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Report

Logic Design Project

Design and Implementation of Button-Controlled LED Effects using ICs

Major: Computer Engineering

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1 Introduction

1.1 Background and Context

The field of logic design is fundamental to the development of modern electronic systems. It provides the foundation for understanding how components can be interconnected to perform specific operations. One of the most visible and interactive applications of logic design is the control and manipulation of light-emitting diodes (LEDs). LEDs have become a staple in electronics due to their efficiency, long lifespan, and versatility in creating dynamic visual effects.

In educational settings, designing circuits that control LEDs serves as an excellent means to teach and reinforce fundamental concepts of logic design. Such circuits help students understand the relationships between input signals, state changes, and outputs. Beyond education, the ability to control LED effects is widely applicable in consumer electronics, entertainment systems, and signaling devices.

Many current solutions for LED effect control rely on programmable microcontrollers or software-defined logic, which offer flexibility but may be overkill for simpler applications. In contrast, hardware-only designs using integrated circuits (ICs) are cost-effective, robust, and accessible to those who wish to focus on the core principles of circuit design. This project explores such a hardware-based approach to controlling LEDs.

1.2 Problem Statement

While microcontrollers have made it easier to design and implement complex LED effects, they come with a steep learning curve for individuals unfamiliar with programming or microcontroller platforms. Additionally, for applications requiring simplicity and low-cost implementation, microcontroller-based solutions can be unnecessarily complex and expensive.

The challenge is to design a purely hardware-driven system capable of changing LED patterns dynamically based on user input, such as a button press. Such a system should demonstrate core principles of logic design, including sequential logic, state changes, and interaction between components, without relying on programmable elements.

This study seeks to address these challenges by proposing a hardware-only solution for LED effect control. The design must be straightforward, scalable, and demonstrate the capabilities of logic design principles.

1.3 Objectives of the Proposal

The primary objectives of this project are as follows: 1. **To Develop an Interactive LED Control System**: The circuit will allow users to change LED patterns dynamically by pressing a button. This interactivity highlights the potential of hardware logic for user-controlled designs. 2. **To Focus on Hardware-Only Solutions**: By avoiding programmable microcontrollers, this project emphasizes the importance of ICs and logic gates in achieving functional designs. 3. **To Demonstrate Sequential and Combinational Logic**: The circuit will showcase the principles of logic design, including the use of clock signals, state transitions, and the relationship between inputs and outputs. 4. **To Create a Scalable and Modular Design**: The schematic should be flexible, allowing for future modifications or expansions to incorporate additional patterns or functionalities. 5. **To Enhance Educational Understanding**: The design will serve as an educational tool, helping students and enthusiasts develop a deeper understanding of logic design and circuit simulation.

1.4 Significance of the Study

This project has significant implications for both education and practical applications. From an educational perspective, it provides an opportunity to explore the capabilities of integrated circuits and their role in implementing logic design principles. By focusing on a hardware-only approach, the project eliminates the dependency on software or programming knowledge, making it accessible to a broader audience.

From a practical perspective, this project demonstrates how cost-effective and reliable systems can be built using readily available components. The ability to control LED patterns dynamically has applications in a variety of fields, including: - **Consumer Electronics**: Devices such as toys, displays, and decorative lighting systems benefit from dynamic and interactive LED effects. - **Signaling Systems**: LED patterns can be used to convey information, such as status indicators or warnings, in industrial or commercial settings. - **Prototyping and Testing**: Hardware-only designs are often used to validate concepts and test functionalities before scaling up to more complex systems.

Additionally, the study underscores the importance of understanding core logic design concepts, such as flip-flops, counters, and sequential logic, which are essential for developing efficient and interactive circuits.

Applications of Button-Press LED Effect Schematic The proposed schematic design can be applied in numerous ways, including: 1. **Educational Demonstrations**: By visualizing the effects of button presses on LED patterns, students can better grasp the concepts of state changes and sequential logic. 2. **Interactive Displays**: The design is well-suited for installations requiring user-controlled lighting effects, such as museum exhibits or event lighting. 3. **DIY Electronics Projects**: Hobbyists can use the design as a foundation for building custom lighting systems for personal use or experimentation. 4. **Training Simulators**: The system can serve as a hands-on training tool for individuals learning circuit design and logic implementation.

This project emphasizes simplicity, modularity, and interactivity, offering a comprehensive understanding of logic design principles while delivering practical applications. The final design aims to be both educational and functional, inspiring further exploration into hardware-based control systems.

2 Circuit Design and Schematic

2.1 Design Overview

The design of the button-controlled LED effect system utilizes various digital ICs to control the switching of 16 LED effects. The core idea of the system is to allow the user to press a button to cycle through multiple pre-defined lighting patterns, with each button press switching to the next effect in the sequence. The system uses a combination of counters, flip-flops, and logic gates to manage the LED outputs efficiently.

The components that make up the circuit are as follows:

- **Button**: The user interacts with the system through a single pushbutton, which is used to cycle through the LED effects. A momentary press of the button will trigger a change in the effect, advancing to the next one in the sequence.
- **ICs (Integrated Circuits)**:
  - **74HC112**: This is a dual JK flip-flop IC that is used for memory storage and controlling the state of the system. It stores the current state of the LEDs, allowing the effects to be switched sequentially.

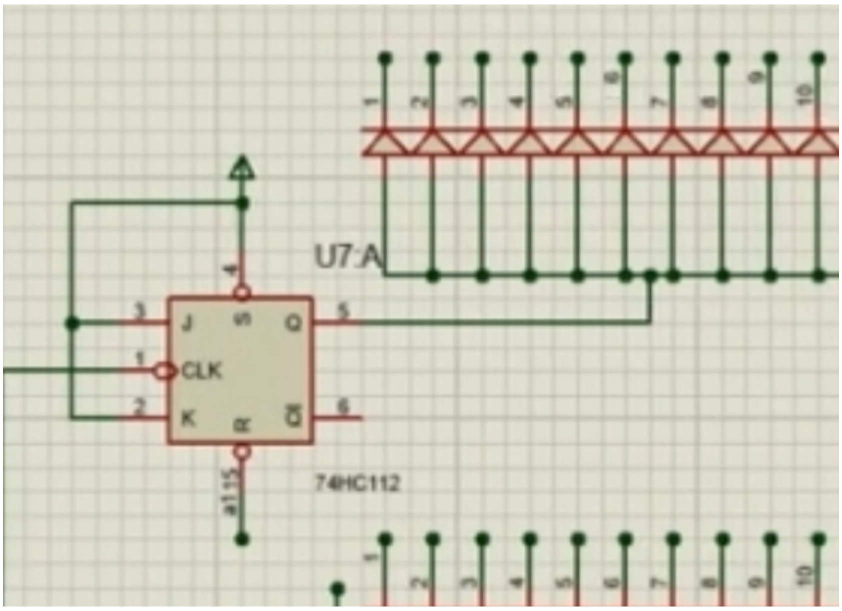

Figure 1: *Component IC 74HC112 in Proteous*

- **74HC164**: This IC is an 8-bit shift register, and it is used to drive the LEDs in a controlled sequence. It converts serial data into parallel outputs, enabling the control of multiple LEDs with fewer lines of input.

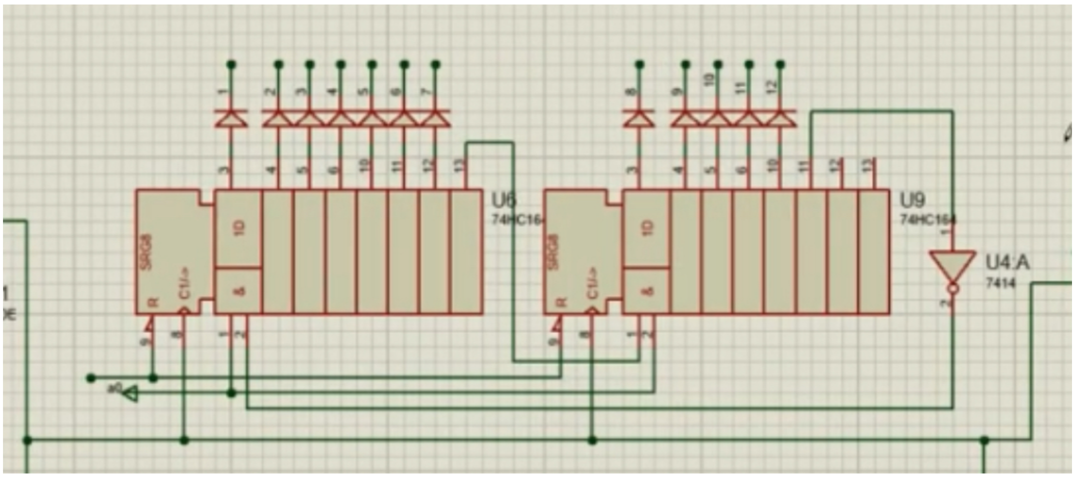

Figure 2: *Component IC 74HC164 in Proteus*

- **555 Timer**: The 555 timer IC is used to generate timing pulses that can be used to debounce the button input, ensuring that multiple presses of the button don't result in erratic behavior or unintended effect switching.

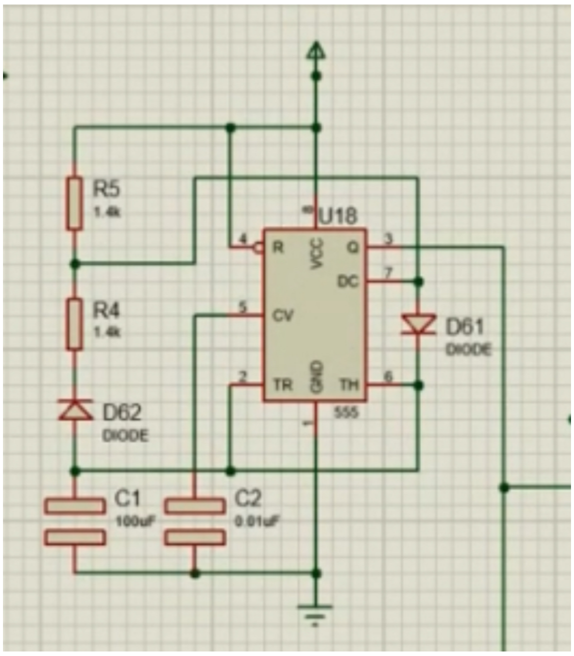

Figure 3: *Component 555 Timer in Proteus*

- **4017 Decade Counter**: This IC is used for counting button presses. The counter increments with each press, and the counter's outputs are used to select which LED effect should be displayed.

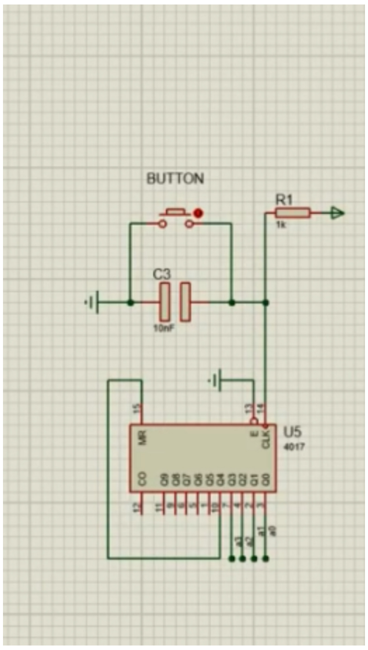

Figure 4: *Component IC 4017 in Proteous*

- **7408 AND Gate IC**: This IC is used for logical control, particularly for combining different signals that help switch between states.

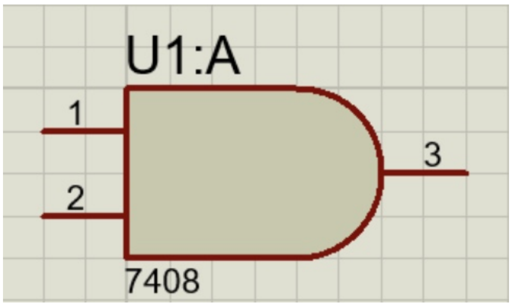

Figure 5: *Component IC 7408 AND Gate in Proteous*

- **7414 Schmitt Trigger Inverter**: Used to clean up the signal from the button press, ensuring a reliable HIGH/LOW logic level transition.

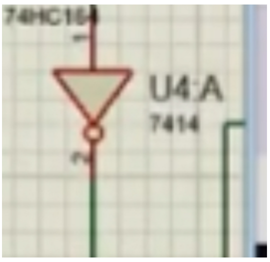

Figure 6: *Component IC 7414 in Proteous*

- **LEDs**: There are two different types of LEDs used in the system:
  - **Blue LEDs**: Used to display the main lighting effects.
  - **Yellow LEDs**: These LEDs are used for secondary or background effects.
- **Capacitors (Cap and Cap-Elec)**: Capacitors are used for debouncing the button input and filtering power supply noise to stabilize the circuit.
- **Resistors and Diodes**: These are used to limit current flow, protect the ICs and LEDs, and ensure correct signal behavior.

The system works by using the counter (4017) to track the number of button presses. Each press increments the counter, and the corresponding output from the counter is used to activate a different LED effect. The 74HC164 shift register plays a crucial role in converting the serial data from the control ICs into parallel outputs, which then light up the LEDs in the desired pattern.

Through the use of the 74HC112 JK flip-flop IC, the system is able to store states between button presses, creating the effect of cycling through different lighting patterns. The 555 timer provides timing pulses to debounce the button, preventing multiple signals from being read as a single press. The combination of these ICs allows for smooth operation of the system, providing the user with a reliable way to control the LED effects through a simple button press.

2.2 Schematic Design in Proteus

2.2.1 Schematic Overview

In this section, the schematic of the button-controlled LED effects circuit designed in Proteus is presented. The schematic includes all the components, wiring, and interconnections that are used to implement the button-controlled system. The design ensures that the circuit behaves as expected when the button is pressed, cycling through 16 different LED effects.

Proteus Schematic Diagram

2.2.2 Component Explanation

The following components are used in the schematic to implement the system:

- **74HC112 (Dual JK Flip-Flop)**: This IC is used to store the state of the system. Each flip-flop holds one bit of information, allowing the system to remember which LED effect is currently being displayed. It plays an essential role in managing the transition between LED effects, ensuring that the effects cycle sequentially with each button press.
- **74HC164 (8-bit Shift Register)**: The 74HC164 shift register is used to drive the LEDs. It takes the serial data input (which is controlled by the flip-flops and counters) and converts it into parallel outputs. Each output pin on the shift register corresponds to one of the LEDs, allowing them to be turned on or off based on the current effect.
- **555 Timer**: The 555 timer is used in a monostable mode to generate a pulse that helps debounce the button input. Debouncing is necessary because mechanical buttons tend to "bounce" when pressed, causing multiple signals to be sent instead of a single one. The 555 timer ensures that only one signal is sent for each press, preventing erroneous button presses from affecting the LED effect switching.
- **4017 Decade Counter**: The 4017 is used to count the number of button presses. The output pins of the counter correspond to different LED effects. With each button press, the counter increments and changes the output that is active, effectively switching between different LED effects.
- **7408 AND Gate**: The AND gate is used for logical control in the circuit. For example, it can be used to combine multiple signals to decide which LED effect should be displayed or to implement more complex control logic.
- **7414 Schmitt Trigger Inverter**: This IC is used to clean up the signal coming from the button. It ensures that the input to the circuit is clean, providing a stable HIGH or LOW logic level as the button is pressed.
- **LEDs (Blue and Yellow)**: The blue and yellow LEDs are the outputs of the system. Each LED corresponds to a specific visual effect. The shift register controls which LED lights up based on the current state of the counter and flip-flop ICs.

- **Resistors and Capacitors**: The resistors are used to limit current flowing through the LEDs, preventing them from burning out. The capacitors are used to smooth out any noise in the power supply and help with debouncing the button press.

2.2.3 Button Input Mechanism

The button input mechanism is critical to the functionality of the system. The button is connected to the input of the 555 timer, which generates a pulse each time the button is pressed. This pulse is fed into the 4017 decade counter, which increments with each press. The counter's outputs are connected to the shift register (74HC164), which controls the LEDs based on the current output from the counter.

Each button press results in a different LED effect being displayed. When the user presses the button, the 4017 counter increments, and the shift register shifts the serial data to the LEDs, turning on the appropriate LEDs for the selected effect.

2.2.4 LED Control Mechanism

The LED control mechanism works through the combined use of the 74HC112 flip-flops and 74HC164 shift register. The flip-flops store the state of the system, while the shift register converts the serial data into parallel outputs to control the LEDs. The 4017 decade counter ensures that each button press results in a change of the effect, moving sequentially from one effect to the next. By utilizing these ICs together, the system is able to switch between 16 different LED effects smoothly and efficiently.

2.2.5 IC Selection Justification

- The **74HC112** flip-flop IC was selected because it offers reliable state storage, which is essential for controlling the sequential switching of the LED effects. The JK flip-flop provides flexibility and ease of control in storing binary data.
- The **74HC164** shift register was chosen because it allows serial-to-parallel conversion, which is ideal for controlling multiple LEDs with a limited number of input lines.
- The **555 timer** is a versatile IC that is widely used for generating precise timing pulses, making it ideal for debouncing the button press and ensuring that only one signal is generated per press.
- The **4017 counter** was selected because it provides a simple method for counting button presses and outputting different states, making it easy to manage the LED effect sequence.
- The **7408 AND gate** and **7414 Schmitt trigger inverter** were chosen for their ability to provide stable logic signal manipulation, ensuring reliable operation of the circuit.

By selecting these ICs, the circuit design achieves a balance of simplicity, cost-effectiveness, and functionality, making it ideal for controlling multiple LED effects with minimal user input.

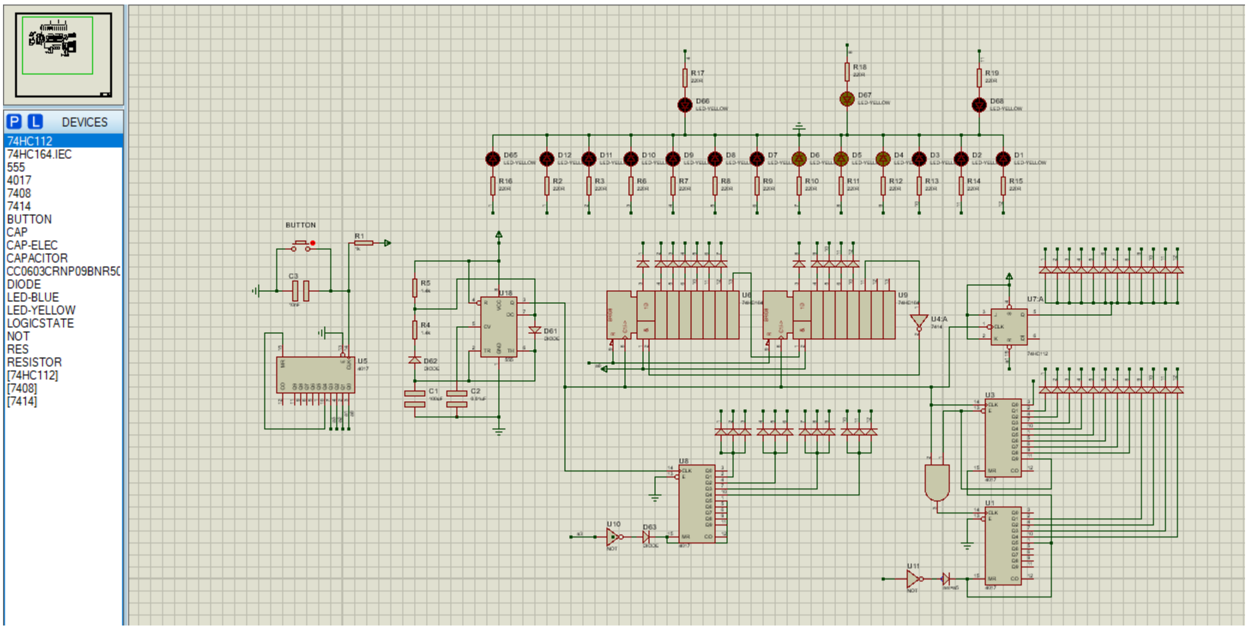

Figure 7: *Design Schematic*

3 Simulation result

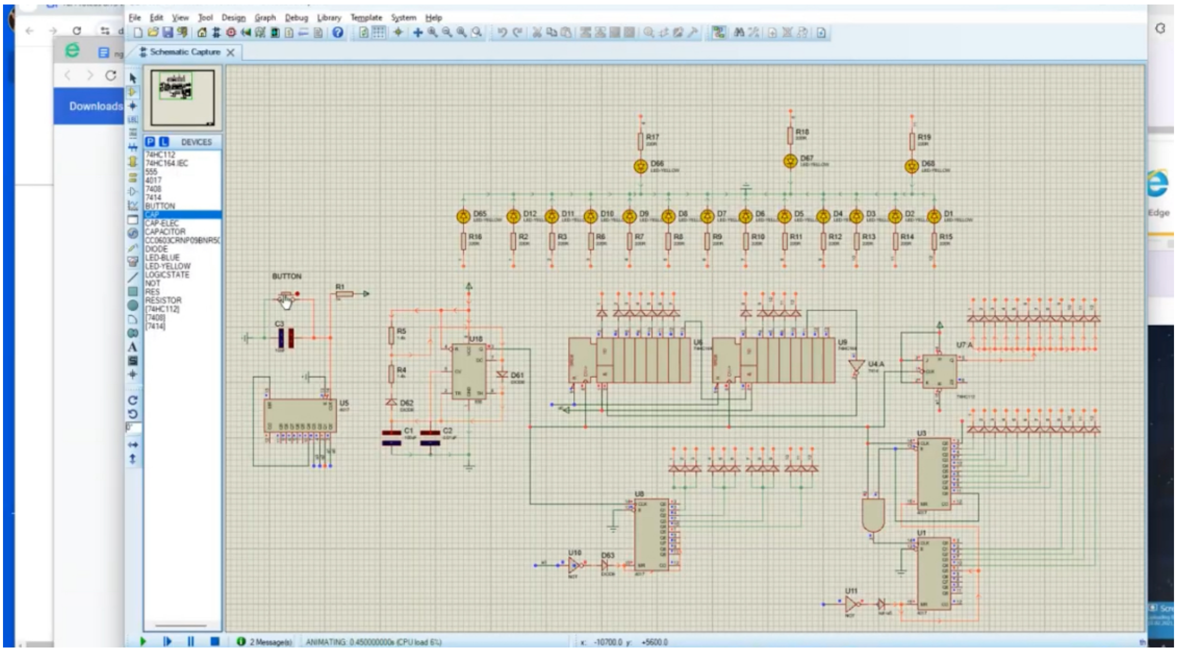

Figure 8: *Effect LED Mode 1 - Blink all the LEDs*

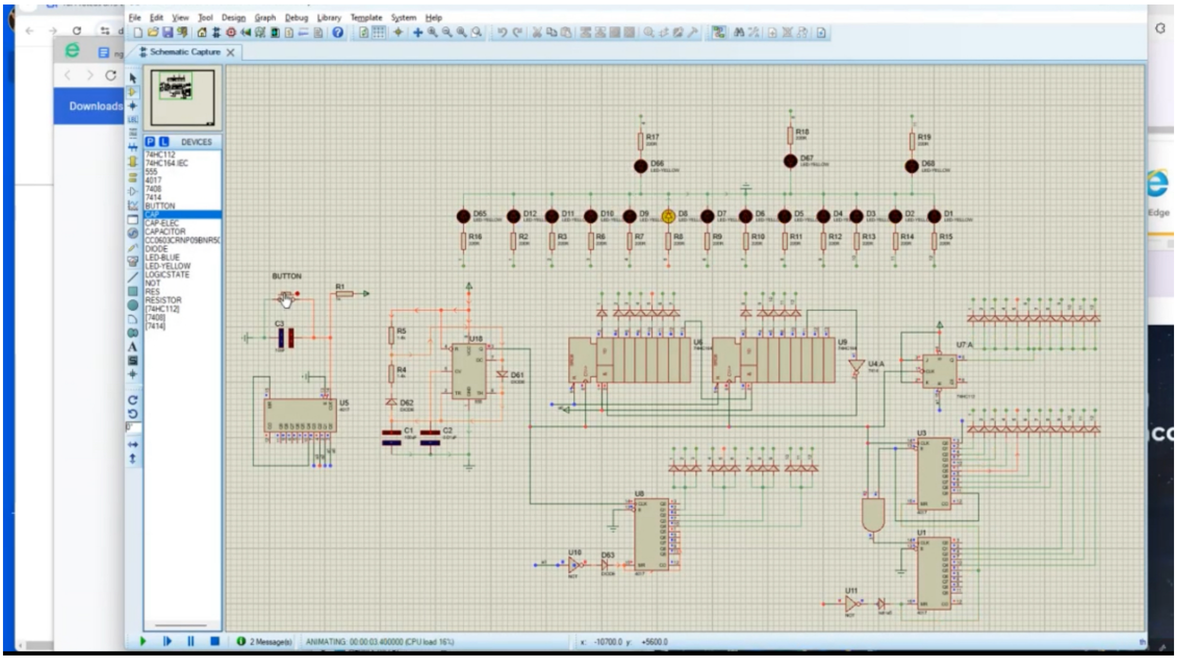

Figure 9: *Effect LED Mode 2 - LEDs run sequentially*

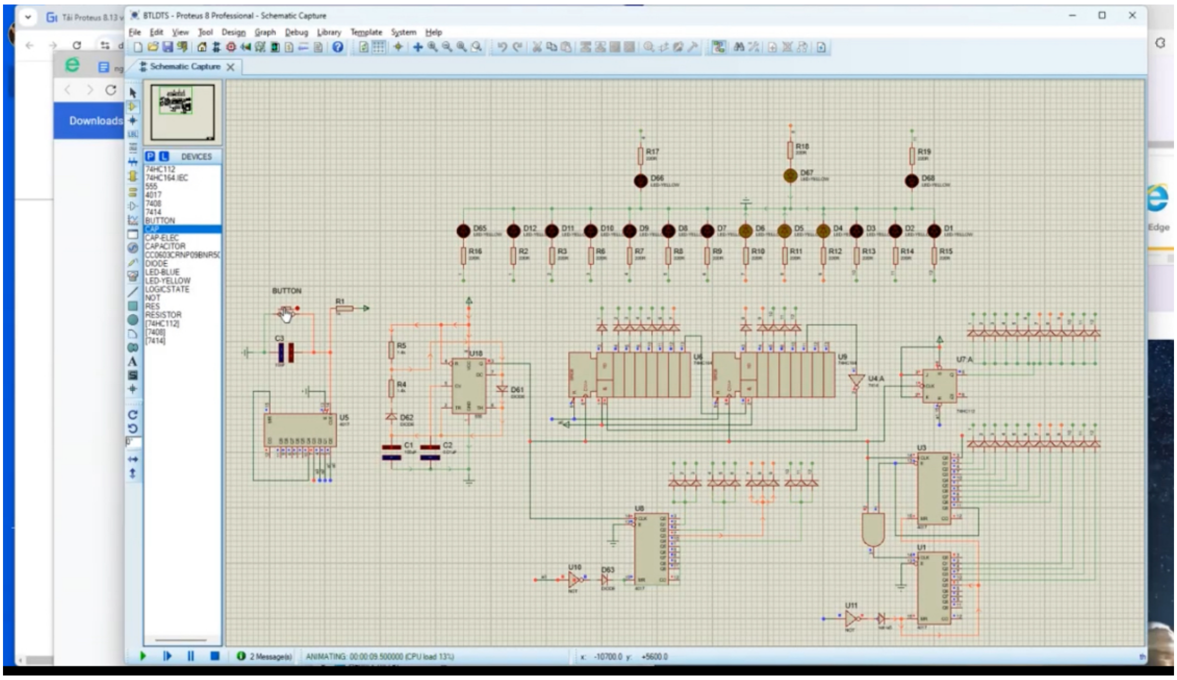

Figure 10: *Effect LED Mode 3 - Blink each 3-4 LEDs at a time*

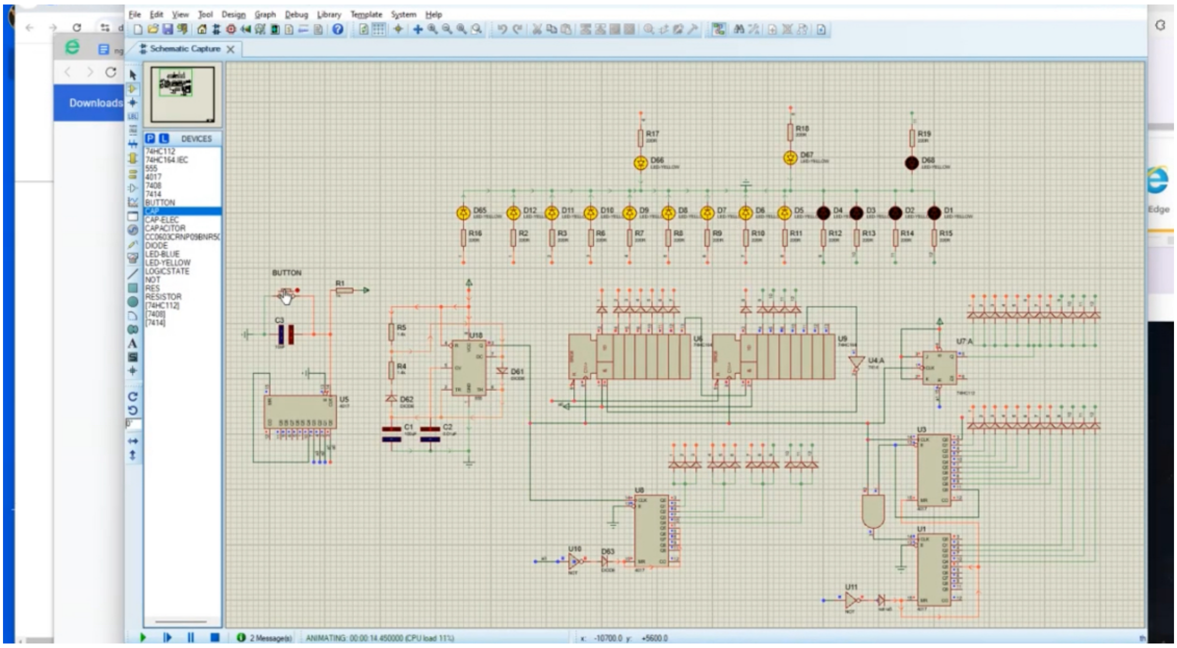

Figure 11: *Effect LED Mode 4 - Turn each LED to turn on, when the last LED is ON, it turns off the LEDs sequentially.*

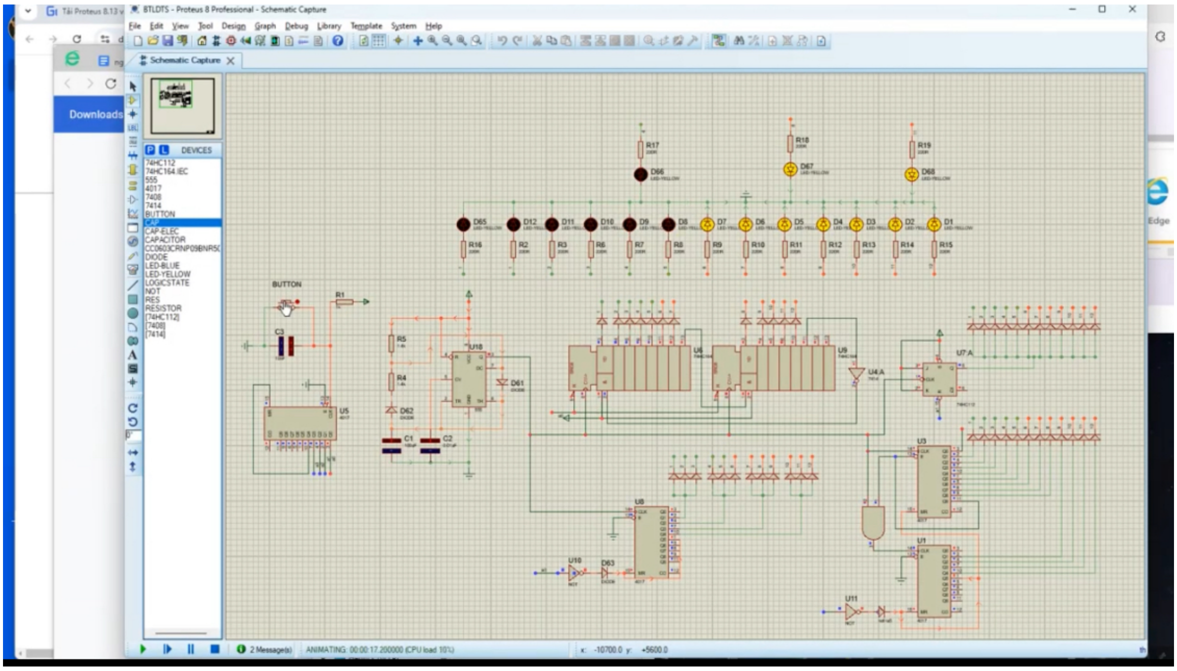

Figure 12: *Effect LED Mode 4 - Turn each LED to turn on, when the last LED is ON, it turns off the LEDs sequentially.*

4 Conclusion

In this project, we successfully designed a logic-based schematic to control LED effects using button presses. The implementation relies solely on ICs, showcasing the power and versatility of combinational and sequential logic circuits in practical applications. This design emphasizes a hardware-only approach, eliminating the need for microcontrollers or software programming, thus making it cost-effective and robust for various use cases.

The study highlights how digital logic principles can be utilized to achieve dynamic LED effects through precise timing and state transitions. By carefully analyzing the requirements and applying logic design techniques, the project demonstrates the seamless integration of user input (button presses) with visual outputs (LED effects). Such systems have significant potential in educational demonstrations, decorative lighting, and user-interactive devices.

The insights gained from this project underline the importance of understanding IC functionality and interconnectivity in creating practical electronics systems. This approach not only fosters creativity but also equips learners with foundational skills to tackle more complex circuit designs in future endeavors.

Link Demo simulation in Proteous:
https://drive.google.com/file/d/19lItMNyFRlFQC9uVtEFT5ntsLSWpLTNA/view?usp=sharing

5 Reference

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