Lab 3: Combinational Logic Circuit

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Section: 2

Purpose of the experiment:

The purpose of this experiment is to teach how to design a combinational circuit by using logic gates on a breadboard.

Methodology:

For this lab, we were asked to recreate the last lab's combinatorial circuit design on a breadboard by using logic gates, counters and LEDs. In the last lab, I chose to check whether a house cat was fed or not. For the circuit I used 1 4-bit counter (74HC163), 1 AND-gate (74HC08) and 1 OR-gate (74HC32), connected 4 red LEDs to the counter to visualize the truth table status, and the output of the AND-gate is connected to a single green LED to again visualize the truth table status. At the end of the procedure, the waveform was obtained by using an oscilloscope.

The equation to check whether the cat was fed or not is:

(mom + dad) . (john + jane) = cat

If cat = 1, this means that the cat is properly fed (at least once for morning and evening), and if cat = 0, this means that at least one of the meals the cat supposed to get has been skipped. In the last lab, Vivado was used to generate the RTL schematic of the circuit and it is shown in Figure.1. The truth table of the equation can be seen in Table.1.

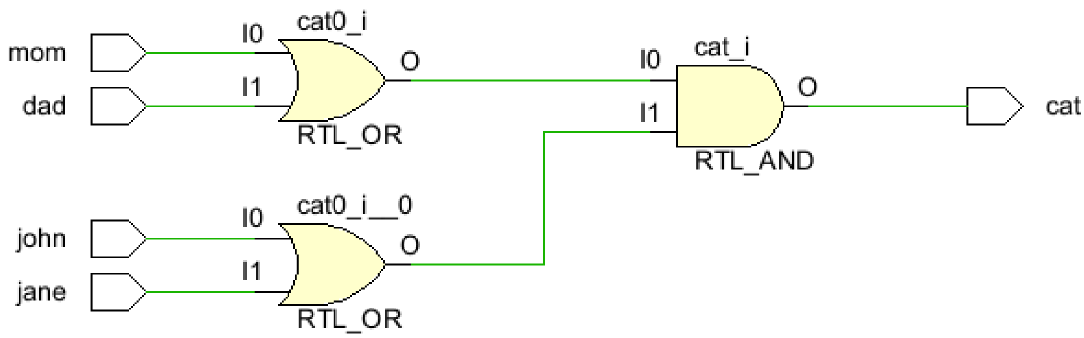


Figure.1 RTL schematic generated by Vivado

mom	dad	john	jane	mom + dad	john + jane	cat
0	0	0	0	0	0	0
0	0	0	1	0	1	0
0	0	1	0	0	1	0
0	0	1	1	0	1	0
0	1	0	0	1	0	0
0	1	0	1	1	1	1
0	1	1	0	1	1	1
0	1	1	1	1	1	1
1	0	0	0	1	0	0
1	0	0	1	1	1	1
1	0	1	0	1	1	1
1	0	1	1	1	1	1
1	1	0	0	1	0	0
1	1	0	1	1	1	1
1	1	1	0	1	1	1
1	1	1	1	1	1	1

Table.1 Truth table of the equation ***(mom + dad) . (john + jane) = cat***

Results:

In the 4-bit counter, pin 2 was CLOCK and connected to the signal generator. The signal generator was set to generate square waves with 5V peak-to-peak amplitude and 1 Hz frequency. Pin 8 was GND and connected to the – line of the breadboard which was connected to the GND of the signal generator and the GND of the power supply at the end. Pin 16 was Vcc and connected to the + line of the breadboard which was connected to the power supply at the end. Q0 (pin 14), Q1 (pin 13), Q2 (pin 12) and Q3 (pin 11) were the output pins and these outputs were connected to the OR-gate by using jumper cables. The binary situations of these outputs were represented by 4 red LEDs. This counter operated at 5V Vcc so the output of the power supply was set at 5V. The range of this counter is from 0 to 15 in binary, so there are 16 different situations this counter can represent.

Both of the logic gates which were used in this lab had similar pin assignments. For both of them, pin 7 is GND and connected to the – line of the breadboard, pin 14 is Vcc and connected to the + line of the breadboard. However, the input-output configurations of this particular circuit are different in each of them. In the OR-gate, pin 1 and pin 2 represented "**mom**" and "**dad**", pin 12 and pin 13 represented "**john**" and "**jane**" respectively. The outputs of these configurations (pin 3 and pin 11) were connected to the input pins (pin 1 and pin 2) of the AND-gate. The output of the AND-gate (pin 3) is connected to a green LED to visualize the ongoing process.

mom : Q0 – Pin 1 of OR-gate

dad : Q1 – Pin 2 of OR-gate

john : Q2 – Pin 12 of OR-gate

jane : Q3 – Pin 13 of OR-gate

cat : Pin 3 of the AND-gate

For better visualization, the schematic of the circuit is drawn by using TinkerCAD. This schematic is shown in Figure.2.

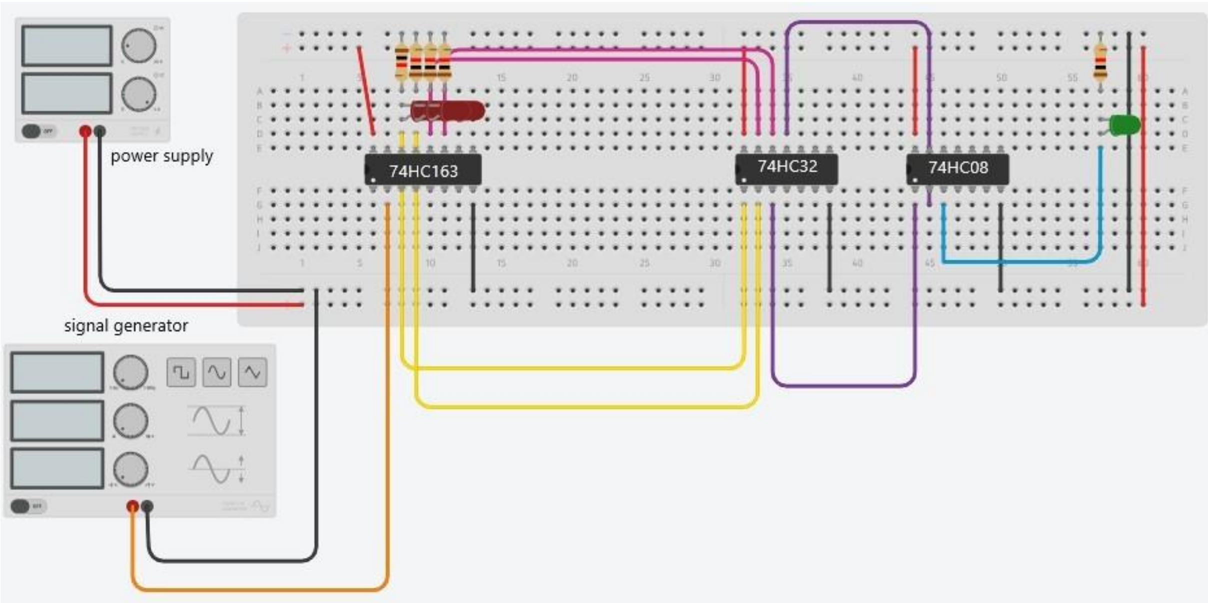
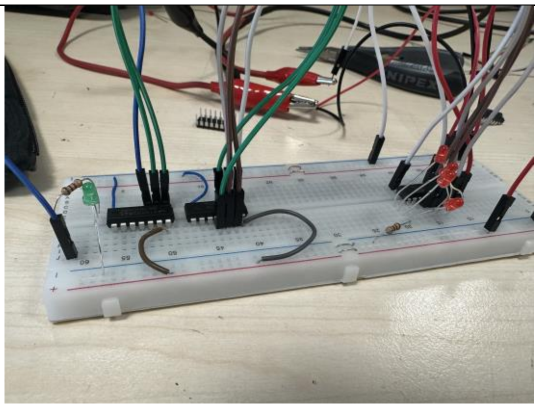
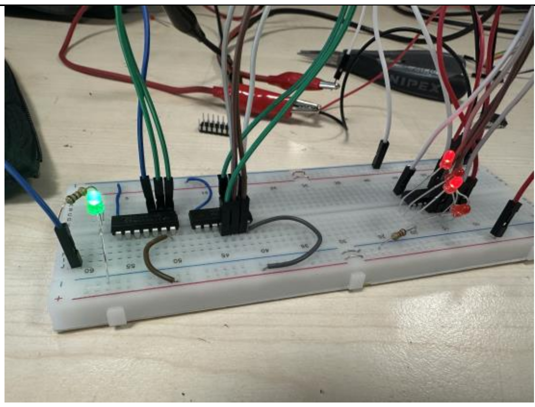
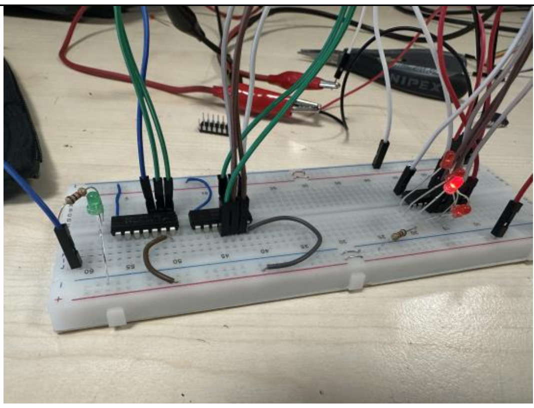
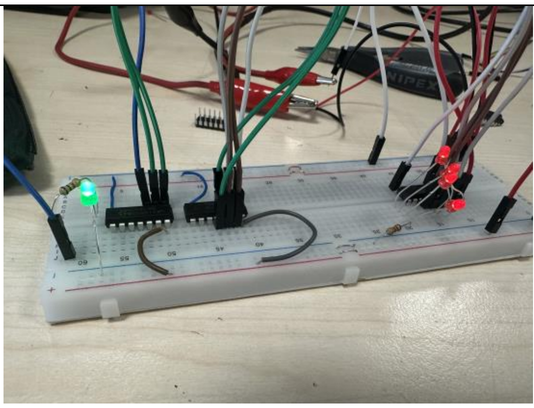


Figure.2 Schematic of the circuit drawn by TinkerCAD

In the following figures, there are different states of my working circuit that proves that the truth table is built correctly.

 Figure.3 Combination 0-0-0-0	**mom** : 0 **dad** : 0 **john** : 0 **jane** : 0 **cat** : 0
 Figure.4 Combination 1-0-1-0	**mom** : 1 **dad** : 0 **john** : 1 **jane** : 0 **cat** : 1

 Figure.5 Combination 0-0-1-0	**mom** : 0 **dad** : 0 **john** : 1 **jane** : 0 **cat** : 0
 Figure.6 Combination 1-1-1-1	**mom** : 1 **dad** : 1 **john** : 1 **jane** : 1 **cat** : 1

Since the counter continues to count up until we disconnect the power supply cable, the waveform on the oscilloscope screen was continuously moving. In this situation, one can either use the STOP button or set the frequency on the signal generator to an appropriate value so that the wave moves slow enough to capture. I chose to lower the frequency instead of using the STOP function. The following figures are representing the waveform at different times on the oscilloscope.

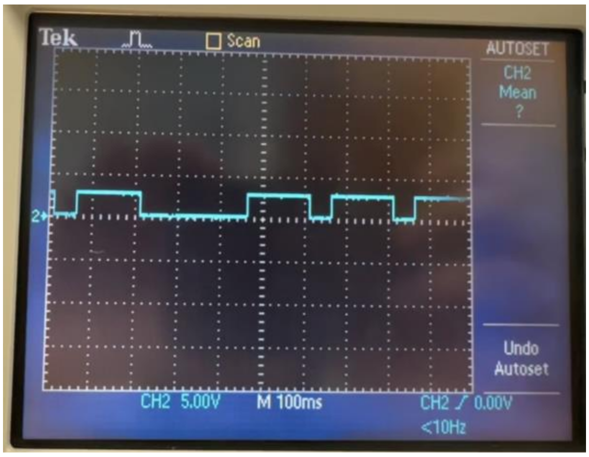


Figure.7 Waveform on the oscilloscope at time t1

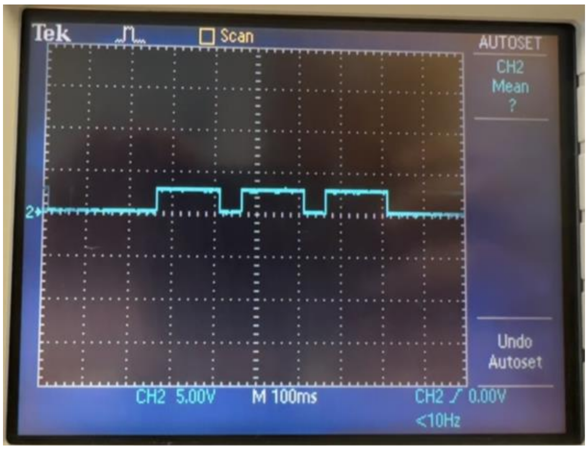


Figure.8 Waveform on the oscilloscope at time t2

Conclusion:

In this lab, we learned how to use build a functional circuit on a breadboard and check whether it was working or not by using an oscilloscope. We familiarized with logic gates and counters and learned how to read the data sheets of circuit components effectively. We used schemes to visualize circuits, and observed waveforms. The waveform showed that there was some delay which was due to the logic gates. As you increase the number of your logic gates, the delay time increases. In order to minimize this delay, I used the least number of logic gates that would give the right output. At the beginning of the testing part of the completed circuit, the 4-bit counter got really hot and started to smoke. I immediately disconnected the power supply and asked for help. After careful examinations, we discovered that one of the jumper cables was not working, so although all of my connections were right, the counter burned and became unusable. All in all, the experiment was successful at the end.