Delay circuit for multiple detonator

Vivek Kumar, Vinay Kumar, Vishal Rai
E&TC Department, Army Institute of Technology, Pune– 411015

Abstract- Blasting is usually the first step in any mining process. Detonators are compact devices that are designed to safely initiate and control the performance of larger explosive charges for blasting. Different kinds of detonators like chemical, mechanical, electrical are available but all of them have several drawbacks and there are various hazards associated with them like accidental initiation due to Electrostatic discharge or Radio frequency interference, improper firing of the circuit or problem in delay or logic of the circuit. Nowadays electronic detonators are being used that eliminate almost every drawback of the earlier inventions. Under the electronic detonator various concepts have been employed for better performance. Different kinds of EED’s (Electro Explosive Devices) are used in the detonators like hotwire bridge, thin film bridge, detonating cords, SCB etc. In this paper the electronic detonator is designed using SCB. SCB is indigenously made by ARDE. We have used SCB due to its excellent properties such as high safety, low ignition energy, fast ignition time, small size, low cost, immunity to EMI (Electro-magnetic interference), ESD (Electrostatic discharge) and RF (Radio Frequency) hazards. The designed detonator comprises of delay circuit, boost converter, firing circuit with SCB and ESD and RF protection circuitry for safety against unintended firing. Detonators will be secured with passwords to avoid unauthorized use.

Keywords: Semiconductor Bridge (SCB), Electro explosive Device, Energy, Firing Circuit

I. INTRODUCTION

The mining and explosives industry is rapidly adopting technology in all forms in order to improve performance. Blasting is usually the first step in any mining process [1]. Initiator is a term that is used in the explosive industry to describe any device that may be used to start a detonation in explosive. The devices that initiate high explosive are called detonators.

Different kinds of delay detonators are available [4]. At first chemical detonator came into picture which employed a train of chemicals for generating delay before blasting. The delay generated was unreliable, inaccurate and caused uncontrolled blasting and destruction. Moreover these detonators did not have any feature for avoiding unauthorized usage.

Next state of the art was the shock tube delay [3] detonator. But the assembly was too complex and costly so it was not used frequently.

The next type of detonator was the electric delay detonator. In this delay was generated using electric signal. This system is highly susceptible to stray currents, AC-DC voltages, electrostatic discharge hence not reliable. A typical non electronic detonator is as shown in figure no. 1.

![Figure no.1 typical detonator](image)

Technology that is being developed to improve blasting efficiency is the electronic detonator. Electronic detonators, of which there are several
different types and designs, all utilize stored electrical energy inside the detonator as a means of providing the timing delay and initiation energy.

Nowadays electronic detonators are being used that eliminate almost every drawback of the earlier inventions. Under the electronic detonator various concepts have been employed for better performance. Different components for delay generation were used, like RC component based delay generation, CR based delay generation has also evolved through many stages. Microcontroller based delay generation [1] is a flexible way to program the delay in laboratory. These programmed chips are then used on field. Initially 40 pin microcontrollers were used for the purpose of delay generation. The size and power limitations led to the use of smaller microcontrollers.

The connecting link between the firing of a warhead and an electronic fusing sensor is the electrical initiated explosive device. Different types of Electro [5] explosive devices (EED’s) are hot bridge wires, exploding bridge wire, thin metal film bridge, shock tube, Semiconductor Bridge. Hot-bridge wire initiator [3] has several disadvantages such as it requires high energy for its functioning, it has response on the order of tens of milliseconds, highly ESD sensitive. In this paper the electronic detonator is designed using SCB. SCB is indigenously made by ARDE. We have used SCB due to its excellent properties such as high safety, low ignition energy, fast ignition time and small size. In the proposed design the size is miniaturized and reliability and safety is increased. Figure no.2 shows the proposed changes in the electronic detonator design.

![Figure 2: Proposed changes in electronic detonator design](image)

**III. SYSTEM DEVELOPMENT**

The system consists of two parts

1) **Setter**

Figure no.3 shows the block diagram of the Setter. The setter consists of LCD, Microcontroller, battery and keypad to enter the password and required delay. The microcontroller sends commands to the delay or timer unit. The detonator ID, delay is fed from the setter which is then sent into the delay unit. Commands including firing and abort are also given through the setter. Two passwords have to be entered, first one is for entering the system and the second one is for firing. The setter is password protected and hence avoids unauthorized usage.

![Figure 3: Block diagram of the setter](image)

2) **Firing and delay circuit**

![Figure 4: Block diagram of firing and delay circuit](image)

Figure no.4 shows the block diagram of the firing and delay circuit. It consists of two parts.

A) ESD and RF protected SCB

B) Circuit consisting of firing circuit, delay unit and boost convertor for boosting voltage.

A) ESD and RF protected SCB
Semiconductor Bridge (SCB) can initiate unintentionally by Electro-Static Discharge (ESD). The ESD protection has the vital importance in design of the SCB devices. The SCB may fire unintentionally by human handling. The protection of explosive initiator is done by using TVS diode. 

RF protection has great importance in the EED systems, the RF protection should be immune to radio frequency radiation and also immune to stray signal associated with RF induced arcing. High-level electromagnetic energy produced by Radio frequency radiation can also induce electrical currents or voltages that may cause premature activation of Electro-Explosive Devices (EEDs) and electrical arcs that may ignite flammable materials. A capacitor is connected to the SCB for RF protection.

As shown in figure no.6 the bridge is formed out of the heavily doped poly silicon layer enclosed by the dashed lines. The overlying aluminum lands define the bridge length and provide a low ohmic contact to the poly silicon layer. Wires are bonded to the lands to permit current flow from land to land through the bridge. When current flows through the bridge, plasma is generated, it is in contact with the explosive material that initiates explosion. Security is provided to the energetic unit by designing the external firing circuit such that a current flows in the circuit and via the flexible substrate to activate the SCB only when desired.

B) Delay and firing circuit

Delay circuit as shown in figure no.7 decides the time when the explosive device should ignite. The timer unit of the detonator has 8 pin microcontroller. The microcontroller stores the delay subroutine to generate the desired delay entered by the user. The DC-DC boost converter is used to boost the input voltage of 3 volts to 30 volts. MOSFET is used as a switch, one MOSFET for PWM and the other for the SCB firing. When the DC voltage is applied then the capacitor starts charging. Input 3 volts will be boosted to 30 volts. When the fire command through the setter is given then the delay will be counted by the timer and after the delay is over the trigger will switch ON the MOSFET 2 and the capacitor will discharge through the SCB and detonator will detonate.
As in figure no.8 multiple detonators are used in mines for blasting. Initially all the capacitors are charged and delay is transferred to each detonator through the setter and after the specified delay each detonator will detonate.

IV. FLOWCHART OF THE SYSTEM

The Flowchart of the entire system is as shown below in figure no.9. User will enter the system password from the setter and then if it is correct detonator ID is entered, then the delay is entered and sent to the firing circuit where the eight pin microcontroller is in sleep mode and after getting delay it will wake up. After the delay elapse the MOSFET will turn on and capacitor will discharge through SCB and firing will take place. Figure no10 shows the flowchart for firing circuit. The PWM and the ADC are initialized. The MOSFETs will be off initially. If output voltage is 30 volts then a delay of 2secs is given as the capacitor takes 2 seconds to charge. After the delay of 4 seconds the MOSFET connected to the SCB will be switched on and firing will take place.

Figure no.9 Flowchart for the system

Figure no.10 Flowchart for the firing circuit

V. SIMULATION

The setter and the firing circuit are simulated in PROTEUS7.7. Before implementing setter on to actual hardware, software simulation has been done.
using widely accepted electronic simulation software PROTEUS 7.7.

**SIMULATION OF SETTER**

Figure 11 shows the image of simulation, it is apparent from image that inputs are entered by the user and delay and firing command are sent to the firing circuit through serial communication. User needs to first enter the password for the system which will avoid unauthorized usage. If correct password is entered by the user then detonator ID and the desired delay has to be entered.

![Figure 11 Simulation of setter in PROTEUS](image1)

Then the user is asked whether to give firing command or to abort. If user wants to abort then the main menu will be displayed again and the system password has to be entered again.

**SIMULATION OF FIRING CIRCUIT**

Figure 12 simulation of the firing circuit

This circuit is the vital part of the design which makes the circuit 3V operated. In this circuit a 3V battery voltage is boosted by the boost converter to 30V. Then trigger pulse is given to switch to discharge CDU. CDU discharges through SCB. In this design the leakage of capacitor should be ultra low. For low leakage current tantalum capacitor is used. With this fire pulse, SCB is ignited then explosive will detonate. This circuit is operated at 3V Li-ion battery which has 240mAh capacity. Typically a CR2032 coin cell is used. Capacitor discharge profile shown in figure 13. Relevant resistor values are used for proper biasing and amplification in simulation model. The discharge profile has significance that it will be directly applied to detonator for initiation.

![Figure 12 Simulation of the firing circuit](image2)

![Figure 13 Capacitor discharge profile](image3)

![Figure 14 PWM waveform](image4)

Relevant values for the capacitor, inductor and the duty cycle for PWM are taken for the boost converter circuit. The duty cycle for the PWM of the microcontroller used in the firing circuit is 92% to obtain the boosted voltage of 30volts. PWM is used
for switching the MOSFET of the boost converter circuit.

V. CONCLUSION

The increased level of accuracy using electronic delay detonator as compared to chemical delay detonators produces large amount of theoretical blasting benefits and to use in critical timing operations in mining applications. The designed circuit has achieved the specifications summarized in the following table (1). The following table specifies the derived specifications of the designed detonator circuit. The detonator is factory settable. Future work can be done for field settable detonators. In this paper one to one detonator is described. Multiple detonator systems are used in mining applications.

The transfer of data between the setter and the firing and delay unit is done by serial communication. RF transmission can also be used for the same. In mining applications multiple detonators are used.

<table>
<thead>
<tr>
<th>Firing voltage</th>
<th>30 Volts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Trigger</td>
<td>4 Seconds</td>
</tr>
<tr>
<td>Secondary Trigger</td>
<td>6 Seconds</td>
</tr>
<tr>
<td>Delay accuracy</td>
<td>+/- 10 m seconds</td>
</tr>
<tr>
<td>SCB ESD protection</td>
<td>Yes</td>
</tr>
<tr>
<td>SCB RF Protection</td>
<td>Yes</td>
</tr>
<tr>
<td>PCB Size</td>
<td>6mm*40mm</td>
</tr>
<tr>
<td>Battery</td>
<td>CR2032 3 volts Lithium Ion</td>
</tr>
</tbody>
</table>

Table No.(1)

ACKNOWLEDGEMENT

We are very thankful for the proper guidance provided by our project guide Mrs. Renuka Bhandari and helping us complete the project report. We would like to express gratitude to Dr. Virendra Kumar, our project guide at ARDE. Despite his busy office schedule he found time to guide us and also check the progress we had made. With keen interest he helped us accomplish our seminar report outcome.

REFERENCES


