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Programmable Electronic Delay Device for Detonator

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ABSTRACT

Delay devices are used to perform various roles like aiding in sequential release of payload, providing safety in flight/ trajectory, enabling self-destruction of ammunitions, allowing blast of the warhead after penetration in runway/ bunker, etc. The delay time is introduced to cause a series of detonation events from the explosive charge, in order to achieve desired efficiency. Inspite of many improvements performed along the years, in search of precise delay compositions, it is noticed that the obtained accuracy in chemical delay compositions is of ±4 %.The present work using microcontroller gives possible accuracy of upto ±1 %.This paper discusses about programmable electronic delay device, timing accuracy of electronic delay device and its merits over chemical delay devices.

Keywords: Microcontroller, detonator, delay, pyrotechnic delay

1. INTRODUCTION

Initiating explosives are designed to safely activate larger explosive charges at a controlled time and in a pre-determined sequence. Initiating explosives can be broadly classified into electric and non-electric types. In electric systems, a device that can generate or store electrical energy transmits that energy to the initiating explosives via a circuit of insulated conductors. Blast sequences can be controlled by means of electric timing systems but delay timing is usually achieved through pyrotechnic delay elements incorporated inside detonators. Non-electric initiating systems use reactive chemicals to store and transmit energy by controlled burning, detonation, or shock waves. Many detonators primary explosive is a mixture called azide stphynate aluminum (ASA) compound. This composition is formed from lead azide, lead styphnate and aluminium and is pressed into place above the base charge, usually tri nitro toulene (TNT) or tetryl in military detonators and penta erythritol tetra nitrate (PETN) in commercial detonators[1]. Fundamentally, the delay detonators must present a pre-determined time delay between initiation and consequent detonation of the connected explosive charge. Presently, the most used delay detonators make use of pyrotechnic delay element with varied lengths, containing in its interior, mixture of solids capable of burning at a defined velocity for obtaining delay time. A pyrotechnic delay element is a self-contained pyrotechnic device consisting of an initiator, a delay column and an output charge, assembled into a specially designed inert housing. Delay time requirement varies from few milliseconds (ms) to several seconds. The application ranges from a simple hand-thrown grenade to an advanced canister launched tactical missile. The main limitation associated with pyrotechnic delay is the accuracy that lies between ± 4 % of mean value over a range of military operating temperatures[2].

An attempt was made to improve the accuracy of delay for enhancing the effectiveness of detonation. A good success has been achieved by developing microcontroller based electronic delay device with an accuracy of ±1%. Safety, time reproducibility, and ignition transfer are considered important parameters to be met. These programmable electronic delay devices output are crimped to detonator to improve the accuracy of timing in detonation. Detonators with electronic delay devices are therefore a key tool in establishing control of the blasting due to their precision delay and consequent ability to ensure sequential firing.

2. ELECTRONIC DELAY DEVICE

This device can be connected to input terminals of detonator and the initiation delay can be varied using its programmability feature for changing the delay time. Various methods are incorporated to design this device by many researchers using electronic circuits[3-5]. The microcontroller based programming unit is developed to change the device delay value. The block diagram of the electronic delay device is as shown in Fig.1. In this, the rectifier is used to make the inputs of electronic delay device, polarity independent. Capacitor is used to store the power for device to function without any live power source. Voltage regulator is used to regulate the micro controller input voltage. Microcontroller is the main control device with feature of programmability using RS232 interface. The connector on electronic delay device is designed such as to use for communication with programming unit and input terminals for detonator.

Microcontroller based programming unit is also designed to program the electronic delay device with desired delay. Both electronic delay device and programming unit have the connectors for serial communication with each other. The delay

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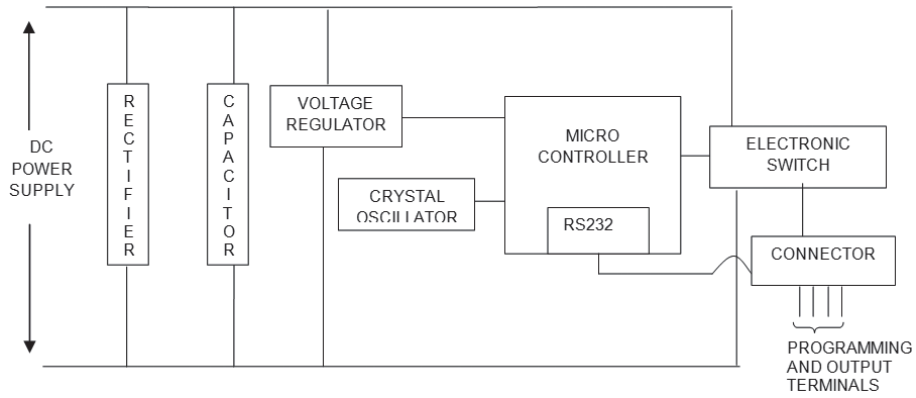

Figure 1. Block diagram of electronic delay device.

value in electronic delay device can be changed by connecting the electronic delay device and programming unit with the provided connectors and entering the desired value using user interface keys and display provided on the programming unit.

Once the delay device is programmed with desired delay using programming device, the delay device can be disconnected and can be used for required applications. The delay times which have been programmed to delay device is stored in non-volatile EEPROM of its microcontroller. The microcontroller on electronic delay device has the ability to check the connectivity of programming unit or a detonator.

When input DC power supply is applied to the delay device, capacitor starts charging and microcontroller starts its timer. After the programmed delay, microcontroller switches on the electronic switch and the charged capacitor discharges through the detonator connected at output terminals of the device. During the capacitor discharge, the detonator initiates. In present work, this delay device can be programmed for 1 to1000 ms delay. Technology has been applied to ensure safe operation. The testing proved that the performance and accuracy is not deviating under various environmental conditions.

3. TEST RESULTS

The timing accuracy of delay device is tested using oscilloscope, by recording the delayed output of electronic delay device from the start of applied DC power supply. For testing electronic delay devices accuracy with actual load, one detonator of known inherent delay and another detonator of same type with electronic delay device of certain delay are initiated simultaneously. Then difference in timing between initiation of two detonators are measured using high speed camera (1000 fps). Inherent delay time of the detonator is subtracted from the difference in timing (already measured) and compared with programmed value of the delay device.

To test the devices over entire range of delay (1 ms to 1000 ms), six devices are programmed with delays of 25 ms, 150 ms, 200 ms, 500 ms, 700 ms, 990 ms and tests were conducted in environmental conditions like high temperature (+55 °C), low temperature(-30 °C), damp heat etc. The measured values for the ambient firing are shown in Table 1. The device programmed with delay of 25 ms is giving the acceptable variation of 24.8 ms to 25.2 ms in different tests. The device programmed with delay of 990 ms is giving the acceptable variation of 985.2 ms to 994.5 ms in different tests. By observing these results at various environmental conditions, it is concluded that these devices are precise and reliable.

4. MERITS OF ELECTRONIC DELAY DEVICE

This device can be used for many applications in defence and industries with few of its advantages as shown below:

- The accuracy of these devices helps in critical timing operations in defence applications.
- For short-delay or long-delay applications, the device size will be the same, which is not possible with the chemical delay device. This is the main advantage during space constraint applications.
- Used for simultaneous operations in parallel[6].
- The device will function without any live power source.

Table 1. Comparison of programmed and measured delays of electronic delay device

Programmed delay (ms)	Measured delays (ms)							
	Test1	Test2	Test3	Test4	Test5	Test6	Test7	Test8
25	24.8	25.2	25.1	25.1	25.2	25.2	25.0	24.9
150	151.2	151.0	151.0	150.0	150.0	150.7	149.5	149.0
200	202.8	202.6	200.0	202.0	203.1	203.4	203.1	202.6
500	503.0	501.0	501.5	502.5	500.0	500.5	502.5	502.0
700	700.5	699.5	700.0	695.0	705.0	702.5	702.5	695.0
990	991.2	991.0	989.5	989.4	990.2	990.5	994.5	985.2

5. CONCLUSION

The lack of guaranteed precision common to all chemical delay devices encourages the development of electronic delay device. The object of this paper is a technological improvement in field of safety and precision concerning time delays for detonators. The increased level of accuracy using electronic delay device as compared to chemical delay detonators produces a large amount of theoretical blasting benefits and to use in critical timing operations in defence applications. The feature of delay device to function without any live power source, benefits many of the armament applications like grenades which have to function without any live power source after certain delay. The limitation of chemical delays in space constraint applications can be overcome by using electronic delay device. The susceptibility of device to various qualification tests benefit them to use in harsh environmental conditions.

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Mr V.S. Rasane is a Graduate through IETE, Delhi and has retired as Associate Director from HEMRL, Pune in December 2012. He was responsible for the development of complete rocket instrumentation at HEMRL, Pune, ACEM, Nasik, BDL, Hyderabad, and OF, Itarsi. He has more than 30 publications to his credit. He is a life member of High Energy Materials Society of India and Fellow member of IETE.