Digital Calculator

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in the partial fulfillment of the requirements
for the award of the degree of

Bachelor of Technology
(a part of Five-Year Dual Degree Course)

School of Engineering

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JAWAHARLAL NEHRU UNIVERSITY
SCHOOL OF ENGINEERING

DECLARATION

We declare that the project work entitled "Digital Calculator" which is submitted by us in partial fulfillment of the requirement for the award of degree B.Tech. (a part of Dual-Degree Programme) to School of Engineering, Jawaharlal Nehru University, Delhi comprises only our original work and due acknowledgement has been made in the text to all other material used.

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CERTIFICATE

This is to certify that the synopsis entitled "Digital Calculator" being submitted by Mr. Sheersho Banerjee (Enrolment No.- 20/11/EE/026), Mr. Sagar Tripathi (Enrolment No. 20/11/EE/023), Mr. Estari Saikiran (Enrolment No. 20/11/EE/016), and Mr. Raj Sonkar (Enrolment No. 20/11/EE/048) in fulfillment of the requirements for the award of the Bachelor of Technology (part of Five-Year Dual Degree Course) in Electronics & Communication Engineering, will be carried out by him under my supervision.

In my opinion, this work fulfills all the requirements of an Engineering Degree in the respective stream as per the regulations of the School of Engineering, Jawaharlal Nehru University, Delhi. This thesis does not contain any work, which has been previously submitted for the award of any other degree.

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Thanks and Regards,

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ABSTRACT

This project aims to design and implement a 4-bit adder, subtractor, and multiplier using logic gates and integrated circuits (ICs) on a breadboard. These fundamental arithmetic operations are essential components of digital systems and play a crucial role in various applications, including computing, and communication. The fundamental concepts of adders, subtractors, and multipliers are used in the arithmetic logic unit (ALU) of a computer. The ALU is a digital circuit that performs arithmetic and logic operations on binary data. It is a crucial component of the central processing unit (CPU). By constructing these circuits using logic gates, we can gain a deeper understanding of their underlying principles and the practical aspects of digital electronics circuit design.

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CHAPTER-1

INTRODUCTION and THESIS OVERVIEW

1.1. INTRODUCTION

In the realm of digital electronics, arithmetic operations form the foundation for performing complex computations. Among these operations, adders, subtractors, and multipliers are particularly fundamental. These circuits enable us to manipulate and process binary data, which is the cornerstone of modern digital systems.

The 4-bit adder, subtractor, and multiplier circuits to be designed in this project will employ logic gates as the basic building blocks. Logic gates are electronic circuits that perform specific logical operations, such as AND, OR, NOT, and XOR. By combining these logic gates in a structured manner, we can construct more complex circuits that execute the desired arithmetic operations.

The implementation of these circuits will utilize integrated circuits (ICs), which are small electronic devices that encapsulate numerous transistors and other components. ICs offer several advantages, including compactness, reliability, and ease of use. They provide a convenient and practical means of constructing complex electronic circuits.

A 2-bit adder can be implemented as an FSM. The inputs are the two bits to be added, and the output is the sum of the two bits. The states of the FSM represent the carry bit and the sum of the two bits.

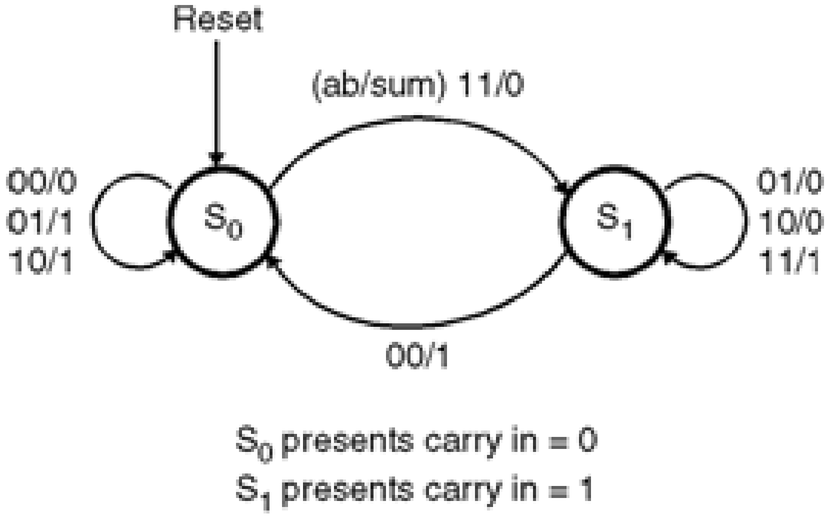


Fig 1.1 Adder as an FSM

1.2. THESIS OBJECTIVE

The primary objective of this project is to :

(i) Perform binary addition of two 4-bit numbers.

(ii) Perform binary subtraction of two 4-bit numbers.

(iii) Perform binary multiplication of two 2-bit numbers.

1.3. ORGANIZATIONS OF CHAPTERS

The thesis consists of five chapters and the overview of all the chapter are as follows:

Chapter 1: This chapter provides a brief introduction on the background and the objectives of the thesis involved in accomplishing the thesis.

Chapter 2: This chapter gives an overview of the available literature on the various IC's.

Chapter 3: describes the details of proposed work and methodology used in this project implementation.
Chapter 4: This chapter gives the discussion about the simulated and measured results.
Chapter 5: presents the conclusion of this project and future scope of the work.
References: In the last section of this thesis, used references are given.

CHAPTER-2

LITERATURE SURVEY

The concept of digital calculators and binary arithmetic has been a fundamental aspect of digital computing since its inception. The literature on this subject spans various domains, including computer architecture, digital logic design, and finite state machines. In this literature survey, we explore key themes and relevant works in these areas to provide a comprehensive understanding of the background and context for the proposed project.

2.1. Integration of Key Integrated Circuits(ICs):

In the proposed "Digital Calculator" project, the seamless integration of specific integrated circuits (ICs) plays a pivotal role in achieving the desired functionalities. Each IC serves a unique purpose, contributing to the overall efficiency and performance of the digital calculator.The integration of specific ICs, namely 7486 (XOR), 7408 (AND), 7432 (OR), and 7483 (Full Adder), is informed by foundational texts in digital design. Classic works by authors such as M. Morris Mano and principles from digital integrated circuits by Jan M. Rabaey lay the groundwork for understanding the significance of these ICs in binary arithmetic operations. These ICs, widely recognized in the field, contribute to the project's efficiency and accuracy in performing binary addition, subtraction, and multiplication.

2.1.1. IC 7486 (XOR):

The IC 7486, housing XOR gates, is fundamental for binary addition and subtraction. XOR gates play a crucial role in bitwise operations, providing the ability to discern when bits in the same position are different. This is essential for accurately calculating binary sums and differences.

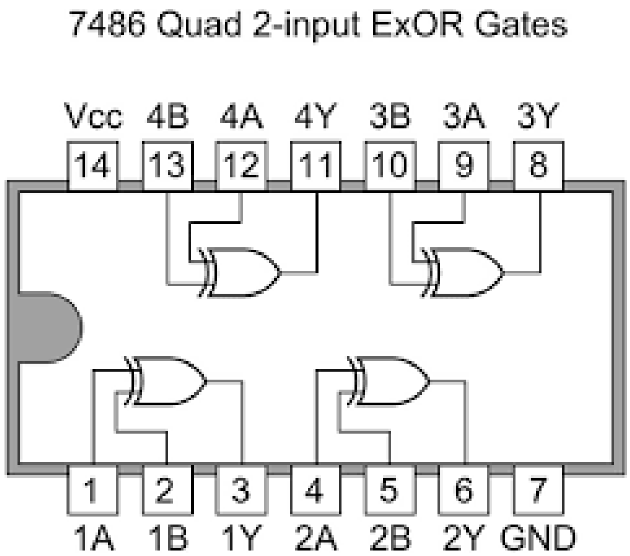


Fig 2.1 IC 7486

2.1.2. IC 7408 (AND):

The IC 7408, comprising AND gates, contributes to the project's logical operations. AND gates are instrumental in performing the binary multiplication operation, ensuring that the product is only true when both corresponding bits are true. This logical conjunction is essential for accurate multiplication outcomes.

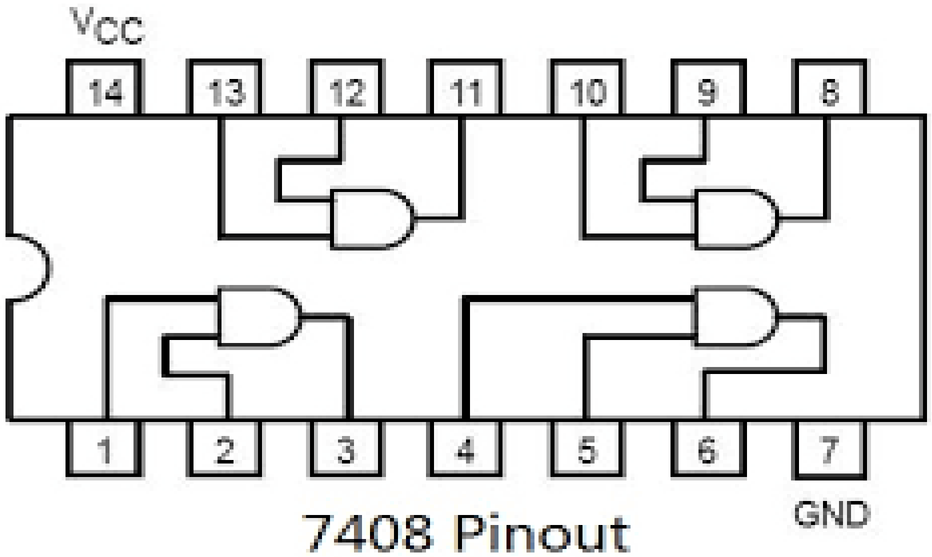


Fig 2.2 IC 7408

2.1.3. IC 7432 (OR):

The IC 7432, housing OR gates, is vital for logical operations as well. OR gates are integral to both addition and multiplication processes, providing the necessary logic to combine bits and generate the correct results. The OR operation is central to determining the carry bits in binary addition and combining partial products in binary multiplication.

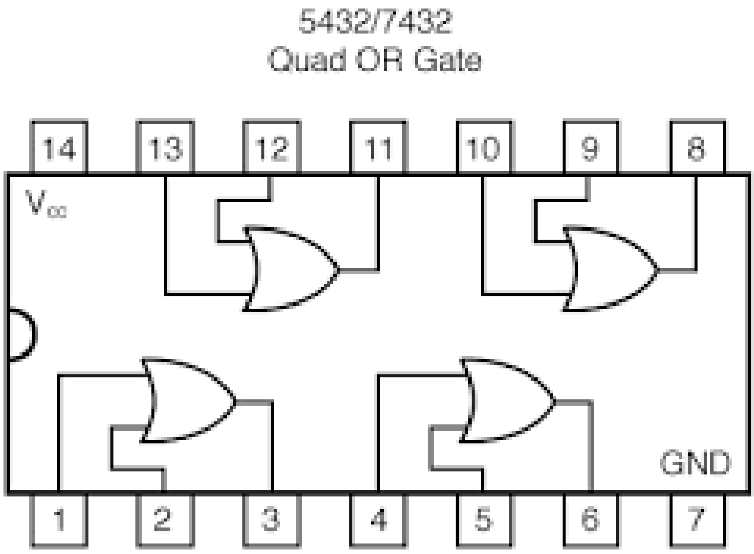


Fig 2.3 IC 7432

2.1.4. IC 7483 (Full Adder):

The IC 7483, a Full Adder, is indispensable for binary addition. It incorporates the logic required to handle the sum and carry bits efficiently. By utilizing the Full Adder, the project ensures accurate and streamlined binary addition, a fundamental operation in the digital calculator's repertoire.

2):

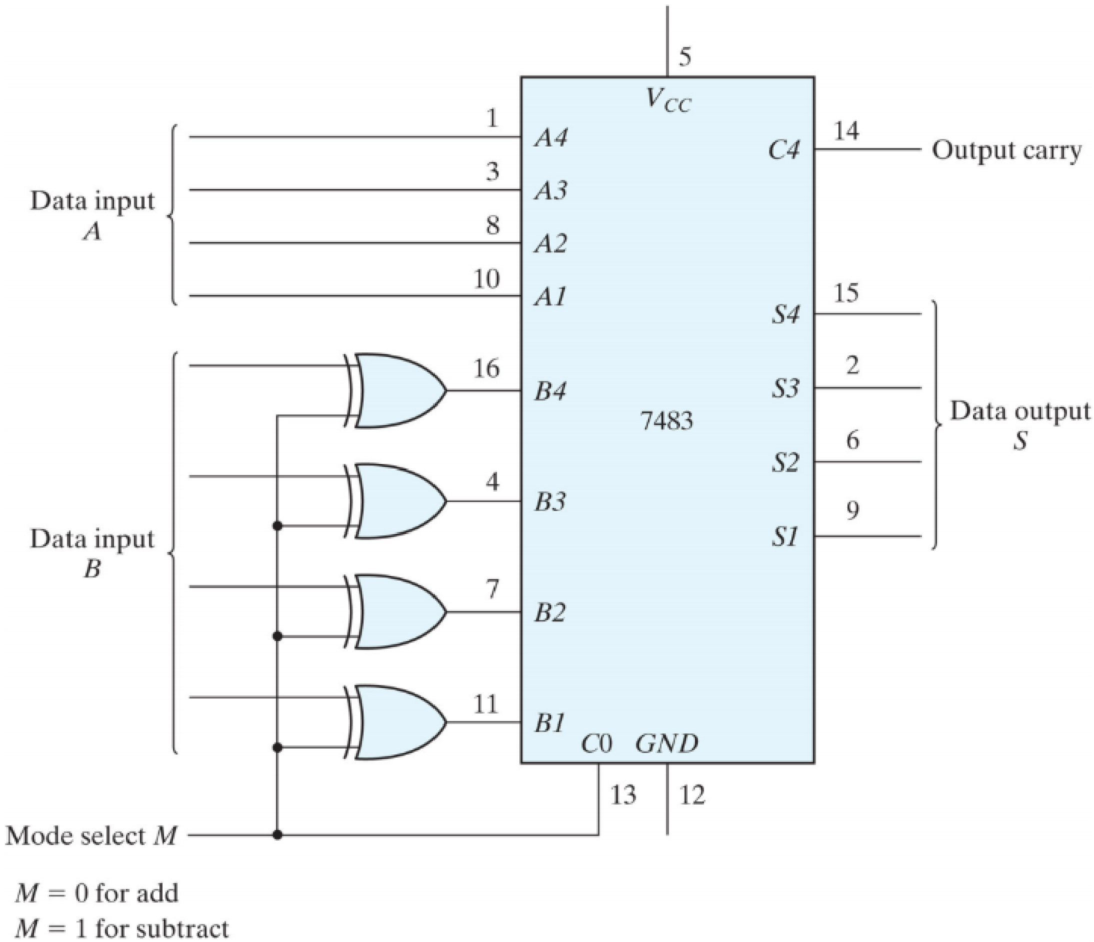


Fig 2.4 IC 7483

2.2. Binary Arithmetic and Digital Computing:

The foundational principles of binary addition, subtraction, and multiplication are extensively covered in literature related to digital computing. Classic texts such as "Digital Design" by M. Morris Mano and "Computer Organization and Design" by David A. Patterson and John L. Hennessy delve into the basics of binary arithmetic and its application in digital systems.

2):

Finite state machines are a powerful theoretical framework widely used in digital system design. "Introduction to Automata Theory, Languages, and Computation" by John E. Hopcroft and Jeffrey D. Ullman provides a solid foundation in FSM theory. Additionally, works by Edward A. Lee and David G. Messerschmitt, like "Digital Communication" and "Introduction to Embedded Systems," highlight the practical implementation of FSM in digital devices.

2.4. Binary Arithmetic Circuits:

Hardware implementation of binary arithmetic involves designing efficient circuits. "Digital Integrated Circuits: A Design Perspective" by Jan M. Rabaey explores the design and optimization of digital circuits, including those for binary arithmetic operations. Research papers on low-power arithmetic circuits and high-speed adders, such as those by Brent and Kung, offer insights into advanced circuit designs.

2.5. Algorithmic Approaches to Binary Multiplication:

The algorithmic aspects of binary multiplication have been widely studied. "Computer Arithmetic: Algorithms and Hardware Designs" by Behrooz Parhami covers various algorithms for binary multiplication, including 'Shift and Add Multiplier.' The works of Donald Knuth in "The Art of Computer Programming" provide in-depth insights into efficient multiplication algorithms.

CHAPTER-3

PROPOSED WORK AND METHODOLOGY

This chapter includes the working of the Adder, Subtractor, and Multiplier

3.1 Adder :-

Full Adder is the adder that adds three inputs and produces two outputs. The first two inputs are A and B and the third input is an input carry as C-in. The output carry is designated as C-out and the normal output is designated as S which is sum.

One full adder can help us in adding two numbers each of one bit only, so we will use N-full adders for adding two numbers each of N-bits.

$$S = (A \oplus B) \oplus C_{in}$$

$$Cout = AB + Cin\,(A \oplus B)$$

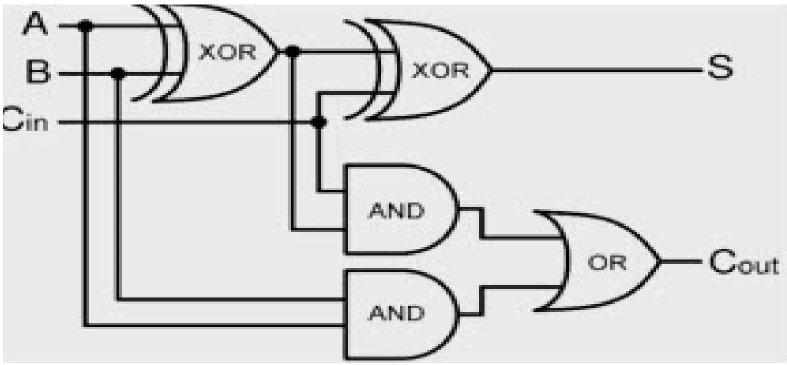


Fig 3.1 Full Adder

We have implemented a 4-Bit Adder. In this, we have connected a series of four full adders. The first full adder will add the Least Significant Bits (LSB) of the two numbers A and B with zero carry input (Cin). The carry output (Cout) from the first full adder will be taken as the carry input (Cin) of the second full adder and so on till the Most Significant Bit (MSB). The carry output (Cout) from the last full adder will be the carry of the entire sum of A and B.

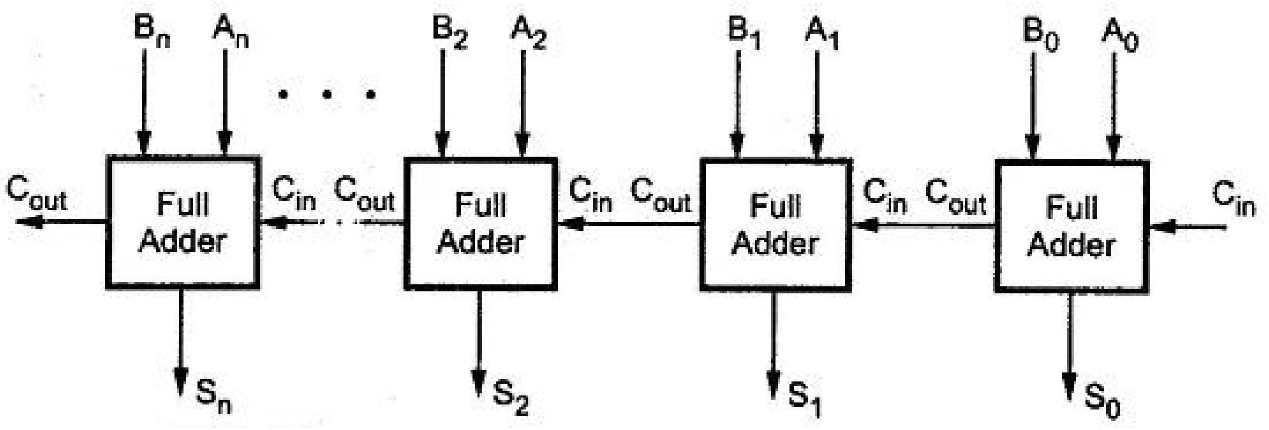


Fig 3.2 Series of Full Adders

3.2 Subtractor :-

For the subtraction of two numbers of A and B, where we will subtract B from A, we will subtract by taking the 2's complement and add it to A bit by bit. We will first start by taking the 1's complement of B by passing each bit of B with 1 using a control line 'M' in the XOR gate.

1' s Complement

B XOR 1 = B'

To take the 2's complement from the 1's complement we will add 1 from the control line 'M' which will go into the Cin of the first full adder.

2' Complement

$$(B \text{ XOR } 1) + 1 = B' + 1$$

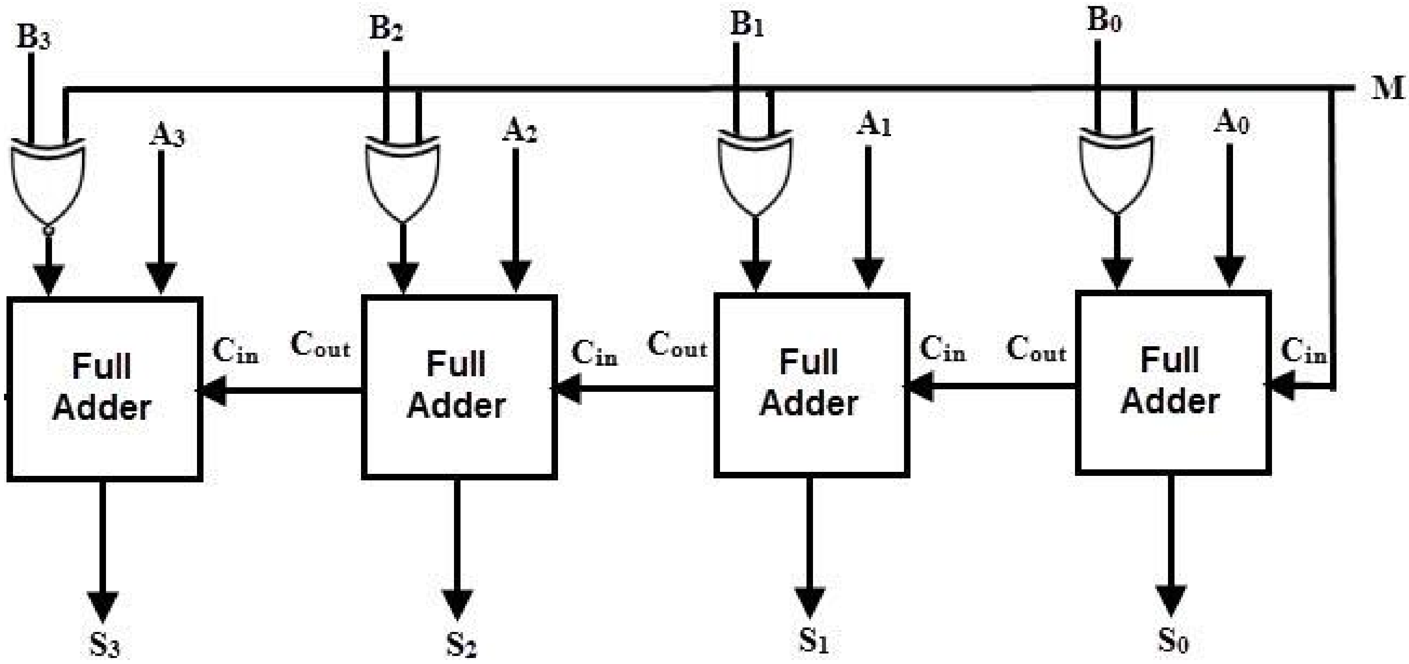


Fig 3.3 Subtractor

3.3 Multiplier :-

For multiplying two 2-bit numbers A and B, and the product P, we will use the 'Shift and Add' algorithm. In this we will multiply the two binary numbers the same way we multiply two decimal (base-10) numbers. If we are multiplying two numbers of N-bits each, then the product P will be stored in a size of 2*N-bits.

A0B0 or A0.B0 is the Bitwise AND of A0 and B0, and this will give us P0. In the second step we have to add B0A1 and B1A0 which will give P1 as the sum and carry C1 which will get added to B1A1. Their subsequent sum will be P2 and the carry C2 will be P3.

$P = A \oplus B$, Carry = A.B *(Product and carry for 1-bit multiplication)*

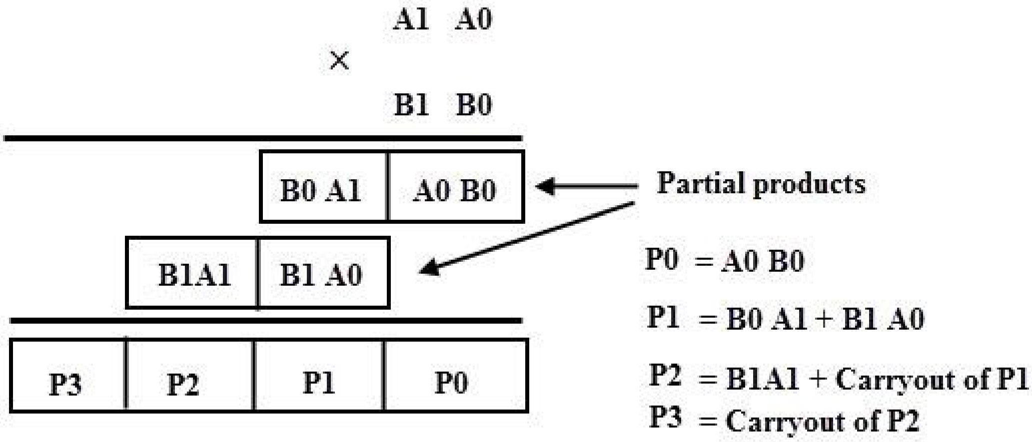


Fig 3.4

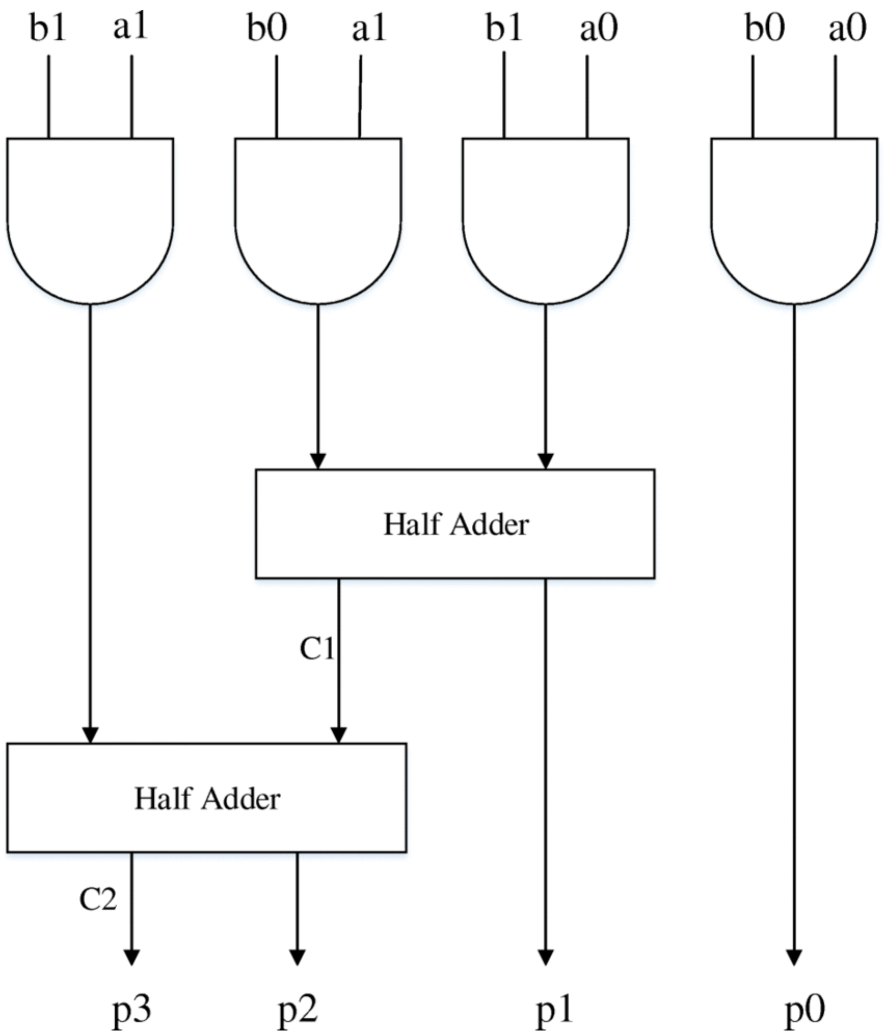


Fig 3.5 2-bit Multiplier

CHAPTER-4

RESULT DISCUSSION :-

4.1 Adder

Addition of two binary numbers A and B

A= 1 0 1 1 and B= 0 1 0 1

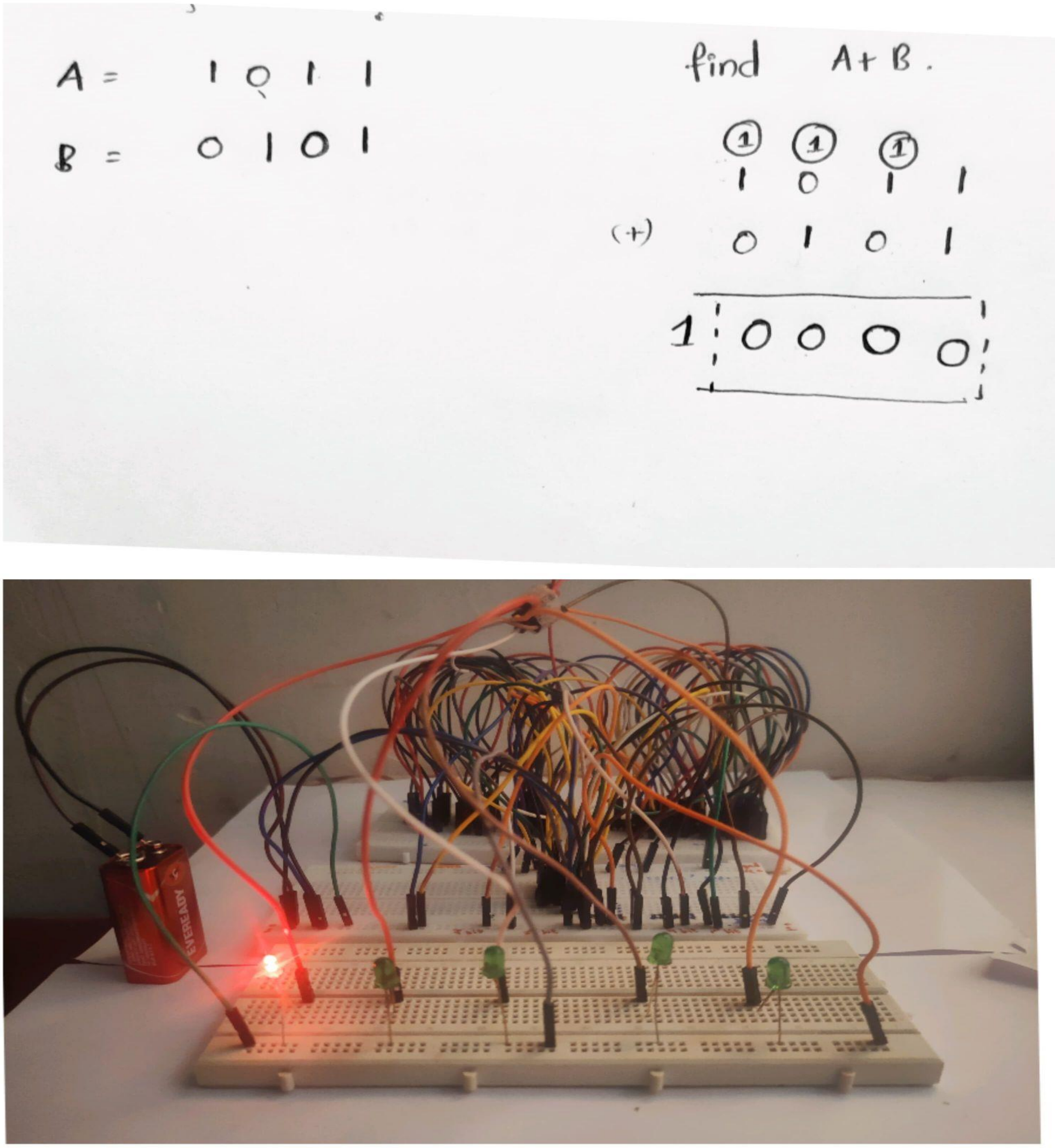


Fig 4.1 Addition example 1

Note: The leftmost small light denotes the carry. After that we have the MSB

Addition of two binary numbers A and B

A= 1 1 1 1 and B= 0 1 0 1

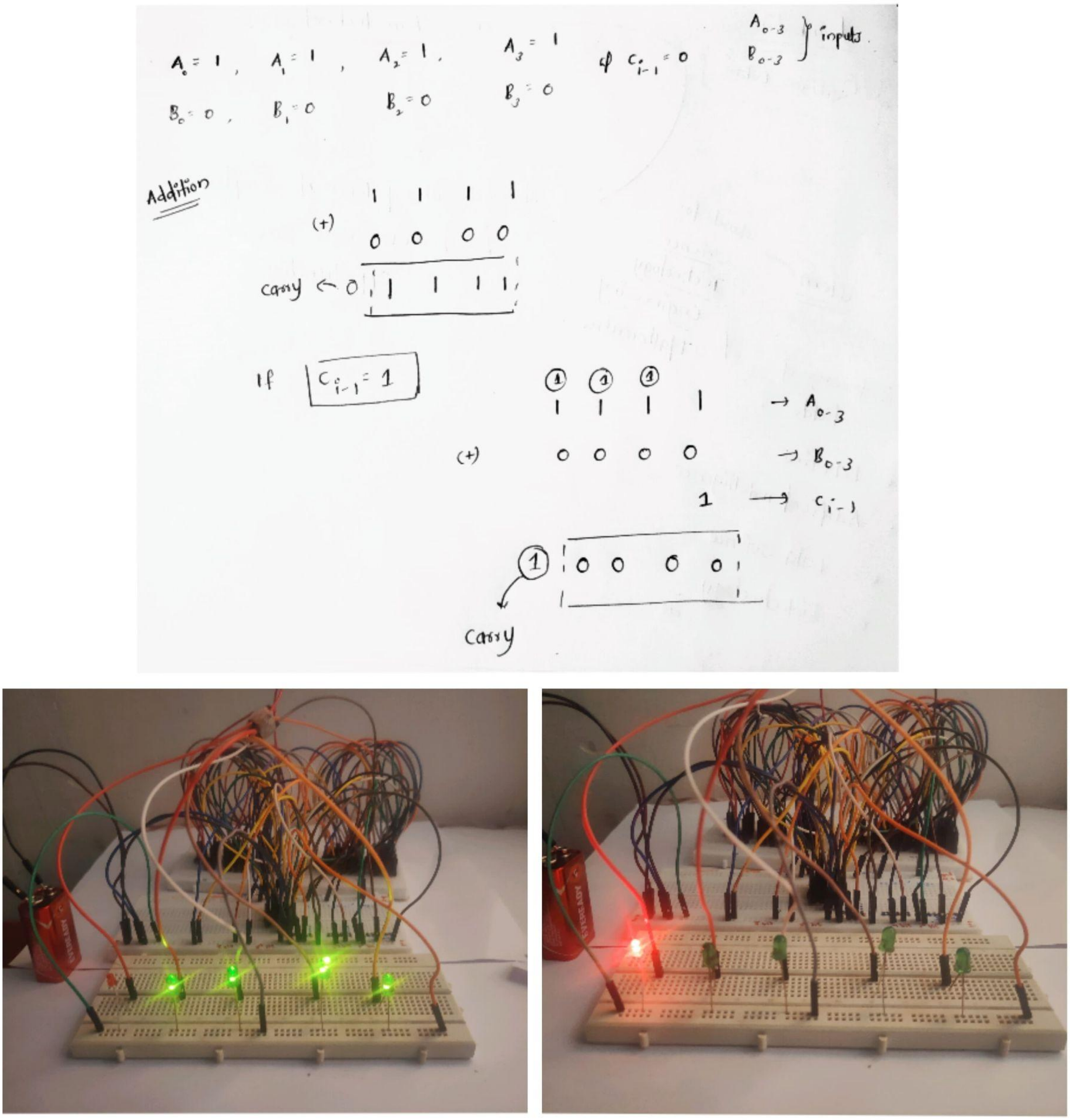
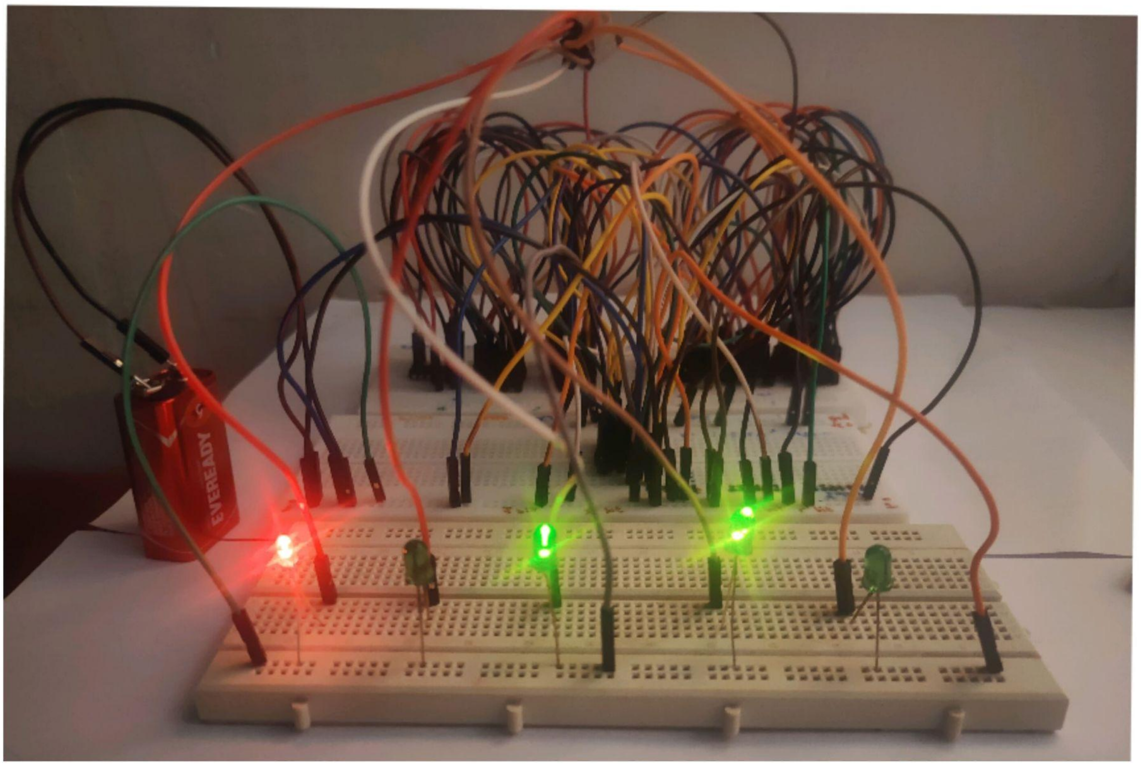


Fig 4.2 Addition example 2

4.2 Subtractor

Subtraction of B from A

A = 1011   and   B = 0101



If A = 1011 & B = 0101 find A+(-B). = A - B.

```
          2
A =     1 0 1 1
B = (-) 0 1 0 1
       _________
        0 1 1 0
```

ignore the carry produced.

Fig 4.3 Subtraction example 1

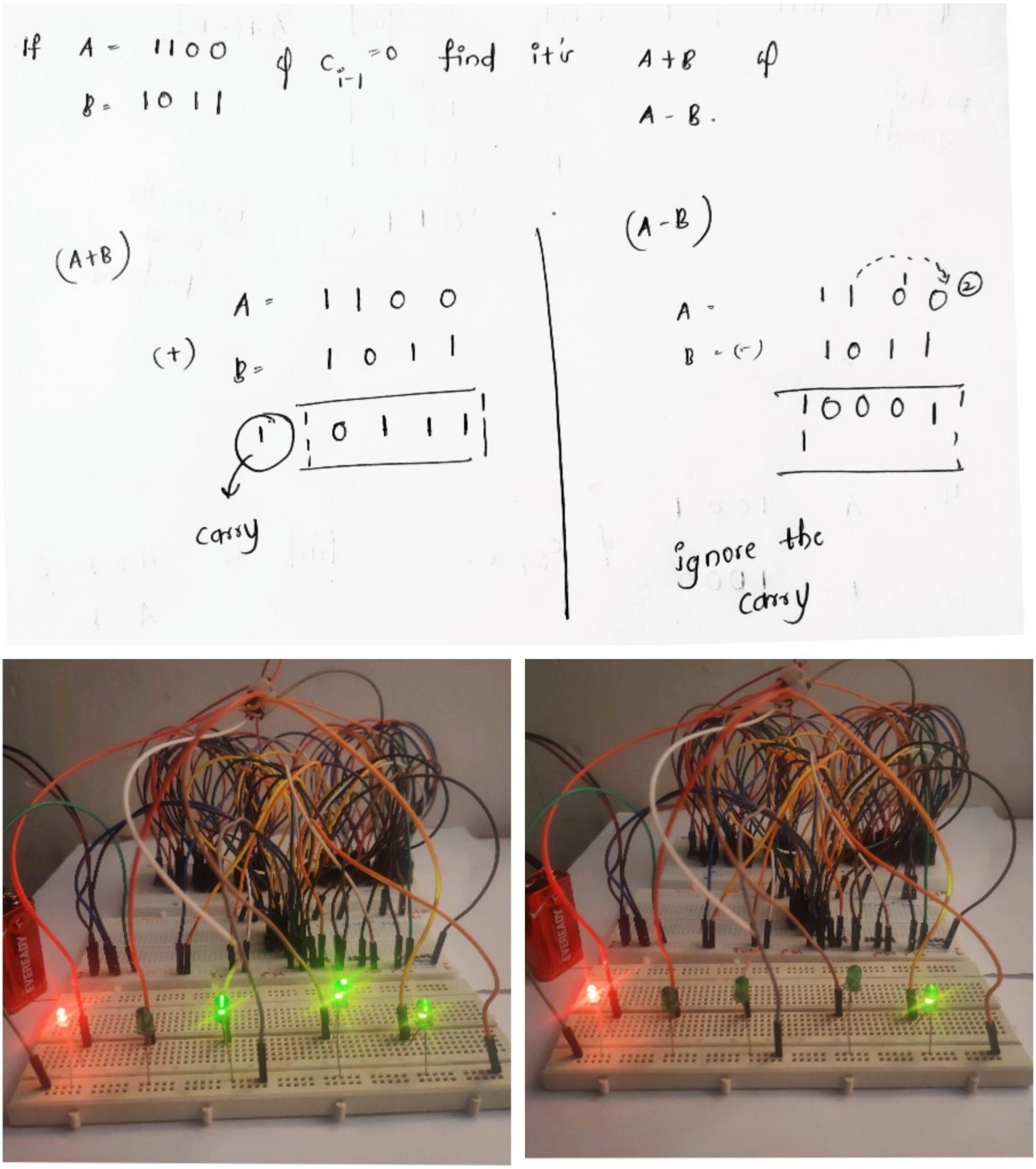
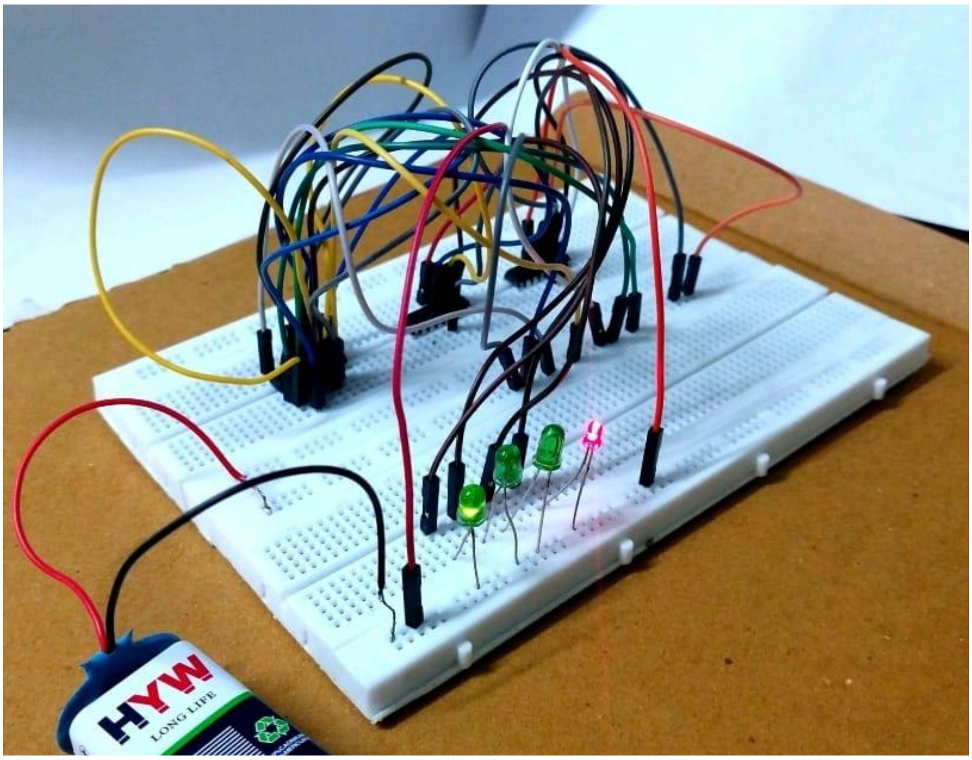


Fig 4.4 Subtraction example 2

4.3 Multiplier

Multiplication of A and B

A = 11   and   B = 11



Multiplier

A = 11 , B = 11

$$A \times B = \begin{array}{cccc} & & 1 & 1 \\ \times & & 1 & 1 \\ \hline & 1 & 1 & 1 \\ & 1 & 1 & \times \\ \hline 1 & 0 & 0 & 1 \\ \hline \end{array}$$

Carry bit

LSB (lit up)

Fig 4.5 Multiplication example

CHAPTER-5

CONCLUSION AND FUTURE SCOPE

5.1. CONCLUSION

We have always heard this saying,- Never believe an idea, until it can actually be realized.
We understand its explicit meaning. What is left for us to comprehend between the lines is, that often we have the illusion of having the right idea.It is our actions that speak loud enough to make us realize that we are yet not done with our search for the idea which perfectly fits our plan.

This might seem a bit philosophical, but science and philosophy have always complemented each other throughout the ages. This idea of actualizing the theory which we learn from lifeless books, is the biggest learning we can get from our project.

We started with a vision to build a calculator.Things seemed kind of impossible.The theories that we learnt were discrete.So we asked the question, what are the basic numbers which we have learnt since the introduction of computers in our life. The answer was simple. Zero and One.We are very familiar with these numbers, so we started with them.

In our btech course, we have been taught several courses like Digital logic design, Digital Electronics, Analog Electronics, Microprocessor... and many others. We had a very good theoretical base on these subjects.This gave us the confidence to use this knowledge to create a binary calculator, with the help of and, or and xor gates. Such a calculator would take binary numbers as an input .This number could be of the length of 4 bits. then the calculator would be able to add and subtract these numbers and give us a 4 bit output.
In Chapter 3, in depth discussion has been done to show how the adder and subtractor works.

As discussed earlier, under this heading, realizing the practical part was an ordeal to us.
With the use of basic knowledge we first arrived at circuit connection, which should have worked theoretically. But as we moved towards the implementation part, we started realizing different aspects, which was wrong with our theoretical conceptualization.
We had to find altogether new ways to implement the designs, and also to make it more comprehensible. We first tested a 1 bit adder and gradually moved on till the 4 bit adder adder and subtractor. Together we made a decision to stop at this juncture. We already have made a very complex circuit using a breadboard and more than a hundred jumper wires. After many trials, we are now getting the desired results in the addition and subtraction of 4 bit adder and subtractor. This has been an achievement for us.

Now we also wanted to not just limit the capabilities of our calculator. So we proceeded further and tried to include a multiplication function to our calculator. This part was very tricky and complex. We knew that multiplication is nothing but a series of addition.So we started to design this idea.

It was soon enough that we realized that we would not be able to implement such a simplified idea. We would have to find a new approach. This process took time.
Working with the breadboard and jumper wires is only good when we try to implement short formats of bits. We stumbled upon a beautiful IC called IC 7483, which is also called a full adder. This IC would help us to skip the big impractical addition part.Moreover we break the multiplication process into different parts, where using gates we can multiply each bit and using the full adder IC 7483, we were able to do the required addition part.

This proved to be a success. We were able to design a 2 bit multiplier, although we could only partially celebrate this success as there were some malfunctioning of the ICs.
Nevertheless, we were able to theoretically design a multiplier which we can practically realize.

We are now at a situation where we can claim that our project of "Digital Calculator", is a success with minor bumps. There is an infinite possibility to improve this calculator, which is discussed under the next heading.

5.2. FUTURE SCOPE

This project has taught us a lot. A lot many times we failed. But persistence is the key, that will help us grow.

Our calculator can be a lot different and much more advanced than what we have built now. A very interesting part of the project will be division. It's quite funny that we generally don't study in our theory how a binary division is done. Definitely it's not going to be the same as the process that we apply for rational numbers. But given a chance again, we would like to work and explore how the function of division can be added to our calculator.

The Multiplication that we have used, cannot actually be fully realized. Theoretically we should be getting the results but we are getting only partial success in the practical. Another upgrade that we would like to do is to increase the input length of the multiplier from 2-bit to at least 4-bit multiplier.

For the addition and subtraction functioning of the calculator, it has a very good future scope to expand to 16 bits, or maybe up to 32 bits. Jumper wires should be replaced with an alternative that occupies less of an area. Some more smart designing can be done to reduce the complexity of the circuit.

This we believe is just a start. We have tried to use only the very basics of the components. In the future stages we can proceed further by using powerful IC. This will help us skip the lengthy process of addition and subtraction and we would be able to design a much more powerful calculator.

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