

Dec. 26, 1967

E. NERHEIM

3,359,904

PIEZOELECTRIC PROJECTILE FUZE

Filed July 5, 1966

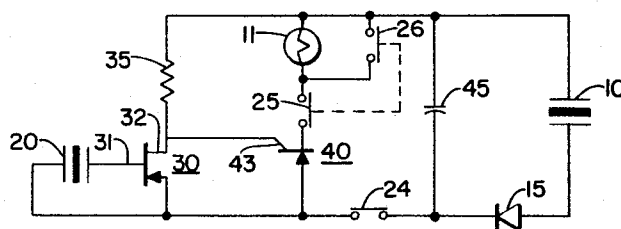


FIG. 1

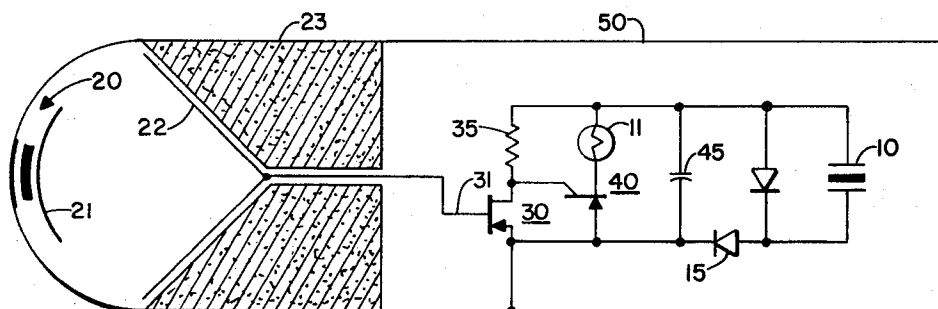


FIG. 2

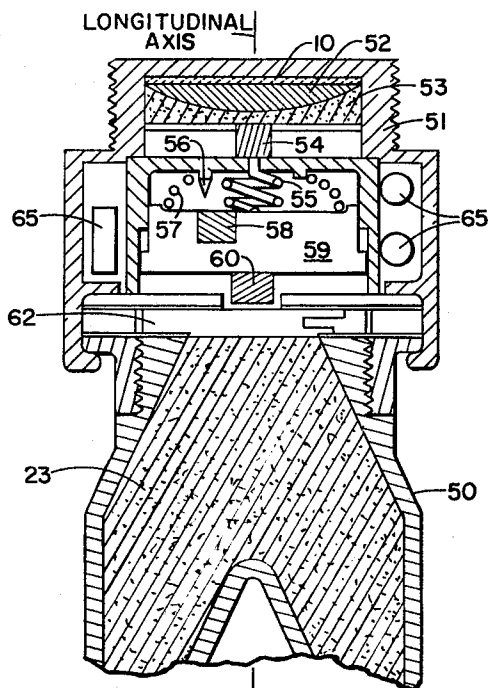


FIG. 3

INVENTOR.
ELDON NERHEIM

BY *Ray W. Jensen*
ATTORNEY

1

3,359,904

PIEZOELECTRIC PROJECTILE FUZE

Eldon Nerheim, Minneapolis, Minn., assignor to Honeywell Inc., Minneapolis, Minn., a corporation of Delaware

Filed July 5, 1966, Ser. No. 562,581

8 Claims. (Cl. 102—70.2)

ABSTRACT OF THE DISCLOSURE

A high-speed contact fuze for detonation of an explosive charge upon impact with the target. A first piezoelectric crystal is compressed by the setback force to produce electric energy which is stored in a capacitor. A second piezoelectric crystal is compressed on the impact with the target to provide an electric signal to operate a switch which directs the stored charge to an electric detonator.

This invention pertains to high speed contact fuze for detonation of an explosive charge upon impact with the target. More particularly the present invention pertains to a super-quick fuze powered by electric energy derived from piezoelectric crystals.

The fuze provided by the present invention stores electrical energy during launching and releases this stored energy nearly instantaneously upon impact. Energy stored during the launching phase is derived from a first piezoelectric crystal which is compressed or crushed by the setback force developed during missile or projectile launching. A special mechanically actuated explosive detonator responsive to the setback force may be provided to augment or replace the setback force if the setback force is not of sufficient magnitude. A capacitor is used to store the piezoelectric crystal charge output. An electronic switch circuit is used to hold the stored charge in the capacitor until a signal is provided to activate the switch and to direct the stored charge into an electric current responsive detonator. The signal for activating the electronic switch circuit is derived from a second piezoelectric crystal which is adapted to sense the target impact and to develop a voltage at the instant of the impact.

An important advantage of the present invention is that the delay between the impact and the detonation is extremely short, so that the bomb explodes above the surface of the ground where it can do most effective damage. Another advantage of the fuze is that a very small force is required at the impact to set off the fuze. In prior fuzes the problem often was that the bombs would not detonate when they would land on soft, shock-absorbing material, such as snow or soft soil.

It is therefore an object of the present invention to provide a highly sensitive, quick-firing fuze.

Another object of the present invention is to provide a quick-firing electric fuze wherein the main detonating current is derived from a first piezoelectric crystal which is compressed in response to the launching of the projectile and wherein the triggering signal is derived from a second piezoelectric crystal which is compressed upon the impact of the projectile with the target.

These and further objects will become apparent to those skilled in the art upon examination of the following specification, claims, and drawing, of which:

FIGURE 1 is a schematic representation of the apparatus according to the present invention;

FIGURE 2 illustrates an alternate embodiment wherein the charge from the piezoelectric crystal responsive to the impact is transmitted to the input of the circuit through capacitive coupling; and

FIGURE 3 illustrates one possible arrangement for

2

explosively crushing the piezoelectric crystal which provides the primary source of electric energy.

The fuze according to the present invention consists of four major elements. These elements are a piezoelectric crystal 10, which is activated during launching setback; a piezoelectric crystal 20, which detects impact with the target; an electrostatic charge detector circuit, which includes a field-effect transistor 30; and a detonator firing circuit comprised of silicon control switch 40 and storage capacitor 45. Safing and arming switches 24, 25, and 26 are provided to prevent accidental detonation during the transportation and the handling of the munition prior to the intended use.

In FIGURE 1, one end of piezoelectric crystal 10 is connected to a first end of electric energy storage capacitor 45. The other end of crystal 10 is connected to a second end of capacitor 45 through an isolation diode 15. Diode 15 is oriented for forward current flow from crystal 10 to capacitor 45. The second end of capacitor 45 is further connected to the anode electrode of silicon controlled switch 40 through an arming switch 24. An electrical detonator 11 is provided with a first electrical terminal connected to the first end of capacitor 45 and a second electrical terminal connected to the cathode electrode of silicon controlled switch 40. A safing switch 25 is connected intermediate detonator 11 and the cathode electrode of silicon controlled switch 40, and a safing switch 26 is connected between said first and second electrical terminals of detonator 11, in parallel with the detonator. Switches 24, 25, and 26 are of the mechanical type. Prior to the use of the fuze, to prevent accidental detonation, switches 24 and 25 are maintained open and switch 26 is closed. Just before the launching of the munition, switches 24 and 25 are closed and switch 26 is opened to place the mechanism into condition for operation. The operation of switches 24, 25, and 26 may be accomplished manually.

The second piezoelectric crystal 20 has one end connected to gate electrode 31 of an insulated gate field-effect transistor 30. Field-effect transistor 30 has a source connected to the other side of crystal 20 and to the anode of silicon controlled rectifier 40, and further has a drain 32. A resistor 35 is connected at one end to drain 32 of field-effect transistor 30 and is connected at its other end to the side detonator 11 which is connected to the first end of capacitor 45.

While the apparatus in FIGURE 1 shows direct coupling between piezoelectric crystal 20 and the gate electrode of field effect transistor 30, a different kind of coupling may be found to be useful for certain applications. In FIGURE 2 a capacitive coupling arrangement is shown for the transmission of the electric signal from piezoelectric crystal 20, upon compression at impact, to the gate electrode of the field effect-transistor 30.

The electrostatic fuze in FIGURE 2 is shown mounted inside a munition shell 50. Munition body 50 is constructed of a conductive material and serves as an electrostatic shield to eliminate interference from external sources and the static charge built up on the munition body during the firing and subsequent flight. Piezoelectric crystal 20 is shown mounted at the forward end of the munition body. One side of the crystal is electrically connected to the conductive munition body 50, while the other side is connected to a transmitting electrode 21. A receiving electrode 22, electrically isolated from transmitting electrode 21, is mounted within the shell body at a certain amount of separation from the forward end of the shell. Receiving electrode 22 is shown in FIGURE 2 as serving a dual-function of an electrode and also of a shaped charge liner for an explosive charge 23. With the exception of this modification, the circuit of FIGURE 2 is similar to the circuit of FIGURE 1.

The fuze circuit has zero stored energy at all times prior to launching. At launch the fuze and arming circuit is actuated. Piezoelectric crystal 10 is compressed by the setback force or by other means responsive to the setback force, such as for example the apparatus of FIGURE 3. Crystal 10 produces an electric charge which is allowed to flow into capacitor 45 through diode 15. Diode 15 prevents the capacitor from discharging back into the crystal after the compression force is removed. Capacitor 45 holds its accumulated charge throughout the projectile flight until the insulated gate field-effect transistor 30 is triggered ON by an electrostatic charge created on impact by the compression force on crystal 20. Silicon control switch 40 and field-effect transistor 30 provide a very high electrical impedance across capacitor 45 prior to the time that they are triggered at impact.

At impact with a surface the piezoelectric crystal 20, mounted in the nose of the projectile, is deformed and drives an electrical charge into gate 31 of field-effect transistor 30. The field-effect transistor presents a very small capacitance load to the impact sensing crystal. As a result, the electrostatic voltage developed can be very high. The potential required to switch the field-effect transistor ON, however, is only 1.5 to 4.0 volts, depending on the type of transistor selected. When the field-effect transistor conducts, a voltage is developed across resistor 35. This voltage across resistor 35 triggers the silicon controlled switch 40 ON, which discharges capacitor 45 through electric detonator 11 and initiates the explosive output.

The operation of the apparatus of FIGURE 2 is in all respects the same as the operation of the apparatus of FIGURE 1, except that the voltage generated by crystal 20 upon impact is transmitted to the gate electrode 31 of field-effect transistor 30 through a capacitive arrangement. The charge from the crystal 20 is accumulated on transmitting electrode 21. The electric charge on electrode 21 induces a similar electric charge on receiving electrode 22. Electrode 22 is connected directly to the gate electrode of field-effect transistor 30 to commence the operation as explained with reference to FIGURE 1.

While in the munition of the type which is shot from guns, and whose maximum velocity and range depend on the muzzle velocity, the setback force generated during the launching is quite great and sufficient to compress crystal 10 to provide the necessary electric charge to capacitor 45, the setback force may not be large enough in a self-propelled rocket-type weapon. For example, setback forces in the neighborhood of 20,000 G's are present in the first type of munition, as compared to setback forces in the neighborhood of 200 G's for the second type. When the detonating circuit of the present invention is to be used in a rocket-type weapon, additional means may have to be provided to crush the first crystal in response to the setback force. FIGURE 3 illustrates such an arrangement.

At the top portion of FIGURE 3 is shown piezoelectric crystal 10 sandwiched between the wall of housing member 51 and a wave shaper 52. An explosive charge 53 is placed in the space just below wave shaper 52. The function of the explosive 53 is to provide the crushing force in response to the setback force shortly after the launching of the weapon. The function of wave shaper 52 is to uniformly distribute the compression force from explosive 53 along the surface of crystal 10.

A power supply detonator 54 is mounted within housing 51 just adjacent explosive charge 53. A stab-sensitive squib 58 is mounted on a movable member 59. Member 59 is adapted for translation of motion along the longitudinal axis of housing 51. A mechanical spring 57 is located between movable member 59 and a wall member of housing 51. The purpose of spring 57 is to bias movable member 59 away from the wall member of housing 51 and to normally maintain a separation between stab-sensitive squib 58 and a firing pin 56 located on the wall

of housing 51 and aligned with squib 58 parallel to the axis along which movable member 59 is free to move. In response to a setback force, movable member 59 compresses spring 57 and firing pin 56 pierces stab-sensitive squib 58. A pyrowire delay 55 connects the stab-sensitive squib 58 to power supply detonator 54. Pyrowire delay 55 has an appropriate delay time constant to delay the activation of power supply detonator until the projectile is a certain distance away from the firing weapon.

A main detonator 60 is carried by movable member 59 on the side opposite from the stab-sensitive squib 58. A centrifugal weight assembly 62 is located between the main detonator 60 and a main explosive charge 23. The electric components include the elements illustrated in FIGURES 1 or 2, are depicted in FIGURE 3 by reference numeral 65.

The operation of the apparatus in FIGURE 3 will now be described briefly. Upon launching of the projectile and during the time when the accelerating forces are being applied to it, a setback force is exerted on movable member 59, causing spring 57 to compress. Stab-sensitive squib 58, carried by movable member 59, is pushed into firing pin 56 and is thereby initiated. On initiation of squib 58, pyrowire 55 ignites and burns toward the power supply detonator 54. After a short delay, pyrowire 55 initiates power supply detonator 54, which in turn detonates explosive charge 53. Explosive charge 53 with the aid of wave shaper 52 creates a shock wave which progresses through piezoelectric crystal 10. The shock wave creates an electric charge in piezoelectric crystal 10 which charges capacitor 45 in the firing circuit. The fuze is thus placed into an armed status.

Centrifugal weight of assembly 62 is a safety device which maintains the main detonator 60 separate from the main explosive charge 23 until after the launching of the projectile. After launching, the projectile is subjected to an angular acceleration and eventually achieves a desired angular spin rate which, together with a given linear acceleration, releases the centrifugal weight. This permits the three component centrifugal weights to move radially outward. The action opens the passage between the detonator and the main explosive charge. A predetermined time after the initiation of the projectile, the linear acceleration ceases and the movable member 59 moves forward in response to spring 57. This arms the fuse by placing detonator 60 against the main explosive charge 23.

Many variations and embodiments are possible within the spirit of this invention. It is, therefore, understood that the particular embodiments shown here are for illustration purposes only, and that the present invention is limited only by the scope of the appended claims.

I claim:

1. Electrical signal producing means responsive to the impact of a projectile with its target, said signal producing means comprising:

a first piezoelectric crystal;

means connected to said first crystal to generate energy for crystal activation in response to the setback force produced in the launching of the projectile;

an electric energy storage means connected to said first piezoelectric crystal to receive and store the electric energy generated by said first crystal;

output means;

switching means having a first terminal connected to said electric energy storage means, a second terminal to said output means, and further having a control terminal;

a second piezoelectric crystal;

means connected to said second crystal for compressing said second crystal and generating an electric signal in response to the impact of the projectile with the target; and

means connecting said second crystal to said control electrode of said switching means, whereby said switching means is operated in response to the elec-

5

tric signal generated by said second crystal to direct the electric energy stored in said storage means to said output means.

2. Apparatus according to claim 1 wherein said output means is an electric detonator.

3. Apparatus according to claim 1 wherein said electric energy storage means is a capacitor.

4. Apparatus according to claim 1 wherein said switching means is a silicon controlled rectifier.

5. Apparatus according to claim 1, wherein said means connecting said second crystal to said control electrode of said switching means includes a transmitting electrode connected to said second crystal and a receiving electrode, spatially isolated from said transmitting electrode, connected to said control electrode.

6. A high speed contact fuze for detonation of an explosive charge in a projectile upon the impact of said projectile with the target, said fuze comprising:

a first piezoelectric crystal for providing a source of electric energy upon compression;

an electric energy storage means connected to said first piezoelectric crystal for receiving and storing the electric energy produced by said first crystal;

further means connected to said first piezoelectric crystal for applying compression force on said first crystal after the launching of said projectile, said further means being responsive to the setback force developed at the launching of the projectile;

a detonator responsive to electric current;

a semiconductor switching means having first and second main terminals and a control means for opening and closing the current path between said pair of terminals;

means connecting said detonator between said first terminals of said switching means and one end of said electric charge storage means and means connecting the other end of said storage means to said second terminal of said switching means;

a second piezoelectric crystal positioned at the forward end of said projectile for compression upon impact with the target and for providing an electric voltage output signal when compressed; and

6

means connecting said second piezoelectric crystal to said semiconductor switching means whereby the current path between said two main terminals of said switching means is closed and the electric energy stored in said electric storage means is directed through said detonator in response to the impact of said projectile with the target.

7. Apparatus according to claim 6, wherein said means connecting said second crystal to said control electrode of said switching means includes a transmitting electrode connected to said second crystal and a receiving electrode connected to said control electrode, said two electrodes being spatially isolated from each other.

8. Apparatus according to claim 6, wherein said further means connected to said first piezoelectric crystal for applying compression force on said first crystal includes: an explosive charge positioned adjacent said first crystal;

a power supply detonator connected to said explosive charge; and

means connected to said power supply detonator for operating said detonator and detonating said explosive charge in response to the setback force on said projectile.

References Cited

UNITED STATES PATENTS

2,505,042	4/1950	Gourdon	102—70.2
2,934,017	4/1960	Ellet	102—70.2
2,970,545	2/1961	Howe	102—70.2
2,991,716	7/1961	Israel et al.	102—70.2
3,101,054	8/1963	Stevenson et al.	102—70.2
3,200,749	8/1965	Downs	102—70.2
3,225,695	12/1965	Kapp et al.	102—70.2

FOREIGN PATENTS

909,549	10/1962	Great Britain.
944,961	12/1963	Great Britain.

40 BENJAMIN A. BORCHELT, *Primary Examiner*.
W. ROCH, T. H. WEBB, *Assistant Examiners*.