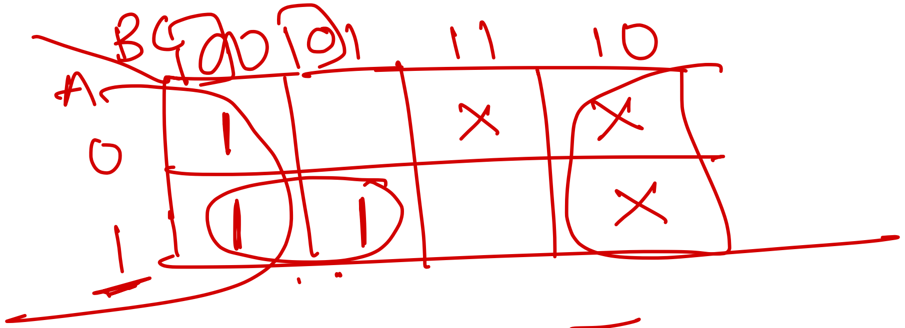
K-Map

- Simplify the Boolean function F= x’y’z + x’yz +xy’
- Simplify the Boolean function F(A,B,C) =$\Sigma(1,5,6,7)$
- Simplify the Boolean function F(A,B,C) =$\Sigma(0,1,3,4,5)$
- Simplify the Boolean function F(A,B,C,D) =$\Sigma(0,2,4,6,8,9,10)$
- Don’t care condition
  - F(A,B,C) = $\Sigma(0,4,5)$ are minterms (2,3,6) are don’t care

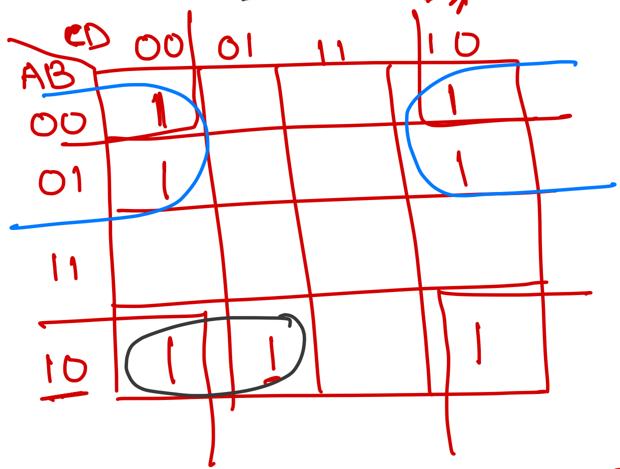


$= \overline{C} + A\overline{B}$

- Simplify the Boolean function $F(A,B,C,D) = \Sigma(0,2,4,6,8,9,10)$

$SOP = \Sigma = 1$

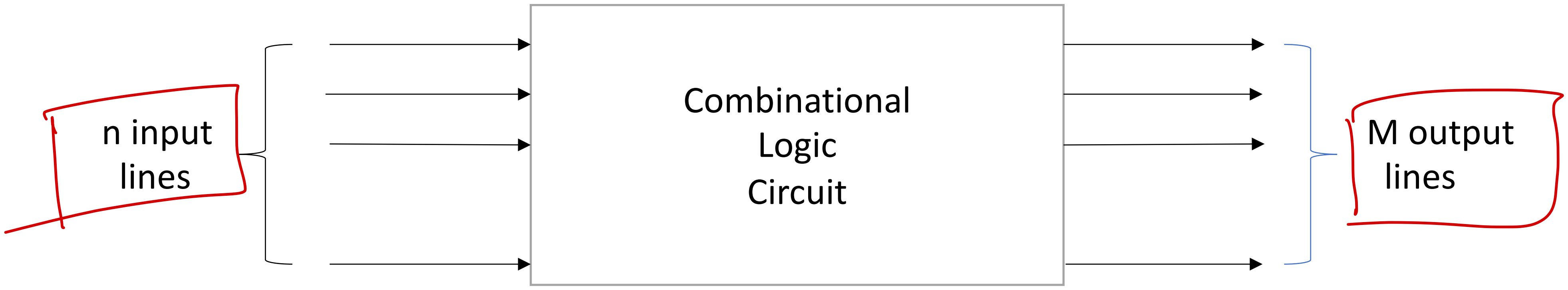
$POS = \Pi = 0$



$= \bar{B}\bar{D} + \bar{A}\bar{D} + A\bar{B}\bar{C}$.

Combinational Logic Circuit

- **Combinational Logic Circuits** are made up from basic logic AND, OR, NAND, NOR, or NOT gates that are "combined" or connected together to produce more complicated switching circuits.
- The logic gates are combined in such a way that the output state depends entirely on the input states. Combinational logic circuits have no memory.
- Examples of common combinational logic circuits include: half adders, full adders, multiplexers, demultiplexers, encoders and decoders
- A combinational circuit consists of Input variables, Logic gates, Output variable



Half Adder

$$\begin{array}{r} 1 \\ +\ 1 \\ \hline 1\ 0 \end{array}$$

- A half adder adds two one-bit binary numbers A and B.
- It has two outputs:
  - Sum (S)
  - Carry(C)

Symbol dia.

2 i/p

2 o/p

K-Map.

Sum.

A \ B	0	1
0		1
1	1	

$= A\bar{B} + \bar{A}B$

$= A \oplus B$

Carry.

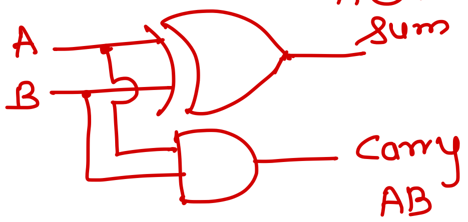
A \ B	0	1
0		
1		1

$= AB$

TT.

A	B	S	C
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

- Equation For SUM and CARRY :
  - SUM = $A \oplus B$
  - CARRY = AB

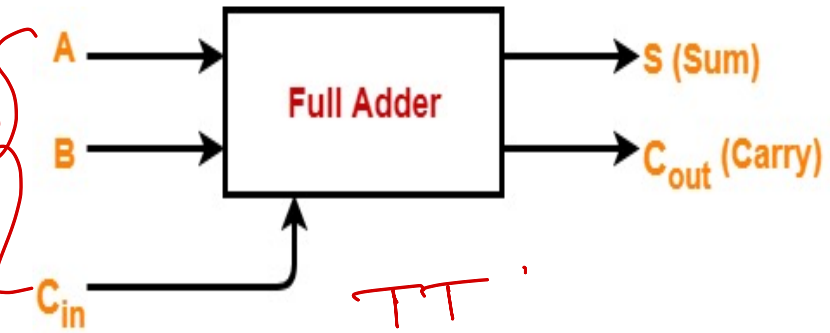


- **Limitation of Half Adder-**
- Half adders have no scope of adding the carry bit resulting from the addition of previous bits.
- This is because real time scenarios involve adding the multiple number of bits which can not be accomplished using half adders.

Full Adder

- The full adder circuit has three inputs: A , B and C, which add three input numbers and generates a Output carry and sum.

3 i/p



2 o/p

TT

A	B	C	Sum	Carry
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

- Equation For SUM and CARRY :
  - SUM = $A \oplus B \oplus C$
  - CARRY = AB + AC + BC

Sum

A \ BC	00	01	11	10
0		1		1
1	1		1	

$= \bar{A}\bar{B}C + \bar{A}B\bar{C} + A\bar{B}\bar{C} + ABC$

$= \bar{C}(\bar{A}B + A\bar{B}) + C(AB + \bar{A}\bar{B})$

$= \bar{C}(A \oplus B) + C(\overline{A \oplus B})$

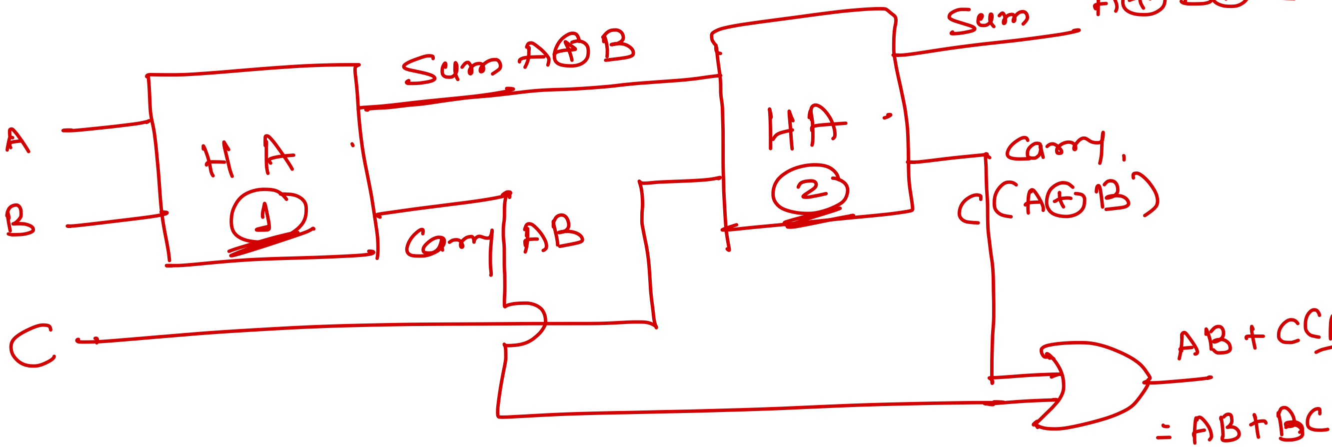
$= A \oplus B \oplus C$

Carry

A \ BC	00	01	11	10
0			1	
1		1	1	1

= BC + AC + AB

FA:



$$AB + \underbrace{C(A \oplus B)}$$

$$= AB + BC + AC.$$

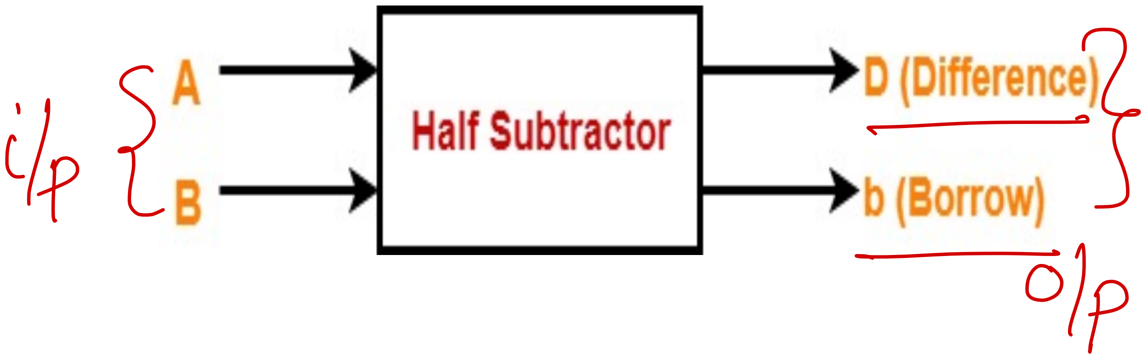
$$A \oplus B$$

$$= AB + A\overline{B}$$

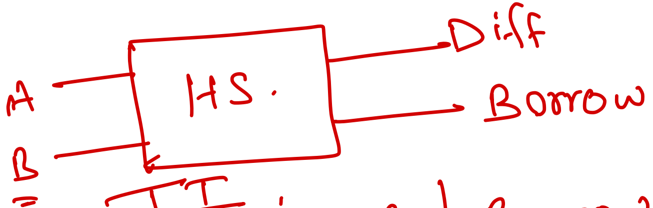
Half Subtractor

- The half-subtractor is a combinational circuit which is used to perform subtraction of two bits.
- It has two inputs, A (minuend) and B (subtrahend) and two outputs D (difference) and B (borrow)

- Equation for Difference and Borrow:
  - D = $A \oplus B$
  - B = A’.B



- **<u>Limitation of Half Subtractor-</u>**
- Half subtractors do not take into account “Borrow-in” from the previous circuit.
- This is because real time scenarios involve subtracting the multiple number of bits which can not be accomplished using half subtractors.



TT

A	B	Diff	Borrow
0	0	0	0
0	1	1	1
1	0	1	0
1	1	0	0

$$\begin{array}{r} 0 \\ -\,1 \\ \hline \end{array}$$

Diff.

A \ B	0	1
0		1
1	1	

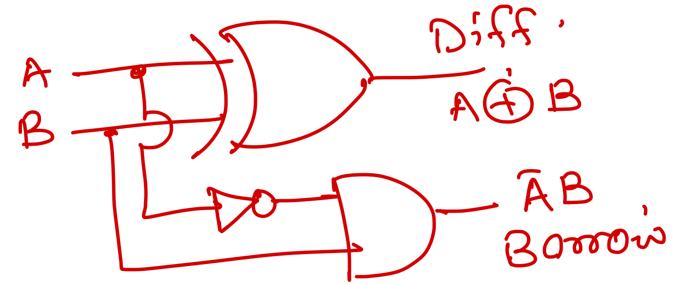
$= \bar{A}B + A\bar{B}$

$= A \oplus B$

Borrow.

A \ B	0	1
0		1
1		

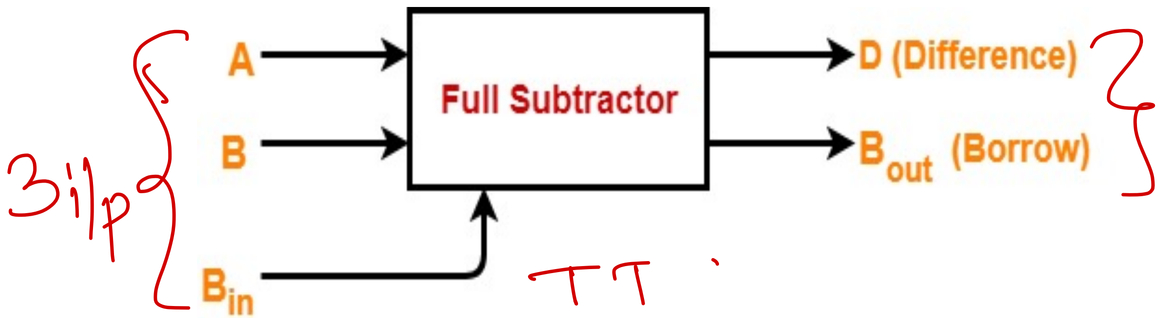
$= \bar{A}B$



Full Subtractor

- The full-subtractor is a combinational circuit which is used to perform subtraction of three bits
- It has three inputs, A(minuend) and B (subtrahend) and C (subtrahend) and two outputs D (difference) and B (borrow).

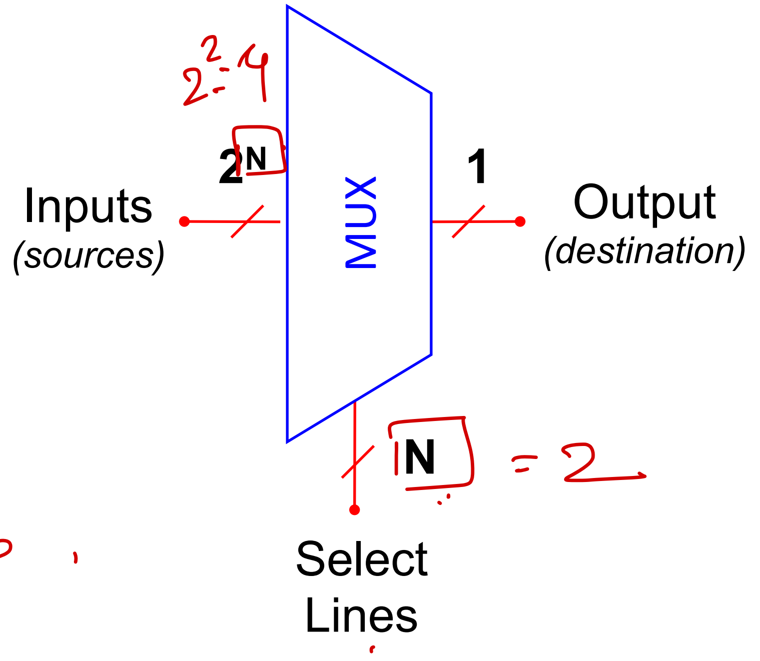
- Equation for Difference and Borrow:
  - $D = A \oplus B \oplus C$
  - $B = A'B + A'C + BC$

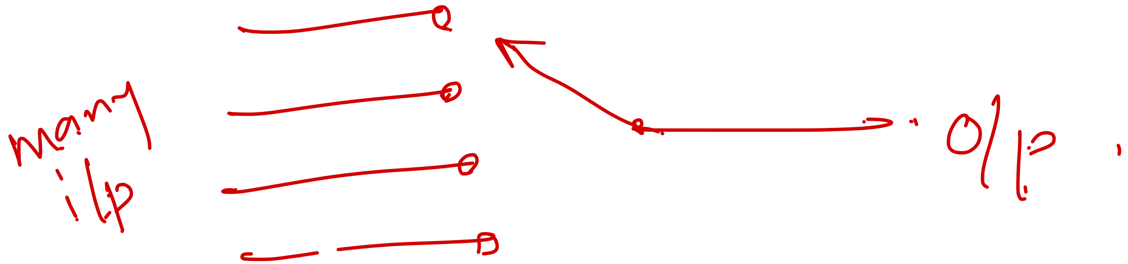


A	B	C	Diff	Borrow
0	0	0	0	0
0	0	1	1	1
0	1	0	1	1
0	1	1	0	1
1	0	0	1	0
1	0	1	0	0
1	1	0	0	0
1	1	1	1	1

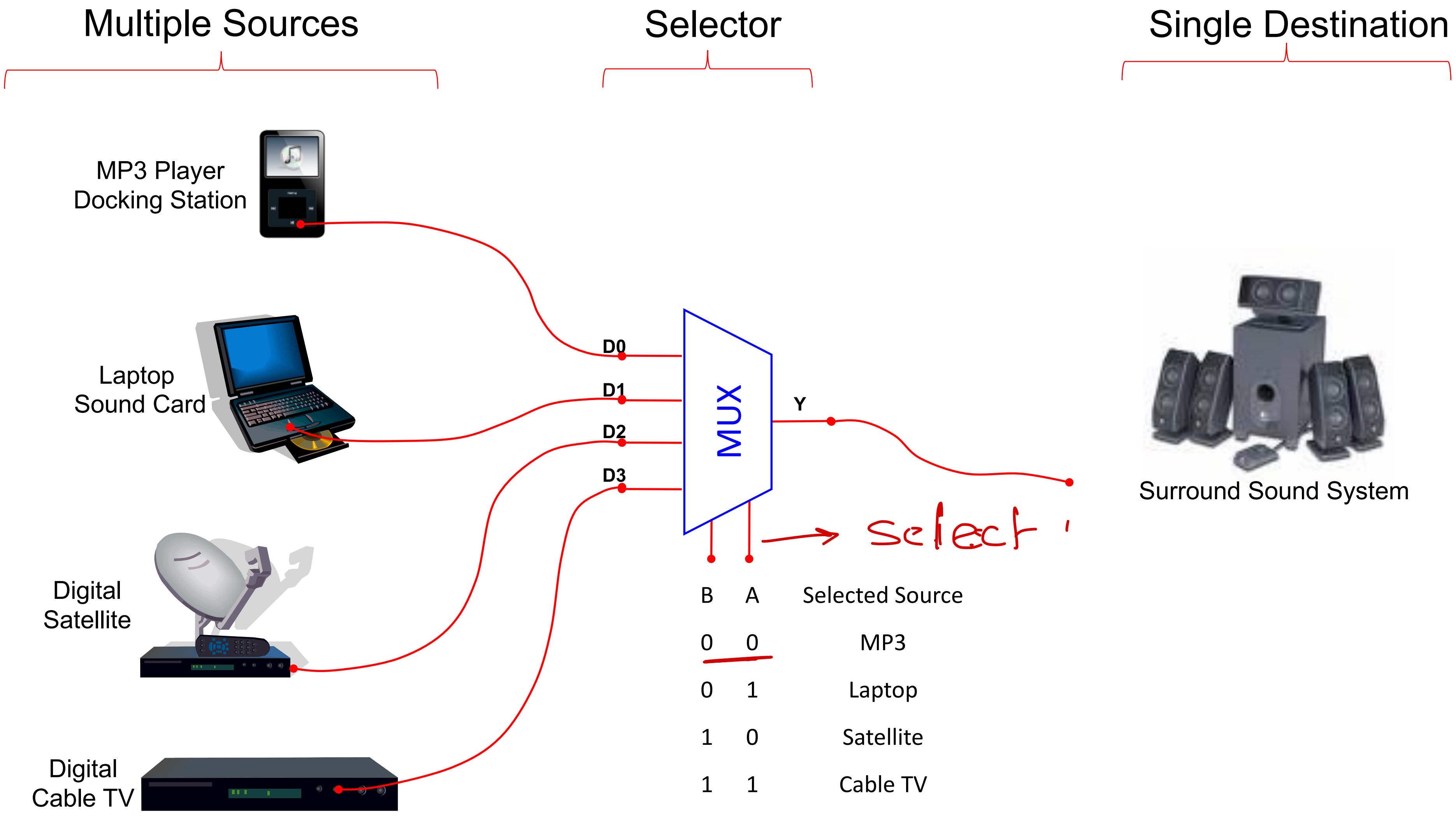
Multiplexer

- A MUX is a digital switch that has multiple inputs (sources) and a single output (destination).
- The select lines determine which input is connected to the output
- MUX Types
  - 2-to-1 (1 select line)
  - 4-to-1 (2 select lines)
  - 8-to-1 (3 select lines)
  - 16-to-1 (4 select lines)





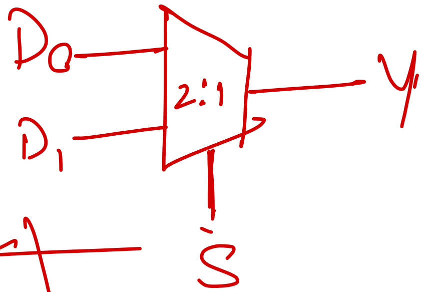
Multiplexer



B	A	Selected Source
0	0	MP3
0	1	Laptop
1	0	Satellite
1	1	Cable TV

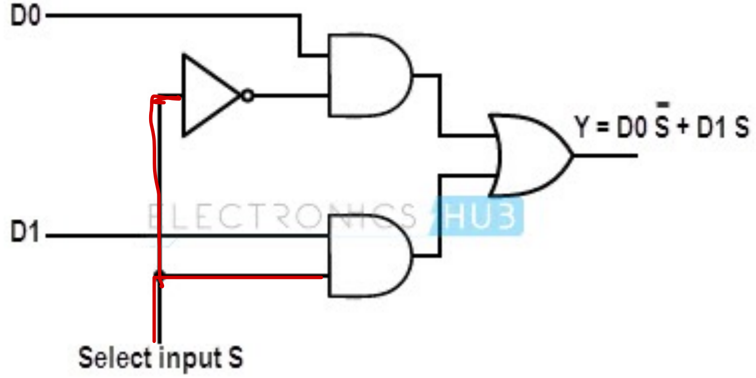
Multiplexer

- **2:1 MUX**



TT

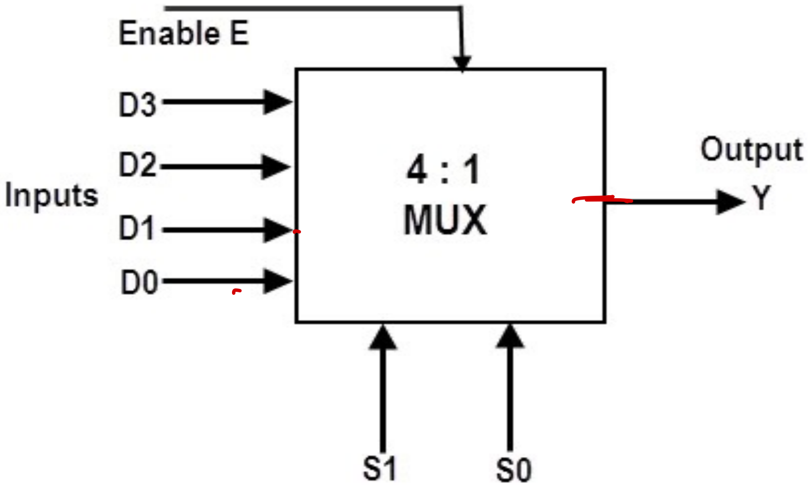
S	D0	D1	Y
0	0	0	0
0	0	1	0
0	1	0	1
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	0
1	1	1	1



S	Y
0	D_0
1	D_1

Multiplexer

- **4:1 MUX**



S_1	S_0	Y
0	0	D_0
0	1	D_1
1	0	D_2
1	1	D_3

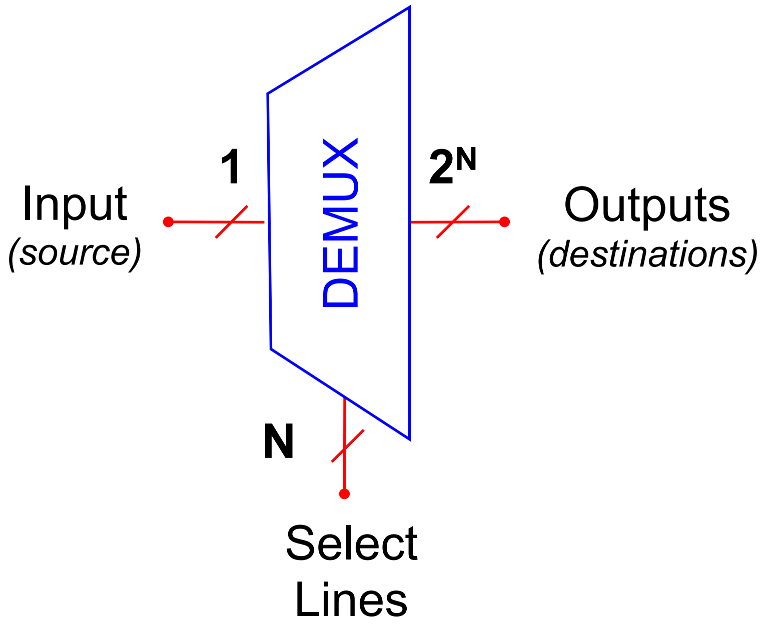
Multiplexer

Application of Multiplexer

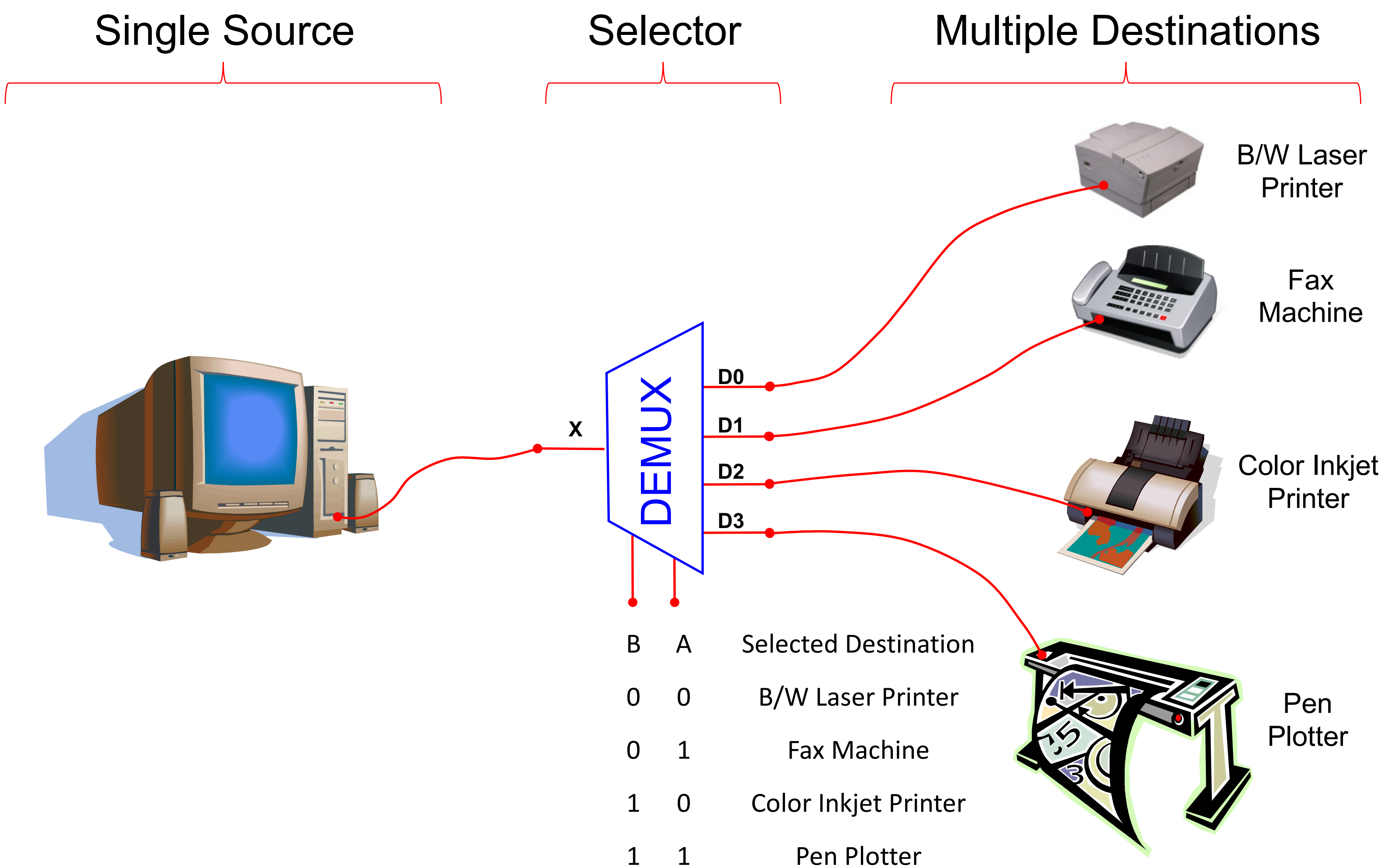
- Data Routing
- Parallel to Serial Conversion
- Time Multiplexing system
- Frequency Multiplexing System

Demultiplexer

- A DEMUX is a digital switch with a single input (source) and a multiple outputs (destinations)
- The select lines determine which output the input is connected to
- DEMUX Types
  - 1-to-2 (1 select line)
  - 1-to-4 (2 select lines)
  - 1-to-8 (3 select lines)
  - 1-to-16 (4 select lines)



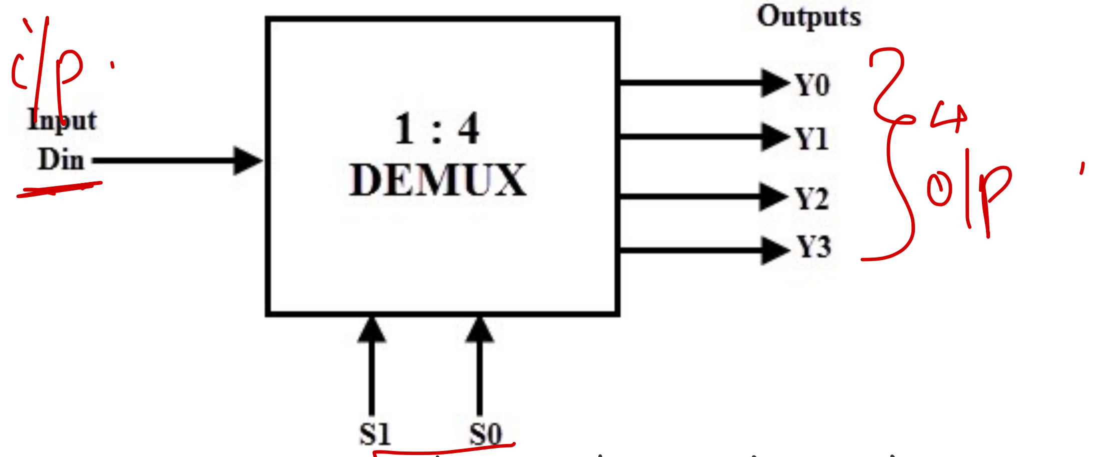
Demultiplexer



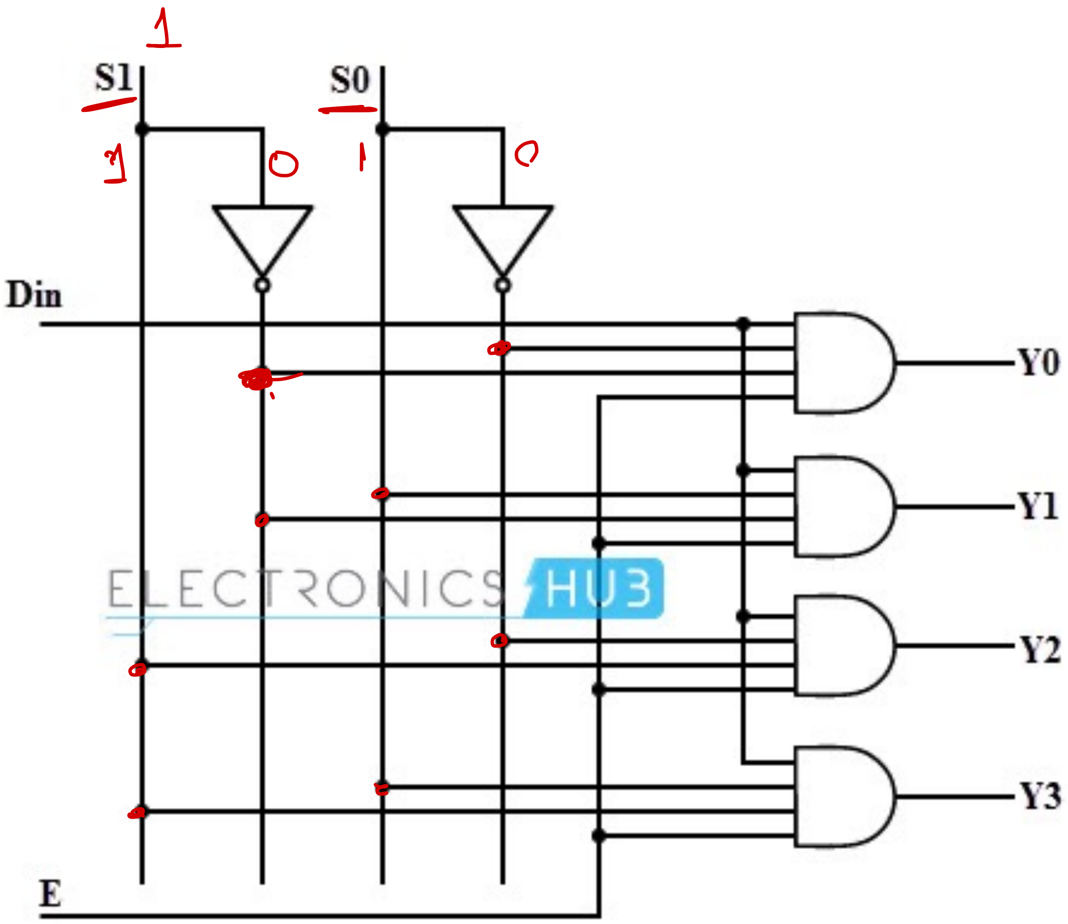
B	A	Selected Destination
0	0	B/W Laser Printer
0	1	Fax Machine
1	0	Color Inkjet Printer
1	1	Pen Plotter

Demultiplexer

- 1:4 DEMUX



S_1	S_0	Y_0	Y_1	Y_2	Y_3
0	0	D	0	0	0
0	1	0	D	0	0
1	0	0	0	D	0
1	1	0	0	0	D



Demultiplexer

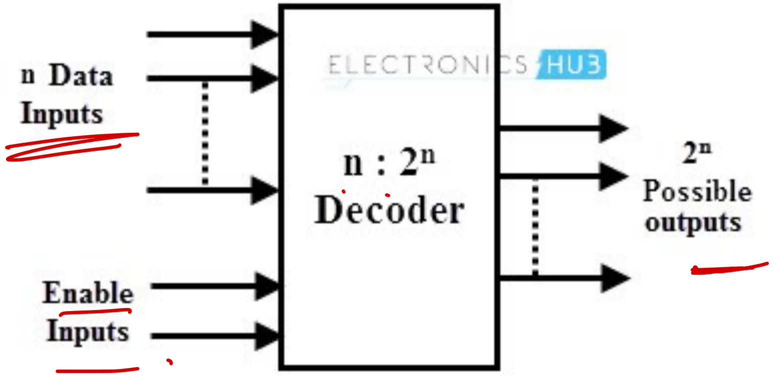
- **Applications of Demultiplexer**
- Synchronous data transmission systems
- Data acquisition systems
- Combinational circuit design
- Automatic test equipment systems
- Security monitoring systems (for selecting a particular surveillance camera at a time), etc.

Decoder

- A binary decoder is a multi-input, multi-output combinational circuit that converts a binary code of n input lines into a one out of 2n output code.
- n-to-m decoder → n input lines, m output lines where $m \leq 2^n$

i/p o/p
2 2^2 4

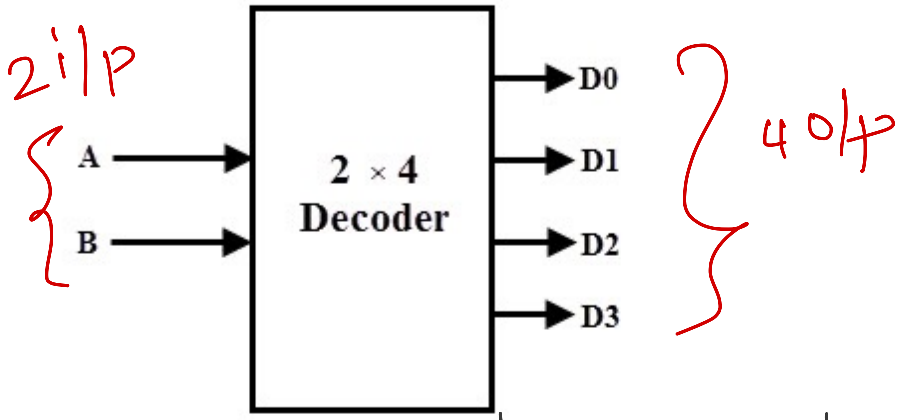
2 : 4



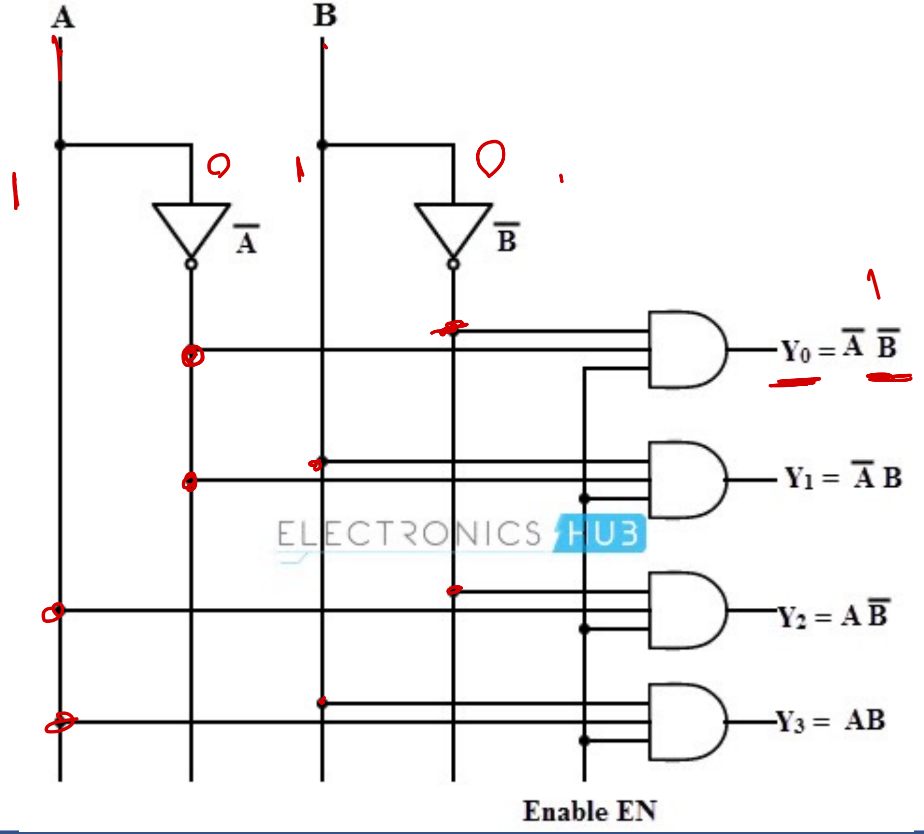
Decoder

2-to-4 Binary Decoder

- In a 2-to-4 binary decoder, two inputs are decoded into four outputs hence it consists of two input lines and 4 output lines. Only one output is active at any time while the other outputs are maintained at logic 0 and the output which is held active or high is determined the two binary inputs A and B.



A	B	D_0	D_1	D_2	D_3
0	0	1	0	0	0
0	1	0	1	0	0
1	0	0	0	1	0
1	1	0	0	0	1



Decoder

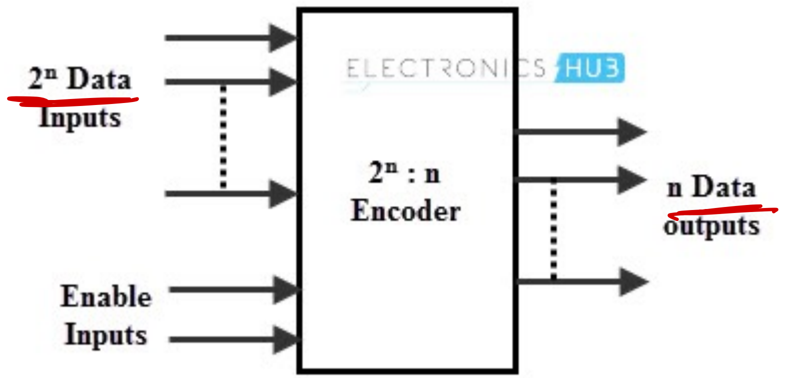
Applications of Decoders

BCD - 7Seg LED.

- Binary to Decimal Decoder
- Address Decoders
- Instruction Decoder

Encoder

- Inverse operation of a decoder.
- A binary encoder has 2n input lines and n output lines, hence it encodes the information from 2n inputs into an n-bit code. From all the input lines, only one of an input line is activated at a time, and depending on the input line, it produces the n bit output code.



Encoder

- **Encoder Applications**
- Encoders are very common electronic circuits used in all digital systems. In case of pocket calculators, these are used to translate the decimal values to the binary in order to perform the binary functions such as addition, subtraction, multiplication, etc.
- These are also used to generate the digital signals in response to the movement which are classified into shaft encoders and linear encoders.

Sequential Circuits

- Sequential circuit is a circuit whose output depends upon the present input, previous output and the sequence in which the inputs are applied.
- Sequential circuit has memory which are capable of storing binary information.

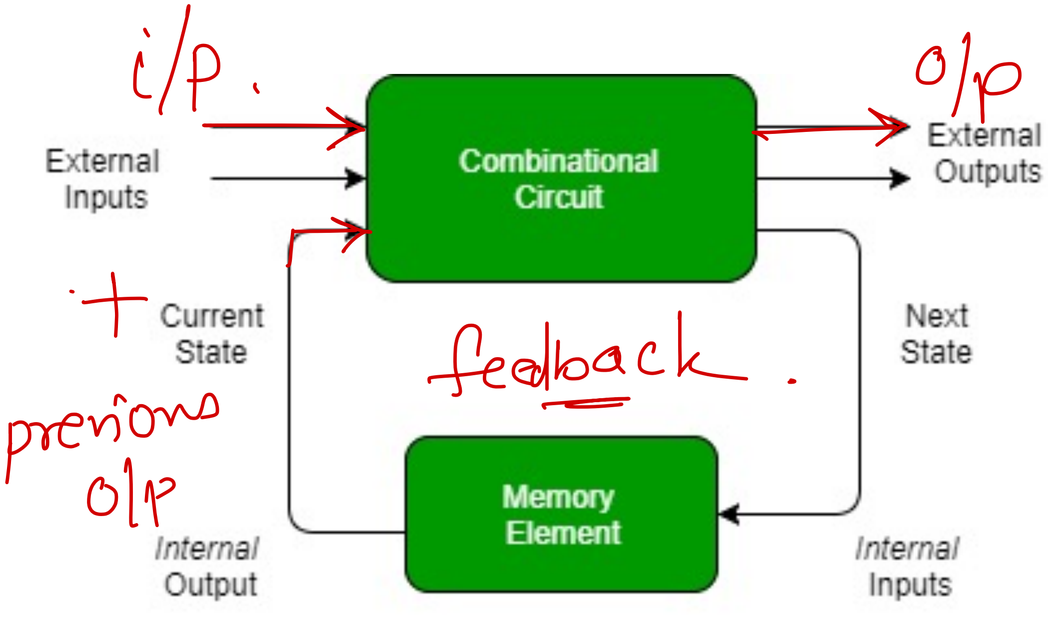
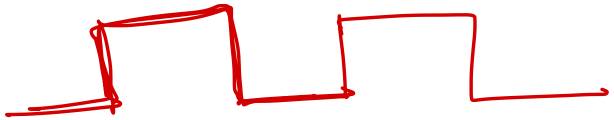


Figure: Sequential Circuit

1-bit

Sequential Circuit



- **Types of Sequential Circuits are**
  - 1 Asynchronous Sequential Circuit
  - 2 Synchronous Sequential Circuit

- **Asynchronous sequential circuit**
  - These circuit **do not use a clock signal** but uses the pulses of the inputs.
  - These circuits are **faster** than synchronous sequential .
  - These circuits are more **difficult** to design

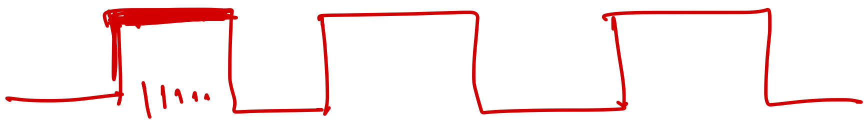
- **Synchronous sequential circuit**
  - These circuit **uses clock signal** and level inputs.
  - These circuits are bit **slower** compared to asynchronous
  - These circuits are **easier** to design .

Sequential circuit

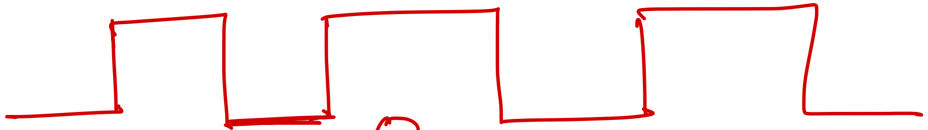
- **FlipFlop** → synchronous. → clk .
  - A flip-flop is a binary storage device capable of storing one bit of information. In a stable state, the output of a flip-flop is either 0 or 1.
  - Flip-flop operate with clock, so output changes only at the clock signal.
  - Flip flop is said to be edge sensitive
- **Latch** Asynchronous → enable .
  - Latch is a binary storage device capable of storing one bit of information.
  - Latch is an un-clocked flip-flop, so output changes at any instant of time doesn't depend on clock.
  - Latch is said to level sensitive.

Sequential circuit

en=1

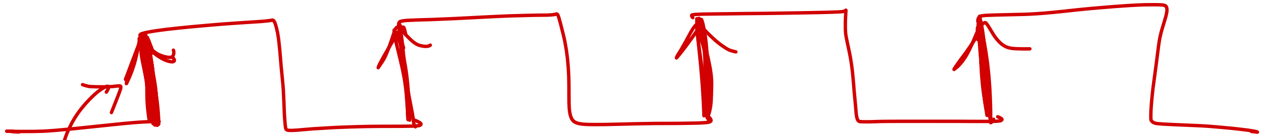


- **Positive Level –triggered**
  - The output changes during the **high** voltage period it is called positive level triggering.



en=0

- **Negative Level –triggered**
  - The output changes during the **low** voltage period it is called negative level triggering

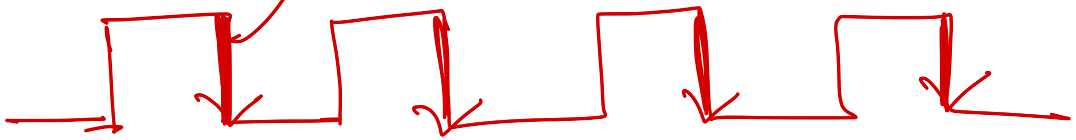


- **Positive-edge triggered**
  - An edge-triggered flip-flop changes states at the **positive edge** (**rising edge**) of the clock pulse

rising edge

falling edge

- **Negative-edge triggered**
  - An edge-triggered flip-flop changes states at the **negative edge** (**falling edge**) of the clock pulse



Squential Circuit

- A Flip Flop is a memory element that is capable of storing one bit of information.
- It is also called as **Bistable Multivibrator** since it has two stable states either 0 or 1.

- **Types of flip-flops**
  - SR Flip-Flop
  - D Flip-Flop
  - T Flip-Flop
  - JK Flip-Flop

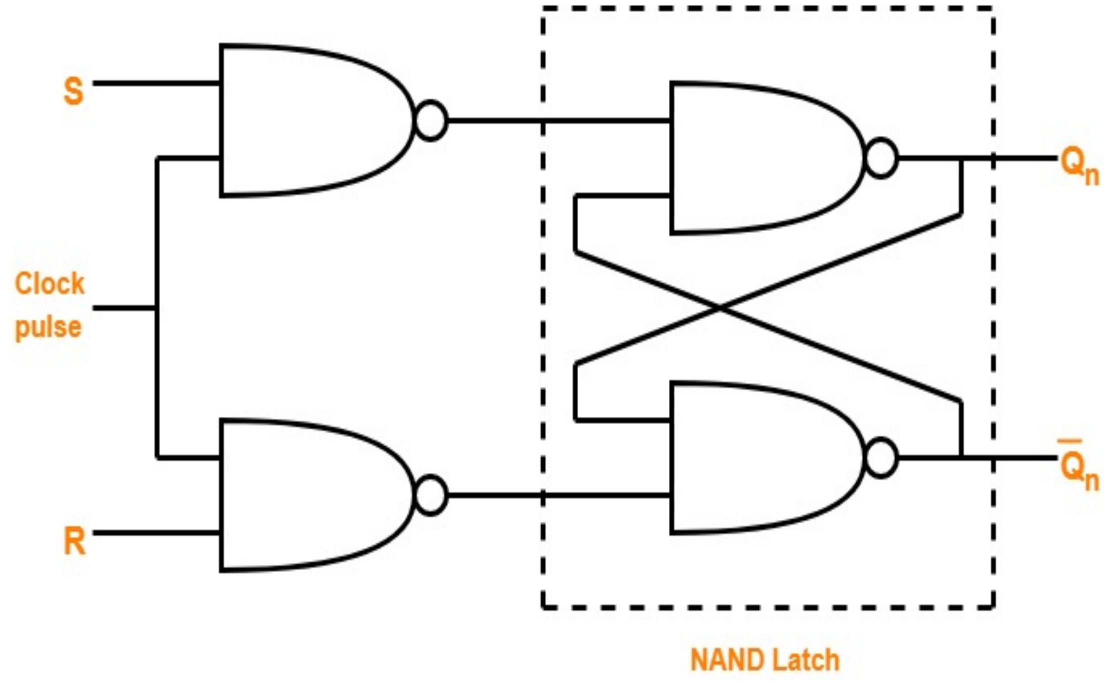
SR-Flip-Flop

NAND or NOR .

- SR flip flop is the simplest type of flip flops.
- It stands for **Set Reset flip flop.**
- It is a clocked flip flop.

NAND .

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0



SR Flip Flop Using NAND Latch

Application of SR

- SR flip-flops are used to eliminate mechanical bounce of switches in digital circuits