JAYPEE UNIVERSITY OF ENGINEERING & TECHNOLOGY, GUNA
DEPARMENT OF COMPUTER SCIENCE & ENGINEERING
Course: Computer Organization & Architecture Lab
Course Code: CS208/18B17CI474
B. Tech. (CSE IV/VI Sem.)

Experiment # 2

Aim: Design of binary adders and subtractors.

Basic binary adders/subtractors are the type of combinational digital circuits (output depends only on present inputs not the previous output and do not require clock signal) that combine binary values to obtain sum/difference. These are the most basic operators of the digital circuits. These are classified according to their ability to accept and combine the number of input bits as followings:-

- **Half Adder/Subtractor**
  - Performs the addition/subtraction of two bits and gives the two outputs sum/difference and carry/borrow. There may be a quarter adder/subtractor that combines two bits and produces only the single (sum/difference) output without carry/borrow.
  - The inputs of half adder/subtractor are known as augend/minuend and addend/subtrahend.
  - Major disadvantage of the half adder/subtractor circuit is that there is no provision for a "carry/borrow-in" from the previous circuit.
- **Full Adder/Subtractor**
  - Performs the addition/subtraction of three bits (two significant bits to be added and one carry/borrow bit from previous circuit) and gives the two outputs sum/difference and carry/borrow.
  - Two half adders/subtractors and one OR gate are needed to implement one full adder/subtractor.

Half Adder

Logic Diagram

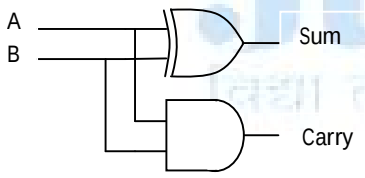

Figure 1: Half Adder

Half Subtractor

Logic Diagram

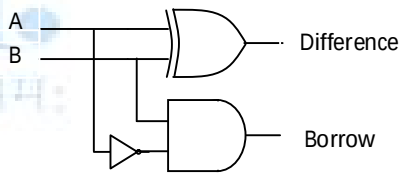

Figure 2: Half Subtractor

Full Adder

Logic Diagram

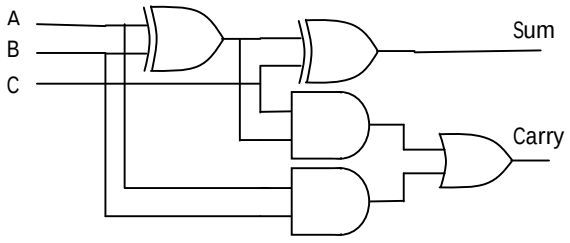

Figure 3: Gate level diagram of full adder

Full Subtractor

Block Diagram

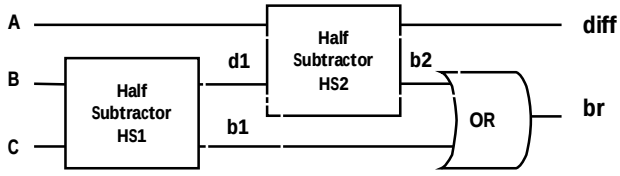

Figure 4: Full subtractor using two half subtractors

- **Ripple Carry Adder:** A ripple carry adder (RCA), also known as parallel adder, is a digital circuit that produces the arithmetic sum of two n-bit binary numbers. It can be implemented with one half adder and n-1 full adders connected is cascaded, with the carry ripples from each full adder connected to the carry input of the next full adder in the chain. Therefore, in the RCA, the sum of the most significant bit is only available after the carry signal has rippled through the adder from the least significant stage to the most significant stage. The block diagram of 4-bit ripple carry adder is shown here below :–

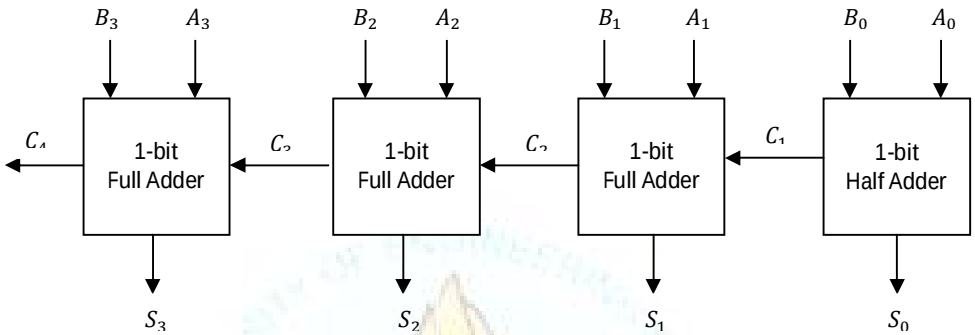

Figure 5: 4-bit ripple carry adder

- **4-bit Binary Adder-Subtractor:** The subtraction of binary numbers can be done most conveniently by means of complements i. e. A – B can be done by taking the 2's complement of B and adding it to A which can be written as A+$\overline{B}$+1. Both addition and subtraction operations can be combined into one common circuit by including an exclusive-OR gate with each full-adder. A 4-bit adder-subtractor circuit is shown in Fig. 2. The initial carry C_0 controls the operation. When C_0 = 0 the circuit is an adder and when C_0 = 1 the circuit becomes a subtractor. Each exclusive-OR gate receives input C_0 and one of the inputs of B. When C_0 = 0, we have B $\oplus$ 0 = B. The full-adders receive the value of B, the initial carry is C_0, and the circuit performs A plus B. When C_0 = 1, we have B $\oplus$ 1 = $\overline{B}$ and C_0 = 1. The B inputs are all complemented and a 1 is added through the input carry.

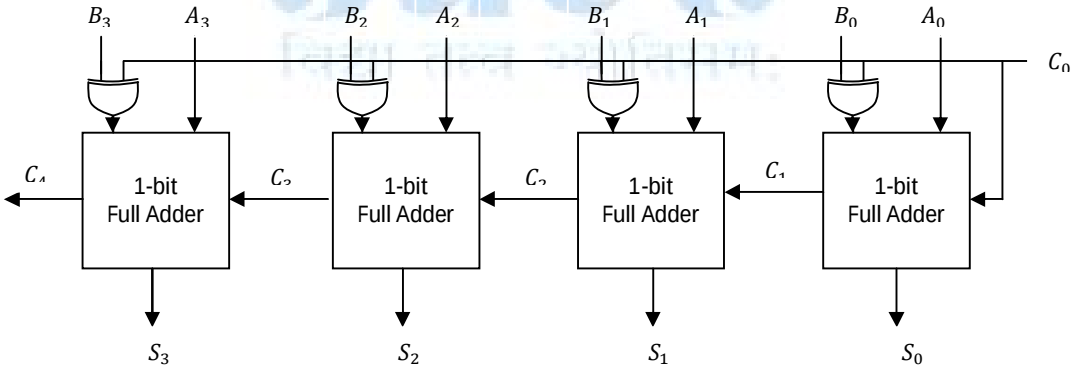

Figure 6: 4-bit Adder-Subtractor

Exercise#1: Design and verify half adder and half subtractor shown in Fig. 1 and Fig. 2 using logisim simulator.

Exercise#2 Design and verify full adder using logisim simulator (i) basic gates only shown in Fig. 3 (ii) by adding half adder (without in-built blocks) as sub circuit similar as shown in Fig. 4.

Steps to get a sub circuit:

- Design a properly labeled circuit to be used as a sub circuit (half adder in this case). Keep only one design on canvas area while designing this circuit.
- Go to **Project >> Add circuit.**
- Input circuit name as target circuit (**Full Adder** in this case).
- Replace **main** with name of sub circuit (**Half Adder** in this case).
- Go to sub circuit (**Half Adder** in this case) and drag it into canvas to build target circuit (**Full Adder** in this case).
- If needed, go to sub circuit (**Half Adder >> Edit Circuit Appearance**) to make changes in the facing of input-output pins as per requirements in the sub circuit. To make the changes in design go to sub circuit (**Half Adder >> Edit Circuit Layout**).

Exercise#3: Design 4-bit binary adder using one half adder and 3-full adders as shown in Fig. 5. Use half adder and full adders as sub circuits in the design. Display both the input digits; output digit and end carry digit using **Hex digit display with splitter** available in logisim simulator.

Design Steps:

- Use sub circuit of half adder designed in Exercise#2.
- Get sub circuit of full adder followings the steps given in Exercise#2.
- Get the design of 4-bit binary adder using above two sub circuits, two hex displays and two splitters at in input side, and two hex displays and two splitters at in output side.

Exercise#4: Design 4-bit binary adder-subtractor using full adders as shown in Fig. 6. Use full adders as sub circuits in the design. Display both the input digits, initial carry digit; output digit, and end carry digit using **Hex digit display with splitter** available in logisim simulator.