Water Level Indicator

Special Assignment and Lab Project Report

Course: 2EC202CC23: FPGA and System Design

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Abstract

The project - "Water Level Indicator " aims to develop a system for water level monitoring . The main objectives aimed are the avoidance of water overflow and wastage, thus preventing common problems arising in households, industries, and agricultural setups. The system also aims to protect water pumps from damage due to dry running by ensuring they only operate when necessary.

The proposed solution includes a water level indicator circuit with multiple sensors at different levels within the tank that will detect and provide water level status. In case the water level drops down to the set low threshold, the system automatically runs the water pump to refill the tank. The controller also cuts off the pump when the tank level hits the preset high threshold to avoid overflows. The indicator reads information from digital signals and displays the actual water level on a 7-segment LED display.

This project provides an efficient and cost-effective approach to water management, ensuring resource conservation and equipment longevity. It can also be scaled to further elaboration with embedded wireless communication and remote monitoring. It can be applied on industry applications involved in smart home and automation systems.

Contents

1. **Introduction**

The "Water Level Indicator " project aims to develop an automated solution for effective water management, targeting issues such as water overflow, dry running of pumps, and water wastage. With growing awareness about water conservation and equipment longevity, this project offers a practical, low-maintenance approach to managing water levels in storage tanks.

This system uses a series of hookup wires positioned at specific levels inside a water tank to measure and relay real-time water level data to a control circuit. The control unit interprets this data and displays the tank's current level on a 7-segment display . When the water drops below a designated level, the system automatically turns on the pump to refill the tank. When the tank reaches a high level, the system shuts off the pump to prevent overflow. This automated approach not only saves water but also ensures pumps operate efficiently, reducing wear and maintenance costs. For remote monitoring, the design can incorporate wireless modules, making it adaptable for use in modern smart systems.

Applications :

1. **Residential Use:** Offers households an automatic refill and shutoff system, conserving water and reducing manual intervention.
2. **Agricultural Systems:** Helps manage water in irrigation tanks, ensuring fields receive adequate water without overuse.
3. **Commercial and Industrial Settings:** Maintains consistent water levels for processes requiring a steady supply, such as cooling or storage operations.
4. **High-Rise Buildings:** Keeps water reserves ready and well-managed, supporting the demand for a stable water supply in larger structures.

This project combines simplicity and practicality, making it a versatile solution for various water management needs.

2. Literature Survey/State of the Art Technology Available :

With the sharp demand for efficient management of water, some technological improvements in water level indicators and controllers have been carried out. In most systems, arrays of sensors, automation controllers, and IoT technology are used to reduce cases of water wastage, overflow, or dry running of the pump. The following are some common technologies and designs of similar projects:

1. Sensor-Based Water Level Detection

The traditional method of water level control relies on float switches or conductive sensors measuring the levels of water in the tanks. Capacitive and ultrasonic sensors proved more popular since they can accurately read without having any direct contact with water, thus making them more durable. For example, with regard to a water tank automation system in Kumbhar & Joshi's (2018) work, capacitive sensors were well suited for steady readings. Ultrasonic sensors were used to ensure non-contact measurements. Such sensors have therefore made it possible to control the water level in an efficient manner and with reduced maintenance needs.

2. Microcontroller-Based Systems

Most water level controllers will use microcontrollers such as Arduino, ESP8266, or Raspberry Pi to make the sensor measurements and pump switching. This is relatively cheaper and can be programmed easily. A study by Shewale et al. in 2020 further demonstrated the possibility of using microcontrollers for executing water management tasks, since flexibility and reliability were offered as opposed to mechanical switch operations.

3. IoT and Remote Monitoring Solutions

IoT integration becomes popular, which allows getting the access to water levels by way of mobile applications or could-based systems. Such kind of solution uses Wi-Fi or GSM modules that proffer a network connection point for the water level controller making possible a check of tank status, setting adjustment, and alerts regardless of location. Other projects, such as Patil et al. (2022), demonstrate that IoT-enabled water controllers would indeed provide a real-time monitoring and reporting system that would be great news for large facilities or multi-story buildings.

4. Machine Learning for Predictive Maintenance

The advanced systems apply machine learning algorithms that analyze the prediction of maintenance for pump optimization and water usage optimality. These patterns examine sensor data as well as from the users to detect anomalies, which then raise maintenance alerts before the breakdown. For example, Sundaram et al. (2021) discussed predictive maintenance on industrial water systems, showing the use of AI-enhanced control systems to reduce downtime and increase efficiency. However, these technologies are still in the developmental stage regarding small-scale water management.

5. Smart Home Integration

Actually, all contemporary water controllers are modernized to integrate with intelligent home platforms like Google Home or Amazon Alexa. This is, therefore, possible for users to easily regulate water systems even by voice commands or even application-based interfaces. While its technology is aimed at being convenient, it will even enhance the preservation of water as users can schedule water usage on demand, as outlined in studies such as Nadkarni & Shah (2019).

3. Proposed Solution/Methodology

This project proposes a Water Level Indicator and Controller system that uses different ICs (Integrated Circuits) for the working and functionality of the project in addition with a 7-segment common cathode display that displays the water level reached at various levels within the tank. Wires are positioned at specific levels within the tank , allowing the circuit to track the water level and indicate the same on the 7-segment display.

For the controller system , a simple circuit has been designed with a NOR gate IC (7402) and a LED that emits light in accordance with the water level in the underground tank and upperhead tank. When water reaches a low threshold in the upperhead tank , the LED gets ON (implies that the controller triggers the pump to refill the tank) , and when it reaches a high threshold in the upperhead tank , the LED switches OFF (imples that the controller stops the pump). The operation of the controller circuit also depends on the level of water in the underground tank . If there is no water in the underground tank the LED will remain OFF (the pump will not start) .

Methodology

1. System design and component selection : The first step involves designing the overall system architecture and selecting components, including different ICs , battery, capacitors, resistors, male to male wires, LEDs and 7-segment displays.

2. Sensors placement : Hookup wires (sensors) are installed at designated points within the tank to accurately detect different water levels.

3. Programming and logic implementation : A Verilog code has been designed for the Indicator and Controller circuit in the Quartus software that takes inputs the different water levels and the output is shown on the FPGA kit on the 7-segment display or LED.

Truth table and logic expression of both the circuits helps in understanding and proper working of the project.

4. Testing and validation : The system will undergo testing under various cases as per the truth table to ensure reliability.

Justification of approach :

The justification for this approach lies in its simplicity, cost-effectiveness, and ease of implementation. This approach is advantageous because it offers a straightforward solution for households or small facilities where water levels need to be managed efficiently. The use of 7-segment display provides a clear visual indication of the tank’s water level, making it easy for users to monitor. This solution is practical, reliable, and accessible to a wide range of users, especially in residential or small-scale applications.

4. Block Diagram & Circuit Diagram

- Provide a high-level **block diagram** of your system, showing the main functional units and their interactions.
- Include state diagram if applicable (Optional)
- Include a **circuit diagram** if applicable, illustrating the specific electrical connections or logic gates used in your design.
- Both diagrams should be well-labeled and easy to interpret.

5. Design

5.1 Verilog implementation steps/flowchart

Steps :

1. Define Module :

- Begin by defining the module named "`Indicator`"
- Specify the inputs and outputs:

  - BCD : A 4-bit input representing water levels from 0 to 9 in binary form.
  - seg : A 7-bit output controlling a common cathode 7-segment display.

2. Set up combinational logic with "always" block.

3. Implement case statement for BCD to 7-segment encoding :

- Inside the always block, use a case statement to define the segment patterns for each BCD value from 0 to 9. Each case assigns a 7-bit binary code to seg to display the corresponding digit.
- Use the default case to turn off the display for any BCD values outside the range i.e., levels 10-15.

4. End the always and case blocks .

5.2 Circuit design :

- **Truth Table :**

  1. Water Level Indicator (BCD to 7-segment common cathode display) :
  2. Controller :

- **Calculations and Equations :**

6. Details of All Hardware Components Used and Its Justification :

- **List of hardware components :**

1. Water level Indicator :

- 9V battery
- 7805 voltage regulator
- 104pF capacitor
- 7-segment common cathode display
- 560kohm resistors and 100ohm resistor
- Hookup wires
- Male to male jumper wires
- Breadboard

- **Justification :**

1.

The **FPGA DE2 Board** is a development platform based on **Altera Cyclone II FPGA**, widely used for **digital system design, prototyping, and hardware implementation**. It features:

GPIO pins for sensor interfacing

7-segment displays, LEDs, switches, and push buttons

SDRAM, Flash, and SRAM memory

VGA, USB, RS-232, and Audio interfaces

Quartus II support for Verilog & VHDL programming

In the **Water Level Indicator** project, the DE2 board processes **sensor input through GPIO pins** and displays water levels on a **7-segment display**, demonstrating **real-time monitoring and automation**.

2. 9V battery : The 9V battery serves as a compact and portable power source for the circuit. Batteries are affordable, widely available, and ideal for small circuits like this.

3. 7805 Voltage Regulator: The 7805 voltage regulator converts the 9V input from the battery down to a stable 5V, which is necessary for powering the logic ICs (74HC147, 74HC04, and CD4511) in the circuit. It ensures a consistent voltage, protecting sensitive components from fluctuations.

4. 104pF Capacitor : The 0.1 µF or 104pF capacitor is commonly used in digital circuits to filter out high-frequency noise and stabilize the power supply to the ICs. It reduces voltage fluctuations and it is a standard value for bypassing high-frequency noise and is often used for decoupling purposes in digital circuits.

5. 100 ohm resistor : It is used to limit the current flowing into the 7-segment display to protect the LED segments from excessive current. Also by adding a 100-ohm resistor, the circuit ensures that the output current from the CD4511 does not exceed its maximum current rating, protecting both the IC and the display. This resistor value is chosen as a balance to provide sufficient brightness for the display without compromising the components' safety.

6. 560kohm resistor : It ensures that the circuit inputs maintain a defined logic level, preventing floating or fluctuating inputs. The choice of a 560 kΩ resistor balances sensitivity and response time. A higher resistance (such as 1 MΩ) might lead to slower response times while a lower resistance (such as 100 kΩ) could lead to more current consumption. Thus, a 560 kΩ resistor provides a suitable middle ground, offering stability and noise suppression without consuming significant current.

7. 7-Segment Display: The 7-segment display visually represents the current water level in numeric form (0-9). It provides a straightforward, low-cost way for users to monitor water levels at a glance. The common cathode display works well with the CD4511 driver, allowing for efficient control of individual segments to form the desired digits.

8. Conductive Probes or hookup wires (inside water tank): Conductive probes detect water at different levels in the tank and send signals to the priority encoder. They are an affordable and effective way to measure discrete water levels, providing reliable contact-based detection without requiring complex sensor technology.

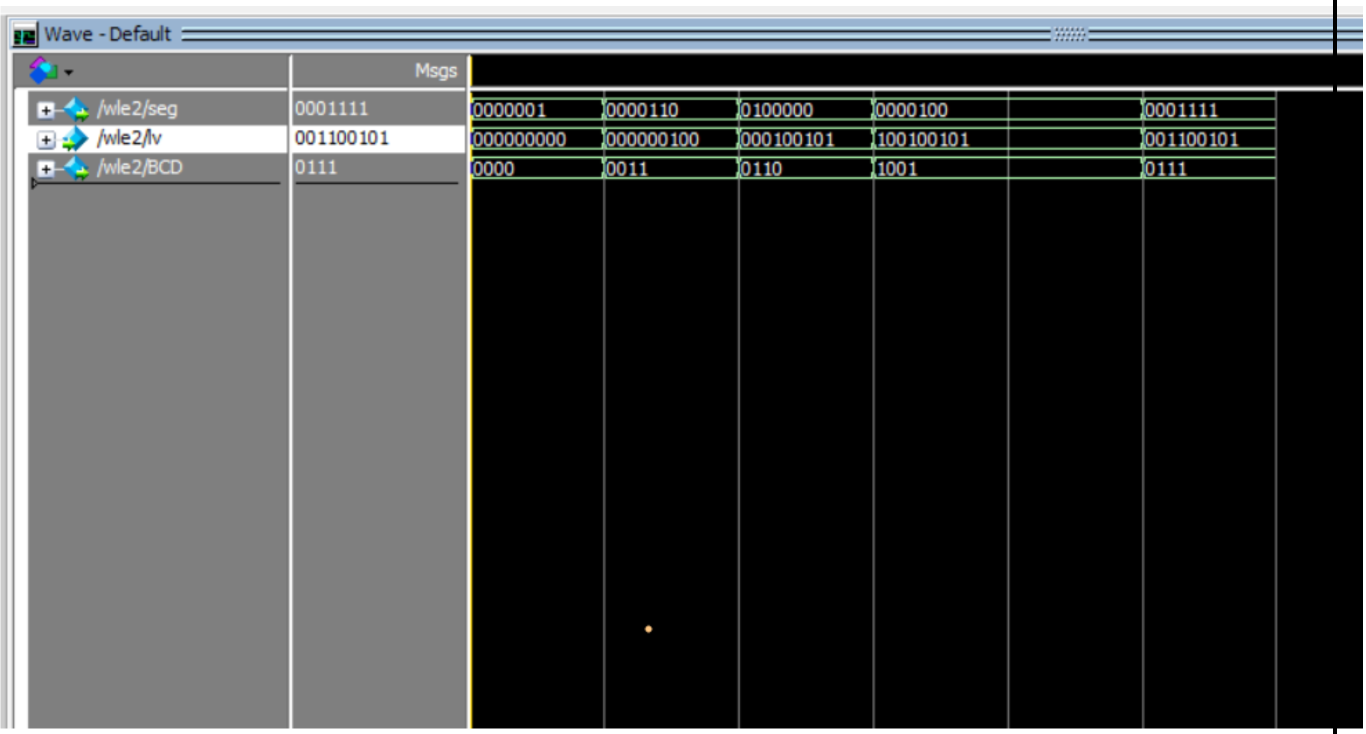
9. Breadboard : It allows components to be quickly connected and disconnected without soldering. Components like the ICs can be easily rearranged or replaced, making it ideal for refining the design. Overall, it simplifies and speeds up the development process, enabling non-permanent, flexible circuit assembly.

7. Simulation Results

7.1 Modelsim Simulation

- The Verilog code for the water level indicator and controller system was designed in the Quartus || 13.0sp1 software and was simulated in Modelsim.
- Simulation in ModelSim helps in verifying the functionality of the water level indicator and controller circuit by allowing developers to test the circuit's behavior in a virtual environment before physically building it. It provides a controlled environment to verify the circuit's functionality, identify and correct errors, analyze timing, and optimize component values.

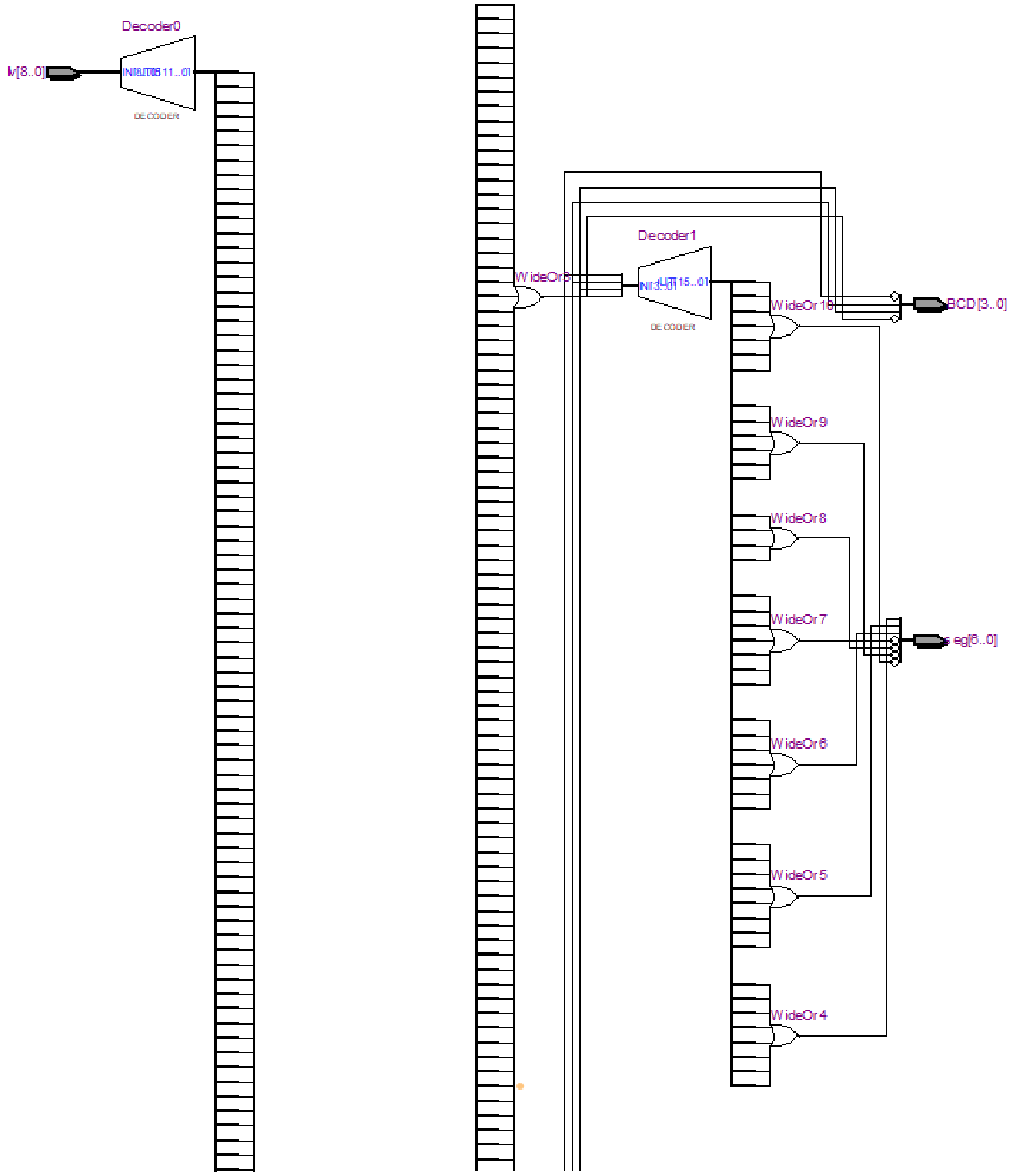
1. Water Level Indicator :

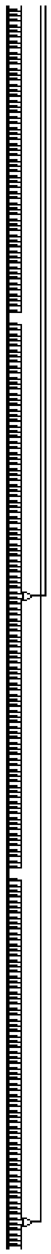


- This simulation verifies that the water level indicator's Verilog design correctly maps each BCD input to a 7-segment display output. It ensures the circuit will function as intended in real hardware by testing various inputs and confirming the output is accurate and responsive at each step

Results and Measurements

1. Water Level Indicator :





A. RTL Viewer :

This RTL (Register Transfer Level) viewer shows a BCD to 7-segment decoder circuit in a hierarchical structure:

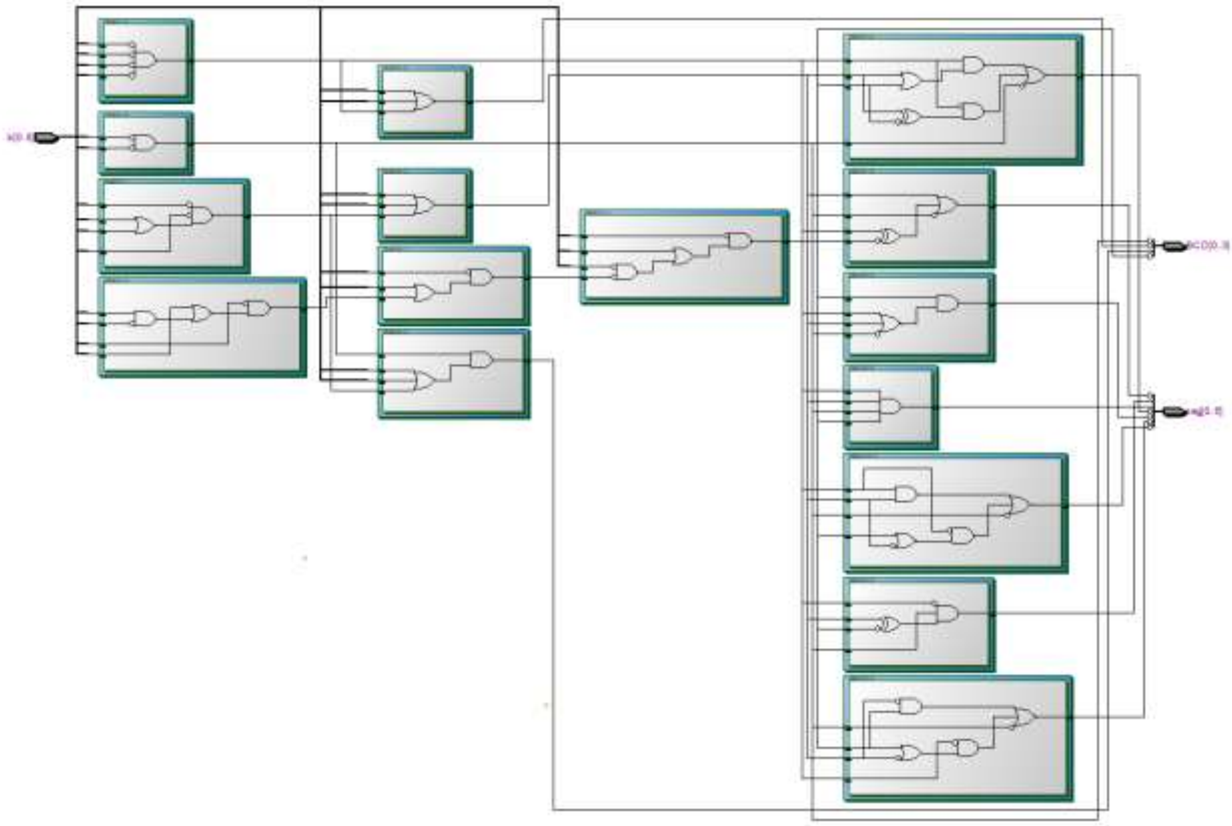
1. Input (BCD[3:0]): Accepts a 4-bit Binary-Coded Decimal (BCD) input to represent numbers 0-9.

2. Decoder Logic: Contains several submodules (likely using logic gates) that interpret the BCD input.

3. Output (Seg[6:0]): Drives the segments of a 7-segment display to display the correct digit based on the BCD input.

This setup maps each BCD input to specific segments on the display, enabling numerical representation.

B. TTL Viewer :



FPGA implementation :

1. Design Description and Implementation on FPGA:

- Verilog HDL: The design is written in Verilog (or VHDL), describing the logic for converting Binary-Coded Decimal (BCD) inputs to the corresponding 7-segment display outputs.
- Components on FPGA:
    - BCD to 7-Segment Decoder: Converts the BCD input (representing water levels) to display the corresponding digit.
    - Input Encoding and Logic: The FPGA will manage the logic for each water level signal and convert it to the appropriate BCD format.

2. Steps for FPGA Implementation:

- Code Simulation and Verification: Simulate the Verilog code in tools like ModelSim to verify logic correctness.
- Synthesis: Use FPGA synthesis tools (e.g., Quartus) to translate Verilog code into a format the FPGA can use.
- Pin Assignment: Map input and output pins on the FPGA to connect the water level sensors and 7-segment display.
- Programming the FPGA: After synthesis, load the design onto the FPGA and test its functionality with actual inputs.

3. FPGA Advantages:

- High Speed: FPGAs provide faster processing than microcontrollers for digital logic operations, ensuring real-time response to changes in water level.
- Parallel Processing: FPGAs allow multiple logic processes to run simultaneously, which is ideal for managing multiple input signals (such as different water level sensors) without delays.
- Programmable and Reconfigurable: Logic can be modified and reprogrammed as needed, allowing easy design updates without changing hardware.

Thus, implementing the water level indicator on an FPGA provides a flexible, high-speed, and reprogrammable solution, ideal for real-time applications.

Circuit Implementation :

Implementing the water level indicator and controller circuit involves integrating several key components to detect water levels, encode these levels, and display the information on a 7-segment display.

1. Implementation Steps:

- Breadboard Setup: Initially, the circuit is built on a breadboard for easy testing and modifications.
- Connecting Components: The encoder, inverter, display driver, and display are connected according to the design, with sensors connected to the encoder inputs.
- Testing and Calibration: After assembling the circuit, each water level is tested by applying voltage to simulate sensor signals. The display output is checked to ensure correct functionality.

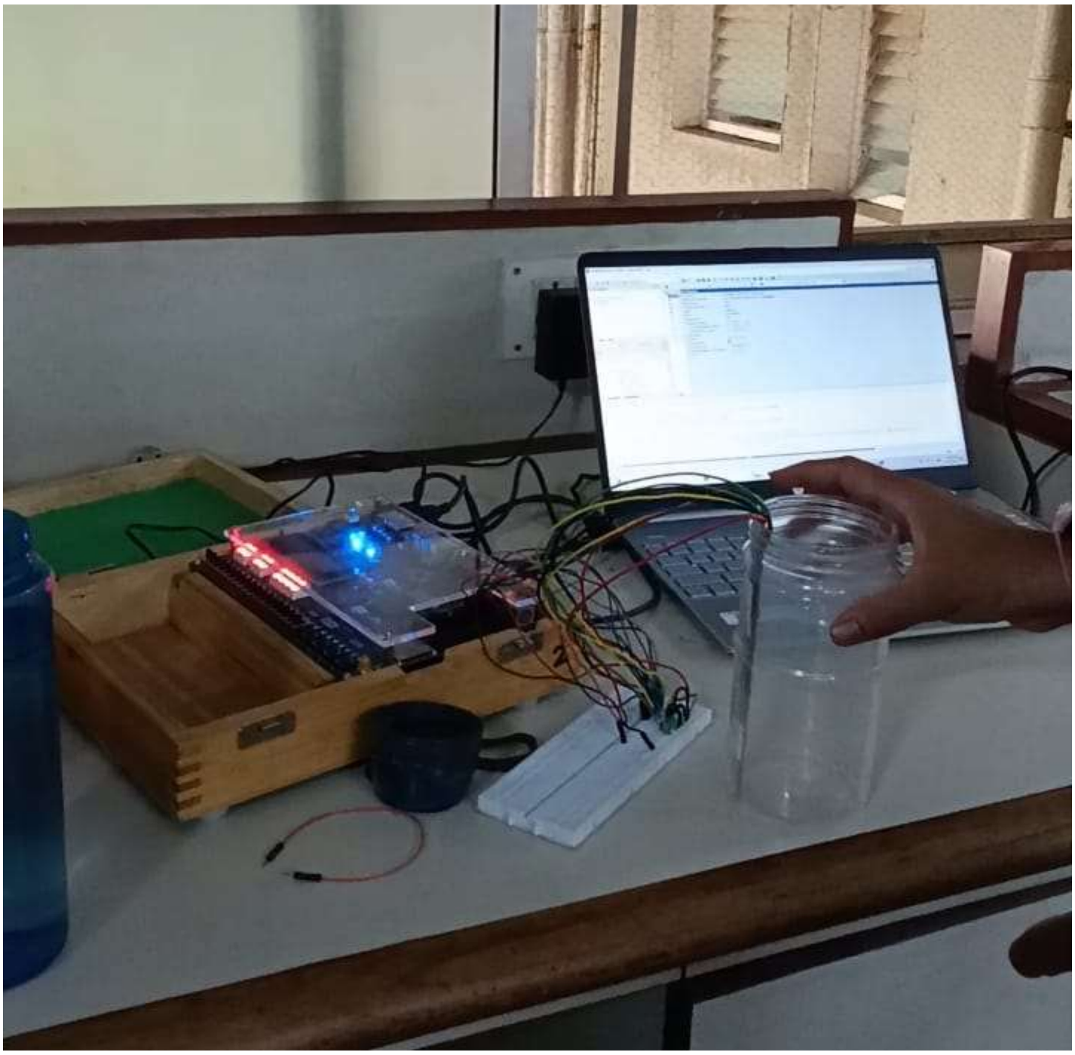
2. Benefits of this Circuit Implementation:

- Low Cost: Uses readily available, low-cost components.
- Simple Design: Straightforward layout with minimal components for reliable operation.
- Real-Time Display: Provides an immediate and clear indication of water levels, useful for monitoring and control purposes.

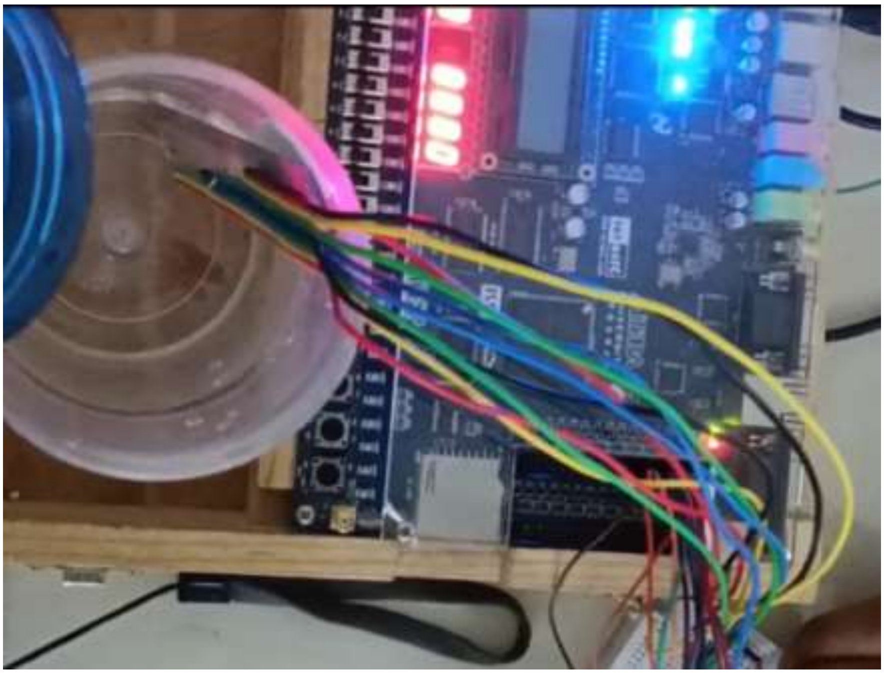
This circuit implementation combines simple, efficient components to create an effective water level indicator and controller. Each component is chosen to ensure accurate level detection, signal encoding, and user-friendly display output.

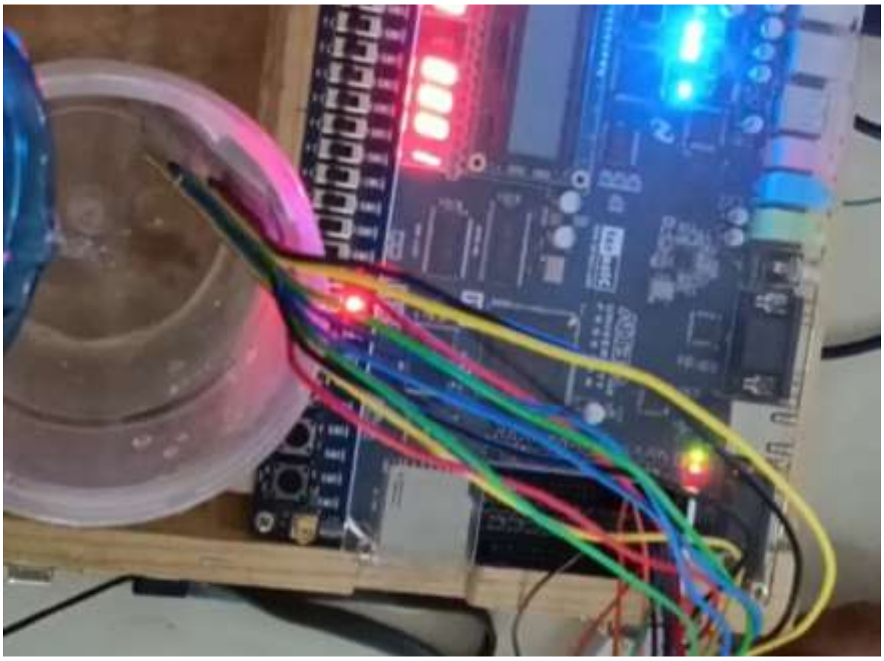
Results :

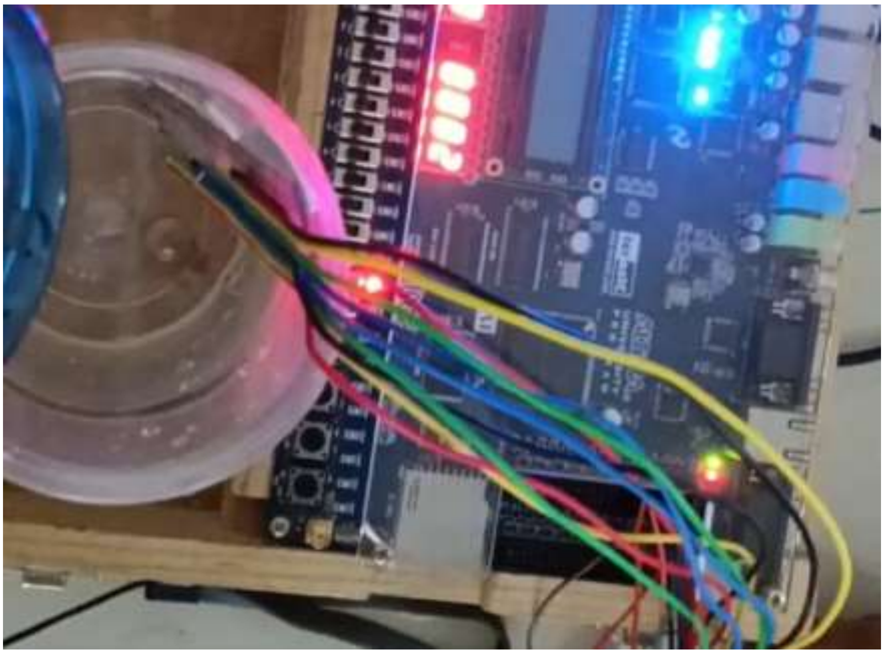
1. Water Level Indicator

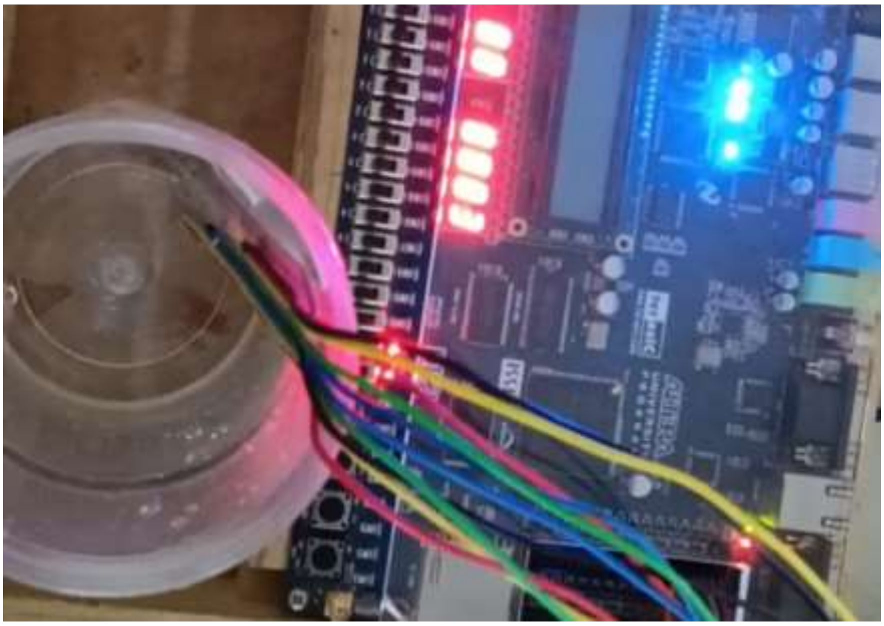


Levels:









8. Conclusion, Learning Outcome, and Future Scope

Conclusion

The water level indicator and controller project successfully achieved its primary objectives of accurately detecting water levels in a tank and displaying them on a 7-segment display. The use of BCD encoding and a display driver simplified the circuit design, while the simulation verified the accuracy of each component’s functionality before hardware implementation. The design proved effective and reliable, meeting the requirements of real-time level monitoring and display.

Learning Outcome

This project provided valuable insights into digital circuit design and implementation, including:

- Logic Design : Understanding how to use BCD encoders, inverters, and display drivers for efficient signal processing and display.

- Verilog Programming and Simulation : Learning to write Verilog code and simulate it in ModelSim to verify circuit behavior before actual hardware implementation.

- Component Selection and Circuit Assembly : Gaining practical skills in selecting appropriate components, constructing circuits, and troubleshooting on breadboards.

Future Scope

The project can be further improved and extended in several ways:

- Automatic Control : Add a relay control to automatically operate a pump based on water levels, making the system fully autonomous.

- Wireless Monitoring : Integrate wireless modules to remotely monitor water levels through a mobile app or web dashboard.

- Expanded Display and Indicators : Use an LCD screen or LEDs to display more detailed information, such as “Low,” “Medium,” or “High” water levels, or connect to multiple tanks in larger applications.

9. References

https://www.alldatasheet.com/

www.flyrobo.in

[1] A. Kumar, *Fundamentals of Logic Design*. New Delhi, India: Prentice-Hall, 2005.

10. Appendix

1. Water Level Indicator :

```
module wle2(
   input [8:0] lv,
   output reg [3:0] BCD,
   output reg [6:0] seg
);

   always @(*) begin
      casex(lv)
         9'b1xxxxxxxx : BCD = 4'b1001;
         9'b01xxxxxxx   : BCD = 4'b1000;
         9'b001xxxxxx   : BCD = 4'b0111;
         9'b0001xxxxx   : BCD = 4'b0110;
         9'b00001xxxx  : BCD = 4'b0101;
         9'b000001xxx  : BCD = 4'b0100;
         9'b0000001xx : BCD = 4'b0011;
         9'b00000001x   : BCD = 4'b0010;
         9'b000000001   : BCD = 4'b0001;
         9'b000000000   : BCD = 4'b0000;
         default: BCD = 4'b1111;
      endcase
   end

   always @(*) begin
      case(BCD)
         4'b0000 : seg = 7'b0000001;
         4'b0001 : seg = 7'b1001111;
         4'b0010 : seg = 7'b0010010;
         4'b0011 : seg = 7'b0000110;
         4'b0100 : seg = 7'b1001100;
         4'b0101 : seg = 7'b0100100;
         4'b0110 : seg = 7'b0100000;
         4'b0111 : seg = 7'b0001111;
         4'b1000 : seg = 7'b0000000;
         4'b1001 : seg = 7'b0000100;
         default: seg = 7'b1111111;
```

```
        endcase
    end
endmodule
```

Thank You