Digital Electronics – IE2010

Assignment

Topic: **Automated Water Pump Control System**
Batch Number: Y2.S1.WD.CSNE.01.1

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Abstract

This lab report outlines the design and implementation of an automated water pump control system for managing the filling of an overhead tank from an underground storage facility. The system monitors water levels in an overhead tank and an underground storage unit based on sensor inputs implemented using NAND gates, controlling an electric water pump. The logical conditions for pump control are to ensure the efficient filling of the overhead tank from underground storage while maintaining the desired water levels in the overhead tank. The objective is to prevent overfilling or draining of the overhead tank and optimise water utilisation.

Introduction

Effective water management is crucial in many home settings to guarantee a constant water supply while reducing waste. The system described in this lab report automates the operation of an electric water pump in charge of filling an overhead tank from an underground storage unit by employing NAND gates.

Creating a Diagram and Explanation of the Scenario

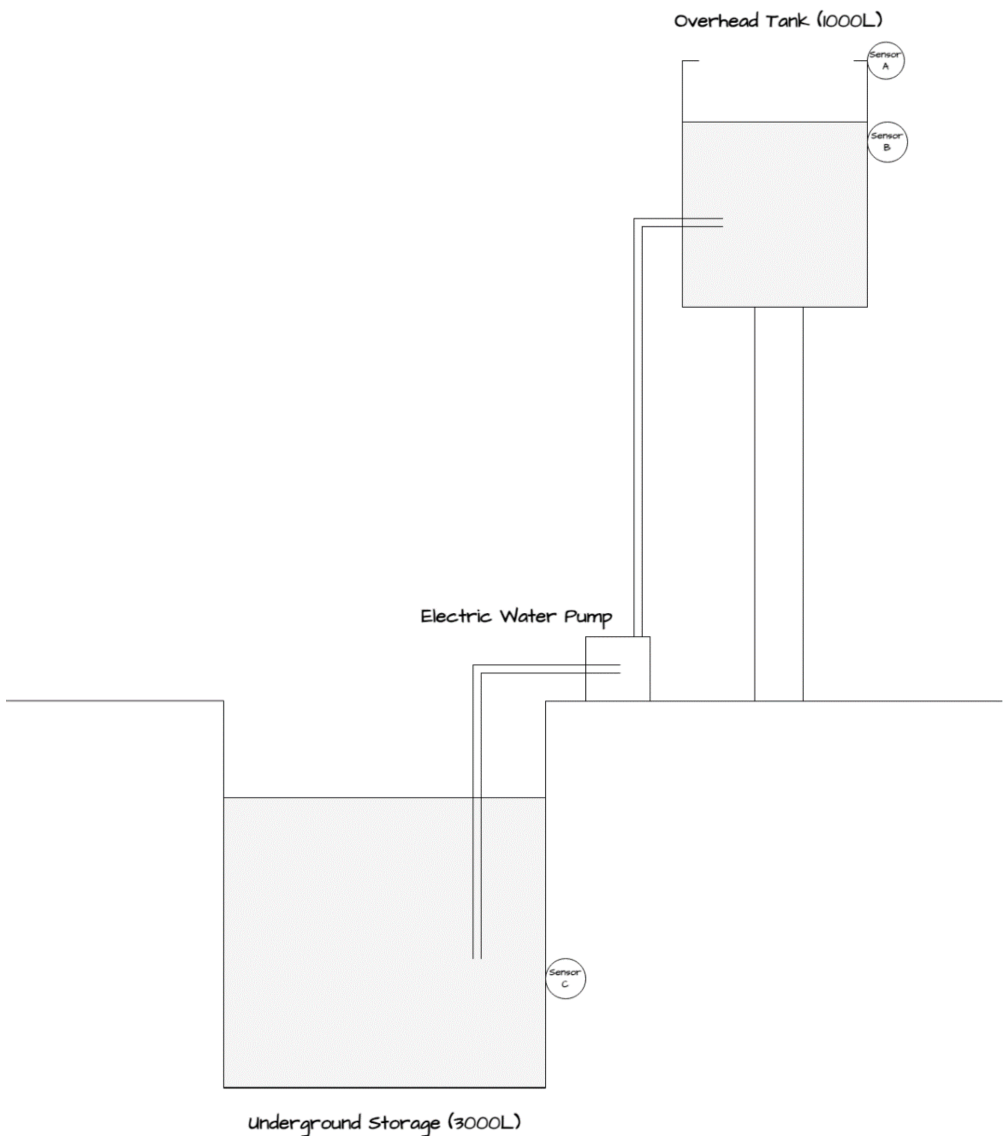

Figure 1 Representation of the Water Pump Control System

The mechanism assures these crucial conditions:

Two water storage tanks are used in this system: an underground storage tank with a maximum capacity of 3000 litres and an overhead tank with a maximum capacity of 1000 litres. For water level control, it employs three sensors with the names A, B, and C. The electric water pump is started when the overhead tank fills to its 1000-litre capacity, at which point the switch connected to Sensor A, which is positioned at that level, closes. When the water level is less than 1000 litres, the switch opens.

When the overhead tank has more water than or equal to 750 litres, the switch connected to Sensor B, which is placed at that level, closes. When the water level drops below 750 litres, the switch connected to Sensor B opens.

When the subterranean storage tank has at least 1000 litres of water, the switch connected to Sensor C, which is located at that level, closes. When the water level is below 1000 litres, the switch connected to Sensor C opens.

When in use, the electric water pump activates when the overhead tank's water level falls below 750 litres (with Sensors A and B both inactive) and the underground storage tank has at least 1000 litres of water (with Sensor C active). Until the overhead tank fills to its 1000-litre capacity (when Sensor A is active), water is continually pumped from the underground storage into the overhead tank. At that time, the pump shuts off.

Methods and Materials

Components Used:

1. 2 quad NAND gate integrated circuits (7400 series or equivalent)

2. Power supply

3. Small breadboard

4. 3 slide-switches

5. LED

6. Jump wires

Deriving a Simplified Expression for F with NAND Gates:

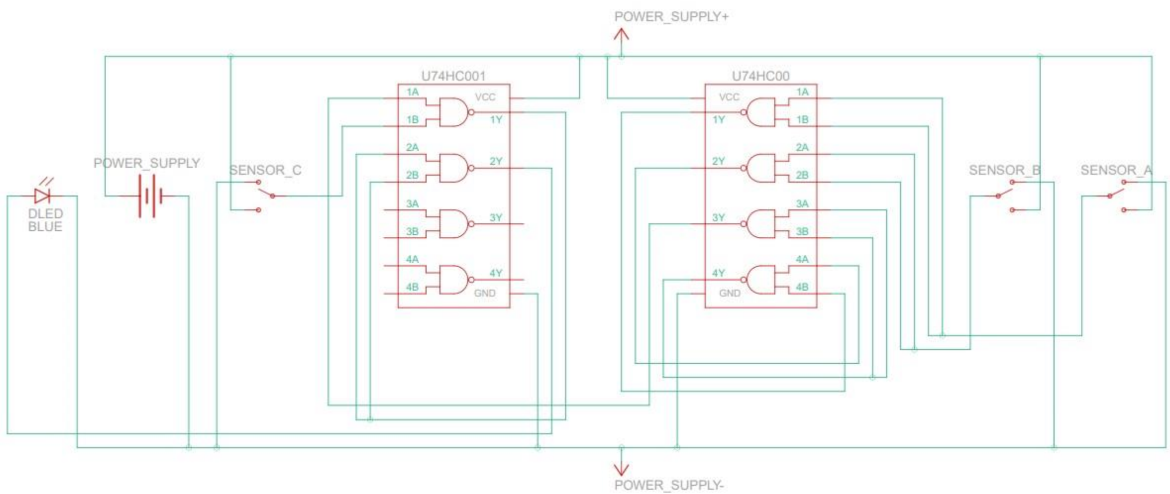

Figure 2 Schematic View of the Breadboard Circuit

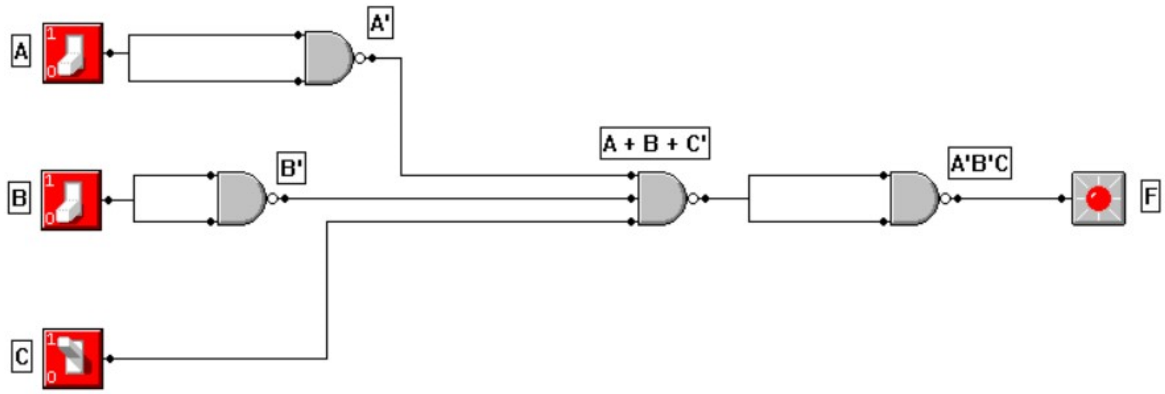

Figure 3 Simplified NAND Logic Gate Circuit

Circuit Implementation:

- Connect the positive terminal of the power supply to the top of the positive power rail of the small breadboard using a jump wire.
- Connect the negative terminal of the power supply to the top of the negative power rail of the small breadboard using another jump wire.
- At the bottom of the breadboard, use wires to connect the power rails linked to the power supply to their corresponding counterparts on the opposite side of the breadboard.
- Attach three slide switches to terminal strips (5-hole rows) of the breadboard, representing our three sensors A, B, and C.
- For each of these switches, connect terminal 1 to the negative power rail of the breadboard and terminal 2 to the positive power rail.
- Position two quad NAND gate integrated circuits (74HC00 or equivalent) on the centre divider of the breadboard.
- Connect the power for the first IC to the positive power rail and the ground to the negative power rail of the breadboard.
- Repeat this process for the second IC.
- Link the common terminal of switch A to both inputs 1A and 1B of the first IC.
- Likewise, connect the common terminal of switch B to inputs 2A and 2B of the first IC.
- Connect output 1 of the first IC to input 4B, and output 2 to input 4A.

- Connect output 4 to input 3B and input 3A.
- Connect output 3 of the first IC to input 1A of the second IC.
- Connect the common terminal of switch C to input 1B of the second IC.
- Connect the anode of an LED to output 2 of the second IC, and connect the cathode of the LED to the ground of the IC.

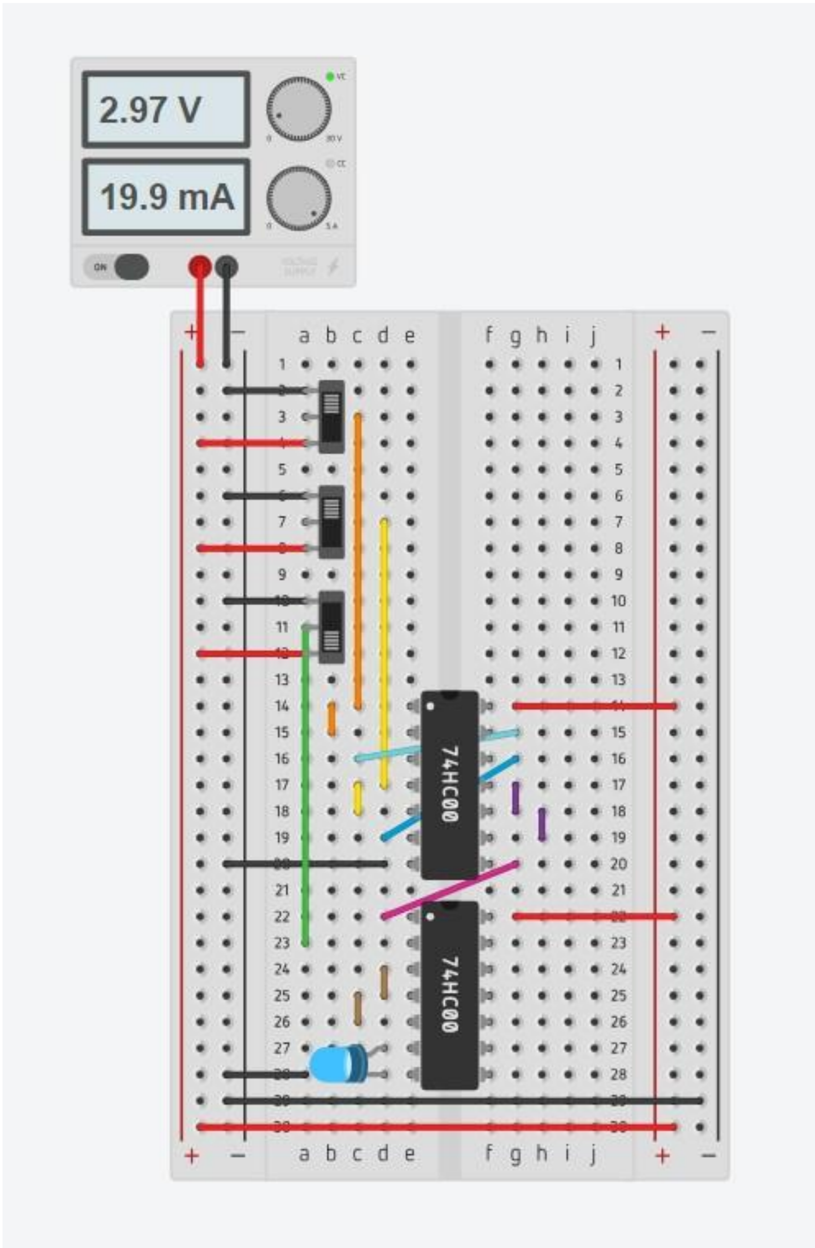

Figure 4 Circuit View of the Breadboard Circuit

Observations

Upon implementing the circuit and applying input conditions, the control system successfully maintains the water levels in both the overhead tank and the underground storage and operates the water pump according to the specified conditions in the truth table below. The LED indicator turns on when the water level in the overhead tank falls below 750L and remains on until the tank reaches 1000L. The underground storage level is also monitored to ensure it stays above 1000 litres. Therefore, it prevents overfilling of the overhead tank and ensures a minimum level of underground storage for continuous water supply.

Truth Table for Output F Using A, B, and C

A	B	C	F
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	0

Prohibited states

Figure 5 Truth Table for the Motor Operation

Discussion

The discussed circuit effectively automates water pump control by employing NAND gates, ensuring the pump operates as expected based on logical conditions. This system activates the water pump when the overhead tank's water level drops below 750 L and maintains a minimum underground storage level of 1000 L while also deactivating the pump once the tank reaches 1000 L. This implementation using NAND gates exemplifies an efficient and compact logic design.

Such automated water pump control systems play a crucial role in optimising water management in both residential and commercial settings. These systems offer numerous advantages, including water conservation by preventing overfilling of the overhead tank, ensuring a continuous water supply even during peak usage, maintaining the underground storage level, and enhancing user-friendliness as residents no longer need to manually control the water pump.

Possible Reasons for Omitting a Sensor to Detect Maximum Water Level in Underground Storage

It can be noticed that there is no sensor for detecting the maximum water level of the underground storage. The reasons for this are typically based on practical and cost-related factors, such as:

- **Cost Constraints:** Installing sensors can be expensive, especially high-precision ones. If budget constraints exist, omitting this sensor can save costs.
- **Assumed Maximum Capacity:** If the underground storage is unlikely to exceed its maximum capacity in regular use, it may be deemed unnecessary.
- **Simplicity:** A simpler system with fewer sensors can lead to easier installation and lower maintenance requirements.
- **Maintenance Concerns:** Sensors require regular maintenance, and eliminating non-essential sensors can reduce this burden.
- **Reliability:** Fewer sensors mean fewer potential points of failure in the system.

Conclusion

In summary, we have designed and implemented an automated water pump control system that effectively manages water levels in both an overhead tank and an underground storage unit. This system operates using NAND gates and sensor inputs, demonstrating the practical application of logic gates in real-world automation scenarios. By maintaining optimal water storage and usage, this technology proves valuable for ensuring a reliable water supply in residential and commercial settings while promoting water conservation.

References

1. Harris, S., & Harris, D. (2016, January 1). Combinational Logic Design. Elsevier eBooks. https://doi.org/10.1016/b978-0-12-800056-4.00002-9

2. List of 7400-series integrated circuits. (2023, August 28). Wikipedia. https://en.wikipedia.org/wiki/List_of_7400-series_integrated_circuits