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Smart Fireworks Controller using Wireless Communication

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Abstract: *Fireworks are often used in festivals, celebrations, and public events. However, traditional ways of igniting fireworks are manual and come with significant risk because they require people to be close to explosive materials. This paper introduces a Smart Fireworks Controller system that allows for safe and remote ignition of fireworks using wireless communication. The system is built with an Arduino microcontroller, RF transmitter and receiver, relay modules, and timing circuits like the NE555 timer and CD4017 counter. It allows for the sequential firing of multiple fireworks with accurate timing control. This not only improves safety but also makes the overall visual presentation of firework displays better. The system is affordable, easy to use and suitable for real-time applications.*

Keywords: Firework Controller, Arduino, RF Communication, Relay Module, Safety System

I. INTRODUCTION

Fireworks have always played a key role in celebrations like festivals, weddings, cultural events, and national holidays. They create visual excitement and entertainment for large crowds. However, the traditional way of lighting fireworks is entirely manual. A person has to get close and use a flame or spark to ignite them. This method is not only inconvenient but also very dangerous. Each year, many accidents happen because of improper handling of fireworks, resulting in burns, injuriesand sometimes significant property damage.

Another major drawback of manual ignition is the difficulty in timing and coordination. It's hard for a person to light multiple fireworks in a precise sequence or at exact intervals. Consequently, the display might seem chaotic and less impressive. During large events, manual operation becomes even riskier because of the number of fireworks involved.

With the fast growth of electronics and communication systems, we can now create safer and smarter solutions for these issues. Embedded systems and wireless communication technologies offer a reliable way to control devices from a distance. By using these technologies, we can create a system that lets fireworks be ignited from a safe distance without direct human involvement.

The Smart Fireworks Controller system is based on this idea. It uses a microcontroller and wireless communication modules to control multiple fireworks efficiently. The system not only enhances safety but also offers better control over timing and sequence. This results in a more organized and visually appealing firework display.

The main goal of this project is to develop a low-cost, user friendlyand reliable system for real-life use. It aims to reduce human risk, improve performanceand show the practical application of embedded systems in safety-critical situations. addition to safety concerns, manual ignition also lacks precision and efficiency. It is extremely difficult for a person to control the exact timing of multiple fireworks, especially when a synchronized display is required. Human limitations make it nearly impossible to achieve perfect coordination, leading to irregular sequences and poorly timed explosions. This reduces the visual appeal and professionalism of the display. In largescale events, where hundreds of fireworks are used, manual control becomes not only inefficient but also highly risky and impractical.

With advancements in modern technology, particularly in the fields of embedded systems and wireless communication, there is an opportunity to overcome these challenges. Embedded systems enable automation and precise control of electronic devices, while wireless technologies allow remote operation without physical presence. By integrating these technologies, it is possible to design a system that can ignite fireworks safely from a distance, eliminating the need for direct human interaction.

The Smart Fireworks Controller System is developed based on this concept. It utilizes a microcontroller as the central processing unit, along with wireless communication modules to control the ignition process. The system can manage multiple fireworks simultaneously, ensuring accurate timing and proper sequencing. This results in a more synchronized, organized, and visually appealing display. Additionally, remote operation significantly reduces the risk to human life, making the entire process much safer.

Another important advantage of this system is its flexibility and scalability. It can be programmed to create different firing patterns, delays, and sequences according to the requirements of the event. Whether it is a small celebration or a large public event, the system can be adapted accordingly. Furthermore, the use of cost-effective electronic components ensures that the system remains affordable and accessible. The primary objective of this project is to design and develop a low-cost, reliable, and user-friendly fireworks control system that enhances safety and performance.

II. LITERATURE REVIEW

Over the years, several methods have been developed to improve firework ignition systems. Initially, fireworks were ignited manually with simple tools like matches or lighters. This method is simple, but it is unsafe. It also does not provide control over timing or sequence. To address these issues, researchers introduced electrical ignition systems that used relays and switches. These systems enabled fireworks to ignite with electrical signals, reducing direct contact with fire. However, they still needed wired connections, which limited flexibility and added complexity. [1]

The work by Wang et al. (2025) presents a self-powered ignition system based on a ZnO–PVDF nanogenerator, which eliminates the need for external power sources like batteries. The system utilizes piezoelectric energy harvesting, where mechanical vibrations or pressure generate electrical energy sufficient to trigger ignition circuits. By incorporating ZnO nanoparticles into PVDF, the piezoelectric performance is enhanced, resulting in improved voltage output (up to ~32 V). The study also uses electrospinning to improve material alignment and efficiency. Overall, this approach provides a compact, reliable, and energy-efficient solution for smart ignition systems by integrating energy harvesting, storage, and controlled discharge mechanisms..[2]

This study presents a fast-response, low-energy micro igniter designed to overcome the limitations of traditional ignition systems, which require high power and respond slowly. The proposed device uses a thin-film titanium resistive bridge combined with thermite materials like aluminum and copper oxide. When voltage is applied, heat generated through Joule heating quickly triggers the thermite reaction, producing a high-temperature flame. The igniter demonstrates an ultra-fast response time (less than 1 ms) and very low energy consumption (below 2 mJ). Its compact size, reliabilityand tunable design make it suitable for applications in aerospace, automotive safety, MEMS, and smart firework systems.[3]

This research paper presents a low-cost and efficient fire detection and control system using an Arduino-based platform. The system uses sensors like flame, temperature, and smoke/gas sensors to continuously monitor the environment. When fire is detected, it automatically activates alarms (buzzers and LEDs) and control systems such as water pumps or sprinklers. It can also send alerts through GSM or IoT for remote monitoring. The system is reliable, easy to implement, and helps improve safety while reducing fire-related risks.[4]

III. HARDWARE DESCRIPTION

A. RF Transmitter and Receiver Module

The RF (Radio Frequency) transmitter and receiver are used for wireless communication in the system. The transmitter sends signals from the user side, and the receiver collects these signals and forwards them to the microcontroller. This helps in controlling the fireworks from a safe distance without direct contact.

- Operating Frequency: 433 MHz

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- Range: Up to 50–100 meters
- Modulation Type: ASK (Amplitude Shift Keying)
- Operating Voltage: 3V – 12V
- Application: Wireless signal transmission

B. Arduino Microcontroller (Arduino Uno)

The Arduino is the main control unit of the system. It receives the signal from the RF receiver, processes it, and controls the firing of fireworks. It ensures proper timing and coordination between different components.

- Operating Voltage: 5V
- Input Voltage: 7–12V
- Digital I/O Pins: 14
- Analog Input Pins: 6
- Clock Speed: 16 MHz

C. NE555 Timer IC

The NE555 timer is used to generate timing pulses in the system. These pulses help control the delay between firing different fireworks, ensuring proper sequence and timing.

- Operating Voltage: 4.5V – 15V
- Output Type: Digital Pulse
- Timing Mode: Astable Mode
- Frequency Range: Adjustable

D. CD4017 Decade Counter

The CD4017 is used to control the sequence of fireworks. It activates outputs one by one, which helps in igniting fireworks in a proper order instead of all at once.

- Operating Voltage: 3V – 15V
- Number of Outputs: 10 (Q0 to Q9)
- Function: Sequential Output Activation
- Clock Input: From 555 Timer

E. Relay Module

The relay module acts as a switch that controls the ignition circuit. It allows a low-power signal from Arduino to control a high-power circuit safely. It also provides electrical isolation for protection.

- Operating Voltage: 5V
- Relay Type: Electromechanical
- Contact Capacity: High current switching
- Function: Firework ignition control

F. Transistor (BC547)

The transistor is used as a switching device to drive the relay. It amplifies the signal coming from the Arduino so that the relay can operate properly.

- Type: NPN Transistor
- Operating Voltage: Up to 45V
- Current Gain: High
- Function: Signal amplification and switching

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G. Power Supply

The power supply provides the required energy to all components in the system. It ensures stable and continuous operation.

- Supply Type: DC Battery
- Voltage Range: 5V – 12V
- Protection: Overvoltage and short circuit protection
- Function: Powering the entire system. Relay Module

IV. METHODOLOGY

The Smart Fireworks Controller system operates through a clear sequence of steps to ensure safe and effective use. First, the system powers on and initializes all components. The Arduino checks the status of all connected modules to confirm they are working correctly. After this initialization, the system enters standby mode and continuously waits for a signal from the RF transmitter.

When the user sends a command, the RF receiver captures the signal and sends it to the Arduino. The Arduino processes the signal and determines the specific command, such as which firework to ignite. Once the command is clear, the Arduino activates the timer circuit. The NE555 timer generates clock pulses that go to the CD4017 counter. The counter activates its outputs one after the other based on these pulses.

Each output connects to a transistor, which controls a relay. When the relay is switched on, it completes the ignition circuit, causing the firework to ignite. After firing one firework, the system checks for any additional commands. If there are more commands, the process continues with the next firework. If no further commands come in, the system safely turns off all outputs to prevent accidental ignition.

This method ensures a controlled, sequential, and safe operation of fireworks.

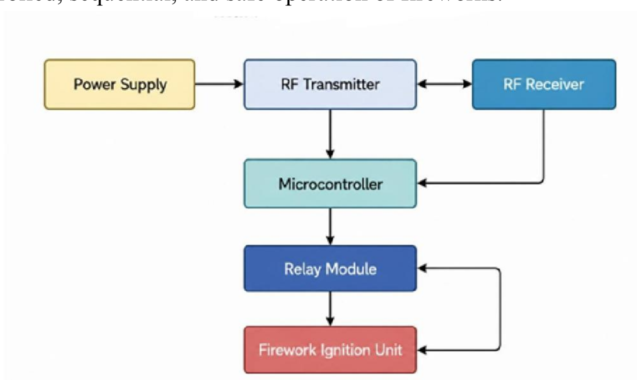

Fig. 1. Block Diagram of Smart Firework Controller System.

V. IMPLEMENTATION AND RESULTS

A. Implementation

The system was implemented by using general electronic components like Arduino, RF module, relay, and timer IC. All the components were connected to the prototype circuit board and were tested under certain circumstances. All necessary measures regarding insulation and safety were observed while implementing the system.

B. Results

Following results were obtained for the system implementation:

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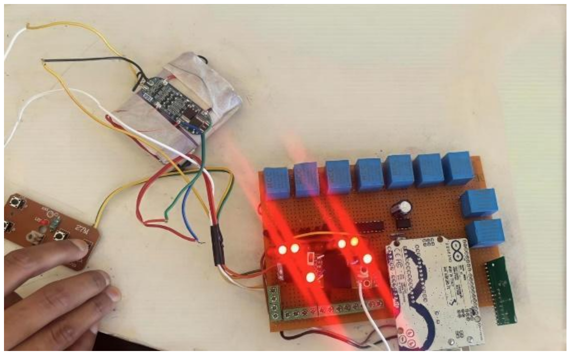
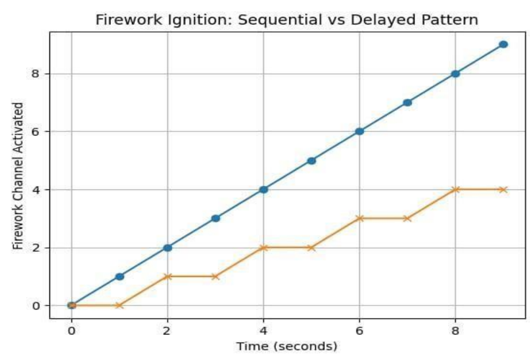


Remote ignition of the fireworks without making any physical contact was performed
The fireworks could be set off sequentially
Timings among all the fireworks remained consistent

C. Performance Analysis

Performance was satisfactory with no delays in transmission of signals. The wireless mode of transmission also worked efficiently within the given range. Low power consumption was one of the features observed for the given project



D. Practical Application

The prototype suggested that the system can have practical applications in real life like in festivals and other events.

VI. SAFETY ANALYSIS

Safety is the most important part of this system because it involves explosive materials. Several safety measures have been added to lower risks.

The use of wireless communication allows the user to operate the system from a safe distance, which reduces the chance of injury. Relay modules create electrical isolation between the control and ignition circuits, preventing damage to parts.

Proper insulation of wires and connections helps prevent short circuits. The system also uses sequential firing, which stops multiple fireworks from igniting at the same time, lowering the risk of overload or explosion.

Additionally, battery protection systems prevent overheating and electrical faults. These safety features make the system reliable and practical for use.

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VII. CONCLUSION

The Smart Fireworks Controller system is a practical solution to the issues linked with traditional firework ignition methods. By using wireless communication and embedded systems, it improves safety, efficiency, and control. The system removes the need for direct human interaction, which lowers the risk of accidents. It also guarantees proper timing and sequencing, leading to better firework displays. The design is straightforward, affordable, and suitable for practical use. Overall, this system shows how modern technology can address real-world problems and enhance safety in everyday activities.

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