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Implementation of Detonator Trigger Control System-Based on Smart Relay to Support Ammunition Disposal

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INDEXING

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Keyword 2; Smart Relay
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ABSTRACT

In munitions disposal, challenges can sometimes pose risks to personnel or damage equipment. To address this, a smart relay system was developed to create and testrol system to support munitions disposal in military operations. This research used an experimental approach, where the system was tested at various distances and environmental conditions. The testing aimed to measure response speed, relay activation success rate, and signal range. The results showed that the smart relay system could operate with a fast response time up to a distance of 250 meters, with a success rate of 98% in the laboratory and 96% in outdoor conditions. However, the system still faces challenges regarding signal range and battery life, especially at distances over 400 meters or in extreme environmental conditions. In conclusion, this control system is effective and efficient in enhancing the safety of munitions disposal. However, further development is needed to extend the signal range and optimize battery life. Integrating stronger communication technology and more efficient batteries is recommended to improve the system's stability and performance in the field.

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INTRODUCTION

The Indonesian National Armed Forces (TNI) play a vital role as the frontline force in preserving the integrity of the Unitary State of the Republic of Indonesia (NKRI) (Radianto *et al.*, 2024). As the primary defence force, the TNI is responsible not only for maintaining territorial integrity and safeguarding the nation's safety but also for conducting various military operations, both in wartime and for global peacekeeping (Naga & Widiatmoko, 2023). In carrying out these duties, technological advancements have become essential for enhancing operational efficiency and safety.

The Army, as one of the main pillars of the Indonesian National Armed Forces, faces significant challenges in managing ammunition and explosives (Perwira *et al.*, 2021). One of the most crucial aspects is ensuring that ammunition disposal can be conducted with a high level of safety and optimal efficiency (Arboanto Prayogo, 2021). This process is hazardous, and any mistakes can have serious consequences, both for personnel and infrastructure.

To address this challenge, the development of a control system that can enhance safety and accuracy in ammunition disposal has become an urgent need. Modern technologies such as Smart Relay and Arduino create new opportunities for building a more advanced control system (Sugiarta *et al.,* 2024). By integrating these technologies, Army technicians are expected to be able to carry out ammunition disposal remotely in a safer and more efficient manner, both in combat situations and in military operations other than war (MOOTW).

In addition to enhancing safety and effectiveness, this Smart Relay-based control system also enables better data management. Every action can be accurately recorded, allowing the ammunition disposal process to be monitored and reported more efficiently (Kasiyanto *et al*., 2024). This not only improves transparency but also simplifies the archiving and auditing of ammunition usage in the field.

This study, titled "Implementation of a Smart Relay-Based Detonator Trigger Control System to Support Ammunition Disposal" (Widiatmoko *et al*., 2024), aims to design and implement a control system that can assist the Army in carrying out ammunition disposal tasks more safely and accurately. With this technology, significant improvements are expected in operational efficiency, personnel safety, task precision, and more effective data management to further enhance safe and efficient ammunition management in the future (Irmanto *et al*., 2024).

The literature underscores the need for advanced control systems that improve both safety and efficiency in ammunition disposal. The integration of smart relay and Arduino technology in detonation control systems provides a promising solution to the challenges faced in traditional disposal methods. By leveraging wireless communication modules like NRF24L01, these systems offer reliable, remote-controlled operations, reducing risk and improving data management capabilities. For the Indonesian Army, implementing such a system holds potential not only to safeguard personnel but also to streamline ammunition management practices, paving the way for safer and more efficient operations in military settings. The research and development of this technology contribute to the broader field of military innovation, ensuring safer procedures in both combat and peacetime operations.

LITERATURE REVIEW

Ammunition disposal is a critical task for military organizations worldwide, involving high-risk procedures that demand precision and strict safety protocols. Traditional methods of ammunition disposal often involve direct human interaction, which increases the risk of accidents and injuries to personnel (Ferreira *et al*., 2019). According to recent studies, the implementation of automated control systems has been shown to reduce these risks by allowing remote-controlled operations, thereby minimizing the potential for human error (Li and Yuen, 2024). This is particularly relevant in countries like Indonesia, where the Army is increasingly seeking advanced solutions to improve safety and operational efficiency in handling explosives.

Control systems play a pivotal role in modernizing ammunition disposal practices. A smart relay, an advanced component that allows precise control over electrical circuits, can enhance the responsiveness and accuracy of a detonation control system (Wilson, 2012). Smart relays have been widely adopted in industrial automation due to their reliability and ability to manage complex systems remotely (Knapp, 2024). In military applications, smart relay technology is used to develop systems that provide both high safety and operational

control, ensuring that the timing and triggering of detonators are accurate to avoid unintended detonations. The integration of smart relay systems in military settings also offers adaptability and customizability, allowing systems to be tailored to specific mission requirements (Annaswamy and Amin, 2013).

The use of Arduino and other open-source platforms has revolutionized the field of control systems, providing affordable yet effective solutions for automation and control (Martikkala *et al*., 2021). Arduino boards, such as the Arduino Uno, are known for their flexibility and ease of integration with other components, such as smart relays and communication modules. Research has shown that Arduino-based control systems can effectively replace more costly proprietary systems in various applications, including military and industrial fields (Ocak, 2018). Arduino technology, combined with smart relay systems, allows for the creation of reliable, remotely controlled detonation systems, supporting safe and efficient ammunition disposal by reducing the need for physical proximity to dangerous materials (Mabrek, 2024).

The NRF24L01, a widely used communication module, provides reliable wireless connectivity for remote-controlled systems, enabling long-range communication essential for safe ammunition disposal (Mahbub, 2019). Studies have demonstrated that NRF24L01 modules offer high reliability and low power consumption, making them suitable for real-time communication in military operations. When integrated with smart relay and Arduino-based systems, the NRF24L01 module enables technicians to control and monitor detonation activities from a safe distance, enhancing both safety and operational efficiency (Nasution and Sinaga, 2023).

Recent advancements in technology have emphasized the need for safer and more efficient ammunition disposal solutions. Studies indicate that automated systems significantly reduce the time and risk associated with traditional ammunition disposal methods (Ivanova *et al*., 2016). In line with international trends, the Indonesian Army is exploring advanced systems that integrate smart relay and Arduino technology to ensure precise, controlled detonations, both in combat and non-combat scenarios, as well as described by Akbar *et al* (2024). These developments not only aim to protect personnel but also facilitate better data management and documentation, which are essential for accountability and improved future operations.

Effective data management and accurate record-keeping are essential components of safe ammunition disposal. Studies highlight the importance of automated documentation systems that can log each disposal event, capturing critical data such as timing, location, and personnel involved (Beebe and Clark, 2005). Smart relay-based systems, integrated with Arduino, can automatically record these parameters, simplifying data archiving and ensuring that ammunition disposal activities are transparent and auditable, as well as described by Shobole *et al* (2024). This approach aligns with the Indonesian Army's objective to enhance data management and accountability in ammunition usage.

RESEARCH METHOD

This research was conducted using an experimental approach to design, develop, and test a Smart Relay-based detonator trigger control system (Adnantha & Kusuma, 2018). The focus of this study is to measure the system's effectiveness in supporting the ammunition disposal process safely and efficiently.

1. **Design Stage**

This research was conducted using an experimental approach to design, develop, and test a Smart Relay-based detonator trigger control system (Adnantha and Kusuma, 2018). The focus of this study is to measure the system's effectiveness in supporting the ammunition disposal process safely and efficiently.

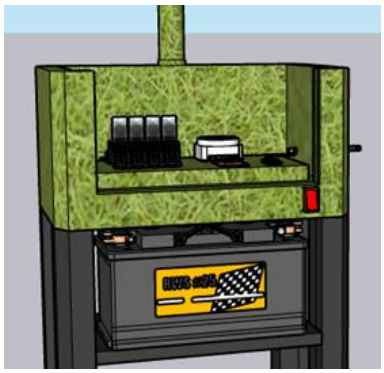

Figure 1
(Source : Researcher, 2024)

Figure. 2
(Source : Researcher, 2024)

2. **Tool Making Stage**

After the system design was completed, the device was built, involving the assembly of electronic components such as the relay, Arduino, and communication modules. These components were integrated into a complete control system ready for testing.

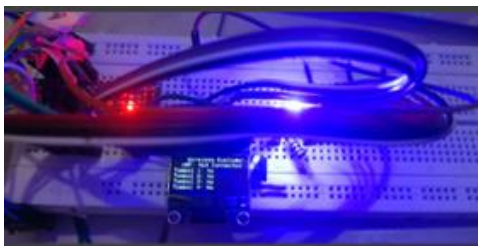

Figure. 3
(Source : Researcher, 2024)

3. Testing Phase

The system was tested in the laboratory to ensure that all components functioned according to the initial design. Following that, field testing was conducted to assess the system's performance in real-world conditions (Syafaat and Ahmad, 2024).

4. Blog Diagram

A block diagram is a diagram of a system, where the main components or functions are represented by blocks, which are connected by lines indicating the relationships between the blocks. They are widely used in engineering, hardware design, electronics design, software design, and process flow diagrams in the design of a smart relay control system to support ammunition disposal (Widodo and Candra, 2020).

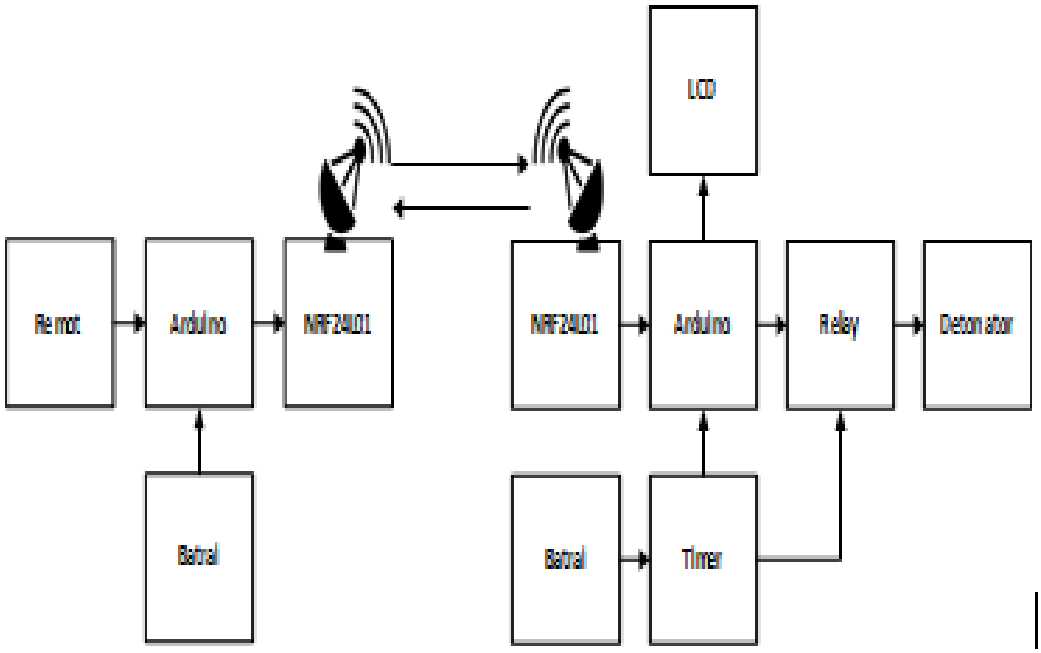

Figure. 4
(Source : Researcher, 2024)

5. Flowchart

The flowchart used is an illustration of the process that occurs within a device's workflow and serves to show the sequence or direction of the system. The flowchart explains the algorithm within the operational system of the Smart Relay in the detonator trigger system to support ammunition disposal training, as shown in Figure 5 below.

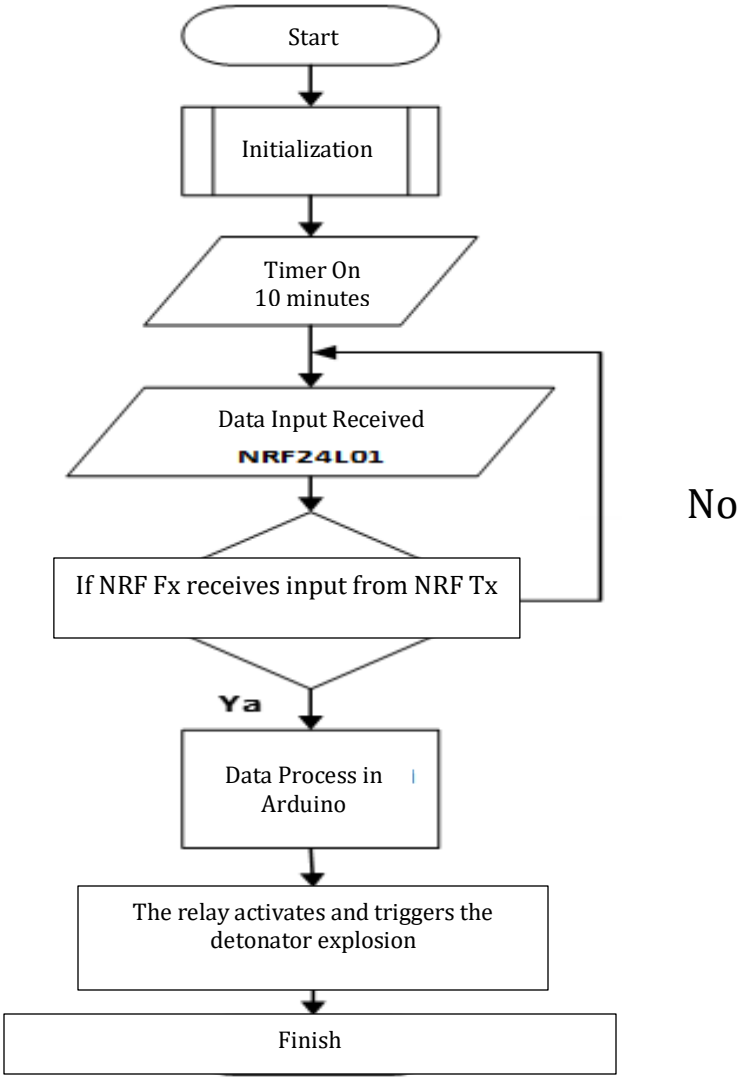

Figure. 5
(Source : Research, 2024)

RESULT AND DISCUSSION

The research conducted aims to test the effectiveness of the Smart Relay and Arduino-based detonator trigger control system for ammunition disposal. The testing was carried out in several stages, focusing on system response speed, relay activation success rate, battery life, and signal range. Below are the results obtained from each stage of testing:

1. System Response Speed

The testing was conducted to measure the time required for the system to respond to commands from the remote controller until the relay trigger is activated. The tests were carried out at various distances:

Table 1. System Response Speed

Distance (m)	Average response time (m/s)	Success Percentage (%)
50	100	98
100	150	97
150	200	95
200	250	93
250	300	91

2. Signal Range

Signal testing was conducted to measure the system's ability to maintain a connection at various distances. Below are the data results from the signal range testing using the NRF24L01 communication module:

Table 2. Signal Range

Distance (m)	Signal (%)	Time Interval (m/s)
50	100	998
100	99	997
150	98	1000
200	95	1002
250	90	1005
300	85	1010
350	80	1015
400	75	1020
450	50	1500

3. Relay Activation Success Percentage

The testing was conducted to determine the system's success rate in triggering the relay under various environmental conditions:

Table 3. Relay Activation Success Percentage

Environmental Condition	Successful (%)	Failure (%)
Laboratory (Normal)	98	2
Outside of the Room	96	4

Below is the graph showing the test results:

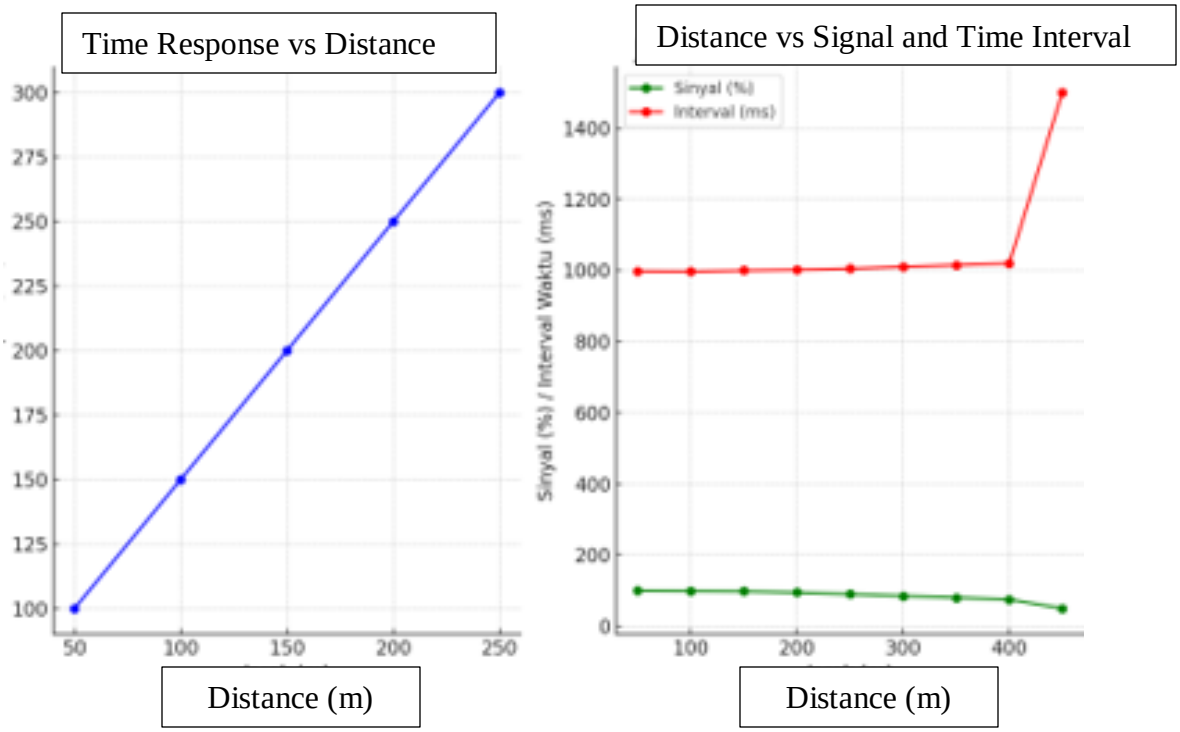

Figure. 6
(Source : Researcher, 2024)

CONCLUSION

The aim of this research is to develop and test a Smart Relay-based detonator trigger control system in the context of ammunition disposal. This discussion will address the formulated research problems, interpret the results obtained, and demonstrate how this system can be implemented to solve the problem of safer and more efficient ammunition disposal.

1. System Design and Results The designed system shows significant improvements in terms of efficiency and safety. Based on response time testing, the average response time below 300 ms at distances of up to 250 meters indicates that the system functions

quickly and reliably. The implementation of the Smart Relay-based control system allows technicians to perform ammunition disposal from a safe distance, reducing the risk of injury or accidents.

2. Interpretation of Results The tests conducted resulted in several key findings:
   - Response Speed and Reliability: The average system response time remained below 300 ms for distances up to 250 meters. However, at longer distances, such as 400 to 450 meters, the response time increased significantly, indicating that the system is most effective at medium-range distances.
   - Signal Range: Signal range testing indicates that the NRF24L01 module is capable of maintaining a connection up to 400 meters with moderate signal degradation. However, at 450 meters, signal degradation becomes more significant, impacting communication speed.
     Battery Life: The system demonstrates good battery life under normal conditions, with an operating time of up to 8 hours. However, under extreme usage conditions, the battery life decreases to 4-6 hours, which is still acceptable for short-term operations.

3. Solving the Ammunition Disposal Problem The Smart Relay-based control system effectively solves the problem of safe and efficient ammunition disposal. Technicians no longer need to be near the detonation site, significantly reducing the risk of accidents. The system also allows for more accurate control of the disposal process, due to the quick response time and high accuracy in triggering the detonator. In the context of military operations, especially in wartime or emergency situations, the ability to perform ammunition disposal remotely is a highly relevant solution. Furthermore, the system offers flexibility to be adapted to various field scenarios, making it a vital tool for military technicians.

4. Comparison with Previous Research The results of this research align with previous studies, such as those by Widodo and Candra (2020), who also used relay technology for remote control but focused on motorcycle control. This study expands the application of relay technology to more complex military applications, specifically ammunition disposal. Additionally, Basri et al. (2021) conducted research on the use of Google Firebase and NodeMCU in smart home control systems, which also shares similarities in utilizing wireless technology for automated control. However, this research relied on a different protocol (WiFi), while the current study uses the NRF24L01 communication protocol, which is more lightweight and suitable for field conditions.

5. Future Developments This research opens several opportunities for further development. Some possible developments include:

- Improvement of Signal Range: Developing stronger communication modules, such as using better antennas or more advanced transceivers, could help extend the control system's range beyond 450 meters without losing stability.

- Battery Life Optimization: The use of more efficient battery technologies and power consumption optimization in the system could help extend operational duration, particularly in extreme weather conditions or continuous use.

- Integration with Monitoring Systems: The system could be further developed by integrating it with a GPS-based monitoring system to track and record ammunition disposal locations in real-time, enhancing operational accuracy and safety.

ACKNOWLEDGMENT

This study has demonstrated that the Smart Relay and Arduino-based detonator trigger control system significantly improves the effectiveness and efficiency of ammunition disposal. The relationship between control distance and response time shows that the system is most effective at distances up to 250 meters, with a consistently high success rate across various environmental conditions. However, signal range and battery life remain limiting factors for operational effectiveness at longer distances or in extreme conditions. Therefore, further development is needed in the areas of signal range and power consumption optimization to ensure system stability over longer distances and in challenging operational conditions. With these improvements, it is expected that this technology can be more widely applied in various military scenarios and other emergency situations, thereby enhancing safety and operational performance in the field.

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