— Lecture - 5 | 21 Aug, 2019 —

Last Lecture :-

— Basic arithmetic circuit design
- Half adder (to add two single bit)
- Full adder (to add three single bit)
- n-bit ripple carry adder (to ~~n-bit~~ two n bit numbers)
- Adder Subtractor (to add or subtract two n-bit number)

Today's Lecture :-

— Multiplier Design

— ALU Design

Multiplier Design :-

Two bit Multiplication :-

b_0	a_0	Mul
0	0	0
0	1	0
1	0	0
1	1	1

} AND operation

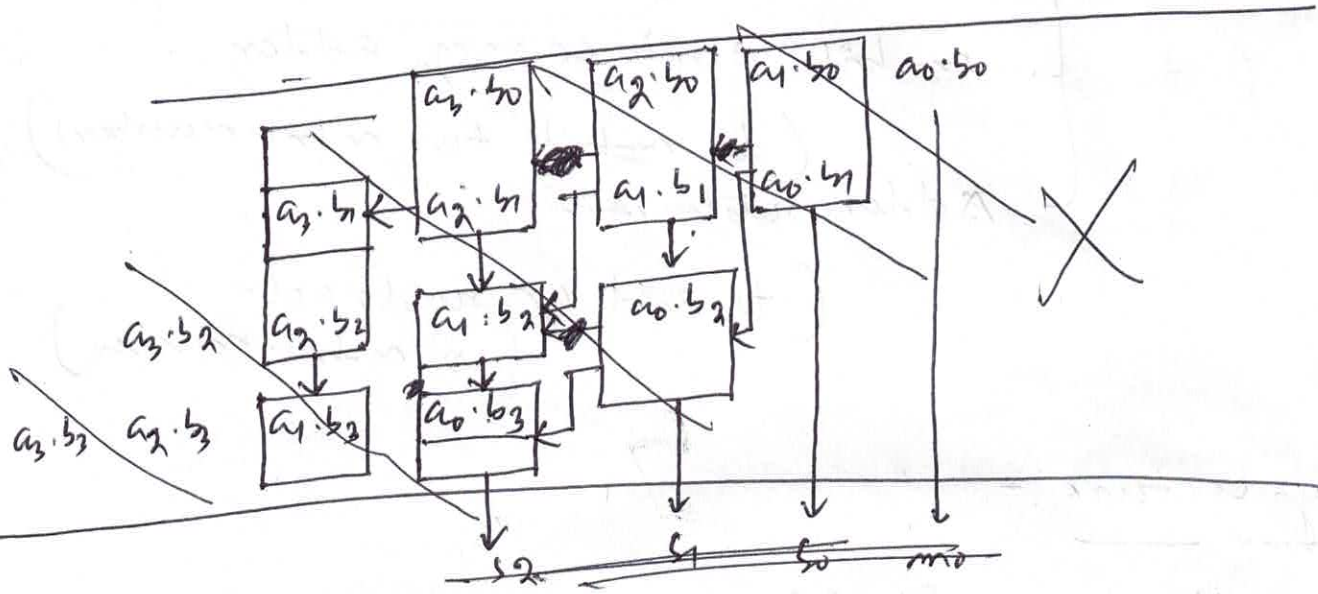
→

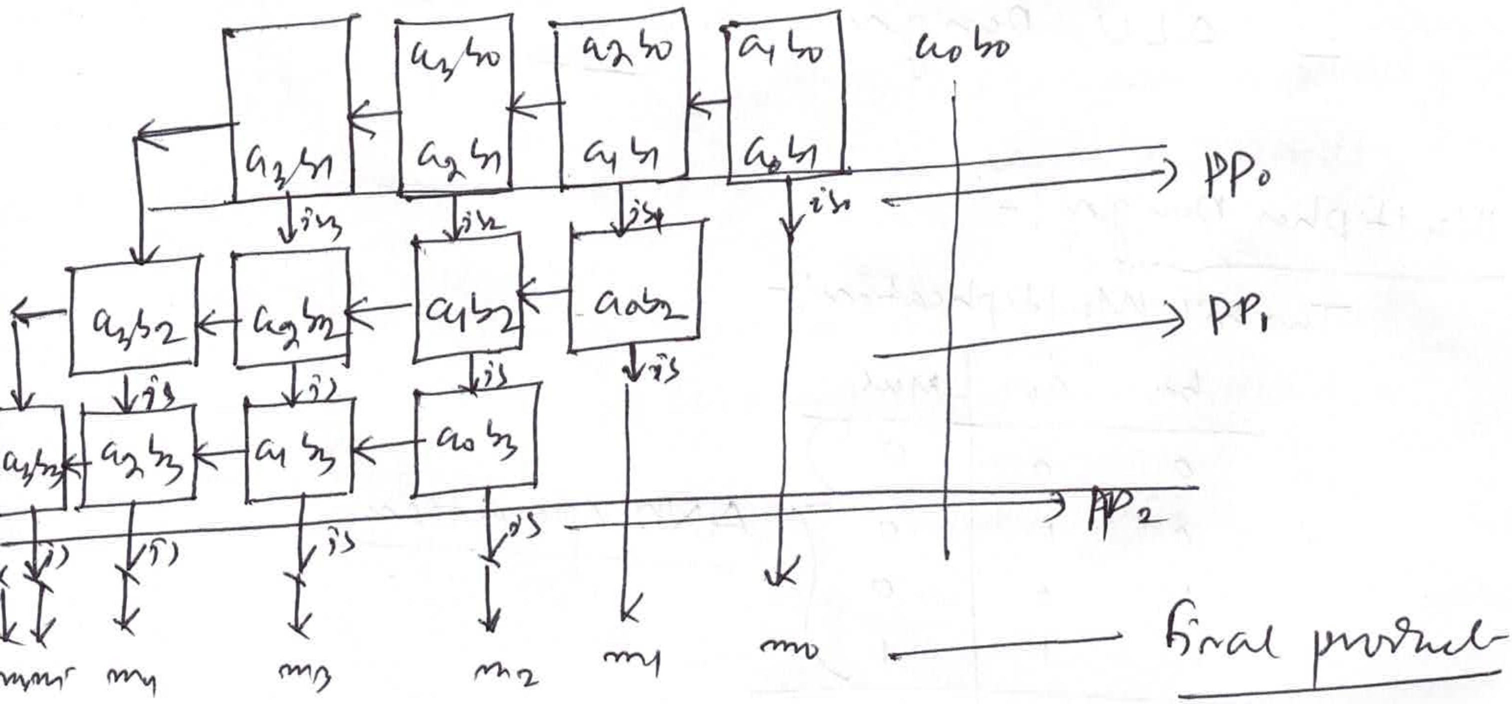
② Multiplication of two n-bit numbers

Lets try for 4-bit number :-

$a_3 \quad a_2 \quad a_1 \quad a_0$

$b_3 \quad b_2 \quad b_1 \quad b_0$



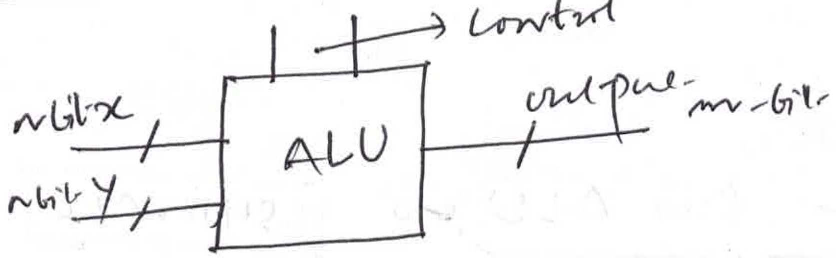


Basic Hw for Multiplier

→ Reuse the ripple carry adder layer by layer

ALU Design :-

~~Easy & inefficient way :-~~

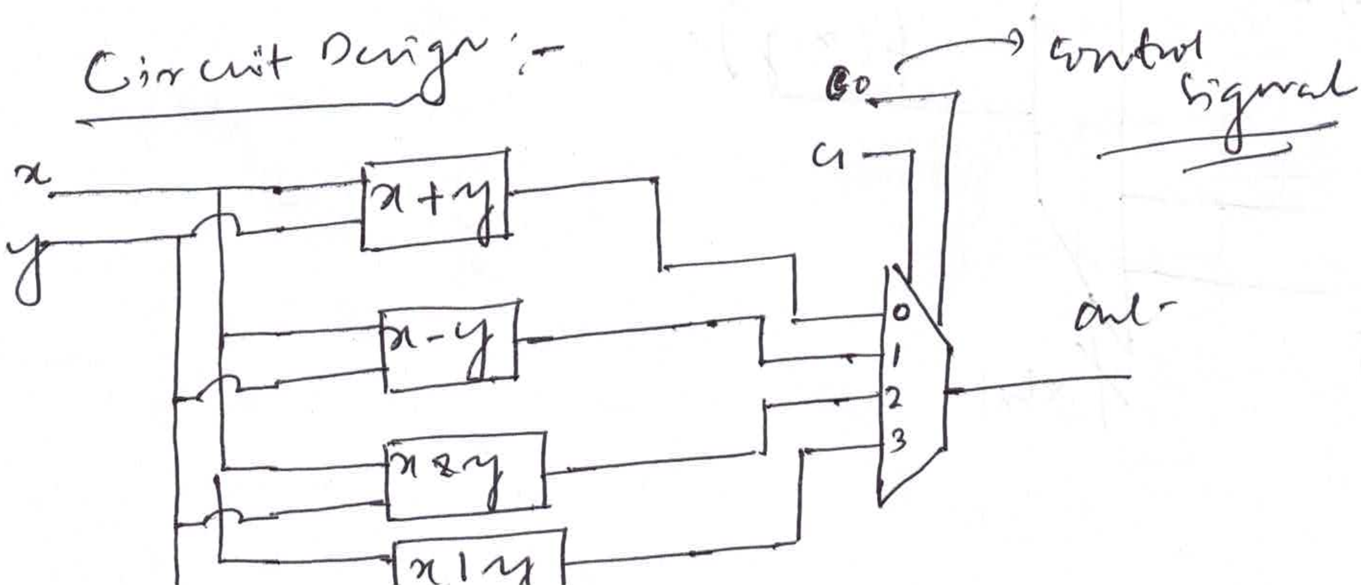


Easy & inefficient way of design :-

The required functionality -

- Addition (x+y)
- Subtraction (x-y)
- Logical And (x&y)
- Logical Or (x|y)

Circuit Design :-



(4)

Control signal

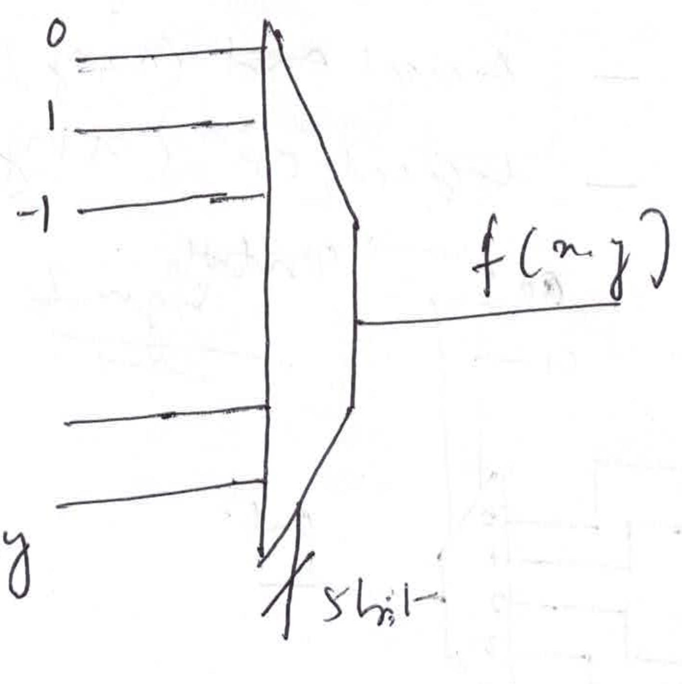
c_1	c_0	f(x,y)
0	0	ADD
0	1	SUB
1	0	AND
1	1	OR

~~Designing~~

Design of Our ALU in CS410ALU

Specification :- 16 bit, two input
16 bit, one output

Easy and in-efficient way of design :-



Efficient ALU Design :

Size – 16 bit & 32 bit

ALU16 | ALU32

Top view

Functionality :-

$0 =$

$1 =$

$-1 =$

$x =$

$y =$

$\bar{x} =$

$\bar{y} =$

$-x =$

$-y =$

$x+1 =$

$y+1 =$

$x-1 =$

$y-1 =$

$x+y =$

$x-y =$

$y-x =$

$x \& y =$

$x | y =$

$\overline{x \& y} =$

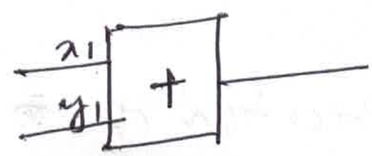
$\overline{x | y} =$

Design principles :-

1. Find out the compulsory unit.
2. Derive remaining ~~functional~~ functionality around ~~that~~ the compulsory unit.

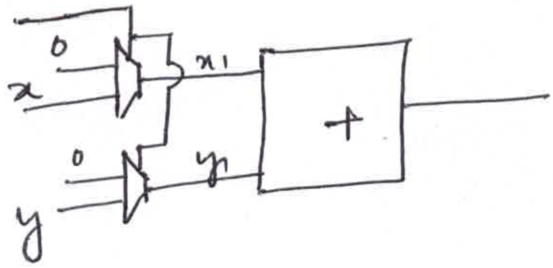
Compulsory Unit :-

Adder :- $x+y$



Specification for zero :-

Irrespective of any value in x & y the output should be zero.

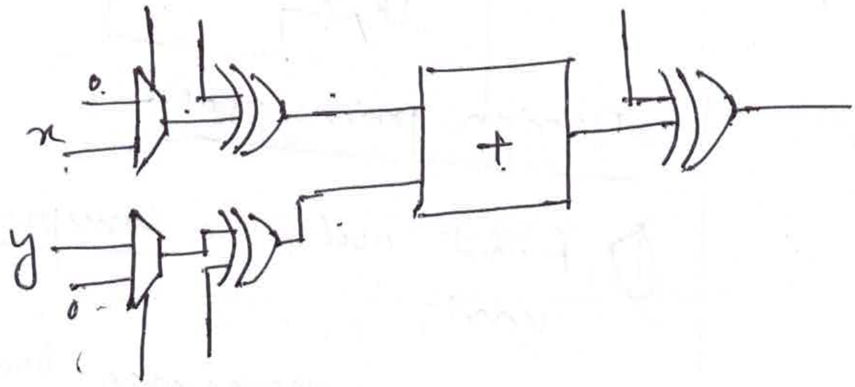


⑥

specification for one :-

$1 = \overline{(-1) + (-1)} = \overline{(-2)} = \overline{(110)} = 001$ ✓

$=$



specification for −1 :-

$-1 + 0 = -1$

irrespective of any input of x & y the output should be -1

specification of x :-

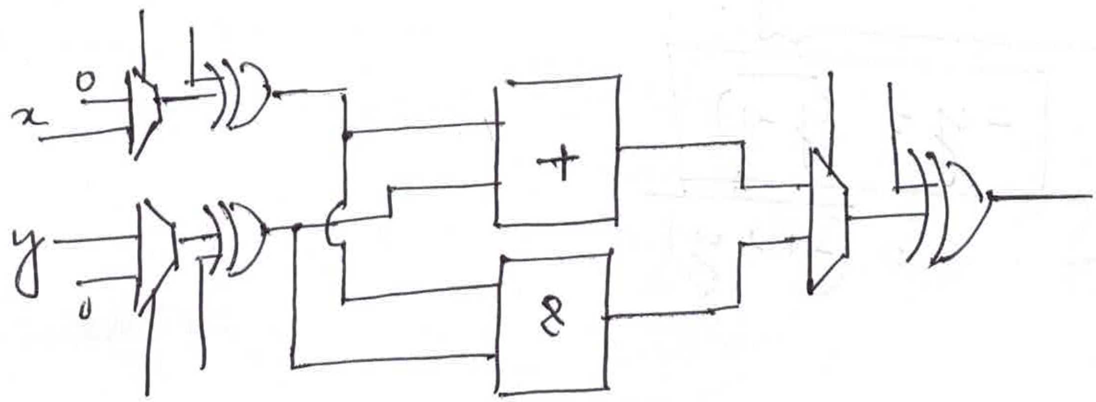
Irrespective of any input in y the output should always be x

$\rightarrow x + 0$

$\rightarrow x \,\&\, (-1) = x \,\&\, (1111\ldots1) = x$

$= x \,\&\, \overline{(0000\ldots0)}$

$= x \,\&\, \bar{0}$



specification for y :- Always 'y' irrespective of x

$\rightarrow$ $0 + y$

$\rightarrow$ $(-1) \& y$

specification for $\bar{x}$:-

$\rightarrow$ $\bar{x} = \overline{x \& (-1)}$

$\rightarrow$ $\bar{x} = \overline{(x + 0)}$

specification for $\bar{y}$:-

$\rightarrow$ $\bar{y} = \overline{((-1) \& y)}$

$\rightarrow$ $\bar{y} = \overline{(0 + y)}$

specification for $-x$:-

$-x = \bar{x} + 1$

$\Rightarrow -x - 1 = \bar{x}$

$\Rightarrow -(z - 1 + 1) = \overline{(z-1)}$ (let $x = z - 1$

$\Rightarrow -z = \overline{(z-1)}$ $\rightarrow$ $\boxed{-x = \overline{(x-1)}}$

⑧

specification for $-y$:-

$$-y = \overline{(\bar{y}-1)}$$

$$= \overline{(-1+\bar{y})}$$

specification for $(x+1)$:-

$$-x = \bar{x}+1 = \overline{(x-1)}$$

$$\Rightarrow y+1 = \overline{(\bar{y}-1)} \quad (\text{let } \bar{x} = y)$$

$$\Rightarrow x+1 = \overline{(\bar{x}-1)} \quad (\text{let } x = y)$$

$$= \overline{\bar{x}+(-1)}$$

specification for $(y+1)$:-

$$y+1 = \overline{((-1)+\bar{y})}$$

specification for $(x-1)$:-

$$x-1 = x+(-1)$$

specification for $(y-1)$:-

$$y-1 = (-1)+y$$

Specification for $(x+y)$:-

$$\boxed{x+y = x+y}$$

$\Rightarrow$ out $= x+y$, for $x=x$ & $y=y$

~~specification~~

Specification for $(x-y)$:-

$$\boxed{out = x-y}$$ for $x=x$ & $y=y$

$-x = \bar{x}+1$

$\Rightarrow -x-1 = \bar{x}$

$\Rightarrow -x+y-1 = \bar{x}+y$

$\Rightarrow -(x-y)-1 = \bar{x}+y$

$\Rightarrow -z-1 = \bar{x}+y$ (let $x-y=z$)

$\Rightarrow \bar{z} = \bar{x}+y$

$\Rightarrow \overline{x-y} = \bar{x}+y$ (let $z=x-y$)

$$\Rightarrow \boxed{x-y = \overline{(\bar{x}+y)}}$$

Specification for $(y-x)$:-

$$y-x = \overline{(\bar{y}+x)}$$

$$\boxed{y-x = \overline{(x+\bar{y})}}$$

<u>specification for (x & y) :-</u>

| Out = x & y | when x = x and y = y

<u>specification for (x | y) :-</u>

out = x | y (OR operation)

$x | y = \bar{x} \& \bar{y}$

<u>Exercise :-</u>

Find out the control signal for following :-

(e1) . Nand → $\overline{x \& y}$ → Easy

(e2) Nor → $\overline{x | y}$ → Easy

(e3) XOR → $x \oplus y$ → Moderate difficulty

(e4) XNor → $\overline{x \oplus y}$ → Moderate difficulty.

~~(e5)~~ → Multiplication → x * y

↳ this will require additional functional unit and a control signal.

(e5) Comparator :-
- Less than x<y
- Equal x=y
- greater x>y

(e6)