Cal Poly Pomona

LAB 10
COUNTERS

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INTRODUCTION

Digital counters play a crucial role in a variety of electronic systems, ranging from basic timekeeping to complex control systems. This laboratory exercise focuses on the design and implementation of counters using both an off-the-shelf integrated circuit (IC) and discrete logic components. The primary objectives of this lab are to design two different counter circuits.

In the first part of the lab, the counter follows a binary sequence using 74LS93 4-bit binary counter IC and employs a 7-segment display to visually represent the count sequence. The second part of the lab is simulated in order to implement an non-binary counter sequence using D flip-flops and discrete logic chips and employ a 7-segment display similarly.

By using a more "off the shelf" solution in the first part, we can create a cost-effective implementation at the cost of detail control over parameters such as count sequence, number of bits and limited flip-flop input logic.

4-BIT BINARY COUNTER CIRCUIT USING 74LS93 IC

Instructions:

Use the 74LS93 4-bit binary counter chip as an "off the shelf" solution to binary counting. Read the datasheet to determine how to configure the device to be used as a 4-bit counter.

Step 1: Setting up our 74LS93 IC

We need to read the datasheets for the components we are going to use. In this 4-bit counter we are going to use off the shelf parts such as the 74LS93 4-Bit Counter, 74LS47 7-Segment Display Decoder/Driver, and a 7-Segment Display. Our counter bits will feed into our decoder which will then drive our 7-Segment Display which will display an output. We also need to tie our CKB input to our QA output in order for our IC to count its maximum count length, along with tying both of our reset pins R01 and R02 to low since having them not tied to anything will result in our counter not functioning.

Step 2: Setting up a clock signal

We need to set up a clock signal for our 74LS93 IC to trigger. Instead of utilizing a 555 timer IC, we will use one of the signal generators available to us in our lab. We set a square wave with a low level of 0 volts, and a high level of 5 volts. We also set our frequency to 1Hz so that we can easily read our display's outputs. We then set this clock to the "Clock" pin on our 74LS93 IC.

Step 3: Set up our 74LS47 IC

We then connected the 74LS93 output pins to our 74LS47 decoder input, along with all of the necessary VCC, Ground, and miscellaneous pins such as "LED Test" were set to their respective high or low.

Step 4: Connect the 7-Segment Display

Our last step is to connect our decoder IC to our 7 Segment Display. Each input to our display is connected with a current limiting resistor so that our display doesn't burn.

The YouTube link to the counter working: https://youtube.com/shorts/IVXMAM7lW-0

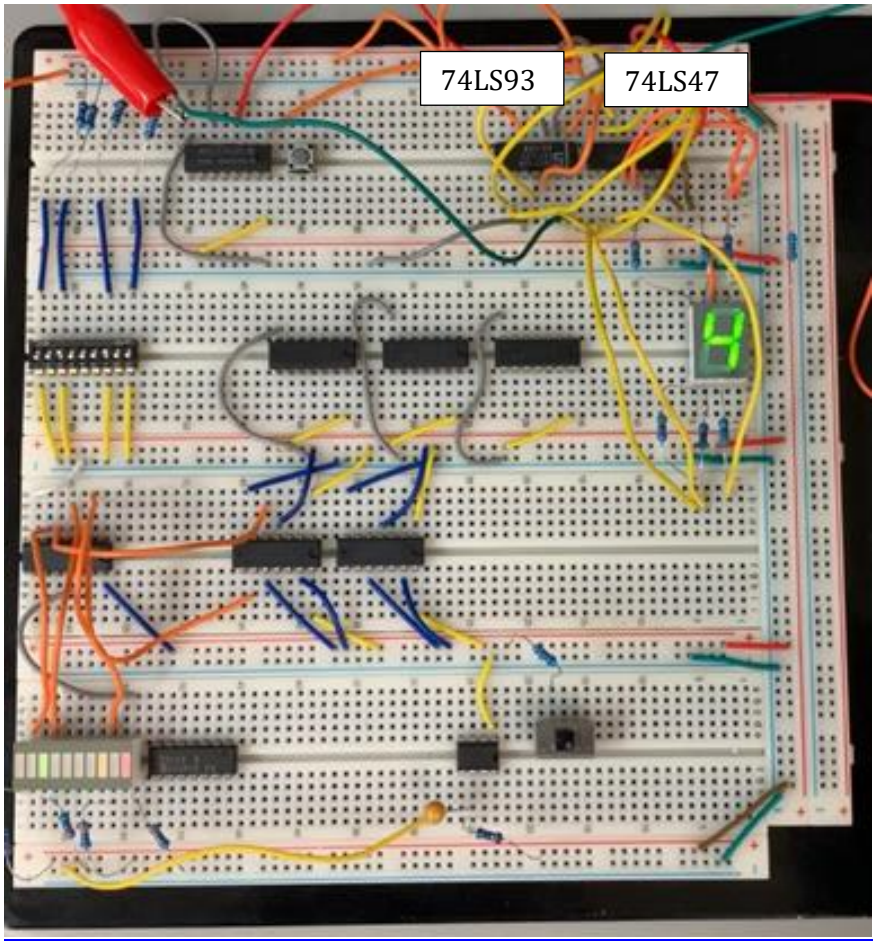

Figure 1 – Circuit board for the 4-bit Binary Counter at state 4

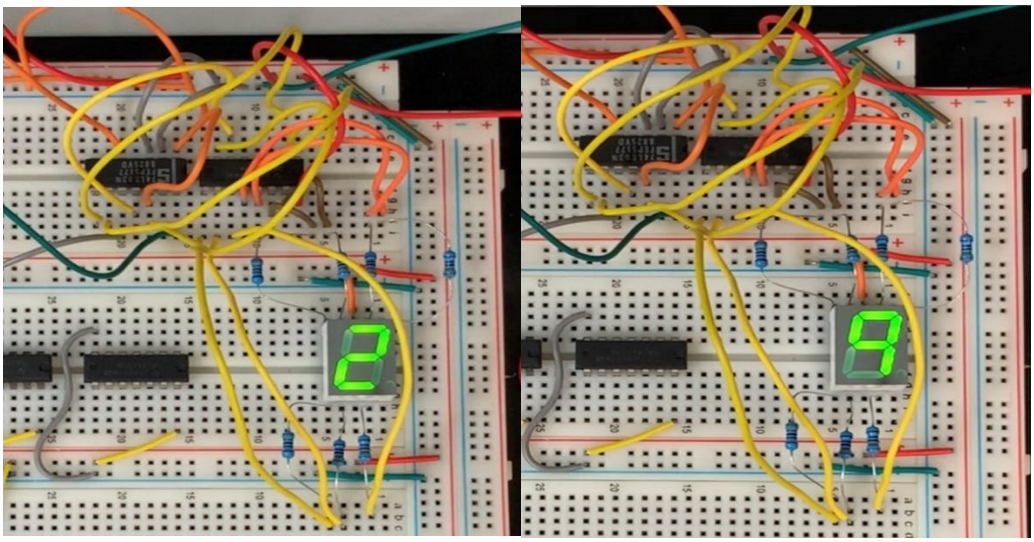

Figure 2 – Pictures of the counter states 2 and 9

DESIGN OF A NON-BINARY COUNTER USING DISCRETE LOGIC GATES AND FLIP-FLOPS

INSTRUCTIONS:

Design a 3-bit counter using 74LS74 D-flip flops to count the following sequence: 0, 4, 2, 3, 6, 0, … and repeat. Draw the K-map using don't cares to represent any count not mentioned in the sequence (i.e. 1, 5, 7). Simulate your circuit using Multisim and verify the sequence. You can use "digital probes" as indicators for the Q outputs of each flip flop and use a function generator as the clock. Choose a frequency that is low enough that you can actually see the indicators change. Something around 1 Hz is appropriate. Captures some screenshots of the counter in operation displaying different count values. Also, in addition to the digital probes, use a 74LS47 and 7-segment display to display the current count.

SOLUTION:

Step-1: Draw the State Diagram

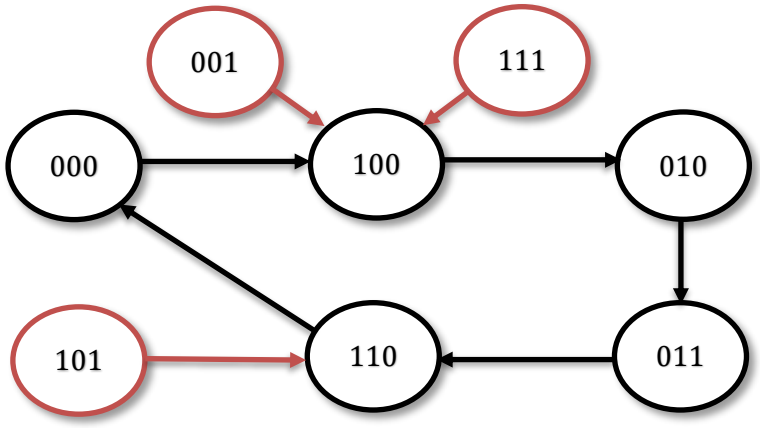

Figure 3 – Complete Counter State Diagram

Step-2: Find the State Table

Present State			Next State			D-ff Inputs		
a_2	a_1	a_0	a_2+	a_1+	a_0+	D_2	D_1	D_0
0	0	0	1	0	0	1	0	0
1	0	0	0	1	0	0	1	0
0	1	0	0	1	1	0	1	1
0	1	1	1	1	0	1	1	0
1	1	0	0	0	0	0	0	0

Table 1 – Valid Counter States Table

Step-3: Minimization

K-map for D_2

a_2 \ $a_1 a_0$	00	01	11	10
0	1	X	1	
1		X	X	

$$D_2 = a_0 + \overline{a}_2 \overline{a}_1$$

K-map for D_1

a_2 \ $a_1 a_0$	00	01	11	10
0		X	1	1
1	1	X	X	

$$D_1 = a_2 \overline{a}_1 + \overline{a}_2 a_1 = a_1 \oplus a_2$$

K-map for D_0

a_2 \ $a_1 a_0$	00	01	11	10
0		X		1
1		X	X	

$$D_0 = \overline{a}_2 a_1 \overline{a}_0$$

Step-4: Schematic

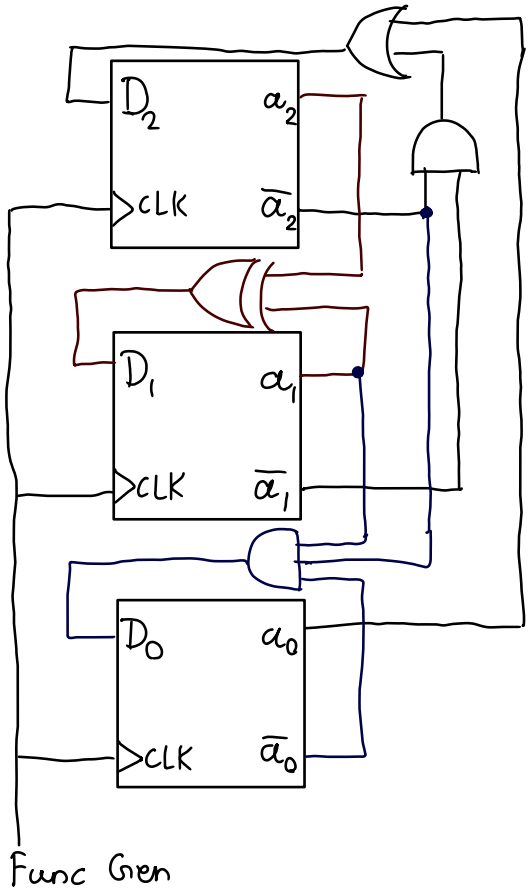

Figure 4 – Schematic Manual Drawing

Step-5: Complete State Table based on the D-ff input functions

Present State			Next State			D-ff Inputs		
a_2	a_1	a_0	a_2+	a_1+	a_0+	D_2	D_1	D_0
0	0	1	1	0	0	1	0	0
1	0	1	1	1	0	1	1	0
1	1	1	1	0	0	1	0	0

Table 2 – Invalid Counter States Table

Since invalid counts 001, 101 and 111 go to valid counts in the next clock pulse, this counter design is self-correcting.

Step-6: Simulate the circuit using Multisim

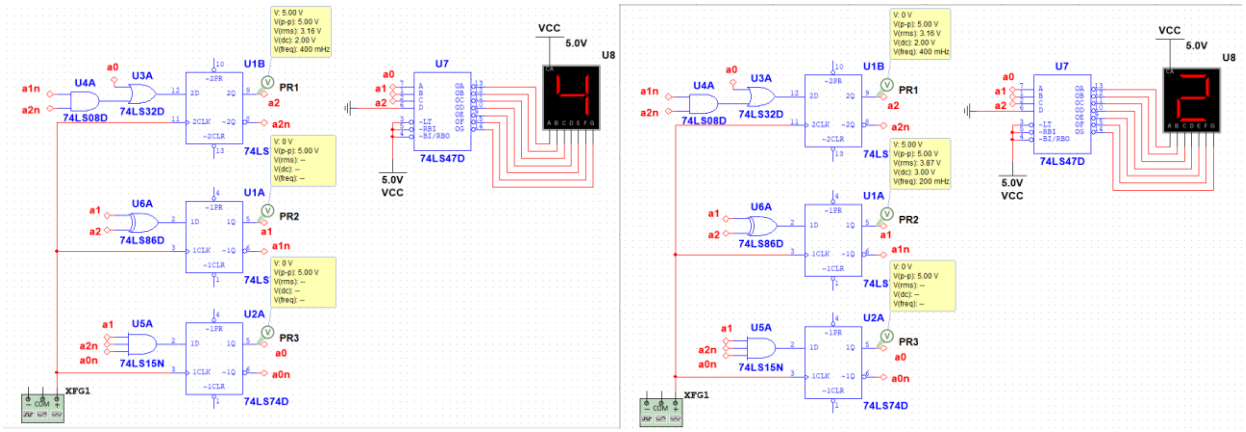

Figure 5 – Count States 4 and 2

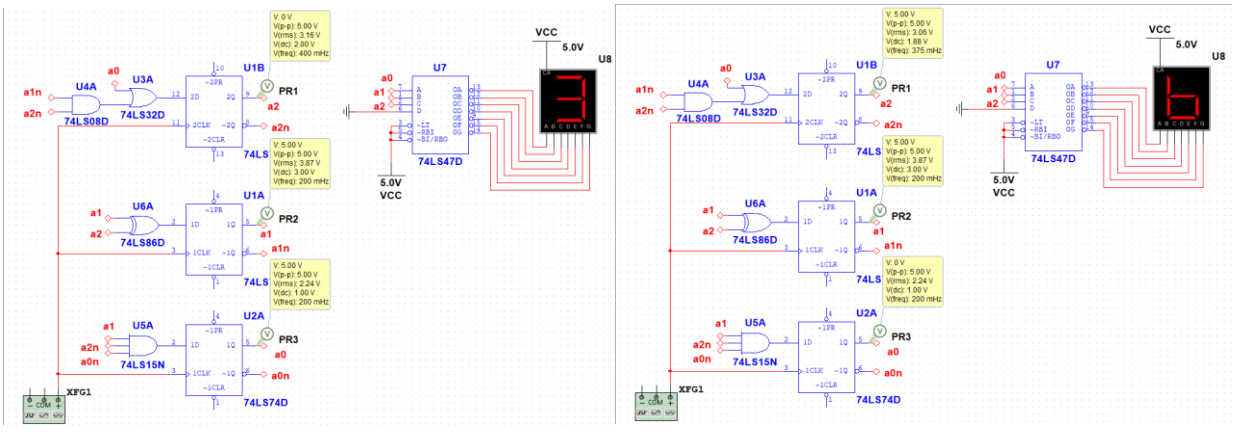

Figure 6 – Count States 3 and 6

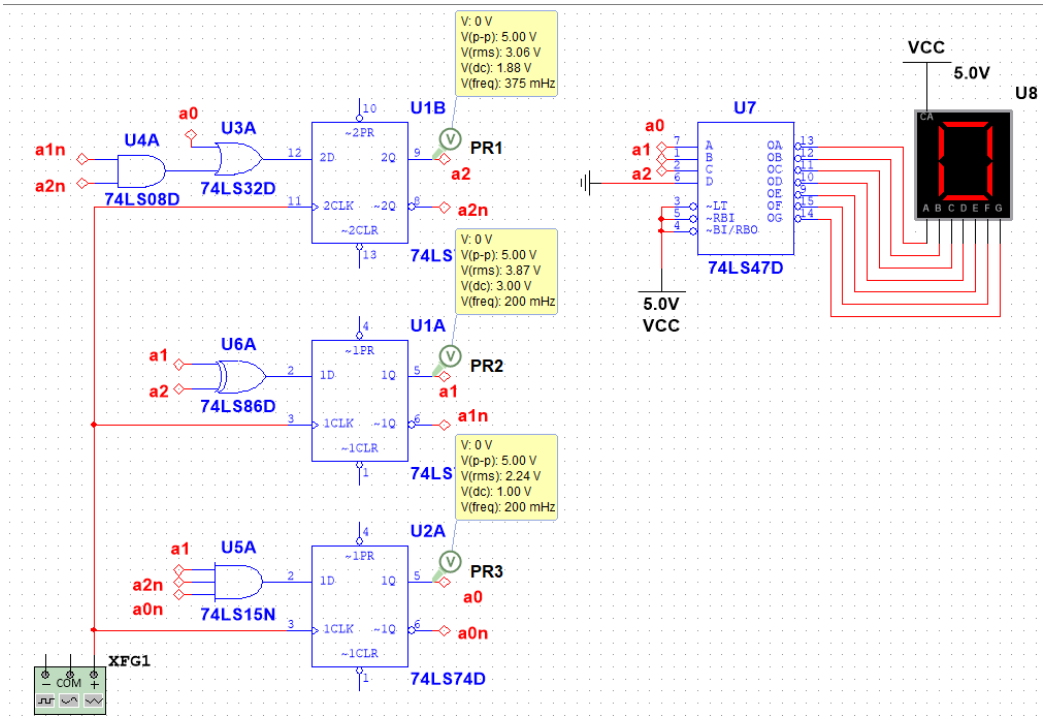

Figure 7 – Count State 0

CONCLUSION

In conclusion, this laboratory exercise provided valuable hands-on experience in the design and implementation of digital counters. By first employing the 74LS93 4-bit binary counter IC, we gained practical insights into configuring and utilizing off-the-shelf solutions for binary counting. The integration of a function generator, seven-segment display, and driver enriched the learning experience, allowing for a visual representation of the count sequence. This section of the lab reinforced essential skills in IC usage and circuit connectivity.

Moving on to the design of a custom 3-bit counter using 74LS74 D-flip flops, we applied theoretical knowledge such as state tables, diagrams and K-maps to create a circuit that accurately followed a predefined count sequence. The use of Multisim for simulation, digital probes for signal monitoring, and a 74LS47 with a 7-segment display for visual verification emphasized the comprehensive nature of digital logic design. Overall, this lab not only solidified understanding of counter circuits but also equipped us with practical skills applicable to real-world applications in digital electronics.