Unit 2
Boolean Algebra and Logic Gates

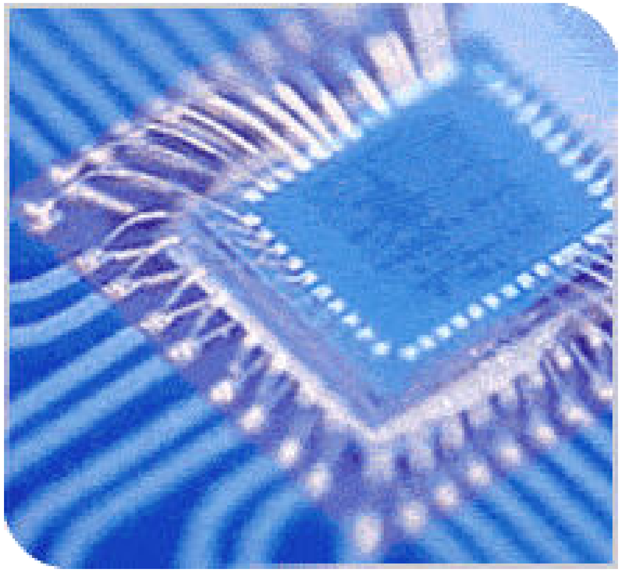
Er. Sachita Nand Mishra

Integrated Circuits

- Concept of DIP, SIMM, linear and digital ICs
- RTL,TTL,MOS,CMOS,I^2L
- Positive and Negative Logic
- Special Characteristics
- Characteristics of IC logic Families

Integrated Circuits

- **Integrated circuit** (also called a *chip*) A piece of silicon on which many gates have been embedded
- An Integrated circuit is an association (or connection) of various electronic devices such as resistors, capacitors and transistors etched (or fabricated) to a semiconductor material such as silicon or germanium.
- It is also called as a **chip** or **microchip**.
- An IC can function as an amplifier, rectifier, oscillator, counter, timer and memory.



Types of ICs

- **Analog or Linear ICs:**

➢ They produce continuous output depending on the input signal.

➢ From the name of the IC we can deduce that the output is a linear function of the input signal.

➢ When the input and output relationship of a circuit is linear, linear IC is used.

➢ Input and output can take place on a continuous range of values

➢ Op-amp (operational amplifier) is one of the types of linear ICs which are used in amplifiers, timers and counters, oscillators etc.

Types of ICs

- **Digital ICs**:

➢ Unlike Analog ICs, Digital ICs never give a continuous output signal. Instead it operates only during defined states.

➢ When the circuit is either in ON state or OFF state and not in between the two, the circuit is called digital circuit and the IC used in such circuit is called digital IC.

➢ Digital ICs are used mostly in microprocessor and various memory applications.

➢ Logic gates are the building blocks of Digital ICs which operate either at 0 or 1.

Types of ICs

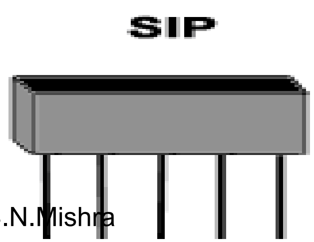
Linear ICs	Digital ICs
Linear ICs (Linear Integrated Circuits) are called as analog IC.	Digital ICs (Digital Integrated Circuits) are also called as non linear IC.
Linear integrated circuits inputs and outputs can take on a continuous range of values and the outputs are generally proportional to the inputs.	Digitals ICs contain circuits whose inputs and outputs voltage are limited to two possible levels low or high.
It is used in aircraft, space, vehicles, radars, PLL, Oscilloscopes etc.	Its used in microprocessor, computers, clocks, digital watches, calculator etc.
The design requirements are more drastic as compared to digital ICs.	The design requirement as less drastic as compare To linear ICs.
It is commercially available as operational amplifiers, voltage multipliers, voltage comparator, regulators, microwave amplifiers Etc.	Its commercially available as microprocessor chips, memory chips, analog to digital chips , digitals to analog chips, logic gates, flip flops, counters, registers etc.
Its consist of very less number of transistor as compared to digital ICs..	Its consist of more number of transistor as compared to linear ICs.

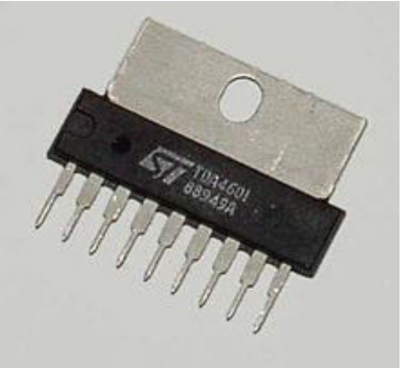
IC-Levels of Integration

- SSI (small-scale integration): Up to 100 electronic components per chip
- MSI (medium-scale integration): From 100 to 3,000 electronic components per chip
- LSI (large-scale integration): From 3,000 to 100,000 electronic components per chip
- VLSI (very large-scale integration): From 100,000 to 1,000,000 electronic components per chi
- ULSI (ultra large-scale integration): More than 1 million electronic components per chip

SIP (Single In-line Package)

- A **single in-line package** is an electronic device package which has one row of connection pins.
- It is not as popular as the dual in-line package (DIP) which contains two rows of pins, but has been used for packaging RAM chips and multiple resistors with a common pin.
- SIPs group RAM chips together on a small board.
- The board itself has a single row of pin-leads that resembles a comb extending from its bottom edge, which plug into a special socket on a system or system-expansion board.
- SIPs are commonly found in memory modules.





Dual in-line package (DIP)

- Dual in-line package (DIP) is a type of semiconductor component packaging.
- It is an electronic device package with a rectangular housing and two parallel rows of electrical connecting pins.
- DIPs can be installed either in sockets or permanently soldered into holes extending into the surface of the printed circuit board.
- DIP is relatively broadly defined as any rectangular package with two uniformly spaced parallel rows of pins pointing downward, whether it contains an IC chip or some other device(s), and whether the pins emerge from the sides of the package and bend downwards.
- A DIP is usually referred to as a **DIP*n***, where *n* is the total number of pins.
  Eg IC 741 is DIP8

SIMM (Single In-line Memory Module)

- SIMM has a single line of connector.
- In a SIMM pins on opposite sides of board are tied together to form one electrical path.
- Short for **Single In-line Memory Module, SIMM** is a circuit board that holds six to nine memory chips per board, the ninth chip usually an error checking chip (parity/non parity) and were commonly used with Intel Pentium or Pentium compatible motherboards.
- SIMMs are rarely used today and have been widely replaced by DIMMs.
- SIMM ha 32 bit data path
- SIMMs are available in two flavors: 30 pin and 72 pin.
- 30-pin SIMMs are the older standard, and were popular on third and fourth generation motherboards.

- 72-pin SIMMs are used on fourth, fifth and sixth generation PCs.

DIMM (Dual In-line Memory Module)

- DIMM has two lines of connectors.
- Short for **Dual In-line Memory Module**, **DIMM** is a circuit board that holds memory chips.
- In a DIMM opposite pins remain electrically isolated to form two separate contact.
- DIMMs have a 64-bit data path because of the Pentium Processor requirements.
- Because of the new bit path, DIMMs can be installed one at a time, unlike SIMMs on a Pentium that would require two to be added
- **SO-DIMM** is short for **Small Outline DIMM** and is available as a 72-pin and 144-pin configuration.
- SO-DIMMs are commonly utilized in laptop computers.

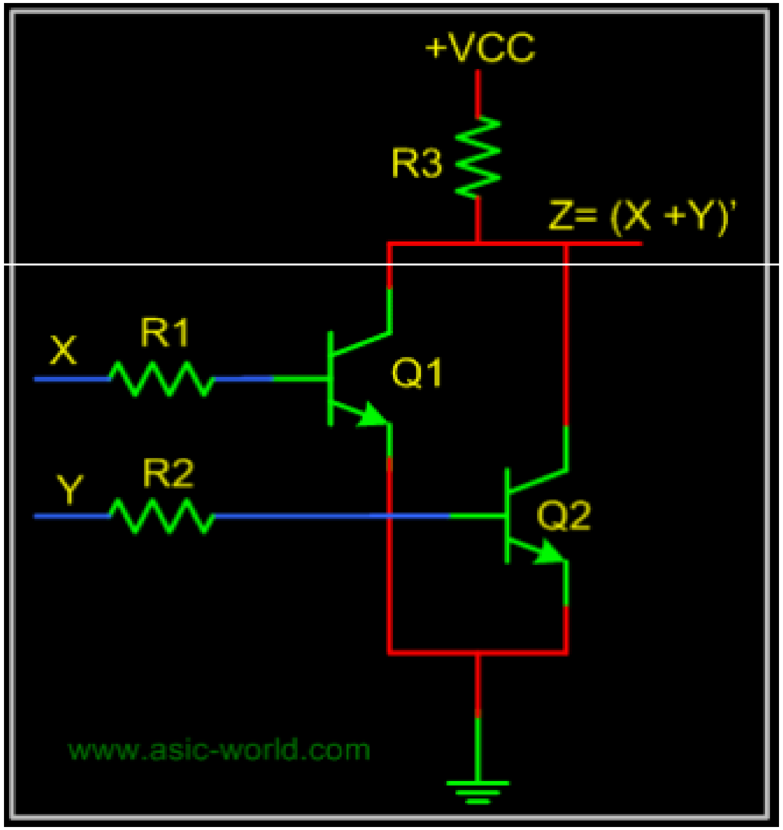
DIMM (Dual In-line Memory Module)

- Advantages DIMMs have over SIMMs:
- DIMMs have separate contacts on each side of the board, thereby providing twice as much data as a single SIMM.
- The command address and control signals are buffered on the DIMMs. With heavy memory requirements this will reduce the loading effort of the memory.

Register Transistor Logic(RTL)

- As its name suggests, RTL circuits mainly consists of resistors and transistors that comprises RTL devices.
- Inputs to the NOR gate shown above are ‘input1’ & ‘input2’. The inputs applied at these terminals represent either logic level HIGH (1) or LOW (0).
- The logic level LOW is the voltage that drives corresponding transistor in cut-off region, while logic level HIGH drives it into saturation region.
- If both the inputs are LOW, then both the transistors are in cut-off i.e. they are turned-off. Thus, voltage Vcc appears at output I.e. HIGH.
- If either transistor or both of them are applied HIGH input, the voltage Vcc drops across Rc and output is LOW.

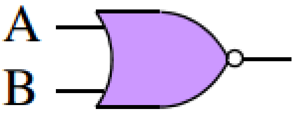
Register Transistor Logic(RTL)



NOR gate using RTL

NOR

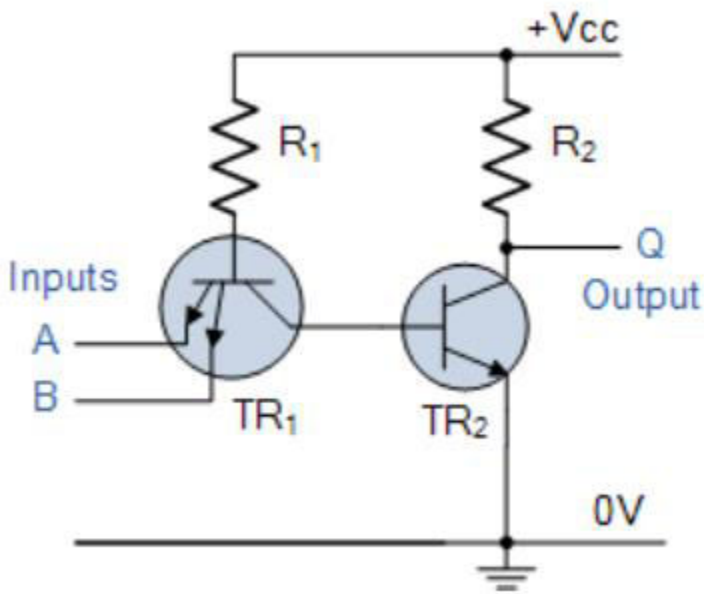
X	Y	Z
0	0	1
0	1	0
1	0	0
1	1	0



TTL (Transistor-Transistor Logic)

- The TTL family evolved from a previous technology that used diodes and transistors for the basic NAND gate.
- This technology was called DTL for diode-transistor logic.
- Later the diodes were replaced by transistors to improve the circuit operation and the name of the logic family was changed to TTL.
- It has come to existence so as to overcome the speed limitations of DTL family.
- The basic gate of this family is TTL NAND gate.

TTL (Transistor-Transistor Logic)



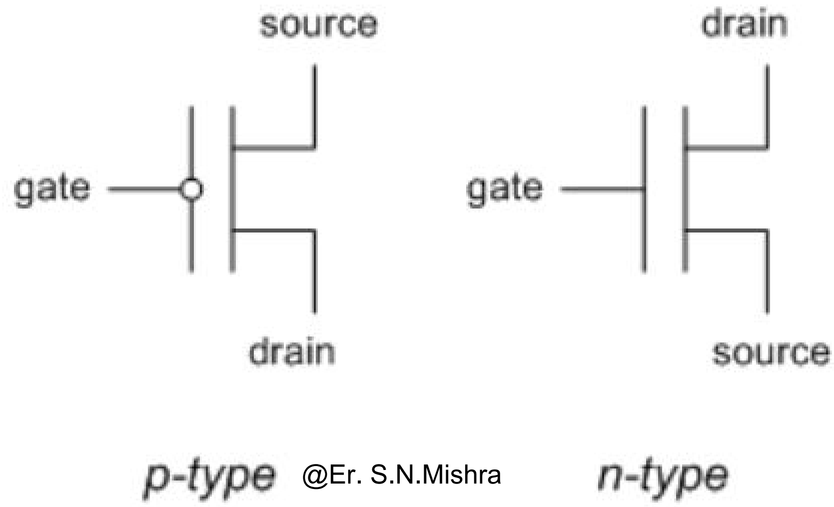
2-input NAND Gate

When at least one of inputs are at 0 V, the multiple emitter base junctions of transistor TR_1 are forward biased whereas the base collector is reverse biased and transistor TR_2 remains off and therefore the output voltage is equal to VCC

Applying a logic '1' input voltage to both emitter inputs of TR_1 reverse-biases both base-emitter junctions, causing current to flow through R1 into the base of TR_2, which is driven into saturation. In this case output is low.

MOS (Metal-Oxide Semiconductor)

- The metal-oxide semiconductor (MOS) is a unipolar transistor that depends upon the flow of only one type of carrier, which may be electrons (n-channel) or holes (p-channel), this is in contrast to the bipolar transistor used in TTL and ECL gates, where both carriers exist during normal operation.
- A p-channel MOS is referred to as PMOS and an n-channel as NMOS.



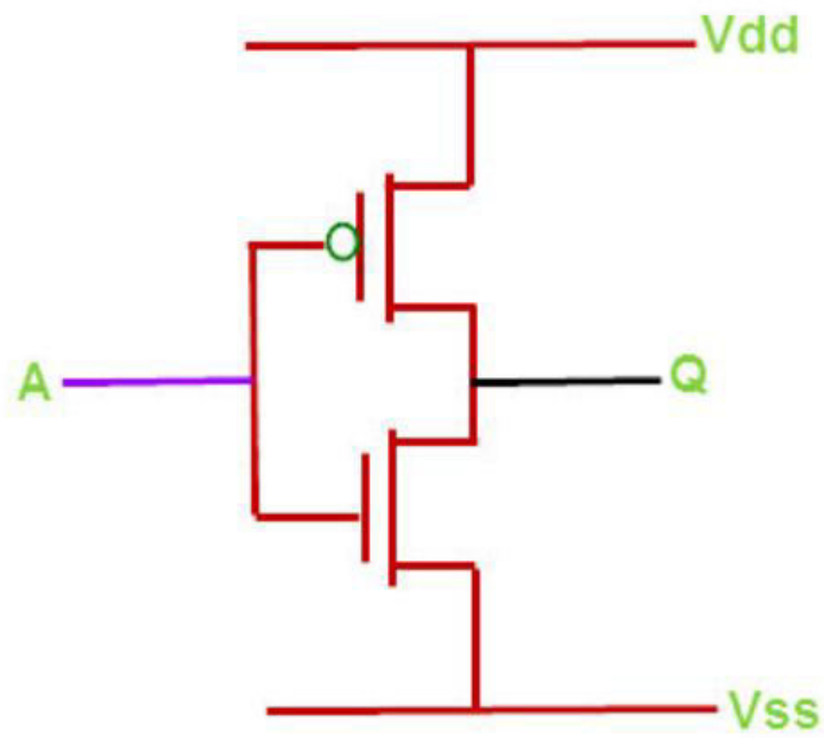
CMOS (Complementary Metal-Oxide Semiconductor)

- Complementary MOS (CMOS) technology uses one PMOS and one NMOS transistor connected in a complementary fashion in all circuits.
- The most important advantages of MOS over bipolar transistors are the high packing density of circuits, a simpler processing technique during fabrication, and a more economical operation because of the low power consumption.
- The main advantage of this is low static power consumption and noise immunity.
- High operating speed.

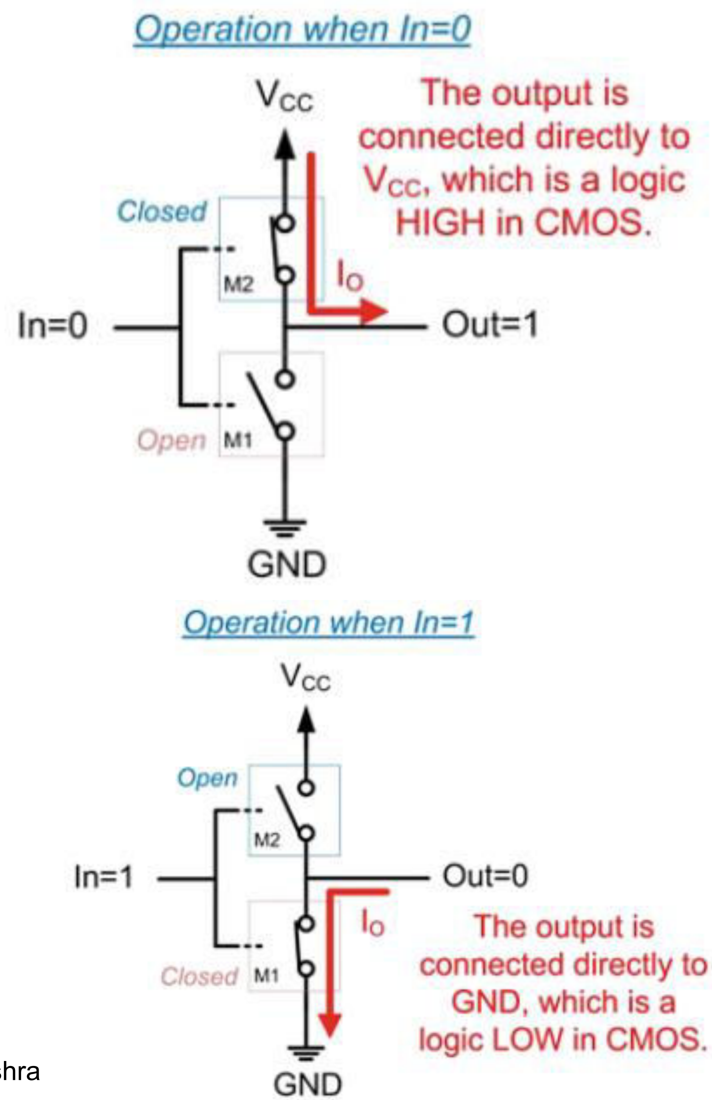
CMOS (Complementary Metal-Oxide Semiconductor)

- A CMOS inverter has two transistors namely a PMOS transistor and an NMOS transistor that is connected to the gate and drain terminals, a VDD (voltage supply) at the PMOS source terminal, and a GND terminal connected to the NMOS source terminal, where the input voltage is connected to the gate terminals and output terminal is connected to the drain terminals.
- It is significant to observe that the CMOS doesn’t have any resistors, which creates more power capacity than a regular resistor MOSFET inverter.

CMOS (Complementary Metal-Oxide Semiconductor)



CMOS-Inverter



CMOS (Complementary Metal-Oxide Semiconductor)

- CMOS technology devices are used in a variety of applications with analog circuits such as data converters, image sensors, etc.
- The benefits of CMOS technology over NMOS technology include the following.
  - ✓ Static power consumption is very slow.
  - ✓ The complexity of the circuit reduces
  - ✓ The high density of logic functions on a chip
  - ✓ High noise immunity

IIL (Integrated Injection Logic)

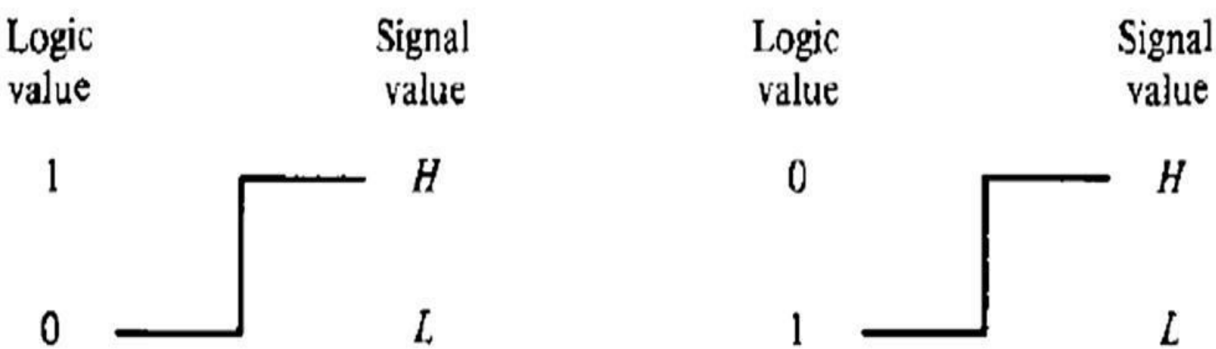
- Integrated injection logic (**IIL**, **I^{2}L**, or **I2L**) is a class of digital circuit technology built with multiple collector bipolar junction transistors (BJT).
- When introduced it had speed comparable to TTL yet was almost as low power as CMOS, making it ideal for use in VLSI (and larger) integrated circuits. Although the logic voltage levels are very close (High: 0.7V,Low: 0.2V),
- I^{2}L has high noise immunity because it operates by current instead of voltage.
- Sometimes also known as Merged Transistor Logic.

Logic

- **Logic**
  - A logic in which the voltage levels represent logic 1 and logic 0.
  - Level logic may be Positive or Negative.
  - A **"Positive Logic"** is the one which the higher of the two voltage levels represents the logic 1 and the lower of the two voltage level represents the logic 0.
  - A **"Negative Logic"** is the one which the lower of the two voltage levels represents the logic 1 and the higher of the two voltage level represents the logic 0.

Positive and Negative Logic

- The binary signal at the inputs and outputs of any gate has one of two values, except during transition.
- One signal value represents logic-1 and the other logic-0.
- Choosing the high-level *H* to represent logic-1 defines a **positive logic system**.
- Choosing the low-level *L* to represent logic-1 defines a **negative logic system**.



(a) Positive logic (b) Negative logic

✓ **Positive Logic**

Logic 0 (LOW)=0V

Logic 1 (HIGH)=+5V

✓ **Negative Logic**

Logic 0 (LOW)=+5V

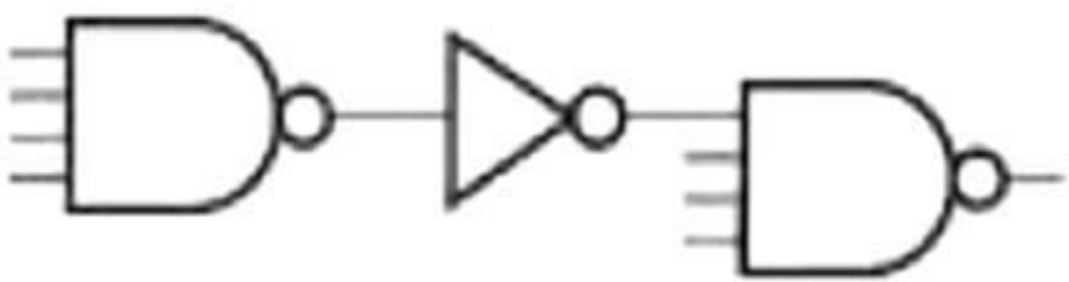
Logic 1 (HIGH)=0V

Characteristics of digital logic families

- Fan-in
- Propagation delay
- Fan-out
- Power dissipation
- Noise margin

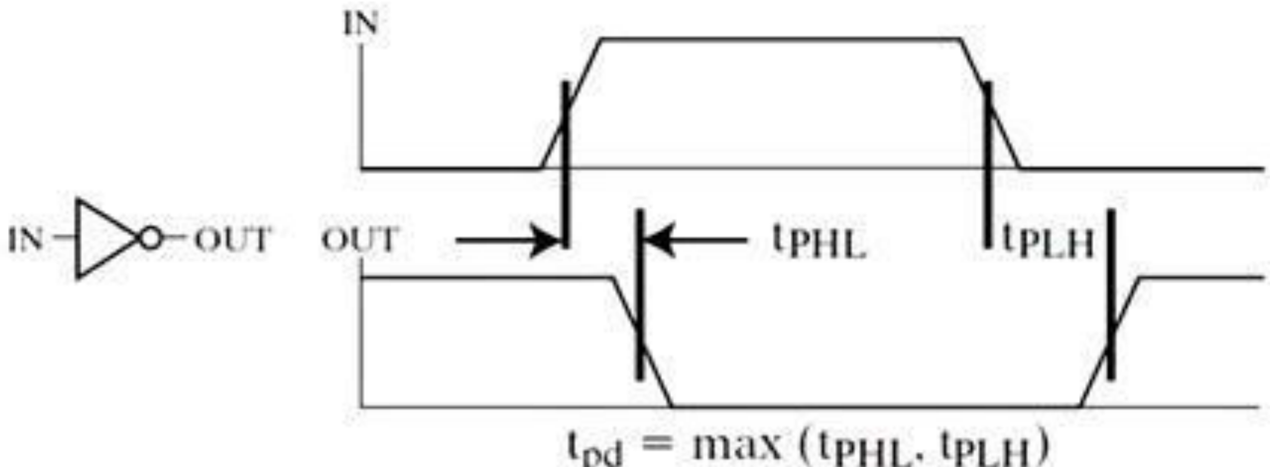
Fan-in

- For high-speed technologies, *fan-in,* the number of inputs to a gate, is often restricted on gate primitives to no more than four or five.
- The maximum umber of inputs that can be applied to a logic gate.
- This is primarily due to electronic considerations related to gate speed.
- To build gates with larger fan-in, interconnected gates with lower fan-in are used during technology mapping.
- A mapping for a 7-input NAND gate is made up of two 4- input NAND and an inverter as shown in figure.



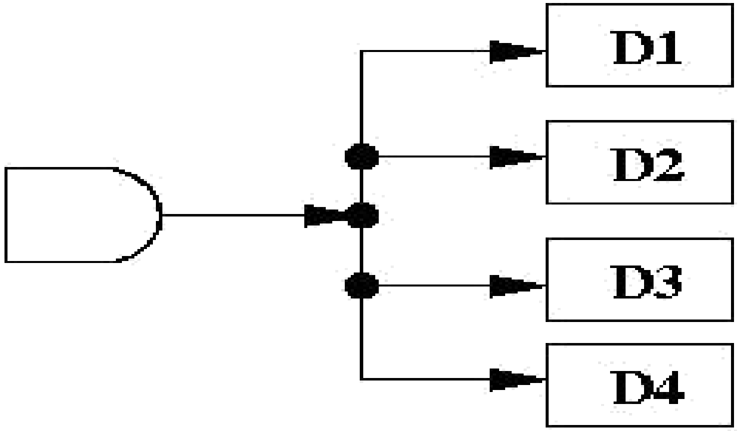
Propagation delay

- The signals through a gate take a certain amount of time to propagate from the inputs to the output. This interval of time is defined as the **propagation delay of the gate**.
- Propagation delay is measured in nanoseconds (ns).
- The signals that travel from the inputs of a digital circuit to its outputs pass through a series of gates.
- The sum of the propagation delays through the gates is the total delay of the circuit.



Fan-out

- Fan-out specifies the number of standard loads driven by a gate output
- Fan-out is a measure of the ability of a logic gate output to drive a number of inputs of other logic gates of the same type.
- Maximum Fan-out for an output specifies the fan-out that the output can drive with out exceeding its specified *maximum transition time*



Power Dissipation

- Every electronic circuit requires a certain amount of power to operate.
- The power dissipation is a parameter expressed in millwatts (mW) and represents the amount of power needed by the gate.
- The number that represents this parameter does not include the power delivered from another gate; rather, it represents the power delivered to the gate from the power supply.
- An IC with four gates will require, from its power supply, four times the power dissipated in each gate.
- The amount of power that is dissipated in a gate is calculated as:

$$\mathbf{P_D\ (Power\ Dissipation) = V_{CC} * I_{CC}}$$

Where V_{cc} = *supply voltage and*

I_{cc} = *current drawn by the circuit*

Power Dissipation

- The current drawn from the power supply when the output of the gate is in the high-voltage level is termed I_{CCH}.
- When the output is in the low-voltage level, the current is I_{CCL}.
- The average current is

$$I_{CC}(\text{avg}) = \frac{I_{CCH} + I_{CCL}}{2}$$

- And used to calculate the average power dissipation as,

$$P_D(\text{avg}) = I_{CC}(\text{avg}) \times V_{CC}$$

Noise Margin

- Thus, noise is a term used to denote an undesirable signal that is superimposed upon the normal operating signal.
- ***Noise margin*** is the maximum noise voltage added to an input signal of a digital circuit that does not cause an undesirable change in the circuit output.
- The ability of circuits to operate reliably in a noise environment is important in many applications.
- Noise margin is expressed in volts and represents the maximum noise signal that can be tolerated by the gate.
- **NMH (NOISE MARGIN high) = Voh - Vih**
- **NML (NOISE MARGIN low) = Vil – Vol**

Noise Margin