SMART ASSISTANCE SYSTEM FOR MARITIME BORDER SECURITY AND FISHERMEN NAVIGATION

A PROJECT REPORT

Submitted by

ANBARASU S 710021105006

MOHANRAJ R 710021105027

SELVANAGARAJAN M 710021105035

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ANNA UNIVERSITY::CHENNAI 600 025

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BONAFIDE CERTIFICATE

Certified that this project report **“SMART ASSISTANCE SYSTEM FOR MARITIME BORDER SECURITY A ND FISHERMEN NAVIGATION”** is the Bonafide work of “ **ANBARASU S, MOHANRAJ R, SELVANAGARAJAN M”** who carried out the project work under my supervision.

SIGNATURE	**SIGNATURE**
Dr. S. SARAVANA KUMAR M.E., Ph.D.,	Dr. M. NEWLIN RAJKUMAR M.S., Ph.D.,
HEAD OF THE DEPARTMENT	**SUPERVISOR**
ELECTRICAL AND ELECTRONICS ENGINEERING	ELECTRICAL AND ELECTRONICS ENGINEERING
ANNA UNIVERSITY REGIONAL CAMPUS, COIMBATORE- 641046	ANNA UNIVERSITY REGIONAL CAMPUS, COIMBATORE- 641046

Submitted for project viva-voce examination held on ....

INTERNAL EXAMINER **EXTERNAL EXAMINER**

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ANBARASU S 710021105006,

MOHANRAJ R 710021105027,

SELVANAGARAJAN M 710021105035

ABSTRACT

This project presents a Smart Assistance System designed to improve maritime border security and ensure the safe navigation of fishing vessels. The system uses Arduino UNO microcontrollers and LoRa (Long Range) communication technology to deliver a low-cost, energy-efficient, and real-time solution for monitoring boat locations near international maritime boundaries. The system consists of two main components: a transmitter unit placed on the fishing vessel and a receiver unit located at a shore-based control center. The transmitter is connected to a GPS module that constantly tracks the real-time geographic position of the vessel. This location data is transmitted wirelessly via LoRa to the receiver, which analyzes the coordinates and determines the vessel's position in relation to predefined maritime zones. These zones are classified as safe, warning, or restricted based on their proximity to international boundaries. After receiving the boat's coordinates, the receiver performs a zone analysis and sends feedback to the vessel. Visual and audio alerts are used to inform the fishermen of their current zone using colored LEDs (green, yellow, and red) and a buzzer. This allows them to respond quickly and make informed navigational decisions. In addition, the system features an automatic control mechanism that adjusts the boat's motor speed depending on the zone, helping to prevent unauthorized or accidental entry into restricted maritime areas. In summary, this Smart Assistance System supports safer and more responsible fishing practices while contributing to broader goals of maritime security and coastal safety. It offers an affordable, practical, and scalable solution that can be adopted by coastal regions facing similar challenges near maritime borders. The system helps both fishermen and authorities by improving real-time awareness, preventing border violations, and supporting sustainable coastal operations.

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LIST OF ABBREVIATIONS

GPS	- Global Positioning System
LoRa WAN	- Long Range
LCD	- Liquid Crystal Display
LED	- Light Emitting Diode
IOT	- Internet Of Things
WSN	- Wireless Sensor Network
GSM	- Global System for Mobile communication
IDE	- Integrated Development Environment
UPS	- Uninterruptible Power Supply
Vcc	- Voltage Common Collector (Power supply pin)
PCB	- Printed Circuit Board
Tx/Rx	- Transmit/Receiver
GND	- Ground

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CHAPTER – 1
INTRODUCTION

1.1 OVERVIEW

Maritime border security and the safety of fishermen are vital issues, particularly in coastal regions where international maritime boundaries are either poorly marked or completely invisible at sea. In such areas, fishermen who rely on traditional methods of navigation often face the risk of unintentionally crossing into restricted or foreign waters. These accidental intrusions can lead to serious consequences, including legal penalties, heavy fines, detention, or even imprisonment by foreign authorities. The lack of real-time awareness and technological support exposes both the fishermen and national maritime security to significant risks.

To mitigate these challenges, the proposed Smart Assistance System offers a technologically advanced yet cost-effective solution, utilizing the capabilities of Arduino UNO microcontrollers, GPS modules, and LoRa (Long Range) wireless communication. This system is specifically tailored to assist fishermen in safe navigation while simultaneously supporting maritime border enforcement. It continuously tracks the location of fishing vessels using a GPS module installed on the transmitter (TX) unit placed aboard the boat. The real-time location data is then transmitted wirelessly to a receiver (RX) unit located onshore, such as at a harbour control room or a coastal surveillance centre, via the energy-efficient and long-range LoRa communication protocol.

For efficient monitoring and alert management, the maritime area is logically segmented into three distinct zones: Zone 1 (safe zone), Zone 2 (caution or warning zone), and Zone 3 (restricted or border zone). Based on the live GPS coordinates, the system determines the current zone of the fishing vessel and immediately triggers appropriate alerts on the TX side. These alerts are conveyed to the fishermen through simple yet effective indicators—green, yellow, and red LEDs corresponding to the respective zones, along with an audible buzzer for heightened awareness in critical situations.

Beyond alerting, the system also incorporates an intelligent motor control feature. When a vessel begins to approach or enter Zone 3, the system automatically reduces the speed of the boat's motor or can even halt it temporarily, acting as a preventive safety mechanism. This not only minimizes the chances of accidental border crossing but also buys the fishermen time to reassess and navigate safely back into permitted waters. From a broader perspective, the system empowers fishermen with better situational awareness while aiding maritime authorities in remotely monitoring boat movements, thereby enhancing overall coastal vigilance and national security.

Designed with low-cost hardware components and minimal power requirements, the system is ideal for deployment in resource-constrained fishing communities. Its scalability and simplicity make it a practical tool for widespread adoption across various coastal regions facing similar maritime boundary challenges. In essence, this Smart Assistance System addresses both humanitarian and security aspects by protecting the livelihood and freedom of fishermen while supporting international border compliance and surveillance.

1.2. OBJECTIVE

Fishermen operating near international maritime boundaries face critical challenges due to the lack of clearly marked borders at sea. These invisible boundaries make it difficult for traditional and small-scale fishermen to determine their exact location, leading to unintentional border crossings. Such incidents often result in arrests, penalties, vessel confiscation, and strained international relations.

A key issue is the inaccessibility of advanced navigation tools like GPS chart plotters and satellite-based systems, which are typically expensive and require technical expertise. Most traditional fishermen lack real-time location awareness and alert mechanisms, increasing the risk of unknowingly entering restricted or foreign waters.

This situation poses both safety risks for fishermen and national security concerns for coastal states, especially in regions with sensitive or disputed maritime boundaries. The inability to monitor and manage vessel movements effectively limits the enforcement of maritime laws.

To address these challenges, a Smart Assistance System has been proposed. This system is built on an Arduino-based microcontroller platform, integrated with GPS for real-time location tracking and LoRa communication technology for long-range data transmission. Key features include:

- Real-time vessel tracking
- Zone-based analysis of maritime boundaries
- Immediate audio-visual alerts when entering warning or restricted zones
- Automated motor control to assist with legal compliance

The system is designed to be affordable, user-friendly, and reliable, making it suitable for traditional fishermen. By providing timely alerts and tracking capabilities, it enhances fishermen's safety, supports maritime law enforcement, and contributes to improved border management.

1.3. PROBLEM STATEMENT

Fishermen operating near international maritime boundaries often encounter serious challenges stemming from the absence of clearly marked or visible border demarcations at sea. Unlike land borders, maritime boundaries are not physically defined, making it extremely difficult for fishermen—especially those using traditional boats—to determine their precise location relative to these invisible borders. As a result, accidental border crossings are common, and these unintentional violations frequently lead to severe consequences, such as arrest, imprisonment, fines, and the confiscation of fishing vessels by foreign coast guards or naval authorities. These events not only disrupt the livelihoods of the fishermen and their families but also strain diplomatic relations between neighbouring countries.

Compounding the issue is the lack of access to reliable navigation tools. Most traditional or small-scale fishermen cannot afford sophisticated marine navigation equipment like GPS chart plotters or satellite-based tracking systems, which are often expensive, complex, and require technical expertise. The absence of a real-time alert or communication system means that fishermen have no way of knowing when they are nearing a restricted zone, leaving them vulnerable to crossing into foreign waters unknowingly. In many coastal areas, there is also limited infrastructure for maritime surveillance, making it difficult for authorities to track vessel movements or respond proactively to border breaches.

This situation not only places the safety and freedom of fishermen at risk but also presents a broader national security concern. In regions with sensitive or disputed maritime borders, such unchecked movement complicates border enforcement and undermines the effectiveness of maritime security operations. Therefore, there is a critical and urgent need for a solution that can assist both fishermen and authorities—a system that is affordable, easy to operate, and capable of delivering real-time location monitoring and alerts. To address this gap, the proposed Smart Assistance System has been conceptualized. It utilizes an Arduino-based microcontroller platform integrated with GPS and LoRa (Long Range) communication technology to create a real-time, zone-based navigation aid. The system is designed to track the vessel's position continuously, analyse it against predefined maritime zones, and provide immediate audio-visual alerts to the fishermen as they approach or enter warning or restricted areas. Additionally, it offers automated motor control functionality to regulate the boat's movement, helping to enforce legal compliance. By doing so, this system not only safeguards the lives and livelihoods of coastal fishing communities but also enhances maritime border security and supports government efforts to manage and monitor effectively.

CHAPTER 2

LITERATURE REVIEW

2.1 IOT-BASED FISHING VESSEL TRACKING AND ALERT SYSTEM FOR MARITIME SAFETY

Authors: Kumar, A., & Rathi, P.

Journal/Conference: Marine Science and Technology, 28(5), 729-738.

Year: 2020

Abstract:

This paper presents the design and implementation of an IoT-based fishing vessel tracking and alert system to enhance maritime safety. The system integrates GPS technology and real-time location tracking with an alert mechanism to inform fishermen when they approach maritime boundaries or restricted zones. The system uses low-power sensors, which communicate data through a wireless network to a centralized monitoring system. The goal is to improve the security of fishermen by providing them with timely warnings, thereby reducing accidents and ensuring legal compliance in international waters.

Methodology:

The proposed system uses a GPS module to track the position of the fishing vessel and a wireless communication network to transmit location data to the monitoring station. The system employs an Arduino-based microcontroller to process and manage the GPS data, which is then transmitted via an IoT network. Based on predefined geographic zones (safe, warning, restricted), alerts are generated when the vessel approaches or enters the restricted zone. The system features a mobile application to display real-time data to the fishermen and provide instant alerts.

Results:

The system successfully tracked the location of the fishing vessel and provided real-time alerts when approaching predefined boundaries. Testing showed that the system was able to transmit location data over long distances, with minimal power consumption. The alert mechanism, consisting of visual and auditory signals, was effective in notifying fishermen about their proximity to danger zones. Additionally, the system demonstrated its ability to function under varying weather conditions, with good accuracy in GPS data reception.

2.2 GPS TRACKING AND MONITORING SYSTEM FOR COASTAL MARINE VESSELS

Authors: Zhang, Y., & Zhao, L.

Journal/Conference: Navigation, 72(4), 871-885.

Year: 2019

Abstract:

This paper discusses the design of a GPS-based tracking and monitoring system for coastal marine vessels, aiming to improve navigation safety and border control. The system integrates GPS technology with a centralized monitoring platform to continuously track vessels' locations in real-time. It also provides geofencing capabilities to alert when vessels enter restricted areas. The system is designed to be cost-effective, efficient, and easily deployable in various coastal regions.

Methodology:

The GPS tracking system collects real-time position data from the vessels using GPS receivers. This data is then transmitted to a centralized monitoring system where it is processed and visualized. The system incorporates a geofencing feature to define virtual boundaries and trigger alerts if a vessel enters restricted or dangerous zones. The effectiveness of the system is tested by deploying it on several vessels and monitoring their movements within the defined areas.

Results:

The GPS tracking system successfully tracked the position of marine vessels and provided real-time alerts when they entered restricted zones. The system showed high accuracy in location tracking and was able to maintain communication even in challenging coastal conditions. The geofencing feature was particularly useful in monitoring maritime boundaries and preventing illegal fishing activities or unintentional crossings into foreign waters. The system proved to be reliable, with minimal latency in the alerts.

2.3 A COMPREHENSIVE REVIEW ON IOT-BASED APPLICATIONS FOR SMART MARITIME SYSTEMS

Authors: Manogaran, G., & Thiruvengadam, P.

Journal/Conference: Ocean Engineering, 175, 92-103.

Year: 2019

Abstract:

This paper provides a comprehensive review of Internet of Things (IoT)-based applications in smart maritime systems, focusing on their potential to enhance safety, navigation, and environmental monitoring in marine environments. The review covers a wide range of IoT applications, from vessel tracking and border security to weather monitoring and pollution detection. The paper discusses the integration of IoT technologies with sensors, cloud computing, and data analytics to create more efficient and reliable maritime systems.

Methodology:

The methodology involves a detailed analysis of existing IoT-based maritime applications, examining the technologies used, their effectiveness, and the challenges faced in implementation. Case studies of IoT systems deployed in marine environments are reviewed, including vessel tracking, environmental monitoring, and smart port management. The paper identifies key trends and innovations in IoT for maritime applications and suggests areas for future research and development.

Results:

The review concludes that IoT has a significant potential to improve various aspects of maritime operations, including vessel tracking, border security, and environmental monitoring. The integration of IoT sensors and cloud-based data analysis can enable real-time decision-making and improve the overall safety and efficiency of maritime systems. However, the study also highlights challenges such as data security, power consumption, and connectivity in remote maritime areas.

2.4 A REAL-TIME MONITORING SYSTEM FOR MARITIME BOUNDARY SECURITY

Authors: Goh, H., & Loh, H.

Journal/Conference: Maritime and Coastal Technologies, 110-118.

Year: 2019

Abstract:

This paper explores the design and implementation of a real-time maritime boundary monitoring system that aims to enhance security along maritime borders. The system integrates satellite-based GPS tracking with a monitoring platform that processes location data in real-time to detect boundary breaches or other suspicious activities. It is designed to ensure that maritime vessels remain within safe and legal zones, providing alerts when boundaries are breached.

Methodology:

The methodology involves the development of a real-time monitoring system that utilizes GPS technology to track vessel locations. The system combines GPS data with a boundary detection algorithm to determine when a vessel crosses predefined maritime zones. The data is transmitted via wireless communication to a central monitoring station. Alerts are triggered when a vessel enters a restricted zone, and real-time updates are provided through a user interface.

Results:

The system successfully detected boundary breaches and provided real-time alerts for vessels entering restricted zones. The accuracy of the GPS data and the responsiveness of the alert mechanism were found to be satisfactory under typical operating conditions. The system was tested in a simulated maritime environment and proved effective in detecting boundary violations, highlighting its potential for real-world deployment.

2.5 DEVELOPMENT OF A SMART MARITIME SECURITY SYSTEM FOR FISHERMEN USING GPS AND IOT-BASED COMMUNICATION

Authors: Rajendran, A., & Viswanathan, P.

Journal/Conference: Marine Science and Technology, 42(1), 84-92.

Year: 2020.

Abstract:

This paper focuses on the development of a smart maritime security system for fishermen, integrating GPS and IoT-based communication technologies. The system tracks the real-time location of fishing vessels, monitors proximity to restricted zones, and provides alerts through a wireless communication system. The goal is to ensure that fishermen can navigate safely while complying with maritime regulations.

Methodology:

The system is built using a combination of GPS modules and IoT devices. Real-time GPS location data is transmitted via IoT communication systems to a central platform, which processes and stores the data. A geofencing mechanism is implemented to monitor boundary conditions and send alerts when a vessel approaches restricted zones. The system was implemented on test vessels, and performance was evaluated based on accuracy, response time, and power consumption.

Results:

The smart maritime security system successfully monitored the location of fishing vessels in real-time. The geofencing feature was effective in detecting when vessels entered restricted zones and triggered alerts. The system operated with minimal power consumption, which is ideal for long-duration use. The real-time data transmission and alert mechanism were found to be highly reliable in enhancing safety and security for fishermen.

CHAPTER 3

SYSTEM STUDY

3.1 EXISTING SYSTEM

The existing system focuses on enhancing the safety and legal compliance of fishermen operating near international maritime boundaries using Global Positioning System (GPS) technology and Wireless Sensor Networks (WSNs). The core goal is to prevent fishermen from unintentionally crossing national borders, particularly between countries like India and Sri Lanka, which share sensitive coastal zones. Border violations by fishermen often result in serious consequences, including boat seizures and arrests by foreign coast guards. This system aims to mitigate such incidents by providing real-time alerts and control mechanisms using GPS, GSM, and Internet of Things (IoT) technologies.

In the existing model, each fishing vessel is equipped with a GPS receiver that continuously tracks the location of the boat using latitude and longitude coordinates. These coordinates are then compared to predefined maritime boundaries. When the vessel approaches a border, the system issues a series of alerts to the fishermen. A loudspeaker acts as a siren, and a Liquid Crystal Display (LCD) visually notifies the user. This two-layered alert mechanism ensures the fishermen are made aware of their proximity to the boundary. If the boat continues to approach or crosses into restricted waters, the system includes a fail-safe feature: the boat’s engine is automatically turned off using a relay circuit. This automatic control helps prevent accidental entry into foreign territory and forces the vessel to stop or turn back, thereby avoiding violations.

The communication between the boat and remote servers or monitoring systems can be established using WSNs, making it possible for authorities or vessel owners to monitor the boat's location remotely. Additionally, this technology ensures that both the Indian and Sri Lankan governments can have simultaneous access to the location data, promoting transparency and international cooperation in maritime monitoring. The system is designed with the specific challenges of coastal fishing communities in mind. Many fishermen from areas like Tamil Nadu, India, lack formal navigation training and rely heavily on environmental cues. This makes technological assistance essential. The integration of GPS and GSM in the system ensures that location tracking is accurate and data transmission is efficient even in remote marine regions. Moreover, the alert messages delivered through audio and visual means make the system accessible and user-friendly, even for those with limited technical skills. This border alert system also displays real-time data such as the vessel's speed, allowing fishermen to make informed decisions about navigation. The design intends to be a low-cost, practical solution that does not require constant manual supervision. Instead, it automates the monitoring and alerting process, thereby enhancing safety, compliance, and peace of mind for both fishermen and coastal security forces.

In conclusion, the existing system offers a reliable, GPS-based method for detecting and alerting fishermen about maritime borders. It plays a vital role in preventing accidental border crossings, enhancing coastal safety, and reducing diplomatic tensions arising from such incidents.

3.1.1 DRAWBACKS OF EXISTING SYSTEM

- GSM fails in remote waters.
- High power consumption.

- SIM-based costs.
- Engine auto shutdown risks.
- Signal loss leads to false alerts.
- Fishermen face tech literacy issues.
- No protection from foreign coast guards.
- High hardware maintenance in marine weather.

3.2 PROPOSED SYSTEM

To address the challenges faced by fishermen near international maritime boundaries and to support coastal authorities in enforcing border security, a Smart Assistance System is proposed. This system combines Arduino UNO, GPS technology, and LoRa (Long Range) wireless communication to create a reliable, low-cost, and user-friendly platform for real-time location monitoring, alert generation, and vessel control.

The system consists of two main components:

1. Transmitter (TX) Unit – Onboard the Fishing Vessel:
   - This unit is equipped with a GPS module that continuously captures the real-time coordinates of the boat.
   - The data is processed by an Arduino UNO, which prepares the location information for wireless transmission.
   - Using a LoRa module, the GPS data is sent to a remote receiver station onshore.
   - Based on feedback from the receiver (regarding the boat’s zone), the onboard system uses LED indicators (green, yellow, red) and a buzzer to notify fishermen about their proximity to restricted or international zones.

- The system is also capable of automatically controlling the motor speed—slowing down or stopping the boat when approaching dangerous or restricted zones, thus preventing accidental violations.

2. Receiver (RX) Unit – Located at the Shore or Monitoring Station:

- This unit receives the GPS data from the vessel through LoRa communication.
- It compares the boat's location with predefined maritime zone coordinates, such as:
- Zone 1 (Safe Zone): Normal operation.
- Zone 2 (Warning Zone): Alert the fisherman via yellow LED and buzzer.
- Zone 3 (Restricted/Border Zone): Issue a red alert and send control signals to adjust the motor.
- The receiver can also log the data for real-time tracking, enabling maritime authorities to monitor vessel movement and respond quickly to unauthorized entries.

Key Features of the Proposed System:

- Low-Cost & Scalable: Utilizes affordable microcontroller-based hardware suitable for small-scale fishing communities.
- Real-Time Monitoring: Ensures continuous tracking of vessel location with immediate alerts.
- Long-Range Communication: LoRa provides reliable communication over several kilometers, even in remote maritime areas.
- User-Friendly Alerts: Simple LED and buzzer interface to convey critical information without the need for complex equipment or technical knowledge.
- Safety & Compliance: Automated motor control ensures physical deterrence from entering illegal zones.

- Support for Authorities: Enables real-time tracking and logging of vessel movements for enforcement and policy planning.
- This Smart Assistance System offers a practical, efficient, and impactful solution to reduce accidental maritime border crossings, protect fishermen from legal consequences, and enhance national security through improved coastal monitoring.

3.2.1 ADVANTAGES OF PROPOSED SYSTEM

- Reliable Long-Range Communication.
- Low Power Consumption.
- Improved Data Transmission in Remote Areas.
- Cost-Effective Operation.
- Resilient and Weather-Tolerant Communication.
- Centralized Monitoring with Real-Time Alerts.
- Custom Alert Levels and Safer Engine Control.
- Better Integration with IoT and GPS.
- Adaptable for Training and Localization.
- Scalable and Easily Deployable.

CHAPTER 4

HARDWARE AND SOFTWARE REQUIREMENTS

4.1 HARDWARE REQUIREMENTS

- ARDUINO UNO
- POWER SUPPLY
- BUZZER
- MOTOR DRIVER
- DC MOTOR
- LCD
- GPS MODULE
- BATTERY
- LORA MODULE
- LED
- RESISTOR
- CONNECTING WIRES

4.2 SOFTWARE REQUIREMENTS

- Arduino IDE 1.8
- Embedded Programming
- Proteus 8

CHAPTER 5

SYSTEM DESIGN

5.1 BLOCK DIAGRAM

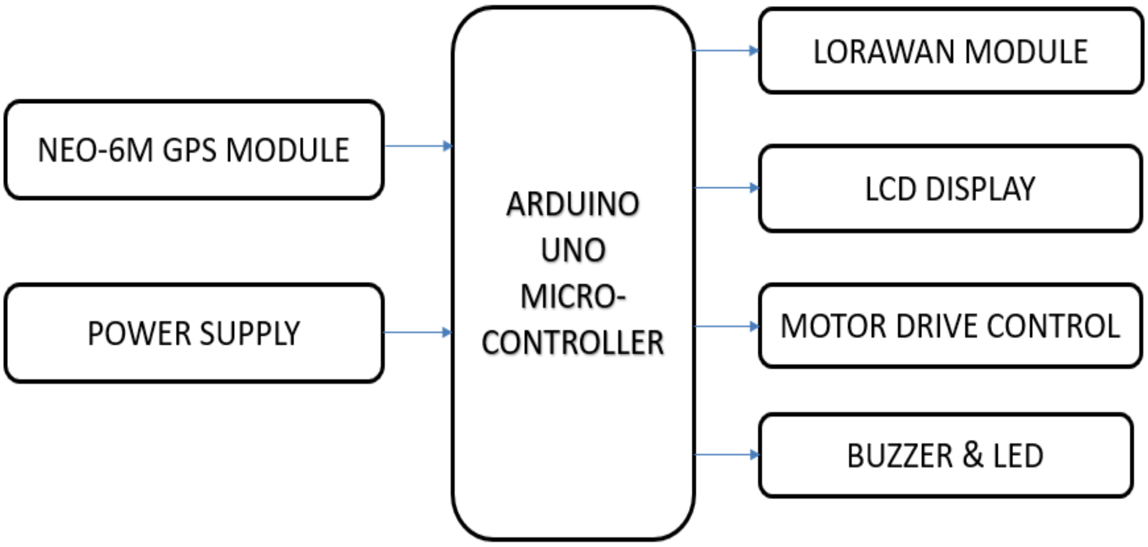


Fig. 5.1 BLOCK DIAGRAM

The block diagram illustrates the architecture of a Smart Assistance System designed to aid fishermen near maritime borders. At the core is the Arduino Uno microcontroller, which coordinates the entire system. A NEO-6M GPS module provides real-time location data, enabling the system to track the boat's position. The LoRaWAN module facilitates long-range wireless communication, allowing location updates to be sent to monitoring stations. An LCD display shows important data such as coordinates and alert messages to the user. The system also includes buzzer and LED indicators that provide audio-visual alerts when the vessel approaches or crosses into restricted zones. A motor drive control unit can intervene by regulating the boat's movement to prevent further border violations. The power supply ensures stable operation of all components. This integrated solution enhances the safety of fishermen, reduces accidental border crossings, and supports effective maritime monitoring and law enforcement.

5.2 SIMULATION DIAGRAM

The following diagram describes the GPS coordinates in realtime Fig 5.2,

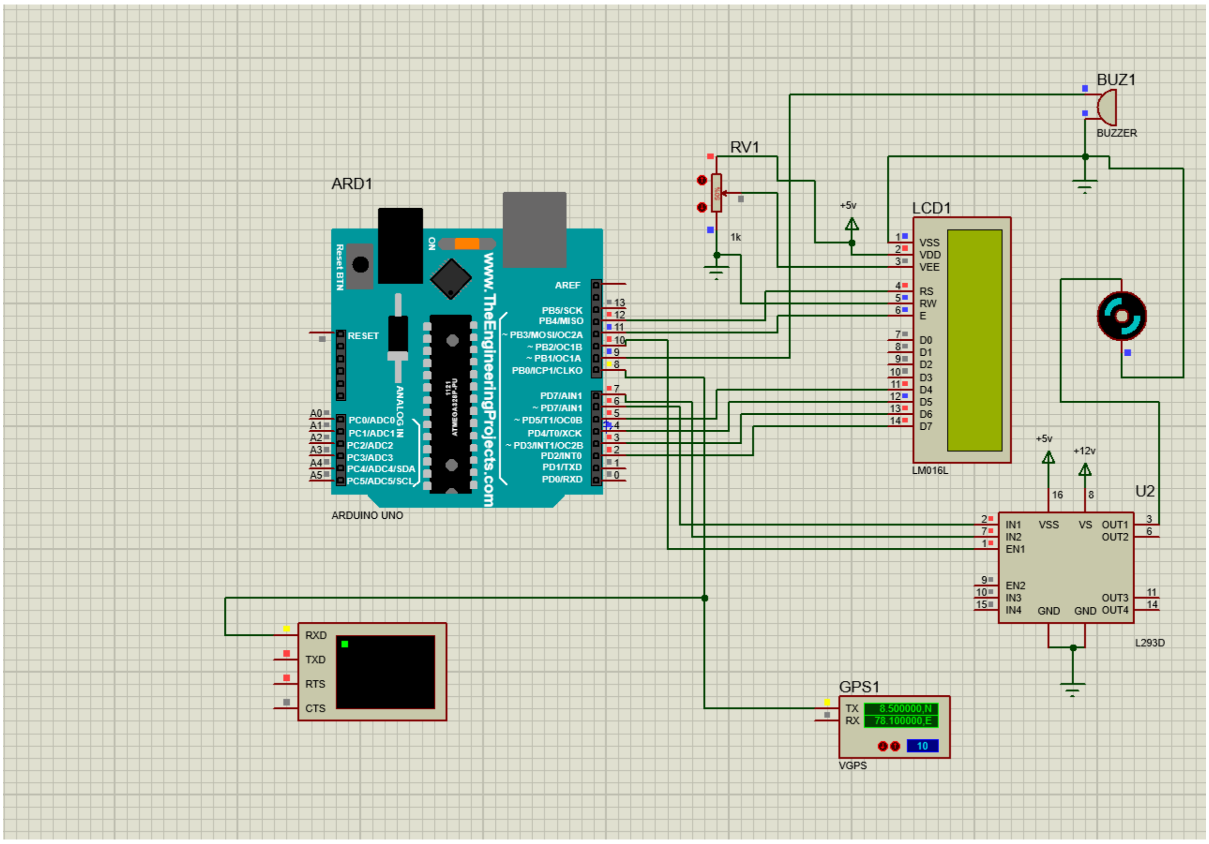


Fig. 5.2 Simulation diagram for GPS coordinates real time

The simulation diagram shows the implementation of a GPS-based Smart Assistance System using an Arduino Uno. It includes a NEO-6M GPS module for location tracking, an LCD display for real-time data output, a buzzer and LED for alerts, and a motor driver (L293D) for motion control.

CHAPTER 6

HARDWARE DESCRIPTION

6.1 ARDUINO UNO

INTRODUCTION TO ARDUINO

Arduino interface boards provide the engineers, artists, designers, hobbyists and anyone who tinker with technology with a low-cost, easy- to-use technology to create their creative, interactive objects, useful projects etc., A whole new breed of projects can now be built that can be controlled from a computer. Arduino is a open source electronics prototyping platform based on flexible, Easy - to-use hardware and Software. It’s intended for artists, designers, hobbyists, and anyone interested in Creating interactive objects or environments. It’s an open-source physical computing platform based on a microcontroller board, and a development environment for writing software for the board. In simple words, Arduino is a small microcontroller board with a USB plug to connect to your computer and a number of connection sockets that can be wired up to external electronics, such as motors, relays, light sensors, laser diodes, loudspeakers, microphones, etc., They can either be powered through the USB connection from the computer or from a 9V battery. They can be controlled from the computer or programmed by the computer and then disconnected and allowed to work independently.

ARDUINO UNO

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board. To do so you use the Arduino programming language (based on Wiring), and the Arduino Software (IDE), based on Processing.

Over the years Arduino has been the brain of thousands of projects, from everyday objects to complex scientific instruments. A worldwide community of makers - students, hobbyists, artists, programmers, and professionals - has gathered around this open-source platform, their contributions have added up to an incredible amount of accessible knowledge that can be of great help to novices and experts alike.

Arduino was born at the Ivrea Interaction Design Institute as an easy tool for fast prototyping, aimed at students without a background in electronics and programming. As soon as it reached a wider community, the Arduino board started changing to adapt to new needs and challenges, differentiating its offer from simple 8-bit boards to products for IOT applications, wearable, 3D printing, and embedded environments. All Arduino boards are completely open-source, empowering users to build them independently and eventually adapt them to their particular needs. The software, too, is open-source, and it is growing through the contributions of users worldwide.

MICROCONTROLLER

Microcontroller can be described as a computer embedded on a rather small circuit board. To describe the function of a microcontroller more precisely, it is a single chip that can perform various calculations and tasks, and send/receive signals from other devices via the available pins. Precisely what tasks and communication with the world it does, is what is governed by what instructions we give to the Microcontroller. It is this job of telling the chip what to do, is what we refer to as programming on it. However, the micro controller by itself cannot accomplish much; it needs several external inputs: power, for one; a steady clock signal, for another. Also, the job of programming it has to be accomplished by an external circuit. So typically, an uC is used along with a circuit which provides these things to it; this combination is called a microcontroller board The Arduino Uno that you have received, is one such microcontroller board. The actual microcontroller at its heart is the chip called Atmega328. The advantages that Arduino offers over other microcontroller boards are largely in terms of reliability of the circuit hardware as well as the ease of programming and using it

OPEN-SOURCE HARDWARE

Open-source hardware shares much of the principles and approach of free and open-source software. The founders of Arduino wanted people to study their hardware, to understand how it works, make changes to it, and share those changes with the world. To facilitate this, they release all of the original design files (Eagle CAD) for the Arduino hardware. These files are licensed under a Creative Common Attribution Share-Alike license, which allows for both personal and commercial derivative works, as long as they(people) credit Arduino and release their designs under the same license. The Arduino software is also open-source. The source code for the Java environment is released under the GPL and the C/C++ microcontroller libraries are under the LGPL.

HISTORY OF ARDUINO

While teaching a physical computing class at the Interaction Design Institute Ivrea in 2005, Massimo Banzi’s students were unwilling to spend the 76euros for the basic Stamp microcontrollers commonly used in such applications. Banzi and his colleges looked for alternatives, finally settling on the wiring platform developed by one of Banzi’s students.

In his own words: we started to figure out how could we make the whole platform even simpler, even cheaper, even easier to use. And then we started to essentially re implement the whole thing as an opensource project. Once they had a prototype, a student wrote the software that would allow wiring programs to reunion the new platform. Upon seeing the project, visiting professor Casey Reas suggested that there might be wider applications than just design schools for the new product. The prototype was redesigned for mass production and a test run of 200 boards was made. Orders began coming in from other design schools and the students looking for Arduinos. The Arduino project was born and Massimo Banzi and David Cuartielles became its founders. ARDUINO is an Italian word, meaning STRONG FRIEND. The English version of the name is Hardwin. As of May2011, more than 300,000 Arduino units are in the wild.

HARDWARE

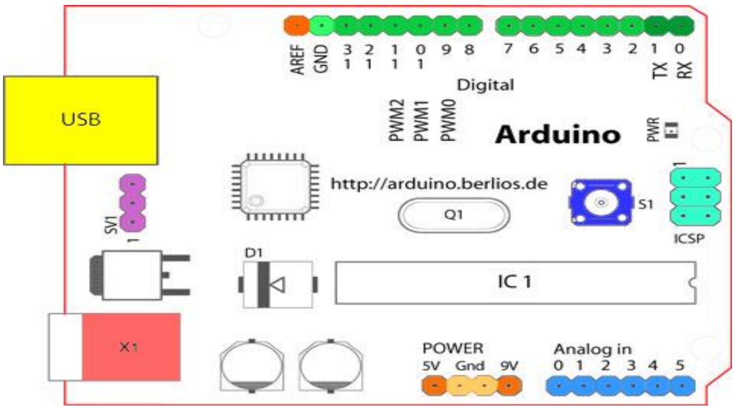


Fig. 6.1 Arduino UNO board layout

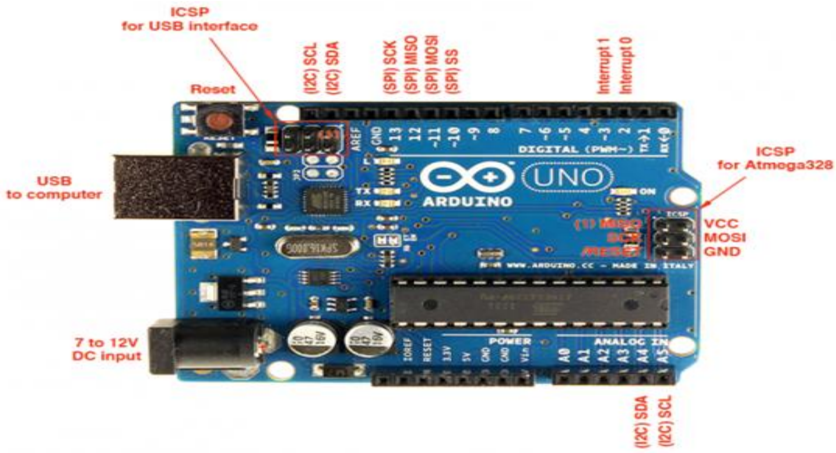


Fig. 6.2 Arduino UNO pins

TABLE 6.1 PIN DISCRIPTION FOR TRANSMITTER SIDE:

S. No	Component	Pin Name (Module)	Arduino UNO Pin	Description
1	GPS Module (Neo-6M)	TX (GPS)	D3	GPS TX → Arduino RX (software serial)
		RX (GPS)	D11	GPS RX ← Arduino TX (software serial)
		VCC	5V	Power supply
		GND	GND	Ground
2	LoRa TX Module (e.g., SX1278)	MISO (DOUT)	D12	SPI MISO
		MOSI (DIN)	D11	SPI MOSI
		SCK	D13	SPI Clock
		NSS (CS)	D10	Chip Select
		RESET	D9	Reset Pin
		DIO0	D2	Interrupt Pin
		VCC	3.3V	Power Supply
		GND	GND	Ground
3	LCD 16x2 (I2C Module)	SDA	A4	I2C Data Line
		SCL	A5	I2C Clock Line
		VCC	5V	Power Supply
		GND	GND	Ground
4	LED	Anode (+)	D7	Digital output (via resistor)
		Cathode (–)	GND	Ground
5	Motor (via L298N)	IN1, IN2	D5, D6	Motor control pins

6	Buzzer	+	D4	Buzzer control pin (digital HIGH/LOW)
		–	GND	Ground

TABLE 6.2 PIN DISCRIPTION FOR RECEIVER SIDE:

S. No	LoRa Receiver Pin	Arduino UNO Pin	Function
1	VCC	3.3V	Power supply
2	GND	GND	Common ground
3	SCK	D13	SPI Clock
4	MISO (DOUT)	D12	SPI Master-In Slave-Out
5	MOSI (DIN)	D11	SPI Master-Out Slave-In
6	NSS (CS)	D10	SPI Chip Select
7	RESET	D9	Module Reset
8	DIO0	D2	Interrupt pin for Rx Done

FEATURES OF ARUDUINO UNO

- The operating voltage is 5V
- The recommended input voltage will range from 7v to 12V
- The input voltage ranges from 6v to 2
- Digital input/output pins are 14
- Analog i/p pins are 6
- Flash Memory is 32 KB
- SRAM is 2 KB
- EEPROM is 1 KB
- CLK Speed is 16 MHz

6.2 POWER SUPPLY

Power Supply is an electronic device that supplies the required power to the device & circuitry. The purpose of a mains power supply is to convert the power delivered to its input by the sinusoidally alternating mains electricity supply into power available at its output in the form of a smooth and constant direct voltage.

There are three major types of power supplies

- Unregulated Power Supply
- Linear Regulated Power Supply
- Switching
- Ripple Regulated Power Supply

These power supplies convert AC input to DC output voltage. Common power supplies of daily use include Cell Phone charging adaptors, laptop computer charging adaptors, Uninterrupted Power Supply (UPS) Computers or electronic circuits are very delicate. A heavy 220V of current or AC can damage the circuit but a constant DC at low voltage is safe for the electronic circuits.

THEORETICAL BLOCK DIAGRAM

So, the basic purpose of a power supply is to convert an AC signal to a DC Signal. The block diagram of the power supply would be something like given below

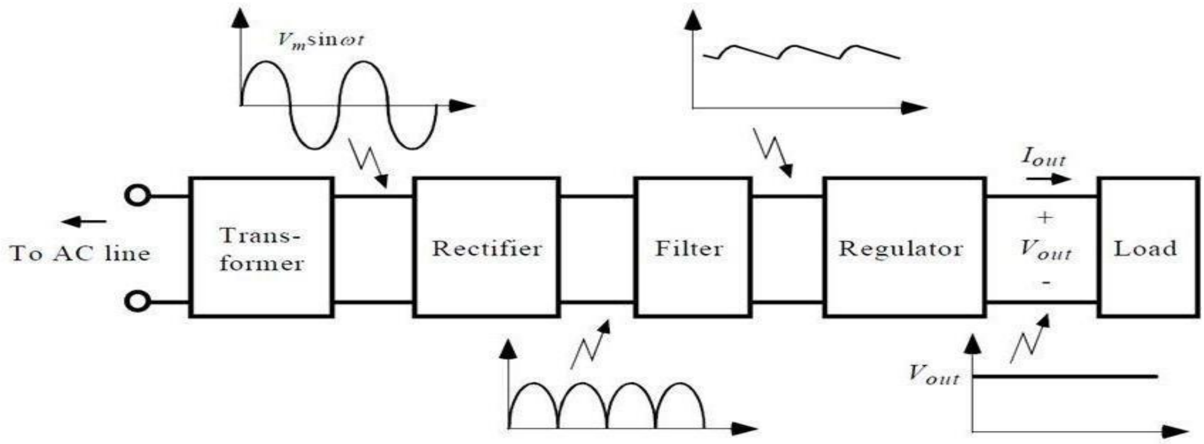


Fig. 6.3 Block diagram of power supply

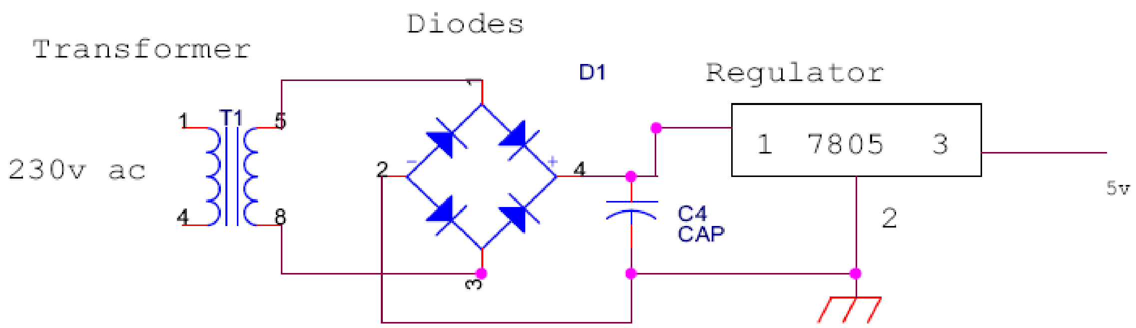


Fig. 6.4 AC-DC Converter

As said earlier electronic circuits cannot handle high voltage current. So a transformer is used to reduce the AC input and required value and will give the required AC voltage value. Now to convert an AC signal to a DC signal A rectifier is used. The output from the rectifier is not a pure DC output. It contains a lot of ripples and it is highly not smooth. To make the DC output smooth and remove the AC content of the rectifier a filter circuit is used. This filter is either an LC (inductor-capacitor) filter or, an RC (resistive–capacitive) filter. The choice of the filter depends on the designer of the circuit and the type of power supply. The output now becomes a full DC with a constant signal but still, it is unregulated voltage. Meaning that a designer is receiving a higher than-required voltage. So, to get a variable (5-30V) or constant output of 5,12,24 V a voltage regulator is used. This power supply provides the variable or constant voltage output at constant current or it is independent of current output.

AC- DC CONVERTER:

A rectifier is an electrical device that converts an AC signal into a DC signal. The process of conversion of AC signal to DC signal is called rectification

REGULATOR:

The regulator regulates the output voltage to be always constant.

Regulators have two types.

- Positive regulator (78XX)
- Negative regulator (79XX)

The output voltage is maintained irrespective of the fluctuations in the input AC voltage. As and then the AC voltage changes, the DC voltage also changes. Thus to avoid this Regulators are used. Also, when the power supply's internal resistance is greater than 30 ohms, the output gets affected. Thus this can be successfully reduced here. The regulators are mainly classified as low voltage and high voltage. Here we used a 7805 positive regulator. It reduces the 12V DC voltage to 5V DC.

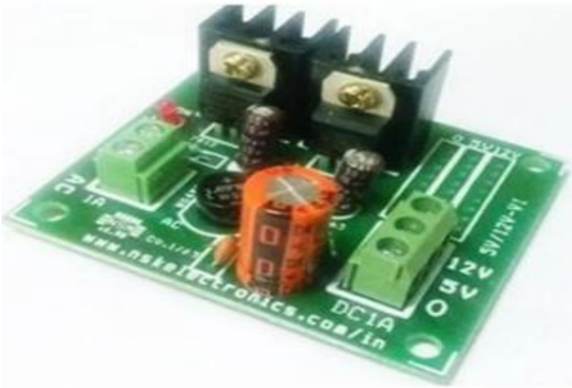


Fig. 6.5 Power supply regulator

The Filter circuit is often fixed after the Regulator circuit. The capacitor is most often used as a filter.

The principle of the capacitor is to charge and discharge. It charges during the positive half cycle of the AC voltage and discharges during the negative half cycle. So it allows only AC voltage and does not allow the DC voltage. This filter is fixed after the Regulator circuit to filter any of the possibly found ripples in the output received finally.

Here we used a 0.1µF capacitor. The output at this stage is 5V and is given to the Microcontroller In the power supply circuit two regulators are used. 7805 regulator is used to produce positive 5V dc.

The microcontroller and sensors are operated at 5V DC voltage. The output of the 7805 regulator is connected to the Arduino Nano microcontroller

6.3 BUZZER

The buzzer is a sounding device that can convert audio signals into sound signals. It is usually powered by DC voltage. It is widely used in alarms, computers, printers and other electronic products as sound devices. It is mainly divided into piezoelectric buzzer and electromagnetic buzzer, represented by the letter "H" or "HA" in the circuit. According to different designs and uses, the buzzer can emit various sounds such as music, siren, buzzer, alarm and electric.

HISTORY

This buzzer was launched in the year 1831 by an American Scientist namely Joseph Henry but, this was used in doorbells until they were eliminated in 1930 in support of musical bells, which had a smooth tone.

These buzzers were invented by manufacturers of Japanese & fixed into a broad range of devices during the period of 1970s – 1980s. So, this development primarily came due to cooperative efforts through the manufacturing companies of Japanese. In the year 1951, they recognized the Application Research Committee of Barium Titanate that allows the corporations to be cooperative competitively & bring about numerous piezoelectric creations. A buzzer or piezo speaker is an audio signaling device commonly used to produce sound. Piezo buzzer produces sound based on the reverse principle of the piezoelectric effect. The buzzer is a less costly and light-weighted electronic device that's why it is used in computers, alarm devices, refrigerators, microwave ovens, security devices, and so on

Fig. 6.6 Buzzer

There are two conductors available inside the buzzer along with a piezo crystal between them. Whenever the potential is applied across the crystal than the conductor's position gets changed due to which 2 to 4 kHz sound wave produced by the buzzer.

There are two types of piezoelectric buzzers that are commonly used in electronics projects – active buzzers and passive buzzers. Active buzzers are called active because they only need a DC voltage to produce sound. Passive buzzers need an AC voltage to produce sound.

PIN CONFIGURATION

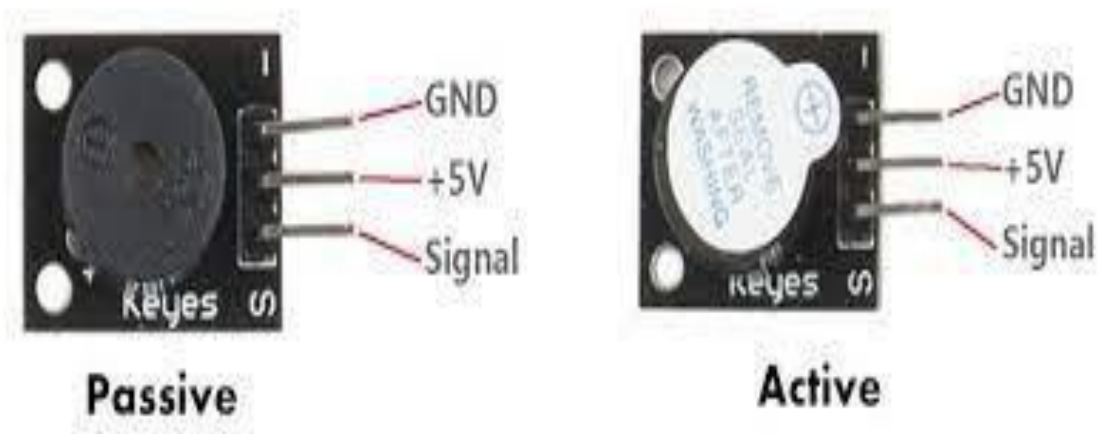


Fig. 6.7 Buzzer pin configuration

The pin configuration of the buzzer is shown below. It includes two pins namely positive and negative. The positive terminal of this is represented with the '+' symbol or a longer terminal. This terminal is powered through 6Volts whereas the negative terminal is represented with the '-'symbol or short terminal and it is connected to the GND terminal.

WORKING OF BUZZER

There are two types of buzzers, active buzzers, and passive buzzers. Most of the active buzzer works at a voltage range of 3.3V – 5V and generate only one sound frequency. It can only generate a sound of fixed frequency when you provide the required voltage to it. On the other hand, you have a passive buzzer. Passive buzzers can generate a sound of a wide frequency range (> 31Hz). It needs a fixed frequency signal to generate a specific tone. This tone can be changed by changing the input signal frequency. We can use a PWM signal or Arduino tone() function to generate this type of input signal and generate a tone

Specifications:

The specifications of the buzzer include the following.

- Color is black
- The frequency range is 3,300Hz
- Operating Temperature ranges from – 20° C to +60°C
- Operating voltage ranges from 3V to 24V DC
- The sound pressure level is 85dBA or 10cm
- The supply current is below 15mA

How to use a Buzzer?

A buzzer is an efficient component to include the features of sound in our system or project. It is an extremely small & solid two-pin device thus it can be simply utilized on breadboard or PCB. So in most applications, this component is widely used. There are two kinds of buzzers commonly available like simple and readymade. Once a simple type is power-driven then it will generate a beep sound continuously. A readymade type looks heavier & generates a Beep. Beep. Beep. This sound is because of the internal oscillating circuit within it. This buzzer uses a DC power supply that ranges from 4V – 9V. To operate this, a 9V battery is used but it is suggested to utilize a regulated +5V/+6V DC supply. Generally, it is connected through a switching circuit to switch ON/OFF the buzzer at the necessary time interval.

Advantages:

The advantages of a buzzer include the following.

- Simply Compatible
- Frequency Response is Good
- Size is small
- Energy Consumption is less
- The Range of Voltage usage is Large
- Sound Pressure is high

Disadvantages:

The disadvantages of the buzzer include the following.

- Controlling is a little hard
- Generates Annoying Sound
- Training is necessary to know how to repair the condition without just turning off.

Applications

The applications of the buzzer include the following.

- Communication Devices
- Electronics used in Automobiles
- Alarm Circuits
- Portable Devices
- Security Systems
- Timers
- Household Appliances
- Electronic Metronomes
- Sporting Events
- Annunciator Panels
- Game Shows

6.4. MOTOR DRIVER

A motor driver is basically a current amplifier which takes a low-current signal from the microcontroller and gives out a proportionally higher current signal which can control and drive a motor. In most cases, a transistor can act as a switch and perform this task which drives the motor in a single direction.

Fig. 6.8 Motor driver

Turning a motor ON and OFF requires only one switch to control a single motor in a single direction. What if you want your motor to reverse its direction? The simple answer is to reverse its polarity. This can be achieved by using four switches that are arranged in an intelligent manner such that the circuit not only drives the motor but also controls its direction. Out of many, one of the most common and clever designs is an H-bridge circuit where transistors are arranged in a shape that resembles the English alphabet “H”.

A H bridge is an electronic circuit that allows a voltage to be applied across a load in any direction. H-bridge circuits are frequently used in robotics and many other applications to allow DC motors to run forward & backward. These motor control circuits are mostly used in different converters like DC-DC, DC-AC, AC-AC converters, and many other types of power electronic converters. In specific, a bipolar stepper motor is always driven by a motor controller having two H-bridges.

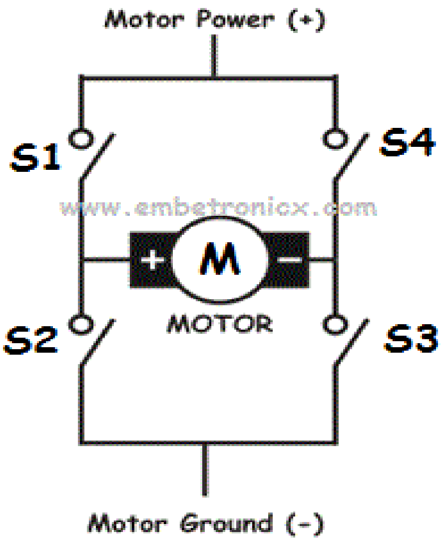


Fig. 6.9 Motor driver circuit

A H-bridge is fabricated with four switches like S1, S2, S3 and S4. When the S1 and S4 switches are closed, then a +ve voltage will be applied across the motor. By opening the switches S1 and S4 and closing the switches S2 and S3, this voltage is inverted, allowing invert operation of the motor.

Generally, the H-bridge motor driver circuit is used to reverse the direction of the motor and also to brake the motor. When the motor comes to a sudden stop, as the terminals of the motor's are shorted. Or let the motor run free to a stop when the motor is detached from the circuit. The table below gives the different operations with the four switches corresponding to the above circuit.

Fig. 6.10 Motor driver pins

VCC pin supplies power to the motor. Voltage anywhere between 5 to 35V can be applied. Remember, if the 5V-EN jumper is in place, you need to supply 2 extra volts than the motor's actual voltage requirement, in order to run the motor at its maximum speed.

GND is the common ground pin.

5V pin supplies power to the switching logic circuitry inside the L298N IC. If the 5V-EN jumper is in place, this pin acts as output and can be used to power up the

Arduino. If the 5V-EN jumper is removed, you need to connect it to the 5V pin on Arduino.

ENA pins are utilized to control the speed of Motor A. Supplying this pin with HIGH logic makes the Motor A rotate, supplying it with LOW logic causes the motor to stop. Removing the jumper and connecting this pin to the PWM input let us control the speed of Motor A.
IN1 & IN2 pins are used to control the direction of Motor A. If IN1 is HIGH and IN2 is LOW, Motor A spins in a certain direction. To change the direction, make IN1 LOW and IN2 HIGH. If both the inputs are either HIGH or LOW, Motor A stops.

IN3 & IN4 pins are used to control the direction of the Motor B. If IN3 is HIGH and IN4 is LOW, Motor B spins in a certain direction. To change the direction, make IN3 LOW and IN4 HIGH. If both the inputs are either HIGH or LOW, the Motor B stops.

ENB pin can be used to control the speed of Motor B. Supplying this pin with the HIGH signal makes the Motor B turn, supplying it LOW cause the motor to stop. Eliminating the jumper and interfacing this pin to PWM information let us control the speed of Motor B.

OUT1 & OUT2 pins are connected to Motor A.
OUT3 & OUT4 pins are connected to Motor B.

6.5 DC MOTOR

A 12V DC motor is an electromechanical device that converts electrical energy into mechanical energy, widely used in applications like robotics, automotive systems, and small machinery. It operates on direct current (DC) at a nominal voltage of 12 volts, making it suitable for low-voltage, battery-powered systems. Understanding its theory is essential for effective integration into projects.

The motor's operation is based on electromagnetic principles. It consists of a stator (stationary part) and a rotor (rotating part). In a typical brushed DC motor, the stator houses permanent magnets or field windings that create a fixed magnetic field. The rotor, or armature, comprises conductive windings connected to a commutator. When a 12V DC supply is applied, current flows through the armature windings, generating an electromagnetic field that interacts with the stator's magnetic field. This interaction produces a torque, causing the rotor to rotate.

The commutator, coupled with carbon brushes, ensures continuous rotation by periodically reversing the current direction in the armature windings, maintaining torque as the rotor spins. The motor's speed is proportional to the applied voltage, while torque depends on the current. A 12V DC motor typically operates within a safe current range to prevent overheating, with efficiency optimized by proper load matching.

Key parameters include rated voltage (12V), no-load speed (RPM), stall torque, and efficiency. Speed control is achieved using techniques like pulse-width modulation (PWM), which adjusts the effective voltage, or by varying the supply voltage. Direction control is managed by reversing the polarity of the input voltage.

Advantages of 12V DC motors include simplicity, cost-effectiveness, and ease of control. However, brushed motors require maintenance due to brush wear, and efficiency may be lower than brushless alternatives. For project applications, selecting a motor involves matching torque, speed, and power requirements to the load while ensuring compatibility with the 12V power source.

Fig. 6.11 DC Motor

6.6 LIQUID CRYSTAL DISPLAY (LCD)

The term liquid crystal is used to describe a substance in a state between liquid and solid but which exhibits the properties of both. Molecules in liquid arrange themselves until they all point in the same specific direction. This arrangement of molecules enables the medium to flow as a liquid.

And particular nature of a substance, liquid crystals can exist in one of several distinct phases. Liquid crystals in a nematic phase, in which there is no spatial ordering of the molecules, for example, are used in LCD technology. Here this used to display the password entered by us to ON/OFF the circuit breakers. The entered password will be processed by the Arduino and will displayed by the LCD. It consists of 16 rows and 4 columns to display the numeric and alphanumeric contents.

Fig. 6.12 LCD Display

6.7 GPS MODULE

GPS (Global Positioning System) is a satellite-based navigation system. It provides time and location-based information to a GPS receiver, located anywhere on or near the earth's surface. GPS works in all weather conditions.

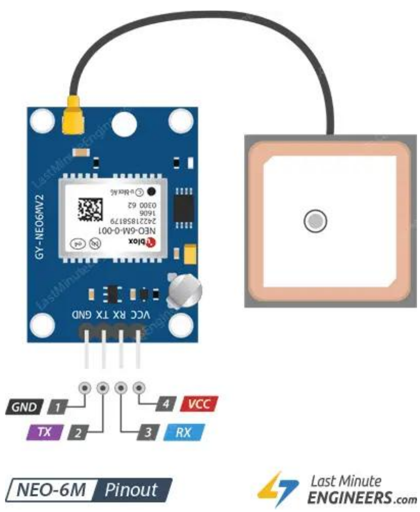


Fig. 6.13 GPS Module

Definition: The term GPS full form is “Global Positioning System” which is a satellite navigation system that furnishes location and time information in all climate conditions to the user. GPS is used for navigation in planes, ships, cars, and trucks also. The system gives critical abilities to military and civilian users around the globe. GPS provides continuous real-time, 3-dimensional positioning, navigation, and timing worldwide.

PINOUT

- GND is the ground pin and needs to be connected to the GND pin on the Arduino.
- TxD (Transmitter) pin is used for serial communication.
- RxD (Receiver) pin is used for serial communication.
- VCC supplies power to the module. You can connect it directly to the 5V pin on the Arduino.

How does GPS System Work?

The GPS consists of three segments:

- The space segment: the GPS satellites
- The control system, operated by the U.S. military,
- The user segment, which includes both military and civilian users and their GPS equipment.

Space Segment:

The space segment is the number of satellites in the constellation. It comprises 29 satellites circling the earth every 12 hours at 12,000 miles in altitude. The function of the space segment is utilized to route/navigation signals and to store and retransmit the route/navigation message sent by the control segment. These transmissions are controlled by highly stable atomic clocks on the satellites. The GPS Space Segment is formed by a satellite constellation with enough satellites to ensure that the users will have, at least, 4 simultaneous satellites in view from any point at the Earth’s surface at any time.

Control Segment:

The control segment comprises a master control station and five monitor stations outfitted with atomic clocks that are spread around the globe. The five monitor stations monitor the GPS satellite signals and then send that qualified information to the master control station where abnormalities are revised and sent back to the GPS satellites through ground antennas. The control segment also referred to as a monitor station.

User Segment:

The user segment comprises the GPS receiver, which receives the signals from the GPS satellites and determines how far away it is from each satellite. Mainly this segment is used for the U.S military, missile guidance systems, civilian applications for GPS in almost every field. Most of the civilians use this from survey to transportation to natural resources and from there to agriculture purpose and mapping too.

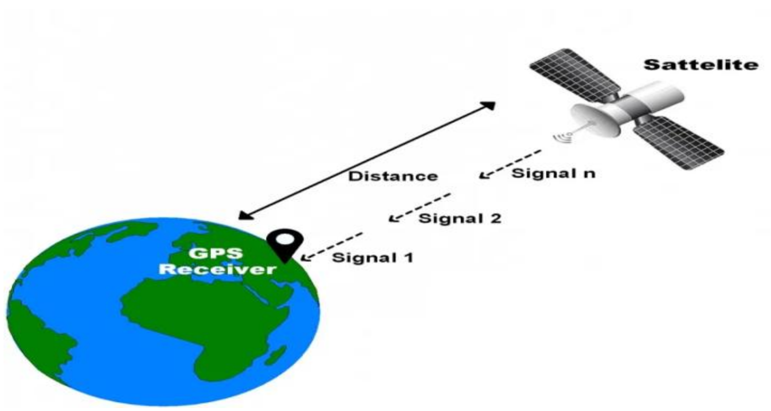


Fig 6.14 Working of GPS

GPS works through a technique called trilateration. Trilateration is the process of determining your position based on the intersection of spheres. When a receiver receives a signal from one of the satellites, it calculates its distance from the satellite considering a 3-D sphere with the satellite located at the center of the sphere. Once the receiver does the same with 3 other GPS satellites, the receiver then proceeds to find the intersection point of the 3 spheres to calculate it's location. Used to calculate location, velocity, and elevation, trilateration collects signals from satellites to output location information.

The GPS module receives a timestamp from each of the visible satellites, along with data on where in the sky each one is located (among other pieces of data). From this information, the GPS receiver now knows the distance to each satellite in view. If the GPS receiver's antenna can see at least 4 satellites, it can accurately calculate its position and time.

A single satellite broadcasts a microwave signal which is picked up by a GPS device and used to calculate the distance from the GPS device to the satellite. Since a GPS device only gives information about the distance from a satellite, a single satellite cannot provide much location information. Satellites do not give off information about angles, so the location of a GPS device could be anywhere on a sphere's surface area.
When a satellite sends a signal, it creates a circle with a radius measured from the GPS device to the satellite.

When we add a second satellite, it creates a second circle, and the location is narrowed down to one of two points where the circles intersect.
With a third satellite, the device's location can finally be determined, as the device is at the intersection of all three circles.

6.8 BATTERY

An electric battery is a source of electric power consisting of one or more electrochemical cells with external connections for powering electrical devices. When a battery is supplying power, its positive terminal is the cathode and its negative terminal is the anode. The terminal marked negative is the source of electrons that will flow through an external electric circuit to the positive terminal. When a battery is connected to an external electric load, a redox reaction converts high-energy reactants to lower-energy products, and the free-energy difference is delivered to the external circuit as electrical energy. Historically the term "battery" specifically referred to a device composed of multiple cells; however, the usage has evolved to include devices composed of a single cell.

Primary batteries are used once and discarded, as the electrode materials are irreversibly changed during discharge; a common example is the alkaline battery used for flashlights and a multitude of portable electronic devices. Secondary (rechargeable) batteries can be discharged and recharged multiple times using an applied

electric current; the original composition of the electrodes can be restored by reverse current. Examples include the lead–acid batteries used in vehicles and lithium-ion batteries used for portable electronics such as laptops and mobile phones.

Batteries come in many shapes and sizes, from miniature cells used to power hearing aids and wristwatches to, at the largest extreme, huge battery banks the size of rooms that provide standby or emergency power for telephone exchanges and computer data centers. Batteries have much lower specific energy (energy per unit mass) than common fuels such as gasoline. In automobiles, this is somewhat offset by the higher efficiency of electric motors in converting electrical energy to mechanical work, compared to combustion engines.

Fig. 6.15 Battery

6.9 LoRaWAN TECHNOLOGY

The term LoRa stands for Long Range. It is a long-range, low power wireless platform that has become the de-facto technology for Internet of Things (IoT) networks worldwide. LoRa is a spread spectrum modulation technique derived from chirp spread spectrum (CSS) technology. LoRa was introduced by a company called Semtech.

LoRa modules do come in different frequency ranges, the most common being the 433MHz, 915MHz and 868MHz. This LoRa technology can be used to transmit bi-directional information to long-distance (15-20km) without consuming much power. The technology can be utilized by public, private or hybrid networks and provides greater range than Cellular networks. LoRa Technology can easily plug into existing infrastructure and enables low-cost battery-operated IoT applications.

The basic principle is that information is encoded using chirp (a gradual increase or decrease in the frequency of the carrier wave over time). Before sending a message, the LoRa transmitter will send out a chirp signal to check that the band is free to send the message. Once the LoRa receiver has picked up the preamble chirp from the transmitter, the end of the preamble is signalled by the reverse chirp, which tells the LoRa transmitter that is it clear to begin transmission.

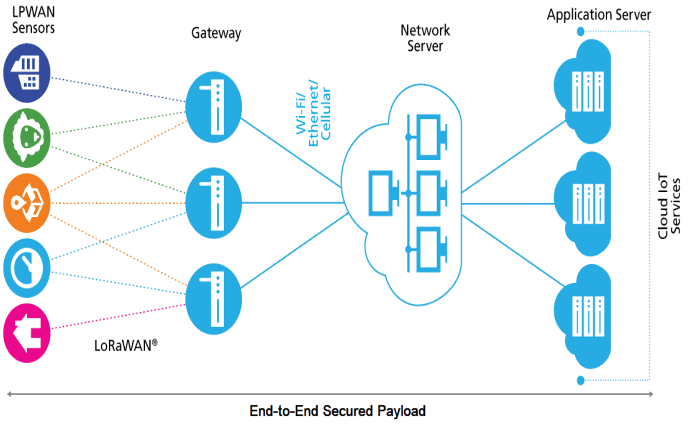


Fig 6.16 Architecture of LoRa WAN

The architecture shown in this figure is explained below:

1.Devices:

It consists of LoRa Modulation, Transceivers & End-Nodes and Picocells & Gateways.

A. LoRa Modulation: LoRa Technology is the physical (PHY) silicon layer, or wireless modulation, used to create the long-range communication link.

B. Transceivers & End-Nodes: Transceivers configured with LoRa Technology are embedded into end-nodes, or sensor devices, designed for a multitude of industry applications.

C. Picocells & Gateways: Sensors capture and transmit data to gateways over distances near and far, indoor and outdoor, with minimal power requirement.

2. Network Server:

Gateways send information via Wi-Fi, Ethernet or Cellular to the network server, which is responsible for network management functions like over-the-air activation, data de-duplication, dynamic frame routing, adaptive rate control, traffic management, and administration.

Application Servers & Cloud IoT Services:

Applications interpret the data collected by LoRa-enabled devices, applying techniques like machine learning and artificial intelligence to solve business problems for a Smarter Planet.

The SX1276/77/78/79 transceivers feature the LoRa® long range modem that provides ultra-long range spread spectrum communication and high interference immunity whilst minimizing current consumption.

SX1278 can achieve a sensitivity of over -148dBm using a low-cost crystal. The high sensitivity combined with the integrated +20dBm power amplifier yields industry leading link budget making it optimal for any application requiring range or robustness. Lora SX1278 also provides significant advantages in both blocking and selectivity over conventional modulation techniques, solving the traditional design compromise between range, interference immunity and energy consumption. Learn more about it at: SX1278 Datasheet.

SX1278 Applications

1. Automated Meter Reading
2. Home and Building Automation
3. Wireless Alarm and Security Systems

4. Industrial Monitoring and Control

5. Long range Irrigation Systems

SX1278 Pinout

There are different versions and types of SX1278 breakout board available in market. But basically all of them has same pinout as LoRa SX1278 is an SPI module. I am using this board as shown in photos below

Fig 6.17 Diagram of lora module (SX1278) Ra-02

INTERFACING SX1278 LORA MODULE WITH ARDUINO

The LoRa module that I am using here is the SX1278 Ra-02 which operates on 433MHz. But this module is not breadboarded friendly neither it has a soldered antenna. So simply I soldered few 2.54″ male connectors to make it breadboard friendly. I also soldered the antenna.

Arduino LoRa SX1278 Transmitter:

Now let us learn SX1278 Arduino Interfacing. For this, we will use two LoRa modules and two Arduino Boards to send data from one board and receive it on the other. We will use Arduino Nano at the transmitter side and Arduino Uno at the receiver side.

The circuit diagram for Arduino LoRa SX1278 Transmitter is given below. You can either make a pcb for this circuit or simply assemble it on the breadboard

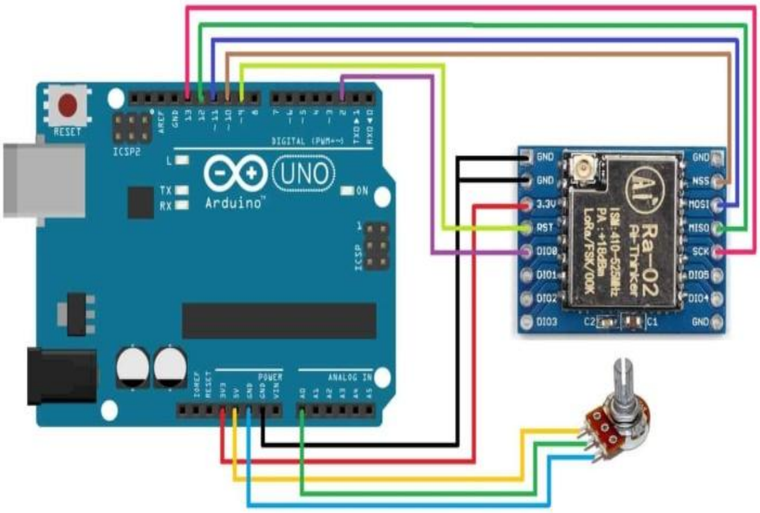


Fig 6.18 Interfacing LoRa Tx with Arduino Uno

The LoRa SX1278 is not 5V friendly so do not supply 5V to it else the board will get damaged. Use 3.3V of Arduino to connect it to VCC pin. Connect all the GND pins to GND. Connect the RST pin to D9 and DIO0 to D2 of Arduino. Connect the SPI Pins NSS, MOSI, MISO, SCK to Arduino D10, D11, D12, D13 of Arduino respectively as shown in circuit diagram above.

Use any potentiometer like 10K and connect its middle pin to A0 of Arduino and remaining two pins to GND and 5V.

Arduino LoRa SX1278 Receiver:

Similarly, the circuit diagram for Arduino LoRa SX1278 Receiver is given below. You can either make a pcb for this circuit or simply assemble it on the breadboard.

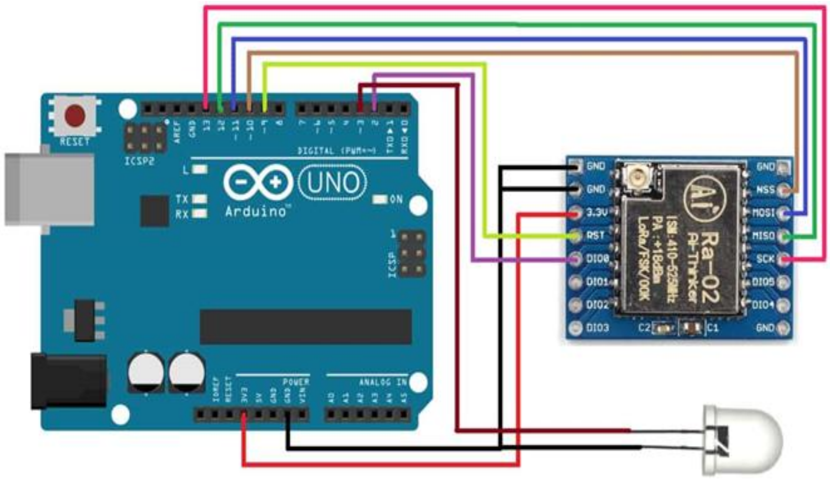


Fig 6.19 Interfacing LoRa Rx with Arduino Uno

The LoRa SX1278 is not 5V friendly so do not supply 5V to it else the board will get damaged. Use 3.3V of Arduino to connect it to VCC pin. Connect all the GND pins to GND. Connect the RST pin to D9 and DIO0 to D2 of Arduino. Connect the SPI Pins NSS, MOSI, MISO, SCK to Arduino D10, D11, D12, D13 of Arduino respectively as shown in circuit diagram above.

Use any LED and connect it to D3 of Arduino as shown in the photos above.

Advantages

- It has a long range providing communication up to 15 km.
- Since data transmission and reception require less than 50 mA of current, power consumption is low, providing up to 10 years of battery life.
- Since it has a bidirectional communication, it can be used for several areas.
- It is based on an open protocol overseeing the standard and its development, ensuring interoperability across networks.
- LoRa WAN provides the ability to use the band without licence for the frequency of any service provider.
- It can be put into use with little investment thanks to low cost base stations and free operating frequencies.

6.10 LED

A Light Emitting Diode (LED) is a semiconductor device that emits light when an electric current passes through it. Unlike traditional incandescent bulbs that generate light through heat, LEDs produce light by electroluminescence—a process where electrons recombine with holes in the material, releasing energy in the form of photons.

An LED consists of a chip of semiconducting material doped with impurities to create a p-n junction. When forward-biased (positive voltage to the p-side), electrons from the n-region and holes from the p-region move toward the junction. When they recombine, energy is released as light. The color of the emitted light depends on the band gap of the semiconductor material used. Common materials include gallium arsenide (GaAs) for infrared LEDs and gallium phosphide (GaP) for green or red LEDs. LEDs are highly efficient, long-lasting, and available in various colors. Their compact size and low power consumption make them ideal for applications in indicators, displays, automotive lighting, and general illumination.

Fig 6.20 LED

6.11 RESISTOR:

A resistor is a passive component that implements electrical resistance circuit element. Resistors act to reduce current flow, and, at the same time, act to lower voltage levels within circuits. Resistors may have fixed resistances or variable crystals tend to ne two terminal electrical as a resistance, such as those found in thermistors, trimmers, photoresistors and potentiometers. The current through a resistor is in direct proportion the voltage across the resistor's terminals. *R* is the resistance of the conductor in units of ohms (symbol: Ω). .

Fig 6.21 Resistor

6.12 CONNECTING WIRES

Connecting wires permits associate degree electrical current to travel from one purpose on a circuit to a different as a result of electricity desires a medium through that it will move. Most of the connecting wires are created from copper.

Fig. 6.22 Connecting wires

CHAPTER 7

RESULT AND DISCUSSION

The maritime border alert and monitoring system was successfully implemented and rigorously tested under various environmental and operational conditions, demonstrating its potential as a reliable and effective tool for ensuring maritime border security and safeguarding the lives of fishermen. The primary objective of the system to prevent unintentional border crossings and enhance maritime situational awareness was achieved through a robust combination of GPS-based real-time tracking, LoRa-based long-range communication, and automated alert and control mechanisms

During field testing, the system consistently delivered accurate location data via the GPS module, which was crucial for determining the vessel's position relative to predefined maritime boundaries. This data was efficiently transmitted using LoRa communication technology, which enabled long-distance wireless communication with minimal power consumption. The system proved capable of maintaining stable communication over extended ranges, making it well-suited for maritime environments where conventional networks such as GSM or Wi-Fi are often unreliable or unavailable.

A key feature of the system was the division of maritime zones into three distinct categories: Safe Zone, Warning Zone, and Restricted Zone. This zoning structure provided a clear and intuitive framework for fishermen to understand their proximity to international borders. As the vessel approached the warning or restricted zones, the onboard alert system—comprising LEDs and buzzers—responded promptly, notifying the fishermen of potential danger. These timely alerts were instrumental in reducing the chances of accidental border violations.

Another innovative aspect of the system was the integration of automatic motor speed control. This feature functioned smoothly, allowing the system to slow down or halt the vessel as it neared restricted zones. By automating this response, the system not only enhanced the safety of the fishermen but also served as an added layer of security by minimizing the risk of unauthorized border crossings due to human error or delayed response.

The hardware architecture was deliberately designed to be low-cost and energy-efficient. By leveraging components such as the Arduino UNO, GPS Neo-6M, and LoRa transceiver modules, the system remains affordable for deployment in economically constrained fishing communities. This cost-effectiveness, coupled with the system's simplicity and reliability, makes it a scalable and practical solution for widespread adoption along coastal regions.

Despite the system's promising performance, a few limitations were noted. In particular, the LoRa communication link occasionally experienced signal interference in areas with thick vegetation, large obstacles, or extreme weather conditions. These factors may temporarily disrupt data transmission or reduce communication range. Similarly, the GPS module, while generally reliable, was prone to occasional signal drops, especially in remote regions with poor satellite visibility or in congested harbours surrounded by high structures.

Nevertheless, these issues are not uncommon in wireless communication and GPS-based systems and can be mitigated through future improvements. Potential enhancements include integrating dual-band GPS receivers for improved location accuracy, using higher-power LoRa modules or mesh networking for better coverage, and adding solar-powered energy systems for extended autonomous operation.

In conclusion, the proposed system meets its intended goals by providing a practical, cost-effective, and technologically sound solution to address maritime border safety. Its successful implementation highlights the potential for real-world deployment to assist coastal security forces and protect the livelihoods of small-scale fishermen. With continued development and support, such systems could play a vital role in national security and maritime safety across international waters.

CHAPTER 8

CONCLUSION AND FUTURE ENHANCEMENT

8.1 CONCLUSION

The proposed maritime border alert and monitoring system was successfully developed, implemented, and tested, fulfilling its objective of enhancing the safety of fishermen and preventing unintentional border violations. By integrating GPS-based location tracking with LoRa communication, the system ensured reliable, real-time monitoring of fishing vessels even in offshore environments where conventional communication methods may fail.

The division of the maritime area into three distinct zones safe, warning, and restricted proved to be an effective method for guiding fishermen and reducing the likelihood of accidental intrusions into unauthorized waters. The use of visual (LED) and auditory (buzzer) alerts ensured timely notifications when a vessel approached danger zones, thereby providing fishermen with the necessary cues to take corrective action.

A standout feature of the system was its automatic motor speed control, which allowed for dynamic speed adjustment based on proximity to restricted zones. This automated response minimized the need for manual intervention, increasing the system’s reliability and preventing border breaches more effectively.

From a hardware perspective, the system was built using low-cost and readily available components, including the Arduino UNO, GPS Neo-6M, and LoRa transceivers. This makes the solution affordable and accessible, particularly for small-scale fishermen and remote coastal communities that require cost-effective maritime safety tools.

However, certain limitations were observed during testing. LoRa signals experienced occasional interference in areas with physical obstructions or dense vegetation, and the GPS module showed brief signal losses in remote or highly congested regions. These challenges, though minor, highlight areas for future enhancement, such as incorporating high-gain antennas, GPS modules with better satellite acquisition, or adding fail-safe communication backups.

Despite these limitations, the overall performance of the system met expectations and demonstrated strong potential for real-world deployment. With further refinements and large-scale implementation, the system can significantly contribute to maritime safety, border security, and fisherman welfare, proving to be a valuable asset for both national authorities and local fishing communities.

8.2 Future Enhancement

The maritime border alert and monitoring system developed in this project has demonstrated considerable potential in improving the safety of fishermen and reducing unintentional border violations. However, there are several opportunities for enhancement and expansion that can be explored in future work to increase the system's efficiency, reliability, and applicability.

One key area of improvement is the integration of GSM or satellite communication as a backup to the existing LoRa-based system. While LoRa works well over long distances with low power consumption, its performance may be affected by physical obstructions or atmospheric interference. A hybrid communication system would ensure continuous data transmission even in challenging conditions or remote areas.

Another promising enhancement is the implementation of geofencing through cloud platforms. By linking the GPS data to an IoT cloud service, real-time tracking of vessels could be accessible not only to the fishermen but also to coast guards and family members. This would enhance situational awareness, improve emergency response, and facilitate better coordination between authorities and fishermen.

The system can also be extended by including environmental sensors to monitor parameters such as weather conditions, sea state, and water quality. This additional data would help fishermen make informed decisions, improve safety at sea, and support marine environmental monitoring.

Further development could include the use of smartphone applications or wearable devices to provide fishermen with real-time alerts and navigation assistance. These interfaces could offer vibration or voice alerts in addition to the LED and buzzer indicators, ensuring that warnings are received in noisy or low-visibility environments.

To increase the precision of vessel positioning, dual-frequency GPS modules or Real-Time Kinematic (RTK) GPS systems could be incorporated. These systems offer centimeter-level accuracy and are particularly useful in scenarios where precise location tracking is critical.

For wider implementation, the system can be miniaturized and modularized into a compact unit, making installation and maintenance easier. Additionally, solar-powered operation can be explored to ensure long-term sustainability and operation without frequent manual recharging, especially for long fishing trips.

Lastly, collaborations with government agencies and maritime authorities can help integrate this system into national security frameworks, enabling automated alerts at control stations and promoting policies that support the adoption of smart technologies for maritime safety.

In conclusion, the current system provides a strong foundation for maritime border protection and has great potential for further development. With continued research and innovation, it can evolve into a comprehensive maritime safety and navigation system that benefits not only fishermen but also national coastal security efforts.

APPENDICES

APPENDIX 1- CODE LISTINGS

LoRa Tx Module

```
#include <SoftwareSerial.h>
#include <TinyGPSPlus.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <SPI.h>
#include <LoRa.h>

// --- Pin Definitions ---
#define BUZ 4
#define LED 7
#define IN_1 5
#define IN_2 6

// --- GPS Serial ---
SoftwareSerial gpsSerial(3, 11); // GPS TX → Pin 3
TinyGPSPlus gps;

// --- LCD ---
LiquidCrystal_I2C lcd(0x27, 16, 2);

// --- LoRa ---
#define LORA_SS 10
#define LORA_RST 9
#define LORA_DIO0 2
```

```
// --- Variables ---
float LATITUDE = 0.0;
float LONGITUDE = 0.0;

// --- Border Area: 9 Points (square/rectangle boundary) ---
const int BORDER_POINTS = 9;
float borderLat[BORDER_POINTS] = {
  11.042576, 11.042150, 11.041578,
  11.041592, 11.041699, 11.042132,
  11.042534, 11.042489, 11.042525
};

float borderLng[BORDER_POINTS] = {
  76.886655, 76.886588, 76.886540,
  76.885948, 76.885491, 76.885485,
  76.885547, 76.886128, 76.886457
};

// --- Point-in-Polygon Function (Ray Casting) ---
bool isInsideBoundary(float lat, float lng) {
  int i, j;
  bool inside = false;
  for (i = 0, j = BORDER_POINTS - 1; i < BORDER_POINTS; j = i++) {
    if (((borderLat[i] > lat) != (borderLat[j] > lat)) &&
        (lng < (borderLng[j] - borderLng[i]) * (lat - borderLat[i]) / (borderLat[j] -
borderLat[i]) + borderLng[i])) {
      inside = !inside;
    }
  }
```

```
  return inside;
}

void setup() {
  Serial.begin(9600);
  gpsSerial.begin(9600);

  pinMode(BUZ, OUTPUT);
  pinMode(LED, OUTPUT);
  pinMode(IN_1, OUTPUT);
  pinMode(IN_2, OUTPUT);
  digitalWrite(BUZ, LOW);
  digitalWrite(LED, LOW);
  analogWrite(IN_1, 255);
  analogWrite(IN_2, 0);

  lcd.init();
  lcd.backlight();
  lcd.setCursor(0, 0);
  lcd.print("MARITIME BORDER");
  lcd.setCursor(0, 1);
  lcd.print("SECURITY SYSTEM");
  delay(2000);
  lcd.clear();

  LoRa.setPins(LORA_SS, LORA_RST, LORA_DIO0);
  if (!LoRa.begin(433E6)) {
    Serial.println("LoRa init failed!");
    while (1);
```

```
  }
  Serial.println("LoRa TX Ready");
}

void loop() {
  while (gpsSerial.available() > 0) {
    gps.encode(gpsSerial.read());

    if (gps.location.isUpdated()) {
      LATITUDE = gps.location.lat();
      LONGITUDE = gps.location.lng();

      Serial.print("Latitude: ");
      Serial.println(LATITUDE, 6);
      Serial.print("Longitude: ");
      Serial.println(LONGITUDE, 6);

      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("LAT:");
      lcd.print(LATITUDE, 4);
      lcd.setCursor(0, 1);
      lcd.print("LNG:");
      lcd.print(LONGITUDE, 4);

      // --- Border Logic ---
      if (!isInsideBoundary(LATITUDE, LONGITUDE)) {
        digitalWrite(LED, HIGH);
        digitalWrite(BUZ, HIGH);
```

```
      analogWrite(IN_1, 120); // Slow motor
      analogWrite(IN_2, 0);
      Serial.println("!! ALERT: OUTSIDE BORDER !!");
    } else {
      digitalWrite(LED, LOW);
      digitalWrite(BUZ, LOW);
      analogWrite(IN_1, 255); // Normal speed
      analogWrite(IN_2, 0);
      Serial.println("Within Safe Zone");
    }

    // Send GPS data over LoRa
    String data = String(LATITUDE, 6) + "," + String(LONGITUDE, 6);
    LoRa.beginPacket();
    LoRa.print(data);
    LoRa.endPacket();

    Serial.print("Sent via LoRa: ");
    Serial.println(data);

    delay(3000);
  }
 }
}
```

LoRa Rx Module

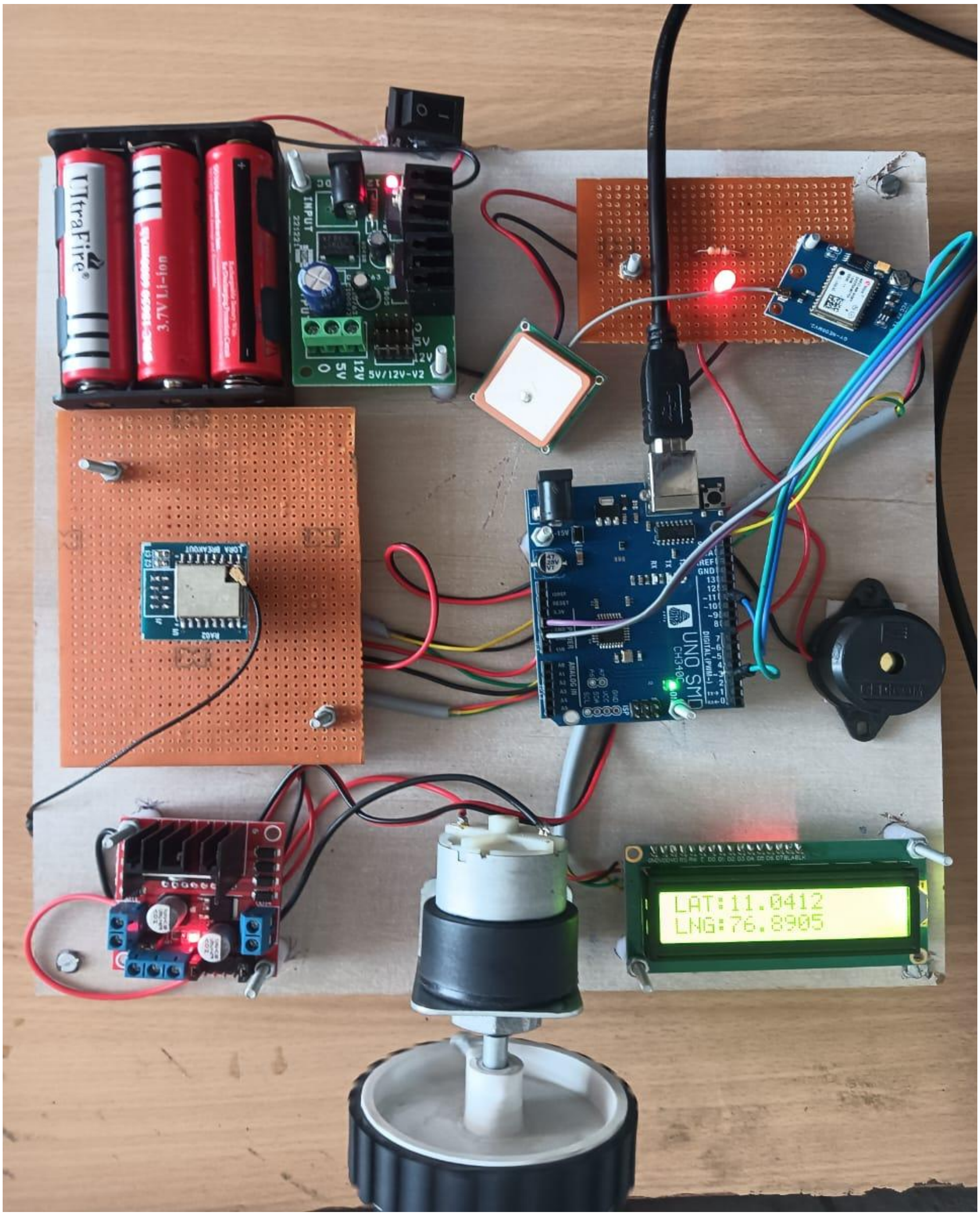
```
#include <SPI.h>
#include <LoRa.h>

// --- LoRa Pins ---
#define LORA_SS 10   // LoRa NSS Pin (Chip Select)
#define LORA_RST 9   // LoRa RESET Pin
#define LORA_DIO0 2  // LoRa DIO0 Pin

void setup() {
  // Initialize serial communication
  Serial.begin(9600);
  while (!Serial);

  // Initialize LoRa
  LoRa.setPins(LORA_SS, LORA_RST, LORA_DIO0);
  if (!LoRa.begin(433E6)) {  // Set frequency to 433 MHz (can be changed to 
868E6 for 868 MHz)
    Serial.println("LoRa initialization failed!");
    while (1);  // Stay here forever
  }
  Serial.println("LoRa Receiver Ready!");
}

void loop() {
  // Check if data is available to receive
  int packetSize = LoRa.parsePacket();
  if (packetSize) {
    String received = "";
```

```
  // Read all bytes from the LoRa packet
  while (LoRa.available()) {
    received += (char)LoRa.read();
  }

  // Print the received data to Serial Monitor
  Serial.print("Received: ");
  Serial.println(received);

  // Split the received data (Latitude and Longitude)
  int commaIndex = received.indexOf(',');
   if (commaIndex > 0) {
    String strA = received.substring(0, commaIndex);
    String strB = received.substring(commaIndex + 1);

    float latitude = strA.toFloat();
    float longitude = strB.toFloat();

    // Print the Latitude and Longitude
    Serial.print("Latitude: ");
    Serial.println(latitude, 6);
    Serial.print("Longitude: ");
    Serial.println(longitude, 6);
  } else {
    Serial.println("Invalid data format received");
  }
}
```

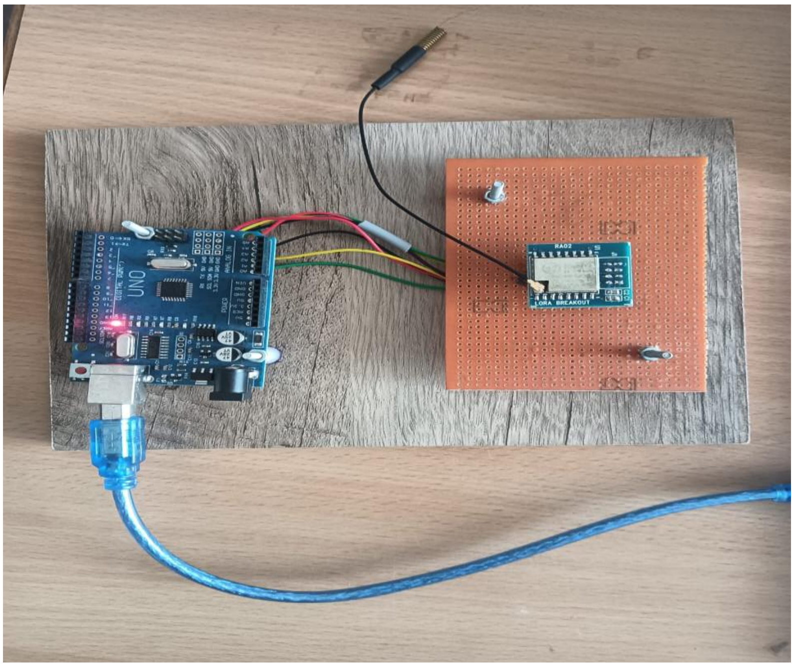
APPENDIX 2-

PROTOTYPE RESULTS:

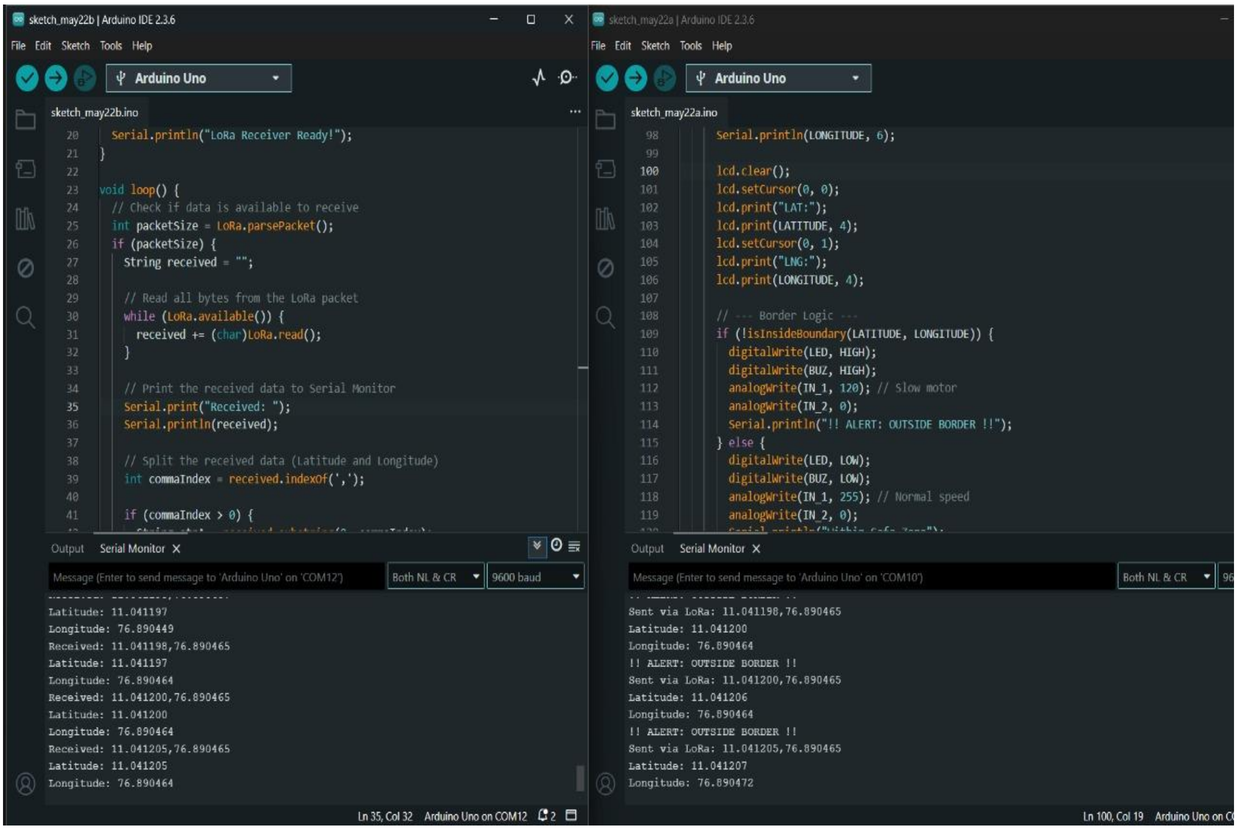
TRANSMITTER SIDE:



RECEIVER SIDE:



DATA TRANSFER USING LoRa WAN:



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