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Blue-on-Blue Prevention in Battle Field Using Embedded Device

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ABSTRACT*:* Friendly fire is the situation where military forces attack on friendly forces while attempting to attack the enemy. Causative reasons may be either misidentifying the target as hostile or due to errors. Such attacks result in unwanted casualties in the battle field. Utilization of improved technology to assist in identifying friendly forces is an ongoing process to prevent any fratricides. In this proposed system one such attempt is made to develop an embedded device to identify friendly forces. In this approach encrypted data is sent through laser beam for an authentication. Implementation method gives special consideration to power down strategies, efficient encryption and decryption methodologies and theft security for the module. Software programming algorithm and their implementation is also discussed.

PIC16F877A from Microchip Corporation is used as heart of this design. It features 256 bytes of EEPROM, self-programming, 8 channels of 10 – bit analog to digital converter, UART. Using mickroC PRO IDE, entire software programming done in embedded C language.

I. INTRODUCTION

In this proposed system encrypted laser beam is being transmitted from the initiative unit to the opponent responder unit. The responder unit is expected to decrypt the received encrypted data and sends back a message indicating friendly force is identified. A soldier equipped with the proposed system has a responder unit on their body armour, and an initiator unit mounted on their rifle. The rifle module transmits an encrypted laser beam. If the rifle points towards a friendly force, phototransistors equipped on the target body armour detects an incident of laser beam. If decryption is the master control unit identifies which friendly force is currently targeted. A pulse detector is used to ensure that the system to be deactivated soon after separation from the soldier body; enemy forces cannot recover system from dead soldier and use it to masquerade as friendly force.

II. LITERATURE SURVEY

- Pil-Song Kim et al. (2023) proposed a battlefield situation awareness model using a hybrid Convolutional-LSTM architecture to process large-scale spatio-temporal data from sensors and imagery. By combining convolutional layers for spatial feature extraction with LSTM layers for temporal pattern learning, the model predicts evolving battlefield states more accurately than traditional approaches. Their work highlights how deep learning can support commanders with timely, data-driven assessments of threats, movements, and tactical changes in complex combat environments.
- Priyanka Mane and Swapna Patil (2024) introduced the SHIELD system, an IoT-based framework that integrates soldiers' health parameters with their location for modern battlefield deployment. Wearable sensors acquire real-time physiological data, which is transmitted along with GPS coordinates to a central monitoring platform for analysis and visualization. The system aims to improve command decisions, resource allocation, and emergency response by giving commanders continuous visibility of each soldier's condition and position.
- Sujitha V. et al. (2022) developed an IoT-based healthcare monitoring and tracking system for soldiers using the ESP32 microcontroller. The prototype interfaces biomedical and environmental sensors with the ESP32 to measure vital signs and location, then sends the information wirelessly to a remote monitoring station. The authors emphasize low cost, compactness, and low power consumption, demonstrating that ESP32-based nodes can provide a practical solution for continuous soldier health surveillance in field conditions.

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➢ Sharef Neemat and Michael Inggs (2012) designed and implemented a digital real-time target emulator for testing Secondary Surveillance Radar and Identification Friend or Foe (IFF) systems.

III. DATASET DESCRIPTION

The dataset is designed to support the prevention of blue-on-blue (friendly fire) incidents in battlefield environments using an embedded device–based identification and alert system. It contains data collected from embedded sensors, communication modules, and identification units carried by friendly soldiers or mounted on military vehicles. The primary objective of the dataset is to enable reliable identification of friendly forces and to assist in real-time decision-making during combat operations.

The dataset includes unique friendly unit or soldier IDs, GPS-based location coordinates (latitude and longitude) and identification status (friendly/unknown/hostile). It also records communication signals exchanged between embedded devices, such as signal strength (RSSI), transmission frequency, response time, and authentication results. Additional parameters may include weapon activation status, distance between units, alert flags generated by the system, and environmental conditions that affect communication, such as terrain type or signal obstruction.

The data is collected in real time under simulated or controlled battlefield scenarios using embedded platforms such as microcontrollers integrated with GPS modules and sensors. The dataset is structured in tabular form, where each row represents a single event or time instance, and each column corresponds to a specific parameter measured by the embedded system. This dataset is useful for analyzing system accuracy, evaluating friendly force identification performance, testing alert mechanisms, and developing algorithms to reduce friendly fire incidents in battlefield operations.

IV. METHODOLOGY

The block diagram shows an ESP32-based smart control and monitoring system. The ESP32 development board acts as the central controller of the entire system. It receives input from the heart rate sensor, which continuously monitors the user's heart rate to assess the physical condition of the person handling the gun.
The key input unit is used to authorize or lock the gun, ensuring that only permitted users can operate it.
Based on the received inputs and programmed logic, the ESP32 controls various output modules. The LCD displays important information such as heart rate status, system messages, and alerts. The GPS module provides real-time location tracking, which can be useful for monitoring and safety purposes. The laser module is controlled by the ESP32 for aiming or indication functions. Bluetooth enables wireless communication between the ESP32 and a mobile Bluetooth application, allowing remote monitoring, alerts, and control through a smartphone.

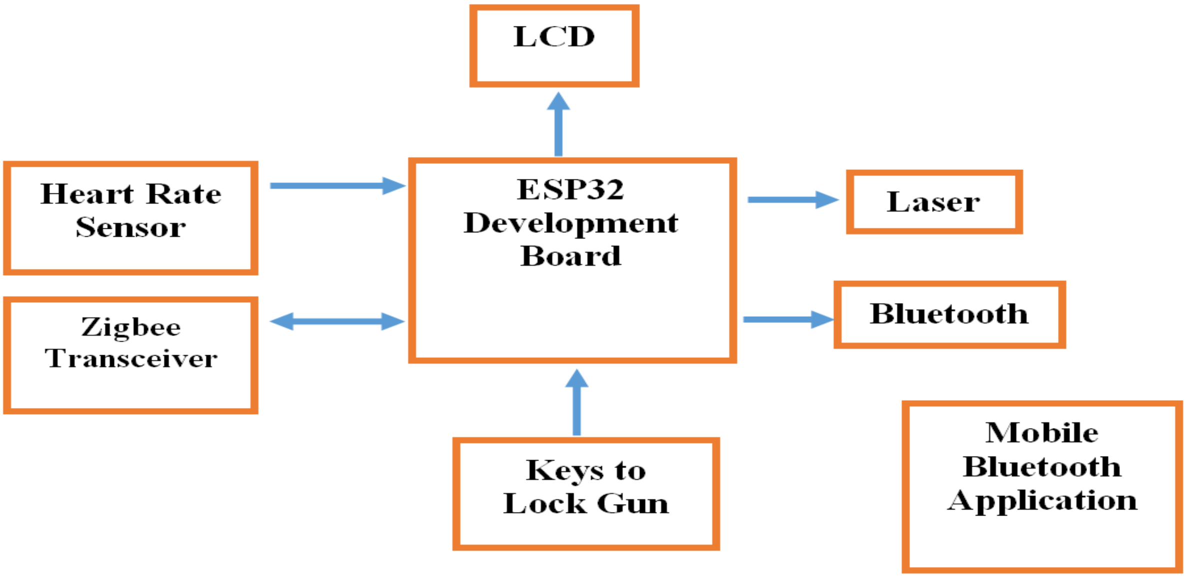

Fig 1: Block Diagram of Proposed System.

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The Soldier Protection System project is implemented using an ESP32 development board programmed in Embedded C and is designed with two main units: Soldier Unit 1, Soldier Unit 2 or Base Station represented by a mobile application for demonstration. Bluetooth communication is used to exchange data between the two soldier units and to update the base station. A heart rate sensor continuously monitors the soldier's health condition, and this physiological data along with GPS location information is transmitted to the base station in real time. Keys or switches are provided to lock the complete unit and to operate a laser gun. For identification and safety purposes, when a soldier needs to verify whether a distant person is a fellow soldier or an enemy, a key is pressed to request an ID code. This request is sent from Soldier Unit 1 to Soldier Unit 2 via Bluetooth, and Soldier Unit 2 automatically responds by transmitting the stored identification code based on the received command, ensuring secure and reliable soldier identification.

A. **ESP32 IOT Development Board**

ESP32 comes with an on-chip 32-bit microcontroller with integrated Wi-Fi + Bluetooth + BLE features that targets a wide range of applications. It is a series of low-power and low-cost developed by **Espress if Systems**.

ESP-WROOM-32E:

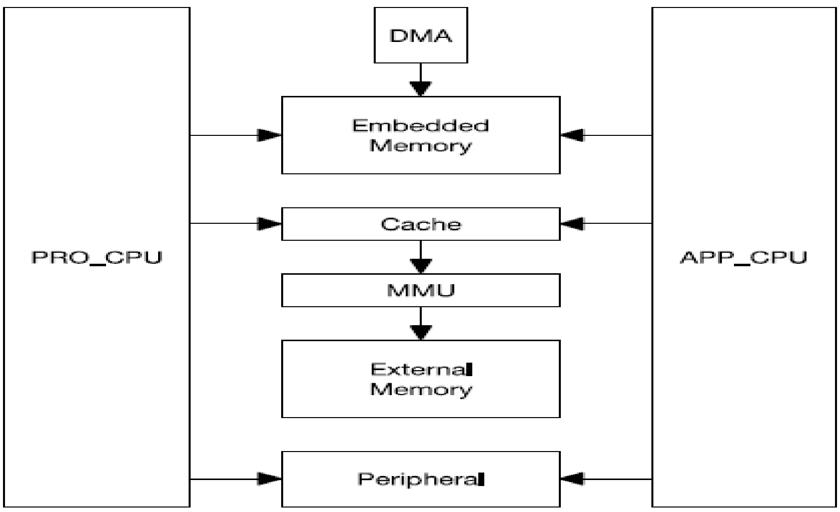
- ESP-WROOM-32E development board containing Tensilica Xtensa® Dual-Core 32-bit LX6 microprocessor operates at 80 to 240 MHz adjustable clock frequency.
- It comes with 448 KB of ROM, 520 KB of on-chip SRAM, and 4MB of Flash Memory.

System Architecture

The ESP32 is a dual-core system with two Harvard Architecture Xtensa LX6 CPUs. All embedded memory, external memory and peripherals are located on the data bus and/or the instruction bus of these CPUs.

The address mapping of two CPUs is almost symmetric, meaning that they use the same addresses to access the same memory. Multiple peripherals in the system can access embedded memory via DMA.

The two CPUs are named "PRO_CPU" and "APP_CPU" (for "protocol" and "application"), however, for most purposes the two CPUs are interchangeable.



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Wireless Connectivity

- On-chip Wi-Fi supports 802.11b/g/n standard
- Operates at 2.4 GHz band, up to 150 Mbps
- It also supports Bluetooth v4.2 BR/EDR and Bluetooth LE specifications this dual mode of Bluetooth makes it even more versatile

Reset/Boot buttons

- In ESP32 board comes with two main push buttons one is the Reset (RST/EN) button another is the BOOT button.
- The reset button is used to reset the ESP32 Chip.
- The use of the boot button is to enter in boot mode to upload the new sketch or program

Advanced Peripheral Interfaces:

GPIO: Total 32 Multifunctional GPIOs are available on the ESP-Wroom-32 development board which can be used for input/output devices. Every GPIO pin can be configured as an internal pull-up, pull-down, or set to high impedance. The input can also be set to edge-trigger or level-trigger to generate CPU interrupts.
Note: GPIO34, GPIO35, GPIO36, and GPIO39 are the only input pins

ADC: On-chip 12-bit SAR (Successive Approximation Registers) ADCs (Analog to Digital Converter) which supports measurements on 16 channels of ESP32.

PWM: ESP32 development board has support 8-bit 32 channels PWM. The pins with the symbol '~' represent that it has PWM support. It can be used for dimming LEDs or controlling motors etc.

I2C: The ESP32 development board has only one I2C bus interface (Supported in Arduino IDE), which can serve as an I2C master or slave, depending on the user's configuration.
The I2C interfaces support:

- Standard mode Support (100 Kbit/s)
- Fast mode Support (400 Kbit/s)
- Support both 7-bit and 10-bit addressing modes
- Dual addressing mode

UART: ESP32 development board has two UART interfaces UART0 and UART1. Both provide asynchronous communication and support to RS232, RS485, and IrDA too.

B. ALPHA-NUMERIC LCD DISPLAY

A **liquid crystal display** (**LCD**) is a flat panel display, electronic visual display, based on Liquid Crystal Technology. A liquid crystal display consists of an array of tiny segments (called pixels) that can be manipulated to present an information. Liquid crystals do not emit light directly instead they use light modulating techniques.

LCDs are preferred to cathode ray tube (CRT) displays in most applications because

1. The size of LCDs come in wider varieties.
2. They do not use Phosphor; hence images are not burnt-in.
3. Safer disposal
4. Energy Efficient
5. Low Power Consumption

It is an electronically modulated optical device made up of any number of segments filled with liquid crystals and arrayed in front of a light source (backlight) or reflector to produce images in color or monochrome.

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C. LASER

A **laser** is a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation. The term "laser" originated as an acronym for *Light Amplification by Stimulated Emission of Radiation*.Lasers differ from other sources of light because they emit light coherently. A laser consists of a gain medium, a mechanism to supply energy to it, and something to provide optical feedback. The gain medium is a material with properties that allow it to amplify light by stimulated emission. Light of a specific wavelength that passes through the gain medium is amplified (increases in power). For the gain medium to amplify light, it needs to be supplied with energy. This process is called pumping. The energy is typically supplied as an electrical current, or as light at a different wavelength. Pump light may be provided by a flash lamp or by another laser.

D. Pulse Sensor

Pulse Sensor is a well-designed plug-and-play heart-rate sensor for Arduino. It can be used by students, artists, athletes, makers, and game & mobile developers who want to easily incorporate live heart- rate data into their projects. The sensor clips onto a fingertip or earlobe and plugs right into Arduino. It also includes an open-source monitoring app that graphs your pulse in real time into their projects. The sensor clips onto a fingertip or earlobe and plugs right into Arduino. It also includes an open-source monitoring app that graphs your pulse in real time.

The Pulse Sensor Kit includes:

- A 24-inch Color-Coded Cable, with (male) header connectors. You'll find this makes it easy to embed the sensor into your project, and connect to an Arduino. No soldering is required.
- An Ear Clip, perfectly sized to the sensor. We searched many places to find just the right clip. It can be hot- glued to the back of the sensor and easily worn on the earlobe.
- Velcro Dots. These are 'hook' side and are also perfectly sized to the sensor. You'll find these velcro dots very useful if you want to make a velcro (or fabric) strap to wrap around a fingertip.
- Velcro strap to wrap the Pulse Sensor around your finger.
- Transparent Stickers. These are used on the front of the Pulse Sensor to protect it from oily fingers and sweaty earlobes.
- The Pulse Sensor has 3 holes around the outside edge which make it easy to sew it into almost anything.

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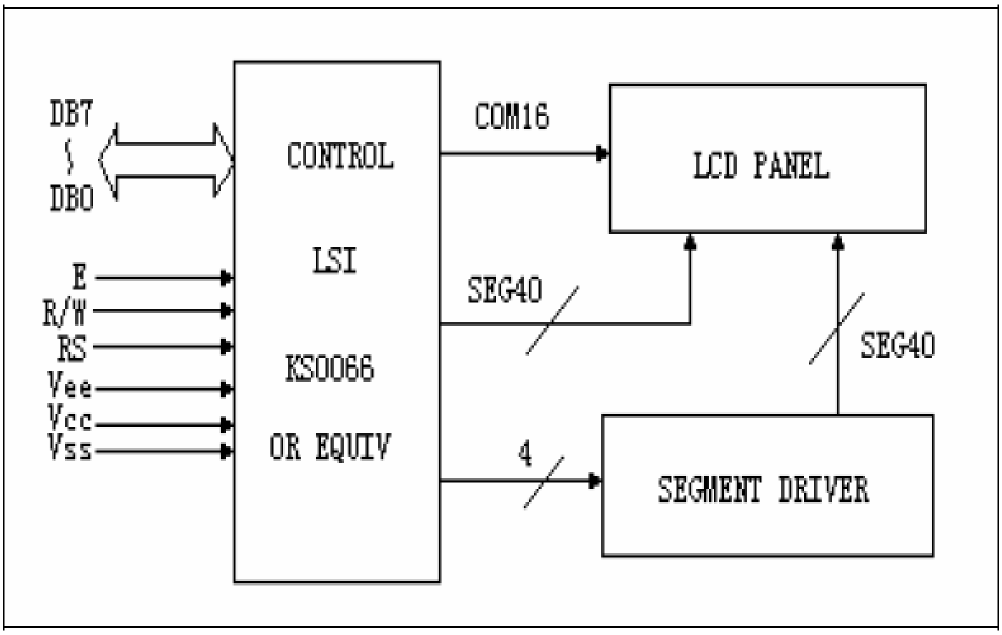
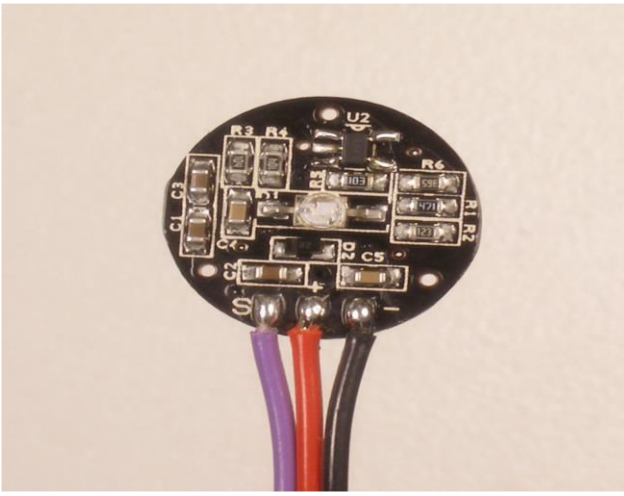


Running The Pulse Sensor Code

Get the latest Arduino and Processing Pulse Sensor software here http://pulsesensor.com/downloads/ Arduino code is called "PulseSensorAmped_Arduino- xx". The Processing code is called "Pulse Sensor Amped_Processing-xx" For Arduino and Processing programming environments: www.arduino.cc www.processing.org.

We strongly advise that you DO NOT connect the Pulse Sensor to your body while your computer or arduino is being powered from the mains AC line. That goes for charging laptops and DC power supplies. Please be safe and isolate yourself from from the power grid, or work under battery power.Connect the Pulse Sensor to: +V (red), Ground (black), and Analog Pin 0 (purple) on your favorite Arduino, or Arduino compatible device, and upload the 'PulseSensoAmped_Arduino-xx' sketch.



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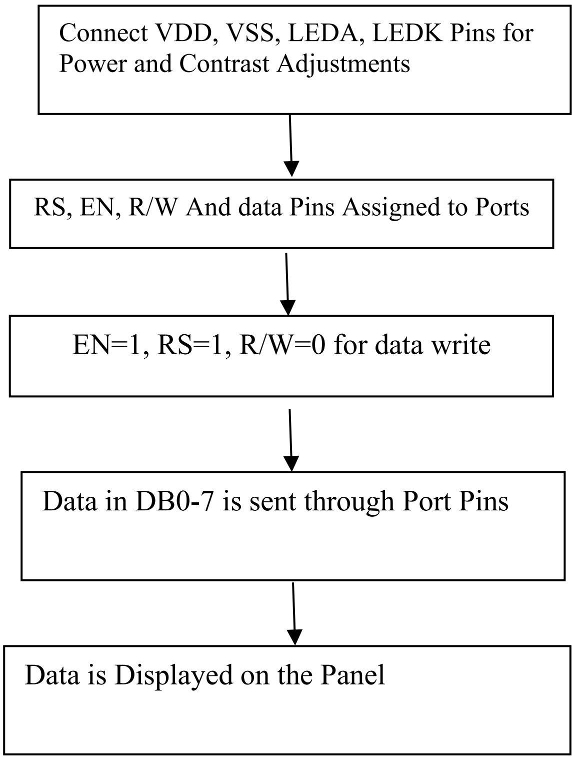
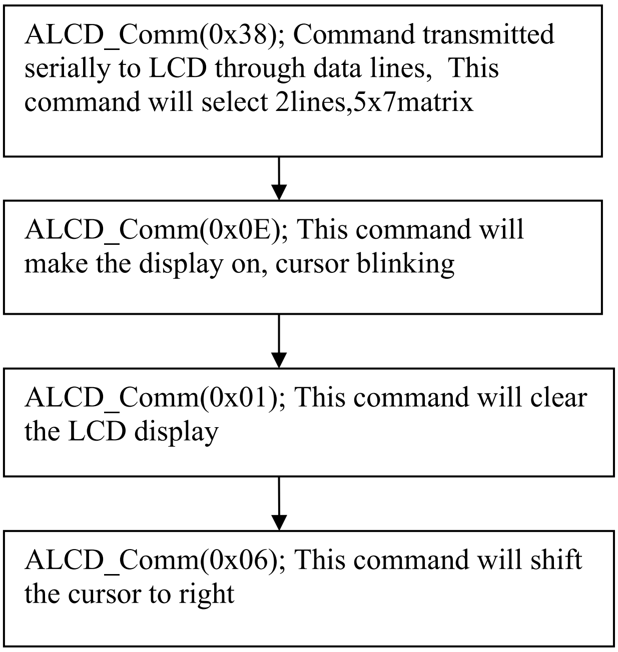
Flow Chart



voidALCD_Init(void)



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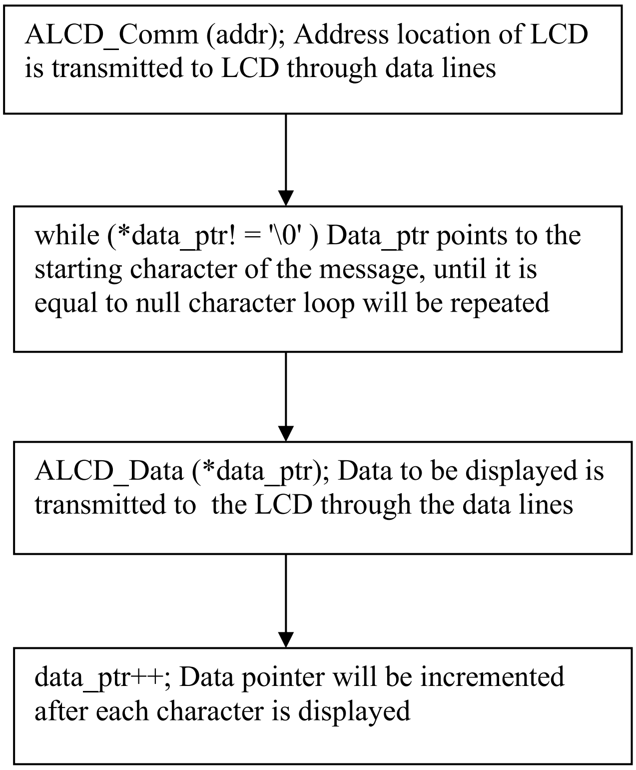
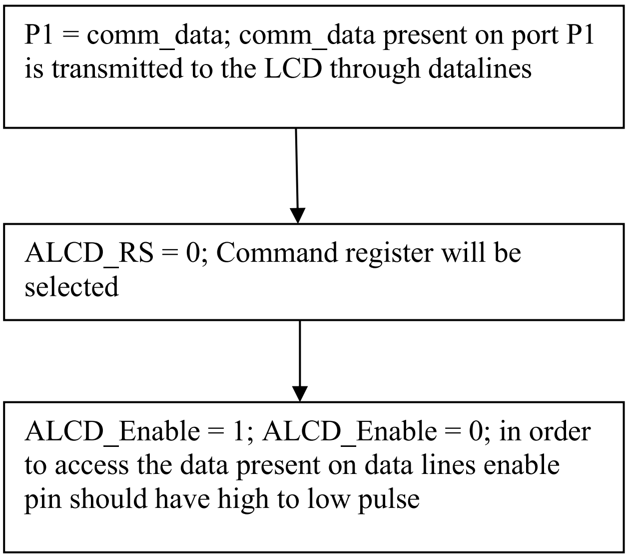
LCD message function
void ALCD_Message (unsigned char addr, unsigned char *data_ptr)



LCD command function
void ALCD_Comm (charcomm_data)



V. RESULTS AND DISCUSSION

The project successfully demonstrates a working prototype of an embedded Blue-on-blue prevention system designed to reduce friendly fire incidents in battlefield environments. The developed system is capable of identifying friendly soldiers or vehicles in real time using unique identification signals transmitted by embedded nodes. Each soldier/unit is equipped with a compact embedded device consisting of a microcontroller, RF/GPS module, and identification

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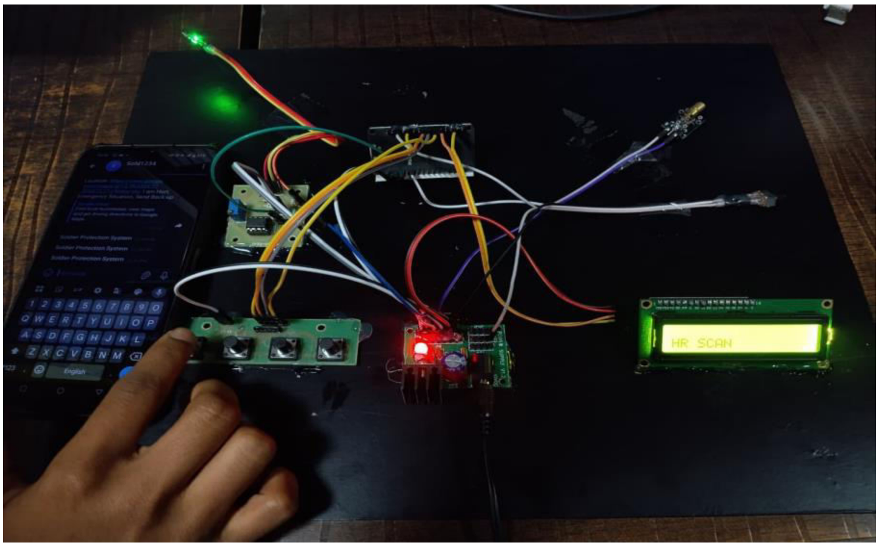
transmitter. When a unit enters the operational range, the system detects and verifies the friendly ID and alerts the user through visual (LED/display) preventing accidental engagement. The system was tested under simulated battlefield conditions and showed accurate detection of friendly units within the defined range, with minimal response delay. The embedded device operates with low power consumption, making it suitable for long-duration missions. The project proves that embedded technology can effectively assist soldiers in decision-making, especially in low-visibility or high-stress combat scenarios.

VI. LIMITATIONS AND FUTURE

Despite its advantages, blue-on-blue prevention systems using embedded devices have several limitations. The performance of such systems heavily depends on communication reliability; RF, GPS, or IR signals can be degraded by terrain, weather conditions, buildings, jamming, or electronic warfare. GPS dependency is another major issue, as GPS



signals may be unavailable, inaccurate, or deliberately spoofed in hostile environments. Embedded devices also face power constraints, since batteries may drain quickly during prolonged missions, reducing system availability. Identification errors can occur due to device malfunction, signal collision, or delays in data transmission, potentially leading to false alarms or missed detections. Additionally, scalability and interoperability are challenges when integrating devices across different units, platforms, or allied forces using varied communication standards. The system may also increase equipment load on soldiers and raises cybersecurity risks, as enemy forces may attempt hacking, spoofing, or signal interception.

The future of blue-on-blue prevention systems is promising with advancements in IoT, AI, and sensor fusion. Future systems can integrate AI and machine learning to improve decision-making accuracy by analyzing movement patterns, behavioral data, and contextual battlefield information. Multi-sensor fusion combining GPS, inertial navigation systems, vision sensors, and biometric identification can reduce dependence on a single technology and enhance reliability. Emerging secure communication technologies, such as encrypted mesh networks and anti-jamming protocols, will improve robustness in contested environments. Miniaturization of embedded hardware and energy-efficient designs will reduce power consumption and soldier load. In the future, these systems may evolve into fully autonomous and interoperable battlefield awareness platforms, significantly minimizing friendly fire incidents and improving mission safety and effectiveness.

VII. CONCLUSION

The project on Blue-on-Blue Prevention in the Battlefield Using an Embedded Device demonstrates the effectiveness of embedded systems in reducing friendly fire incidents and improving situational awareness during combat operations. By using technologies such as unique identification, GPS positioning, and wireless communication, the proposed system enables reliable recognition of friendly forces in real time and provides timely alerts before weapon engagement. This enhances decision-making, operational safety, and coordination among soldiers and military units in complex battlefield environments.

The implementation highlights that embedded device–based solutions are cost-effective, portable, and adaptable to modern warfare requirements. Although challenges such as communication reliability, power limitations, and security concerns exist, the project proves that technological intervention can significantly minimize human error,

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which is a major cause of blue-on-blue incidents. Overall, this project lays a strong foundation for future advancements by integrating intelligent algorithms, secure communication, and advanced sensors, contributing toward safer and more efficient battlefield operations

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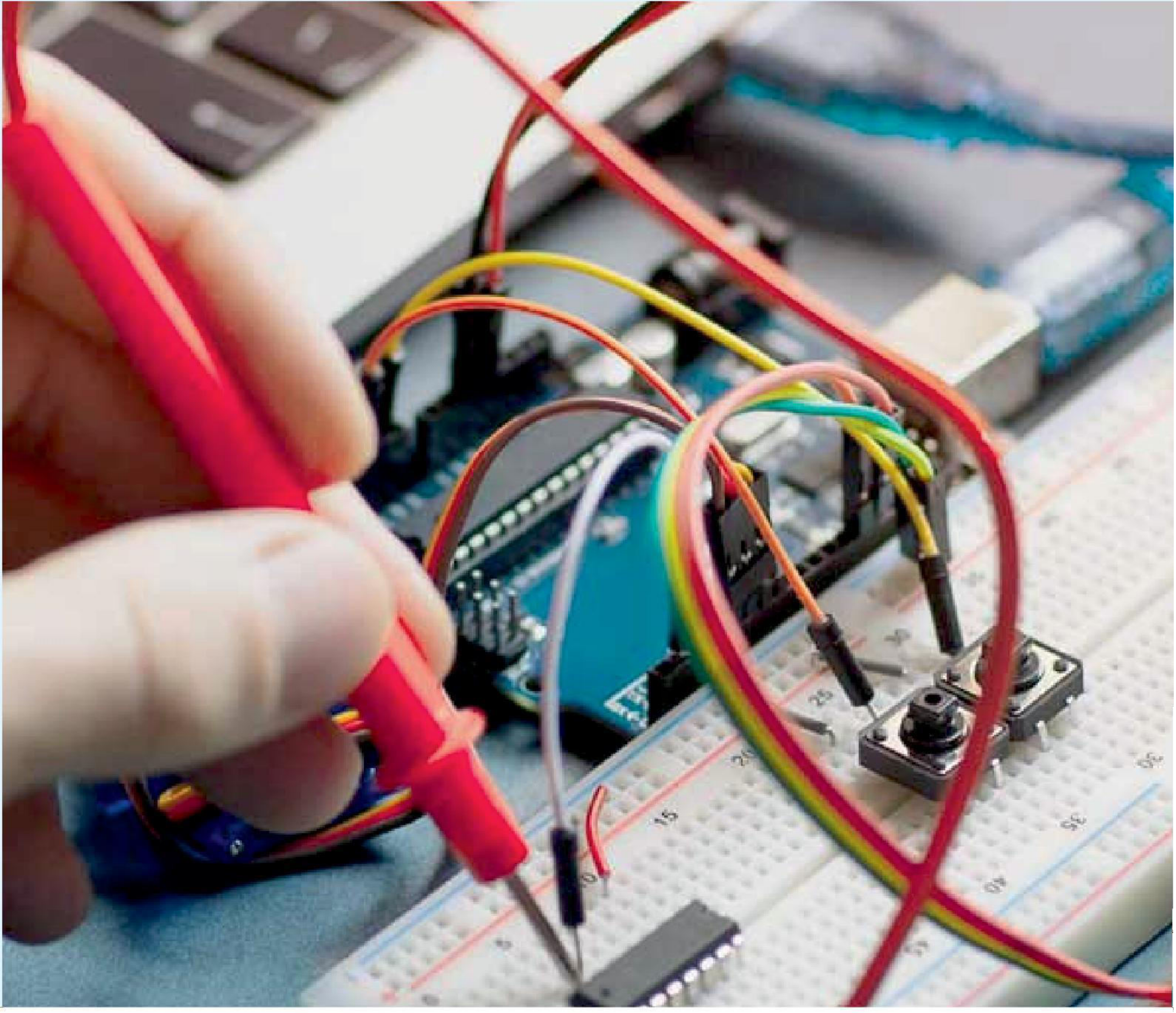

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