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Lab 3 Report: Combinational Logic Circuit

Purpose

The aim of the experiment is to set up a combinational logic circuit on a breadboard using logic gates. By connecting the 4-bit counter and LEDs, we will observe that how output behaves in a real hardware environment.

Design Specifications

In this lab, I designed a combinational logic circuit and implemented it on a breadboard. The circuit creates 4 input signals (A, B, C and D) using 74HC163 counter. The counter starts generating signals starting from 0000 to 1111 continuously. The outputs of the counter are connected to input pins of the logic gates. Specifically, the outputs are connected to SN74HC32N gate which is a Quad 2-input OR gate. My circuit behaves as (A + B) + (C + D). Both A, B, C and D inputs and the output are connected to LEDs so that the LEDs can visualize the behavior of the circuit. In total 5 LEDs were used (4 for inputs and 1 for output function). By reading the datasheets of both counter and logic gates, I made the proper ground, power and clock connections accordingly.

Methodology

I've implemented a combinational logic circuit by using 4-bit counter and 2-input OR gates on a breadboard. The output function F behaves as

$$\boldsymbol{F = (A + B) + (C + D)}$$

where A,B,C, D corresponds to the counter outputs Q_3, Q_2, Q_1, Q_0 respectively. The truth table of the designed logic circuit is given in Figure 1.

A	B	C	D	F
0	0	0	0	0
0	0	0	1	1
0	0	1	0	1
0	0	1	1	1
0	1	0	0	1
0	1	0	1	1
0	1	1	0	1
0	1	1	1	1
1	0	0	0	1
1	0	0	1	1
1	0	1	0	1
1	0	1	1	1
1	1	0	0	1
1	1	0	1	1
1	1	1	0	1
1	1	1	1	1

Figure 1: Output Function of the Circuit

First, I placed the 74HC163 counter on my breadboard and made the proper connections. As shown in Figure 2, I used this schematic and datasheet to decide which pins should I use on 4-bit counter. The VCC, MR, CEP, CET and PE pins were connected to + 5 V. GND pin is connected to ground rail of the breadboard. By using the DC Power supply, 5 V was given to the circuit. Furthermore, Signal generator which generates square waves was connected to CP pin of 4-bit counter. 4-bits were wired to LEDs so that we can observe the inputs of the system. In order not to damage LEDs, I used 560 Ω resistor. Then I connected the inputs of 2-input OR gate (SN74HC32N) and 4-bit inputs according to F function. The schematic for 2-input OR gate can be seen in Figure 3. After setting up the logic gate, the output of the function was also attached to one LED. I observe the behavior of the circuit both on LED and Oscilloscope. I used an Oscilloscope probe to see whether my circuit works correctly or not. After that I compared the waveforms with truth table (Figure 1).

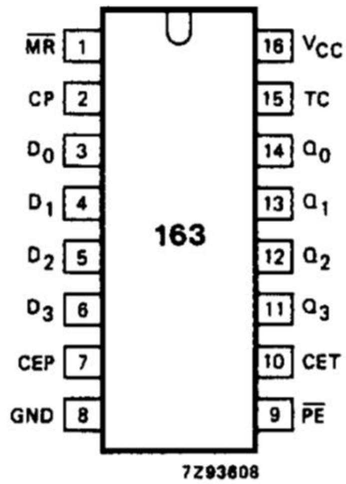

Figure 2: Pin Configuration for 4-bit counter (74HC163)

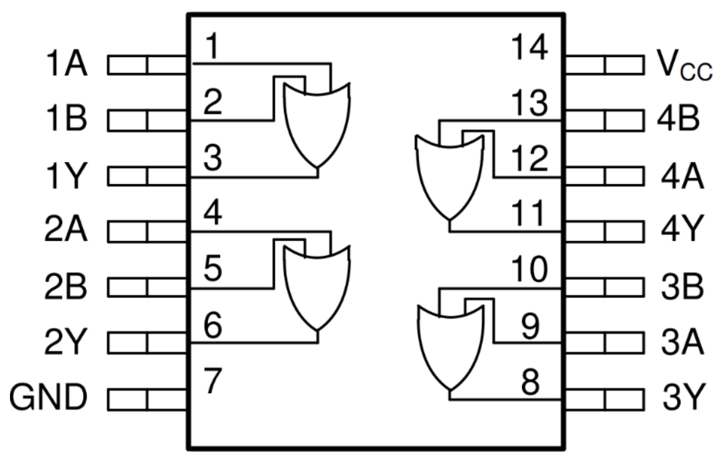

Figure 3: Schematic for 2-input OR gate (SN74HC32N)

Results

The waveform was observed as expected, given in the Figure 4. Because the circuit has a 4-bit counter, the output of the waveform repeats the pattern 0111111111111111 continuously. The output of the waveform also corresponds to the truth table which proves that the circuit works properly.

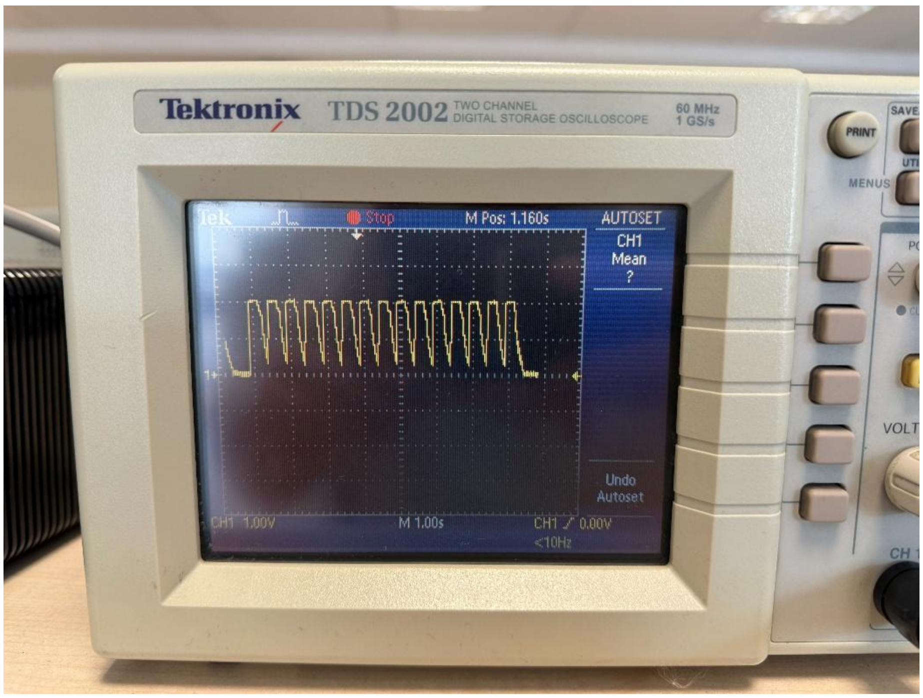

Figure 4: The Output Waveform

Also, I checked the results using the LEDs. The four red LEDs on the right represent the inputs of the 4-bit counter, while the single red LED on the left shows the output of the function. In Figure 5, the circuit set up can be seen before giving power to the system. In Figures 6-21, the output function can be observed for all 16 inputs and all the results are consistent with the truth table.

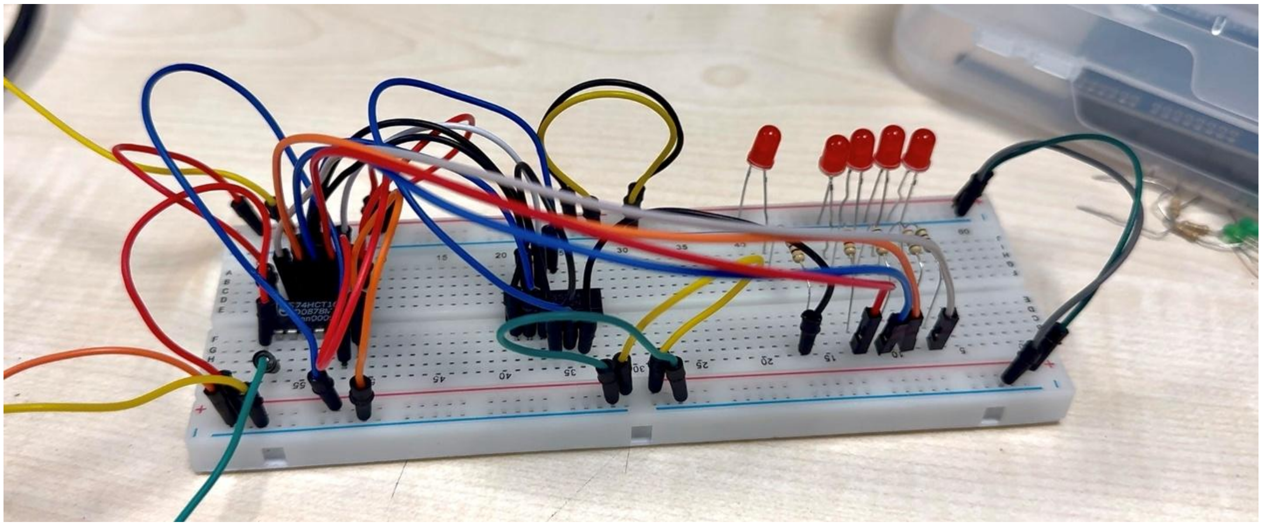

Figure 5: The Setup of The Circuit

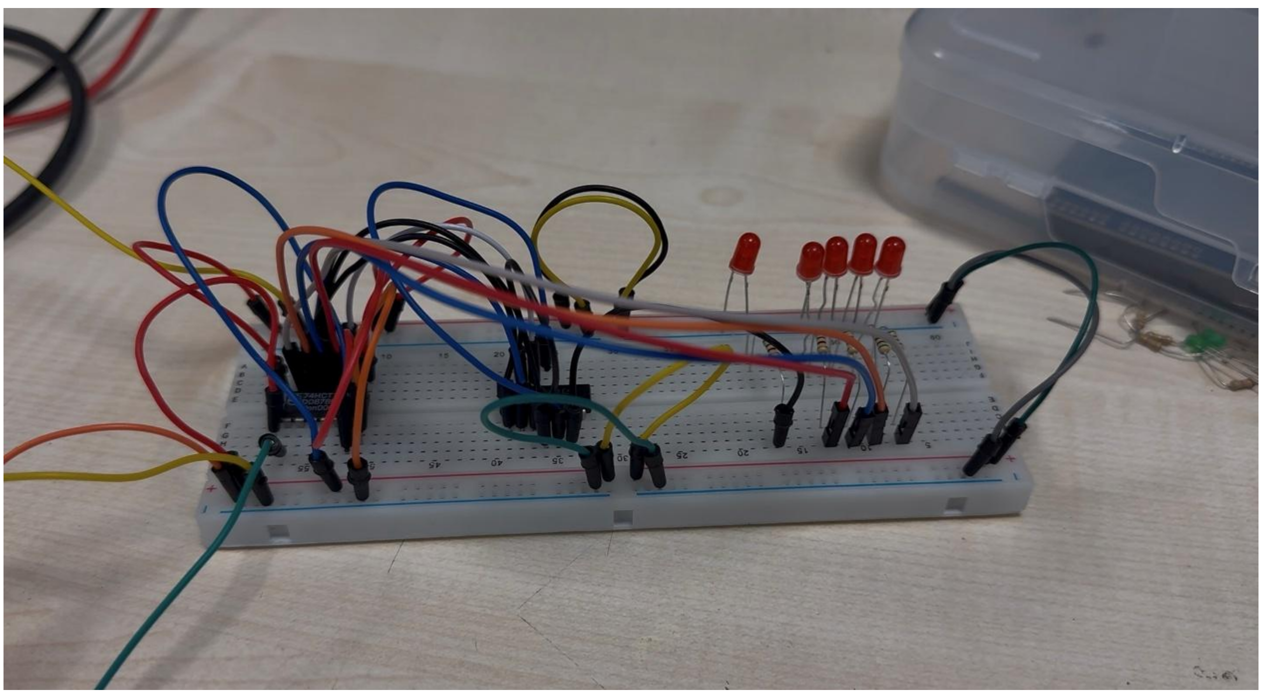

Figure 6: The Inputs A=0 B=0 C=0 D=0 and The Output F = 0

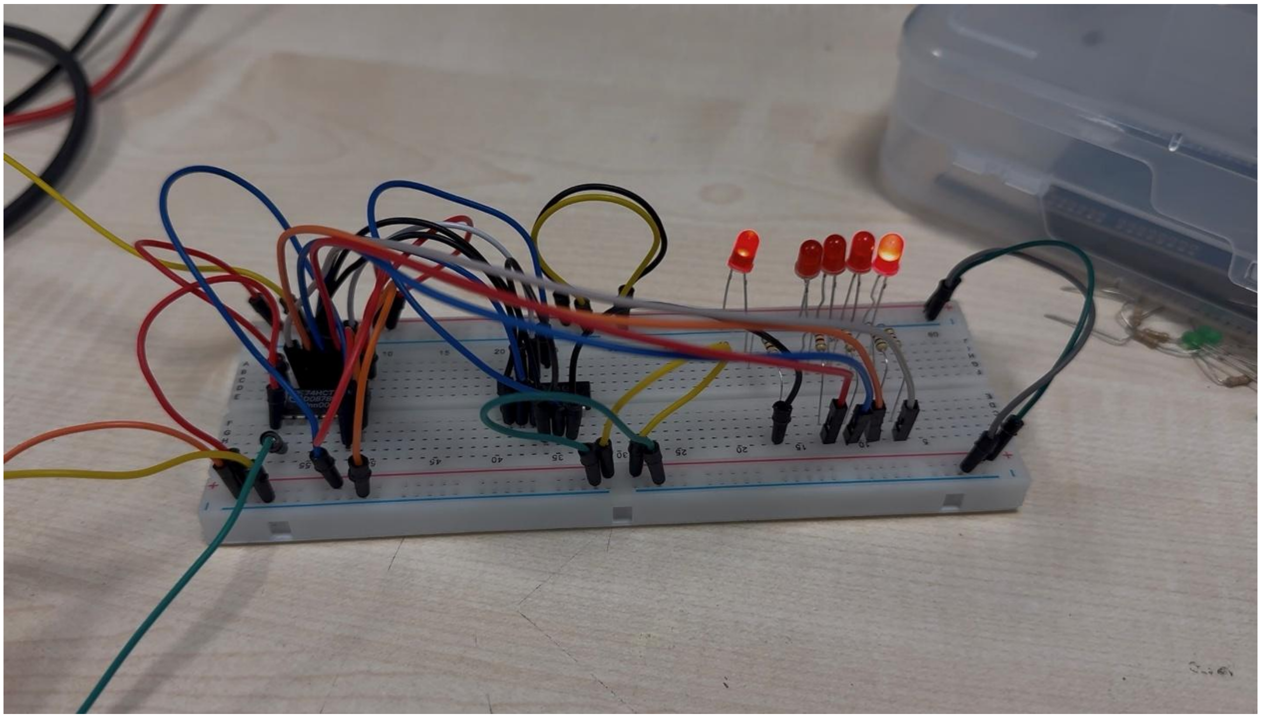

Figure 7: The Inputs A=0 B=0 C=0 D=1 so The Output F = 1

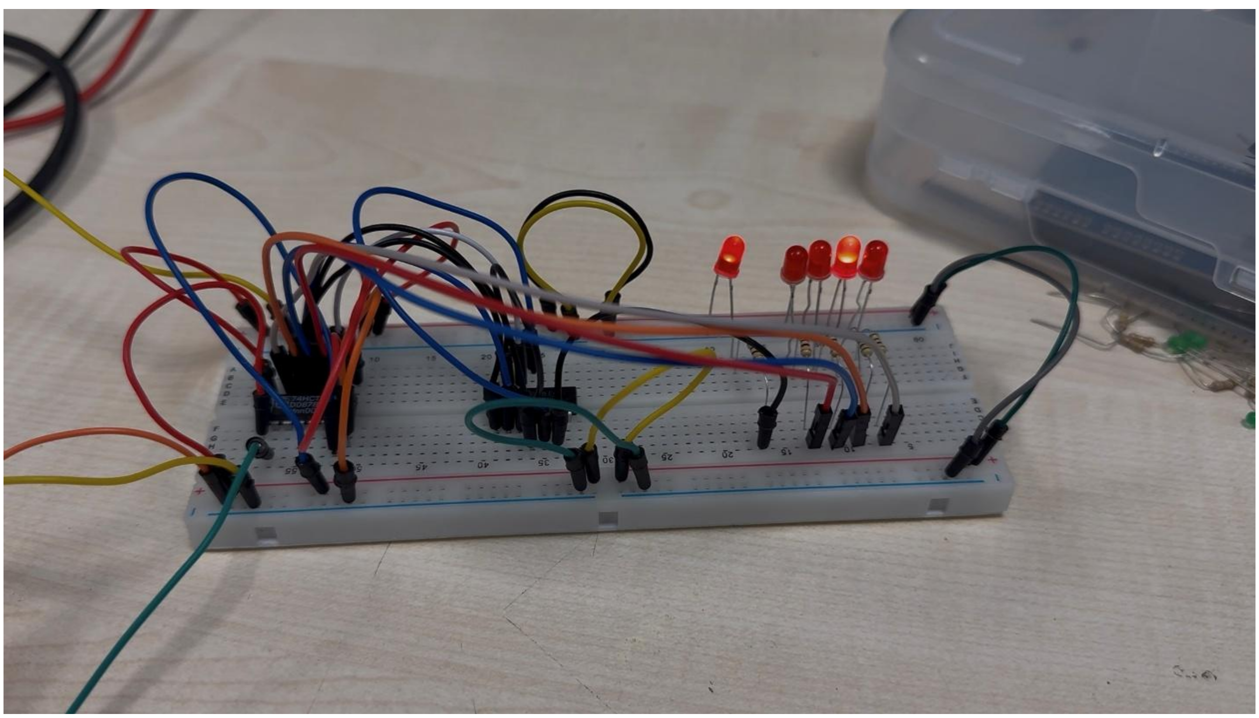

Figure 8: The Inputs A=0 B=0 C=1 D=0 so The Output F = 1

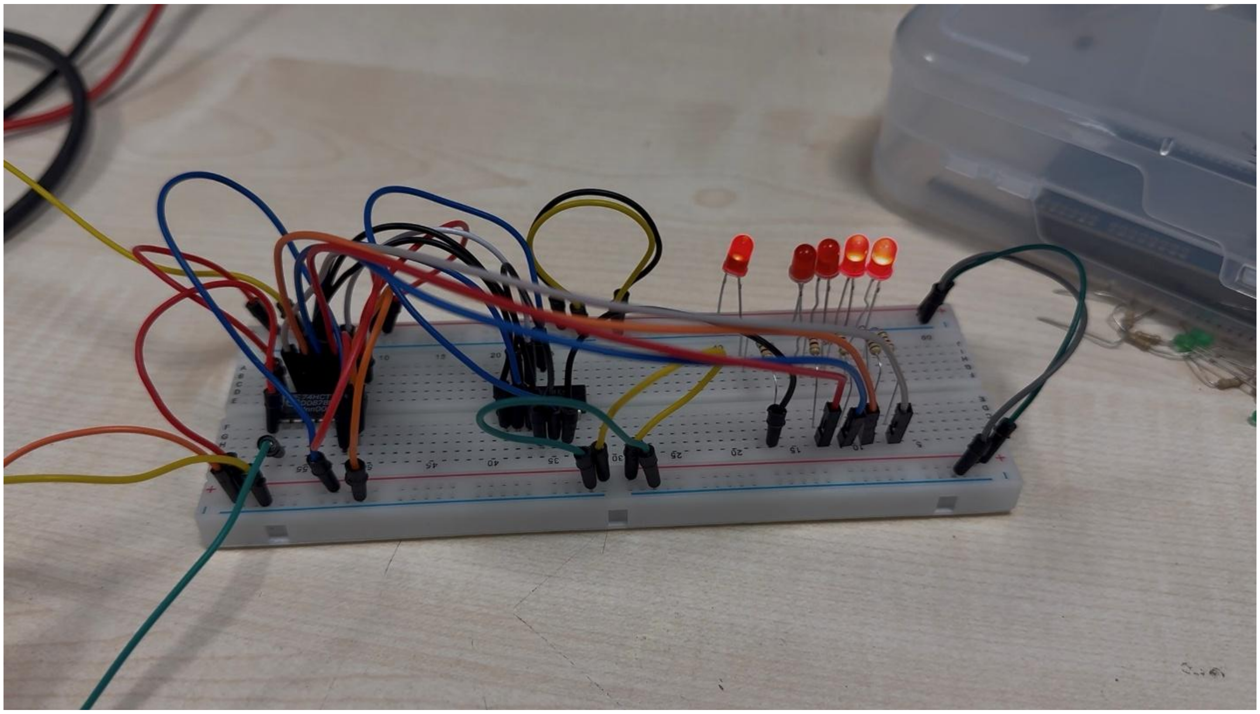

Figure 9: The Inputs A=0 B=0 C=1 D=1 so The Output F = 1

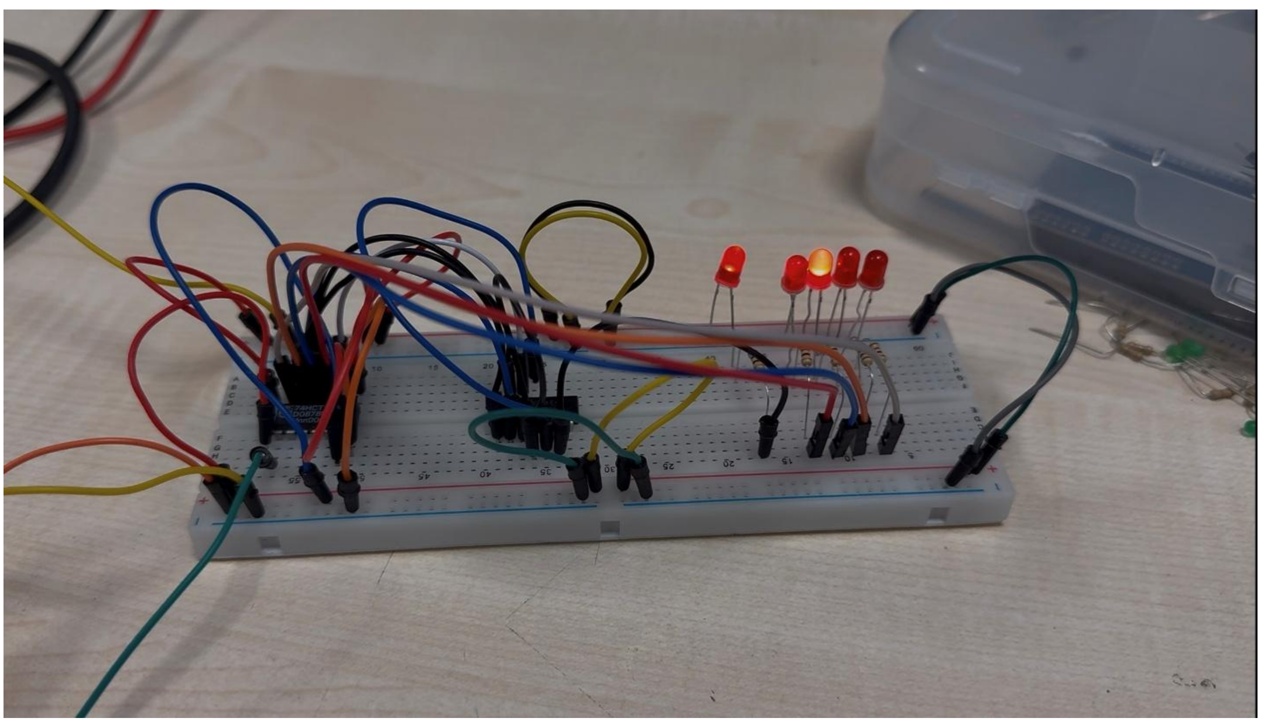

Figure 10: The Inputs A=0 B=1 C=0 D=0 so The Output F = 1

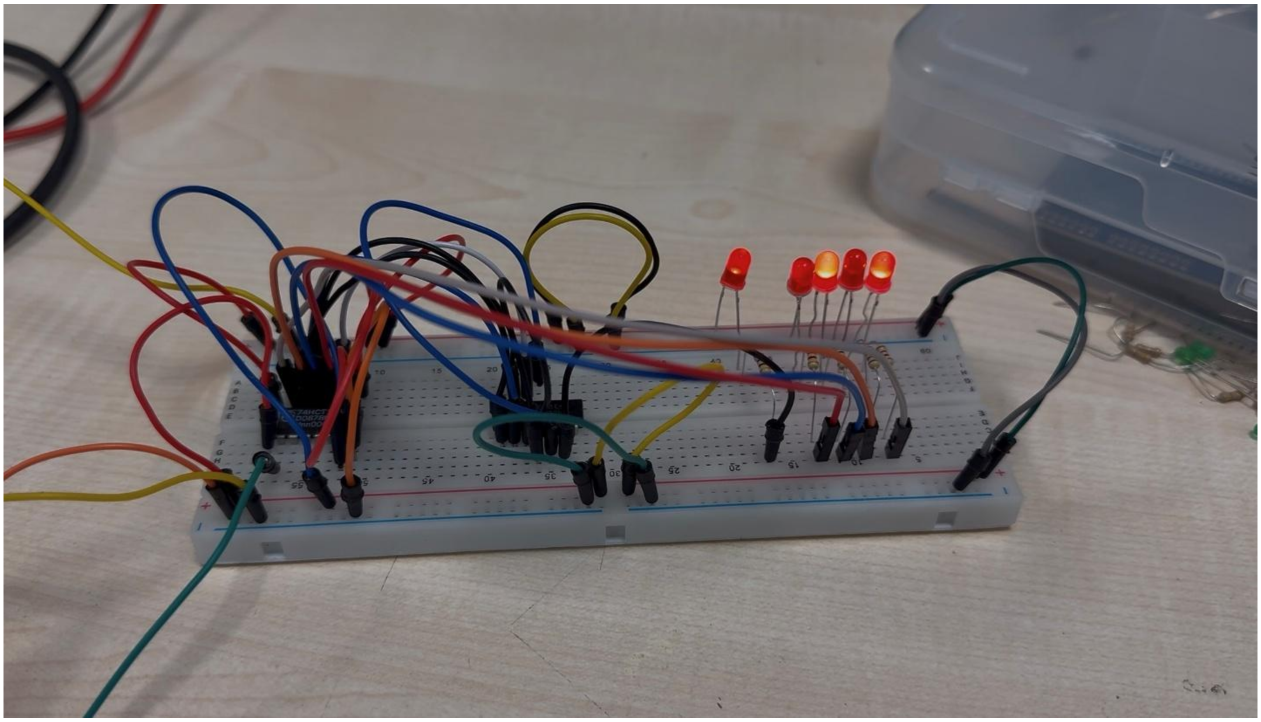

Figure 11: The Inputs A=0 B=1 C=0 D=1 so The Output F = 1

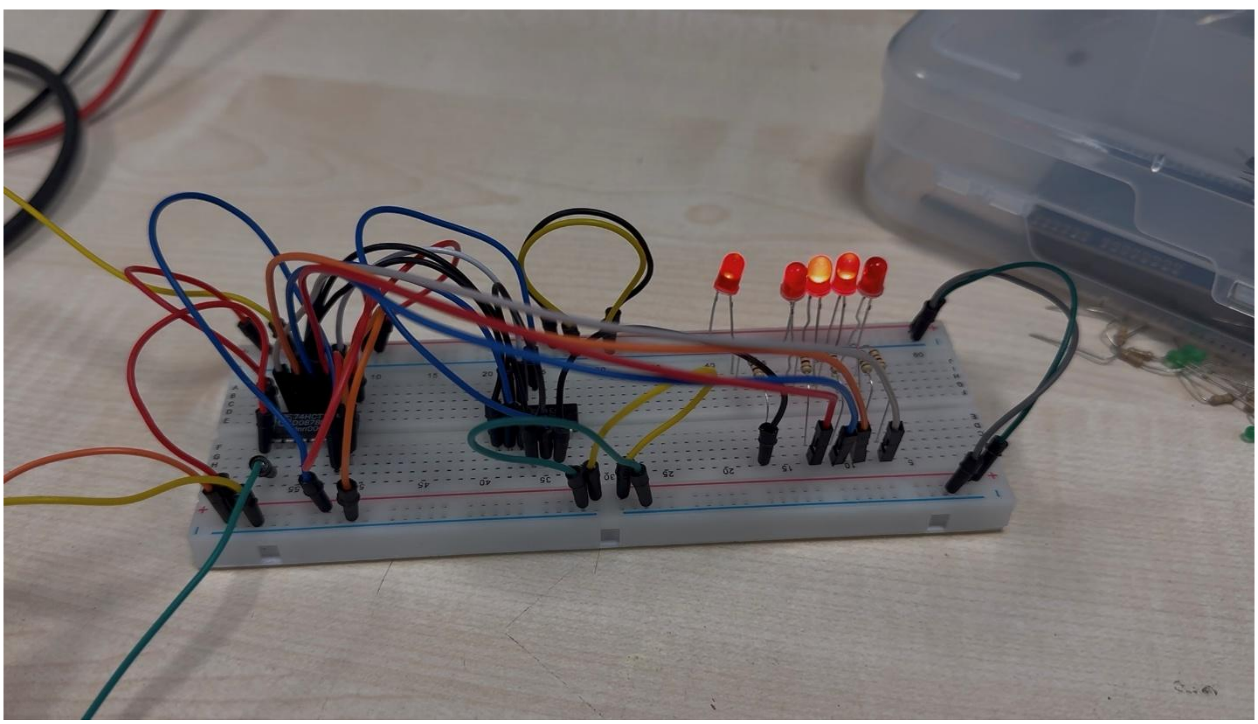

Figure 12: The Inputs A=0 B=1 C=1 D=0 so The Output F = 1

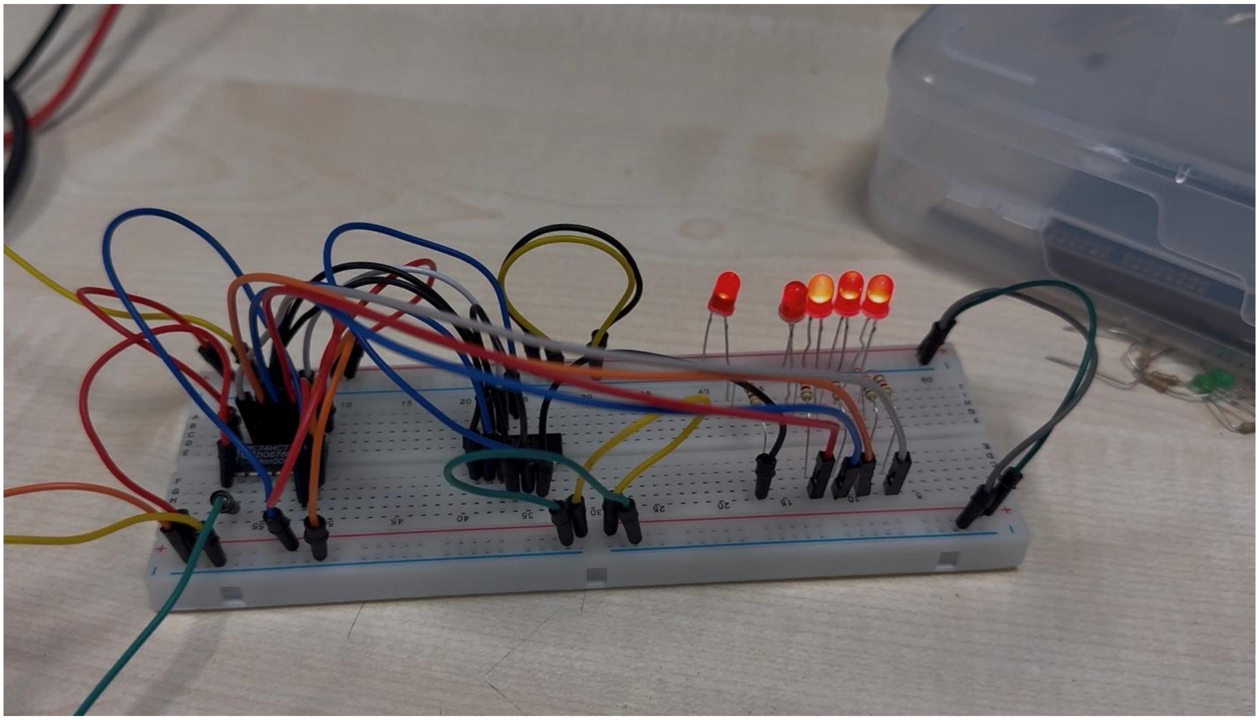

Figure 13: The Inputs A=0 B=1 C=1 D=1 so The Output F = 1

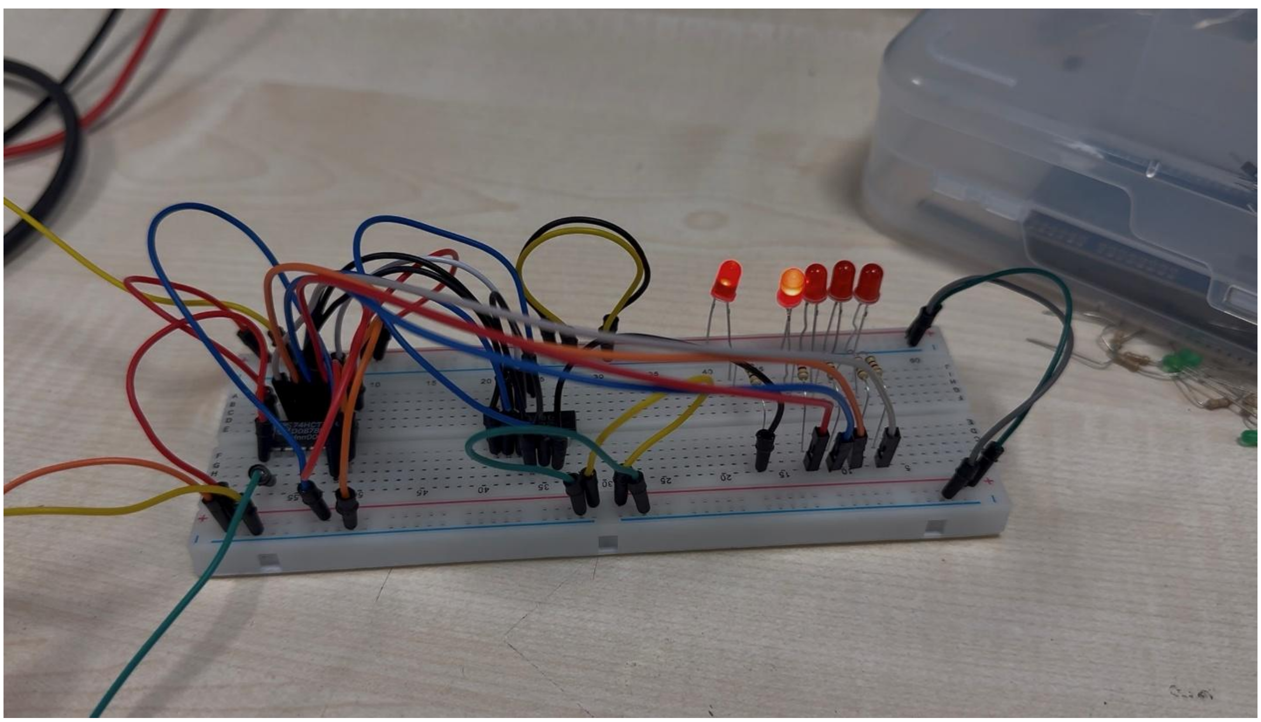

Figure 14: The Inputs A=1 B=0 C=0 D=0 so The Output F = 1

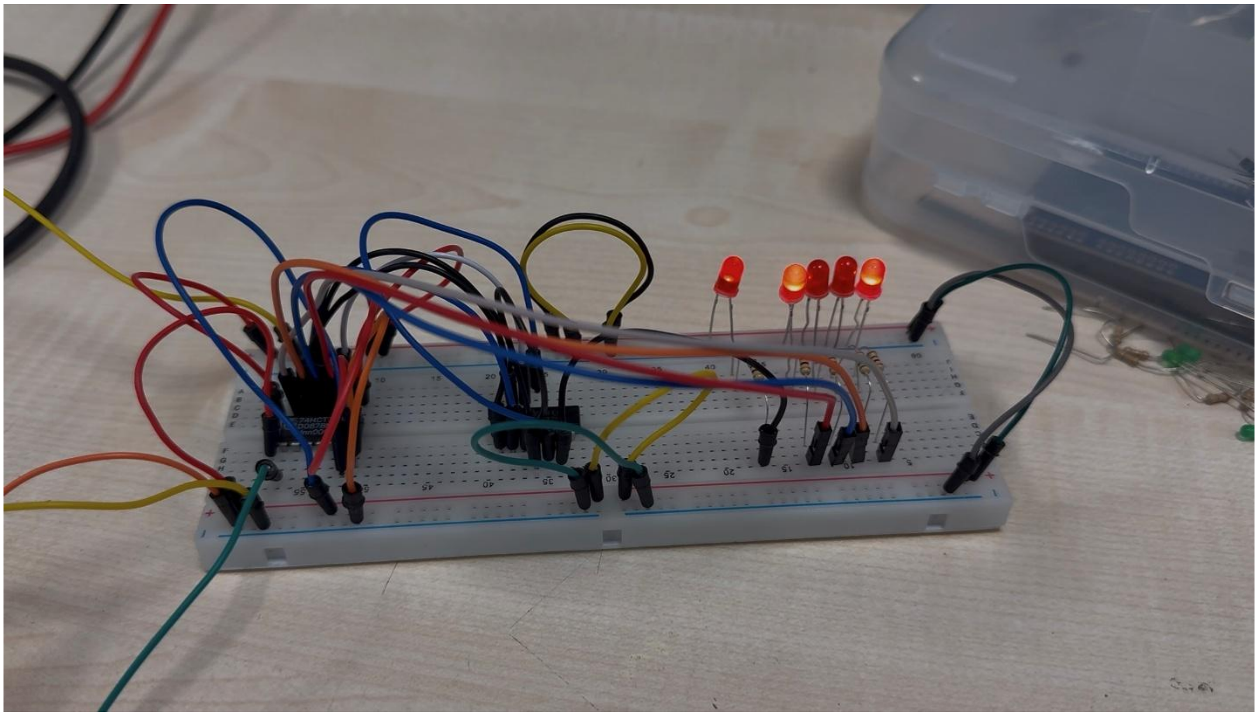

Figure 15: The Inputs A=1 B=0 C=0 D=1 so The Output F = 1

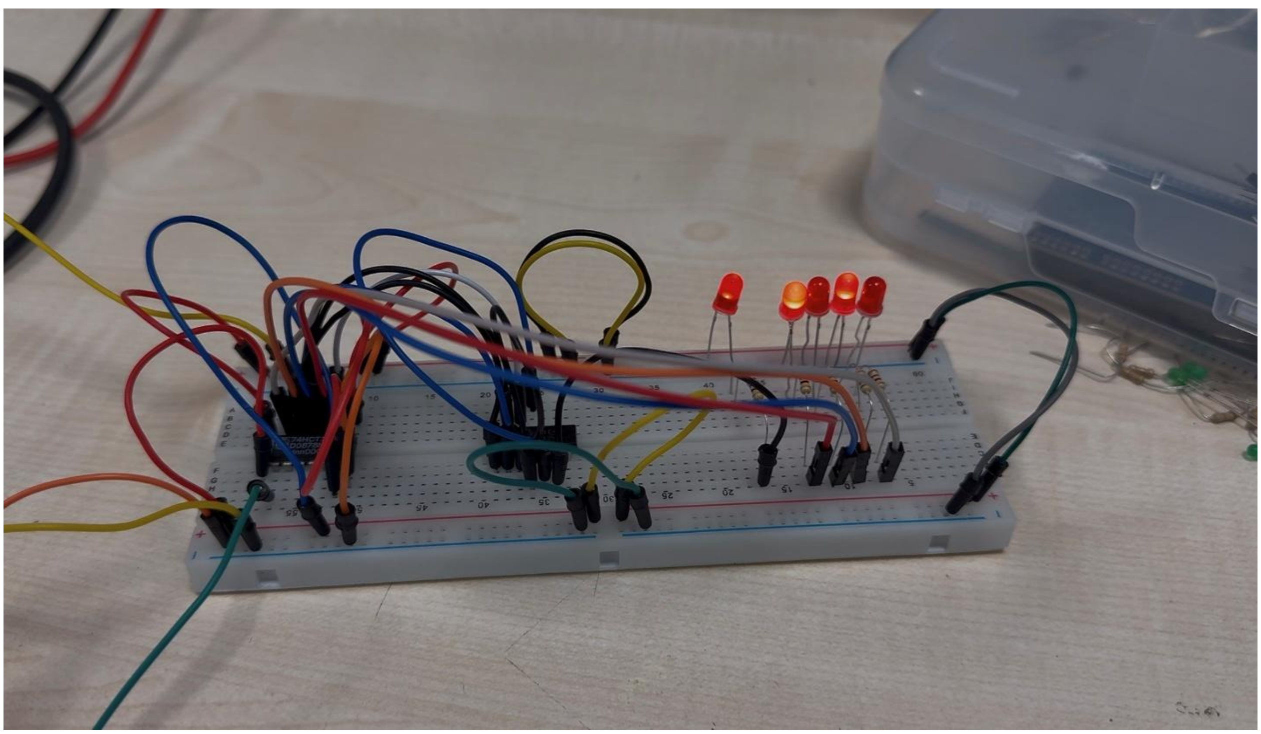

Figure 16: The Inputs A=1 B=0 C=1 D=0 so The Output F = 1

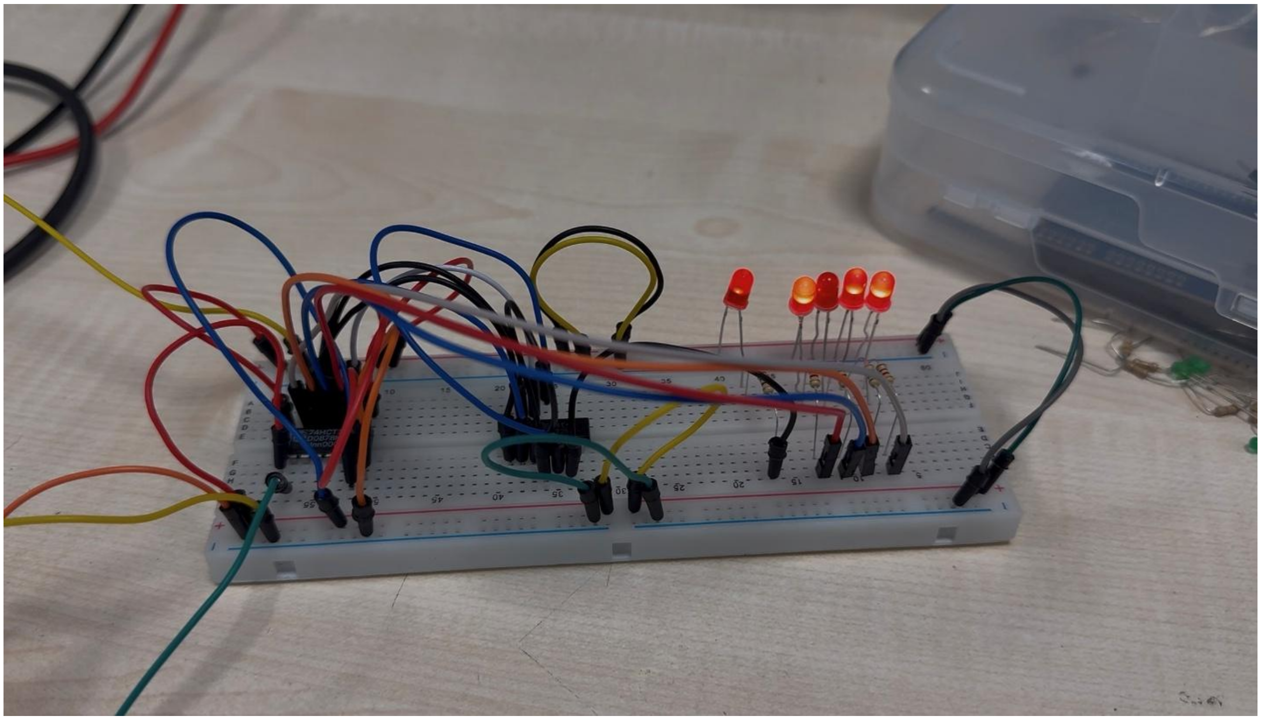

Figure 17: The Inputs A=1 B=0 C=1 D=1 so The Output F = 1

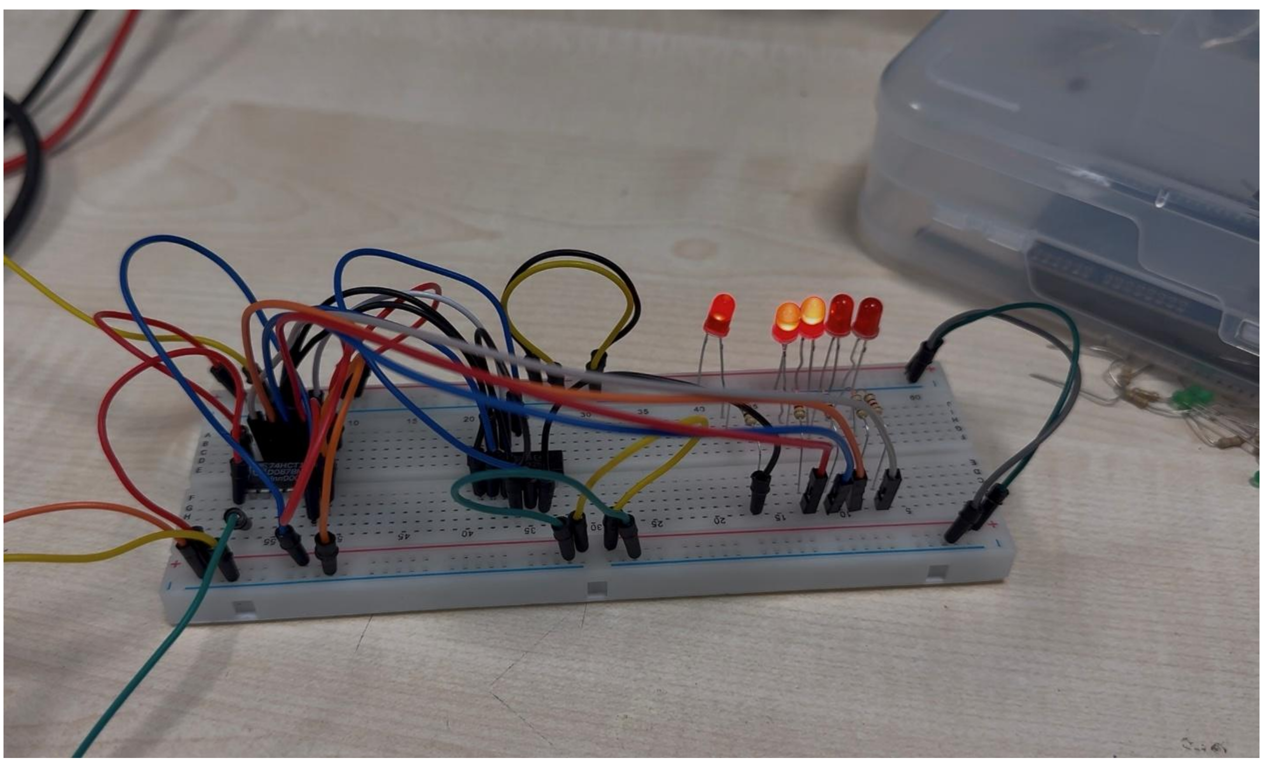

Figure 18: The Inputs A=1 B=1 C=0 D=0 so The Output F = 1

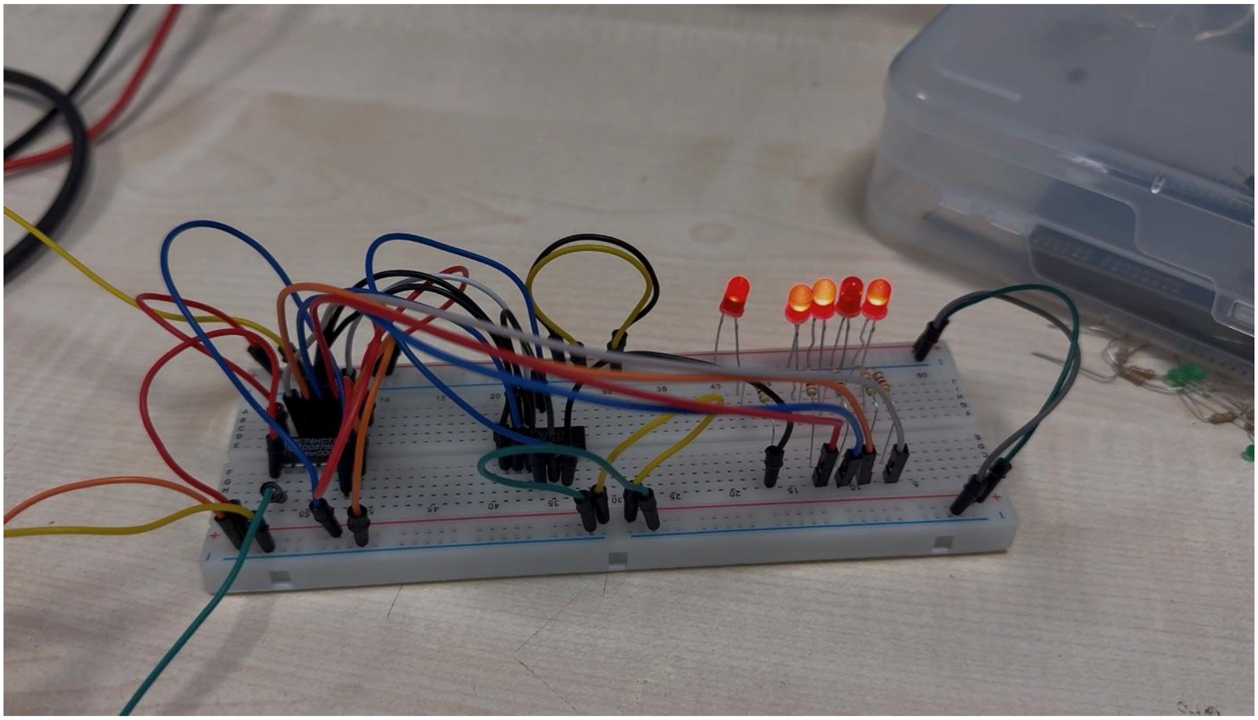

Figure 19: The Inputs A=1 B=1 C=0 D=1 so The Output F = 1

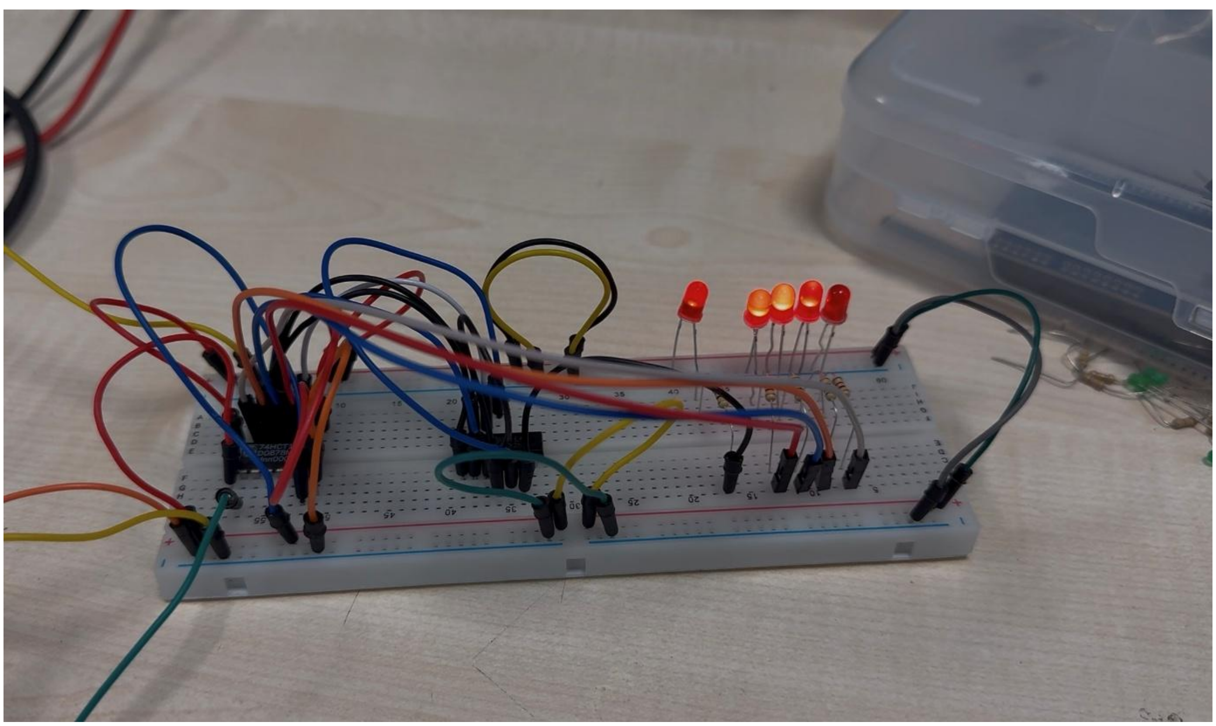

Figure 20: The Inputs A=1 B=1 C=1 D=0 so The Output F = 1

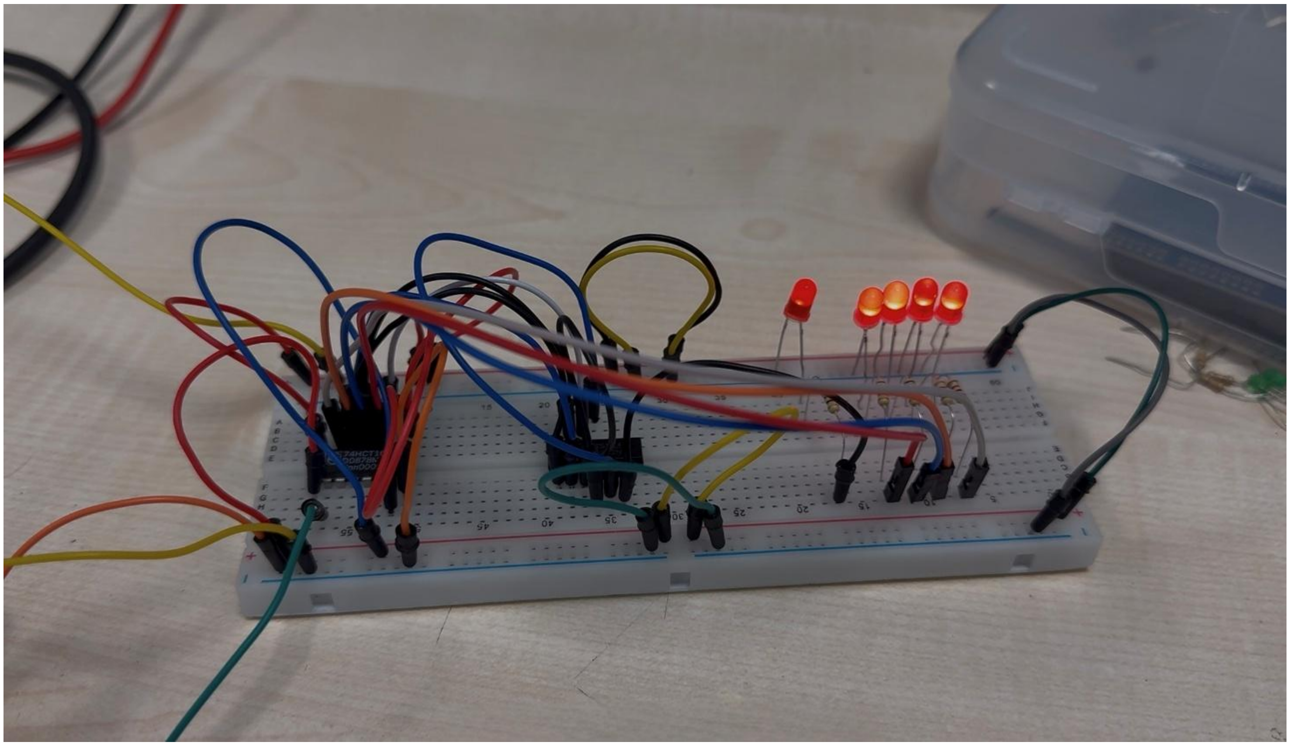

Figure 21: The Inputs A=1 B=1 C=1 D=1 so The Output F = 1

Conclusion

In this lab, I designed and implemented a combinational circuit on a breadboard by using 2-input OR logic gate (SN74HC32N) and 4-bit counter (74HC163). The expected truth table corresponds with LED outputs so that means the experiment was made successfully. The experiment provided me a practical experience on connecting digital components on breadboard, reading datasheets and understanding how combinational logic circuit works in real hardware. I also used oscilloscope in order to verify that counter works properly, this was the first time I've ever tried oscilloscope to observe waveforms in a circuit. I also used the oscilloscope probe to fix issues regarding to my circuit, which helped me a lot. This experiment helped me to understand how counter affects the input sequence of the logic circuit. It improved my understanding of signal observation in real hardware environments and how to properly make connections and set up a circuit on breadboard.

References

74_HC_163.pdf

LogicGates.pdf

https://www.ti.com/lit/ds/symlink/sn74hc32.pdf