Integrated Circuit (IC)

→ Miniature form of electronic circuit.

→ Active and passive component in single crystal (Si).

→ **Advantage**

- low cost, miniature form.
- less power.
- Reliability and performance.
- Mobility
- Speed
- Increased package density.

★ Linear or Digital IC.

- IC
  - Monolithic
    - Bipolar
      - P-N junc.
      - Dielec.
    - unipolar
      - JFET
      - MOSFET
  - Hybrid

→ Amplifier

It increases the gain of the input signal

$$\text{gain} = \frac{O/P}{I/P}$$

In case of operational amplifier

$$V_o \propto (V_1 - V_2)$$

$$V_o = A_d (V_1 - V_2)$$

$$V_o = A_d V_d$$

$$\frac{V_1 + V_2}{2} = \text{common mode signal}$$

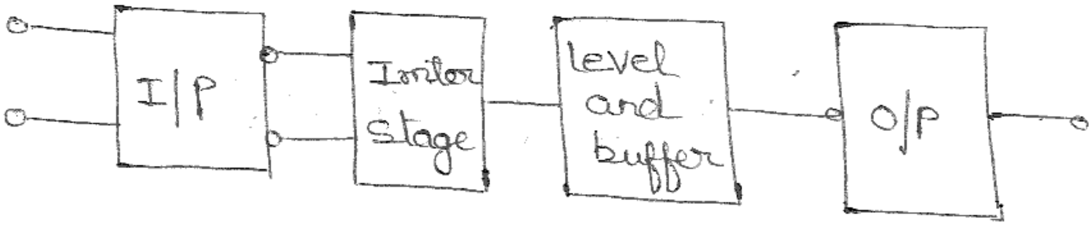
$$V_c = \frac{V_1 + V_2}{2}$$

$$V_o \propto V_c$$

$$V_o = A_c V_c$$

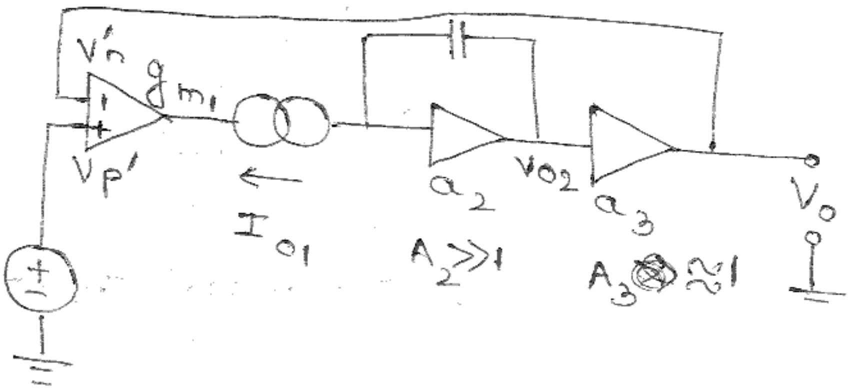
$$V_o = A_d V_d + A_c V_c$$

- Block Diagram



Buffer have unity voltage gain

* Method Of Improving Slew Rate



$$S = \frac{I_{max}}{C}$$

$$S = \frac{I_{01}\ Sat}{C}$$

$$I_{01}\ sat = C\frac{dV_{o2}}{dt}$$

$a_3 \approx 1$ $\qquad V_o \approx V_{o2}$

$$\frac{dV_o}{dt}\, max = \frac{dV_{o2}}{dt} = \frac{I_{01}\ Sat}{C}$$

$$I_{O1} = g_{m1}(V_p' - V_n')$$

$$V_{O2} = Z g_{m1}(V_p' - V_n')$$

$$= \frac{1}{j\omega C} g_{m1}(V_p' - V_n')$$

$$\frac{V_{O2}}{V_p' - V_n'} = \frac{g_{m1}}{j\omega C} \qquad |a| = \frac{g_{m1}}{2\pi f C}$$

$$|a| f = \frac{g_{m1}}{2\pi C}$$

$$f_t = \frac{g_{m1}}{2\pi C}$$

↓

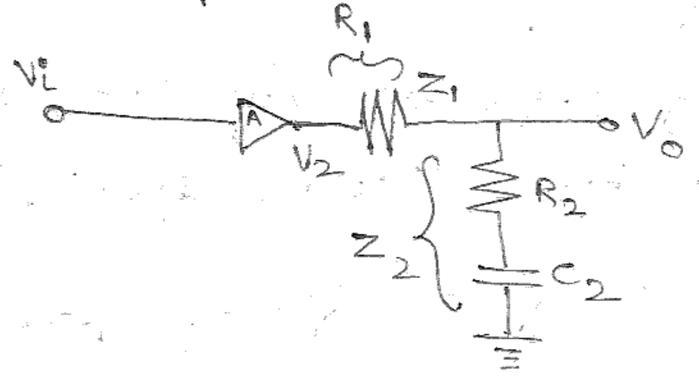
gain bandwidth product

$$C = \frac{g_{m1}}{2\pi f_t}$$

$$S = \frac{I_{O1}\,\text{sat}}{C}$$

$$S = \frac{I_{O1}\,\text{sat} \quad 2\pi f_t}{g_m}$$

* Frequency Compensation Pole Zero Method



Uncompensated transfer function A. zero should be higher freq. than pole.

Transfer of compensation network

$$\frac{V_o}{V_2} = \frac{Z_2}{Z_1 + Z_2}$$

$$Z_1 = R_1 \qquad Z_2 = R_2 + \frac{1}{j\omega C_2}$$

$$\frac{V_o}{V_2} = \frac{R_1}{R_1 + R_2 + \frac{1}{j\omega C_2}} = \frac{1 + j\,f/f_1}{1 + j f/f_o}$$

where,

$$f_1 = \frac{1}{2\pi R_2 C_2} \qquad f_o = \frac{1}{2\pi (R_1 + R_2) C_2}$$

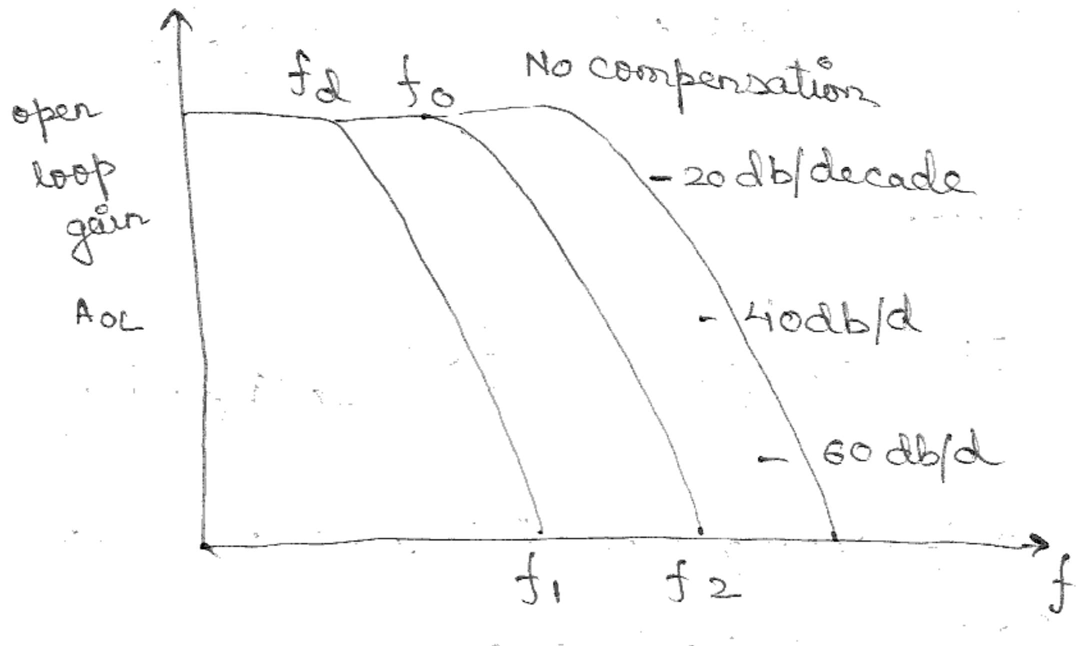
Compensating n/w will have zero at corner freq. of f_1.

f_1 will cancel the pole effect. The pole of compe. n/w will be at corner freq. f_0 we shift the compensating n/w thro f_2 (corner freq). This freq. can be found from graph.

$$A' = \frac{V_o}{V_i} = \frac{V_o}{V_2} \times \frac{V_2}{V_i}$$

$$= \frac{A R_2}{R_1 + R_2} \frac{1 + j f/f_1}{1 + j f/f_0}$$

$$= \frac{A_{OL}}{\left(1 + j f/f_1\right)\left(1 + j f/f_2\right)\left(1 + j f/f_3\right)}$$



★ Internal Compensation

i) Slow changing signal

ii) not required good freq response

iii) Internal capacitance 30pf shunt

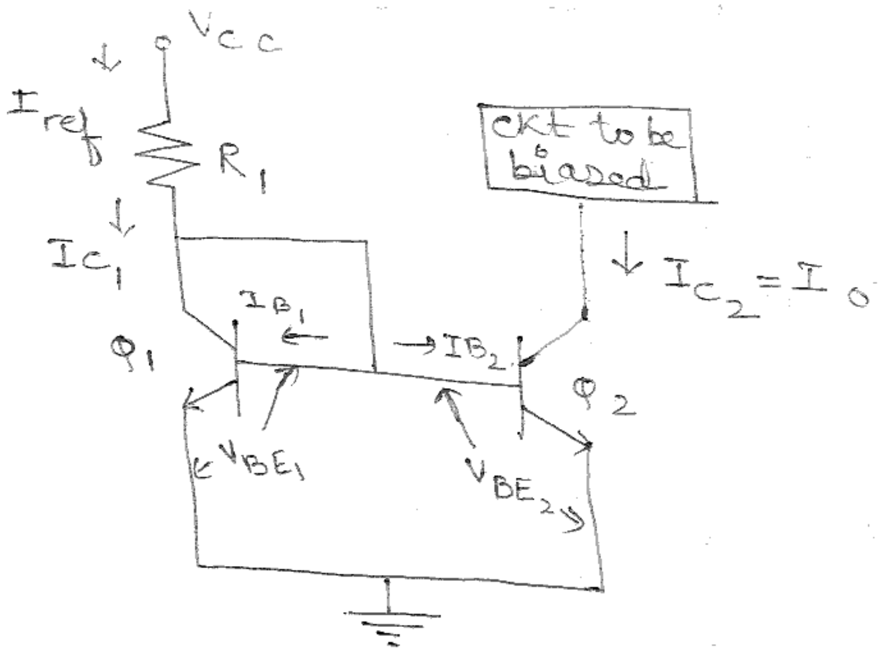
iv) Reduces o/p signal at higher freq.

★ Current Source (Current mirror)

i) Transistors in active region.

ii) I_c is independent of collector voltage.

iii) Q_1 and Q_2 matched.



Analysis

$$\frac{I_{C_1}}{I_E} \approx \alpha_F \cdot e^{V_{BE_1}/V_T}$$

$$\frac{I_{C_2}}{I_E} \approx \alpha_F e^{V_{BE_2}/V_T}$$

$$\frac{I_{C_2}}{I_{C_1}} = e^{(V_{BE_2} - V_{BE_1})/V_T}$$

$$V_{BE_2} = V_{BE_1}$$

$$I_{C_2} = I_{C_1} = I_C = I_0$$

$$\beta_1 = \beta_2 = \beta$$

KCL at ϕ_1 gives

$$I_{ref} = I_{C_1} + I_{B_1} + I_{B_2}$$

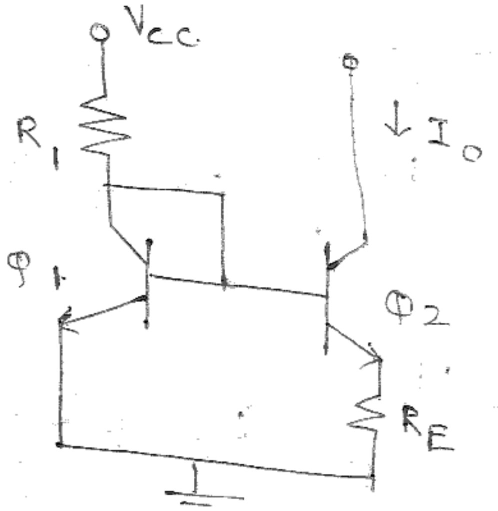
$$= I_{C_1} + \frac{I_C}{\beta_1} + \frac{I_{C2}}{\beta_2}$$

$$= I_C \left[1 + \frac{1}{\beta} + \frac{1}{\beta} \right]$$

$$I_{ref} = I_c \left[\frac{\beta+2}{\beta} \right]$$

$$= I_c \left[1 + \frac{2}{\beta} \right]$$

★ Widlar Current Source



$I_{C_2} << I_{C_1}$

$$\frac{I_{C_1}}{I_{C_2}} = e^{(V_{BE_1} - V_{BE_2})/V_T}$$

$$V_{BE_1} - V_{BE_2} = V_T \ln \left(\frac{I_{C_1}}{I_{C_2}} \right) \quad \text{—— (1)}$$

$\cancel{V_{BE_1} = V_{BE_2}}$

KVL at base emitter loop

$$V_{BE_1} = V_{BE_2} + (I_{B_2} + I_{C_2}) R_E$$

$$V_{BE_1} - V_{BE_2} = \left(\frac{I_{C_2}}{\beta} + I_{C_2} \right) R_E$$

Equating ① and ②

$$V_T \ln\left(\frac{I_{C_1}}{I_{C_2}}\right) = I_{C_2}\left(\frac{1}{\beta}+1\right)R_E$$

$$R_E = \frac{V_T \ln\left(\frac{I_{C_1}}{I_{C_2}}\right)}{\left(\frac{1}{\beta}+1\right)I_{C_2}}$$

$$I_{ref} = I_{B_1} + I_{B2} + I_{C_1}$$

$$= \left(1+\frac{1}{\beta}\right)I_{C_1} + \frac{I_{C_2}}{\beta}$$

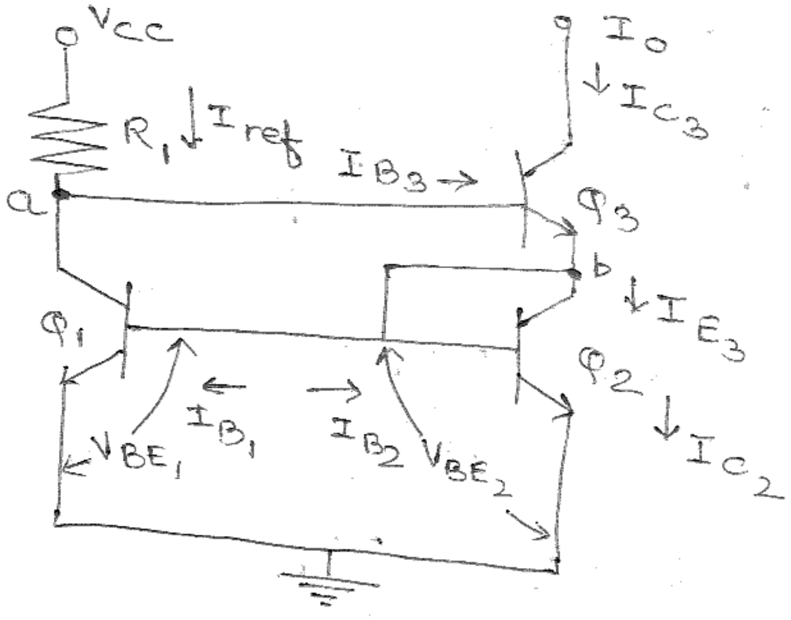
$$= \left(\frac{\beta+1}{\beta}\right)I_{C_1} + \frac{I_{C_2}}{\beta}$$

I_{C_2} is very small

$$I_{ref} = \left(\frac{\beta+1}{\beta}\right)I_{C_1}$$

$$I_{ref} \simeq I_{C_1}$$

★ Wilson Current Source



Analysis

$$V_{BE_1} = V_{BE_2}$$

$$I_{C_1} = I_{C_2}$$

$$I_{B_1} = I_{B_2} = I_B$$

at node b

$$I_{E_3} = I_{B_1} + I_{B_2} + I_{C_2}$$

$$= I_{C_2} + 2 I_B = I_{C_2} + \frac{2 I_{C_2}}{\beta}$$

$$I_{E_3} = I_{C_2}\left(\frac{2}{\beta} + 1\right) \quad \text{—— ①}$$

$$I_{E_3} = I_{C_3} + I_{B_3}$$

$$= I_{C_3}\left(1 + \frac{1}{\beta}\right) \quad \text{--- ②}$$

Eq ① and ②

$$I_{C_2}\left(\frac{2}{\beta} + 1\right) = I_{C_3}\left(\frac{\beta + 1}{\beta}\right)$$

$$I_{C_3} = I_{C_2}\left(\frac{2 + \beta}{\beta + 1}\right)$$

$$I_{C_3} = I_0 = I_{C_2}\left(\frac{2 + \beta}{\beta + 1}\right)$$

$$I_{C_3} = I_0 = I_{C_1}\left(\frac{\beta + 2}{\beta + 1}\right)$$

$$I_{ref} = I_{B_3} + I_{C_1}$$

$$= \left(\frac{\beta + 1}{\beta + 2}\right) I_0 + \frac{I_0}{\beta}$$

$$I_{ref} = I_0 \left[\frac{\beta + 1}{\beta + 2} + \frac{1}{\beta}\right]$$