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Lab Report 3
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# LAB 3: COMBINATIONAL LOGIC CIRCUIT

## Purpose

The purpose of this experiment is to set up a circuit we designed on a breadboard. We will be using a 4-bit-counter for the inputs and LEDs for the outputs.

## Design Specifications

In this experiment, instead of using the BASYS3 board, the circuit is implemented on a breadboard. The inputs X, Y, and Z will be generated by the 74HC163 counter by creating input sequences from 000 to 111. The output L will be represented by an LED, which will light up when the output value of the function is 1. Other than the 4-bit-counter, two types of logic gates are used in the circuit. There is a 74 LS/HC 08 gate (which is a 2-input AND gate) and a 74 LS/HC 02 gates (which is a 2-input NOR gate). In order to observe the changing inputs, I have also connected LEDs to the inputs. The green LEDs are used for the inputs and the red LED is used for the output F.

## Methodology

In order to have fewer problems while implementing the circuit, I have made changes on my previous design. This time, the output function F will be:

$$F = \overline{(XY + YZ)}$$

which can be implemented using two-input AND gates and a two-input NOR gate. The truth table for the function can be seen in Figure 1:

| X | Y | Z | F |
|---|---|---|---|
| 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 1 |
| 0 | 1 | 1 | 0 |
| 1 | 0 | 0 | 1 |

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| | | | |
|---|---|---|---|
| 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 0 |
| 1 | 1 | 1 | 0 |

Figure 1: Truth table for the function

The 74HC163 counter I used in the circuit simulates this truth table. It has 16 pins. The pins VCC, MR, CEP, CET and PE are connected to a source of 5V while the GND pin is connected to the ground. Also, the signal generator which generates square waves is connected to the CP pin. To see whether the counter works properly, I used the oscilloscope to test it. The logic gates 74 LS/HC 08 and 74 LS/HC 02 only have connections for ground, source, inputs, and outputs so it was easier to set them up. For the LEDs, we need to use a 1KΩ resistor in order to prevent them from being damaged. The schematics for the gates can be seen in Figures 2 and 3, and Figure 4 shows the pin configuration of the 4-bit counter. After setting up the circuit, I observed the waveforms of the output on the oscilloscope and compared it to the truth table. To do this, I touched the output LED’s positive terminal with the probe and connected the ground to the ground of the breadboard.

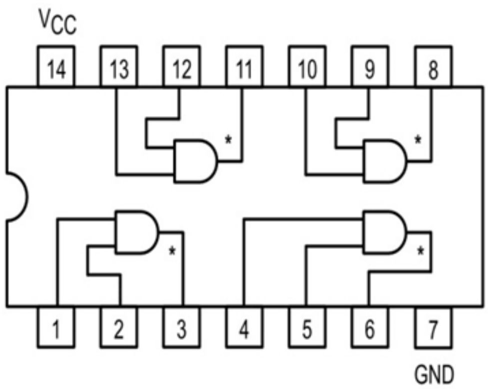


Figure 2: Schematic for the 2-input AND gate (74 LS/HC 08)

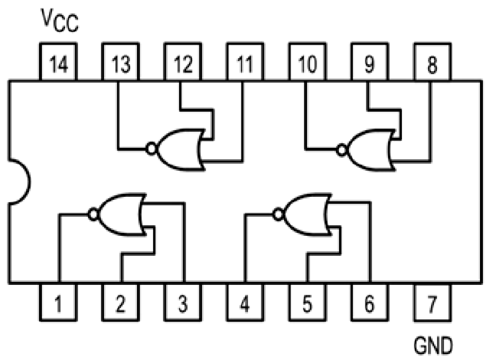


Figure 3: Schematic for the 2-input NOR gate (74 LS/HC 02)

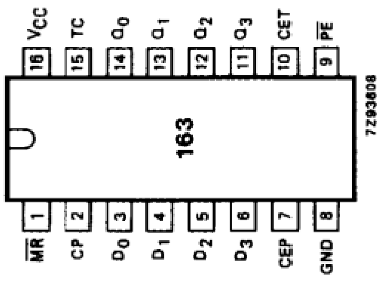


Figure 4: Pin configuration of the 4-bit counter (74HC163)

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## Results

As expected, the output waveforms matched with the values of F in the truth table. It had a pattern 11101100 which repeated continuously. The output waveform can be seen in Figure 5.

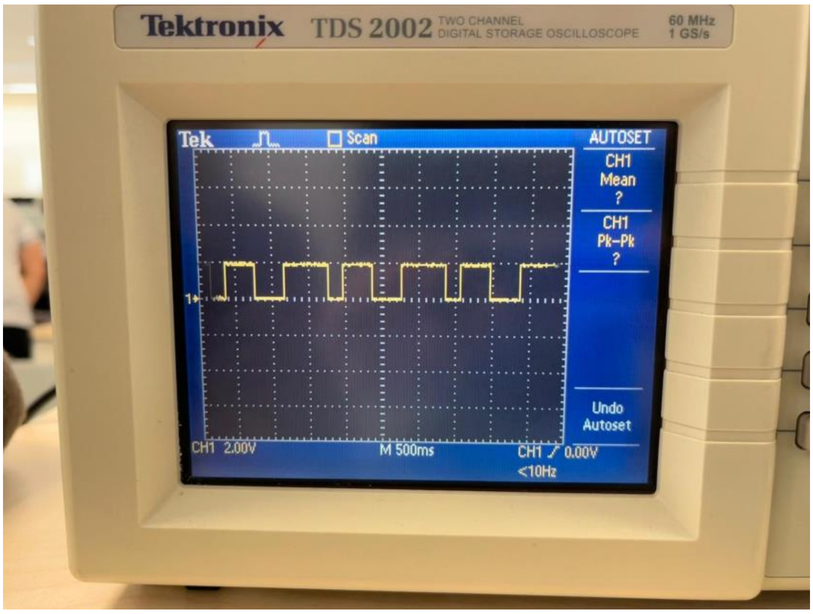


Figure 5: Output waveform of the function

After setting up the circuit, I also checked the results by observing the inputs through the green LEDs. Figure 6 shows the circuit before being connected to the source. Figures 7-14 show the value of the function with corresponding inputs.

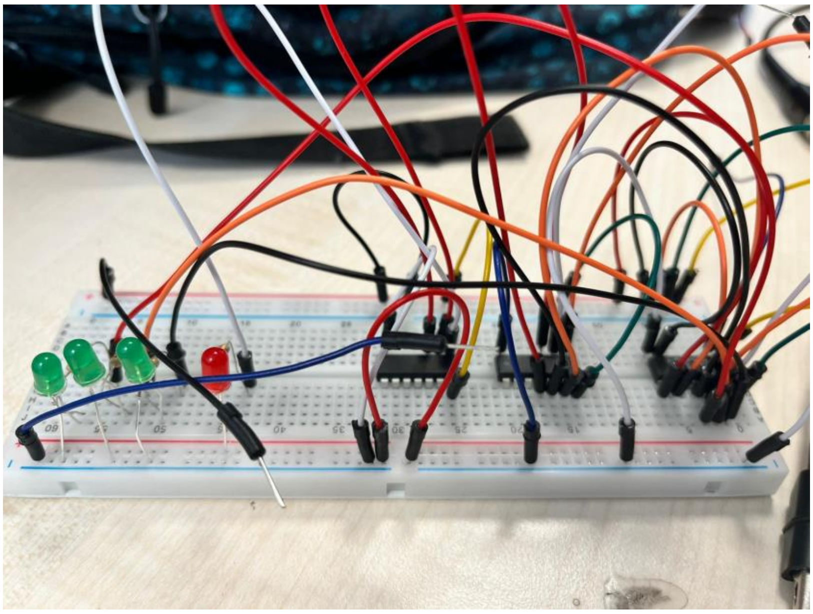

Figure 6: Circuit set up

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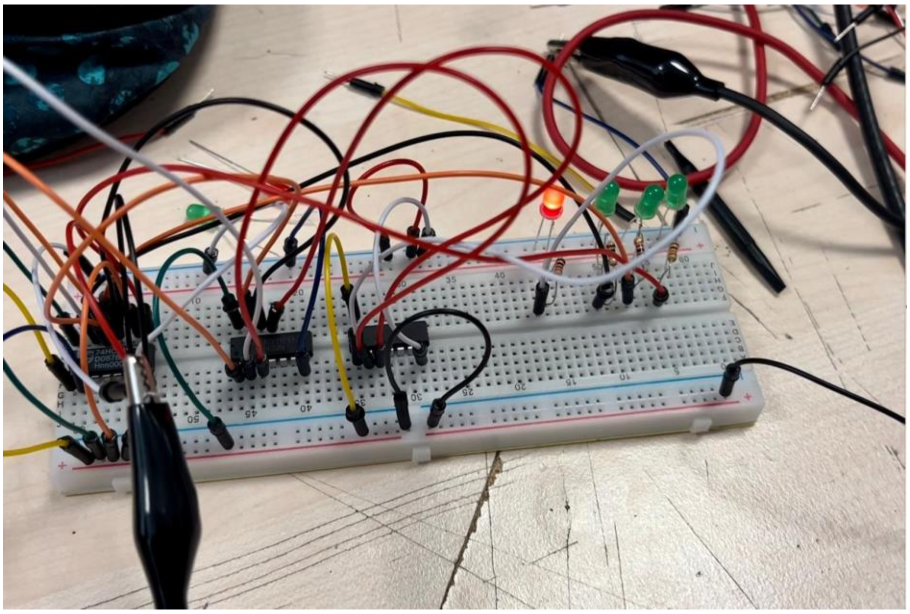

Figure 7: Output F=1 when X=0, Y=0, Z=0

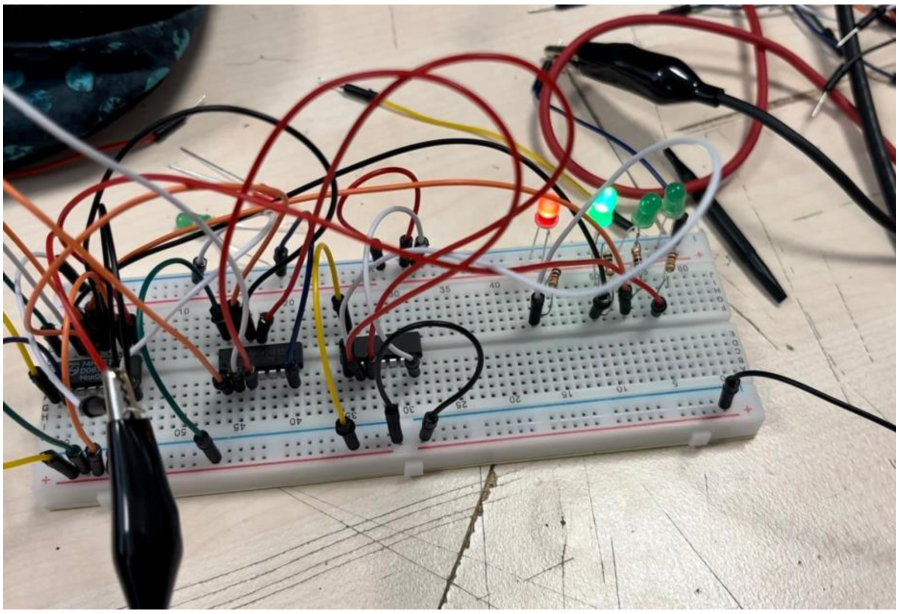

Figure 8: Output F=1 when X=0, Y=0, Z=1

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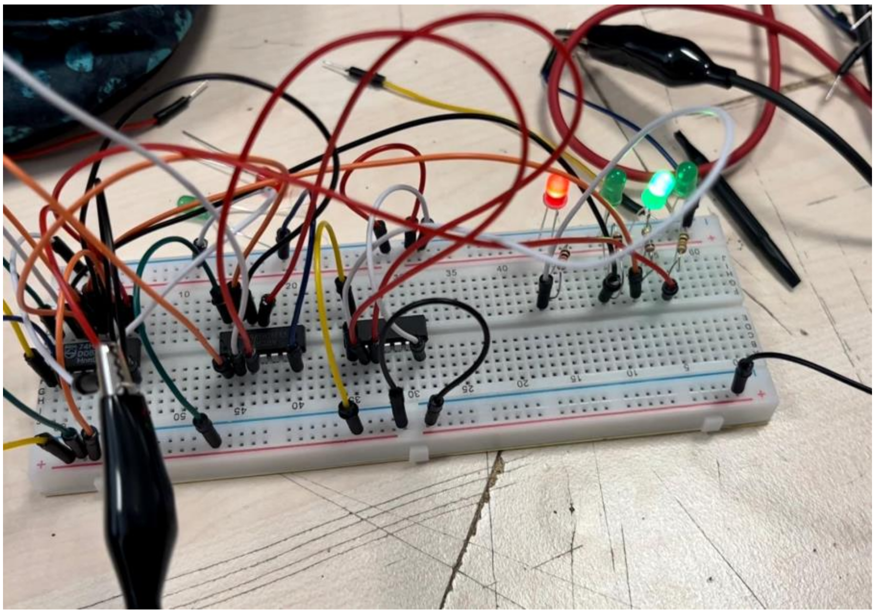

Figure 9: Output F=1 when X=0, Y=1, Z=0

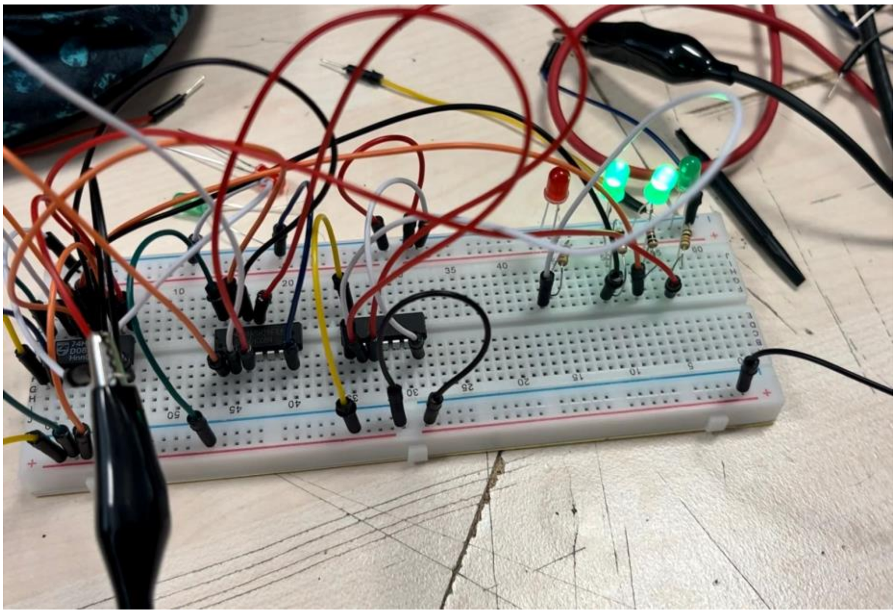

Figure 10: Output F=0 when X=0, Y=1, Z=1

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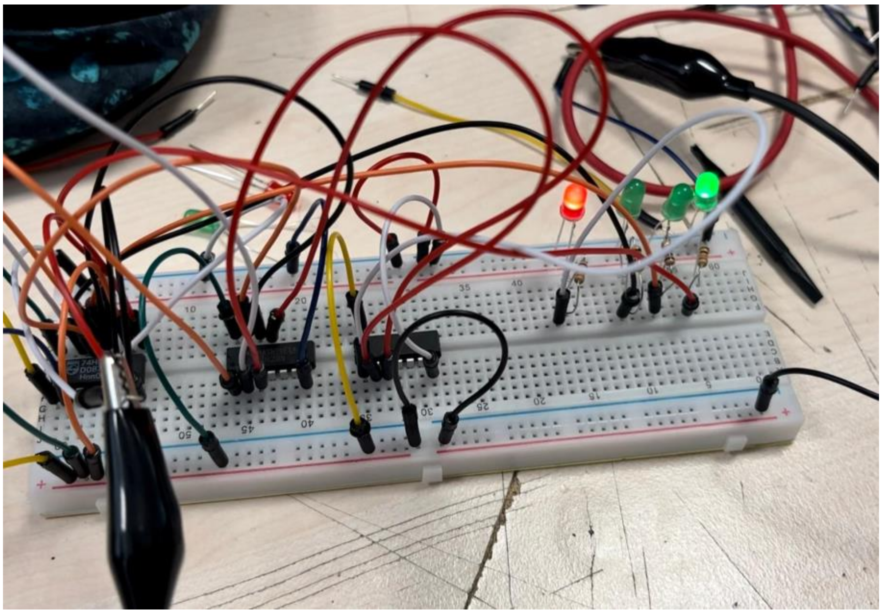

Figure 11: Output F=1 when X=1, Y=0, Z=0

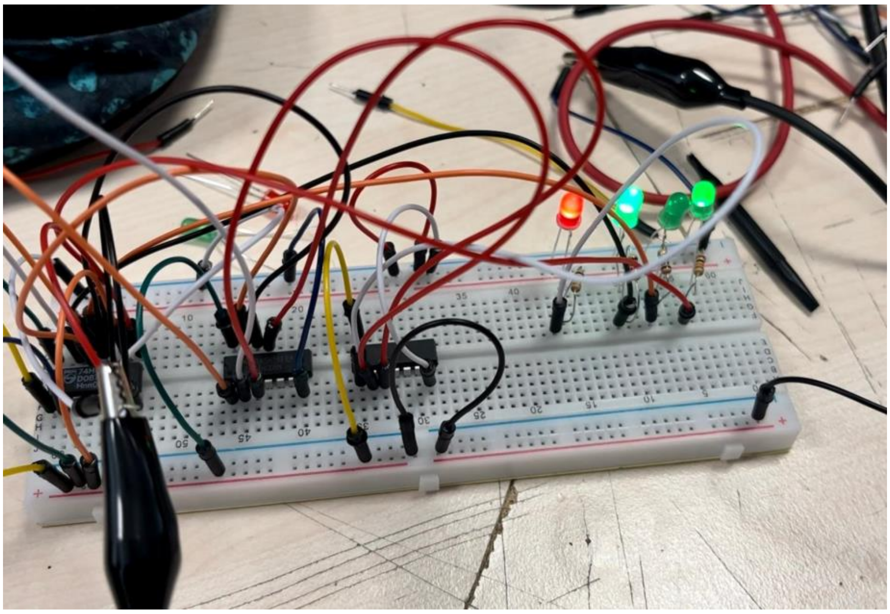

Figure 12: Output F=1 when X=1, Y=0, Z=1

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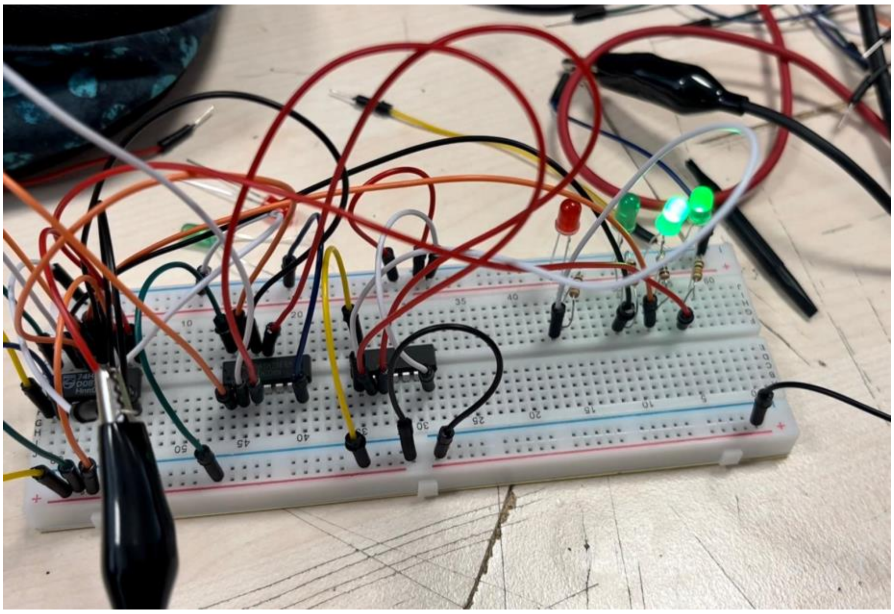

Figure 13: Output F=0 when X=1, Y=1, Z=0

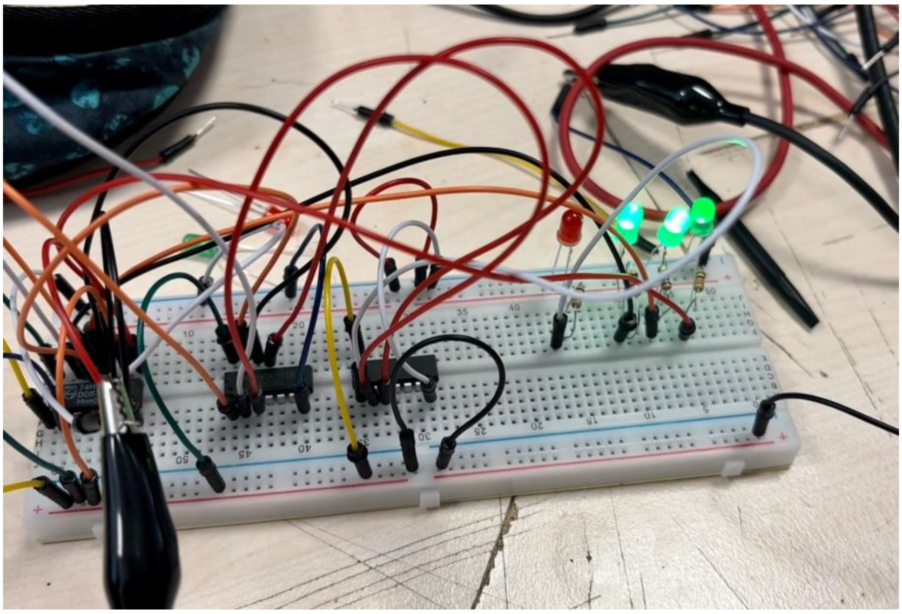

Figure 14: Output F=0 when X=1, Y=1, Z=1

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## Conclusion

With this experiment, we aimed to implement a combinational circuit on a breadboard. For this, I used a 4-bit counter, logic gates, and LEDs. I didn't use VHDL or my BASYS3 board in this experiment. Even though the circuit I designed wasn't necessarily complicated, it still took some time to build it. I had to study the datasheets of every component carefully in order to set them up. To connect the components together, I had to use many jumper wires and this made the experiment difficult even though there weren't many inputs. The experiment was quite helpful for me to understand how a breadboard works and how to set up logic gates using it. For the first time, I used logic gates and a 4-bit counter in a real-life circuit. It was also the first time that I created a real-life implementation of a circuit I designed. Because of this, I can say that this experiment was quite beneficial for me.

## References

74_HC_163.pdf

LogicGates.pdf

https://components101.com/ics/74ls02-nor-gate-ic

https://components101.com/ics/74ls08-and-gate-ic-pinout-datasheet