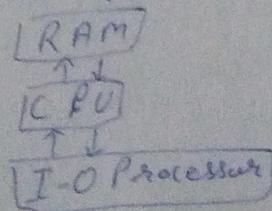


Digital Logic Circuits

Digital Computer

The digital computer is a digital system that performs various computational tasks.

- Digital :- Info in computer is represented by limited no of discrete values. e.g. 0,1,2 ...
- First digital computer developed in late 1940 were used primarily for numerical computations.
- Digital components take two values 0,1
- Digital Computer uses the binary number system 0,1
- the groups of bits are used to develop complete set of instructions for performing various types of computations
- Computer system divides into 2 functional entities hardware & software
- Program :- A sequence of instructions for the computer
- Data base :- The data that are manipulated by the program
- A computer system is composed of its hardware & system software available for its use
- A high-level language program written by a user to solve particular data processing needs an application program
- But compiler that translates the high-level language program to machine language is a System program
- Hardware divided into 3 major parts
 - (1) CPU that contain ALU, LU for manipulating data
 - (2) Registers for storing data (RAM)
 - (3) Control circuit for fetching and executing instructions.



• Computer Organization: It is concerned with the way the hardware components operate and the way they are connected together to form the computer system.

• Computer Design: It is concerned with the hardware design of the computer - what hardware should be used and how the parts should be connected.

• Computer Architecture: It is concerned with the structure and behaviour of the computer as seen by the user. e.g:- information, formats, instruction set, techniques for addressing memory.

• Two basic architectures are

- 1 Von Neumann Architecture
- 2 Harvard Architecture

• Von Neumann Architecture: It describes a general framework or structure, computers hardware, programming, data should follow.

It composed of ALU, RAM, CPU (which fetch the data or instructions from memory to be processed by ALU), Input-output device.

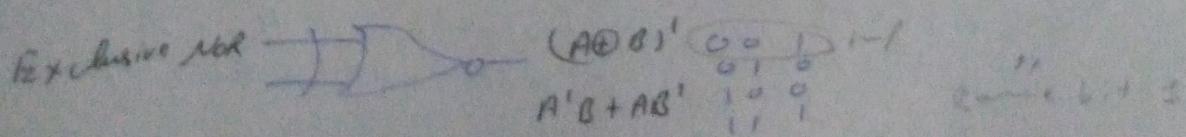
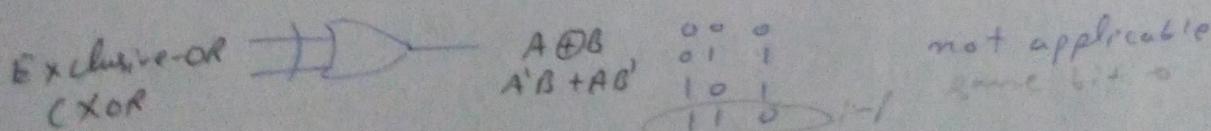
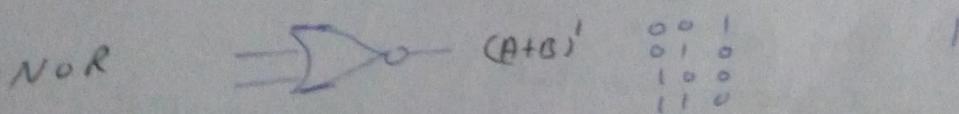
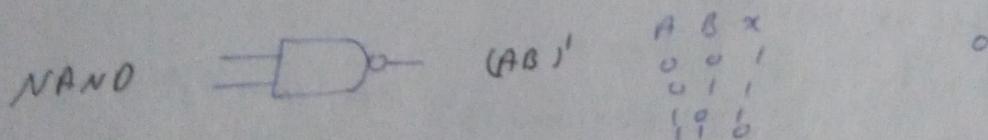
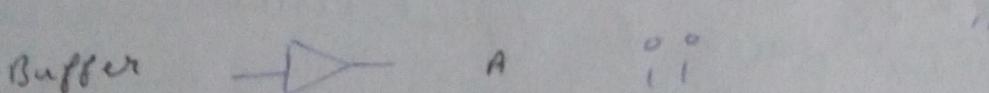
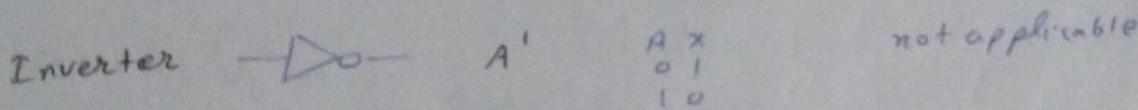
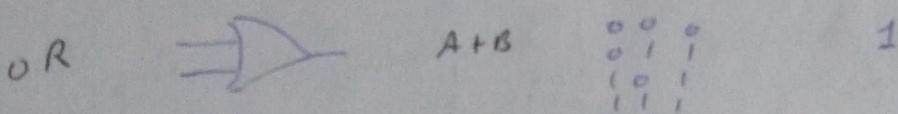
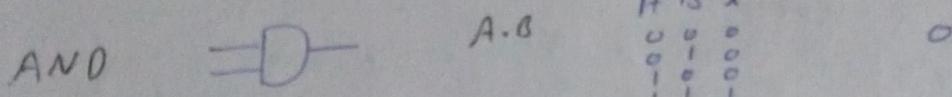
• Here we get L & O only one word reading or writing both can't go together because there is a single pathways and memory

• Harvard Architecture: It uses physically separate storage and signal pathways for their instructions and data. Here CPU read both an instruction and data from memory at the same time, leading the double the memory bandwidth. e.g:- Desktop, Microcontroller, DSP

Logic Gates

- Binary info is represented in digital computers by physical quantities called signals (0,1)
- Electrical signals such as voltages (3v, 0.5v...)
- the manipulation of binary information is done by logic circuits called gates (hardware) (to produce?)
- Input output of gates are represented by truth table
- Multi-input AND gate is sensitive to logic 0 on any one of its inputs
- Small circle in the output of the graphic symbol of an inverter designates a logic complement. A triangle symbol by itself designates a buffer circuit

Input sensitivity



Buffer is to drive other gates that require a large amount of power

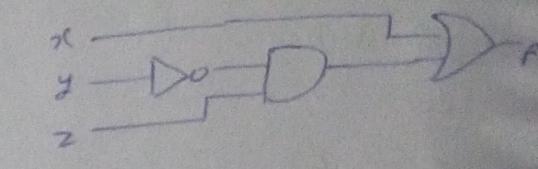
Boolean Algebra

- It consists of set with 2 elements
- Boolean algebra is a switching algebra that deals with binary variables and logic operations.
Variables - A B C
Logic operations - AND, OR, Complement
- Value of the variables, the Boolean fun can be either 1 or 0 $F = xy'z$

To represent a fun in a truth table we need a list of 2^n combinations of n binary variable

$$F = xy'z$$

x	y	z	F
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1



- The purpose of Boolean algebra is to facilitate the analysis and design of digital circuits

- Express as truth table
- Express as logic diagram
- Find simpler circuits for the same fun

- Two ways of forming Boolean expressions are canonical and non-canonical

Canonical forms express all binary variables in a every product (AND) or sum (OR)

e.g. - $F = A'B + C' + ABC$

$$xy + xy' = 1$$

$$= A'B(C+C') + (A'+A)(B+B')C' + ABC$$

$$= A'B(C+C') + A'B'C + ABC' + A'BC' + A'B'C' + ABC + A'BC + A'B'C + ABC' + ABC + A'B'C + ABC$$

Basic Identities of Boolean Algebra

$$x+0=x$$

$$x+1=1$$

$$x+x=x$$

$$x+x'=1$$

$$x+y=y+x$$

$$x+(y+z)=(x+y)+z$$

$$x(y+z)=xy+xz$$

$$(x+y)' = x'y' \text{ Demorgan theorem}$$

$$(x')' = x$$

$$x \cdot 0 = 0$$

$$x \cdot 1 = 1$$

$$x \cdot x = x$$

$$x \cdot x' = 0$$

$$xy = yx$$

$$x(yz) = (xy)z$$

$$* x(yz) = b(y)(x+z)$$

$$(xy)' = x'y' \text{ Demorgan theorem}$$

use in NAND

$$\bullet AB' + C'D + AB' + C'D$$

$$= AB' + C'D$$

- Demorgan's theorem is very important in dealing with NOR & NAND gates

- NAND gate and NOR gates are Universal gates

Map Simplification

- The truth table representation of a funⁿ is unique, but the funⁿ can appear in many different forms when expressed algebraically

Two methods

1. Map method \Rightarrow for functions up to 6 variables

2. Tabular method (Quine-McCluskey method)
(iterative consensus method)

- Map Method also Known as Karnaugh map or K-map

- minterm:- Each combination of the variable in a truth table when truth table have n variable then it have 2^n min term

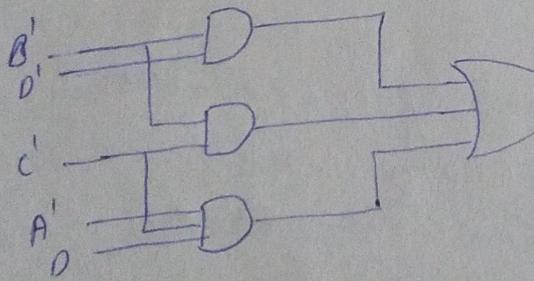
Product - of - Sums Simplification

- The product terms are AND terms and sum denotes the OR terms
- the 1's in themap represent the minterm that produce 1 for the fun
- The square not marked by 1 represents the minterms that produce 0
- If we mark the empty squares with 0's and combine them into groups of adjacent squares we obtain the complement of the fun

1	1	0	1
0	1	0	0
0	0	0	0
1	1	0	1

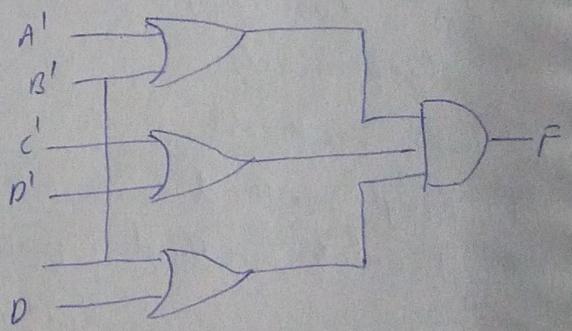
sum of product form

- Combining the squares with 1's give the simplified fun
- If the squares marked with 0's are combined we obtain the simplified complemented fun
- we use here OR gate



Sum of products

$$F = B'D' + B'C'D + A'C'D$$



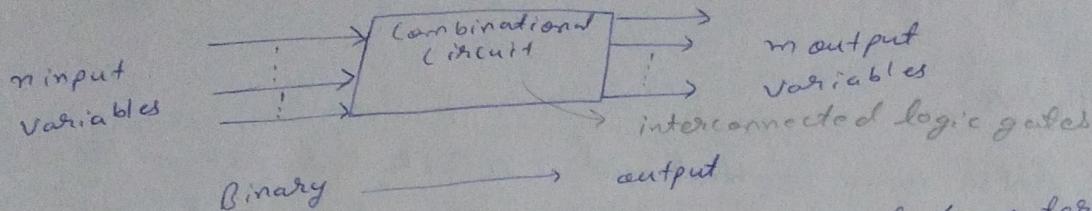
Product of sums

$$F = (A'+B')((C'+D')(B'+D))$$

combinational circuits

Digital logic circuits are 2 types

1. Combinational circuits in which there are no feedback paths from outputs to inputs and there is no memory
2. Sequential circuits in which feedback path exist from outputs to inputs and they have memory.



- Combinational circuit are employed in digital computers for generating binary control decisions and for providing digital components required for data processing
- these are described by a truth table and inverters by truth table

The procedure for design Combinational circuit

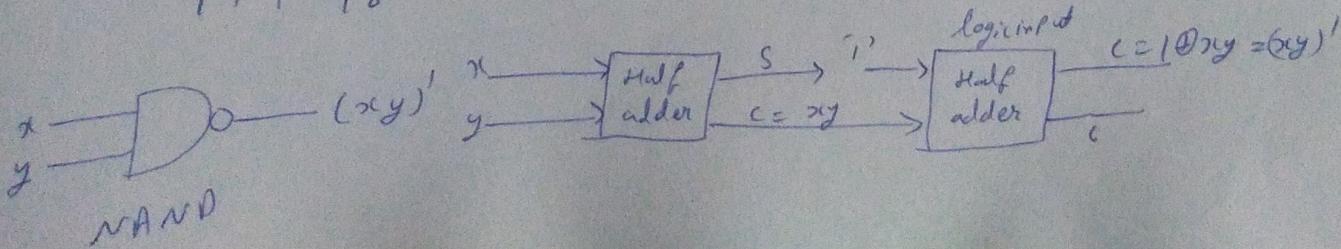
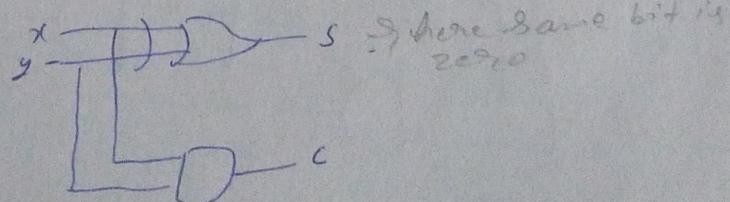
1. The problem is stated
2. the input and output variables are assigned letter symbols
3. The truth table that defines the relationship b/w input and output is derived
4. The simplified Boolean fun for each output are obtained
5. the logic diagram is drawn

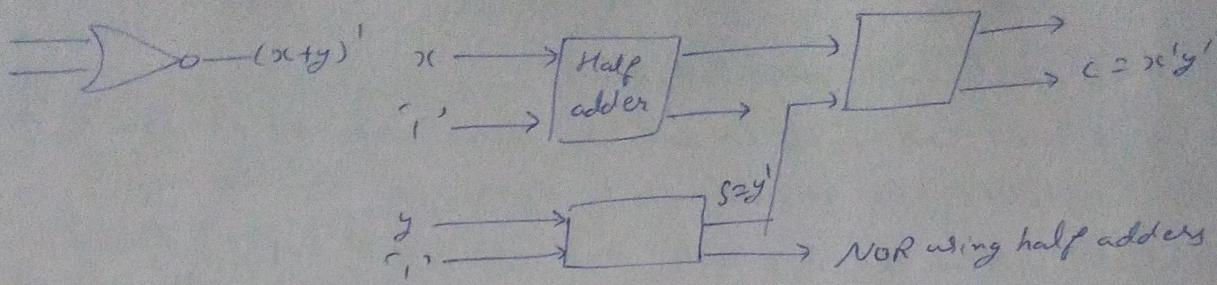
Half-Adder

A Combinational circuit that performs the arithmetic addition of two bits

the input variables of a half adder are called augend and addend bits

input		output	
x	y	C	S
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0





$$g = x'y + xy' = xy \oplus y$$

$$c = xy$$

Full Adder

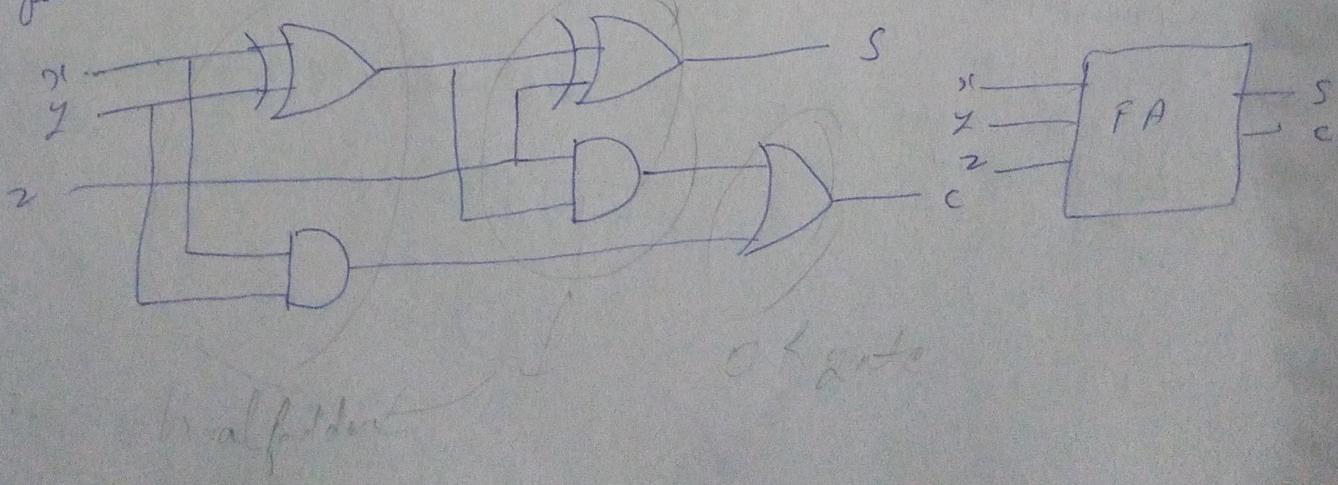
A Full Adder is a combinational circuit that forms the arithmetic sum of 3 input bits. It has 3 input and 2 output. Here 2 inputs are x & y and 3rd will be carry from the previous lower significant position. 2 output are necessary because the arithmetic sum of 3 binary digits ranges in value from 0 to 3 and binary 2 or 3 needs 2 digits.

Inputs			Outputs	
x	y	z	c	s
0	0	0	0	1
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

Possible expression for c is $c = xy + (x'y + y'z)2$
or $c = xy + (x \oplus y)z$

$$s = xy \oplus y \oplus z$$

full adder contain 2 half adder and an OR gate



Flip-Flop

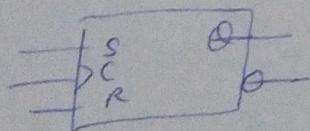
In flip-flop most common type of sequential circuit is the synchronous type. It employ signals that affect the storage elements only at discrete instants of time. It is achieved by a timing device called clock pulse generator. The clock pulses are distributed throughout the system in such a way that storage element are affected only with the arrival of the synchronization pulse.

- the storage elements employed in clocked sequential circuits are called flip-flop
- It has 1 input 2 output (one normal value and one complement)

SR-Flip-flop

It has 3 input (S , R , C lock) and one output, (Sometime it has complemented output (\bar{Q})). There is an arrowhead-shaped symbol in front of letter c (\rightarrow) to designate a dynamic input (c), i.e. if the input clock signal)

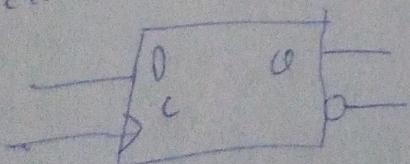
If there is no signal at the clock input c , the output of the circuit can't change irrespective of the value at inputs S & R only clock signal changes from 0 to 1 can the output be affected acc to S & R



S	R	$Q(t+1)$	(after the occurrence of clock transition)
0	0	0 (t)	(output does not change)
0	1	0	
1	0	1	
1	1	? either 0 or 1	{ here is from 0 to 1

D-Flip-flop

- An SR flip flop is converted to D-flip flop by inserting an inverter b/w S & R & symbol \oplus to the single input. Here clock transition from 0 to 1



D	$Q(t+1)$
0	0 — clear to 0
1	1 — Set to 1

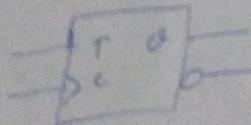
- Advantage of having only one input (excluding C)
 - Disadvantage → it has no "no change" condition.
- No change condition can be accomplished either by disabling the clock signal or by feeding the output back into the input so that clock pulses keep the state of the flop unchanged.

J K Flip flop

Properties

T-flip-flop (toggle flip flop)

- this flip flop is obtained from JK type when input $J = K$ are connected to provide a single input designated by T
- the clock transition does not change the state of the flip flop

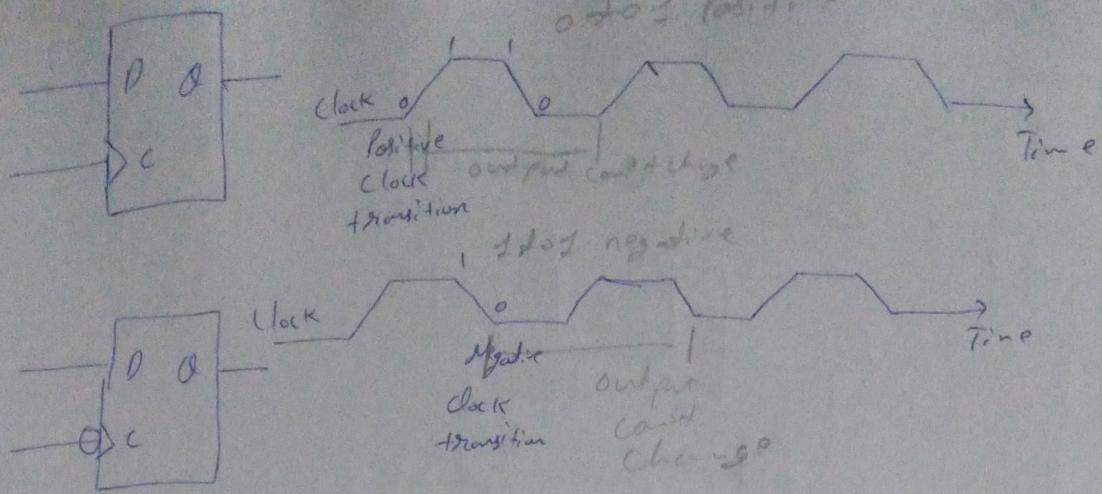


T	$Q(t+1)$
0	$Q(t)$ (unchanged)
1	$Q'(t)$ (complement) of $Q(t)$

Edge-triggered flip-flops

- this is used to synchronize the state change during a clock pulse transition

In this output transitions occurs at a specific level of the clock pulse. When clock pulse input level exceeds this threshold level, the inputs are locked out so that the flip-flop is unresponsive to further strong 1 input until the clock pulse returns to 0 and another pulse occurs.



Excitation Table for flip flop

SR flip flop		S R
$\delta(t)$	$\delta(t+1)$	
0	0	0 X
0	1	1 0
1	0	0 1
1	1	X 0

D flip flop		D
$\delta(t)$	$\delta(t+1)$	
0	0	0
0	1	1
1	0	0
1	1	1

JK flip flop

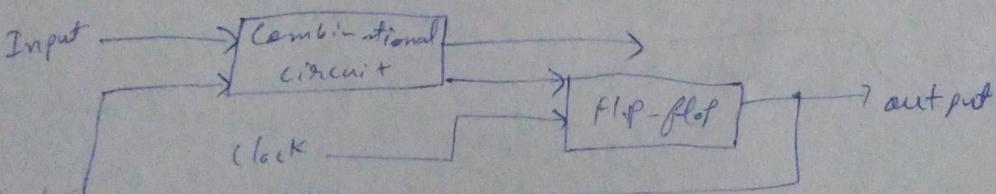
JK flip flop		J K
$\delta(t)$	$\delta(t+1)$	
0	0	0 X
0	1	1 X
1	0	X 1
1	1	X 0

T flip flop

T flip flop		T
$\delta(t)$	$\delta(t+1)$	
0	0	0
0	1	1
1	0	1
1	1	0

Sequential Circuits

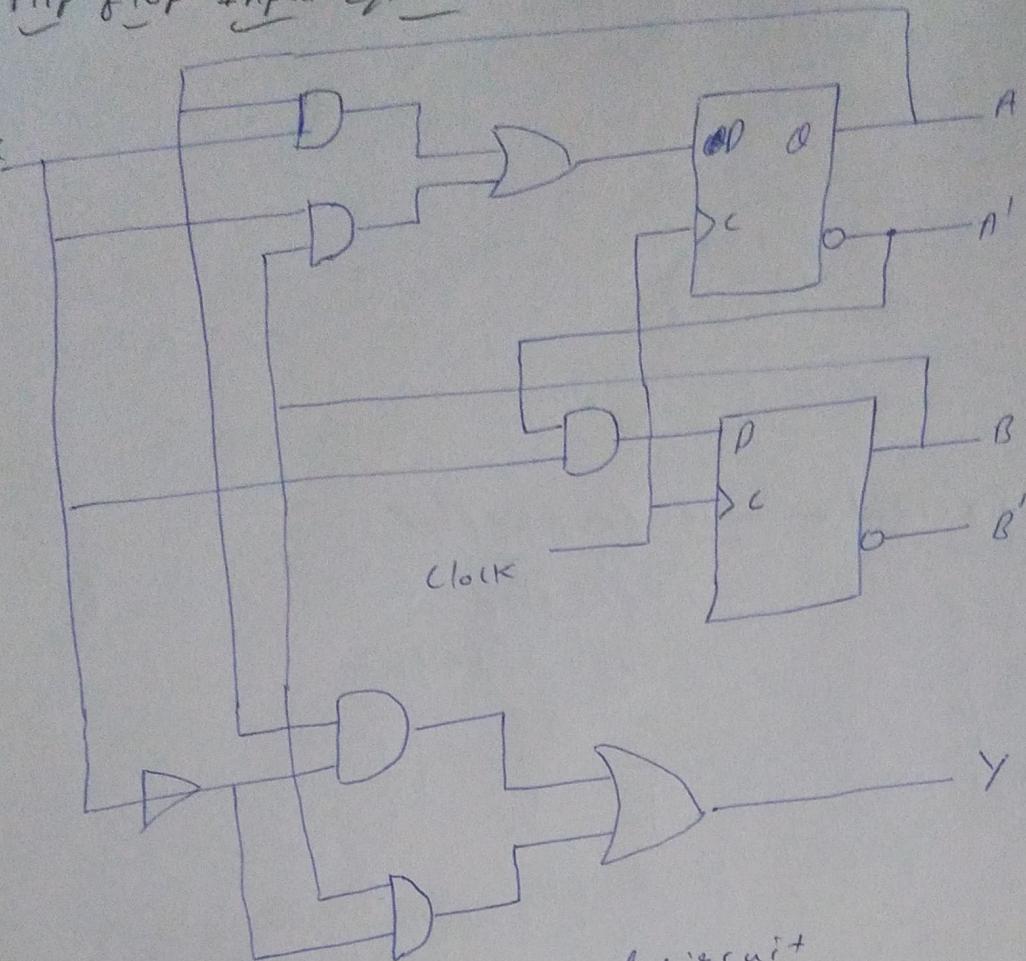
A sequential circuit is an interconnection of flip-flop and gates. The gates by themselves constitute a combinational circuit but when included with the flip flop the overall circuit is classified as a sequential circuit.



Clocked Synchronous Sequential Circuit

- A sequential circuit is specified by a time sequence of external inputs, external outputs, and internal flip-flop

Flip-flop Input Equation



Sequential circuit

- The part of combinational circuit that generates the inputs to flip-flops are described by a set of Boolean expression called flip-flop Input equation

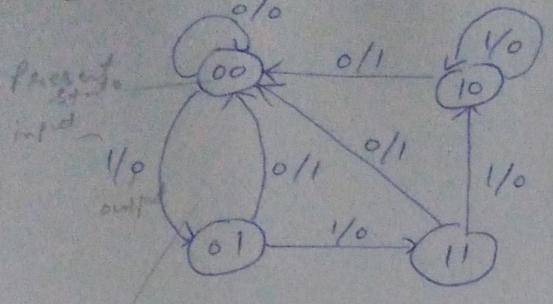
$$D_A = Ax + Bx \quad D_B = A'x \quad y = Ax' + Bx'$$

D input to flip flop
A flip flop name

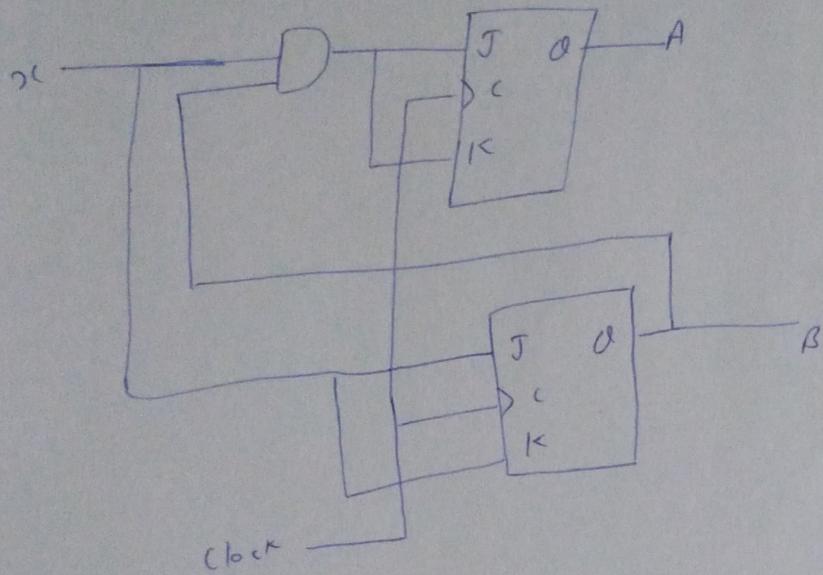
State table

- The table consists of 4 sections, labeled present state, input, next state and output.
present state \rightarrow Show state of flip-flop at time t.
next state \rightarrow Show state of " one clock period later at time t+1
- The present state and input columns are combined and under them we list the 2^{m+n} binary combinations from 0 through $2^{m+n}-1$.

State diagram



clock
shown it goes to next state



Logic diagram of 2 bit binary counter

Counter

- Digital circuit used for counting pulse by counter widget application of flip-flops. It group of flip-flop with clock signal applied

Two types of counter

1. Asynchronous counter
2. Synchronous counter

Digital Components

Integrated Circuits

- It is small silicon semiconductor crystal containing the electronic components for the digital gates.
- In this connections are welded by thin gold wires to external pins
- no of pins 14 - 100
- Each IC has a identification no

SSI (Small-Scale integration) :- It contain several independent gates in a single package
no of gates less than 10 & limited pins

MSI (Medium " ") :- It has 10 - 200 gates in a single package
they usually perform specific elementary digital functions such as decoders, adders and registers

LSI (Large " ") :- It has 200 - few thousand gates in single pack
they used in digital systems, processors, memory chips

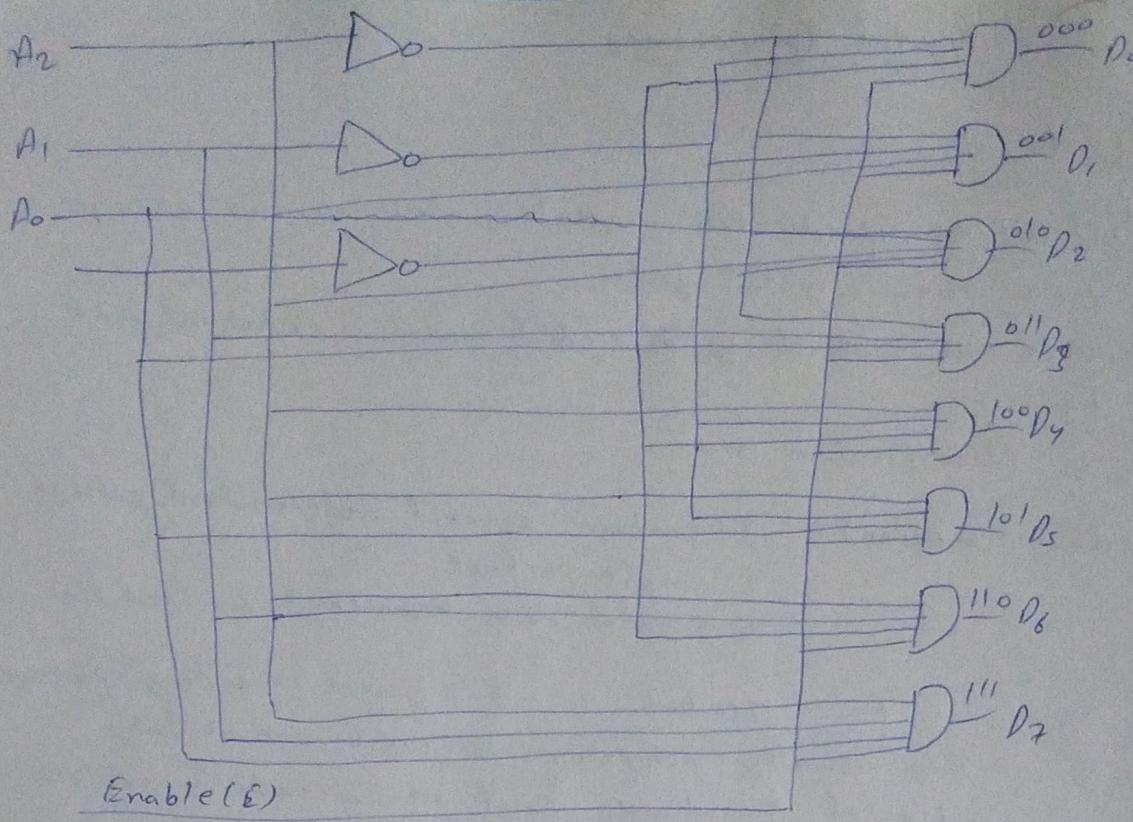
VLSI (Very Large " ") :- It contain thousands of gates in single package
eg:- complex microcomputer, large memory array
the basic circuit in it is either NAND or NOR or a inverter gate

- Electronic components to build circuit

1) TTL	Transistor-transistor logic	Standard
2) ECL	Emitter coupled logic	High speed (microcomputer)
3) MOS	Metal-oxide Semiconductor	High component density
4) CMOS	Complementary metal-oxide semiconductor	Low power consumption
	speed (nsecond)	Power (watt)
TTL	10	10
ECL	2	40
(MOS)	2 ⁻⁵	low

Decoders

- A decoder is a combinational circuit that converts binary info from n coded input to a max of 2^n unique outputs.
- If n bit coded info has unused bit combination decoder may have less than 2^n output



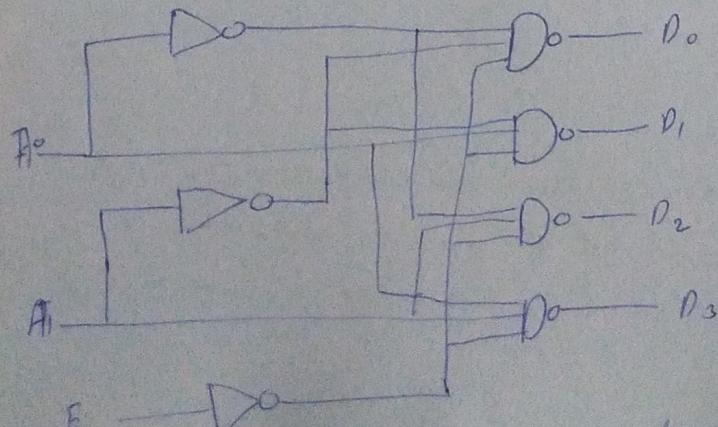
3 to 8 line decoder
Input Output

- The input in binary and output in 8 bit bits of octal no systems
non care condition

E	A ₂	A ₁	A ₀	D ₇	D ₆	D ₅	D ₄	D ₃	D ₂	D ₁	D ₀
0	X	X	X	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	1	0
1	0	0	1	0	0	0	0	0	0	0	0
1	0	1	0	0	0	0	0	0	1	0	0
1	0	1	1	0	0	0	0	0	0	0	0
1	1	0	0	0	0	0	1	0	0	0	0
1	1	0	0	0	0	1	0	0	0	0	0
1	1	1	0	0	1	0	0	0	0	0	0
1	1	1	1	1	0	0	0	0	0	0	0

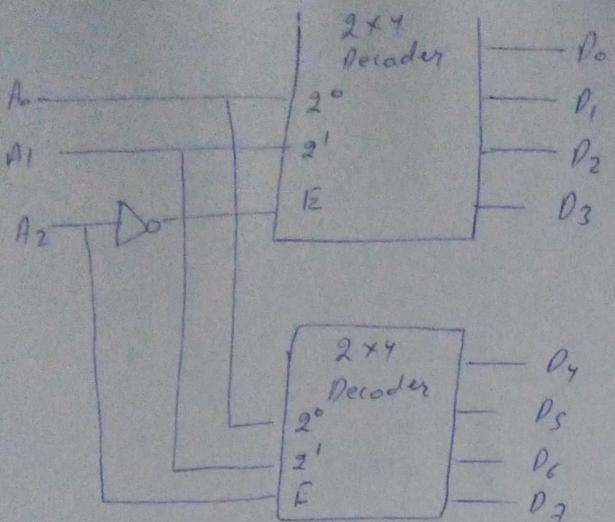
↑ represent octal
↑ equivalent of
binary no

NAND Gate Decoder



2 to 4 line decoder

E	A ₁	A ₀	D ₀	D ₁	D ₂	D ₃
0	0	0	0	1	1	1
0	0	1	1	0	1	1
0	1	0	1	1	0	1
0	1	1	1	1	1	0
1	X	X	1	1	0	0
1	1	1	1	1	0	0



3 to 8 decoder constructed with 2x4 decoder

when \$A_2 = 0\$ upper decoder is enable and lower disable

\$A_2 = 1\$,,, ,,, ,,, disable ,,, ,,, enable

Encoder

- An encoder has \$2^n\$ (or less) input lines and \$n\$ output lines
- It converts octal input in binary output
- It is implemented with OR gates

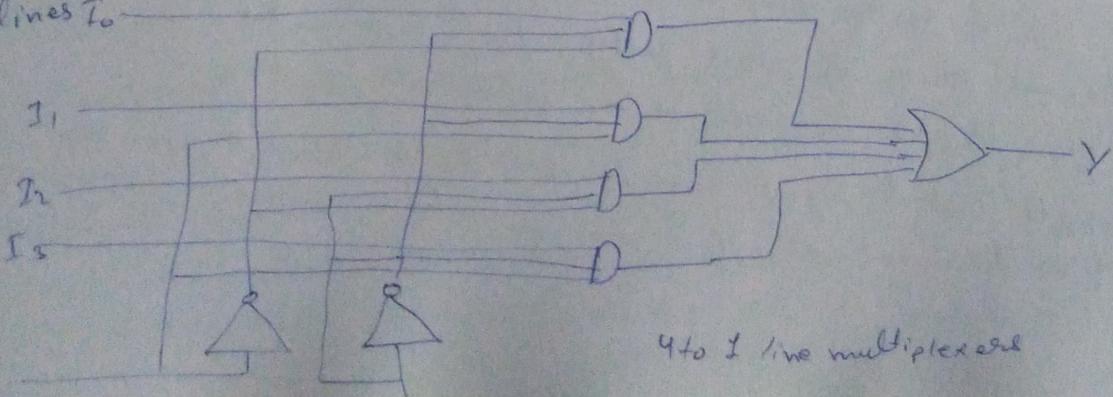
$$A_0 = D_1 + D_3 + D_5 + D_7$$

$$A_1 = D_2 + D_3 + D_6 + D_7$$

$$A_2 = D_4 + D_5 + D_6 + D_7$$

Multiplexers

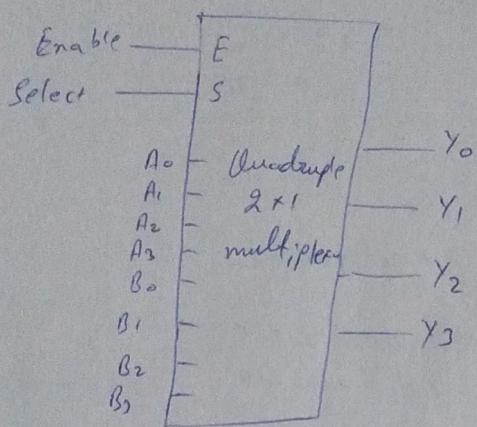
- A multiplexer is a combinational circuit that receives binary info from one of \$2^n\$ input lines and directs it to a single output line
- A \$2^n - 1\$ multiplexer has \$2^n\$ input data lines and \$n\$ input selection lines to



4 to 1 line multiplexer

Function Table for 4 to 1 line multiplexer

Select S_1	Select S_0	Output Y
0	0	I_0
0	1	I_1
1	0	I_2
1	1	I_3



E	S	Y
0	X	All 0's
1	0	A
1	1	B

Quadruple 2 to 1 line multiplexers

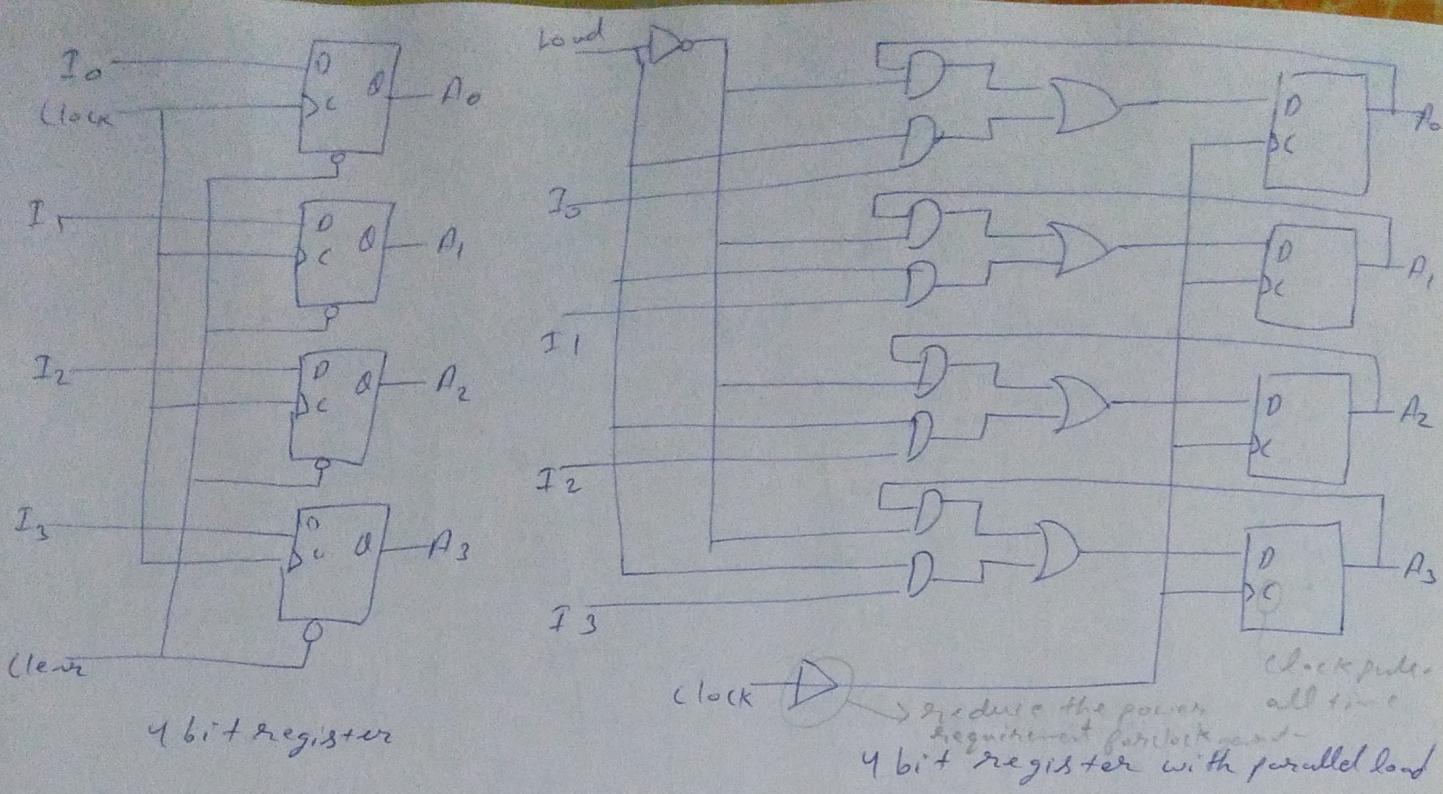
Registers

- Flip-flop contain one bit of info - An nbit register has a group of n flip-flop and is capable of storing any binary info of n bits
- Flip-flop hold the binary info and the gates control when and how new info is transferred into the register
- The transfer of new info into a register is referred to as loading the register. If all bits of register are loaded simultaneously with a common clock pulse transmission we say its loading done in parallel

Register with parallel load

Most digital system have a master clock generator that supplies a continuous train of clock pulses. The clock pulses are applied to all flip-flop & register in the system

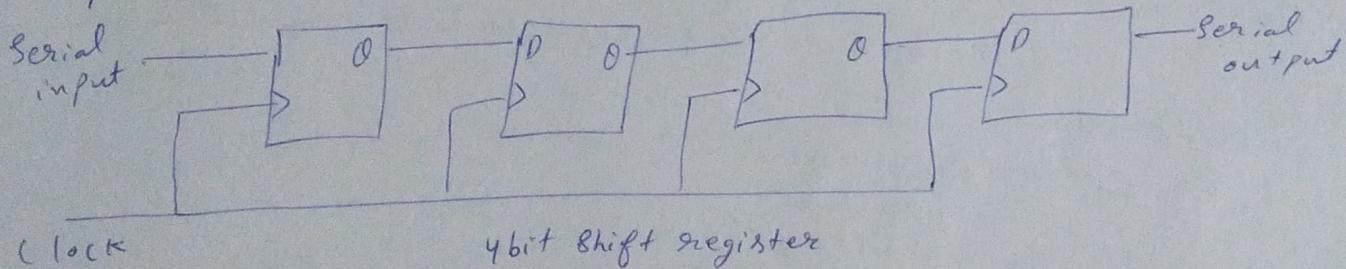
A separate control signal must be used to decide which specific clock pulse will have an effect on particular register



clock pulse → reduce the power requirement for clock and
4 bit register with parallel load

Shift Register

- A register capable of shifting its binary info in one or both direction
- It consists of chain of flip flop one flop output is input of other flip flop and all flip flop receive common clock pulses that initiate the shift from one stage to the next

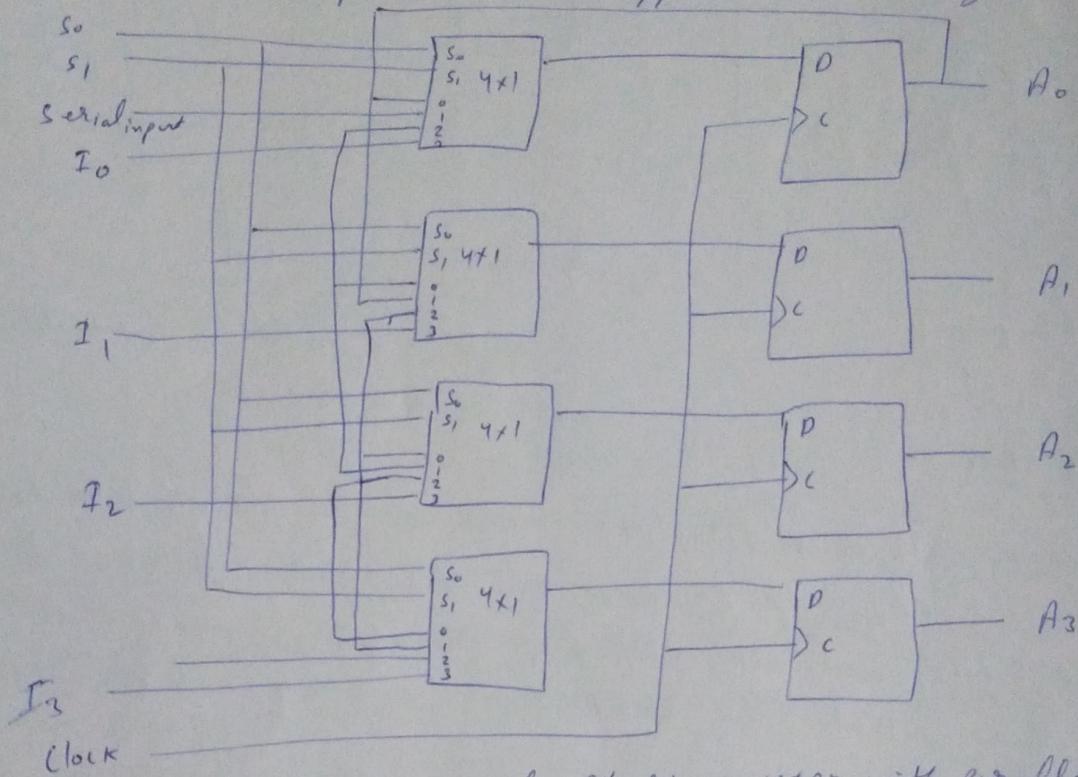


- Serial input :- what goes into the leftmost position during shift
- If we don't want to give clock pulse to some register so to connect the clock to input of an AND gate, and second input of AND gate control the shift by clock.

Bidirectional Shift Register with Parallel Load

- A register that can shift in both directions
- these have capabilities
 1. An input for clock pulses to synchronize all operations
 2. A shift-right operation and a serial input line associate with shift-right

3. A shift left operation and a serial input line associated with shift left
4. A parallel load operation and n input lines associated with the parallel transfer.
5. n parallel output lines
6. A control state that leaves the info in the register unchanged even clock pulses are applied continuously.



Bi-directional shift register with parallel load.

Mode control

		Register operation
S ₁	S ₀	No change
0	0	Shift right (down)
0	1	Shift Left (up)
1	0	Parallel load
1	1	

- Shift register are often used to interface digital system situated remotely from each other. we take eg. total n-bit data transfer from one place to other we take n bits in parallel into shift register than transfer it into serial line one bit at a time when all bits are accumulated we receive all in through parallel line.

Binary Counter

Counter:- A register that goes through a predetermined sequence of states upon the application of input pulses

- The input pulses may be clock pulses that occurs uniform or random interval of time
- Counters are used for counting the no of occurrences of event and are useful for generating timing signals to control the sequence of operation in digital computer

They follow sequences

1. Binary Sequence \rightarrow Binary Counter
2. straightforward

- An n bit binary counter is a register of n flip-flop and associated gates that follows a sequence of states acc. to the binary count of n bits from 0 to $2^n - 1$

Binary Counter with Parallel Load

Counters employed in digital system quite often require a parallel load capability for transferring an initial binary number prior to the count operation.

Memory Unit

- It is collection of storage cells together with associated circuits needed to transfer info in and out of storage
- Group of bits \Rightarrow words
- A group of 8 bits is a byte
- 16 bit word \Rightarrow 2 byte 32 bit word \Rightarrow 4 byte
- Computer memory may range from 1024 words, require an address of 10 bits to 2³² words require 32 address bits.
- $K(\text{Kilo}) = 2^{10}$ $M(\text{Mega}) = 2^{20}$ $G(\text{Giga}) = 2^{30}$

Two types of memory

1. RAM
2. ROM

RAM

- access the memory cell for info transfer from any desired random location
 - Communication b/w a memory and its environment is achieved through data input and output lines, address selection lines, and control lines that specify the direction of transfer.
 - It have certain both read and write operation
- Steps to transferring a new word to be stored into memory
- 1) Apply the binary address of the desired word into the address bus
 - 2) Apply the data bits that must be stored in memory into the data input lines
 - 3) Activate the write input
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- ```

graph LR
 Address[Address lines] --> Memory
 Read[Read] --> Memory
 Write[Write] --> Memory
 subgraph MemoryUnit [Memory unit which stores n words]
 Memory
 end
 Memory --> Output[Data output line]

```

then memory bit take input data lines bit and store in Specified address lines

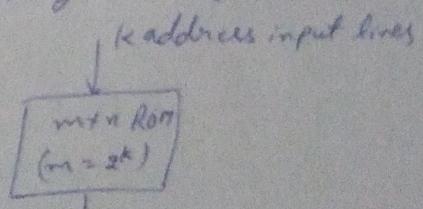
Steps for transferring a word out of memory

- 1) Apply the binary address of the desired word into the address bus
- 2) Activate the read input.

then memory bit take bit and apply them into the output data lines

ROM

- It does not have write capability.
- Info stored in Rom is permanent during hardware production
- An  $m \times n$  Rom is an array of binary cell organized into  $m$  words of  $n$  bits each.



Block diagram of Rom

- Rom doesn't contain read line, output lines automatically provide the  $n$  bits of the word
- A control unit that utilizes a Rom to store binary control info is called microprogrammed control unit

## Types of ROM

pROM (Programmable read only memory)

EPROM (Erasable programmable read only memory)

EEPROM (Electrically erasable... . . . . )

Flash memory

e.g. of EEPROM

1. Storing current time and data in a machine

2. Storing part statuses

e.g. of flash memory

1. Storing messages in a mobile phone

2. Storing photographs in a digital camera.