Solution of Tut Sheet 2

Sol 1 To find the max^m possible value of O/P offset vol., reduce the I/P vol. to zero.

Closed loop gain of the amp^r

$$A = 1 + \frac{R_F}{R_1}$$

$$= 1 + \frac{10k}{1k} = 11$$

As $V_{io} = 10\ mV$ dc max^m

$$V_{oo} = A V_{io}$$

$$= 11 (10 mV)$$

$$= 110\ mV\ dc$$

$\Rightarrow$ O/P terminal can be either at a negative or a positive 110 mV dc with respect to ground even though $V_{in} = 0V$.

Sol. 2

$$V_1 = \frac{V_a + V_b + V_c}{3} \quad \text{(Average of I/Ps)}$$

$$= \frac{2 - 3 + 4}{3}$$

$$= 1V$$

$$V_o = \left(1 + \frac{R_F}{R_1}\right) \frac{1}{3} (V_a + V_b + V_c)$$

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

$$= 3V$$

Sol3 Let vol. at non inverting terminal is V_N

Apply KCL at Pin ③ & find value of V_N

$$\frac{v_1 - V_N}{R_1} + \frac{0 - V_N}{R_2} = 0$$

$$\frac{v_1}{R_1} = \frac{V_N}{R_1} + \frac{V_N}{R_2}$$

$$\frac{v_1}{R_1} = \left(\frac{1}{R_1} + \frac{1}{R_2}\right) V_N$$

$$\frac{v_1}{R_1} = \left(\frac{R_1 + R_2}{R_1 R_2}\right) V_N$$

$$V_N = \left(\frac{R_2}{R_1 + R_2}\right) v_1$$

1) O/P vol. $v_o = \underbrace{-\frac{R'}{R} v_2}_{\text{Due to inverting I/P}} + \underbrace{\left(1 + \frac{R'}{R}\right) V_N}_{\text{Due to non inverting I/P}}$

$$= -\frac{R'}{R} v_2 + \left(1 + \frac{R'}{R}\right)\left(\frac{R_2}{R_1 + R_2}\right) v_1$$

2)

$$v_{cm} = \frac{1}{2}(v_1 + v_2)$$

$$v_d = v_1 - v_2$$

$$\therefore v_1 = v_{cm} + \frac{v_d}{2}$$

$$\& \ v_2 = v_{cm} - \frac{v_d}{2}$$

Put these values in above eq^n of v_o

$$v_o = -\frac{R'}{R}\left(v_{cm} - \frac{v_d}{2}\right) + \left(1+\frac{R'}{R}\right)\left(\frac{R_2}{R_1+R_2}\right)\left(v_{cm}+\frac{v_d}{2}\right)$$

$$v_o = \left[\left(1+\frac{R'}{R}\right)\left(\frac{R_2}{R_1+R_2}\right) - \frac{R'}{R}\right]v_{cm} + \frac{1}{2}\left[\left(1+\frac{R'}{R}\right)\left(\frac{R_2}{R_1+R_2}\right)+\frac{R'}{R}\right]v_d$$

If $\frac{R'}{R} = \frac{R_2}{R_1}$

then $1+\frac{R'}{R} = 1+\frac{R_2}{R_1}$

or $1+\frac{R'}{R} = \frac{R_1+R_2}{R_1}$

Put in above eq^n (Replace $\frac{R'}{R} = \frac{R_2}{R_1}$ in above eq^n)

$$v_o = \left[\left(\frac{R_1+R_2}{R_1}\right)\left(\frac{R_2}{R_1+R_2}\right) - \frac{R_2}{R_1}\right]v_{cm} + \frac{1}{2}\left[\left(\frac{R_1+R_2}{R_1}\right)\left(\frac{R_2}{R_1+R_2}\right)+\frac{R_2}{R_1}\right]v_d$$

$$= \left[\frac{R_2}{R_1} - \frac{R_2}{R_1}\right]v_{cm} + \frac{1}{2}\left[\frac{R_2}{R_1}+\frac{R_2}{R_1}\right]v_d$$

$$= 0 + \frac{R_2}{R_1}v_d$$

$$= \frac{R_2}{R_1}v_d$$

$\Rightarrow$ If $\frac{R'}{R} = \frac{R_2}{R_1}$, then O/P corresponding to ~~eo~~ $v_{cm} = 0$

3) $CMRR = \frac{A_d}{A_c}$

$$v_o = \left[\left(1+\frac{R'}{R}\right)\left(\frac{R_2}{R_1+R_2}\right) - \frac{R'}{R}\right] v_{cm}$$

$$+ \frac{1}{2}\left[\left(1+\frac{R'}{R}\right)\left(\frac{R_2}{R_1+R_2}\right) + \frac{R'}{R}\right] v_d$$

To find A_d put $v_{cm} = 0$ as $A_d = \left.\frac{v_o}{v_d}\right|_{v_{cm}=0}$

so $A_d = \left.\frac{v_o}{v_d}\right|_{v_{cm}=0} = \frac{1}{2}\left[\left(1+\frac{R'}{R}\right)\left(\frac{R_2}{R_1+R_2}\right) + \frac{R'}{R}\right]$

To find A_c put $v_d = 0$ as $A_c = \left.\frac{v_o}{v_{cm}}\right|_{v_d=0}$

so $A_c = \left.\frac{v_o}{v_{cm}}\right|_{v_d=0} = \left(1+\frac{R'}{R}\right)\left(\frac{R_2}{R_1+R_2}\right) - \frac{R'}{R}$

$$\therefore CMRR = \frac{\frac{1}{2R}\left[(R+R')R_2 + R'(R_1+R_2)\right]\frac{1}{R_1+R_2}}{\frac{1}{R}\left[(R+R')R_2 - R'(R_1+R_2)\right]\frac{1}{R_1+R_2}}$$

$$= \frac{1}{2}\frac{\left[(R+R')R_2 + R'(R_1+R_2)\right]}{\left[(R+R')R_2 - R'(R_1+R_2)\right]}$$