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ANTI-BLAST LANDMINE SYSTEM

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ABSTRACT

This paper presents the development and implementation of a cost-effective anti-blast landmine detection and prevention system utilizing embedded technology. The system identifies human presence using motion sensors and verifies identity through RFID authentication before triggering a solenoid-based lock mechanism. Radio frequency (RF) communication enables real-time monitoring and control by a remote authority. The design integrates components such as an STM32 microcontroller, EM-18 RFID module, RCWL-0516 motion sensor, LoRa SX1278 module, and a 12V solenoid lock, all managed through a custom-designed PCB. The system is aimed at military and defense applications for safer navigation in mine-infested zones. The final prototype demonstrates improved security and accessibility in hostile environments.

Keywords: Landmine Detection, Embedded System, RFID Authentication, Lora Communication, Anti-Blast System, Solenoid Lock.

I. INTRODUCTION

Landmines continue to pose a significant threat in war-torn areas and border regions, leading to thousands of civilian and military casualties each year. Manual mine detection methods are not only time-consuming but also dangerous. This paper proposes an embedded-based, low-cost smart landmine system that reduces human risk while maintaining operational efficiency.

The proposed system leverage's identity verification through RFID tags and prevents unauthorized access to restricted zones. With the integration of real-time RF communication, soldiers' activity is remotely monitored and controlled. This work emphasizes hardware design, embedded control logic, and practical PCB implementation.

II. LITERATURE REVIEW

The integration of modern technologies has significantly advanced landmine detection and deactivation methodologies. This section reviews key technological advancements pertinent to the development of an Anti-Blast Landmine Detection and Prevention System.

A. Ground-Penetrating Radar (GPR)

Ground-Penetrating Radar (GPR) has been extensively researched for its efficacy in detecting subsurface anomalies indicative of landmines. **Giovanneschi et al**. discuss modern GPR target recognition methods, emphasizing adaptive processing techniques to enhance detection accuracy in complex environments [1]. Additionally, **Bähnemann et al**. explore the deployment of GPR on micro aerial vehicles, facilitating remote sensing capabilities for landmine detection [2].

B. Robotic Systems for Mine Detection

The deployment of robotic systems has revolutionized demining operations by reducing human exposure to hazardous environments. **Hasselmann et al**. present a multi-robot system designed for the detection of explosive devices, integrating advanced sensor fusion algorithms to improve detection reliability [3]. Furthermore, the Husky Vehicle-Mounted Mine Detection (VMMD) system exemplifies the application of unmanned ground vehicles equipped with detection sensors for efficient mine clearance [4].

C. Sensor Fusion Techniques

Integrating multiple sensor modalities enhances the reliability of landmine detection systems. **Giovanneschi et al.** propose the use of dictionary learning for adaptive GPR landmine classification, demonstrating improved

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target recognition through sparse representations [5]. Such approaches underscore the importance of combining data from various sensors to mitigate false positives and improve detection rates.

D. Challenges in Landmine Detection

Despite technological advancements, challenges persist in landmine detection, particularly concerning environmental variability and the presence of non-metallic mines. The effectiveness of GPR is influenced by soil properties, requiring adaptive techniques to maintain detection performance across different terrains [1]. Additionally, the development of detection systems that can differentiate between landmines and other subsurface objects remains a critical area of research.

E. Innovations in Detection Mechanisms

Recent innovations focus on enhancing the sensitivity and specificity of detection mechanisms. The Fido explosives detector, for instance, utilizes amplifying fluorescent polymers to achieve trace detection of explosive vapors, offering a portable solution for field operations [6]. Such advancements contribute to the development of more effective and user-friendly detection tools.

III. SYSTEM DESIGN & METHODOLOGY

The Anti-Blast Landmine Detection and Prevention System is engineered to enhance safety in mine-prone areas by integrating motion detection, personnel identification, and control mechanisms. The system comprises the following key components:

A. Power Supply Unit

A regulated power supply is established using the LM2596 Buck Converter, which steps down the input voltage (12V) to stable 5V and 3.3V outputs. These outputs power various modules, including the STM32 microcontroller (5V) and the EM-18 RFID reader (3.3V).

B. Microcontroller Unit

The STM32F103C8T6 microcontroller serves as the central processing unit, selected for its efficient real-time processing capabilities. It manages inputs from the motion sensor and RFID reader, controls the relay and solenoid lock, and interfaces with the LoRa communication module.

C. Motion Detection

The RCWL-0516 microwave radar motion sensor detects movement within its vicinity. Unlike traditional PIR sensors, the RCWL-0516 is less affected by environmental factors and can detect motion through certain materials, enhancing its reliability in various conditions.

D. Personnel Identification

Personnel identification is conducted using the EM-18 RFID reader module. Authorized individuals carry RFID tags, and upon detection, the system verifies their identity. The reader communicates with the microcontroller via UART protocol to ensure secure authentication.

E. Control Mechanism

A relay module is employed to control the solenoid lock mechanism. Upon successful RFID authentication, the microcontroller activates the relay, which in turn energizes the solenoid lock to secure the detonation mechanism. In the absence of proper identification, the solenoid remains de-energized, leaving the detonation mechanism in an unsecured state.

F. Communication Module

For future scalability, the system includes the LoRa SX1278 module to facilitate long-range, low-power wireless communication. This allows for potential remote monitoring and control by authorized personnel.

G. Alert System

An auditory alert system is integrated using a buzzer, which is activated upon unauthorized access attempts or system malfunctions. Indicator LEDs provide visual status updates, enhancing user awareness of the system's operational state.

IV. HARDWARE IMPLEMENTATION

The hardware implementation of the Anti-Blast Landmine Detection and Prevention System involved the

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integration of the aforementioned components onto a custom-designed PCB. The assembly process was conducted with precision to ensure system reliability.

A. Component Integration

The major components integrated into the system include:

- STM32F103C8T6 Microcontroller
- EM-18 RFID Reader Module
- RCWL-0516 Microwave Radar Motion Sensor
- LM2596 Buck Converter
- Relay Module
- 12V Solenoid Lock
- LoRa SX1278 Module
- Buzzer and Indicator LEDs
- Slide Switch
- 12V Battery as Power Source

B. PCB Design and Assembly

The PCB was designed using EasyEDA, adhering to standard design rules to ensure signal integrity and component compatibility. The layout accommodated both through-hole and surface-mount components, with considerations for manual soldering during prototyping.

C. System Operation

Upon activation, the motion sensor monitors for movement. When motion is detected, the system awaits RFID authentication. If a valid RFID tag is presented, the microcontroller signals the relay to activate the solenoid lock, securing the detonation mechanism. If authentication fails or is absent, the solenoid remains inactive, leaving the detonation mechanism unsecured.

D. Manual Assembly Process

The assembly involved manual drilling and soldering, with components mounted onto the PCB using headers and sockets where applicable to facilitate testing and potential component replacement. The system was subjected to controlled testing to validate functionality and performance.

E. Schematic Overview and Assembly

The schematic design was simulated and finalized in EasyEDA, and the final PCB was fabricated using a double-layer board. The circuit was manually assembled with through-hole and SMD components, considering ease of soldering for a college-level prototype.

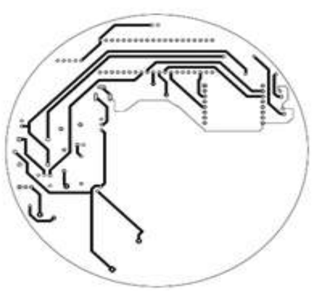

Fig 1: Bottom Layer Layout

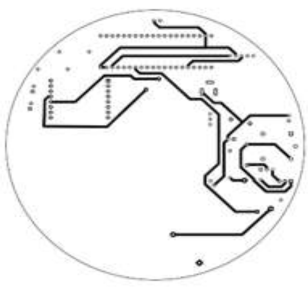

Fig 2: Top Layer Layout

Fig 3: Assembled PCB

C. Working Description

Upon system initialization, the EM-18 RFID module scans for a tag when a soldier approaches. If the tag matches a pre-registered identity of a friendly soldier, the system activates the relay module to power the solenoid lock, thereby disabling the landmine's triggering mechanism. A green LED lights up and a short buzzer beep confirms successful identification and safety.

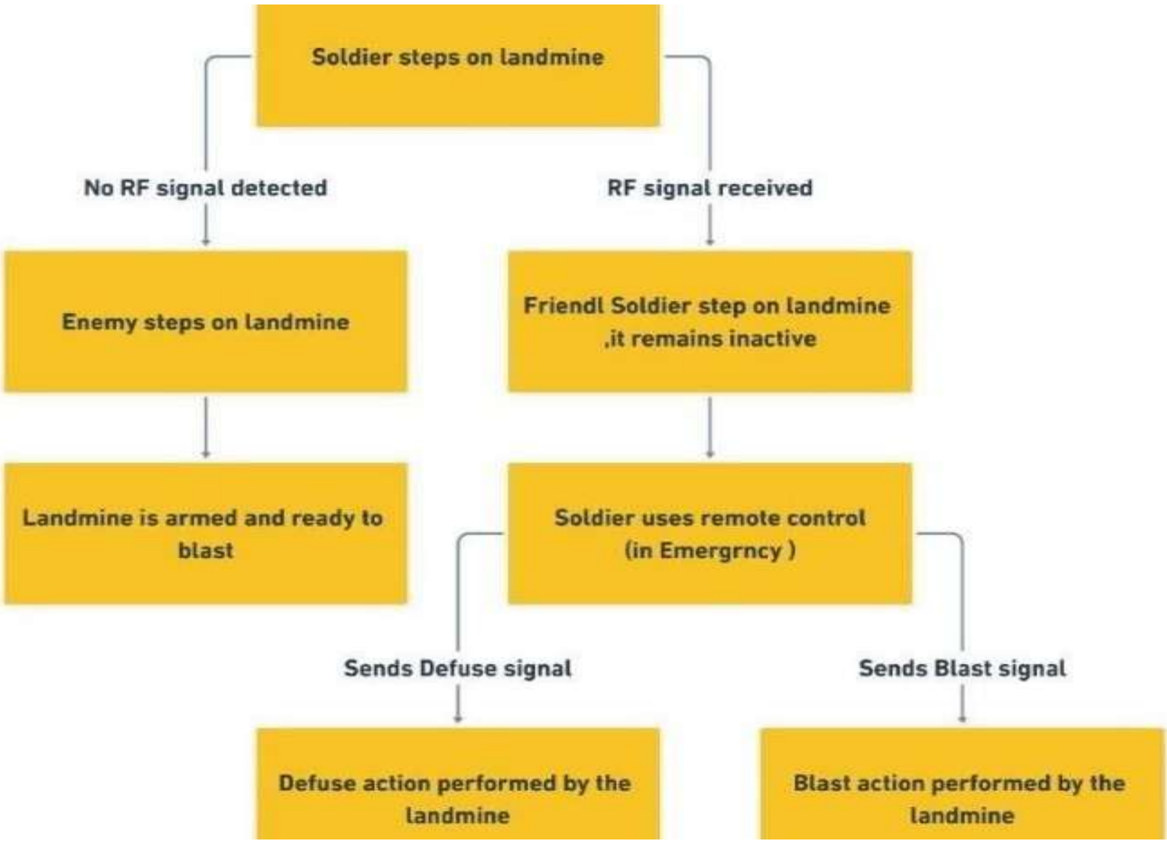

Fig 4: Work Flow Chart

The system's operational flow is depicted in Fig. 4. When motion is detected by the RCWL-0516 sensor:

❖ **The system checks for a valid RFID signal.**

➢ **If a valid tag is detected:**

- The relay activates the solenoid lock, disarming the landmine.
- Green LED and short buzzer indicate a safe zone.
- LoRa module broadcasts the friendly presence to surrounding landmines to prevent false arming in the local vicinity.

➢ **If no valid tag is detected:**

- The landmine remains armed (solenoid lock deactivated).
- Red LED and continuous buzzer alert are triggered.
- LoRa module transmits the unauthorized presence alert to adjacent landmines, which may escalate their readiness or alert status accordingly.

D. Manual Implementation Process

All drilling and soldering processes were carried out manually using basic lab tools. The use of slide switches and headers for components made the system modular and easy to troubleshoot. The board was tested under controlled conditions to verify each module's functionality individually and then as a complete system.

Fig 5: Model Image

V. RESULT & DISCUSSION

The Anti-Blast Landmine Detection and Prevention System was successfully implemented and tested in a controlled environment. The system demonstrated accurate motion detection and effective personnel identification using RFID tags. Key observations from the testing phase are as follows:

1. Motion Detection Performance

The RCWL-0516 radar sensor reliably detected motion within a range of 5–7 meters. It proved effective even through non-metallic barriers, offering an advantage over traditional PIR sensors.

2. RFID Authentication Accuracy

The EM-18 RFID module consistently identified authorized personnel carrying valid RFID tags. Unauthorized attempts to access the system were correctly denied, ensuring reliable access control.

3. Locking Mechanism Response

Upon successful RFID authentication, the relay module energized the solenoid lock, firmly securing the simulated detonation system. In cases of failed or absent authentication, the solenoid remained de-energized, leaving the system unsecured as designed.

4. System Indicators

The buzzer and LEDs provided immediate visual and auditory feedback based on system state (e.g., motion detected, access granted/denied), enhancing situational awareness.

5. Power Management

The LM2596 buck converter successfully regulated power to required voltage levels (3.3V and 5V), ensuring stable operation of all modules.

6. LoRa Module

Although included for future scope, LoRa modules were not actively used during the initial testing phase due to limited remote monitoring requirements in the prototype.

VI. CONCLUSION

The proposed Anti-Blast Landmine Detection and Prevention System presents a reliable and scalable solution for enhancing the safety of personnel operating in mine-infested zones. By integrating motion sensing, RFID-based identification, and a relay-controlled solenoid lock, the system effectively prevents unauthorized access to the landmine’s detonation trigger.

The prototype demonstrated successful real-time motion detection and authentication, with accurate locking behavior of detonation that simulates prevention of accidental or enemy-triggered blasts. The modular design and future scalability with LoRa-based remote control further enhance its practical application.

This project lays the groundwork for intelligent defense systems that can distinguish between friend and foe, potentially reducing casualties and improving operational safety in conflict zones. With minor modifications and field-testing, the system can be deployed in real-world scenarios for life-saving applications.

VII. REFERENCES

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