PROGRAMMABLE ELECTRONIC DELAY DETONATOR

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Abstract-To detonate explosive, detonators are used. Generally detonators can be of two types: Electrical and Percussion. A Percussion detonator responds to some type of mechanical force to activate an explosive. An electrical detonator responds to predefined electrical signal to activate an explosive. But there are various hazards associated with the electrical detonators 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. So there was a need to develop a low energy, reliable and safe initiator in order to prevent catastrophes. Therefore the objective of this project is to design integrated chip for explosive initiation, firing circuit and delay and logic circuit. PIC12CE519 is used because of its features like reduced voltage, energy requirements and small size. Firing circuit is for safe initiation and Delay circuit is for triggering the detonator with accuracy and reliability.

Keywords—Electronic Detonator, PIC12CE519, Delay, Thyristor.

I. INTRODUCTION

A detonator is a device used to trigger an explosive device.

Types of Detonators:

- Chemically initiated
- Mechanically initiated
- Electrically initiated

The commercial explosives use electrical detonators or the capped fuse.

Old detonators used mercury fulminate mixed with potassium chlorate.

1.1 Historical Background

Black powder was first used to fragment rock in mining in early 1600s.Extremely dangerous as unreliable burning speed, resulting in many deaths. Hazardous ignition overcome in 1831 with invention of 'Miners Safety Fuse' by William Bickford.Rope with a strand of yarn infused with black powder.Accidents resulted from borehole ignition by safety fuse and black powder. Hazardous ignition overcomes in 1863

with development of 'practical detonator' by Alfred Nobel. Wooden plug of black powder inserted into larger charge of liquid nitroglycerine, enclosed in metal shell. Nobel experimented with design and eventually developed a mercury blasting cap in 1865[1].

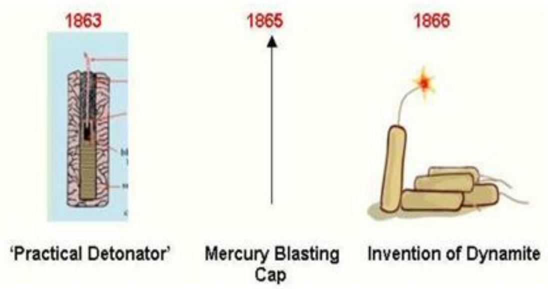

Fig. 1. Evolution of detonator

First Instantaneous Electric Detonator prototype emerged in late 1880s. In this prototype Safety Fuse was replaced by electric wires which were connected to a fuse head. The Initiation of this detonator was done by passing electric current through leg wires. The Delay Electronic Detonator was same as instantaneous electric detonator, except for inclusion of delay powder train. The delay time of these detonators was based on length and composition of delay powder. Delay of half a second was achieved in early 1900s and delay of millisecond was achieved in 1943[2].

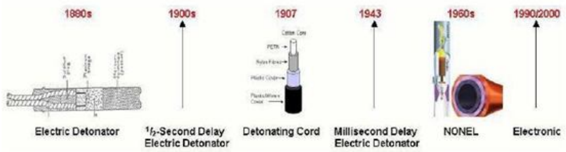

Fig. 2. Evolution of detonator

Around 1943, Development of EBW (Exploding Bridge Wire) detonator was done by Luis Alvarez as part of Manhattan project in the U.S.A. In 1965, Development of the slapper or EFI (Exploding Foil Initiator) detonator was done by John Stroud at the Lawrence Livermore National Laboratory, U.S.A. In 1979, development on atoxic, i.e. lead-free and

barium-free priming compositions for hand-fired ammunition was work carried out by Werner Siegelin and Wolfgang Spranger.In this case, very high lead values were in some cases detected in the blood which could be reduced only slightly by an improved the suction filter system and complete jacketing of the bullet. The main source of lead emission was the trizinate used in conventional SINOXID percussion[3].

In 1987, U.S. Patent 4,708,060 for the Semiconductor Bridge (SCB) Initiator was issued to R.W Bickes, Jr. and A.C. Schwarz.When initiated by a very low-current impulse, the polysilicon-defined bridge bursts into plasma discharge rapidly transporting a high flow of energy into the surrounding explosive/pyrotechnical mixture. The special characteristic of this polysilicon-on-silicon layered igniter is a relatively short response time of a few tens of microseconds. SCB igniters offer a high insensitivity to electrostatic discharge and transient currents. In 1993, Official approval was given to the electronic DYNATRONIC detonator system of Dynamite Nobel AG, Cologne (Troisdorf). The basis of this technology consisted of the development work carried out on the military detonator electronics for the antitank mine 2 (TA2)[4].

II. BLOCK DIAGRAM:

It is an embedded system, to overcome problems faced by traditional detonator. Some of the problems are accuracy, low throughput and lower efficiency. To make the system fully automatic, we are using following hardware:

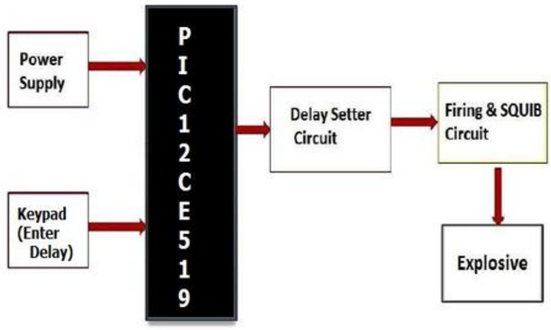

Fig. 3.Block Diagram of Proposed Circuit

INPUT SIGNALS:
1. Delay from Keypad

OUTPUT SIGNALS:
1. Delay Setter

2. Firing and Squib

- **DELAY FROM KEYPAD:** Variable delay can be entered from four different switches with the corresponding delays from 4 to 7 sec.

- **DELAY CIRCUIT:** A Delay Circuit is used to trigger the detonator with accuracy and reliability.

- **SQUIB AND FIRING CIRCUIT:** Used to send the current to detonate the circuit.

III. LITERATURE SURVEY:

A detonator circuit is used to initialize the mining blast sequence or missile blast. The detonator circuit may be electrical, chemical or electronic. With the advancement of electronic circuitry programmable electronic delay detonators came in picture in order to provide field programmability and flexible operation[1].

Multinational companies are big players in this as our final year project, in which we tried to minimize the cost of the product appreciably without compromising over the accuracy of the device. We also insure that one circuitry can be used for both the applications of mining blast and missile blast.

It is an object of the present invention to provide a compact, low cost and highly reliable programmable electronic delay detonator which consumes a low amount of power and is suitable for disposable use[2].

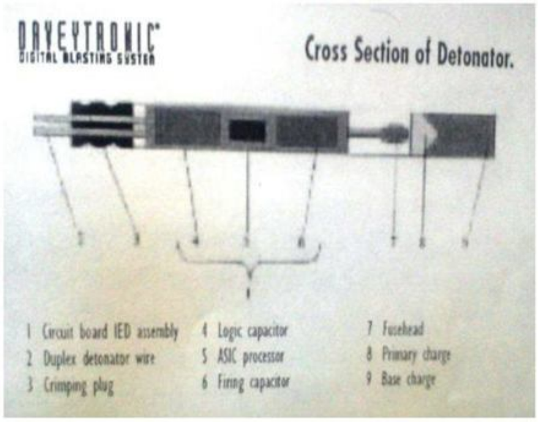

Fig. 4. Cross-Section of Detonator

It is another object of the present invention to provide programmable electronic delay detonator which provides invention to provide programmable electronic delay detonator which prevents malfunction due to a stray current. It is a further object of the present invention to provide a programmable electronic delay detonator of configuration in which proper electrical connection and the number of connections of plural detonators can be readily checked by electrical means and can be used in blasting work using a large number of detonators[3].

In order to achieve the above objects, and in accordance with the present invention, there is provided an electronic delay detonator having an electronic delay timer switch comprising a power supply circuit, an electrical energy storing capacitor (power supply capacitor) for microcontroller is used for setting the time delay at run time and has an o/p of the power i/p circuit applied there to firing n/w. A separate keypad panel is included in the circuit to provide password, time delay and process start key[4].

Timing is being fixed at runtime and the firing circuit starts the detonation after the delay. We have used two variety of firing circuit, one which having a simple AND gate and a current amplifier. The second consists of a SCR and an amplifier. Current signals are used only in order to avoid any attenuation. The delay can be fixed from 32ms to 9999ms[5].

IV. FEATURES:

- A microcontroller based unit for programming electronic time fuses.
- Handy and safe to operate in the field.
- Operation on 5V rechargeable battery or using 240V, 60Hz AC supply.
- Electronic safety.
- Same circuitry can be used for mining blasts.
- No polarity consideration is required.
- Timing accuracy of |1.5%|

V. COMPARISON TABLE:

CHARACTERISITCS	OLD SYSTEM	NEW SYSTEM
1.Current Consumption	1Amp at steady state.	2Amp at steady state.
2.System board	8085 microprocessor + Timer based.	PIC12CE519 Microcontroller based.
3. Size	Bulky.	Compact and more suitable for field uses.
4. Cost	More expensive.	Less expensive and more reliable.
5. Battery	Expensive lithium battery.	Normally used ni-cd battery pack.
6. Complexity	More complex, more wire required for interface.	Less complex, only 5 wires required for interface.

Fig. 5.Comparion Table

VI. CIRCUIT DESCRIPTION:

An electronic delay detonator actuated after the lapse of a predetermined delay time from the application of an input power source, comprises a capacitor for storing the electrical energy supplied from the input power source, a diode bridge from preventing the stored electrical energy from being released reversely towards the input source.

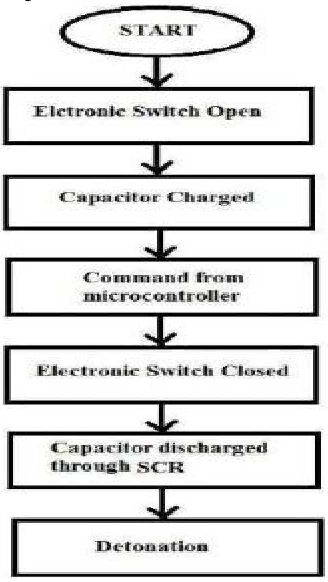

Fig. 6. Flowchart of Working

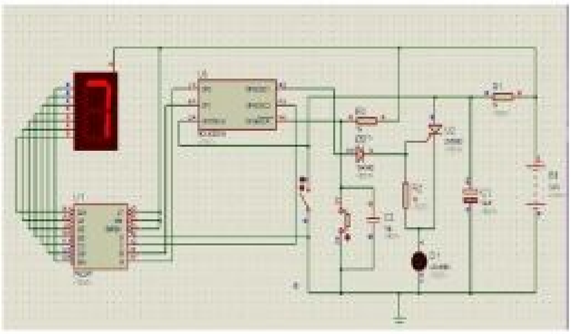

Fig. 7. Circuit Simulation

VII. CIRCUIT OPERATION:

1) SQUIB Firing Circuit

- This is a Simple Squib Firing Circuit Diagram. Capacitor C1 is charged to +3.2V through R1 and stores energy for firing the squib. A positive pulse of 1 mA applied to the gate of SCR1 will cause it to conduct, discharging C1 into the squib load X1.

- With the load in the cathode circuit, the cathode rises immediately to +3.2 V as soon as the SCR is triggered on. DiodeD1 decouples the gate from the gate trigger source, allowing the gate to rise in potential along with the cathode so that the negative gate-to-cathode voltage rating is not exceeded.

- This circuit will reset itself after test firing, since the available current through R1 is less than the holding current of the SCR. After C1 has been discharged, the SCR automatically turns off allowing C1 to recharge.

2) Delay and Logic Circuit

- A Delay Circuit is used to trigger the detonator with accuracy and reliability.
- For this purpose 8 pin microcontroller is used which greatly enhances the precision of the time delay.
- Each detonator can be programmed with unique identification number and delay time. The time base in each detonator can be compensated so that error in the time base is obviated so as to achieve correct delay.
- Delay time of maximum 7 sec should be provided.

VIII. HARDWARE DESCRIPTION:

a) PIC12CE519: High-Performance RISC CPU:

- Only 33 single word instructions to learn
- All instructions are single cycle (1 ms) except for program branches which are two-cycle

- Operating speed: DC - 4 MHz clock input DC - 1 ms instruction cycle

- 12-bit wide instructions

- 8-bit wide data path

- Seven special function hardware registers

- Two-level deep hardware stack

- Direct, indirect and relative addressing modes for data and instructions

- Internal 4 MHz RC oscillator with programmable calibration
- In-circuit serial programming

Peripheral Features:

- 8-bit real time clock/counter (TMR0) with 8-bit programmable prescaler
- Power-On Reset (POR)
- Device Reset Timer (DRT)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code-protection
- 1,000,000 erase/write cycle EEPROM data memory
- EEPROM data retention > 40 years
- Power saving SLEEP mode
- Wake-up from SLEEP on pin change
- Internal weak pull-ups on I/O pins
- Internal pull-up on MCLR pin
- Selectable oscillator options:

  - INTRC: Internal 4 MHz RC oscillator

  - EXTRC: External low-cost RC oscillator

  - XT: Standard crystal/resonator

  - LP: Power saving, low frequency crystal

CMOS Technology:

- Low power, high speed CMOS EPROM/ROM technology
- Fully static design
- Wide operating voltage range
- Wide temperature range:

  -
  - Commercial: 0°C to +70°C

  - Industrial: -40°C to +85°C

  - Extended: -40°C to +125°C

- Low power consumption

  - < 2 mA @ 5V, 4 MHz

  - 15 mA typical @ 3V, 32 KHz

  - < 1 mA typical standby current

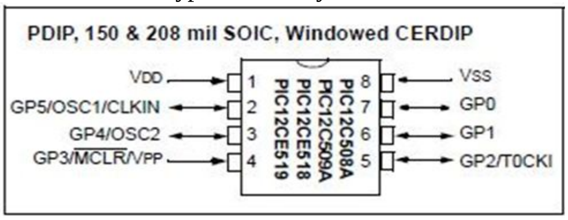

Fig. 8. Pin Description

The PIC12C5XX from Microchip Technology is a family of low-cost, high performance, 8-bit, fully static, EEPROM/EPROM/ROM-based CMOS microcontrollers.

It employs RISC architecture with only 33 single word/single cycle instructions. All instructions are single cycle (1 ms) except for program branches which take two cycles. The PIC12C5XX delivers performance an order of magnitude higher than its competitors in the same price category. The 12-bit wide instructions are highly symmetrical resulting in 2:1 code

compression over other 8-bit microcontrollers in its class. The easy to use and easy to remember instruction set reduces development time significantly.

		PIC12CE519
Clock	Maximum Frequency of Operation (MHz)	4
Memory	EPROM Program Memory	1024 x 12
	RAM Data Memory (bytes)	41
Peripherals	EEPROM Data Memory (bytes)	16
	Timer Module(s)	TMR0
	A/D Converter (8-bit) Channels	—
Features	Wake-up from SLEEP on pin change	Yes
	Interrupt Sources	
	I/O Pins	5
	Input Pins	1
	Internal Pull-ups	Yes
	In-Circuit Serial Programming	Yes
	Number of Instructions	33
	Packages	8-pin DIP, JW, SOIC

Fig. 9. Features of PIC 12CE519

b) SCR - BT169

- Passivity, sensitive gate thyristors in a SOT54 plastic package

- Designed to be interfaced directly to microcontrollers, logic integrated circuits and other low power gate trigger circuits.

- General purpose switching and phase control applications

THYRISTOR BASICS

In many ways the **Silicon Controlled Rectifier**, or the

Thyristor as it is more commonly known, is similar to the transistor. It is a multi-layer semiconductor device, hence the "silicon" part of its name. It requires a gate signal to turn it "ON", the "controlled" part of the name and once "ON" it behaves like a rectifying diode, the "rectifier" part of the name. In

fact the circuit symbol for the thyristor suggests that this device acts like a controlled rectifying diode[1].

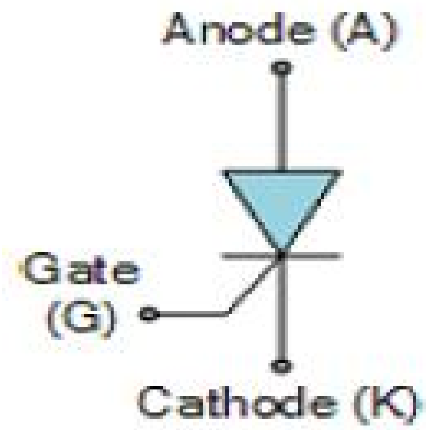

Fig. 10. Thyristor Symbol

Unlike the diode which is a two layer (P-N) semiconductor device, or the transistor which is a three layer (P-N-P, or N-P-N) device, the **Thyristor** is a four layer (P-N-P-N) semiconductor device that contains three PN junctions in series, and is represented by the symbol as shown[2].

Like the diode, the Thyristor is a unidirectional device, that is it will only conduct current in one direction only, but unlike a diode, the thyristor can be made to operate as either an open-circuit switch or as a rectifying diode depending upon how the thyristors gate is triggered. In other words, thyristors can operate only in the switching mode and cannot be used for amplification[3].

The silicon controlled rectifier **SCR**, is one of several power semiconductor devices along with Triacs (Triode AC), Diacs (Diode AC) and UJT's (Unijunction Transistor) that are all capable of acting like very fast solid state AC switches for controlling large AC voltages and currents, and for the Electronics student are very handy devices for controlling AC motors, lamps and phase control[4].

The thyristor is a three-terminal device labeled:

"Anode", "Cathode" and "Gate" and consisting of three PN junctions which can be switched "ON" and "OFF" at an extremely fast rate, or it can be switched "ON" for variable lengths of time during half cycles to deliver a selected amount of power to a load. The operation of the thyristor can be best explained by assuming it to be made up of two transistors connected back-to-back as a pair of complementary regenerative switches as shown[5].

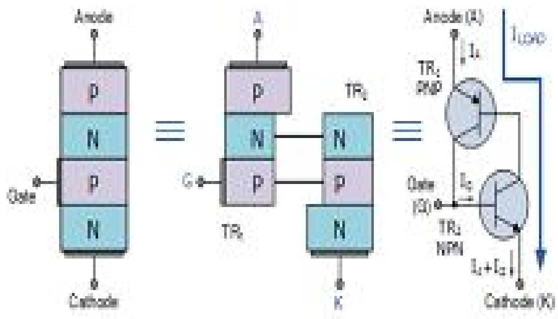

Fig. 11. Two Transistor Analogy

The two transistor equivalent circuit shows that the collector current of the NPN transistor TR2 feeds directly into the base of the PNP transistor TR1, while the collector current of TR1 feeds into the base of TR2. These two inter-connected transistors rely upon each other for conduction as each transistor gets its base-emitter current from the other's collector-emitter current. So until one of the transistors is given some base current nothing can happen even if an Anode-to- Cathode voltage is present[6].

When the thyristors Anode terminal is negative with respect to the Cathode, the centre N-P junction is forward biased, but the two outer P-N junctions are reversed biased and it behaves very much like an ordinary diode. Therefore a thyristor blocks the flow of reverse current until at some high voltage level the breakdown voltage point of the two outer junctions is exceeded and the thyristor conducts without the application of a Gate signal[7].

This is an important negative characteristic of the thyristor, as **Thyristors** can be unintentionally triggered into conduction by a reverse over-voltage as well as high temperature or a rapidly rising dv/dt voltage such as a spike[8].

If the Anode terminal is made positive with respect to the Cathode, the two outer P-N junctions are now forward biased but the centre N-P junction is reverse biased. Therefore forward current is also blocked. If a positive current is injected into the base of the NPN transistor TR2, the resulting collector current flows in the base of transistor TR1. This in turn causes a collector current to flow in the PNP transistor, TR1 which increases the base current of TR2 and so on[9].

Fig. 12. Typical Thyristor

Very rapidly the two transistors force each other to conduct to saturation as they are connected in a regenerative feedback loop that cannot stop. Once triggered into conduction, the current flowing through the device between the Anode and the Cathode is limited only by the resistance of the external circuit as the forward resistance of the device when conducting can be very low at less than 1Ω so the voltage drop across it and power loss is also low[10].

Then we can see that a thyristor blocks current in both directions of an AC supply in its “OFF” state and can be turned “ON” and made to act like a normal rectifying diode by the application of a positive current to the base of transistor, TR2 which for a silicon controlled rectifier is called the “Gate” terminal[11].

The operating voltage-current **I-V** characteristics curves for the operation of a **Silicon Controlled Rectifier** are given as:

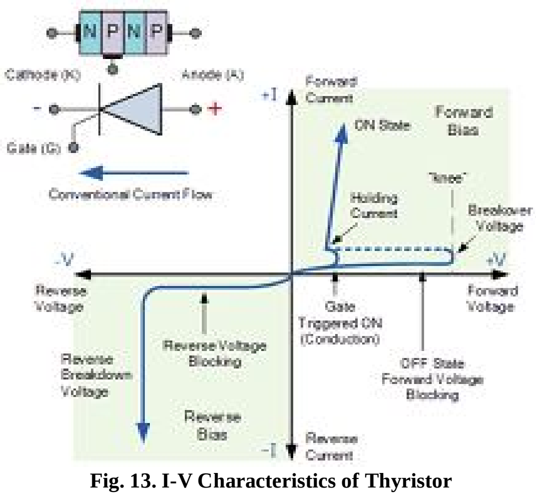

Fig. 13. I-V Characteristics of Thyristor

Once the thyristor has been turned “ON” and is conducting in the forward direction (anode positive), the gate signal loses control due to the regenerative latching action of the two internal transistors. The application of any gate signals or pulses after regeneration is initiated will have no effect at all because the thyristor is already conducting and fully-ON[12].

Unlike the transistor, the SCR cannot be biased to stay within some active region a long a load line between its blocking and saturation states. The magnitude and duration of the gate “turn-on” pulse has little effect on the operation of the device since conduction is controlled internally. Then applying a momentary gate pulse to the device is enough to cause it to conduct and will remain permanently “ON” even if the gate signal is completely removed[13].

Therefore the thyristor can also be thought of as a Bi-stable Latch having two stable states “OFF” or “ON”. This is because with no gate signal applied, a silicon controlled rectifier blocks current in both directions of an AC waveform, and once it is triggered into conduction, the regenerative latching action means that it cannot be turned “OFF” again just by using its Gate[14].

So how do we turn “OFF” the thyristor?. Once the thyristor has self-latched into its “ON” state, it can only be turned “OFF” again by removing the supply voltage and therefore the Anode (IA) current completely or by reducing its Anode to Cathode current by some external means (the opening of a switch) to below a value commonly called the “minimum holding current”, IH[15].

The Anode current must therefore be reduced below this minimum holding level long enough for the thyristors internally latched PN-junctions to recover their blocking state before a forward voltage is again applied to the device without it automatically conducting[16].

Since the thyristor has the ability to turn “OFF” whenever the Anode current is reduced below this minimum holding value, it follows then that when used on a sinusoidal AC supply the SCR will automatically turn itself “OFF” at some value near to the cross over point of each half cycle, and as we now know, will remain “OFF” until the application of the next Gate trigger pulse[17].

Since an AC sinusoidal voltage continually reverses in polarity from positive to negative on every half-cycle, this allows the thyristor to turn “OFF” at the 180o zero point of the positive waveform. This effect is known as “natural commutation” and is a very important characteristic of the silicon controlled rectifier[18].

Thyristors used in circuits fed from DC supplies, this natural commutation condition cannot occur as the

DC supply voltage is continuous so some other way to turn "OFF" the thyristor must be provided at the appropriate time because once triggered it will remain conducting[18].
However in AC sinusoidal circuit's natural commutation occurs every half cycle. Then during the positive half cycle of an AC sinusoidal waveform, the thyristor is forward biased (anode positive) and a can be triggered "ON" using a Gate signal or pulse. During the negative half cycle, the Anode becomes negative while the Cathode is positive. The thyristor is reverse biased by this voltage and cannot conduct even if a Gate signal is present[19].

So by applying a Gate signal at the appropriate time during the positive half of an AC waveform, the thyristor can be triggered into conduction until the end of the positive half cycle. Thus phase control (as it is called) can be used to trigger the thyristor at any point along the positive half of the AC waveform and one of the many uses of a **Silicon Controlled Rectifier** is in the power control of AC systems as shown.

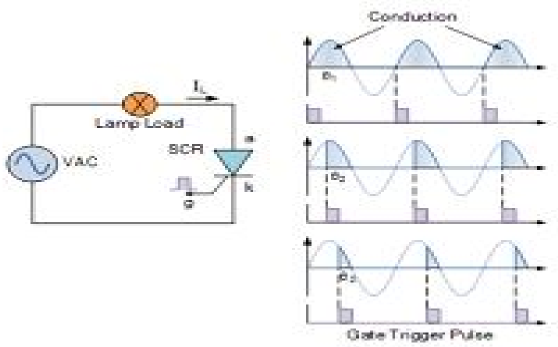

Fig. 14. Thyristor Phase Control

At the start of each positive half-cycle the SCR is "OFF". On the application of the gate pulse triggers the SCR into conduction and remains fully latched "ON" for the duration of the positive cycle. If the thyristor is triggered at the beginning of the half-cycle (θ = 0o), the load (a lamp) will be "ON" for the full positive cycle of the AC waveform (half-wave rectified AC) at a high average voltage of **0.318 x Vp**[20].

As the application of the trigger pulse increases along the half-cycle (θ = 0o to 90o), the lamp is illuminated for less time and the average voltage delivered to the lamp will also be proportionally less reducing its brightness.Then we can use a silicon controlled rectifier as an AC light dimmer as well as in a variety of other AC power applications such as: AC motor-speed control, temperature control systems and power regulator circuits, etc[21].

Thus far we have seen that a thyristor is essentially a half-wave device that conducts in only the positive half of the cycle when the Anode is positive and blocks current flow like a diode when the Anode is negative, irrespective of the Gate signal[22].
But there are more semiconductor devices available which come under the banner of "Thyristor" that can conduct in both directions, full-wave devices, or can be turned "OFF" by the Gate signal. Such devices include "Gate Turn-OFF Thyristors" (GTO), "Static Induction Thyristors" (SITH), "MOS Controlled Thyristors" (MCT), "Silicon Controlled Switch" (SCS), "Triode Thyristors" (TRIAC) and "Light Activated Thyristors" (LASCR) to name a few, with all these devices available in a variety of voltage and current ratings making them attractive for use in applications at very high power levels[23].

IX. MISCELLANEOUS

Specifications:

- The programmer unit should be capable of programming.
- The programmer unit is expected to provide satisfactory performance over the temperature range of 20 to 60˚C.
- The programmer unit is of simplest in construction and can operate with 5V Ni-Cd rechargeable battery.
- No polarity consideration is required by taking war time situation in consideration.
- The unit is mounted in a plastic case with or without battery having the weight typically low as compare to other detonators.

Operating Instructions:

- Switch on power supply.
- Use SPST switch's to set Delay (4sec to 7sec).
- Remove the pin to initiate detonation process.

X. FUTURE PROSPECTS

Technologies are being updated every minute. Today is the age of miniaturization and simplicity. A more compact and reliable material will find its way up in the new age markets[1].
Our project basically works on this main aim. The

Programmable Electronic Delay Detonator uses an advanced version 8051 microcontroller as compared to 8031 microcontroller that has been used until now. This project fulfils the most urgent need of present day state of the art i.e. compaction, reliability and speed[2].

AREAS WHERE RESEARCH IS REQUIRED:
Though most of the goals of our project have been achieved such as compactness, reliability, simplicity but there is always room for improvement. These areas include:

A. Sub munition Warheads:

In the case of sub munition warheads we require many fuses. It is then very difficult to properly route the wires to the particular detonator. The above problem can be eliminated by use serial communication[1].

Here one wire can carry the reference and the other line data. These two wires can be used for programming as well as command with the multiplexing technique[2].

Fortunately this process is already in its final stages at the ARDE. The completion of this method will greatly reduce the multiple fuse connection problems[3].

Programming of many fuses simultaneously can also be achieved by the use of 'FM-FM Telemetry' system. This system is also under research at the ARDE[4].

B. Skilled Manpower:

To interface the detonator and the programmer, it is necessary that a skilled person be involved. This puts a constraint over the availability of skilled manpower. In other words the fuse interface with the programmer can only be done by trained person.

C. Time Consumption:

The above process of the interface is time consuming. One can design an electronic system which will automatically interface the two, once a programmer is ready. This will save both manpower and valuable time.

D. Wear and Tear

As the connector is a mechanical socket thus its wear and tear may take place with time. Often dust particle may enter the connector which can be hazardous for data communication[1].

A loose connection of the connector can result in corruption or loss of data. We hope our project will only be the beginning of a new era of compact and reliable 'Programmable Timer System' which will revolutionize the missile technology and upgrade it manifolds[2].

We also hope that future research will not only help in help in increasing the missile target accuracy but also directly strengthen the defence of our country[3].

CONCLUSION

SCB's have following unique features, which make them superior element for incorporation in new "high tech" electro, initiated explosive devices[1].

When a fast rising current pulse is applied on the semiconductor bridge SCB generate hot plasma for ignition of the explosive powder pressed against the bridge[2].

Ignition is via micro- convective heat transfer process and not merely a thermal conductive heat transfer as with hot wires. Ignition energy for SCB's is one tenth to that of conventional bridge wires& metal foils[3].

SCB function (i.e. produce a usable explosive output) a thousand times faster than bridge wires. By changing the area of bridge one can greatly vary the no fire level of the device without greatly affecting the all fire energy[4].

SCB devices are explosively safe. They have high no fire current. SCBs are highly resistant to ESD pulse. Current pulse required to function SCB is a unique signal preventing their accidental operation[5].

Due to the above unique features SCB's have great benefit for several application of ignition in pyrotechnic, propellants and explosive devices. Thus among many other initiators we are using Semiconductor Bridge initiator[6].

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