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Design and implementation of a water tank controller using Hall effect sensor

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Abstract

This paper presents the design and implementation of an automated water tank controller using Hall effect sensors and a floating magnet system. Traditional water level monitoring systems suffer from reliability issues due to corrosion, sediment accumulation, and mechanical wear. To address these problems, the proposed system employs non-contact Hall effect sensors to detect water levels, which in turn automatically control a water pump. The circuit uses a comparator and relay-based mechanism to switch the pump on or off based on real-time sensor input. This approach ensures precise measurement, high reliability, and minimal maintenance. The system was tested under different water levels, and results demonstrated consistent performance, validating its suitability for both residential and industrial applications.

Keywords: Water Tank Controller, Hall Effect Sensor, Automation, Magnetic Float, Water Level Detection

1. Introduction

Maintaining optimal water levels in storage tanks is essential for ensuring continuous water availability in both residential and industrial environments. Water management systems play a vital role in preventing issues such as overflow[5], dry running of pumps, and inconsistent water supply. Traditional systems for monitoring and controlling water levels often utilize mechanical float switches, open-wire sensors, or conductive probes. However, these systems are susceptible to numerous drawbacks including corrosion, sediment accumulation, electrical shorting, and mechanical wear. Over time, these issues can lead to inaccurate readings, frequent malfunctions, and increased maintenance costs.

To address these challenges, this project proposes the design and implementation of an automated water tank controller using Hall effect sensors. Hall effect sensors detect magnetic fields without requiring physical contact, making them inherently more durable and resistant to environmental degradation. By coupling these sensors with a magnetic float mechanism, the system can monitor water levels accurately and reliably without direct exposure to water or contaminants.[3]

This contactless sensing approach minimizes maintenance requirements and enhances the overall longevity and performance of the system. Furthermore, the simplicity of installation and the low power consumption of Hall effect sensors make the proposed design suitable for both conventional and smart water management applications. The resulting system is a cost-effective, efficient, and scalable solution that significantly improves upon the limitations of traditional water level monitoring methods.

2. Literature Review

Previous studies have shown that conventional water tank control systems suffer from several limitations, including high maintenance requirements, lower precision, and susceptibility to environmental degradation. Mechanical float switches, conductive probes, and ultrasonic sensors—commonly used in traditional systems—are often impacted by sediment accumulation, corrosion, and mechanical wear. These limitations contribute to frequent system failures, reduced accuracy over time, and the need for regular servicing, especially in environments with varying water quality.[5]

In response to these challenges, researchers have explored the integration of solid-state sensing technologies, particularly Hall effect sensors, as a more robust and reliable alternative. The Hall effect, discovered by Edwin Hall in 1879, refers to the production of a voltage across a conductor when it is [1]placed within a magnetic field and an electric current is applied. This phenomenon is the basis for Hall effect sensors, which convert magnetic field variations into electrical signals. These sensors are widely utilized in automation, automotive systems, industrial control, and increasingly in fluid level detection.

Hall effect sensors are primarily available in two types: linear (analog) sensors and threshold (digital) sensors. Linear sensors provide a continuous output proportional to the magnetic field intensity, enabling real-time measurement of varying levels. Threshold sensors, on the other hand, switch states when a magnetic field crosses a predefined threshold, making them suitable for binary level detection such as “tank full” or “tank empty.” Both types offer advantages in water level sensing applications [2]due to their ability to function without direct contact with water, thereby eliminating risks associated with corrosion, fouling, or contamination.

In the context of water tank automation, Hall effect sensors offer several key benefits. They enable durable, contactless, and accurate monitoring of water levels. Unlike ultrasonic sensors, which can be affected by water turbulence, surface foam, or vapor, and unlike mechanical switches, which are prone to mechanical failure, Hall effect sensors maintain stable performance over long durations. Furthermore, they typically require less frequent calibration and demonstrate strong resistance to environmental noise and temperature variations.

Recent studies have validated the efficacy of Hall effect sensors in [3]water level control systems, highlighting their low power consumption, ease of integration with microcontrollers, and flexibility in both residential and industrial settings. Their increasing use in smart systems, often paired with microcontrollers like Arduino or ESP32, has further broadened their applications, including real-time monitoring, automation, and wireless control.

3. Objective of the Work

The objective of this study is to design and implement an automated water level control system using Hall effect sensors, aimed at improving the reliability, accuracy, and efficiency of water tank management. This work seeks to address the limitations of conventional systems—such as mechanical floats and contact-based sensors—which are often affected by corrosion, wear, and maintenance issues.

The specific goals of this research are:

- To utilize Hall effect sensors for non-contact water level detection using a magnetic float mechanism.
- To develop a cost-effective and energy-efficient control circuit that automates pump operation based on sensor feedback.
- To ensure stable, maintenance-free operation suitable for long-term deployment in residential, commercial, and industrial water storage applications.
- To explore the potential for scalability and integration with smart systems for future enhancements like wireless monitoring and predictive analytics.

This work demonstrates a practical application of sensor-based automation to advance sustainable water resource management.

3.1. Problem Statement

Traditional water tank level control systems suffer from issues such as corrosion, mechanical wear, and inaccurate sensing due to direct contact with water. These limitations lead to frequent maintenance and unreliable operation. There is a need for a durable, contactless, and low-maintenance solution to ensure accurate water level monitoring and efficient pump control.

3.2. Block Diagram of Proposed Hardware

The proposed hardware system is designed to automate water level control using Hall effect sensors in a reliable and contactless manner. A 12V DC power supply provides the necessary voltage to all components in the system. The low-level Hall effect sensor detects when the water falls below a critical threshold. When triggered by the presence of a floating magnet, the sensor sends a signal to the comparator.

The comparator compares this signal with a predefined reference voltage. If the sensor signal crosses the threshold, the comparator output changes state and activates a BJT transistor, which functions as a switch. The transistor, in turn, powers the relay module. Once energized, the relay closes the circuit for the water pump, allowing it to operate and fill the tank.

This setup ensures that the pump is activated automatically when the water level is low, without requiring manual input. The use of contactless sensing via the Hall effect improves the system's durability and reduces maintenance needs compared to conventional water level sensing methods. The system is scalable, energy-efficient, and well-suited for both residential and industrial applications.

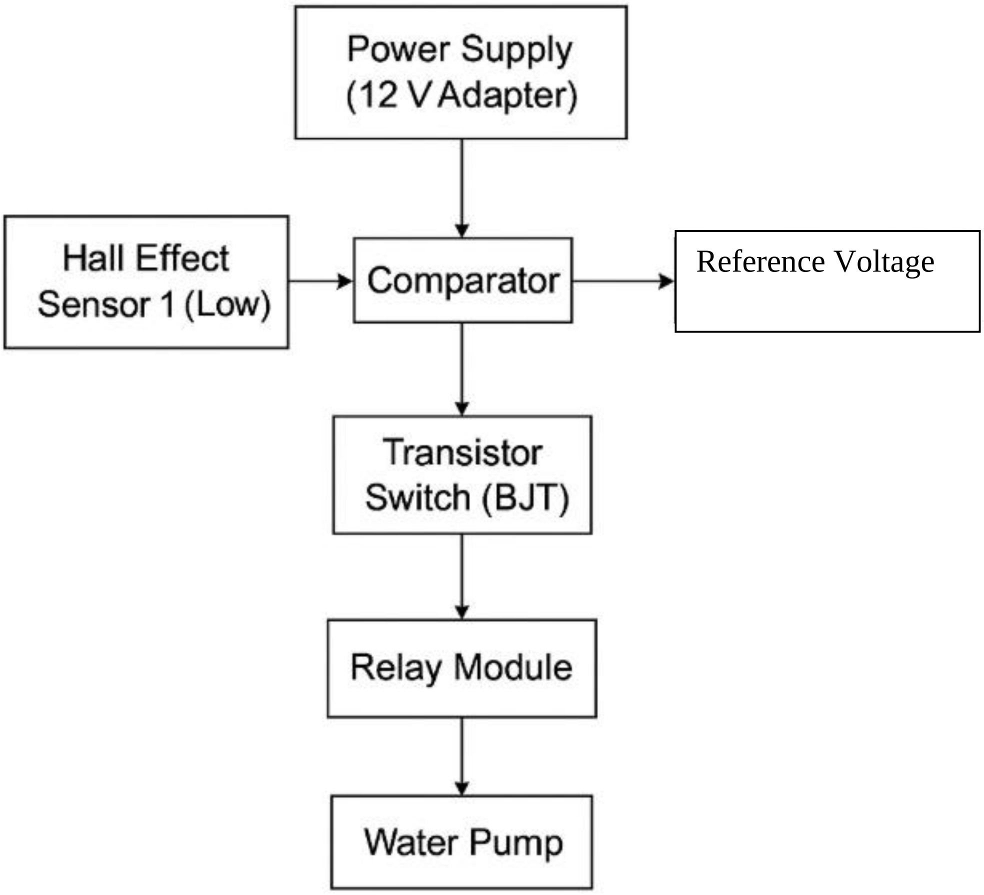


Figure 1.1: Block diagram of proposed hardware of water controller system.

3.3. Flowchart of the Proposed Process Flow

The flowchart illustrates the logical flow of the proposed automatic water tank controller system using Hall effect sensors. The system starts by continuously monitoring the water level through a low-level Hall effect sensor. If the water falls below the low threshold, the sensor activates the relay to turn ON the water pump. The pump remains ON until the high-level sensor detects that the tank is full. Once this condition is met, the pump is automatically turned OFF via the relay. The system then returns to the monitoring state, repeating the cycle without requiring manual intervention.

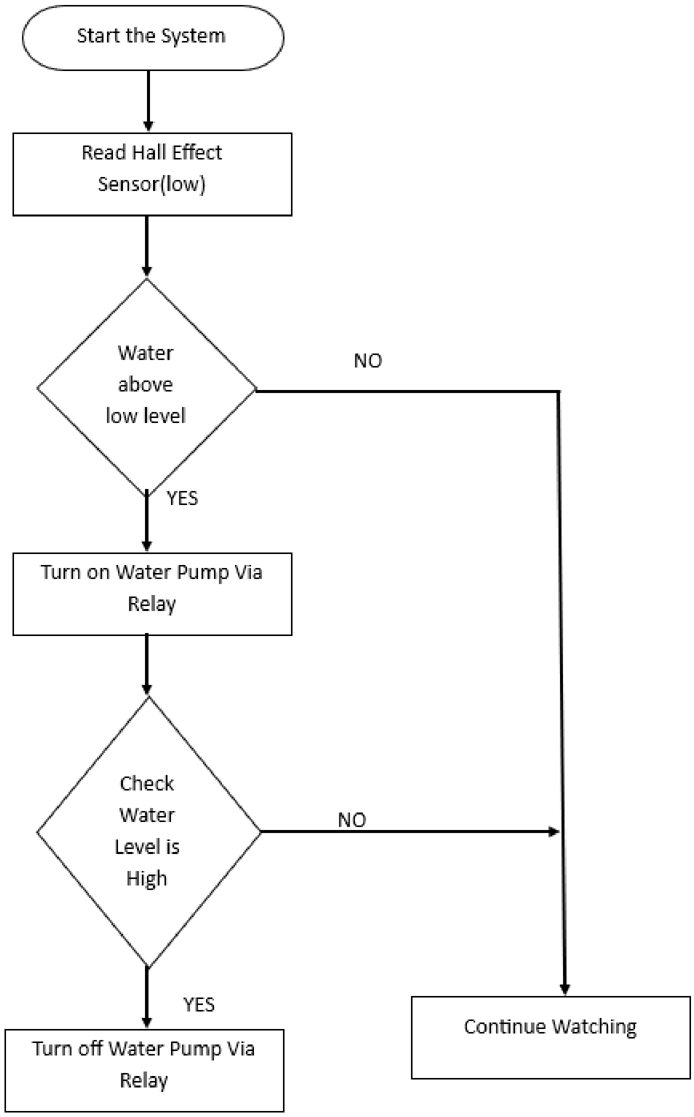


Figure 2: Flowchart of the Proposed water controller System.

4. Hardware Details and Connectivity

4.1. Resistor

Resistors are used to limit current voltage in circuits.
A 10kΩ resistor is commonly used for pull-up/down circuits and signal control.
A 47kΩ resistor is used in voltage dividers and biasing where higher resistance is needed.
Both values are crucial for stabilizing and protecting components in analog and digital circuits.
They help ensure accurate operation and improve circuit efficiency

For regulating the flow of the electric current in the circuit we have used nine resistors. Their specifications are given below:

Resistor Name	Unit(kΩ)
R1	47
R2	47
R3	47
R4	47
R5	10
R5	10
R6	10
R7	10

Table 1

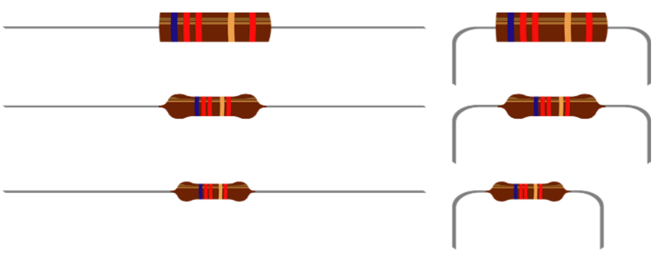


Figure 3: Resistor 10k(ohm)and 47k(ohm)

4.2 Hall Effect Sensor

A Hall-effect sensor, also known as a Hall sensor, monitors magnetic fields with high accuracy, consistency and reliability. Why is that important? Because it enables you to sense the position and movement of objects in a system. In this article, I'll explain what a Hall-effect sensor is, its basic building blocks and functionality, and common use cases for Hall-effect sensing products.

A Hall-effect sensor is not your typical integrated circuit (IC), because unlike most ICs, it indirectly interacts with its key "circuit" – a magnet! As shown in Figure (4) the elementary Hall-effect sensor comprises a Hall element, which turns a magnetic field into a voltage, and processing circuitry such as an operational amplifier. Both analog and digital processing circuitry are critical to a Hall-effect sensor's operation because the output voltage from a Hall element is tiny – sometimes in the microvolt range. One of the simplest Hall-effect sensors uses only three-pin packages, small-outline transistor (SOT)-23 or transistor outline (TO)-92, for the power supply, ground connection and output.

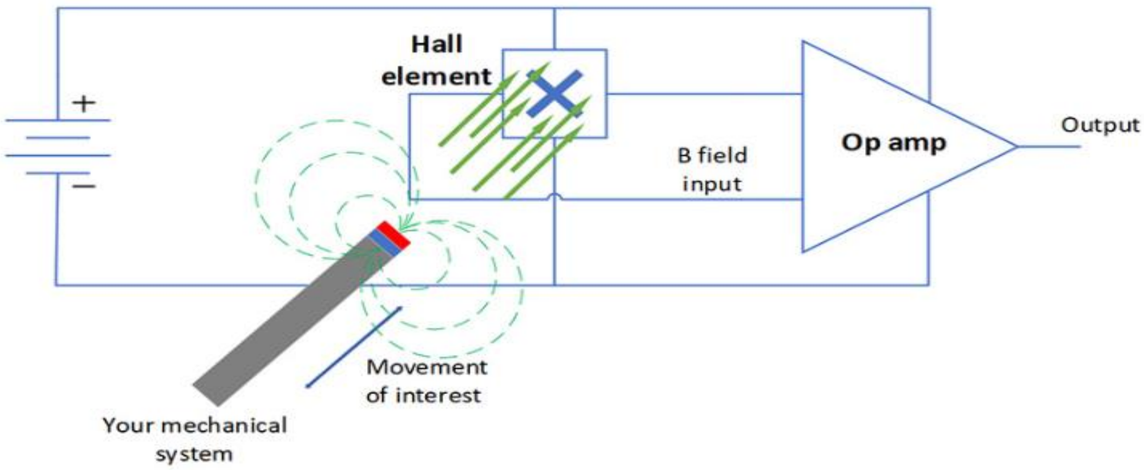


Figure 4: Basic Hall Effect sensor

4.3 Amplifier

An amplifier is an electronic device that increases the voltage, current, or power of a signal. Amplifiers are used in wireless communications and broadcasting, and in audio equipment of all kinds.

There are three amplifiers in the circuit. They are given below:

Amplifier Name in circuit	Amplifier Series
U2:A	LM324
U2:B	LM324
U2:C	LM324

Table :2

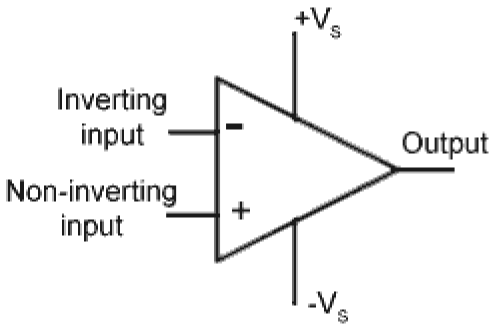


Figure 5: Basic circuit of Amplifier

4.4 Diode

A diode is a semiconductor device, typically made of silicon, that essentially acts as a one-way switch for current. It allows current to flow easily in one direction but severely restricts current from flowing in the opposite direction.

Diodes are also known as rectifiers because they change alternating current (AC) into pulsating direct current (DC). Diodes are rated according to their type, voltage, and current capacity.

There are four diodes used in the circuit. They are given below:

Diode Name in circuit	Diode Series
D1	1N4148
D2	1N4148
D3	1N4148
D4	1N4148

Table:3 Diode Name and Series

Figure :6 Diode

4.5 Transformer

An apparatus that transforms alternating current (AC) from your power source into direct current (DC) at 12 volts is called a DC 12V transformer. This kind of transformer is necessary to power LED lights because they need a constant DC voltage to function properly.

Figure 7: Transformer 12 v

4.6 Bipolar Junction Transistor (BJT)

A BJT, or Bipolar Junction Transistor, is a three-terminal semiconductor device used for amplification and switching. It controls the flow of current between the collector and emitter terminals by using a small current at the base terminal. BJTs are current-controlled devices, meaning the base current determines the current flowing between the collector and emitter.

Key Characteristics of a BJT:

- **Three Terminals:** Base, Collector, and Emitter.
- **Current Controlled:** A small base current controls a larger current between the collector and emitter.
- **Amplification:** BJTs can amplify signals, meaning they can produce a larger output signal from a smaller input signal.
- **Switching:** BJTs can be used to switch electrical power on and off.
- **Two Types:** NPN and PNP.
- **Used in various applications:** Amplifiers, switches, and in integrated circuits.

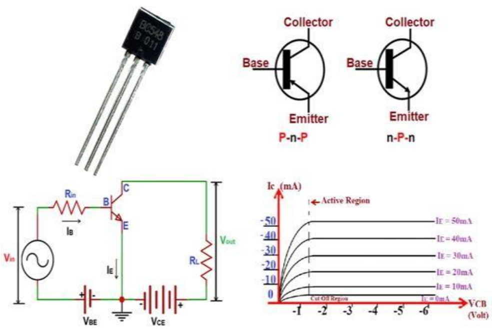


Figure 8: BJT

4.7 Transistor

A transistor is a type of semiconductor device that can be used to conduct and insulate electric current or voltage. A transistor basically acts as a switch and an amplifier. In simple words, we can say that a transistor is a miniature device that is used to control or regulate the flow of electronic signals.

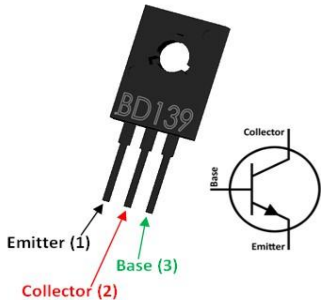


Figure 9: Transistor

4.8 Water Tank

We have used a water jar to store the water on the purpose of applying the project application. The water can be poured from one side to store and also there is a tap to empty the water tank.

4.9 Electrical Wire and casing

Electrical wires and a casing frame are used to make the infrastructure of the electrical circuit.

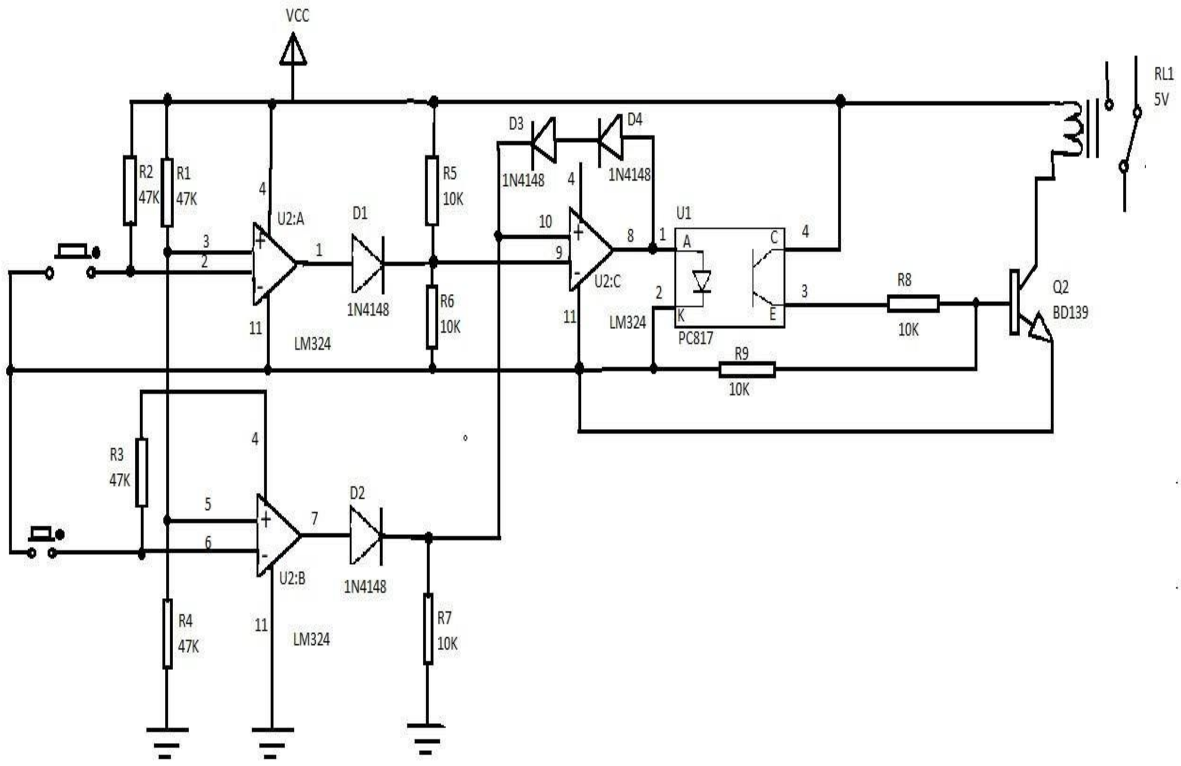


Figure 10: Interconnection of sensor and equipment output modules with Transformer

5. Hardware Implementation

The hardware setup of the automated water tank controller is designed using discrete electronic components, focusing on simplicity, cost-effectiveness, and reliability. The central sensing mechanism involves Hall Effect sensors paired with a floating magnet to detect water levels without direct contact.

Key Components and Their Roles:

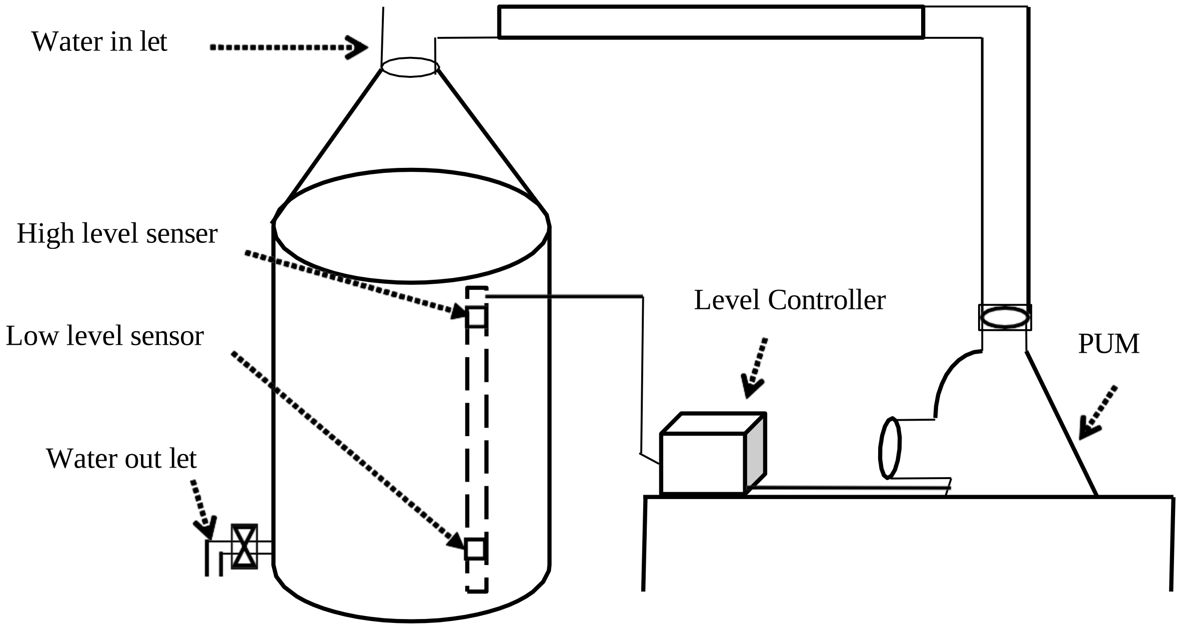
- Hall Effect Sensors: Used to detect the magnetic field from the float magnet, indicating specific water levels.
- Resistors (47 kilo ohm and 10 kilo ohm): Regulate current flow and create reference voltages for the comparator circuits.
- Amplifiers (LM324 series): Function as comparators, comparing the Hall sensor output with a set reference voltage.
- Diodes (1N4148): Protect the circuit from reverse voltage and provide flyback protection for relays.
- Transistor (BD139): Acts as a switch, driven by comparator output to control the relay.
- BJT (PC817): Opto-isolator used for isolation between control and power circuits.
- Relay: Acts as an electromechanical switch to control the water pump.
- Transformer (12V, 600mA): Steps down AC voltage to power the circuit.
- Water Tank & Float Magnet: Represents the physical tank setup; the float moves with the water level and triggers the sensor.

Working Principle:

- The float-mounted magnet changes position with the water level.

- When the water reaches the low-level sensor, the pump is turned on.
- When the high-level sensor is activated, the pump is turned off automatically.
- This feedback mechanism ensures automatic operation without manual intervention.

The system's robustness, low power consumption, and ease of installation make it ideal for home and industrial use.



B Figure 11: Prototype of the Water Controller

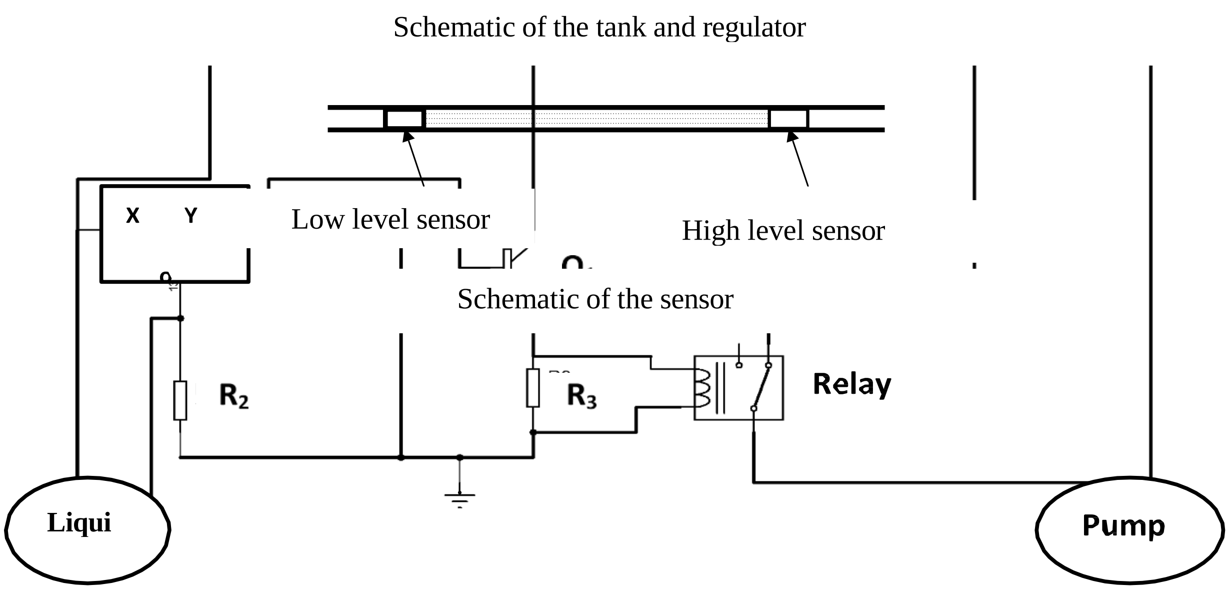


Figure 12: Prototype of Water Level controller

6. Results and Discussions

6.1. Operation

- ✓ When the water level is below the sensor, the magnet is not in proximity, and the Hall sensor output is low.
- ✓ The comparator output remains low, keeping the transistor off and the relay de-energized. The pump remains off.
- ✓ As the water level rises, the magnet approaches the sensor, changing the sensor output.
- ✓ The comparator detects this change and switches its output high, turning on the transistor.
- ✓ The energized relay activates the pump to fill the tank.
- ✓ Once the water level drops again, the magnet moves away, the sensor output goes low, the comparator output switches low, turning off the transistor and de-energizing the relay, stopping the pump.

6.2. Pics of Prototype Circuit

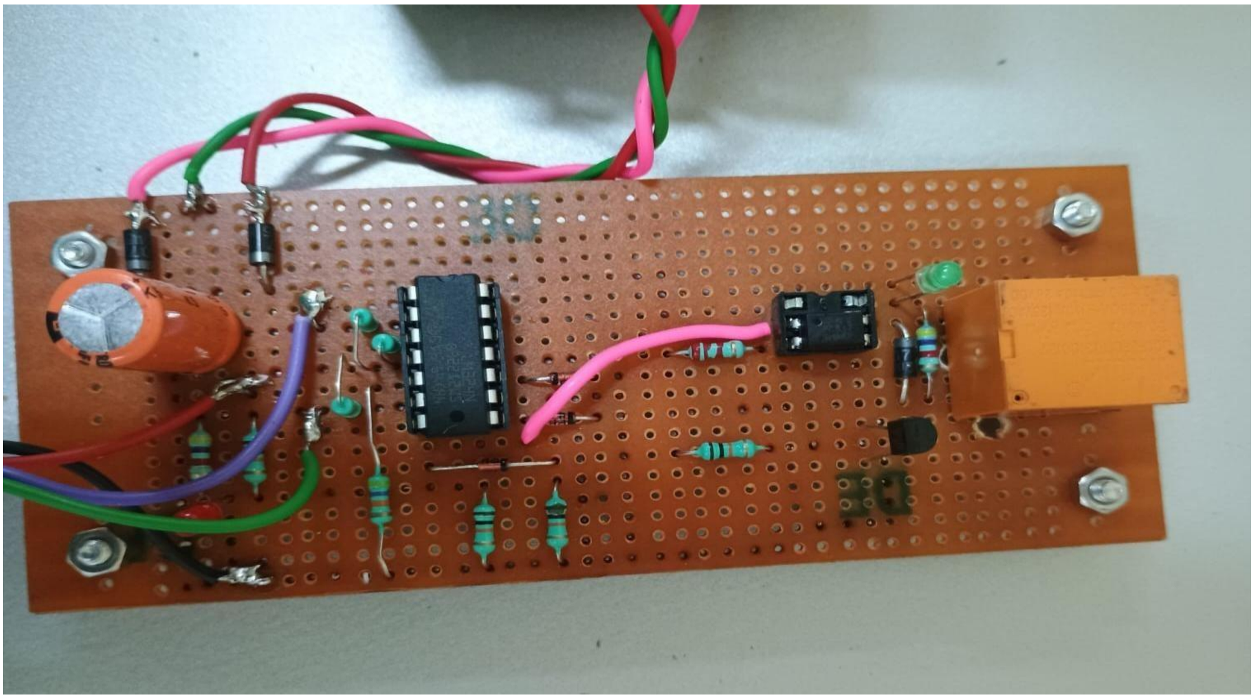


Figure 13: Circuit implementation with Relay Module and Transformer

7. Conclusions

The project on the water tank controller using a Hall effect sensor successfully demonstrates an effective and reliable method for monitoring and managing water levels in a tank. The Hall effect sensor, known for its precision and durability, proved to be an excellent choice for this application. By detecting the magnetic field variations caused by the float's position, the sensor provided accurate real-time data on the water level.

In conclusion, the water tank controller utilizing a Hall effect sensor is a robust solution for automated water management. It addresses common issues associated with traditional water level detection methods and offers a modern, efficient approach to maintaining optimal water levels. Future improvements could include wireless data transmission for remote monitoring and integration with smart home systems to further enhance its functionality and user convenience.

8. Future Scope

The proposed water tank controller demonstrates an effective and low-maintenance solution for water level management. However, the system can be further enhanced and scaled for broader applications. The following developments are possible in future iterations of this project:

- **Wireless Monitoring and Control**

Integration with Wi-Fi or GSM modules can enable remote access to water level data and pump control via smartphones or web applications.

- **IoT Integration**

The system can be connected to Internet of Things (IoT) platforms like Blynk or ThingSpeak for real-time analytics, cloud storage, and automated decision-making.

- **Multi-Tank Support**

Expanding the system to monitor and manage multiple water tanks across buildings or fields from a centralized controller would be beneficial for apartments and farms.

- **Smart Home Compatibility**

Integration with smart home ecosystems (e.g., Google Home, Amazon Alexa) would allow voice-based control and smart alerts.

- **Water Quality Monitoring**

Additional sensors can be added to monitor pH, turbidity, and contaminants, making the system useful for drinking water applications.

- **Solar Power Operation**

To increase sustainability, the system can be powered using solar panels, making it suitable for rural or off-grid areas.

- **Leak Detection and Water Theft Prevention**

Advanced versions can include flow sensors and algorithms to detect leaks or unauthorized water usage, improving resource conservation.

- **Predictive Analytics**

Machine learning algorithms can be employed to analyze usage patterns and predict optimal refill times, enhancing efficiency and reducing wastage.

- **Scalability for Industrial Applications**

With robust shielding and industrial-grade components, the system can be adapted for large-scale storage tanks in factories or irrigation systems.

- **Mobile App with Alerts**

A dedicated mobile application can be developed to provide alerts for overflow, dry conditions, or maintenance needs.

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