Lab Report: Experiment 8

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Experiment:
Designing a synchronous 0-99 counter
with buttons for increment and decrement
using 8 T flip-flops

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1 Objective

To design and implement a digital up/down counter that displays the number of people currently in the mess during peak lunch hours. The system will help students decide whether they can enter the mess based on the current occupancy. The maximum count is set to 99.

2 Materials Required:

- IR Sensors or Ultrasonic Sensors (for detecting entry/exit)
- 7-Segment Display (2-digit, Common Anode or Cathode) OR LCD Display
- Push Buttons (for simulation purposes if sensors are unavailable)
- Power Supply (5V DC for microcontroller and display)
- Breadboard & Jumper Wires
- Resistors (1kΩ, 330Ω for display connections)
- LEDs (Optional for indication of Full/Available status)

3 Circuit

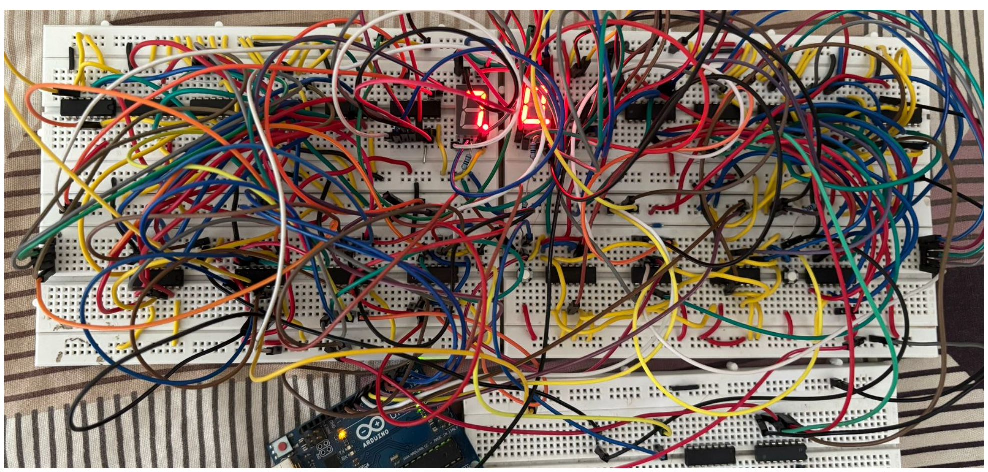


Figure 1: Circuit

The circuit may look daunting and complicated at first, let us break it down and study each module seperately.

3.1 Overview

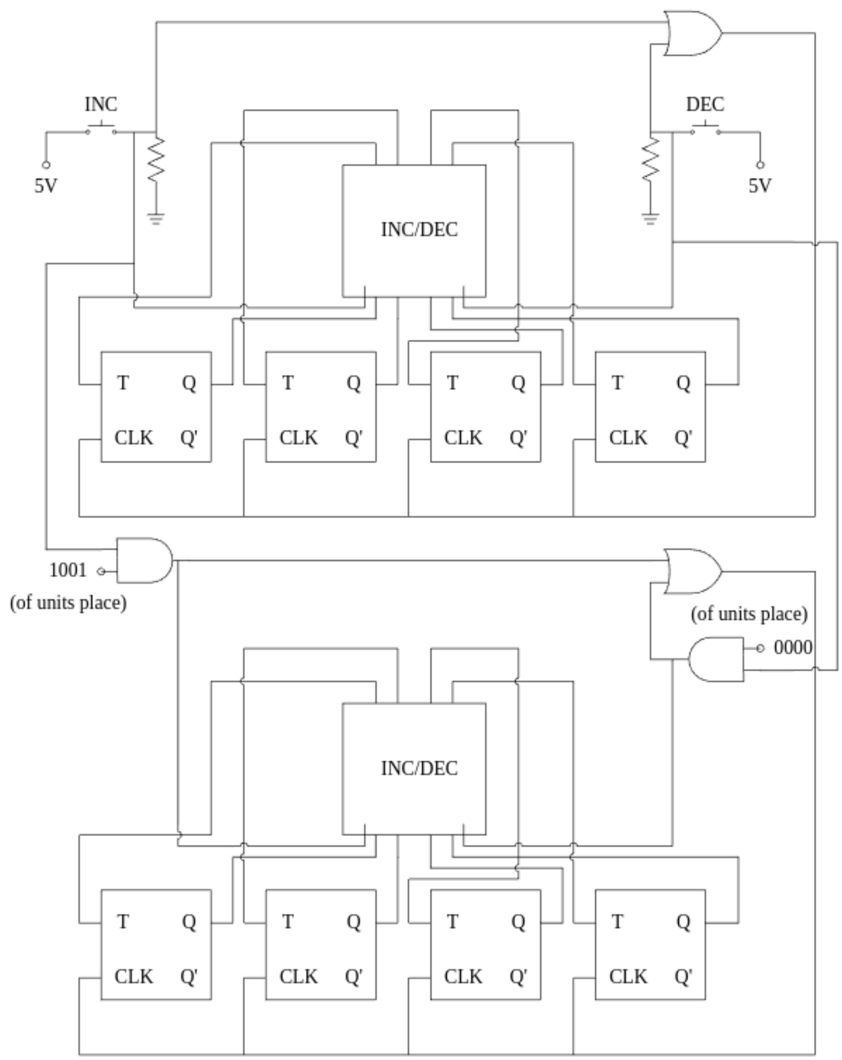


Figure 2: Circuit Overview

The upper part shows the units digit and the lower part shows the tens digit. For each digit, there is a module called INC/DEC that either increments or decrements current count (by 1) depending on which button is pressed and returns the value to the T of the flipflop (which becomes Q of flipflop when clock becomes high). As for clock, logic is slightly different for each digit. For units place, output of the two button presses are ORed and given as clock (so that clock is only high when either button is pressed). For the tens place, each button press is first ANDed with either $\overline{Q_3}.\overline{Q_2}.\overline{Q_1}.\overline{Q_0}$ (decrement) or $Q_3\overline{Q_2}.\overline{Q_1}Q_0$ (increment) of units place and then ORed. This way clock is only high if incrementing button is pressed and units place is 9 or if decrementing button is pressed and units place is 0.

3.2 JK to T Flip-Flop Conversion

Since JK flip-flops were provided instead of T flip-flops, conversion was necessary. Converting a JK flip-flop to a T flip-flop can be done by simply shorting J and K ports of JK flip-flops.

T	Q_n	Q_{n+1}	J	K
0	0	0	0	X
0	1	1	X	0
1	0	1	1	X
1	1	0	X	1

Writing Karnaugh-map for J

		Q_n	
		0	1
T	0	0	X
	1	1	X

We get,

$$J = T$$

Now writing karnaugh-map for K,

		Q_n	
		0	1
T	0	X	0
	1	X	1

We get,

$$K = T$$

3.3 Changing Count

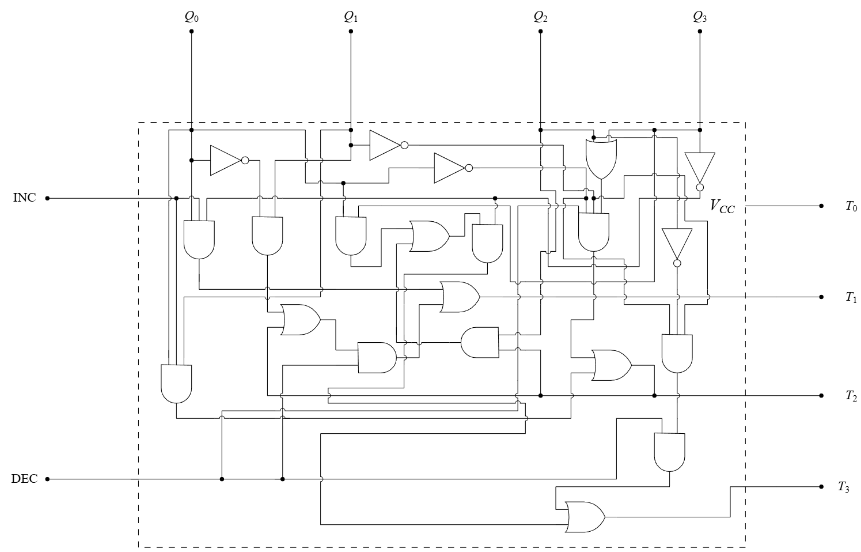


Figure 3: INC/DEC Module

To either increment or decrement count depending on button press, we just AND the button press with their corresponding module (either increment or decrement) and OR the two outputs.

3.4 Incrementing

For the units digit in the UP counter, we derive the T flip-flop inputs using Karnaugh maps:

Current State	T_3	T_2	T_1	T_0	**Next State**
0000	0	0	0	1	0001
0001	0	0	1	1	0010
0010	0	0	0	1	0011
0011	0	1	1	1	0100
0100	0	0	0	1	0101
0101	0	0	1	1	0110
0110	0	0	0	1	0111
0111	1	1	1	1	1000
1000	0	0	0	1	1001
1001	1	0	0	1	0000

Q_3,Q_2 \ Q_1,Q_0	00	01	11	10
00	1	1	1	1
01	1	1	1	1
11	X	X	X	X
10	1	1	X	X

Figure 4: Karnaugh Map for T_0

Q_3,Q_2 \ Q_1,Q_0	00	01	11	10
00	0	1	1	0
01	0	1	1	0
11	X	X	X	X
10	0	0	X	X

Figure 5: Karnaugh Map for T_1

Q_3,Q_2 \ Q_1,Q_0	00	01	11	10
00	0	0	1	0
01	0	0	1	0
11	X	X	X	X
10	0	0	X	X

Figure 6: Karnaugh Map for T_2

Q_3,Q_2 \ Q_1,Q_0	00	01	11	10
00	0	0	0	0
01	0	0	1	0
11	X	X	X	X
10	0	1	X	X

Figure 7: Karnaugh Map for T_3

From the Karnaugh map simplification, we derive:

$T_0 = 1$

$T_1 = \overline{Q_3 Q_0}$

$T_2 = Q_1 Q_0$

$T_3 = Q_3 Q_0 + Q_2 T_2$

3.5 Decrementing

Decrementing is done using Karnaugh Maps,

Current State	T_3	T_2	T_1	T_0	**Next State**
0000	1	0	0	1	1001
0001	0	0	0	1	0000
0010	0	0	1	1	0001
0011	0	0	0	1	0010
0100	0	1	1	1	0011
0101	0	0	0	1	0100
0110	0	0	1	1	0101
0111	0	0	0	1	0110
1000	1	1	1	1	0111
1001	0	0	0	1	1000

Q_3,Q_2 \ Q_1,Q_0	00	01	11	10
00	1	1	1	1
01	1	1	1	1
11	X	X	X	X
10	1	1	X	X

Figure 8: Karnaugh Map for T_0

Q_3,Q_2 \ Q_1,Q_0	00	01	11	10
00	0	0	0	1
01	1	0	0	1
11	X	X	X	X
10	1	0	X	X

Figure 9: Karnaugh Map for T_1

Q_1,Q_0

Q_3,Q_2		00	01	11	10
	00	0	0	0	0
	01	1	0	0	0
	11	X	X	X	X
	10	1	0	X	X

Figure 10: Karnaugh Map for T_2

Q_1,Q_0

Q_3,Q_2		00	01	11	10
	00	1	0	0	0
	01	0	0	0	0
	11	X	X	X	X
	10	1	0	X	X

Figure 11: Karnaugh Map for T_3

From the Karnaugh map simplification, we derive:

$T_0 = 1$

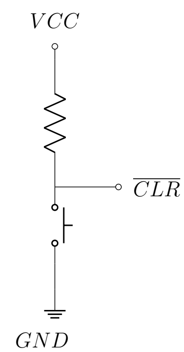
$T_1 = Q_1\overline{Q_0} + \overline{Q_1}.\overline{Q_0}.Q_2 + \overline{Q_1}.\overline{Q_0}.Q_3$

$T_2 = Q_2.\overline{Q_1}.\overline{Q_0} + Q_3.\overline{Q_1}.\overline{Q_0}$

$T_3 = \overline{Q_2}.\overline{Q_1}.\overline{Q_0}$

3.6 Manual Reset Button

A manual asynchronous reset button was added to reset count of number of people in the mess to 0 regardless of current number of people in the mess. This was done by connecting all the $\overline{CLR}$ pins of the flip flops to a leg of the push button whose other end is grounded, and this leg of the push button is connected to VCC through a pull up resistor. Through this process, we can



ensure that $\overline{CLR}$ is always $HIGH$ unless button is pressed in which case $\overline{CLR}$ becomes 0 which due to the design of the flipflop automatically nulls all outputs regardless of input.

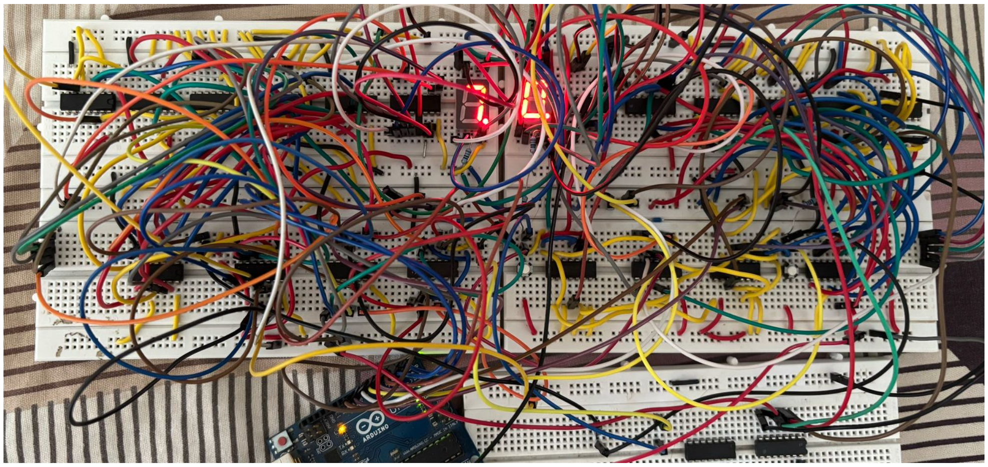
3.7 Clock

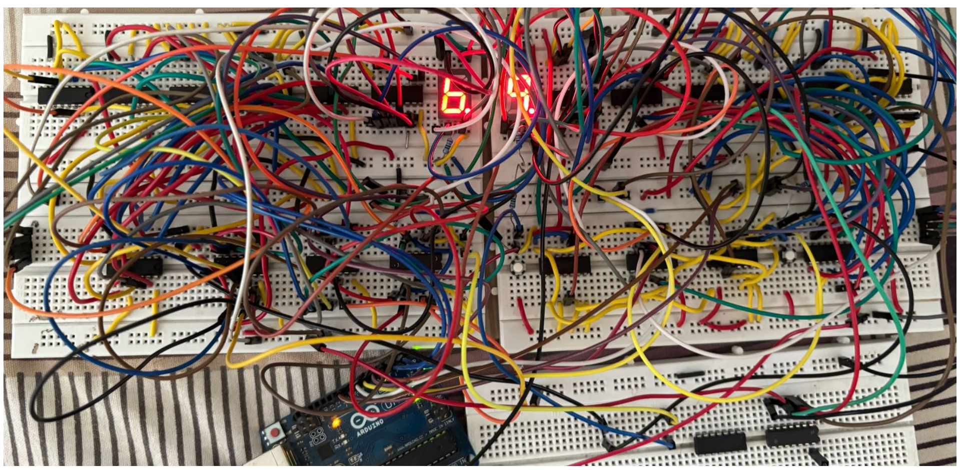
The clock for the units digit is generated by ANDing the two button press signals. For the tens digit, the clock is generated by:

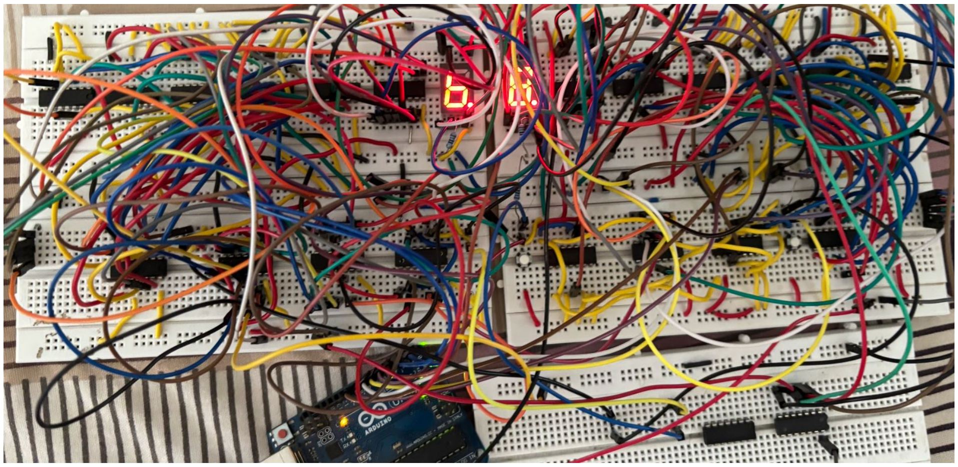
- ANDing the increment button with $Q_3\bar{Q}_2\bar{Q}_1Q_0$ of the units place (1 only when units digit is 9)
- ANDing the decrement button with $\bar{Q}_3\bar{Q}_2\bar{Q}_1\bar{Q}_0$ of the units place (1 only when units digit is 0)
- ORing the output of the two above mentioned AND gates.

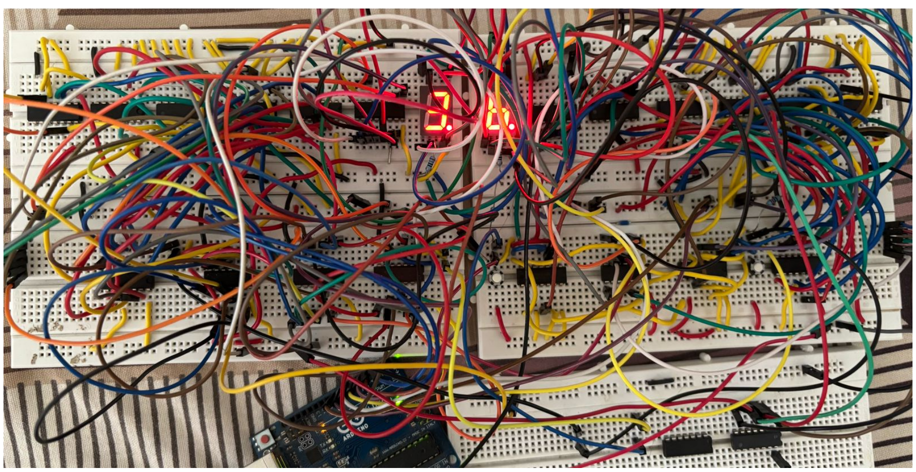
4 Results

Images of circuits for some outputs,









Videos of working may be found here,
`https://github.com/ArjunPavanje/EE1200/tree/main/Experiment_8/vids`

5 Conclusion

The above report shows how a mess counter from 0-99 was built using Karnaugh Maps, multiplexing with a manual reset button.