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Split Time Study with Arduino Base Device for the Measurement of Detonation Times in Blasting Caps

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Abstract: Inaugurators are essential factors in blasting systems, as snares can not be touched off without them. A notable progress in inauguration technology is the creation of electronic detonators, a process that gauged two decades. Although these systems are more precious, they give advanced safety and security. Electronic inauguration systems challenge traditional ways, as electronic detonators deliver lesser delicacy than their pyrotechnic counterparts. This technology effectively resolves challenges associated with-inter-hole and row- to- row firing configurations. The perfection of detention timings between holes and rows has been significantly enhanced by electronic inauguration systems. likewise, the perpetration of Electronic Delay Detonators offers colorful benefits, similar as better gemstone fragmentation, dropped ground climate, and reduced air over pressure and back break. Wireless inauguration systems mark a significant advancement in the mining, construction, and underground tunneling sectors. These systems comprise both software and tackle rudiments for inauguration control, exercising translated wireless communication within the control unit. The remote wireless inauguration system has been designed with slice- edge network security technology

Crucial Terms: Electronic detonator; Pyrotechnic detonator; Precision firing; Timing perfection; Wireless inauguration system.

I. INTRODUCTION

Detonators serve as essential rudiments in military and defense operations, easing the inauguration of controlled explosions for a variety of strategic purposes. These bias are integral to munitions, obliteration conditioning, and the disposal of explosive artillery.

Within the defense sector, detonators guarantee the accurate and reliable activation of snares in landmines, dumdums, losers, andanti-tank artillery. They're also critical for violating operations, controlled devastations, andcounter-explosive strategies. Contemporary defense forces use colorful types of detonators, similar as electric,non-electric, time- detention, and remote-controlled variants, to ameliorate functional effectiveness and safety.

Their responsibility and perfection render them essential in ultramodern warfare and defense tactics. The defense and mining diligence form the foundation for a nation's development. Mineral coffers can be uprooted through two primary styles underground mining and face mining. In both cases, the birth process involves loosening the material. face mining is the most extensively habituated system for ore excavation encyclopedically.

The crucial operations in ore birth include drilling and firing. Drilling involves creating a hole in a hard face, while blasting entails loosening and fragmenting solid material using snares. Blasting represents the most energy-effective phase in the security system, and in mining, the primary ideal is to maximize mineral birth while considering environmental, profitable, and parcel constraints. Conventional firing operations generally involve drilling holes, placing charges and detonators in each hole, and latterly crumping them. A detonator is defined as a device that initiates an explosive response in a controlled manner, supplying the necessary energy to spark either a primary or secondary explosive, which results in a larger explosion.

II. WHAT IS DETONATOR & TYPES OF DETONATORS

A. What is Detonator

A detonator is a specialized device designed to initiate an explosive charge. Its design ensures reliability, precision, and safety in military, mining, and industrial applications.

1) *Electric Detonators* – Actuated by an electrical current.
2) *Non-Electric(Shock Tube) Detonators* – use a shock surge to spark the explosion.
3) *Time- Delay Detonators* – Engineered to explode after a destined duration. An inauguration system is pivotal for furnishing the original energy needed to spark an explosive used in gemstone firing.

This system includes a network that distributes energy to each blast hole and an in- hole element designed to spark a detonator-sensitive net. In the snares sector, the term" generator" encompasses any device able of starting a eruption or deflagration.

When opting factors for inauguration systems, it's vital to consider colorful factors to insure the safety and effectiveness of the firing operation.

B. Basic Components of a Detonator

Casing – A metal or plastic shell that houses internal components, protecting them from external damage.

Primary Explosive – A highly sensitive explosive (e.g., lead azide, mercury fulminate) that ignites upon initiation.

Secondary Explosive – A less sensitive but more powerful explosive (e.g., PETN, RDX) that amplifies the explosion.

Pyrotechnic Delay Compositions (Chemical Delay)-The materials burn at a controlled rate to provide precise delay times before detonation

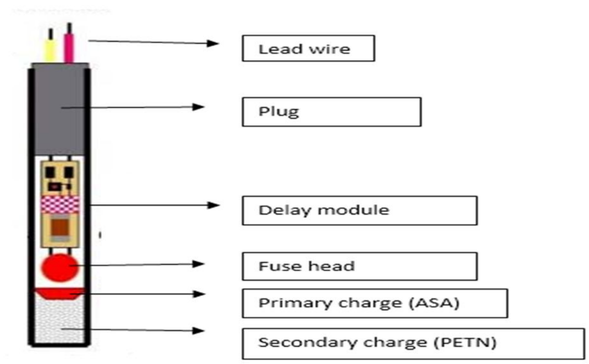

Figure: 1 Sample view of Detonator Blasting cap

III. SPLIT TIME STUDY WITH ARDUINO BASE DEVICE

In contrast to expensive commercial devices like high-speed cameras, VoD meters, or oscilloscopes, the emergence of free hardware and software platforms provides developers with numerous opportunities to create open-source electronic projects at a reasonable cost. Among these platforms, Arduino is particularly notable for its widespread use, making it the preferred choice for constructing the low-cost device discussed in this study. The Arduino platform facilitates the design of electronic circuits that integrate a micro-controller, featuring various digital and analog inputs/outputs capable of interfacing with different sensors.The open-source nature of both the software and hardware empowers developers to craft projects that are fully customized to their specific requirements across a vast array of applications. For instance, Arduino-based applications have been developed in diverse fields such as home automation, agriculture, and energy, among others.

In the mining industry, there exists a variety of applications centered on wearable systems, field monitoring systems, and autonomous systems. Although there is currently no documented use of Arduino in the domain of explosives and blasting, this study highlights the platform's remarkable versatility, thereby expanding its potential applications. Beyond its affordability, another significant advantage of this equipment is its portability and ease of use, enabling straightforward measurements in production blasting environments, whether involving surface connectors or in-hole detonators. Furthermore, it does not cause interference with operations.

A. Operating Principles

The methodology for documenting the moment of detonation for each detonator relies on the disruption of circuit conductivity caused by the impact of an explosion. When the cable is severed, the digital input transitions from a voltage of 5 V (high) to 0 V (low). The precise moment of this occurrence is captured by the micro-controller utilizing its internal clock.

B. Equipment

The eruption time dimension outfit consists of an Arduino mega board with an The micro-controller has a 256 kB flash memory where the program containing the operating instructions is stored.The board has 54 digital input/ affair(I/ O) outstations, of which a aggregate of six outstations are used for the connection of the dimension circuits.

Another six I/ O outstations are used to control the liquid demitasse display(TV) that shows system information. Communication with the micro SD card for data recording occupies another four I/ O outstations.The rest of the digital legs are left free, so the unit could fluently be expanded with a larger number of circuits to measure eruption times. To elect the unit peripherals and check their operation, an original prototype has been erected through connecting the micro-controller to the rest of the factors using a breadboard. This breadboard allows to fluently change the wiring and connections, cloverleaf factors and test the software until the asked functionality is achieved. Once the peripherals, their connections and the programming of the microprocessor had been validated, a PCB board was designed and manufactured so that all the factors could be soldered on it in a solid and resistant way, carrying a suitable unit to use in field conditions

C. Detonation Triggering & Measurement

After determining the necessary corrections to the times recorded by the device, its functionality was assessed through a test that involved measuring the cutting times of four signal cables using a four-channel digital oscilloscope and scissors, as illustrated in Figure 2. This test aimed to confirm the proper operation of the hardware, the programmed code, and the communication protocol between the oscilloscope and Arduino, which will be utilized in the field tests with actual detonators. The wires of the measuring circuits were arranged 1 mm to 10 mm apart using a plastic holder. By adjusting the distance between the wires and the cutting speed, various break times can be achieved. The measured time intervals range from 2 ms to 1 s, encompassing the typical detonation times observed in open-pit mining, underground mining, and other applications.

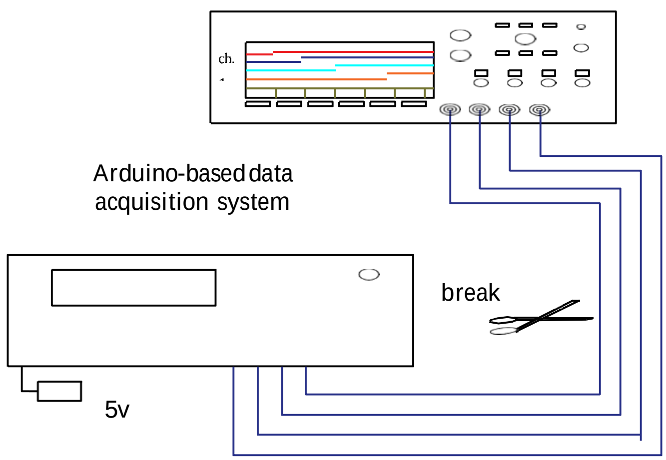

Figure 2 Digital Oscilloscope Testing Conceptual Framework.refer [9]

D. Testing Site

Tests were conducted near an explosives depot, which features a control hut that provides suitable environmental conditions for the oscilloscope and is equipped with a 220 V/50 Hz power supply. From this hut, four bipolar signal cables have been extended to a safe distance of 90 meters, along with the firing cable for the electric detonator that triggers the shock wave transmission tube of the non-electric detonators. A diagram illustrating the test site is presented in .

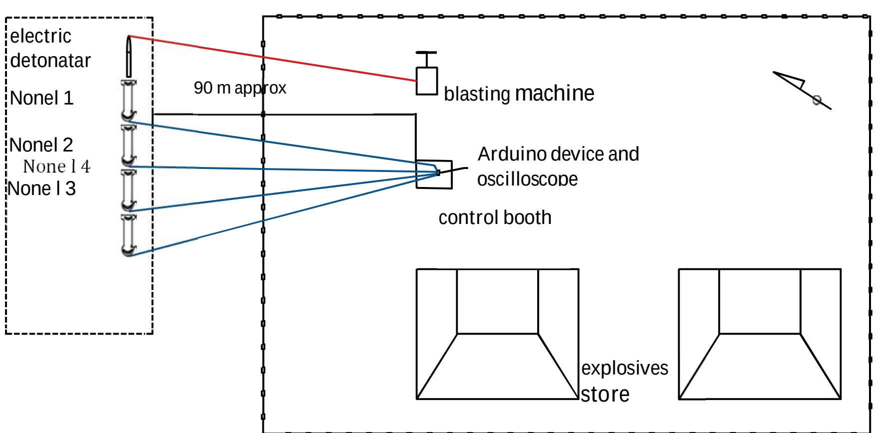

Figure 3 Testing site layout refer [9]

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E. Test Preparation

The dimension circuits have been linked to a four- channel digital oscilloscope.The specifications of a face detonator equipped with a signal line for measuring the eruption moments t1 through t4 are illustrated in This figure also presents the computation of the three eruption intervals t2 – t1, t3 – t2, and t4 – t3, grounded on the time differences observed.

The oscilloscope operates at a slice rate of over to 2.5 Giga samples per second across all analog channels. This capability enables the recording of the transition from 5 V to 0 V for each circuit, achieving a resolution that's four times lesser than that of the micros function, which has a resolution of four forevers.

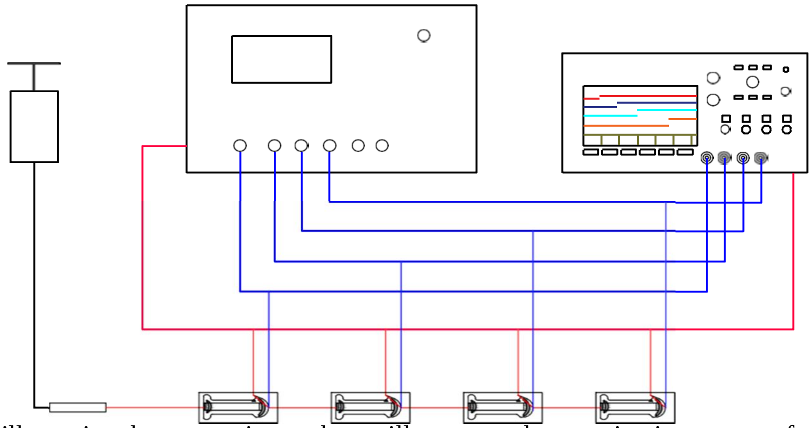


Figure 9. A conceptual diagram illustrating the connection to the oscilloscope and measuring instruments for the simultaneous recording of a wire break event. (b) Surface detonator equipped with a signal wire.refer [9]

IV. TESTING RESULTS AND DISCUSSIONS

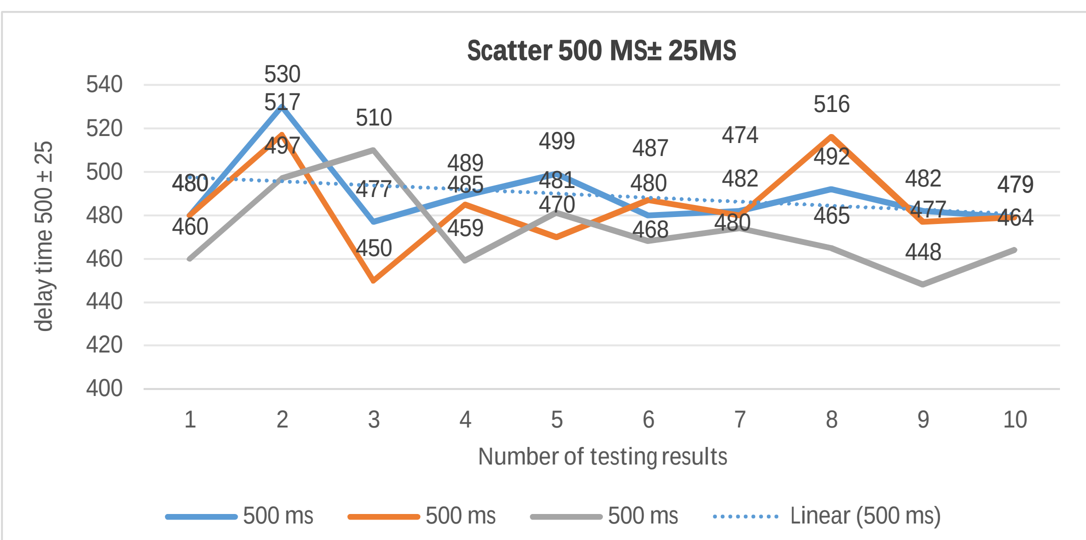
Total number of test done on device. The detonators used for measuring the detonation time is of different pyrotechnic composition batches and having different delay time. Ten number of each delay is tested on device for time accuracy measurement in detonators.Testing shows results of various delay time detonator. delay time shows on display delay time tester machine.

A collection of tests and time measurements conducted with the oscilloscope (500 ms detonator)

Test Collection	tm Measured Time Interval (ms)	tc Adjusted Utilizing Equation (4)	t Oscilloscope (ms)	(tm-t) Difference (milliseconds)
Set1	480	481	471	10
	530	531	475	55
	477	478	463	14
	489	490	463	26
	499	500	459	40
	480	481	475	5
	482	483	462	20
	492	493	480	12
	482	484	463	19
	479	480	453	26
Set 2	480	481	486	-6
	517	518	482	35
	450	451	458	-8
	485	486	463	22
	470	471	462	8
	487	487	493	-6
	480	481	474	6
	516	517	471	45
	477	478	466	11

	479	480	454	25
Set 3	460	461	452	8
	497	498	497	0
	510	511	517	-7
	459	460	477	-18
	481	482	474	7
	468	469	460	8
	474	475	485	-11
	465	466	479	-1
	448	449	493	-45
	464	465	482	-18
Set 4	507	508	480	27
	486	487	455	31
	533	534	507	26
	485	586	465	20
	482	483	525	-43
	514	515	468	46
	526	527	497	29
	593	594	474	119
	485	486	452	33
	499	500	547	-48
Set 5	486	487	501	-15
	497	498	498	-19
	495	496	535	-40
	486	487	523	-37
	492	493	563	-71
	486	487	490	-4
	495	496	519	-24
	510	511	536	-26
	513	514	500	-1
	505	506	518	-13

Table 1 Testing Results shows using device



Graph 1 measured time on Arduino

A relative analysis was conducted on the detention time of a 500 MS detonator to assess the burning speed of a pyrotechnic composition deduced from a chemical admixture. also, the study aimed to determine the applicable rod cutting size for the pyrotechnic composition contained within the tube. The slice size of the tube was modified grounded on the testing issues, and adaptations were made according to the variations observed in the results.

V. CONCLUSIONS

This device proficiently records split times at various phases of detonation, facilitating an in-depth analysis of initiation performance and uniformity. Experimental findings validate that this method can yield high-resolution time measurements, making it applicable for research, quality assurance, and field testing scenarios.

Additionally, the incorporation of digital data logging improves usability by making the interpretation and comparison of results more straightforward. Future enhancements could include the addition of faster sensors, wireless data transmission capabilities, and automated analysis software for real-time monitoring.

this project offers a budget-friendly, portable, and scalable solution for measuring detonation times in blasting caps, thereby enhancing safety and efficiency within the field of explosive engineering.

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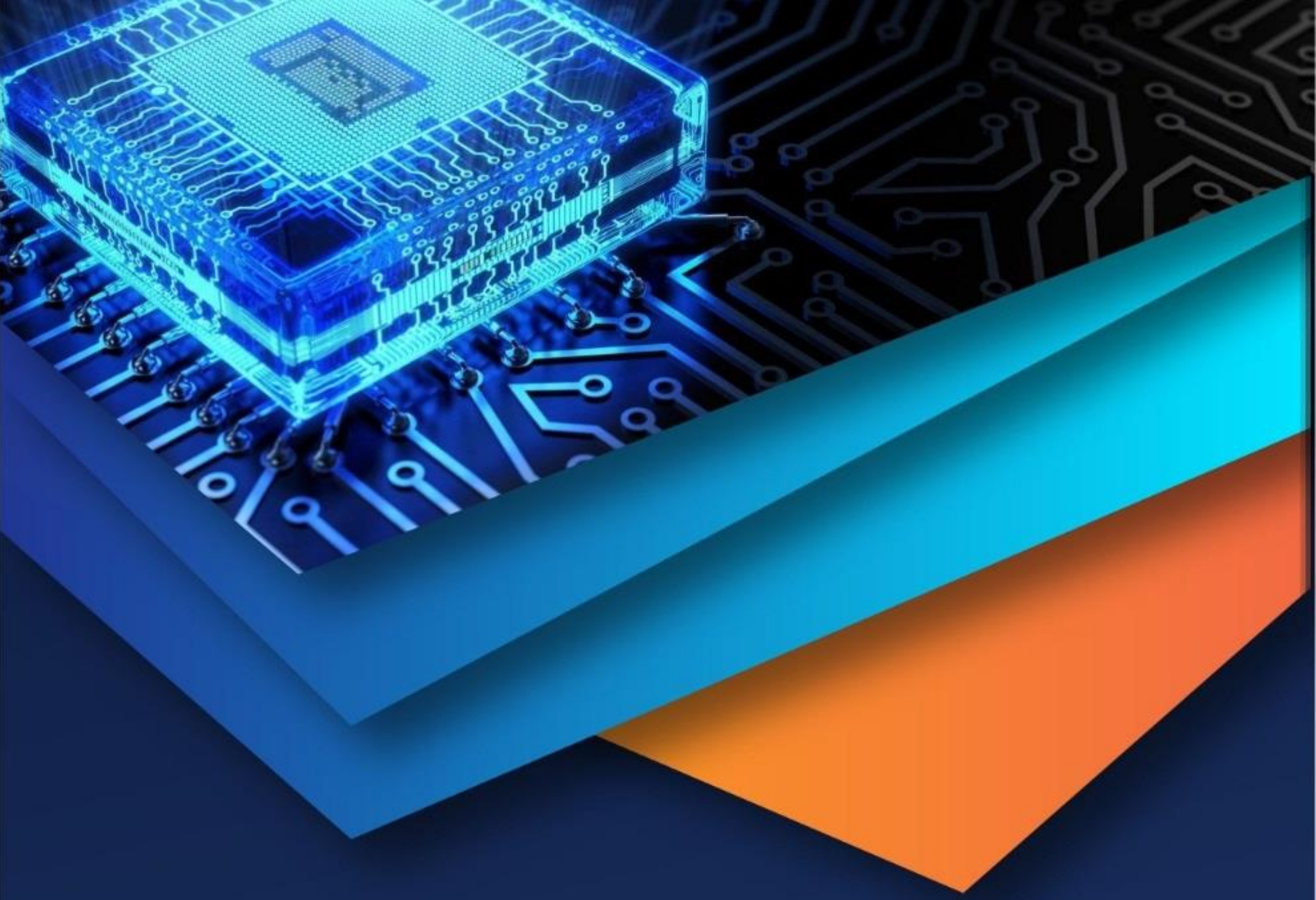

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