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[54] **CIRCUITRY FOR TRIGGERING A SPARK GAP**
3 Claims, 2 Drawing Figs.

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[51] **Int. Cl.** **H05b 37/00,** C06c 3/00
[50] **Field of Search** ..... 307/284, 305; 315/185, 189, 200, 203, 205, 207, 208, 330, 335, 332; 102/18, 19.2, 28, 70.2, 70.2 A; 317/80

[56] **References Cited**
UNITED STATES PATENTS

3,293,527 12/1966 Julich ..... 317/80 X
3,320,889 5/1967 Holtz ..... 102/28 X

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ABSTRACT: A circuit for triggering breakdown of an arc path through a gaseous atmosphere between a pair of spark gap defining electrodes is disclosed. The spark gap includes an auxiliary triggering electrode disposed between the pair of spark gap defining electrodes. A voltage divider network is connected across the pair of spark gap defining electrode with the output of the voltage divider being applied to the triggering electrode. The voltage divider includes a series connection of a first resistive means and a second resistive means. The first resistive means includes one or more four-layer diodes which switch rapidly from a nonconductive state to a conductive state at a certain threshold voltage applied thereacross, whereby when the potential applied across the spark gaping defining electrodes reaches a certain predetermined value the four-layer diodes break into conducting to apply the triggering output potential to the trigger electrode to trigger an arc across the pair of electrodes defining the spark gap.

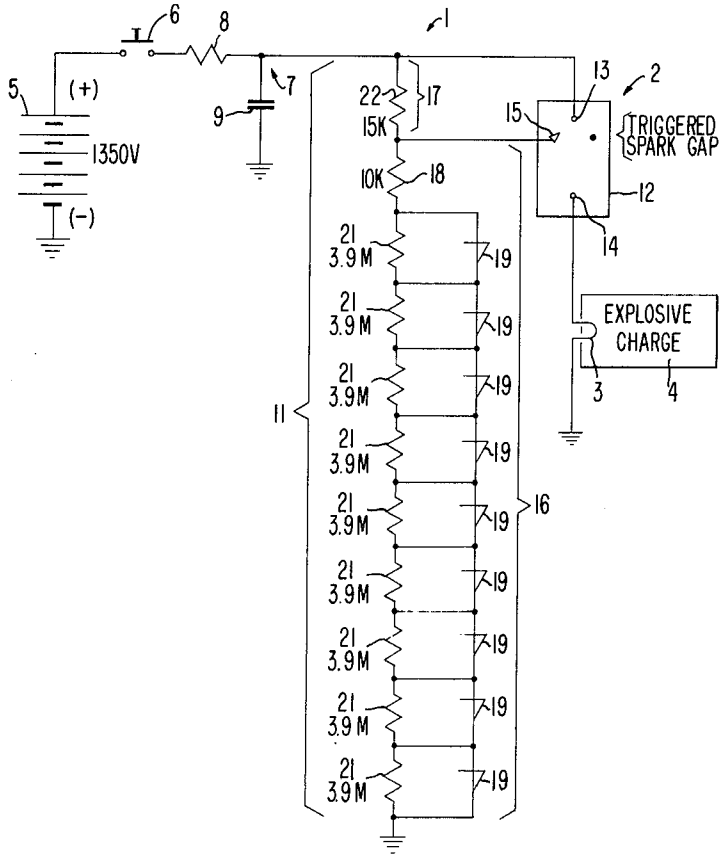

FIG. 1

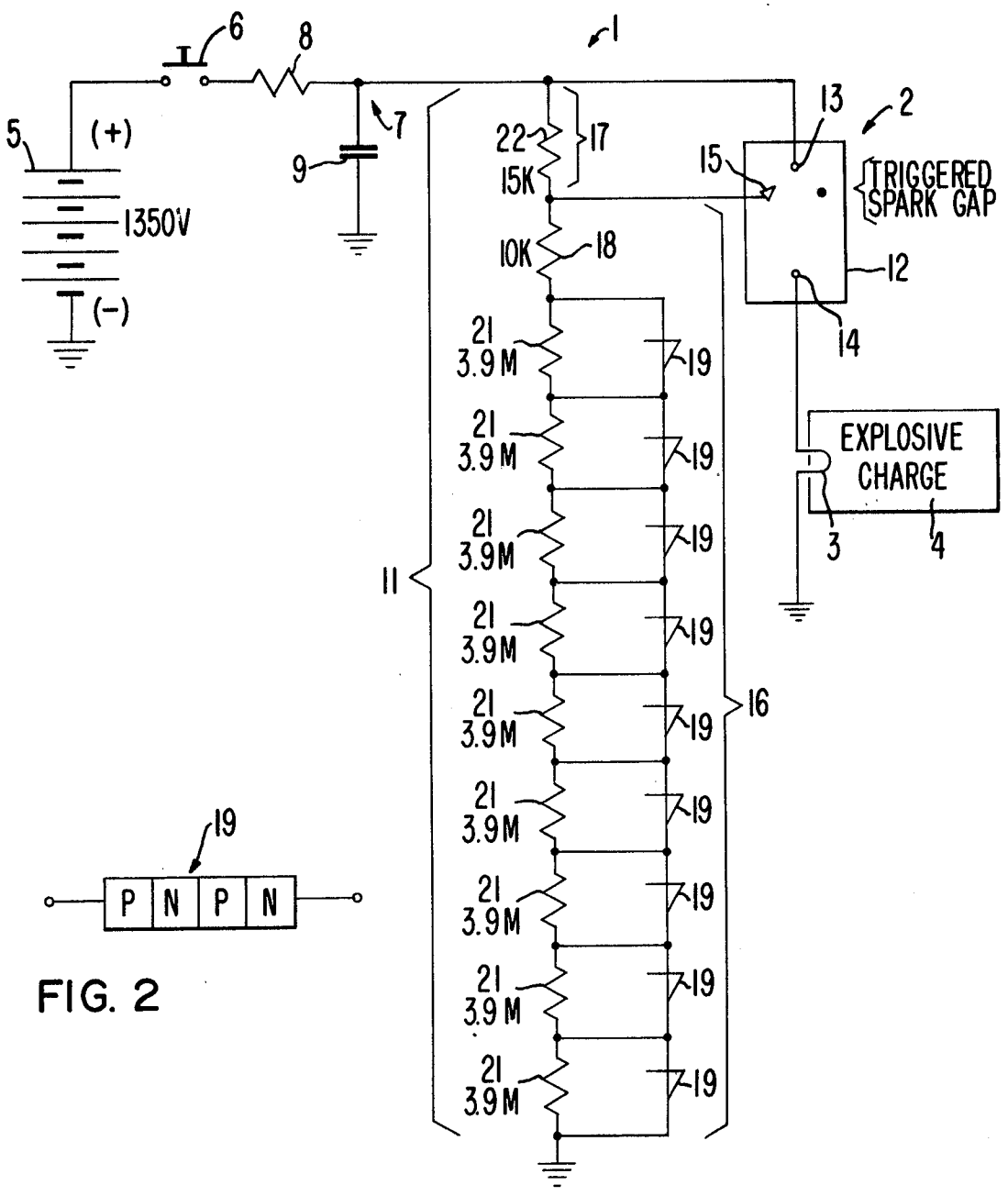

FIG. 2

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CIRCUITRY FOR TRIGGERING A SPARK GAP

DESCRIPTION OF THE PRIOR ART

Heretofore, spark gaps have included triggering electrodes for triggering an arc across the main spark gap of the device when a certain predetermined potential was applied across the spark gap. Typically, the voltage divider included a series connection of a first resistive means and a second resistive means; being a thyratron such that when a certain potential was applied across the main gap of the spark gap and also across the voltage-divider network the thyratron would be triggered to apply an output from the voltage divider to the triggering electrode to trigger the main spark gap. One of the problems associated with the use of thyratrons in such a voltage-divider network is that they consume relatively large amounts of power and do not break down reliably at the certain predetermined threshold voltage. In many applications, such as in detonator circuits, a spark gap is placed in series with a detonator device for detonating explosive charges, rockets and the like and it is especially important that the spark gap be triggered at precisely a predetermined voltage as applied across the voltage-divider network and thus across the main electrodes of the spark gap. Therefore, a need exists for an improved spark gap triggering circuit for triggering spark gaps at certain predetermined threshold voltages. The triggering threshold voltage should preferably have a tolerance on the order of 5 to 10 percent or less.

SUMMARY OF THE PRESENT INVENTION

The principal object of the present invention is the provision of an improved circuit for triggering a spark gap.

One feature of the present invention is the provision, in a spark gap triggering circuit having a voltage-divider network, the output of which is applied to a triggering electrode for triggering a spark gap, of the inclusion of a four-layer diode in one of the arms of the voltage divider, such diode serving to switch from a nonconductive state to a conductive state precisely at a certain predetermined threshold voltage applied thereacross, whereby the spark gap is triggered at a precisely predetermined voltage applied across the gap and the voltage divider.

Another feature of the present invention is the same as the preceding feature including the provision of a current limiting resistor connected in series with a plurality of the four-layer diodes in one arm of the voltage-divider network for limiting the current drawn through the four-layer diodes during conduction therethrough.

Another feature of the present invention is the same as any one or more of the preceding features wherein the voltage-divider network includes a series connection of a plurality of four-layer diodes with a resistive means connected in parallel with each of the four-layer diodes, each of such parallel connected resistors having a resistance substantially greater than that of the other resistive arm of the voltage-divider network, whereby the voltage applied across each of the four-layer diodes is precisely established as a certain fraction of the voltage applied across the voltage-divider network to stabilize triggering of the four-layer diodes.

Other features and advantages of the present invention will become apparent upon a perusal of the following specification taken in connection with the accompanying drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic circuit diagram of a detonator circuit incorporating features of the present invention, and

FIG. 2 is a schematic line diagram of a four-layer diode.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, there is shown a detonator circuit 1 incorporating features of the present invention. The detonator circuit 1 includes a triggered spark gap device 2 series connected with a detonating wire 3 imbedded in an explosive charge 4. A source of potential 5, as of 1,350 volts, is connected across the triggered spark gap device 2 and detonating wire 3 via a pushbutton actuating switch 6 and a low-pass filter 7 consisting of a series connection of a resistor 8 and a shunt capacity 9. A voltage divider network 11 is connected across the triggered spark gap device 2 in parallel with the spark gap device and detonating wire 3.

The triggered spark gap device 2 includes a dielectric insulative envelope structure 12 containing an ionizable gas atmosphere, as of dry nitrogen. A pair of spark gap defining electrodes 13 and 14 pass through the envelope 12 and the space between the inner tips of the electrodes 13 and 14 defines the spark gap. An auxiliary triggering electrode 15 is disposed in the gaseous atmosphere between the pair of spark gap defining electrodes for triggering breakdown of an arc path through the gaseous atmosphere between the pair of spark gap defining electrodes 13 and 14 when a certain predetermined potential is applied across the pair of spark gaps defining electrodes and the triggering electrode 15. The triggering potential is derived from the output of the voltage divider network 11.

The voltage divider network 11 includes a series connection of first and second resistive circuit arm 16 and 17 with the output of the voltage divider network 11 being derived from the node between the two arms 16 and 17.

The first resistive arm 16 of the voltage divider network 11 includes a series connection of a current limiting resistor 18, as of 10 k.Ω, connected in series with a plurality of four-layer diodes 19. A suitable four-layer diode comprises type UF 200—C commercially available from Unitrode Corporation of Watertown, Massachusetts. The four-layer diode 19 has a maximum forward current of 1.5 amps, a forward breakdown voltage of 200 volts and a maximum surge current of 15 amps. The turn on time for each diode is 0.1 to 0.5 microseconds with a turnoff time of between 2 to 5 microseconds.

A typical four-layer diode is a device 19, as shown in FIG. 2, and comprises four layers of alternating P- and N-type semiconductive material with PN junctions formed between each of the adjacent layers. The device is characterized by regenative feedback which produces an extremely fast semiconductive switch for switching substantial current loads in switching times less than one microsecond. Furthermore, the four-layer diode 19 is characterized by having an extremely precise and predictable voltage breakdown level.

Each of the four-layer diodes 19 includes a resistor 21 of relatively high resistance, as of 3.9 megaohms, connected in parallel with each of the diodes 19. The series connection of the relatively high value resistance resistors 21 serves to stabilize the potential applied across each of the four-layer diodes 19. Each of the resistors 21 has a value of resistance much higher than current limiting resistor 18 and of the resistance of the other arm 17 of the voltage-divider network 11. The second resistive arm 17 of the voltage divider 11 comprises a resistor 22, as of 15 k.Ω.

In operation, pushbutton 6 is depressed to apply the 1,350 volts from power supply 5 across the voltage-divider network 11 and the triggered spark gap device 2. The 1,350 volts is insufficient, by itself, to break down the arc path between spark gap defining electrodes 13 and 14. However, the voltage is sufficient to break down the chain of four-layer diodes 19 such that substantially half of the applied voltage appears between trigger electrode 15 and the closest one of the spark gap defining electrodes 13. The spacing between the trigger electrode 15 and the nearest spark gap defining electrode 12 is dimensioned such that the applied voltage from the output of the voltage divider will break down the gap between the trigger electrode and the spark gap electrode 13. When this happens, the spark gap trigger electrode 15 assumes essentially the potential of the spark gap electrode 13 and, thus, the applied potential of 1,350 volts appears between the trigger electrode 15 and the other main spark gap electrode 14. This shifts the arc from the trigger electrode to the other spark gap electrode 14 such that the arc is shifted or triggered between the main

spark gap defining electrodes 13 and 14. When the arc shifts to the main electrodes 13 and 14, the voltage drop across the triggered spark gap device 2 and the four-layer diodes 19 drops to a very low level and the diodes become nonconductive and the discharge is sustained between the electrode 13 and 14. Current passed by the discharge in the triggered spark gap device 2 energizes the detonating wire 3 to detonate the explosive charge 4.

Premature detonation of the explosive charge 4 is prevented by having a precisely predetermined breakdown voltage determined by the series connection of the four-layer diodes 19, such that the applied triggering DC voltage must reach the predetermined voltage level, as of 1,350 volts. Low-pass filter 9 prevents high-frequency transient components from actuating the triggered spark gap device 2.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. In a circuit for triggering breakdown of an arc path through a gaseous atmosphere between a pair of spark gap defining electrodes, an auxiliary triggering electrode disposed in the gaseous atmosphere between said pair of spark gap defining electrodes, first circuitry means for connecting a source of potential across said pair of spark gap defining electrodes, second circuitry means for interconnecting said pair of spark gap defining electrodes and said auxiliary triggering electrode for applying a triggering potential between said auxiliary electrode and one of said spark gap defining electrodes to initiate an arc between said pair of spark gap defining electrodes at a precisely predetermined potential as applied across said pair of spark gap defining electrodes, said second circuitry means including a voltage-divider means with the output of said voltage divider being applied to said auxiliary triggering electrode, said voltage-divider means having a series connection of first and second resistive means with an output connection to said auxiliary electrode disposed therebetween, THE IMPROVEMENT WHEREIN, said first resistive means includes a four-layer diode which switches rapidly from substantially a nonconductive state to a conductive state at a certain threshold voltage applied thereacross, whereby at the precisely predetermined potential applied across said pair of spark gap defining electrodes and said voltage divider network said four-layer diode breaks into conduction to apply an output triggering potential to said auxiliary trigger electrode to trigger an arc across said pair of electrodes defining said spark gap.

2. The apparatus of claim 1 wherein said first resistive means includes a series connection of a current limiting resistor and a plurality of series connected four-layer diodes.

3. The apparatus of claim 2 wherein said first resistive means includes a series connection of a plurality of resistors each of which is connected in parallel across each of said four-layer diodes and each of which has a resistance substantially greater than that of said second resistive means of said voltage divider means.