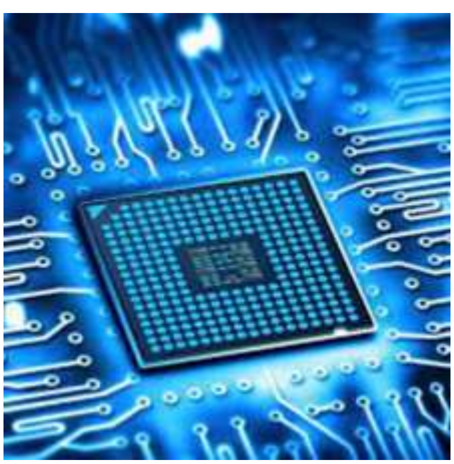
T.Y.B.Sc. SEM – V

Subject: Physics

Paper- 503

Unit -3

INTEGRATED CIRCUIT



- Introduction
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INTRODUCTION:

INTEGRATED CIRCUIT :

- *"An* ***integrated circuit*** *is one in which circuit components such as transistors, diodes, resistors, capacitors etc. are automatically part of a small semiconductor chip."*

- An integrated circuit consists of a number of circuit components (*e.g*. transistors, diodes, resistors etc.) and their inter connections in a single small package to perform a complete electronic function. These components are formed and connected within a small chip of semiconductor material. The following points are worth noting about integrated circuits :

(i) In an *IC*, the various components are automatically part of a small semi-conductor chip and the individual components cannot be removed or replaced. This is in contrast to discrete assembly in which individual components can be removed or replaced if necessary.

(ii) The size of an **IC* is extremely small. In fact, *ICs* are so small that you normally need a microscope to see the connections between the components. Fig. 23.1 shows a typical semi-conductor chip having dimensions 0.2 mm × 0.2 mm × 0.001 mm. It is possible to produce circuits containing many transistors, diodes, resistors etc. on the surface of this small chip.

(iii) No components of an *IC* are seen to project above the surface of the chip. This is because all the components are formed within the chip.

ADVANTAGE & DIS ADVANTAGE OF IC :

Advantages : Integrated circuits possess the following advantages over discrete circuits :

(i) Increased reliability due to lesser number of connections.

(ii) Extremely small size due to the fabrication of various circuit elements in a single chip of semi- conductor material.

(iii) Lesser weight and **space requirement due to miniaturized circuit.

(iv) Low power requirements.

(v) Greater ability to operate at extreme values of temperature.

(vi) Low cost because of simultaneous production of hundreds of alike circuits on a small semiconductor wafer.

(vii) The circuit lay out is greatly simplified because integrated circuits are constrained to use minimum number of external connections.

Disadvantages: The disadvantages of integrated circuits are :

(i) If any component in an *IC* goes out of order, the whole *IC* has to be replaced by the new one.

(ii) In an *IC*, it is neither convenient nor economical to fabricate capacitances exceeding 30 *pF*. Therefore, for high values of capacitance, discrete components exterior to *IC* chip are connected. It is not possible to fabricate inductors and transformers on the surface of semi-conductor chip. Therefore, these components are connected exterior to the semi-conductor chip.

(iii) It is not possible to produce high power *ICs* (greater than 10 W).

(iv) There is a lack of flexibility in an *IC i.e.*, it is generally not possible to modify the parameters within which an integrated circuit will operate.

IC CLASSIFICATION :

- Four basic types of constructions are employed in the manufacture of integrated circuits, namely ;

  (i) mono-lithic (*ii*) thin-film (*iii*) thick-film (*iv*) hybrid.

  Monolithic *ICs* are by far the most common type used in practice. Therefore, in this chapter we shall confine our attention to the construction of this type of *ICs* only.

- It may be worthwhile to mention here that regardless of the type of method used to fabricate active and passive components,
- the basic characteristics and circuit operation of an *IC* are the same as for any of their counterparts in a similar circuit using separate circuit components.

IC SYMBOL :

- **Some of the symbols used with *ICs* are shown below.**

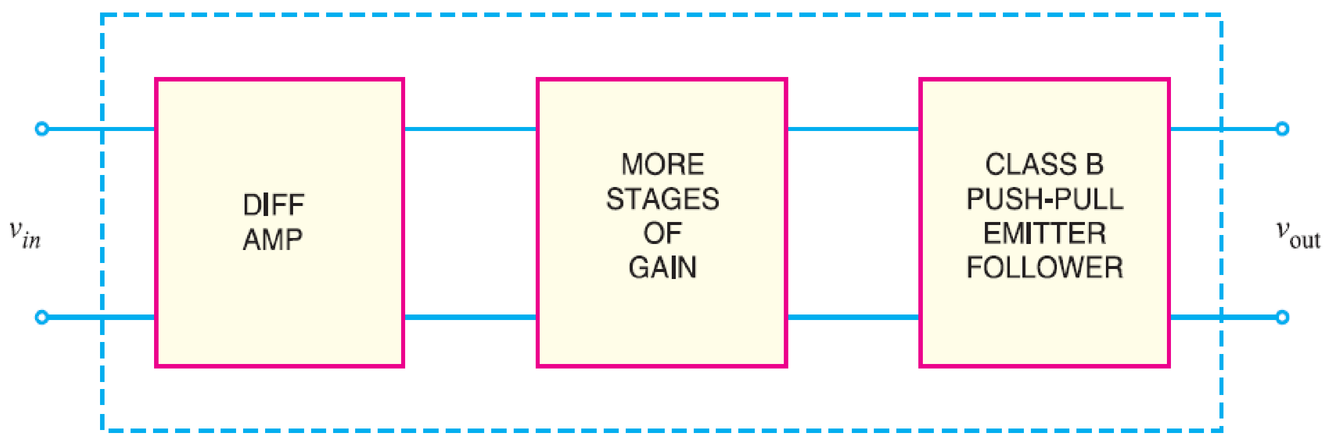
- Fig. 1 shows the symbol of an *IC r-f* amplifier containing 3 transistors, 3 resistors and 8 terminals.
- Similarly, Fig. 2 shows an *IC* audio amplifier which contain 6 transistors, 2 diodes, 17 resistors and has 12 terminals.

SCALE OF IC :

Scale of integration	Abbreviation	Number of components
Small	*SSI	1 to 20
Medium	MSI	20 to 100
Large	LSI	100 to 1000
Very large	VLSI	1000 to 10,000
Super large	SLSI	10,000 to 100,000

OPERATIONAL AMPLIFIER :

- *An* **operational amplifier** (*OP-Amp*) *is a circuit that can perform such mathematical operations as\ addition, subtraction, integration and differentiation.*
- Fig. shows the block diagram of an operational amplifier. Note that *OP*-Amp is a multistage amplifier. The three stages are : differential amplifier input stage followed by a high-gain *CE* amplifier and finally the output stage.
- *The key electronic circuit in an OP-Amp is the* **differential amplifier.** A differential amplifier (*DA*) can accept two input signals and amplifies the difference between these two input signals.



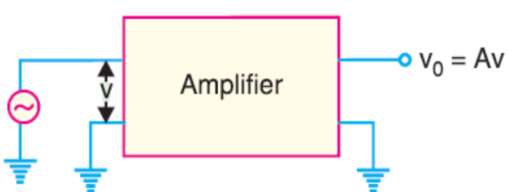
Block diagram of OP-Amp

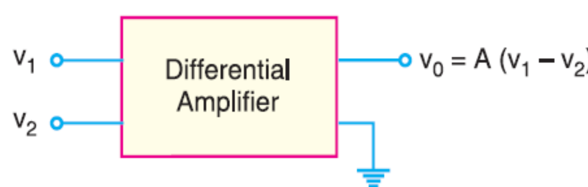
The following points may be noted about operational amplifiers (*OP*-Amps) :

- The input stage of an *OP*-Amp is a *differential amplifier* (*DA*) and the output stage is typically a class *B* push-pull emitter follower.
- The internal stages of an *OP*-Amp are *direct-coupled i.e.*, no coupling capacitors are used. The direct coupling allows the *OP*-Amp to amplify d.c. as well as a.c. signals.
- An OP-Amp has *very high input impedance* (ideally infinite) and *very low output impedance* (ideally zero). The effect of high input impedance is that the amplifier will draw a very small current (ideally zero) from the signal source. The effect of very low output impedance is that the amplifier will provide a constant output voltage independent of current drawn from the source.
- An OP-Amp has *very high *open-loop voltage gain* (ideally infinite); typically more than 200,000.
- The OP-Amps are almost always operated with negative feedback. It is because the open loop voltage gain of these amplifiers is very high and we can sacrifice the gain to achieve the advantages of negative feedback including large bandwidth (*BW*) and gain stability.

DIFFERENTIAL AMPLIFIER :

"A ***differential amplifier*** *is a circuit that can accept two input signals and amplify the difference between these two input signals."*





CMRR :

A differential amplifier should have high differential voltage gain (A_{DM}) and very low common-mode voltage gain (A_{CM}). The ratio A_{DM}/A_{CM} is called common-mode rejection ratio ($CMRR$) *i.e.*,

$$CMRR = \frac{A_{DM}}{A_{CM}}$$

Very often, the $CMRR$ is expressed in decibels (dB). The decibel measure for $CMRR$ is given by;

$$CMRR_{dB} = 20\log_{10}\frac{A_{DM}}{A_{CM}} = 20\log_{10}CMRR$$

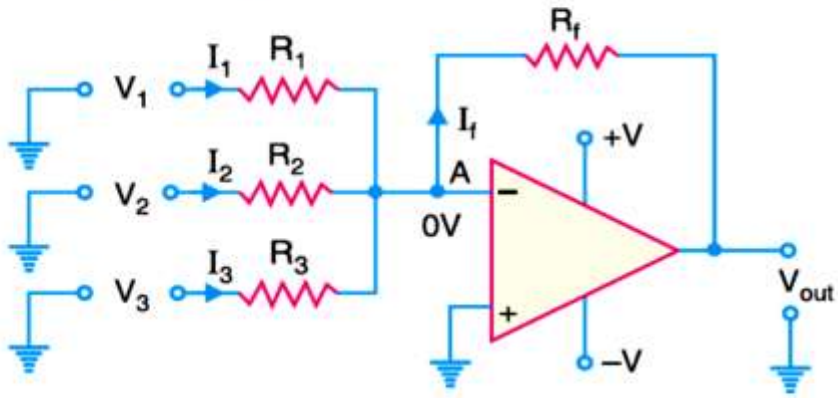
The following table shows the relation between the two measurements :

$CMRR$	$CMRR_{dB}$
10	20dB
10^3	60dB
10^5	100dB
10^7	140dB

SUMMING AMPLIFIER :

- A summing amplifier is an inverted *OP*-amp that can accept two or more inputs. *The output voltage of a summing amplifier is proportional to the negative of the algebraic sum of its input voltages.* Hence the name **summing amplifier**.
- Fig. shows a three-input summing amplifier but any number of inputs can be used. Three voltages *V*1, *V*2 and *V*3 are applied to the inputs and produce currents *I*1, *I*2 and *I*3.
- Using the concepts of infinite impedance and virtual ground, you can see that inverting input of the *OP*-amp is at virtual ground (0*V*) and there is no current to the input. This means that the three input currents *I*1, *I*2 and *I*3 combine at the summing point *A* and form the total current (*If*) which goes through *Rf* as shown in Fig.

$$I_f = I_1 + I_2 + I_3$$



When all the three inputs are applied, the output voltage is

$$\text{Output voltage, } V_{out} = -I_f R_f = -R_f(I_1 + I_2 + I_3)$$

$$= -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right)$$

$$\therefore \quad V_{out} = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right)$$

If $R_1 = R_2 = R_3 = R$, then, we have,

$$V_{out} = -\frac{R_f}{R}(V_1 + V_2 + V_3)$$

Thus the output voltage is proportional to the algebraic sum of the input voltages (of course neglecting negative sign). An interesting case results when the **gain of the amplifier is unity.** In that case, $R_f = R_1 = R_2 = R_3$ and output voltage is

$$V_{out} = -(V_1 + V_2 + V_3)$$

Thus, when the gain of summing amplifier is unity, the output voltage is the algebraic sum of the input voltages.

Summing amplifier with gain greater than unity. When R_f is larger than the input resistors, the amplifer has a gain of R_f/R where R is the value of each input resistor. The general expression for the output voltage is

$$V_{out} = -\frac{R_f}{R}(V_1 + V_2 + V_3 + \ldots)$$

As you can see, the output voltage is the sum of input voltages multiplied by a constant determined by the ratio R_f/R.