Project 2

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EECE 235

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Introduction

Problem Statement:

Create Circuits with D Flip Flops:

1. Serial In – Serial Out Shift Register
2. Design a circulating light

(combined onto one breadboard)

Create Circuits with JK Flip Flops:

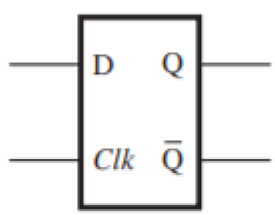
3. A Ripple Counter
4. Design a Circuit that will make a LED flash every time a count of 14 is reached

(combined onto one breadboard)

What are D Flip Flops?:

Clk	D	$Q(t+1)$
0	x	$Q(t)$
1	0	0
1	1	1

(b) Characteristic table



(c) Graphical symbol

Figure 1: Truth table and graphic symbol of a D flip-flop [1]

The D flip-flop uses one input. A D flip-flop is a SR flip-flop with an inverter for the input. One of the issues that the SR flip-flop has is that when both S and R are 1, it is an invlaid output. “By adding an inverter (NOT gate) between the Set and Reset inputs, the S and R inputs become complements of each other ensuring that the two inputs S and R are never equal (0 or 1) to each other at the same time allowing us to control the toggle action of the flip-flop using one single D (Data) input.” [2]

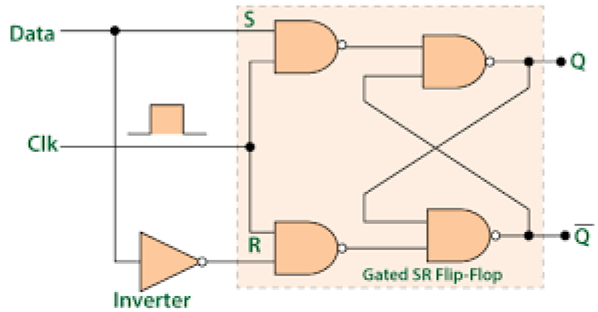


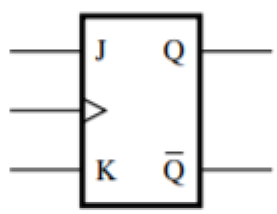
Figure 2: Circuit diagram of D flip-flop [3]

As stated above, the D flip-flop is an SR flip-flop with an inverter. So the D flip-flop consists of four 2-input NAND gates and one NOT gate. A D flip-flop can store one bit of memory so for n flip-flops, n bits of memory can be stored. This can be useful for data storage, data transfer, counters, and registers. D flip-flops are used to create shift registers. D flip-flops are preferred when creating event detectors. D flip-flops are preferred in these applications because of their simplicity and because of how common they are.

<u>What are JK Flip Flops?:</u>

J	K	$Q(t+1)$
0	0	$Q(t)$
0	1	0
1	0	1
1	1	$\overline{Q}(t)$

(b) Characteristic table



(c) Graphical symbol

Figure 3: Truth table and graphic symbol of JK flip-flop [1]

The JK flip-flop uses two inputs. It behaves the same as an SR flip-flop (refer to the truth table for the first 3 cases), except for when J and K are equal to one. With the SR flip-flop, the case where both inputs are 1 is avoided. With the JK flip-flop, this case does not have to be avoided because the output state is not invalid. The JK flip-flop consists of two 3-input AND gates which feed into two 2-input NOR gates.

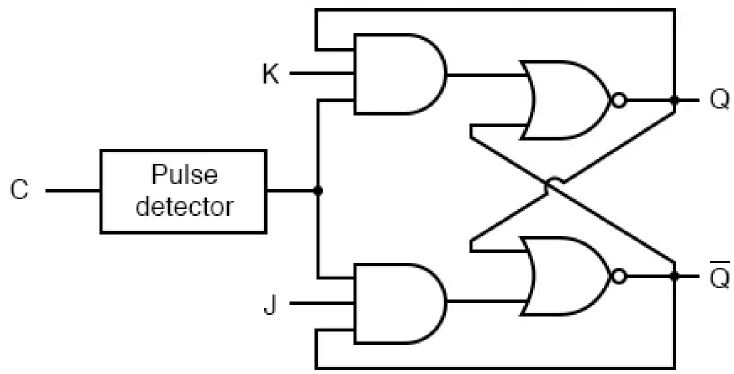


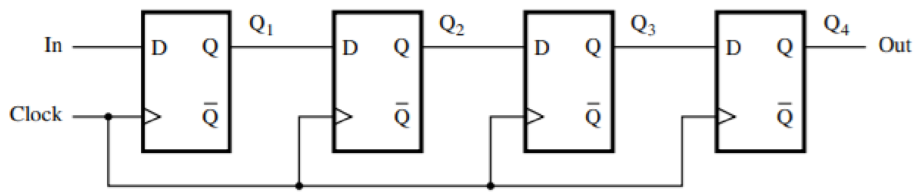
Figure 4: Circuit diagram of JK flip-flop [4]

A JK flip-flop, like most flip-flops, can store one bit of memory. So for n flip-flops, n bits of memory can be stored. This can be useful for data storage, data transfer, counters, and registers. For counters, more specifically ripple counters, the JK flip-flop is most commonly used. JK flip-flops are preferred for creating frequency dividers. For most applications requiring flip-flops, the JK flip-flop is preferred. This is because it "can toggle its state if both the inputs are high, depending on the clock pulse," [5]. This characteristic is unique to the JK flip-flop.

JK vs D Flip Flops:

The first notable difference between D flip-flops and JK flip-flops is that D flip-flops use one input and JK flip-flops use two inputs. With D flip-flops, the SR inputs are never equivalent because of the inverter. With JK flip-flops, the two inputs can be equivalent and set to high and it will still have a valid output. JK flip-flops are also much more versatile compared to D flip-flip flops because of their complex logic.

What is a shift register?:



(a) Circuit

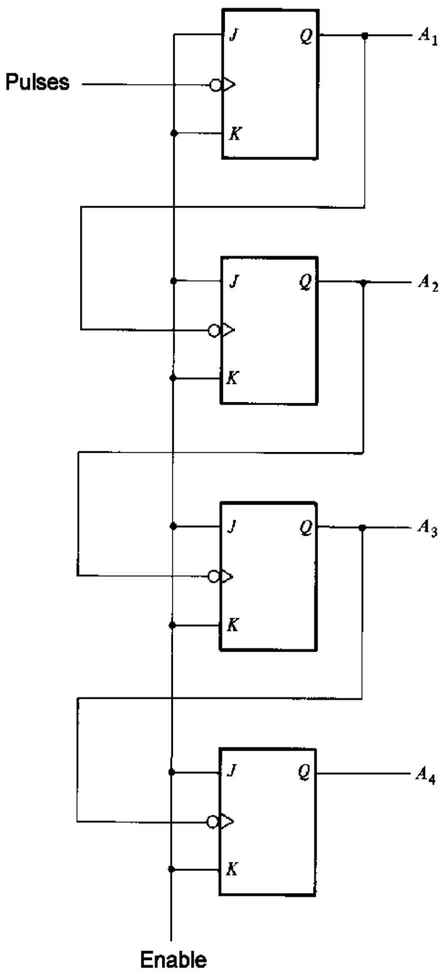
	In	Q_1	Q_2	Q_3	Q_4 = Out
t_0	1	0	0	0	0
t_1	0	1	0	0	0
t_2	1	0	1	0	0
t_3	1	1	0	1	0
t_4	1	1	1	0	1
t_5	0	1	1	1	0
t_6	0	0	1	1	1
t_7	0	0	0	1	1

(b) A sample sequence

Figure 5: Circuit diagram and truth table for basic shift register [1]

A shift register takes the given bit(s) that is then multiplied by 2, aka shifts one bit position to the left. A 0 is then inserted on the right as the new least-significant bit. This is a left-shift register. A right-shift register takes the given bit(s) that is then divided by 2, aka shifts one bit position to the right. A 0 is then inserted on the left. With flip-flops, the stored bits are shifted to the next flip-flops in series and bit 0 is stored in the initial flip-flop. The bits are shifted again to the next flip-flops in series and bit 0 is again stored in the initial flip-flop. This sequence is repeated. Shift registers are used for temporary data storage and data transfer. They can also be used to create time delays for digital circuits.

What is a ripple counter?:



Counter State	Q_2	Q_1	Q_0
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1
6	1	1	0
7	1	1	1

Figure 6: Truth table for ripple counter [6]

Figure 7: Circuit diagram for ripple counter [7]

A ripple counter is an asynchronous counter. A n-bit ripple counter can count up to 2^n states. For example, a 4 bit ripple counter can count up from 0 to 15. The JK flip-flop is most commonly used to create a ripple counter. The output of each flip flop feeds into the clock of the next flip flop. When each bit of the previous flip-flop changes from 1 to 0, the bit of the next higher order flip-flop changes from either 0 to 1 or 1 to 0. Another way to put this, is when the previous flip-flop reaches a low state, the next higher order flip-flop changes state. If LEDs are connected to the outputs of the flip-flops, a counter in binary is displayed.

Methods/Materials

$$
\begin{aligned}
5 &= V_{LED} + V_R \\
V_{LED} &= 3\,V \\
I_{LED} &= .03A \\
2V &= V_R \\
R &= \frac{V_R}{I_{LED}} \\
R &= \frac{2V}{.03A} \\
R &= 66\Omega
\end{aligned}
$$

Figure 8: Calculation for minimum required resistor value (made in google docs equations)

A resistor was placed in series with the LEDs to lower the voltage over the LEDs. This was done to limit the voltage over the LED to less than 3V to prolong the life. Figure () shows that the resistor value must be at least 66Ω to have a voltage of 3V or less across the LED. In both of the circuits, 200 Ω resistors are used in series with the LEDs. We used 200 Ω resistors instead of a standard value closer to 66 Ω (like 100 Ω) because we did not need the LEDs to be as light as possible for this project. This helps prolong the LEDs life and ensures it operates successfully for longer.

Circuit 1&2: Serial In-Serial Out Shift Register and Circulating Light

NOTE: The only difference between the shift register circuit and circulating light circuit, is the shift register has no wire connection between pin 4 and 15, and the circulating light circuit has a wire connecting between pin 4 and 15.

<u>Materials:</u>

Resistors: 1 x 220 Ω, 4 x 200 Ω, 2 x 10k Ω

- Measured Values: 217 Ω, 196 Ω, 195 Ω, 195 Ω, 195 Ω, 9.87k Ω, 9.88k Ω

Capacitor: 47 uF

- Measured Value: 47.77 uF

LEDs: 1 yellow, 1 red, 1 green, 1 blue

Tactile Push Button

555 timer

74L5175 chip (D Flip Flop)

Circuit Design:

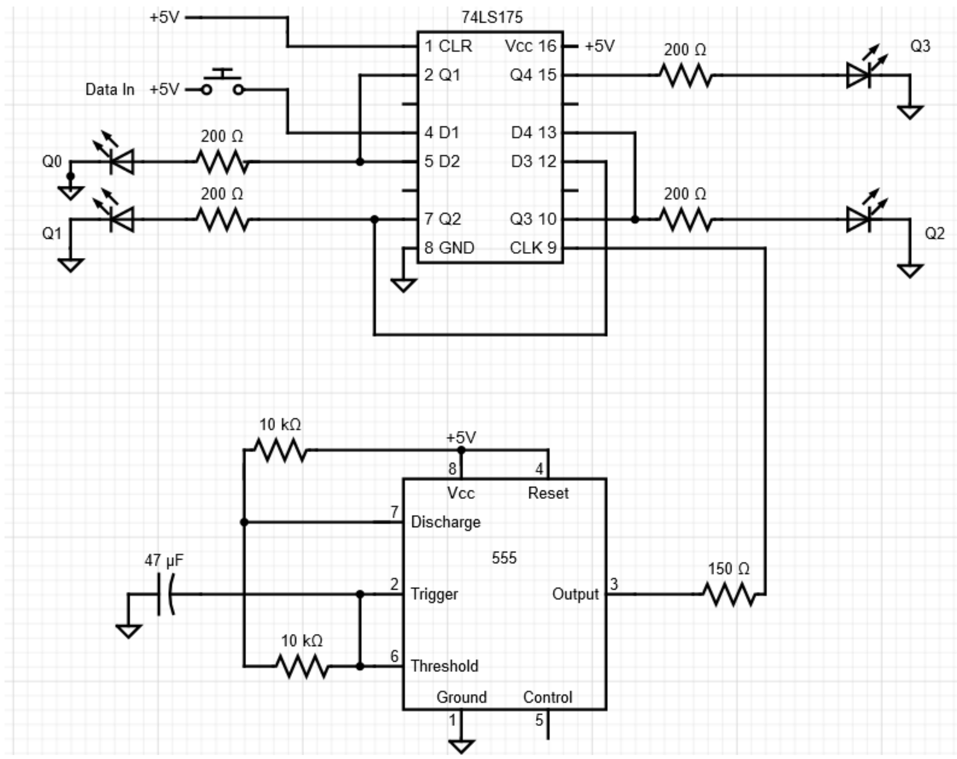


Figure 9: Circuit diagram of serial in - serial out shift register (drawn by Olivia Egbert)

Figure 10: Circuit diagram of circulating light circuit (drawn by Olivia Egbert, edited by Lillian Tucker)

Wired Circuit:

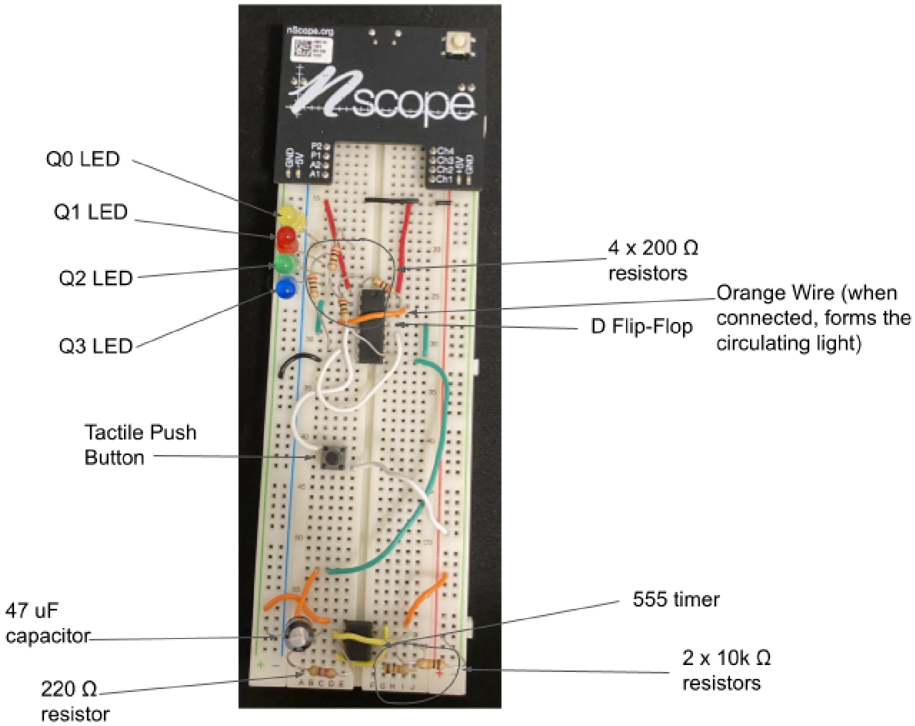


Figure 11: Wired and annotated circuit of serial in-serial out shift register and circulating light circuit (annotated on google slides)

Circuit 3&4: Ripple Counter and 14-Count LED

Only 1 of the 6 NOT gates were used in the hex inverter chip when creating the circuit. Only 3 of the 4 AND gates were used in the AND gate chip when creating the circuit.

Materials:

Resistors: 5 x 200 Ω, 1 x 220 Ω

- Measured values: 195 Ω, 195 Ω, 195 Ω, 194 Ω, 198 Ω, 217 Ω

LEDs: 2 blue, 1 green, 1 white, 1 clear

Mini Push Button

2 x 74LS112 chips (JK Flip Flop)

SN74LS08N chip (AND gates)

SN74LS04N chip (hex inverters)

Circuit Design:

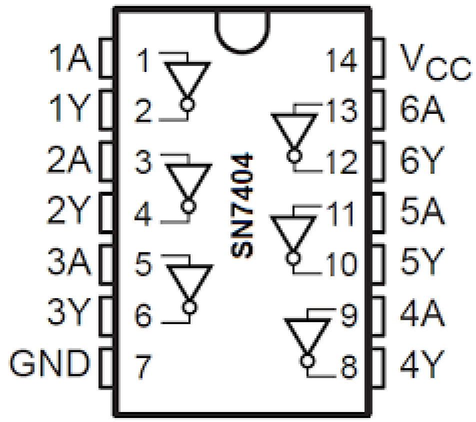


Figure 14: Pinout diagram of SN74LS04N hex inverter chip [8]

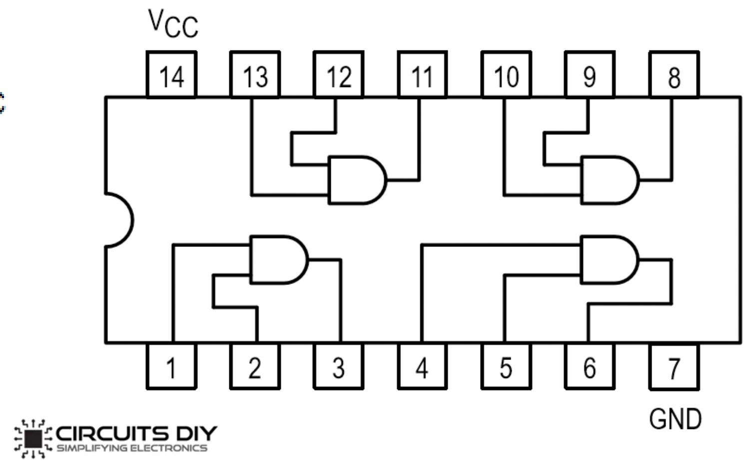


Figure 15: Pinout diagram of SN74LS08N AND gate chip [9]

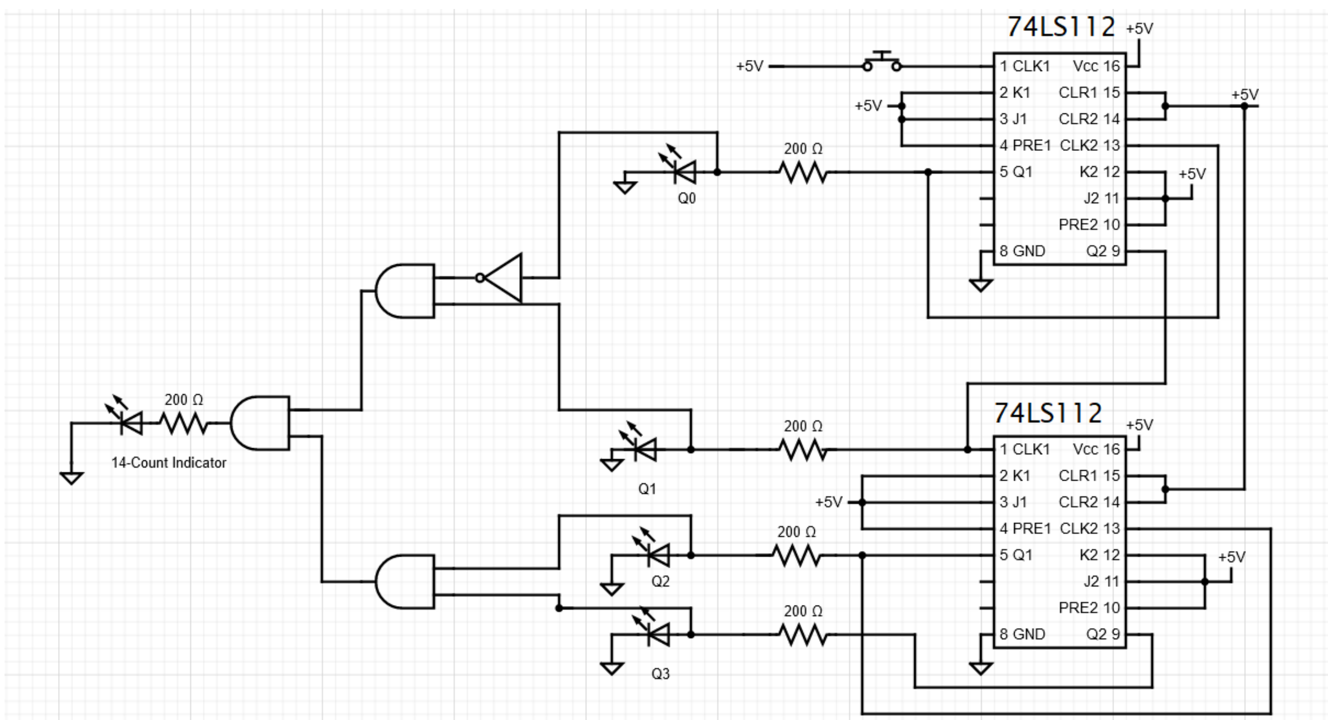


Figure 12: Circuit diagram of ripple counter circuit and 14 count circuit (drawn by Olivia Egbert)

Wired Circuit:

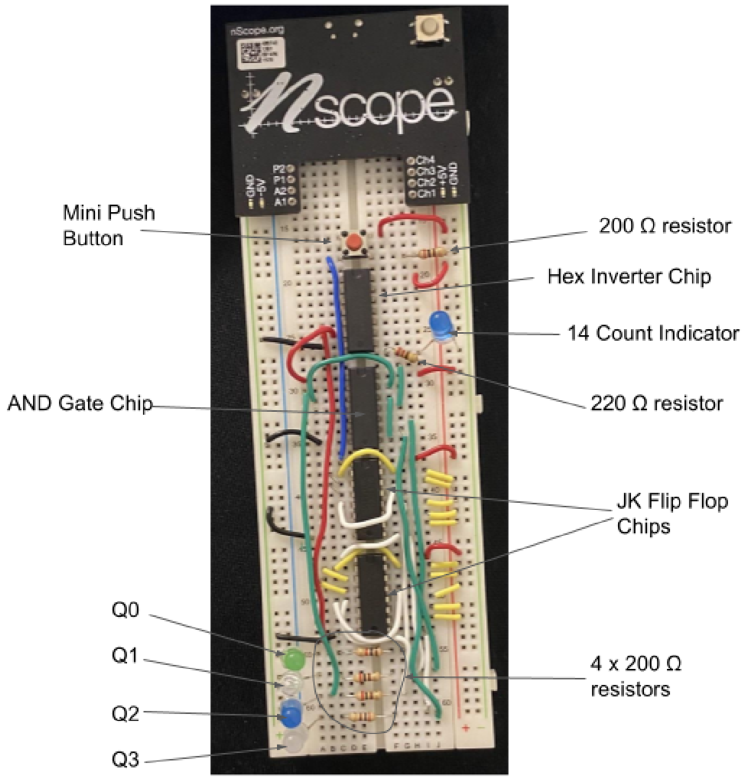


Figure 13: Wired and annotated circuit of ripple counter circuit and 14 count circuit (annotated in google slides)

Results

Circuit 1&2: Serial In-Serial Out Shift Register and Circulating Light

These two circuits are negative edge triggered so any changes in state occur when the clock reaches a falling edge or when voltage across the capacitor is NOT equal to the charging voltage.

Shift Register - The most significant bit is the blue LED(Q3) and the least significant is the yellow LED(Q0). 1 = LED is on, 0 = LED is off. When the power supply is turned on, the display output of the LEDs is 0000. When the button is pressed, the display output of the LEDs is 0001. With the 555 timer, the display output automatically updates. The next LED display is 0011. The next is 0111. The last LED display is 1111. Refer to Shift register.MOV video for detailed explanation of the circuit.

Circulating Light - The most significant bit is the blue LED(Q3) and the least significant is the yellow LED(Q0). 1 = LED is on, 0 = LED is off. When the power supply is turned on, the display output of the LEDs is 0001. With the 555 timer, the display updates automatically. The bit circulates through the LED display:0001 → 0010 → 0100 → 1000

Refer to Circulating Light.MOV video for detailed explanation of the circuit.

Circuit 3&4: Ripple Counter and 14-Count LED

These two circuits are negative edge triggered so any changes in state occur when the “clock” reaches a falling edge. In this case, there are not any changes in states until the button is released when there is not any voltage coming through the button.

The most significant bit is the white LED(Q3) and the last significant bit is the green LED(Q0). 1 = LED in on, 0 = LED is off. When the power supply is turned on the initial display is 1111. When the button is pressed, the display is then reset. Each button press cycles through the next LED display: 1111 → 0000 → 0001 → 0010 → 0011… This pattern continues until a binary LED display of 1111 (15) is reached. The next button press resets the display to 0000 and the sequence can then be repeated. The 14 count LED display references the bit outputs of the ripple counters to determine when the LED will light up. When the ripple counter LED display reads 1110 (14), the 14 count LED will light up. Any other binary value of the ripple counter and the 14 count LED is off.

Refer to Circuits 3and4.MOV video for a more detailed explanation.

Conclusion

The goal of the product was achieved: 1) build a serial in-serial out shift register, a circulating light circuit from the shift register circuit, and 2) build a ripple counter and a light circuit that blinks when the ripple counter reaches a count of 14.

Through this project, I learned how D flip-flops are used to create shift registers and how JK flip-flops are used to create ripple counters. It was very fun and interesting to see how the flip-flops in series interact to carry bits to display binary results. It was also insightful to see the flip-flops change states when the clock input reached a certain state rather than just seeing it simulated on modelsim.

<u>Unexpected Results:</u>

When wiring the ripple counter circuit, we ran into an issue where the light outputs were unpredictable and did not follow any sort of pattern and were not following the expected output of a ripple counter. We even tried controlling the input states manually without the button and still got random and unexpected results. We initially had a 10k Ω resistor in series with the button to ensure the input would reach a low level state. This was the reason we were getting the unexpected results of our outputs. We switched the 10k Ω resistor for a 200 Ω resistor and this seemed to fix this problem. After making this replacement we had a functional ripple adder. With the 10k Ω resistor, the input was likely not able to reach a definite high level state so the input was only 1 sometimes.

When making and testing the circuits, we found that the buttons were often finicky. To make them as consistent as possible, we had to make sure that the buttons were very secure in the breadboard and that the buttons were pressed firmly.

Once we had made our finalized circuits, we found that every once in a while, we would get some unexpected results with the LED outputs. For example, for the shift register and circulating light, when the button was pressed, sometimes it would not register so the LEDs would not always turn on and start the sequence. For the ripple counter, when the button was pressed, sometimes it would not register or it would cause the wrong display for the next count (ie. the LEDs would display 2 in binary and then instead of displaying 3 when pressing the button, it would display 6). After this, we made sure each time we pressed the button we waited at least 2 seconds before the next button press and pressed the button firmly for 1 second. Doing this improved results significantly.

References

[1] S. D. Brown and Z. G. Vranesic, *Fundamentals of digital logic with Verilog design*. New York: McGraw-Hill Higher Education, 2014.

[2] Electronics Tutorials, "D-type Flip Flop Counter or Delay Flip-flop," *Basic Electronics Tutorials*, 04-Jul-2021. [Online]. Available: https://www.electronics-tutorials.ws/sequential/seq_4.html. [Accessed: 10-Nov-2021].

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[5] B. Davis, "Why JK flip flop is used in counters?," *Physics*, 05-Jul-2020. [Online]. Available: https://www.mvorganizing.org/why-jk-flip-flop-is-used-in-counters/. [Accessed: 10-Nov-2021].

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