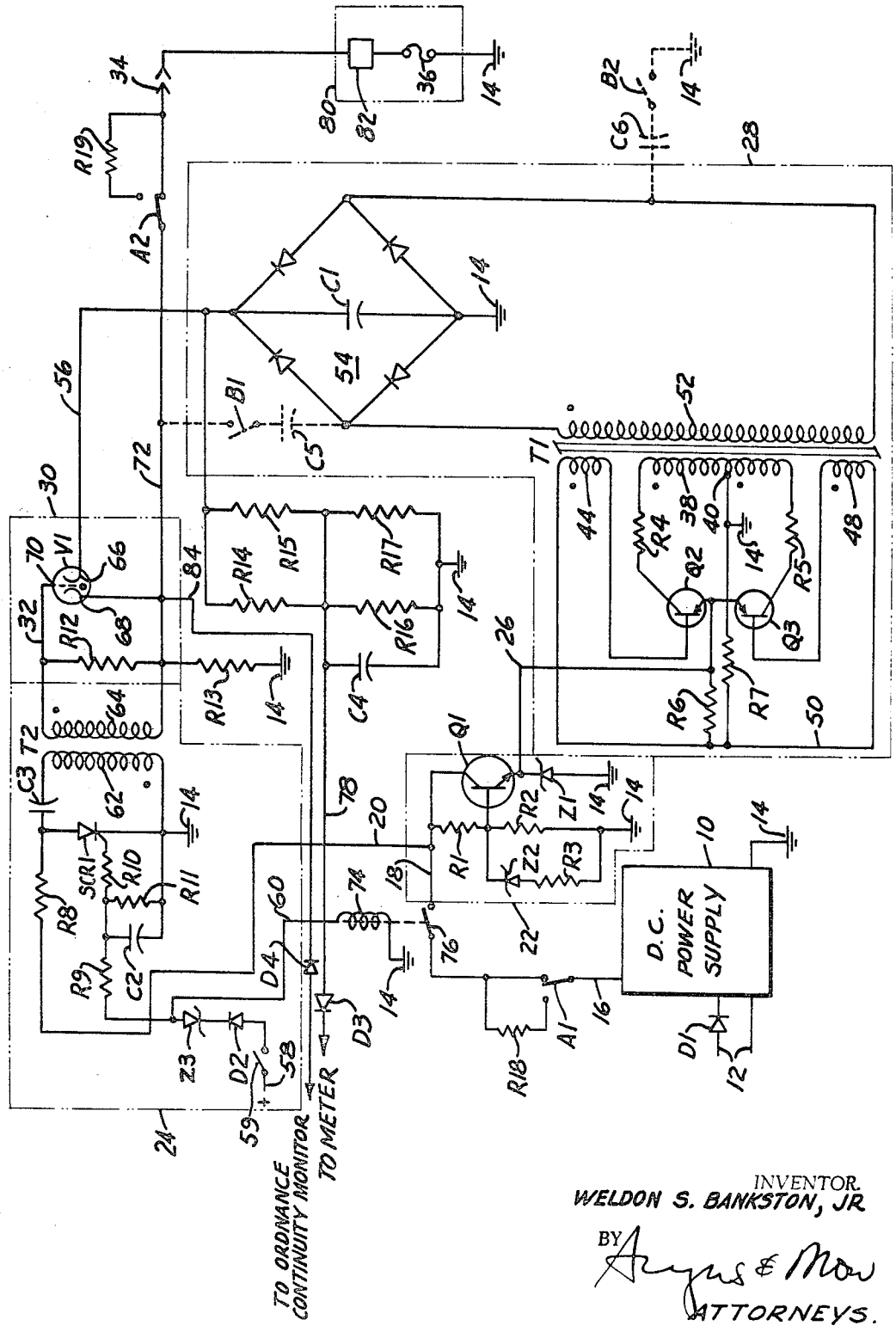
Nov. 5, 1968 W. S. BANKSTON, JR 3,409,804

ORDNANCE CONTROL CIRCUIT

Filed Aug. 25, 1966



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United States Patent Office 3,409,804 Patented Nov. 5, 1968

3,409,804

ORDNANCE CONTROL CIRCUIT

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Filed Aug. 25, 1966, Ser. No. 574,986
16 Claims. (Cl. 317—80)

This invention relates to exploding bridgewire and high voltage ordnance.

Most conventional ordnance devices utilize a wire which is exploded or heated up, or a gap in which a spark is discharged, to explode a charge. Spark gaps and heated wires are suitable for exploding relatively insensitive materials, but are usually not adequate to initiate less sensitive materials. For these materials, exploding bridgewires which discharge hot plasma onto the charge are often used. Such bridgewires enable explosives to be used which are much safer to handle because they are more stable.

In the case of an exploding bridgewire, a relatively high voltage, high amperage current is passed through the bridgewire in a short pulse which explodes the wire and discharges its hot plasma on the charge to ignite the same. For example, several known bridgewires are caused to explode by a current which reaches a peak of about 2,000 amperes in about one-half microsecond due to the discharging of a capacitor charged to about 2,000 volts.

Circuits are known for controlling the capacitor discharge in order to produce the high currents and rapid transients which are required to explode the bridgewire. However, the prior art circuits are generally objectionable because they operate on a high-level logic in which all switching and logic control is performed at high-voltage which may be dangerous to personnel and operators who operate the circuit. Furthermore, they are not suited for controlling certain new and novel types of ordnance devices.

It is an object of the present invention to provide a low-level logic circuit, that is, one which utilizes relatively low voltages for the switching and logic control of the relatively high voltages and currents for exploding a bridgewire, and which is more versatile than known circuits.

In application Ser. No. 439,170, filed Mar. 12, 1965 by Weldon S. Blankston, Jr., now Patent no. 3,344,744, for "Safetied Ordnance Device," and assigned to the same assignee as the present invention, there is described a safetied ordnance device comprising an exploding bridgewire and a switch means to prevent premature exploding of said bridgewire. The switch means is essentially a solid state gap placed in the circuit of the exploding bridgewire and having properties whereby it is switched to a low impedance by placing a predetermined voltage across it, and switched to a high impedance by passing a predetermined current through it.

The present invention comprises a circuit capable of exploding a safetied ordnance type bridgewire of the class described in the aforementioned application Ser. No. 439,170 as well as other types. It includes a D.C. source. Terminal means is adapted to be connected to said bridgewire. A converter means is connected to said source for supplying a D.C. voltage having a value capable of exploding said bridgewire to a firing means. The firing means is connected to said converter means for supplying said D.C. voltage to said terminal means at a predetermined time. A first conditioning means is provided for switching the ordnance device to its lower impedance by application of a predetermined voltage.

According to a preferred but optical feature of this invention, there is included within the circuit for exploding the bridgewire a second conditioning means capable of swtiching the safetied ordnance device to a substantially

higher impedance by application of a predetermined current.

According to another preferred but optional feature of the present invention, the second conditioning means may include means for monitoring the continuity of the ordnance device.

The above and other features of this invention will be fully understood from the following detailed description and the accompanying drawing in which the single figure shows the presently preferred embodiment of the invention.

In the drawing there is shown a D.C. power supply **10** receiving an input from a suitable source at **12** with suitable connections through a diode **D1**. The D.C. supply is preferably grounded at **14** and supplies a suitable positive voltage to lead **16**, for example 28 volts. Leads **18** and **20** supply voltage from the power supply to a voltage regulator **22** and a pulse generator **24**, respectively. Lead **26** supplies a constant voltage output from the voltage regulator to a D.C.-to-D.C. converter **28**. The output of the D.C.-to-D.C. converter is stored in capacitor **C1** which is, in turn, connected to a trigger device **30**.

The trigger device is controlled via lead **32** by the pulse generator. When the trigger device is triggered with a pulse from the pulse generator, the voltage stored in capacitor **C1** discharges through the terminal **34** and bridgewire **36**.

The voltage regulator of the present invention comprises a NPN transistor **Q1** having its collector connected to lead **18** and its emitter connected to output lead **26**. A Zener diode **Z1** connects the emitter to ground. Resistors **R1** and **R2** are serially connected between lead **18** and ground. The base of transistor **Q1** is connected to the midpoint of resistors **R1** and **R2**. A Zener diode **Z2** and resistor **R3** are serially connected across resistor **R2**.

Lead **26** is connected to the emitters of PNP transistors **Q2** and **Q3** in the D.C.-to-A.C. converter section of the D.C.-to-D.C. converter **28**. The collector of transistor **Q2** is connected through resistor **R4** to one side of a winding **38**, the other side of which is connected through resistor **R5** to the collector of transistor **Q3**. The center-tap **40** of winding **38** is connected to ground. The base of transistor **Q2** is connected through lead **42** to a winding **44**, while the base of transistor **Q3** is connected through a lead **46** to a winding **48**. The opposite sides of windings **44** and **48** are connected together via lead **50**. A resistor **R6** is connected between leads **26** and **50** while a resistor **R7** is connected between lead **50** and ground.

Transistors **Q2** and **Q3** are connected together in a push-pull manner so as to cause oscillation. The resulting alternating current across primary winding **38** is reflected through saturable core transformer **T1** to a secondary winding **52**.

An A.C.-to-D.C. converter comprising diode bridge **54** is connected across secondary winding **52**. Capacitor **C1** is connected across the output of the diode bridge **54**. The negative side of the bridge may be grounded, as indicated at **14**, while the positive side of the bridge and capacitor **C1** is connected to lead **56**.

Lead **20** supplies D.C. power from the supply **10** to the pulse generator **24**. Lead **20** is connected through resistor **R8** to the anode of silicon controlled rectifier **SCR1**. The cathode of the silicon controlled rectifier is preferably connected to ground, as indicated at **14**.

Lead **58** is connected from the D.C. power supply **10** through a suitable switching means **59** through diode **D2** and Zener diode **Z3** to lead **60**. Resistors **R9** and **R10** are serially connected between the Zener diode **Z3** and the gate electrode of the silicon controlled rectifier. The junction between resistors **R9** and **R10** is connected to ground by the parallel combination of capacitor **C2** and resistor **R11**. A capacitor **C3** is connected to the junction

between resistor R8 and the anode of the silicon controlled rectifier. Primary winding 62 of the transformer T2 is connected between the opposite side of the capacitor C3 and the cathode of the silicon controlled rectifier. The secondary winding 64 of transformer T2 is connected via line 32 to the trigger device 30.

The trigger device 30 comprises a gas discharge tube V1 having electrodes 66 and 68 and a control electrode 70. The lead 32 is connected to the control electrode. The gas discharge tube receives its trigger impulse from the secondary winding 64 via lead 32, connected to control electrode 70, and lead 72, connected to electrode 68. A resistor R12 is connected between leads 32 and 73. Preferably resistor R13 is connected between lead 72 and ground.

The operation of the circuit thus far described is as follows: The D.C. power supply 10 supplies voltage through the voltage regulator 22 to the D.C.-to-D.C. converter 28. The output voltage of the converter is stored in capacitor C1, and is approximately 2,500 volts. The voltage stored in capacitor C1 is supplied to the electrode 66 in the trigger 30.

At the same time, the D.C. power supply is connected via line 20 to the pulse generator 24. Since the silicon controlled rectifier is initially in its non-conducting state, capacitor C3 charges to substantially 28 volts, the voltage available from the D.C. power supply.

At a predetermined time, switch 59 is closed connecting the D.C. power supply 10 to the pulse generator 24 causing the voltage to rise across capacitor C2 and resistor R11. At the same time, voltage is supplied to relay winding 74 causing its contact 76 to open, breaking the circuit between leads 16 and 18. When the voltage at the control electrode of the silicon controlled rectifier reaches a predetermined point, the silicon controlled rectifier switches to its on, or conducting, state causing capacitor C3 to discharge through the silicon controlled rectifier and the primary winding 62. The pulse generated by capacitor C3 is reflected across transformer T2 to the trigger electrode 70 of the trigger device 30.

Relay winding 74 opens contact 76 prior to the generation of the pulse by the pulse generator preventing the pulse generator circuit from drawing further current from the D.C. supply 10.

When the trigger device 30 operates, capacitor C1 is allowed to discharge through electrodes 66 and 68 to lead 72, terminal 34, and the bridgewire 36. The discharge of capacitor C1 through the bridgewire 36 is of the order of 2,000 amperes in about one-half microsecond. Thus, it is readily apparent that the discharge of capacitor C1 is performed at the low-level logic of approximately 28 volts.

Connected across capacitor C1 is a voltage divider network comprising resistors R14, R15, R16 and R17. The voltage divider has a filter capacitor C4 connected across the output and an output lead 78 which may be connected to a meter through a diode D3. Thus, the voltage appearing on the meter (not shown) is representative of the voltage across capacitor C1.

The present circuit is suitable for operation of a safetied ordnance device, such as disclosed in the aforementioned application Ser. No. 439,170. The ordnance device is schematically shown generally at 80 having a bridgewire 36, as hereinbefore described, and a solid state gap 82. As described in the aforementioned patent application, gap 82 has the properties such that it may be switched to a low resistance, approximately 10 ohms, by applying approximately 800 volts across it; and it may be switched to a high resistance, for example, several megohms, by passing approximately 10 milliamperes through the gap 82. The switching to low resistance may be performed with either alternating or direct current at a value of about 800 volts, which is substantially below the voltage necessary to fire the bridgewire 36.

It is preferable to switch gap 82 to its low resistance by using a D.C. voltage.

For D.C. switching, a switching means having a pair of contacts A1 and A2 connect a pair of resistors into the circuit to reduce the voltage output at terminal 34. Switch A1 has a first position normally connecting lead 16 from the D.C. supply 10 to lead 18 through normally-closed relay contact 76. In its second position, switch A1 connects a resistor R18 into the circuit between leads 16 and 18. Switch A2 operates in unison with switch A1 and has a first position normally connecting lead 72 directly to terminal 34. In its second position, switch A2 connects a resistor R19 into the circuit between lead 72 and terminal 34.

When switch A1 is placed in its second position, power from the D.C. supply 10 is connected through lead 16, voltage reducing resistor R18, and lead 18 to the voltage regulator 22. Thus, the voltage stored across capacitor C1 is substantially less than the 2,500 volts normally stored by capacitor C1.

When voltage is supplied to the lead 58 in the pulse generator, a pulse is reflected across transformer T2 to fire the gas tube 70 causing discharge of the voltage stored in capacitor C2 through the tube V1 to lead 72. Since at the same time switch A2 is in its second position, the voltage discharged through the trigger is further reduced through voltage reducing resistor R19 so that approximately 800 volts D.C. appears at terminal 34 to switch gap 82 to its low resistance state.

Alternatively, switching may be done with A.C. by connecting the secondary winding 52 across the gap 82 through a pair of capacitors. Capacitor C5 is connected through a first switch B1 between lead 72 and one side of the winding 52. Another capacitor C6 is connected to a second switch B2 to ground. Switches B1 and B2 operate in unison. Thus, when switches B1 and B2 are closed, alternating current is supplied through terminal 34 to the ordnance device 80. Capacitors C5 and C6 reduce the alternating current to a voltage of approximately 800 volts for switching the gap 82 to its low resistance state.

Lead 84 connects terminal 34 to a suitable ordnance continuity monitor circuit (not shown) through diode D4. The continuity of the bridgewire 36 and switch gap 82 may be tested with this circuit. The monitor circuit preferably operates at approximately 10 to 20 milliamperes to insure the proper switching of gap 82 to its high resistance state. Thus the monitor circuit provides the dual junction of monitoring the continuity of the ordnance device 80 and switching the gap 82 to its high resistance state.

It is to be understood that the present invention may be performed using other devices than those described in the detailed specification. For example, PNP transistors may be substituted for NPN transistors, and NPN transistors may be substituted for PNP transistors. Suitable semiconductor switching devices may be used for the gaseous tube V1, and likewise tubes may be used for any of the semiconductor devices. Semiconductor switching devices may be substituted for any of the manual switches shown.

The present invention provides a circuit for operating and exploding a safetied ordnance-type bridgewire wherein the switching is performed at voltage substantially below the voltages necessary for exploding the bridgewire. The circuit is reliable and economical and safer to operate than prior art circuits, and more versatile than the prior art systems. Costs of component parts are reduced due to the low-level logic switching utilized.

This invention is not to be limited by the embodiment shown in the drawing and described in the description, which is given by way of example and not by way of limitation, but only in accordance with the scope of the appended claims.

I claim:

1. A circuit for exploding a bridgewire, said bridgewire forming a portion of a safetied ordnance device capable of being switched to a first impedance by application of a predetermined current and to a second

impedance by application of a predetermined voltage, said second impedance being substantially less than said first impedance, said circuit comprising: a D.C. source; terminal means adapted to be connected to said bridgewire; converter means connected to said source for supplying a D.C. voltage having a value capable of exploding said bridgewire; firing means connected to said converter means for supplying said D.C. voltage to said terminal means at a predetermined time; and first conditioning means connected to said firing means for applying said predetermined voltage to said ordnance device to switch said ordnance device to its second impedance.

2. A circuit according to claim **1** wherein said firing means comprises a trigger means connected to said converter means for supplying said D.C. voltage to said terminal means upon receipt of a predetermined pulse and a pulse generator means connected to said source for generating said predetermined pulse at said predetermined time.

3. A circuit according to claim **1** wherein said first conditioning means comprises a first switching means and a first voltage reducing resistor connected between said D.C. source and said converter means.

4. A circuit according to claim **3** wherein said first conditioning means further includes a second switching means acting in unison with said first switching means and a second voltage reducing resistor connected between said firing means and said terminal means.

5. A circuit according to claim **1** wherein said first conditioning means comprises a switching means and a voltage reducing resistor connected between said firing means and said terminal means.

6. A circuit according to claim **1** wherein said converter means comprises a voltage regulator connected to said source, a D.C.-to-A.C. converter connected to said voltage regulator, an A.C.-to-D.C. converter connected to said D.C.-to-A.C. converter, and means connected to said A.C.-to-D.C. converter for storing said D.C. voltage.

7. A circuit according to claim **6** wherein said first conditioning means comprises a switching means and an A.C. impedance means connected between said ordnance device and said D.C.-to-A.C. converter.

8. A circuit according to claim **7** wherein said impedance means is a capacitor.

9. A circuit according to claim **1** further including a voltage dividing means connected to said converter means, and a meter means connected to said dividing means for indicating the value of said D.C. voltage.

10. A circuit according to claim **1** further including second conditioning means for applying said predetermined current to said ordnance device to switch said ordnance device to its first impedance.

11. A circuit according to claim **10** further including means for monitoring the continuity of said ordnance device.

12. A circuit according to claim **10** wherein said first conditioning means comprises a first switching means and a first voltage reducing resistor connected between said D.C. source and said converter means.

13. A circuit according to claim **12** wherein said first conditioning means further includes a second switching means acting in unison with said first switching means and a second voltage reducing resistor connected between said firing means and said terminal means.

14. A circuit according to claim **10** wherein said first conditioning means comprises a switching means and a voltage reducing resistor connected between said firing means and said terminal means.

15. A circuit according to claim **10** wherein said converter means comprises a voltage regulator connected to said source, a D.C.-to-A.C. converter connected to said voltage regulator, an A.C.-to-D.C. converter connected to said D.C.-to-A.C. converter, and means connected to said A.C.-to-D.C. converter for storing said D.C. voltage.

16. A circuit according to claim **15** wherein said first conditioning means comprises a switching means and an A.C. impedance means connected between said ordnance device and said D.C.-to-A.C. converter.

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