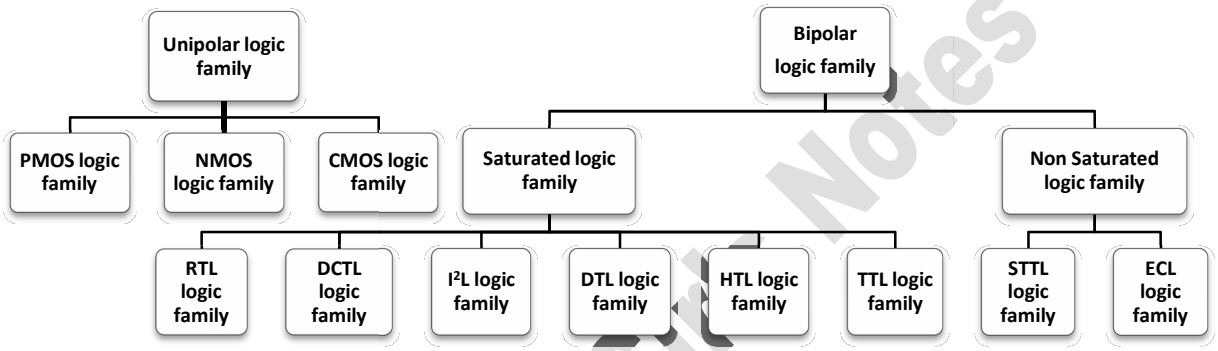
1.22 INTRODUCTION

Logic circuits are available in the market in different forms of integrated circuits. There are two basic types of integrated circuits ICs using logic circuits. They are known as Unipolar and Bipolar logic families. The TTL i.e. Transistor Transistor Logic ICs and the CMOS i.e. Complementary Metal Oxide Semiconductor are their further classifications. According to their properties and working their family is decided. In this chapter, we shall study two basic families: unipolar and bipolar along with TTL & CMOS and their other types.

1.23 CLASSIFICATION OF LOGIC FAMILIES

The classification of different logic families is given in the following diagram –



Unipolar logic families: The logic circuits in this family contain semiconductor devices, in which current flows due to either holes or electrons. This family contains –

- PMOS logic circuits, which has only P–channel MOSFETs
- NMOS logic circuits, which has only N–channel MOSFETs
- CMOS logic circuits, which has combination of both NMOS & PMOS

Bipolar logic families: The logic circuits in this family contain semiconductor devices, in which current flows due to holes and electrons both. This family is further subdivided into following types –

Saturated bipolar logic families, which contain:

- Resistor-transistor logic circuits (RTL)
- Direct-coupled transistor logic circuits (DCTL)
- Integrated-injection logic circuits (I^2L)
- Diode-transistor logic circuits (DTL)
- High threshold logic circuit (HTL)
- Most widely used Transistor-transistor logic circuits (TTL)

Non–saturated bipolar logic families, which contain:

- Schottkey transistor-transistor logic circuits (STTL)
- Emitter-coupled logic circuits (ECL)

1.24 CHARACTERISTICS OF LOGIC FAMILIES

Propagation delay: It is defined as the time required changing the output from one logic state to another, *after* input is applied. *It decides the operating speed of the logic gate*.

Power dissipation: The power dissipation is defined as the product of operating voltage and current consumed by the IC.

Figure of merit: Figure of merit is defined as the *product* of propagation delay and power dissipation of the IC or logic family. It is always measured in *Pico-Joules*.

Fan-in & Fan-out: Fan-in is defined as number of inputs *to* a gate. And fan-out is defined as the maximum number of gates *(i.e. loads)* from the *same family*, which can be driven *reliably*.

Voltage & current parameters: For voltage and current of a digital IC, there are four important parameters. They are specified by the manufacturer. They are as follows –

Voltage parameters:
High level input voltage: the minimum input voltage, which is recognized as logic-1.
Low level input voltage: maximum input voltage, recognized as logic-0.
High level output voltage: minimum output voltage, recognized as logic-1.
Low level output voltage: maximum input voltage, recognized as logic-0.

Current parameters:
High level input current: The minimum amount of current that must be supplied by the driving source corresponding to logic-1 voltage level.
Low level input current: Minimum current that must be supplied corresponding to logic-0 voltage level.
High level output current: It is maximum current, which the gate can source to the load corresponding to logic-1 voltage level.
Low level output current: It is maximum current, which the gate can source to the load corresponding to logic-0 voltage level.

Noise immunity: It is defined as the maximum noise voltage, which the device can withstand WITHOUT MAKING A FALSE CHANGE in its output state.

Operating temperature: For 74xx series ICs the operating temperature is from 0°C to 70°C for industrial, consumer's applications. For 54xx series ICs the operating temperature is from –55°C to 125°C for military applications.

1.25 COMPARISON OF TTL & CMOS LOGIC

Sr. Nos.	Family	TTL	CMOS
1	Basic circuit	Transistor-transistor circuit	Complementary MOSFET circuit
2	Noise immunity	Good	Very good to excellent
3	Supply voltage	Strictly +5V	+3V to +18V
4	Noise generation	High	Low
5	Propagation delay	10ns	50ns
6	Compatibility with other families	With DTL, CMOS etc.	Only with TTL when working on +5V
7	Power consumption	10mW	10nW
8	Fan out	10	50
9	Sensitive to static electricity	Immune	Sensitive and hence, it must be shielded.

Self Examination

Objective questions

1. The integrated circuits in which the electric current is carried by both holes and electrons is called as _____.
2. _____ is the logic family in which current is carried by either holes or electrons.
3. The logic circuits which contain PMOS and NMOS are called as _____.
4. Schottkey TTL belongs to _____ logic family.
5. The time required to change the state of a logic circuit is known as _____.
6. The number of inputs of any gate is known as _____.
7. The product of operating speed and power dissipation of an IC is called as _____.
8. In a logic circuit if the speed of operation is increased then the total amount of power dissipated in it _____.
9. In CMOS NAND gate, the NMOS transistors are connected in _____ and the PMOS transistors are connected in _____.
10. In tri-state logic circuit, the third state of the output is known as _____.

Long answer questions (4 Marks)

1. Classify the different types of logic families with one example of each.
2. Explain following terms of digital ICs –
3. Noise margin, power dissipation, propagation delay, fan out.
4. Draw the circuit of CMOS NAND gate and explain the function of the circuit. Also draw the truth table and explain which transistor conducts and which doesn't in every state of the output.
5. With neat circuit diagram explain the working of TTL NOR gate.
6. State and explain any four characteristics of digital ICs.
7. Draw the circuit of CMOS NOT gate and explain its working with truth table.
8. Explain the basic concept of tri-state logic circuit. Draw its circuit diagram and explain its working also.
9. Compare TTL and CMOS logic families with any four points.
10. Draw the circuit of TTL NOT gate and TTL NAND gate. Compare them and explain the difference. Thus, give your reasoning to explain the idea of universal building block using NAND gate.