Qais Abu El Haija, abuelhaq
400294443

Deliverable / Lab 6 - ENG PHYS 2E04

Qais Abu El Haija, abuelhaq - 400294443

- Logic / Problem:

Finding the factors of the number 10 in a range of numbers from 0 to 10

- Step 1:

Use Karnaugh mapping, K-mapping, to produce a simplified SOP or POS implementation for the logic, then convert it to an implementation of the logic using only NANDs, and then to AND/OR, and NOT gates.

- Step 2:

Simulate your circuit using Multisim and confirm the desired logic is reproduced.

- Step 3:

Build the circuit on the breadboard and confirm that the logic is reproduced (use LED indicators as the outputs)

Qais Abu El Haija, abuelhaq
400294443

Analytical Method

Word Problem: Find numbers in the range 0 to 10 that are factors of 10.

- Generating a Truth Table for the above word problem:

Number	A	S	D	F	Y1 (Output)
0	0	0	0	0	0
1	0	0	0	1	1
2	0	0	1	0	1
3	0	0	1	1	0
4	0	1	0	0	0
5	0	1	0	1	1
6	0	1	1	0	0
7	0	1	1	1	0
8	1	0	0	0	0
9	1	0	0	1	0
10	1	0	1	0	1
11	1	0	1	1	X
12	1	1	0	0	X
13	1	1	0	1	X
14	1	1	1	0	X
15	1	1	1	1	X

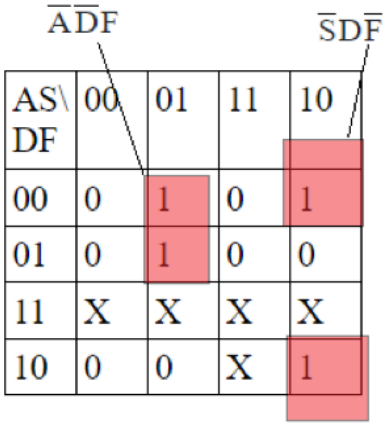
Truth Table (A)

- The above truth table above shows that there is a true value (1), for the numbers **1 ,2 ,5 and 10,** while the rest are false (0). For this word problem, A, S, D, F are the 4 binary inputs which are used to attain the output Y1, resulting in the factors of the number 10.

Qais Abu El Haija, abuelhaq
400294443

The K-mapping for the above truth table is done and two Boolean expressions are obtained using the SOP and POS method.

- The above table shows **the K-mapping done using the SOP method** and a simplified Boolean expression is obtained which is:



AS\ DF	00	01	11	10
00	0	1	0	1
01	0	1	0	0
11	X	X	X	X
10	0	0	X	1

$$\overline{A}\overline{D}F + \overline{S}D\overline{F}$$

- The K-mapping is also done **using the POS method** as shown below and a Boolean expression is acquired.

AS/ DF	00	01	11	10
00	0	1	0	1
01	0	1	0	0
11	X	X	X	X
10	0	0	X	1

$$(D + F)(\overline{D} + \overline{F})(\overline{S} + F)(\overline{A} + D)$$

The Boolean expression can be further simplified using Boolean algebra. It is simplified to:

$$D\overline{F}\overline{S} + F\overline{D}\overline{A}$$

Qais Abu El Haija, abuelhaq
400294443

Since the Boolean expression acquired in both, the SOP and POS methods are the same. Only one of either POS or SOP is needed to be tested to check if it is accurate compared to the truth table shown above.

- The sample calculation for the attaining the final value is shown below.

4 bits for number 5 (From Truth Table A) = 0101
Plugging into the above equation:

(1)(1)(1) + (0)(0)(0) = 1

The calculation is done for all the 4-bit inputs in the 0 to 10 range and the values obtained are shown in the truth table below

Truth table obtained from Boolean calculation.

Number	**A**	**S**	**D**	**F**	Y1
0	0	0	0	0	0
1	0	0	0	1	1
2	0	0	1	0	1
3	0	0	1	1	0
4	0	1	0	0	0
5	0	1	0	1	1
6	0	1	1	0	0
7	0	1	1	1	0
8	1	0	0	0	0
9	1	0	0	1	0
10	1	0	1	0	1

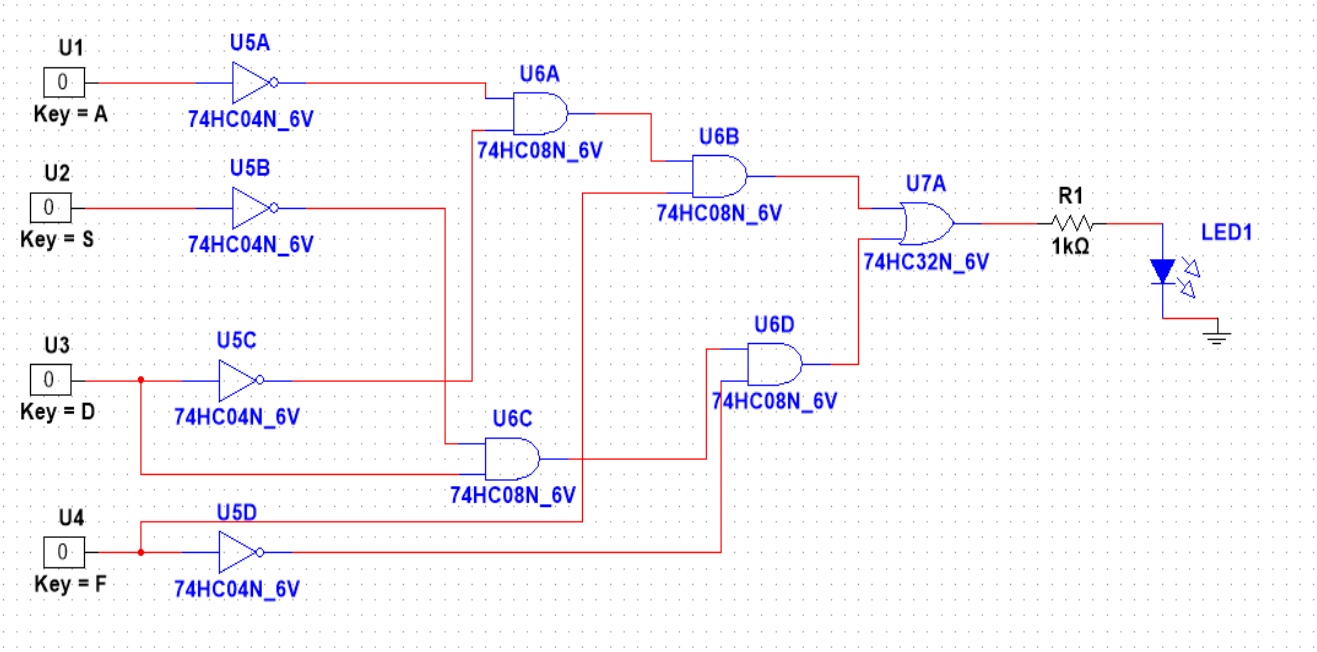
Truth Table (B)

- The truth table obtained above is the same as the one shown at the start of the analytical method. **It can be seen in both truth tables the max value is at 1,2,5 and 10 and the rest are 0.**

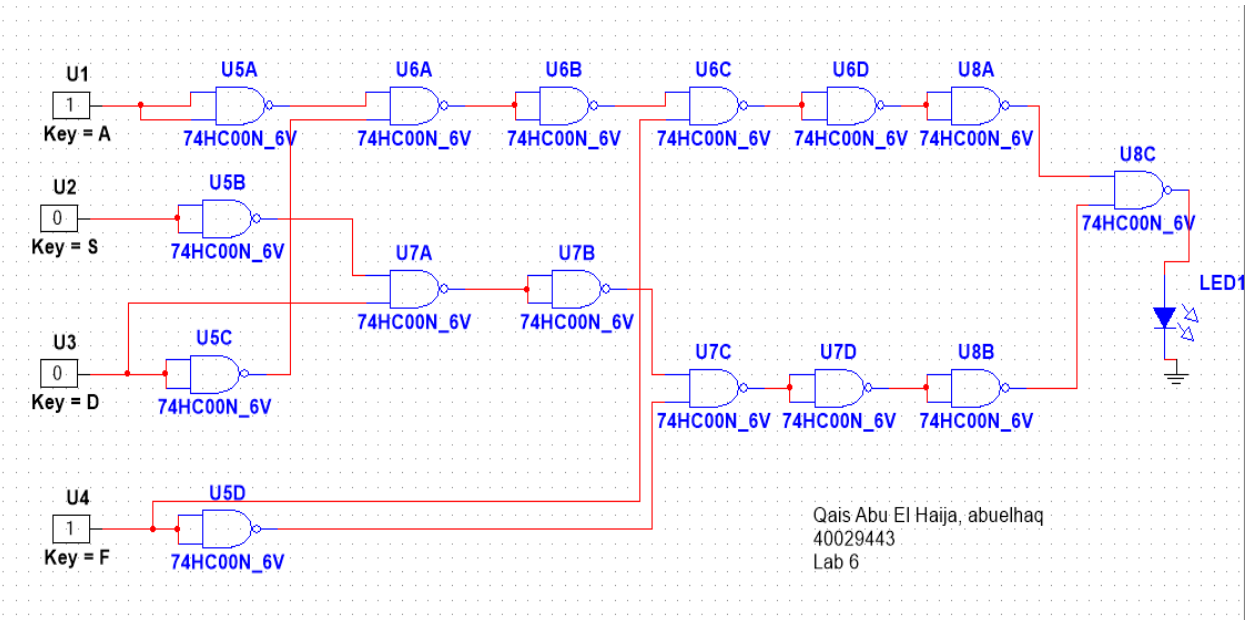
Qais Abu El Haija, abuelhaq
400294443

Multisim Method

- The logic circuit can be built using **AND, OR, and NOT** gates as shown below:



- The logic circuit can also be built using **NAND gates** as shown below:



Qais Abu El Haija, abuelhaq
400294443

The above circuit shown where simulated in Multisim with the inputs being the interactive digital constant.

- For the first circuit, 4 74HC04N not gates, 4 74HC0ND and gates and one 74HC32N or gate is used to build the circuit. A 1k ohm resistor and a red LED is used for the output.

- For the second circuit 15 74HC00N NAND gates are used to build a circuit with the same logic and using the same output. The simulation of both videos in which the range of input from 0 to 10 are checked can be found in the link below.

AND, OR and NOT gate circuit simulation:

https://drive.google.com/file/d/1fpsylTmxYYdzV38j_YJ77rRkYyWvjQiU/view?usp=sharing

NAND gate circuit simulation:

https://drive.google.com/file/d/1tE2iG_Tiy2veve7xeBJBAxXwCd0piiL-/view?usp=sharing

As it can be seen from the videos above the LED lights up only 4 times for each circuit these values for the input are recorded and shown below:

A	S	D	F
0	0	0	1
0	0	1	0
0	1	0	1
1	0	1	0

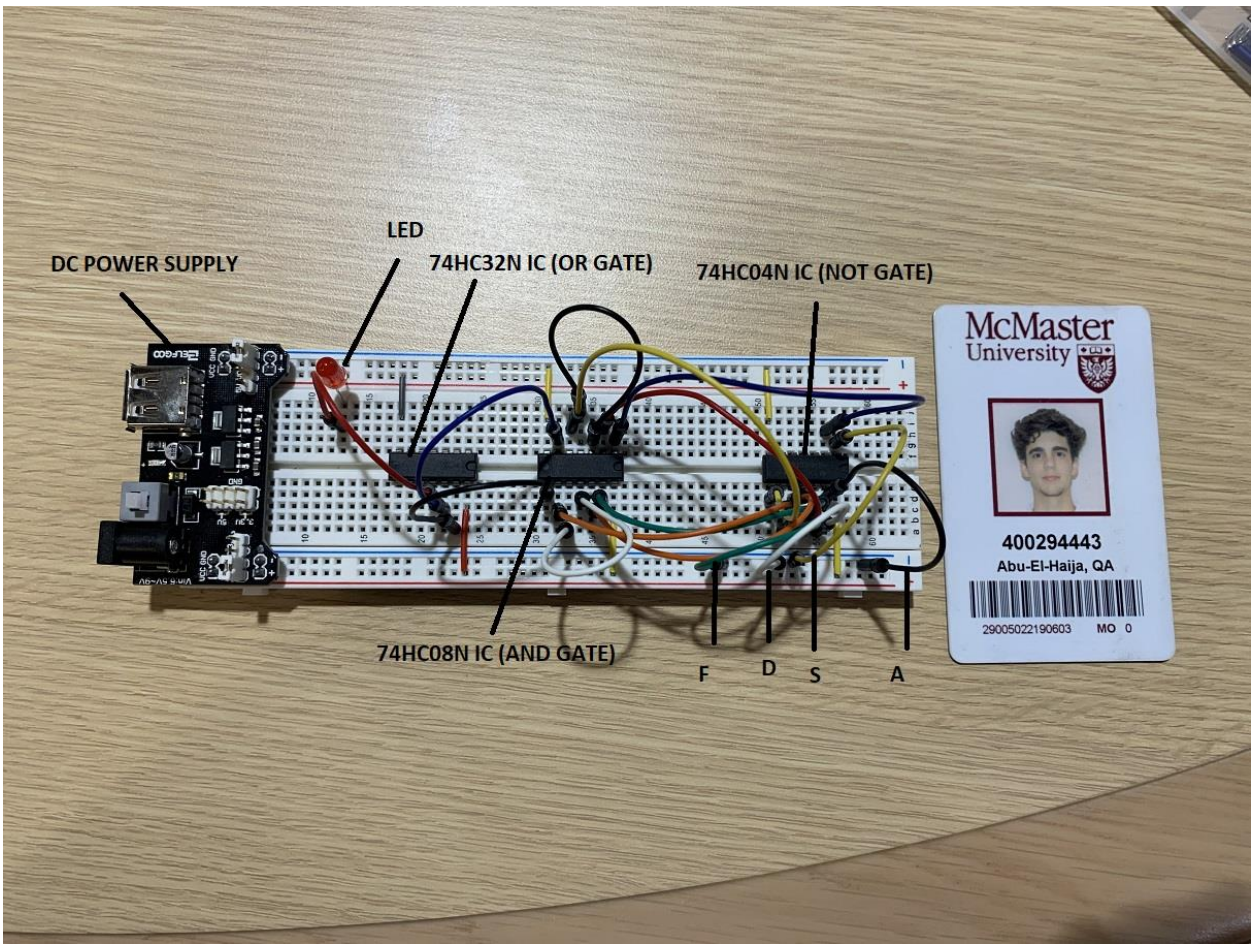
The values obtained are compared with the truth table obtained from the analytical method and when comparing the values where the LED lights up is the same as when the value of the output Y1 is 1. These are at the values 1,2,5 and 10 which are factors of the number 10.

Qais Abu El Haija, abuelhaq
400294443

Experimental Method

The logical circuit was set up using the Home-Kit using the Soul Bay power supply as the main source of power and the IC chips are used for the logic gates.

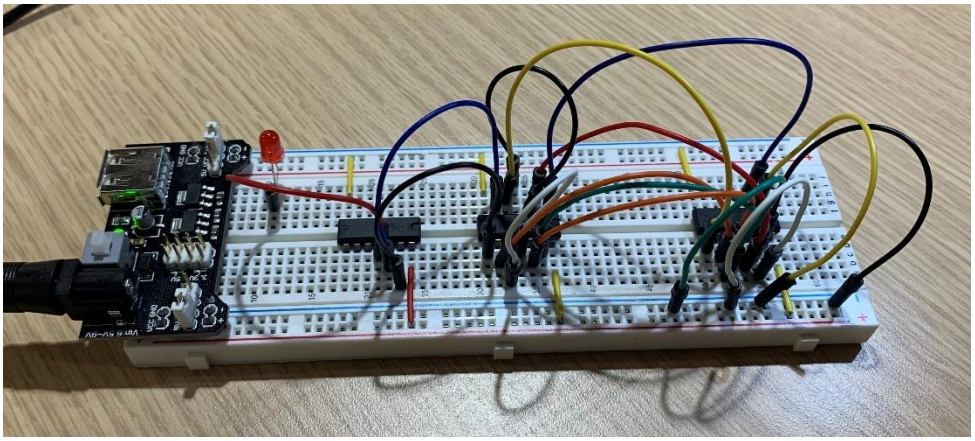
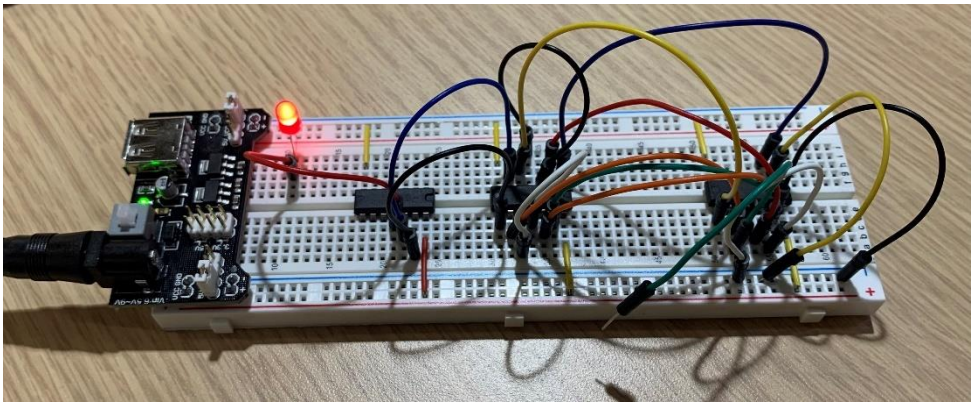
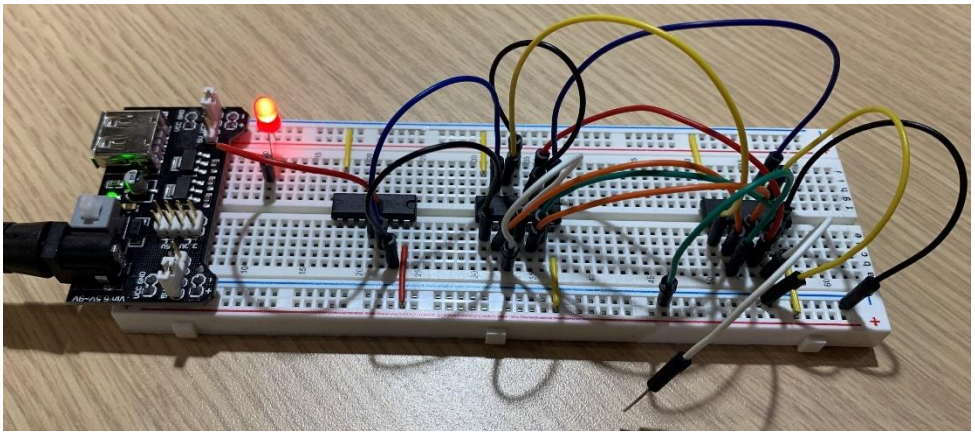
- The **AND, OR, and NOT** circuit built:



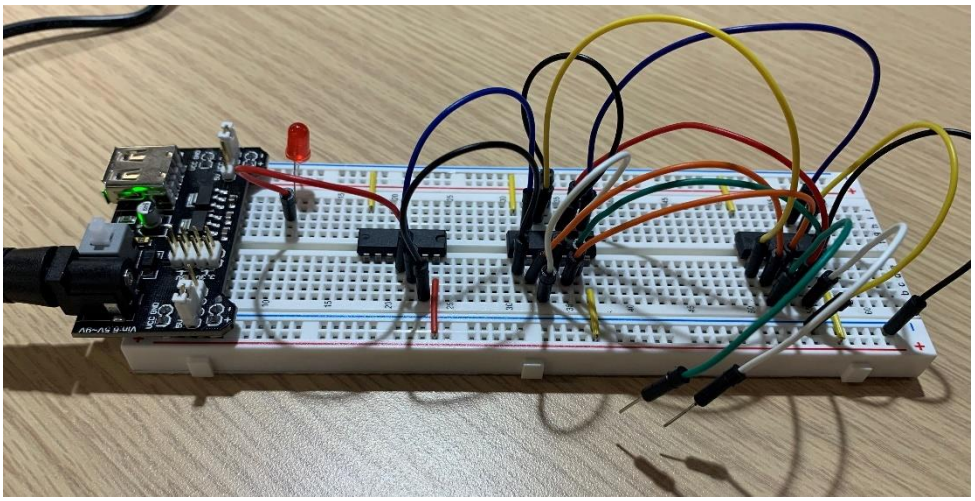
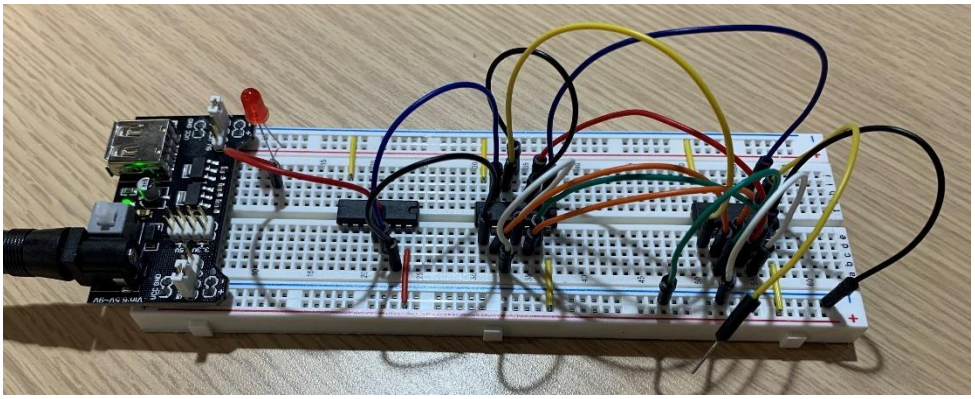
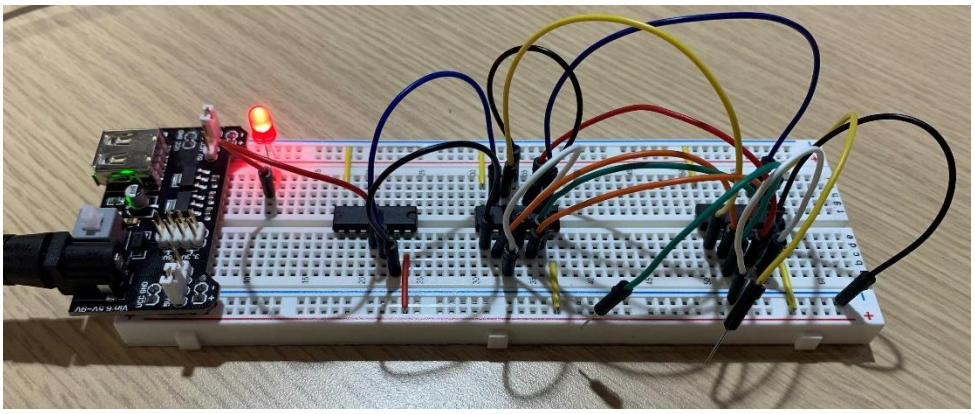
- It can be seen in the picture above that the circuit consists of 4 input values A, S, D and F and one output which is the Red LED. 3 IC chips are used, the first one is 74HC04N which is the IC which contains 4 NOT gates. The second one is the 74HC08N, which contains 4 AND gates and the third one is the 74HC32N, which contains 1 OR gate.

Qais Abu El Haija, abuelhaq
400294443

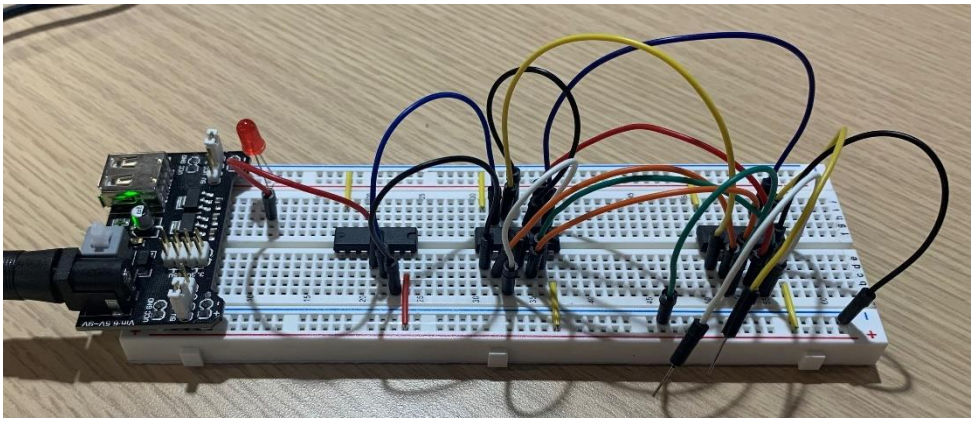
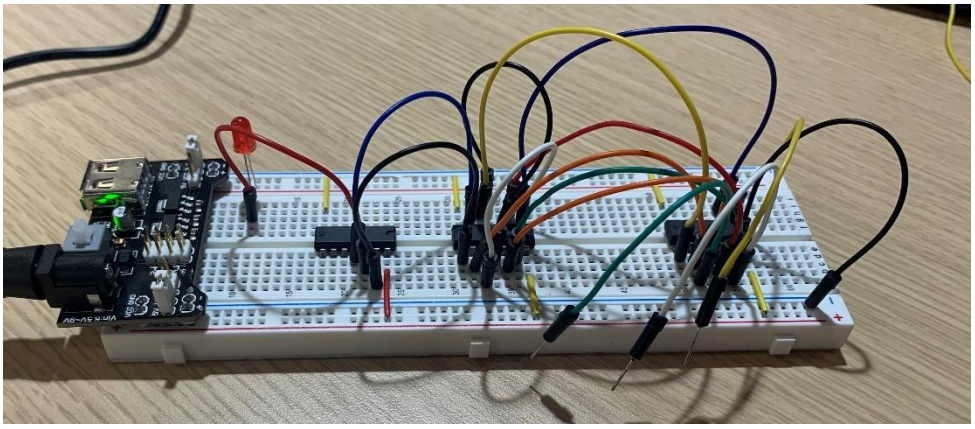
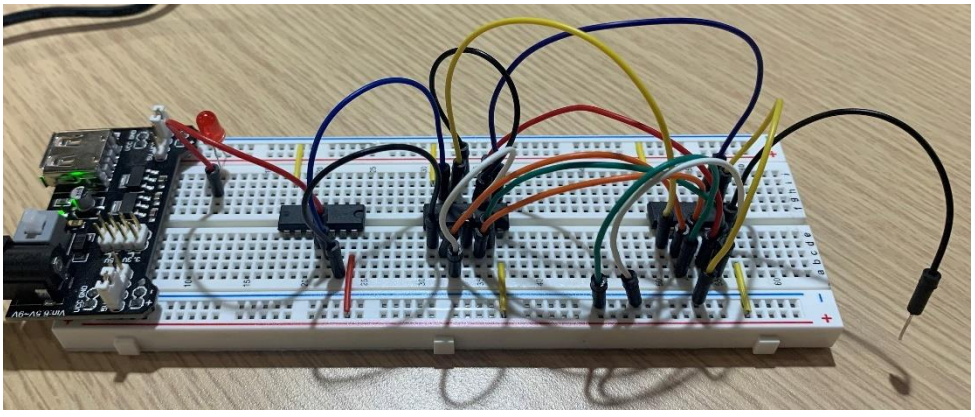
- **AND, OR and NOT** gate circuit results are displayed in the below table:

A	S	D	F	Output
0	0	0	0	
0	0	0	1	
0	0	1	0	

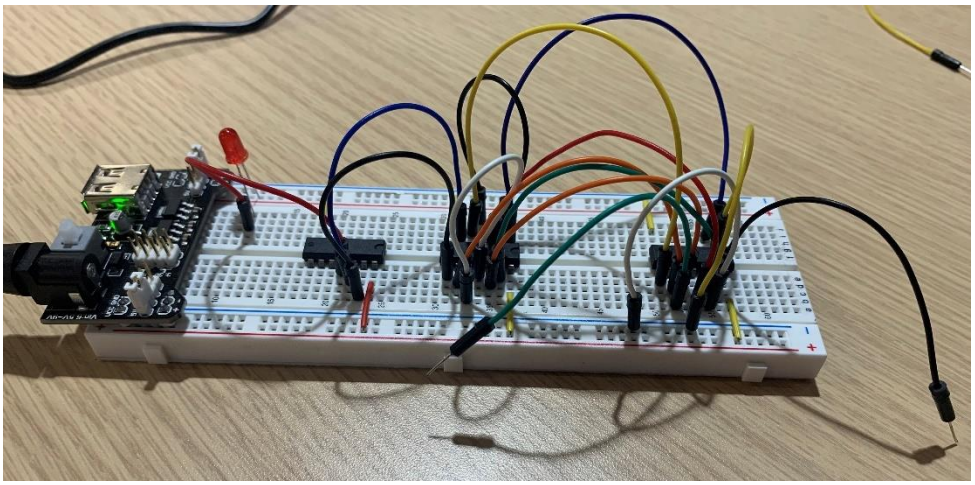
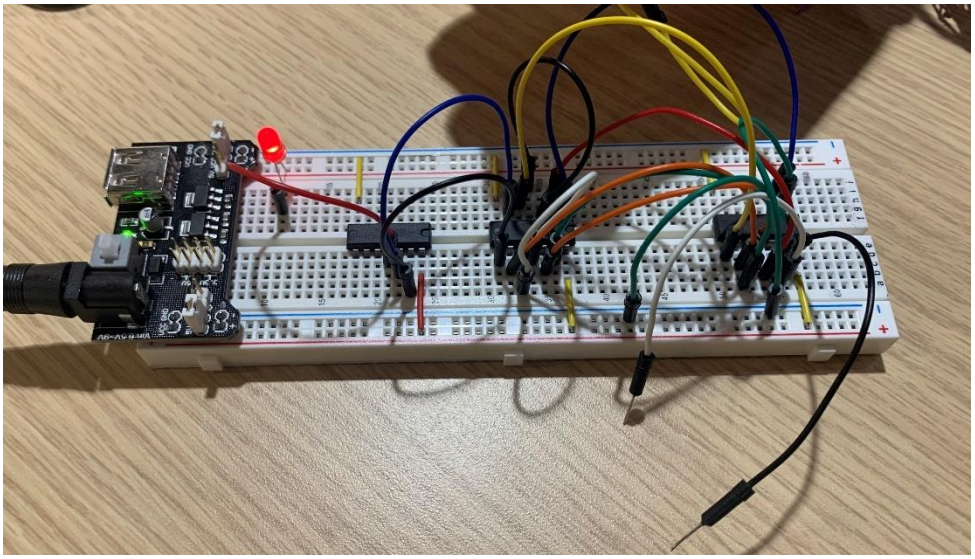
Qais Abu El Haija, abuelhaq
400294443

0	0	1	1	
0	1	0	0	
0	1	0	1	
0	1	1	0	

Qais Abu El Haija, abuelhaq
400294443

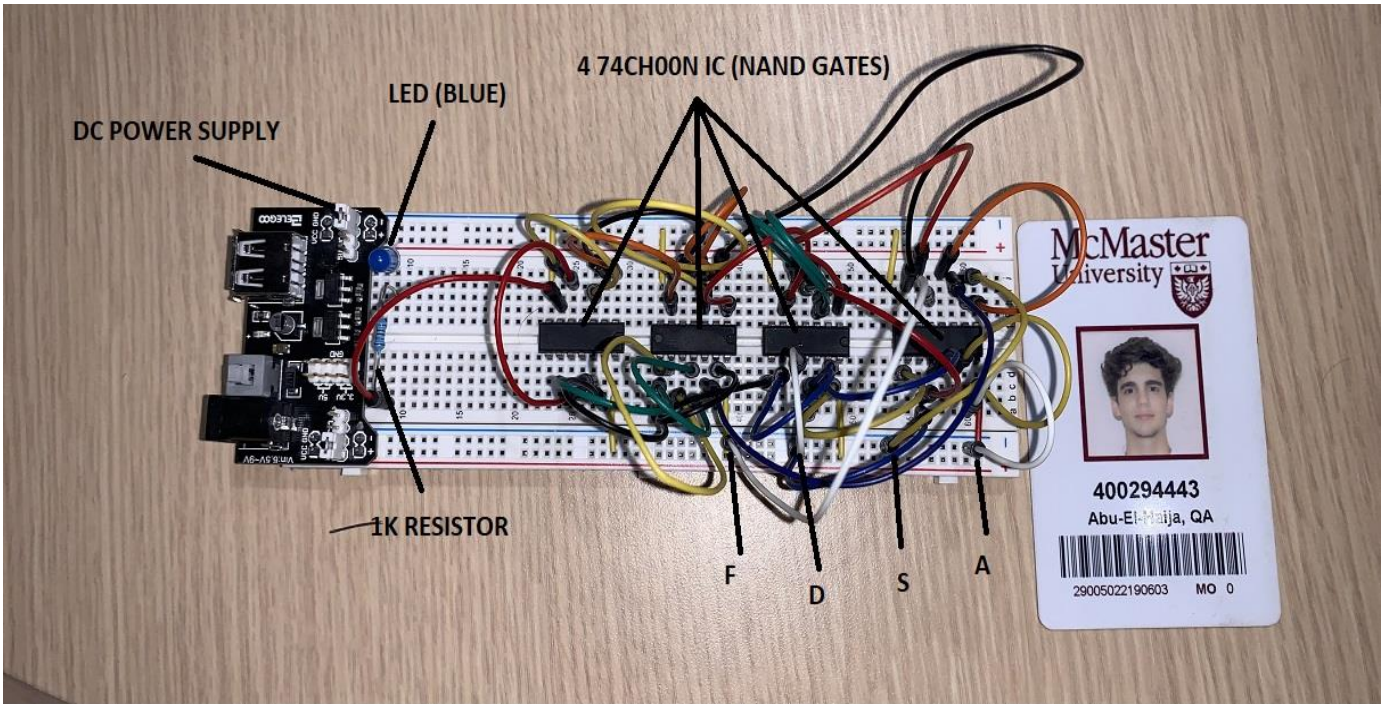
				
0	1	1	1	
1	0	0	0	

Qais Abu El Haija, abuelhaq
400294443

1	0	0	1	
1	0	1	0	

Qais Abu El Haija, abuelhaq
400294443

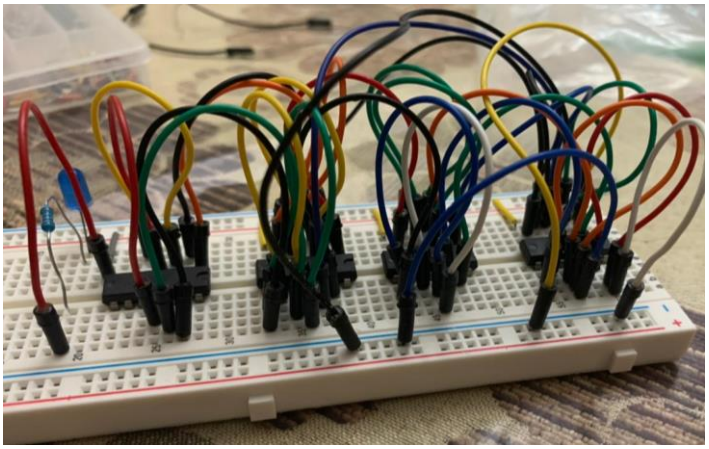
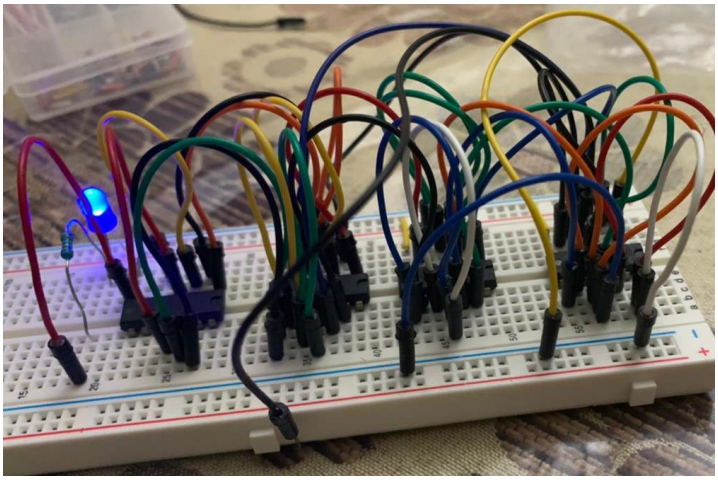
- The **NAND** gate circuit built:



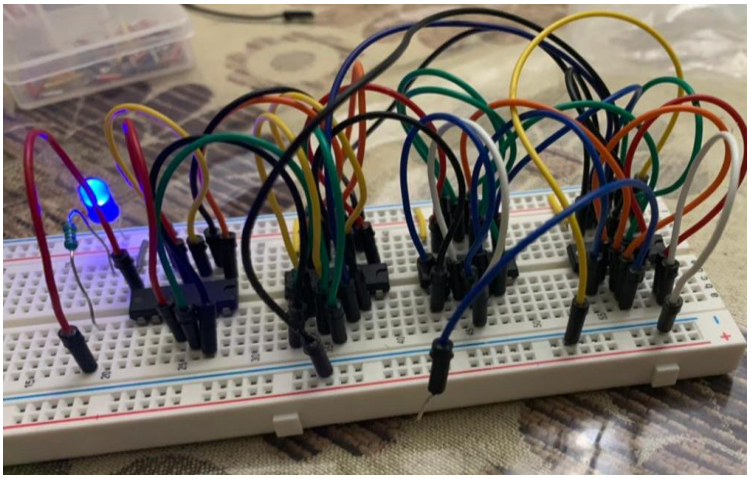
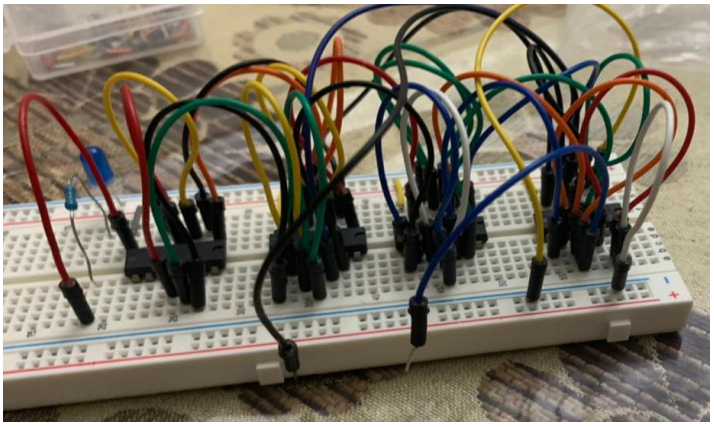
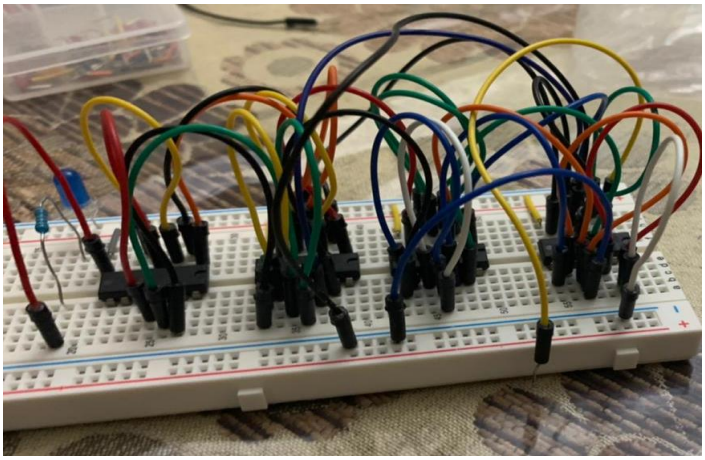
- It can be seen in the picture above that the circuit consists of 4 input values A, S, D and F and one output which is the Blue LED. 4 IC chips are used, where all of them are 74HC00N NAND gates.

Qais Abu El Haija, abuelhaq
400294443

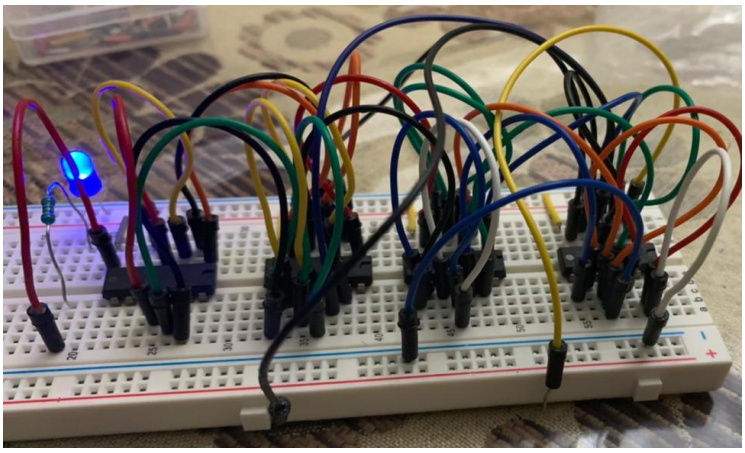
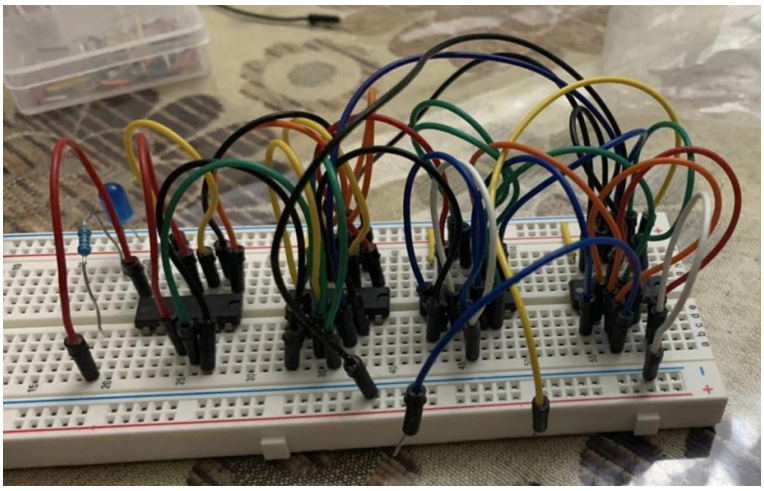
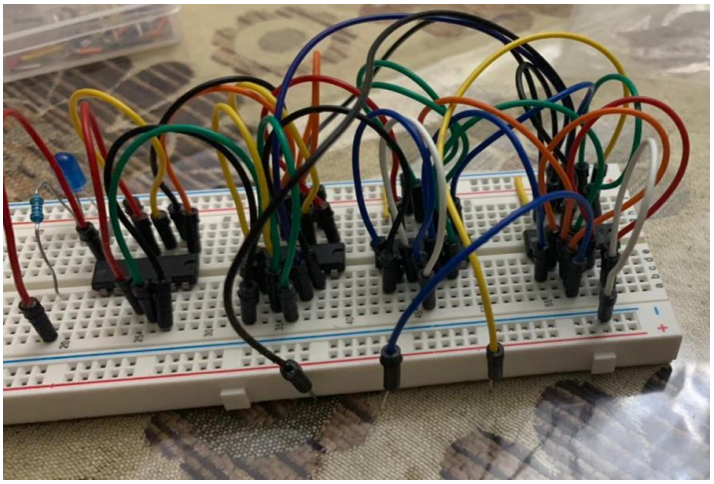
- The **NAND** gates circuit results are displayed in the below table:

A	S	D	F	Output
0	0	0	0	
0	0	0	1	
0	0	1	0	

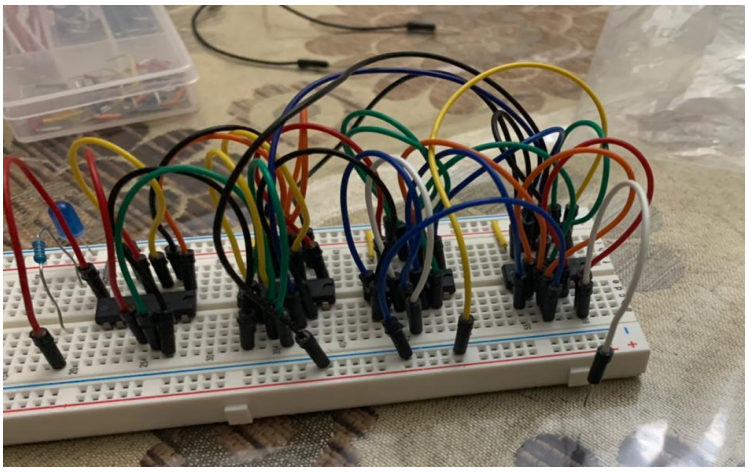
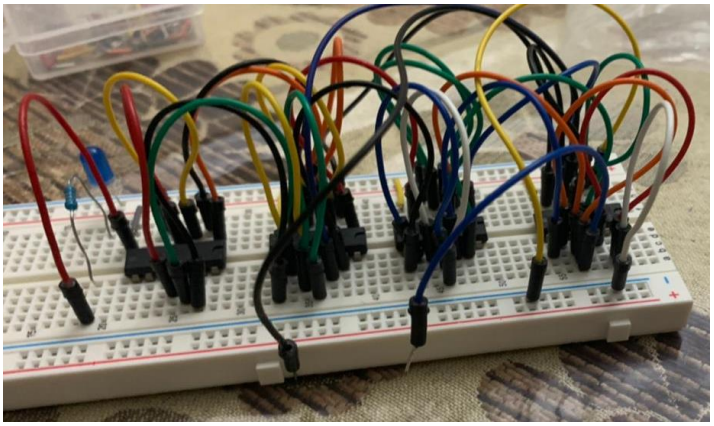
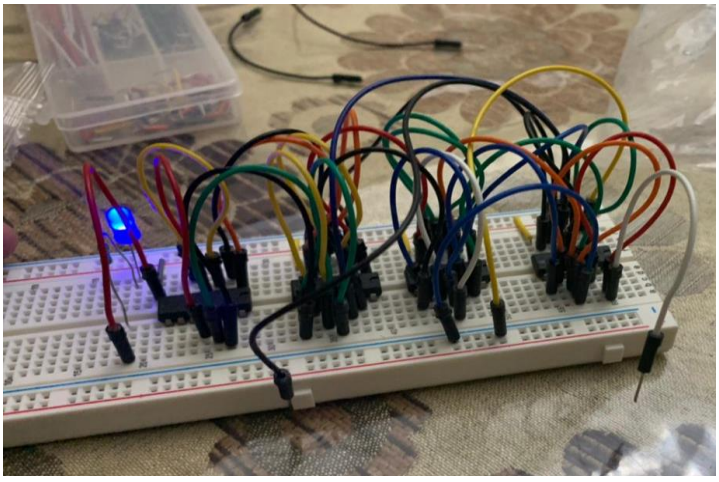
Qais Abu El Haija, abuelhaq
400294443

				
0	0	1	1	
0	1	0	0	
0	1	0	1	

Qais Abu El Haija, abuelhaq
400294443

				
0	1	1	0	
0	1	1	1	
1	0	0	0	

Qais Abu El Haija, abuelhaq
400294443

				
1	0	0	1	
1	0	1	0	

- From both tables obtained by both circuits, there were 4 instances when the LED lit up, first was when F is 1 and the rest are 0. Secondly, when D is 1 and the rest are 0. Thirdly, when S and F are 1 and the rest are 0 and finally when A and F are 1 and the rest are 0. This can be shown in the table below

Qais Abu El Haija, abuelhaq
400294443

A	S	D	F
0	0	0	1
0	0	1	0
0	1	0	1
1	0	1	0

Therefore, the circuit made experimentally using 4 74HC00N NAND gates, as well as the circuit made using the 74HC04N NOT Gate, the 74HC08N AND gate, and the 74HC32N OR gate, where experimentally done correctly.

Discussion

It can be seen from the three methods that the values obtained for the results are identical. All three methods attained the same results of giving an output of 1 or the LED lighting up when the input entered the 4 bits were the factors of the number 10, which are 1,2,5 and 10. The analytical part was solved using K-mapping using the POS and SOP method to attain the Boolean expression. The Boolean expression from both the methods was simplified and the same expression was obtained. The Boolean expressions were used to create a circuit using AND, OR and NOT gates and one using NAND gates. The first circuit requires 9 gates and the second requires 14 gates, the NAND circuit requiring more. The circuits were created in Multisim and were simulated by inputting various inputs from the range of 0 to 10 and the results obtained were the same as the analytical method.

The experimental part of the experiment was the most complex; the number of gates required in this circuit were plenty which made it difficult in building since the pinout of each chip was required to be known and the number of wires for each circuit were very high. This made it difficult navigating through the wires. The signal was off since it can be seen in the video that when the input was outside the led was still lighting up indicating some noise or unwanted signal was present which would have led to an error.

Reflection

The topic was very interesting as the basics of digital circuits was learned. I got to learn about various types of gates that can be used to change the input in different ways such as the AND, OR, NOT, XOR gate. I also got to learn about the importance of the NAND gate being one of the most common gates and therefore being used the most in applications. This topic was also very fun as we got to learn about Boolean expressions and how to simplify them using laws such as Dem Morgans rule and others. Also learned how to derive the Boolean expression from the truth table using the K mapping using the POS and SOP method. Digital circuits are used in electronics devices such as mobile phones and laptops. Digital circuits are used in applications such as rocket science and quantum computing. Finally digital circuits are also used in traffic signals to control when the light color will change.

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400294443