

BINARY ADDERS AND SUBTRACTORS

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ROLL NO.: 2025102061

TABLE NO.: 13

GROUP: G9

EXPERIMENT 3 – PART A: Half Adder

Aim:

To design and implement a Half Adder circuit using basic logic gates and verify its truth table.

Components Required:

1. Digital Test Kit (DSM Lab Kit)
2. Breadboard
3. Connecting wires
4. IC 7486 (XOR gate)
5. IC 7408 (AND gate)

Circuit Implementation:

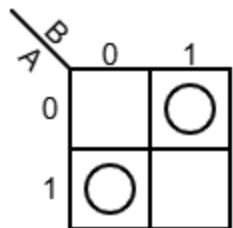
The circuit can be designed using the knowledge of K-Maps and prior knowledge of Binary Addition.

We know that,

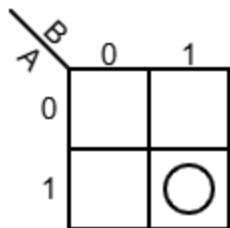
Input A	Input B	Binary Addition
0	0	0
1	0	1
0	1	1
1	1	10

Using this we can write a K-map for SUM and CARRY.

SUM



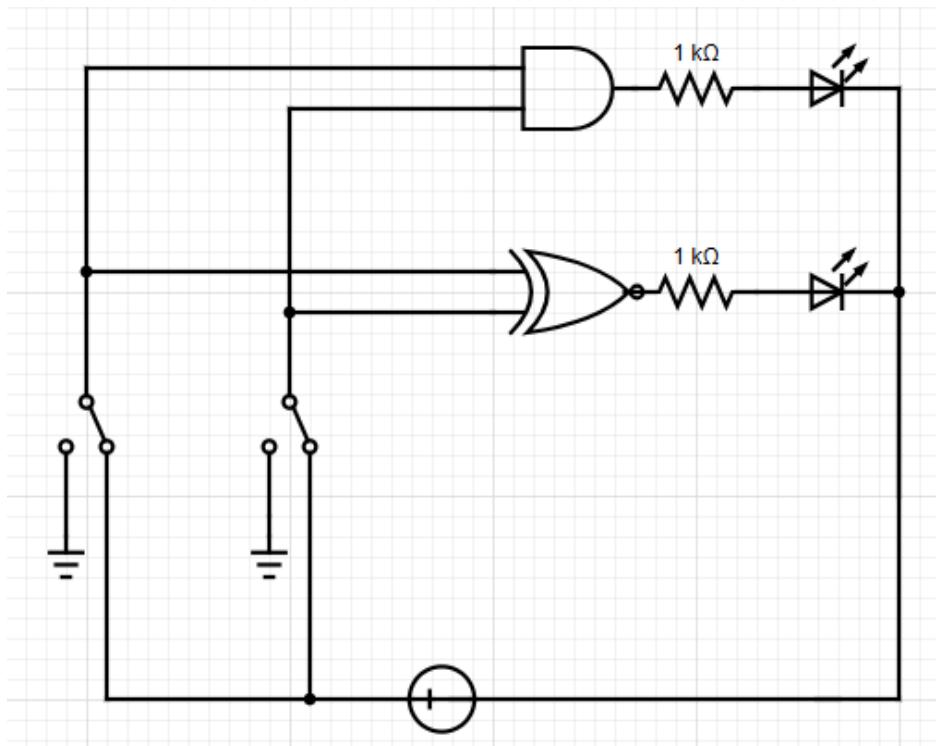
CARRY



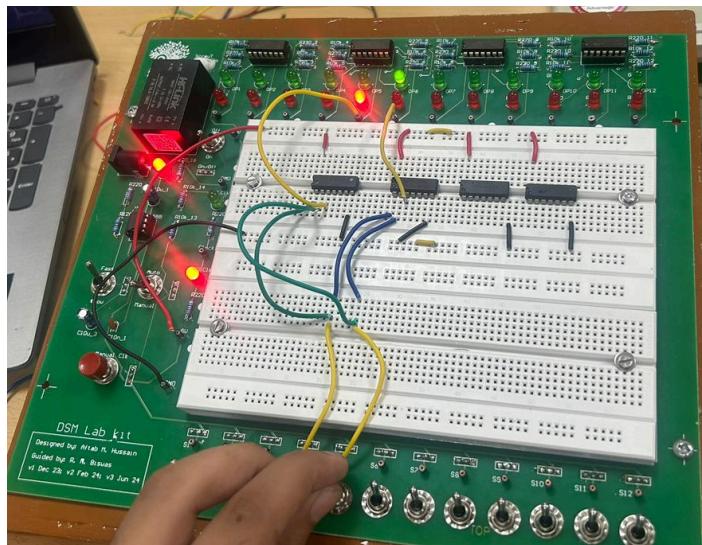
From the K-map it is clear that,

- ❖ $\text{SUM} = AB' + A'B = A \oplus B$
- ❖ $\text{CARRY} = A \cdot B$

Reference Circuit:



Visual Circuit:



Procedure:

1. Using K-Maps design a circuit.
2. Connect the required ICs to the breadboard and supply VCC and GND.
3. Provide two binary inputs A and B from the Digital Test Kit switches.
4. Use XOR gate output for SUM.
5. Use AND gate output for CARRY.
6. Connect the outputs to LEDs in the Digital Test Kit
7. Record observations by varying the inputs.

Observation:

The experimental observations:

Input A	Input B	Output - SUM	Output - CARRY
1	1	0	1
1	0	1	0
0	1	1	0
0	0	0	0

It was observed that the SUM LED glows when the total number of HIGH inputs is odd, confirming XOR operation. The CARRY LED glows only when both inputs are HIGH, confirming the expected Half Adder logic.

Result and Analysis:

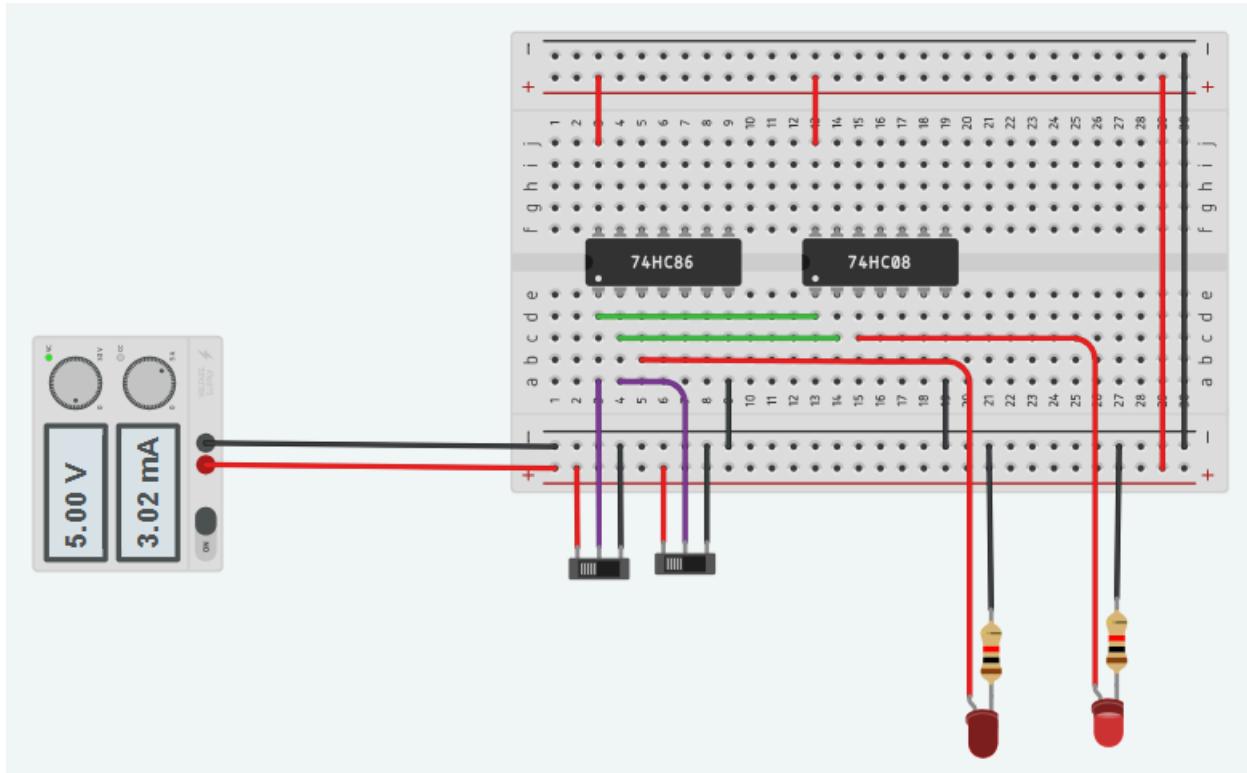
The Half Adder circuit was successfully implemented.

- The SUM output was observed to be HIGH only when the inputs differed, confirming XOR gate operation.
- The CARRY output was HIGH only when both inputs were HIGH, confirming AND gate functionality.

Thus, the experimental outputs matched the theoretical truth table.

Circuit Simulation:

https://www.tinkercad.com/things/7zlxRwXVTWL-half-adder?sharecode=y26VQZNAmS-Ue2ICRvHtBnG0sFLHqdR0XxiKCWv_J_s



EXPERIMENT 3 – PART B: Full Adder

Aim:

To design and implement a Full Adder circuit using two Half Adders and verify its truth table.

Components Required:

1. Digital Test Kit (DSM Lab Kit)
2. Breadboard
3. Connecting wire.
4. IC 7486 (XOR gate)
5. IC 7408 (AND gate)

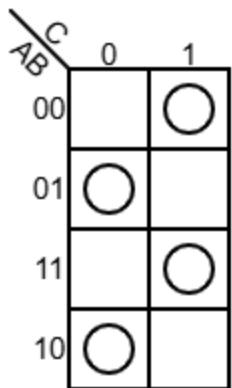
Circuit Implementation:

The Full Adder can be designed using the knowledge of K-Maps and Binary Addition. We know that a Full Adder adds *three inputs*: A, B, and Carry-in (C).

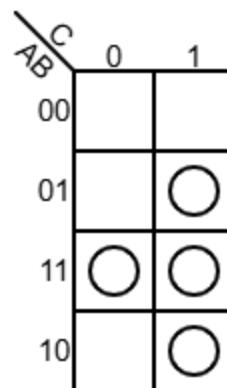
Input A	Input B	Input C	Binary Addition	Carry
0	0	0	0	0
1	0	0	1	0
0	1	0	1	0
1	1	0	0	1
0	0	1	1	0
1	0	1	0	1
0	1	1	0	1
1	1	1	1	1

Using this we can write K-Maps for SUM and CARRY.

SUM



CARRY



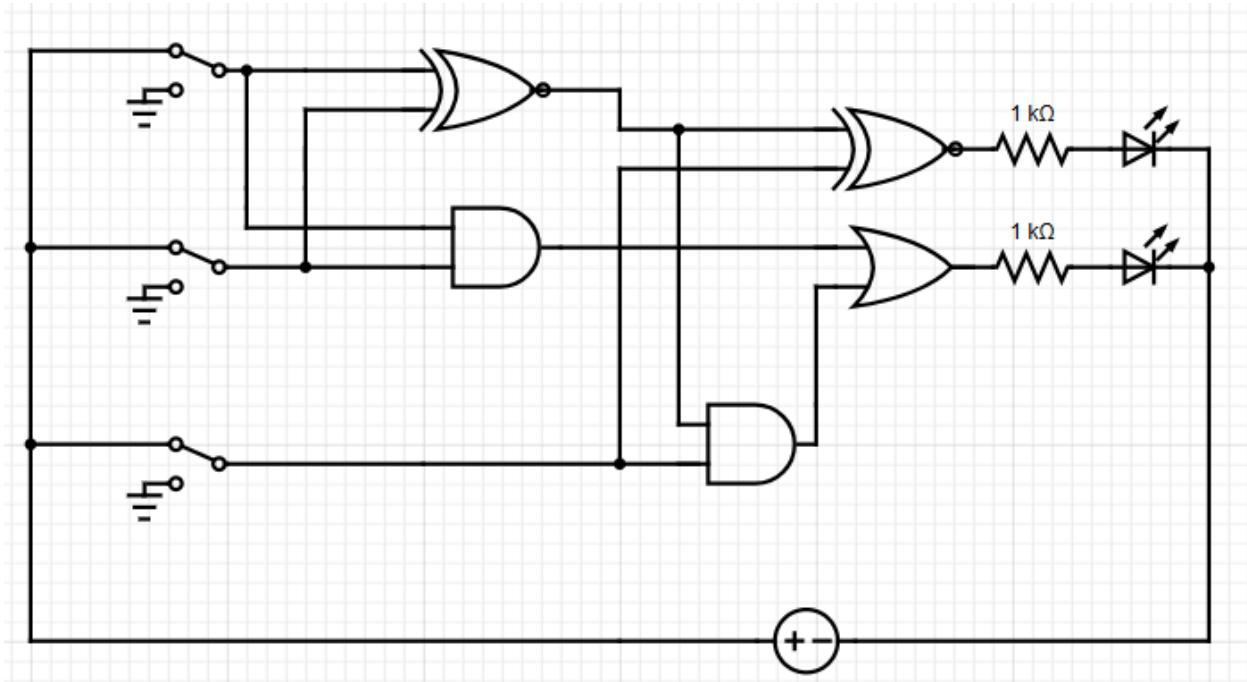
From the K-Map it is clear that:

- ❖ $\text{SUM} = A \oplus B \oplus C$
- ❖ $\text{CARRY} = C \cdot B + B \cdot A + C \cdot A$

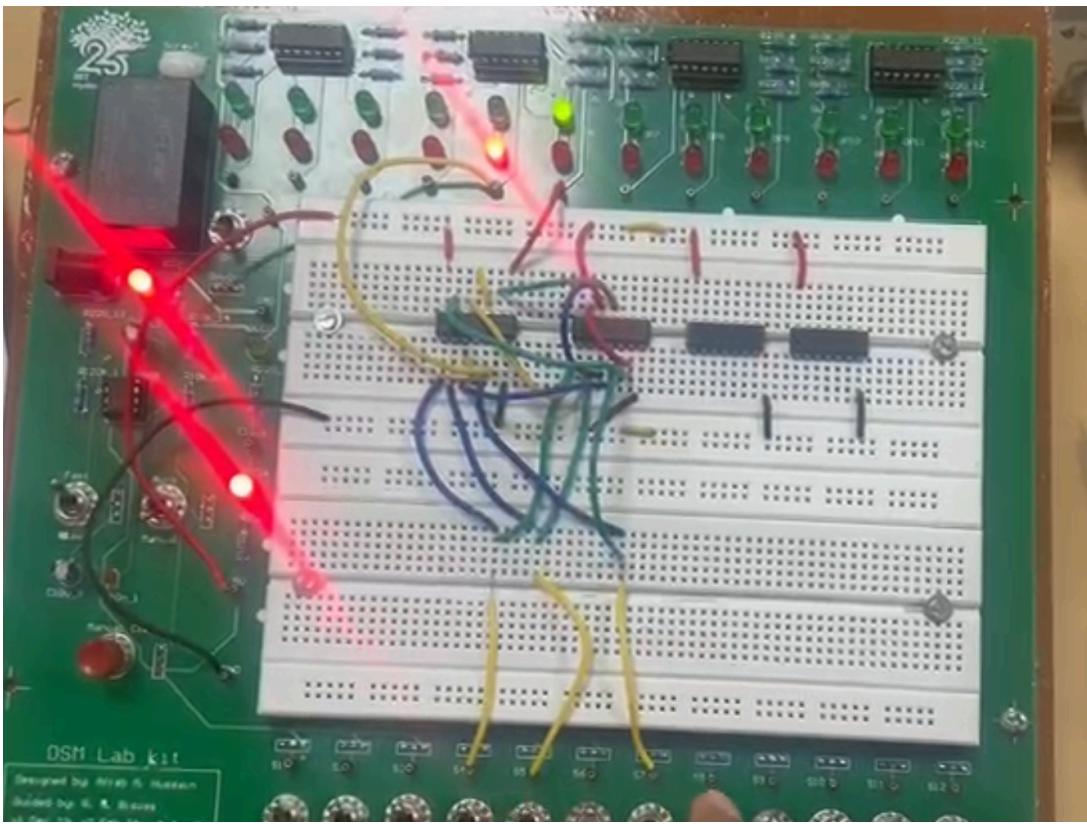
This carry could be simplified to reduce the number of gates

$$\begin{aligned}
 & A \cdot B + B \cdot C + A \cdot C \\
 &= AB + AC(B + B') + BC(A + A') \\
 &= AB + (ABC + AB'C) + (ABC + A'BC) \\
 &= AB + AB'C + A'BC + ABC \\
 &= AB + AB'C + A'BC \\
 &= AB + C(AB' + A'B) \\
 &= (AB' + A'B)C + AB \\
 &= (A \oplus B) \cdot C + A \cdot B
 \end{aligned}$$

Reference Circuit:



Visual Circuit:



Procedure:

1. Using K-Maps, design the Full Adder circuit.
Connect the ICs (XOR and AND) to the breadboard and supply VCC and GND.
Implement the first Half Adder using inputs A and B.
2. Connect the SUM output (S1) with input C into the second Half Adder.
3. Generate the final CARRY using AND-OR equivalent logic from the intermediate carries.
4. Connect SUM and CARRY outputs to LEDs in the Digital Test Kit.
5. Record observations by varying inputs A, B, and C.

NOTE:

- ❖ The OR Gate in the circuit can be eliminated by using XOR Gate and AND Gate alone.
- ❖ Assume you want to do OR of C1 and C2

$$\Rightarrow (C1 + C2) = (C1 \oplus C2) \oplus (C1 \cdot C2)$$

Observation:

The experimental observations:

Input A	Input B	Input C	Binary Addition	Output - SUM	Output - CARRY
0	0	0	0	0	0
1	0	0	1	1	0
0	1	0	1	1	0
1	1	0	10	0	1
0	0	1	1	1	0
1	0	1	10	0	1
0	1	1	10	0	1
1	1	1	11	1	1

It was observed that the SUM LED glows when the total number of HIGH inputs is odd, confirming XOR operation. The CARRY LED glows when any two or more inputs are HIGH, confirming the expected Full Adder logic.

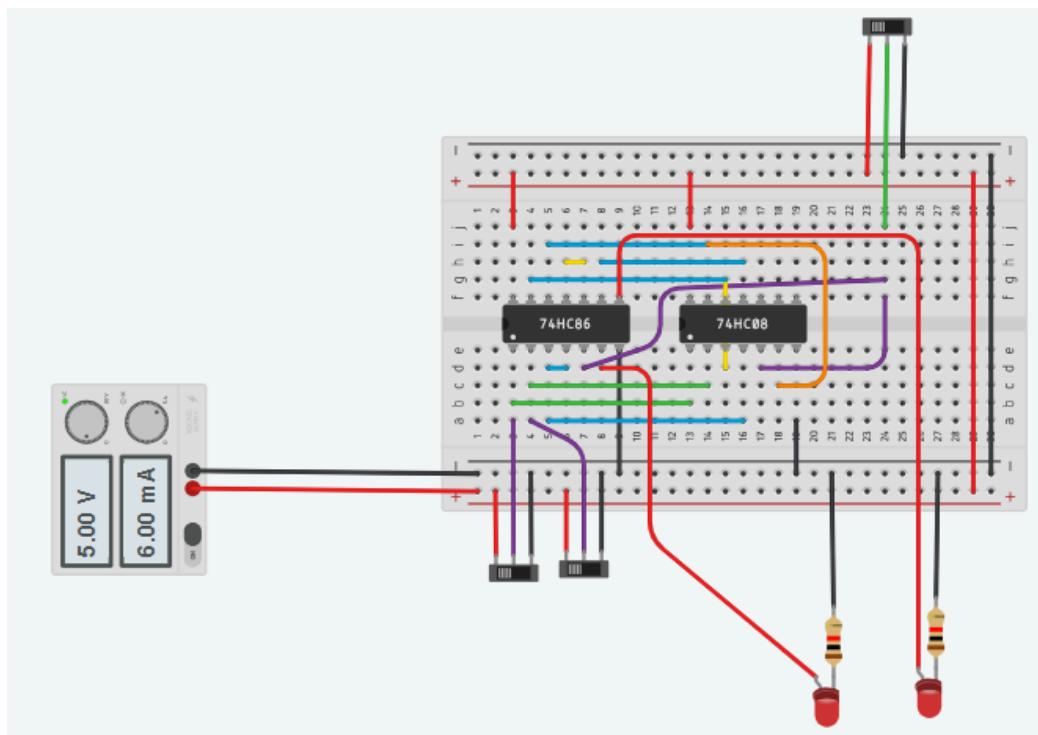
Result and Analysis:

The Full Adder circuit was successfully implemented using two Half Adders.

- The SUM output was HIGH when an odd number of inputs were HIGH
 - The CARRY output was HIGH when at least two inputs were HIGH.
- Thus, the experimental outputs matched the theoretical truth table.

Circuit Simulation:

<https://www.tinkercad.com/things/48oA3HiB1ny-full-adder?sharecode=SYJ-6i6uaC0YgJatfWdcjKp-87BAB6dTbZkwkK8Wk-w>



EXPERIMENT 3 – PART C: Half Subtractor

Aim:

To design and implement a Half Subtractor circuit using basic logic gates and verify its truth table.

Components Required:

1. Digital Test Kit (DSM Lab Kit)
2. Breadboard
3. Connecting wires
4. IC 7486 (XOR gate)
5. IC 7408 (AND gate)

Circuit Implementation:

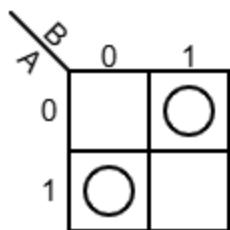
The circuit can be designed using the knowledge of K-Maps and prior knowledge of Binary subtraction.

We know that,

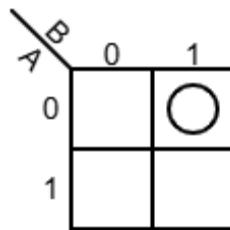
Input A	Input B	Binary Subtraction	Borrow
0	0	0	0
1	0	1	0
0	1	-1=1	1
1	1	0	0

Using this we can write a K-map for DIFFERENCE and BORROW.

DIFFERENCE



BORROW



From the K-map it is clear that,

- ❖ DIFFERENCE = $AB' + A'B = A \oplus B$
- ❖ BORROW = $A' \cdot B$

We will require an extra NOT gate to obtain A' instead if we do,

$$(A \oplus B) \cdot B$$

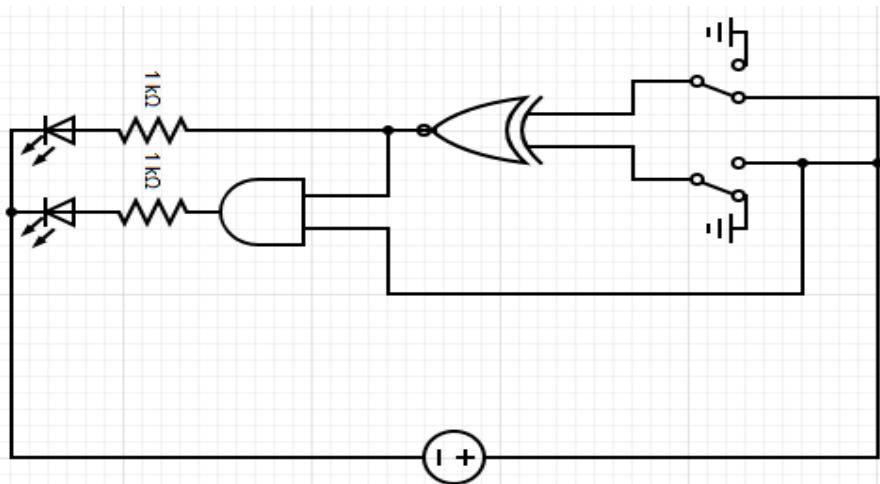
$$= (AB' + A'B) \cdot B$$

$$= (AB'B + A'BB)$$

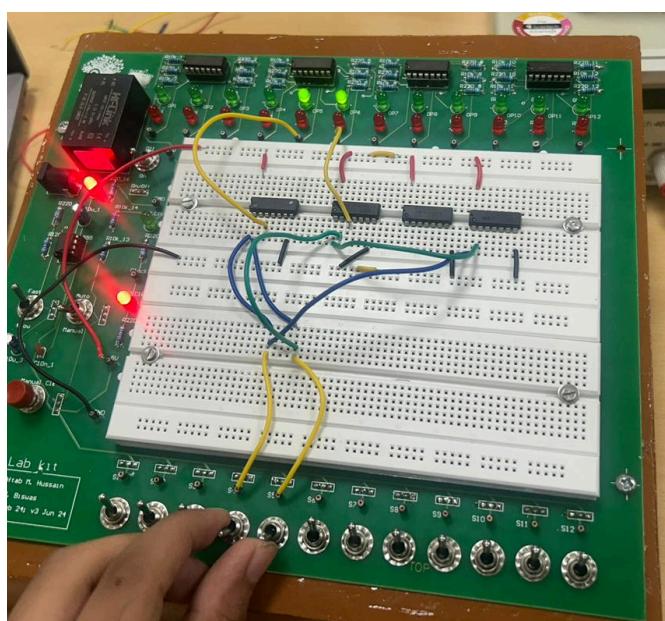
$$= (0 + A'B) = A' \cdot B$$

We can finish the experiment with just 2 gates.

Reference Circuit:



Visual Circuit:



Procedure:

1. Using K-Maps design a circuit.
2. Connect the required ICs to the breadboard and supply VCC and GND.
3. Provide two binary inputs A and B from the Digital Test Kit switches.
4. Use XOR gate output for DIFFERENCE.
5. Use XOR output as one input for AND gate and B as the 2nd input.
6. Use AND gate output for BORROW.
7. Connect the outputs to LEDs in the Digital Test Kit
8. Record observations by varying the inputs.

Observation:

The experimental observations:

Input A	Input B	Output - DIFFERENCE	Output - BORROW
1	1	0	0
1	0	1	0
0	1	1	1
0	0	0	0

It was observed that the DIFFERENCE LED glows when the number of HIGH inputs is odd, confirming XOR operation. The BORROW LED glows when the minuend input is LOW and the subtrahend input is HIGH, confirming the expected Half Subtractor logic.

Result and Analysis:

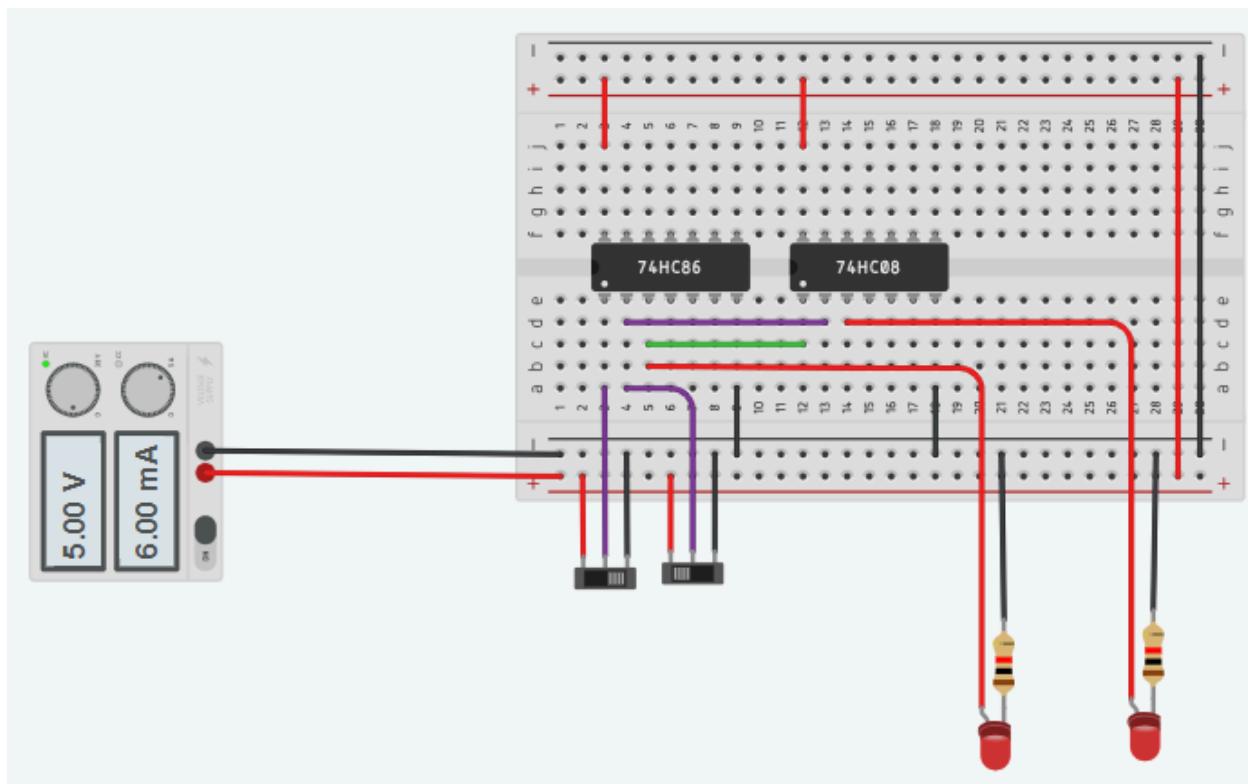
The Half Subtractor circuit was successfully implemented.

- The DIFFERENCE output was observed to be HIGH only when the inputs differed, confirming XOR gate behavior.
- The BORROW output was HIGH only when A was LOW and B was HIGH, confirming the logic expression $B_1 = A' \cdot B$.

Thus, the experimental outputs matched the theoretical truth table.

Circuit Simulation:

<https://www.tinkercad.com/things/iL9u7hyzup-half-subtractor?sharecode=undefined>



EXPERIMENT 3 – PART D: Full Subtractor

Aim:

To design and implement a Full Subtractor circuit using two Half SubTRACTors and verify its truth table.

Components Required:

1. Digital Test Kit (DSM Lab Kit)
2. Breadboard
3. Connecting wires
4. IC 7486 (XOR gate)
5. IC 7408 (AND gate)

Circuit Implementation:

The circuit can be designed using the knowledge of K-Maps and prior knowledge of Binary subtraction.

We know that,

Input A	Input B	Input C (Borrow input)	Binary Subtraction	Borrow
0	0	0	0	0
1	0	0	1	0
0	1	0	-1 = 1	1
1	1	0	0	0
0	0	1	-1 = 1	1
1	0	1	0	0
0	1	1	-2 = 0	1
1	1	1	-1 = 1	1

Using this we can write a K-map for DIFFERENCE and BORROW.

DIFFERENCE

	0	1
00		
01	○	
11		○
10	○	

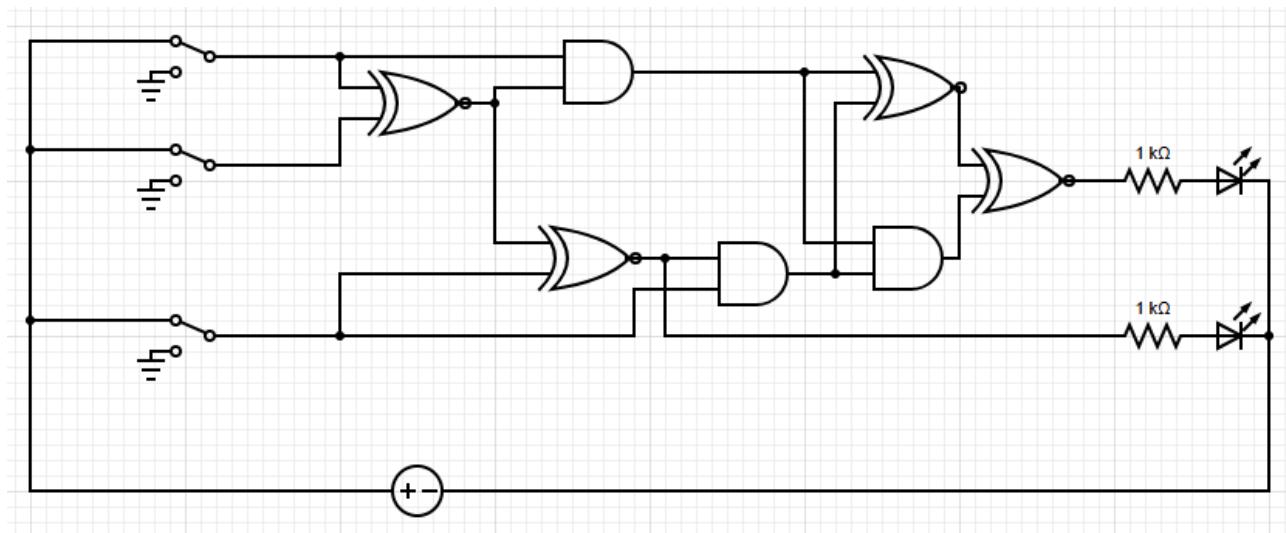
BORROW

	0	1
00		
01	○	○
11		○
10		

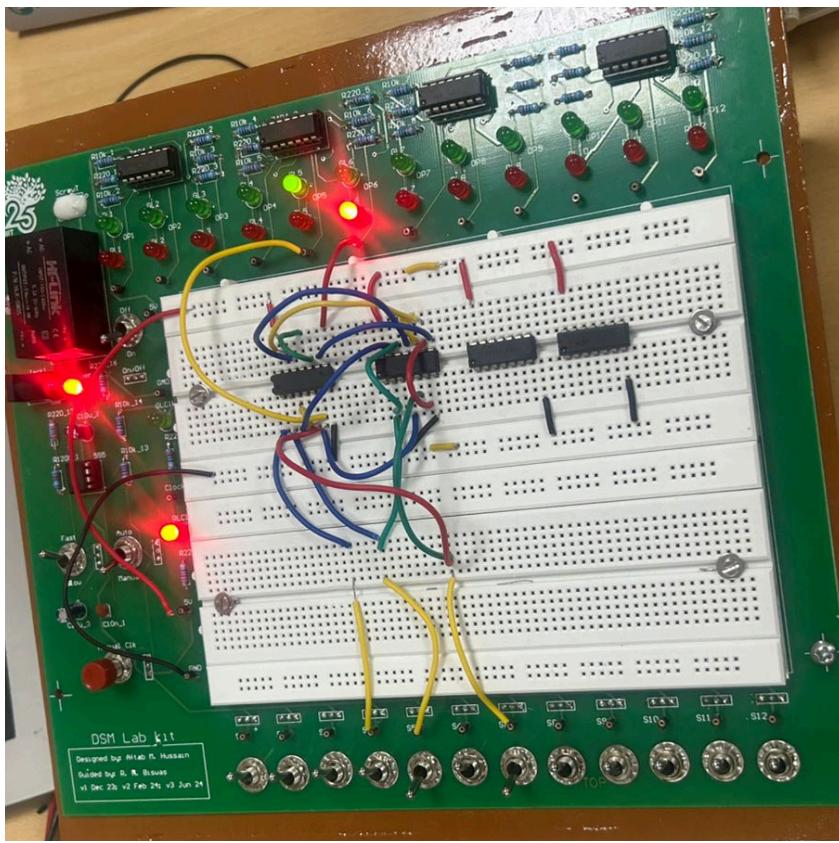
From the K-Map it is clear that:

- ❖ DIFFERENCE = $A \oplus B \oplus C$
- ❖ BORROW = $A'B + A'C + BC$
 - $A'BC + (A'B' + BA)C + A'B$
 - $A'B + (A'B' + BA)C$
 - $A' \cdot B + (A \oplus B \oplus C) \cdot C$

Using The OR Gate equivalent from pg 9, we can build a circuit.



Visual Circuit:



Procedure:

1. Using K-Maps, design the Full Subtractor circuit.
2. Connect the ICs (XOR, AND) to the breadboard and supply VCC and GND.
3. Implement the first Half Subtractor using inputs A and B.
4. Connect the DIFFERENCE output (D1) with input C into the second Half Subtractor.
5. Generate the final BORROW using intermediate borrow output.
6. Connect DIFFERENCE and BORROW outputs to LEDs in the Digital Test Kit.
7. Record observations by varying inputs A, B, and C.

Observation:

The experimental observations:

Input A	Input B	Input C (Borrow input)	Output Difference	Output Borrow
0	0	0	0	0
1	0	0	1	0
0	1	0	1	1
1	1	0	0	0
0	0	1	1	1
1	0	1	0	0
0	1	1	0	1
1	1	1	1	1

Result and Analysis:

The Full Subtractor circuit was successfully implemented using two Half SubTRACTORS.

- The DIFFERENCE output was observed to be HIGH when the number of HIGH inputs was odd, confirming XOR functionality.
- The BORROW output was HIGH whenever input A was smaller than B + C, confirming the expected borrow logic.

Thus, the experimental outputs matched the theoretical truth table.

Circuit Simulation:

https://www.tinkercad.com/things/cY5DJdWsUv3-full-subtractor?sharecode=Vmvoa_emdNT1bExy409LOCYIIII7xVuITkf797xuKal

