LoRa-Based Water Tank Management System for Sustainable Water Management

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***Abstract*—This paper presents a novel water tank management system utilizing LoRa (Long-Range) amplification technology, integrating sensors, transceivers, and embedded system. The system enables real-time monitoring and management of water levels at a substantially lower cost than conventional methods, aiding in optimizing water supply planning, mitigating shortages, and curbing wastage through timely visualization and alerts. Supported by a rural case study, its effectiveness across diverse sectors, including agriculture, industries, urban areas, and domestic settings, is underscored. Leveraging LoRa technology, the system offers a scalable and energy-efficient solution for addressing common water management challenges such as overflow and provide sufficient amount of water. Overall, this innovative system promotes efficient water usage and significantly contributes to sustainable water resource management efforts, empowering stakeholders to advocate for responsible practices and participate in the conservation of valuable water resources.**

***Index Terms*—Real-time monitoring, LoRa technology, ATmega328P, Magnetic sensor, Wireless, Water management, Low- power, Long-Range, Automation, Efficient, Cost-effective.**

I. Introduction

The escalating challenges of water depletion and contamination present a pressing global concern, necessitating innovative solutions for efficient water management [1]. This research paper introduces a Wireless Water Management System utilizing LoRa technology, aimed at addressing water overflow issues prevalent across various settings. By leveraging the long- range communication capabilities of LoRa technology, this system enables real-time remote monitoring and automation of water pumps and motors, thereby optimizing water usage and significantly reducing wastage.

This paper delves into the development, functionality, and diverse applications of the Wireless Water Management System across agriculture, industries, urban, and residential areas. Its adaptability and effectiveness in different scenarios underscoreits potential impact in mitigating water-related challenges. Moreover, the system's emphasis on low-power consumption ensures cost-effectiveness, aligning with environmental sustainability objectives. In our wireless water management system, careful hardware selection is pivotal for robust performance and efficiency. We have chosen ATmega328 microcontroller [2], LoRa SX1278 transceiver, and Magnetic Sensor due to their specific advantages, low cost, and effectiveness in real-world applications. Below is a summary of some reasons for selecting LoRa [3] over other available modules in the market, as outlined in the table.

TABLE I
Comparison of LoRa over other wireless modules

Feature	RF(RX-TX) Modules	Bluetooth	Wi-Fi	LoRa
Range	Short	Short to Medium	Medium	Long
Data Rate	Low	Moderate to High	High	Low
Power Consumption	Variable	Low (BLE)	High	Low
Frequency Band	Varies	2.4 GHz (BLE)	2.4 GHz, 5 GHz	Sub-GHz
Topology	Variable	Point-to-Point, Mesh	Star, Infrastructure	Star-of-Stars

The reasons for choosing a magnetic float sensor [4] over other sensors are detailed in the table below.

TABLE II
COMPARISON OF DIFFERENT SENSORS

Sensor Type	**Float Sensor**	**Switch Sensor**	**Carbon Sensor**	**Magnetic Sensor**
Operation	Float mechanism	Water bridging electrodes	Carbon conductivity	Magnetic field detection
Reliability	Moderate	Moderate	Low	High
Maintenance	Periodic cleaning	Electrode cleaning	Frequent, carbon rod	Minimal
Cost	Moderate	Moderate	Low	Moderate
Applications	Domestic, sump pumps	Residential, commercial	Limited due to quality	Various agriculture
Response Time	Moderate	Fast	Fast	Fast
Environment Suitability	Limited to clean water	Suitable for various liquids, affected by various impurities	Limited to clean water	Versatile suitable for various environments

II. METHODOLOGY

A. Transmitter Working

The foundation of the transmitter's functionality lies in its power supply management and seamless communication protocol. The transmitter is powered by a 7.5V lithium-ion cell, which undergoes a meticulous process of voltage regulation to ensure optimal performance of its integral components.

1) Voltage Regulation: The input voltage of 7.5V needs to be regulated to supply the required voltages for the compo- nents in the transmitter. This regulation is achieved using an AMS1117 voltage regulator SMD. Two output voltages are generated from this regulator:

- 5V: This voltage is used to power the transmitter controller, which in this case is an ATmega328P microcon- troller.
- 3.3V: This voltage is used to power the LoRa module, specifically the SX1278, as it operates at 3.3V.

2) Connection between Controller and LoRa Module: SPI (Serial Peripheral Interface) [5] is used for communication between the microcontroller (controller) and the LoRa module.SPI is a full-duplex communication protocol [6], meaning datacan be transmitted and received simultaneously. It typically involves a master-slave configuration.

- MOSI is a communication line used in SPI protocol where the master device (such as a microcontroller) sends data to the slave device (such as a LoRa module). The master device sends data serially over the MOSI line,and the slave device receives this data on its MOSI pin.
- MISO is another communication line used in SPI, allowing the slave device to send data back to the master device. When the master sends a request or initiates communication with the slave, the slave responds by sending data back over the MISO line. This line is unidirectional from the slave to the master, enabling bidirectional communication between the devices.
- SCK (Serial Clock): SCK is the clock signal line used to synchronize data transmission between the master and the slave devices in SPI communication. Both the master and the slave devices have synchronized clocks, ensuringthat data is transferred at the correct timing. The clock signal is generated by the master device and is used by both devices to determine the timing of data transmission.
- SS (Slave Select): SS, also known as the Slave Selector Chip Select line, is used by the master device to select a specific slave device with which it wants to communicate. In scenarios where multiple slave devices are connected to the same SPI bus, each slave device is assigned a unique SS line.

Connections of LoRa Transmitter and ATmega328P is shown below:

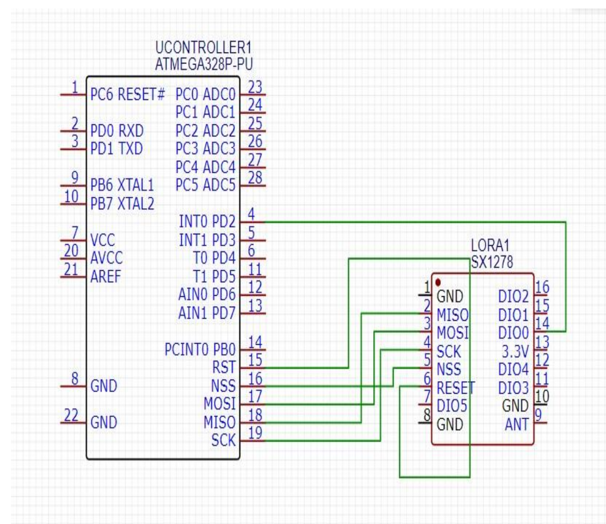

Fig. 1. Connections of LoRa Transmitter with ATmega328P

3) SPI Communication Flow: The microcontroller (AT- mega328P) sends commands or data to the LoRa module (SX1278) via MOSI. The LoRa module responds by send- ing data or acknowledgment back to the microcontroller via MISO. Communication occurs continuously in both directionsas needed for the operation of the transmitter.

4) 3D Layout of Transmitter side:

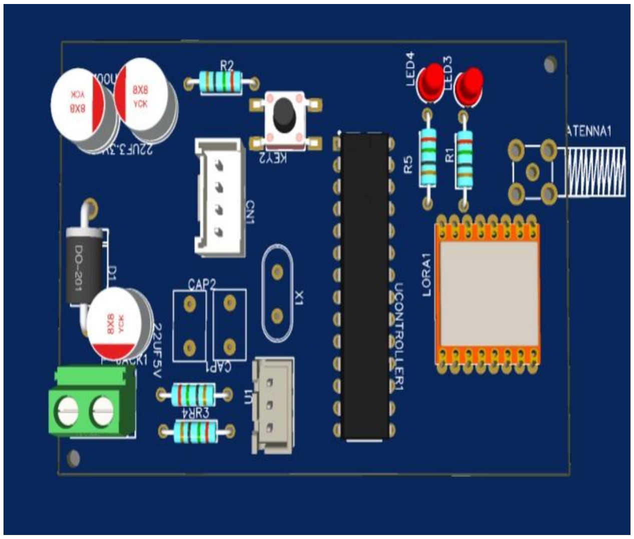

Fig. 2. 3D Layout of Transmitter Module (Front side)

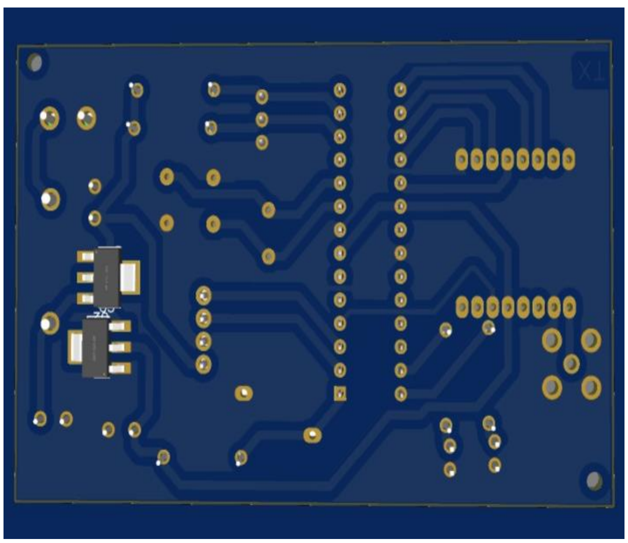

Fig. 3. 3D Layout of Transmitter Module (Back side)

B. Receiver Working

The receiver in this setup likely serves to control and mon- itor the operation of the motor based on commands received from the transmitter.

1) Power Supply: The receiver needs a power supply to operate. Since the input voltage from the adapter is 12V, it can be regulated using the same AMS1117 voltage regulator SMD [7] used in the transmitter to provide 5V and 3.3V as required by the components in the receiver circuit.

2) Microcontroller: The receiver circuit likely includes a microcontroller, similar to the one used in the transmitter (e.g.,ATmega328P), to control the operation of the receiver and process incoming commands from the transmitter.

3) LoRa Module: Similar to the transmitter, the receiver includes a LoRa module (e.g., SX1278) operating at 3.3V. This module is responsible for wirelessly receiving commandssent by the transmitter over the LoRa network. Connectionsof LoRa Receiver and ATmega328P is shown below:

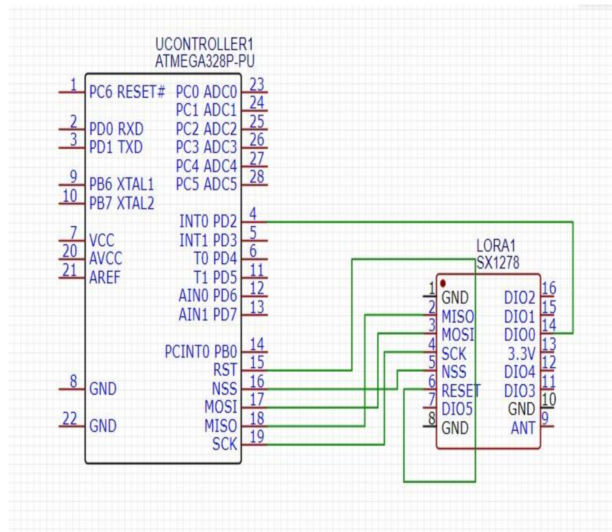

Fig. 4. Connections of LoRa Receiver with ATmega328P

4) SPI Communication: The microcontroller communicates with the LoRa module using SPI. This allows the microcon- troller to receive data packets containing commands or instruc- tions from the transmitter. The SPI communication protocol enables bidirectional data transfer between the microcontroller and the LoRa module, facilitating the reception of commands from the transmitter.

5) Relay Control: The receiver likely includes a relay (e.g., SLA-12VDC-SLC 10Amp relay) to control the operation of the motor. The relay isolates the low-voltage DC control signalfrom the microcontroller from the high-voltage AC supply needed to power the motor. An Optocoupler (e.g., PC817 IC) [8] is used to provide isolation between the low-voltage control signal and the high-voltage AC supply, ensuring safety and preventing electrical interference. The microcontroller sends control signals to the relay through the optocoupler based on the commands received from the transmitter. These signals determine when the relay should be activated or deactivated, thereby controlling the motor's operation.

6) Motor Operation: The motor is connected to the relay, which switches the AC supply to the motor on or off based on the commands received from the transmitter. When the microcontroller activates the relay in response to a command from the transmitter, the relay allows the AC supply to power the motor, causing it to turn on and perform its intended function. Conversely, when the microcontroller deactivates the relay, the AC supply to the motor is cut off, stopping its operation.

7) 3D layout of Receiver side:

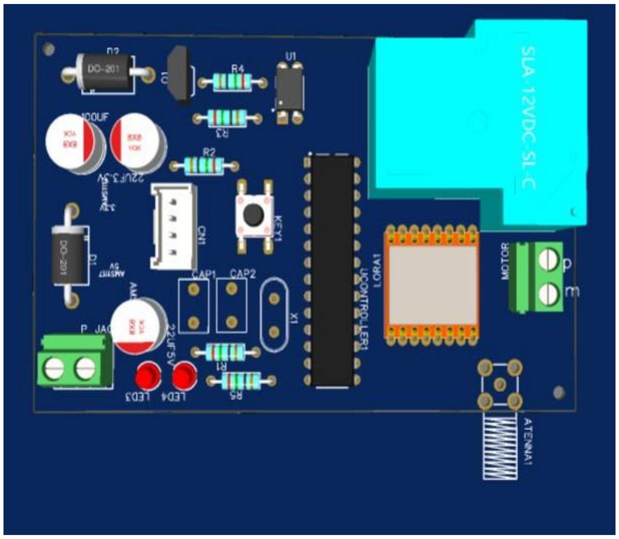

Fig. 5. 3D Layout of Receiver Module (Front side)

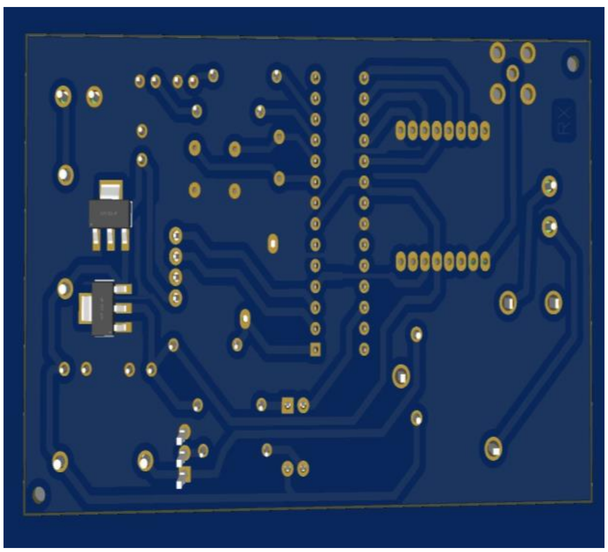

Fig. 6. 3D Layout of Receiver Module (Back side)

III. Problem Faced and Solutions Implemented

A. Frequency Selection Challenges

When designing a water management system in India, one of the primary hurdles encountered was selecting an appropri- ate frequency band. This was critical due to regulatory con- straints and the potential for interference issues [9]. To ensure seamless communication and adherence to local regulations, finding an available, interference-free frequency band was imperative. Extensive research led to the identification of the 865 MHz frequency band [10] as suitable for the application. Opting for this frequency not only ensured compliance with local regulations but also minimized the risk of interference, thereby establishing a stable communication channel essential for the project's success.

B. Range Limitation and Antenna Enhancement

Initially, the water management system faced limitations in communication range [11], as the spiral antenna provided coverage of only approximately 150 meters. However, the project's requirements dictated coverage over a significantly larger distance of 3.5 km. To address this challenge effectively, the team decided to implement an omnidirectional antenna solution. By upgrading to the omnidirectional antenna, the system experienced a notable improvement in range and coverage for LoRa communication. This enhancement enabled the water management system to efficiently transmit and receive data across the required distance, ensuring comprehensive monitoring and control capabilities crucial for efficient water management practices [12]. Ultimately, the antenna enhancement played a pivotal role in overcoming range limitations, thus enabling the system to achieve its objectives effectively.

IV. Results

When the water level rises and triggers the lower magnetic float sensor, the sensor floats on the water surface, indicating that the water level has reached a certain threshold. As the water pump is activated and continues to fill the tank, the water level eventually reaches the upper magnetic float sensor. At this point, the system recognizes that the tank is full and automatically switches off the water pump to prevent overfilling. Subsequently, as the water level decreases andfalls below the lower magnetic float sensor, the water pump is automatically activated again to refill the tank until the upper sensor is triggered, signalling that the tank is once more at capacity.

In summary, this system offers a reliable and automated method of monitoring and controlling water levels in the tank,ensuring efficient usage and preventing overflow.

V. Conclusion

The implementation of a water tank management system utilizing LoRa technology signifies a significant leap in efficient water resource management. This innovative solution enables remote monitoring and management, preventing overflow or dry tanks with timely interventions. With LoRa's long-range communication and low power consumption, the system is ideal for deployment in remote and rural areas where reliable water management tools are essential.

Our Low-Powered Water Management System, powered by LoRa wireless communication, demonstrates substantial reductions in water wastage and enables real-time monitoring across various sectors. This research emphasizes the importance of strategic hardware selection and frequency planning, serving as a blueprint for similar applications. Moving forward, this technology underscores our commitment to advancing sustainable water management practices, ensuring a watersecure future for generations to come.

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