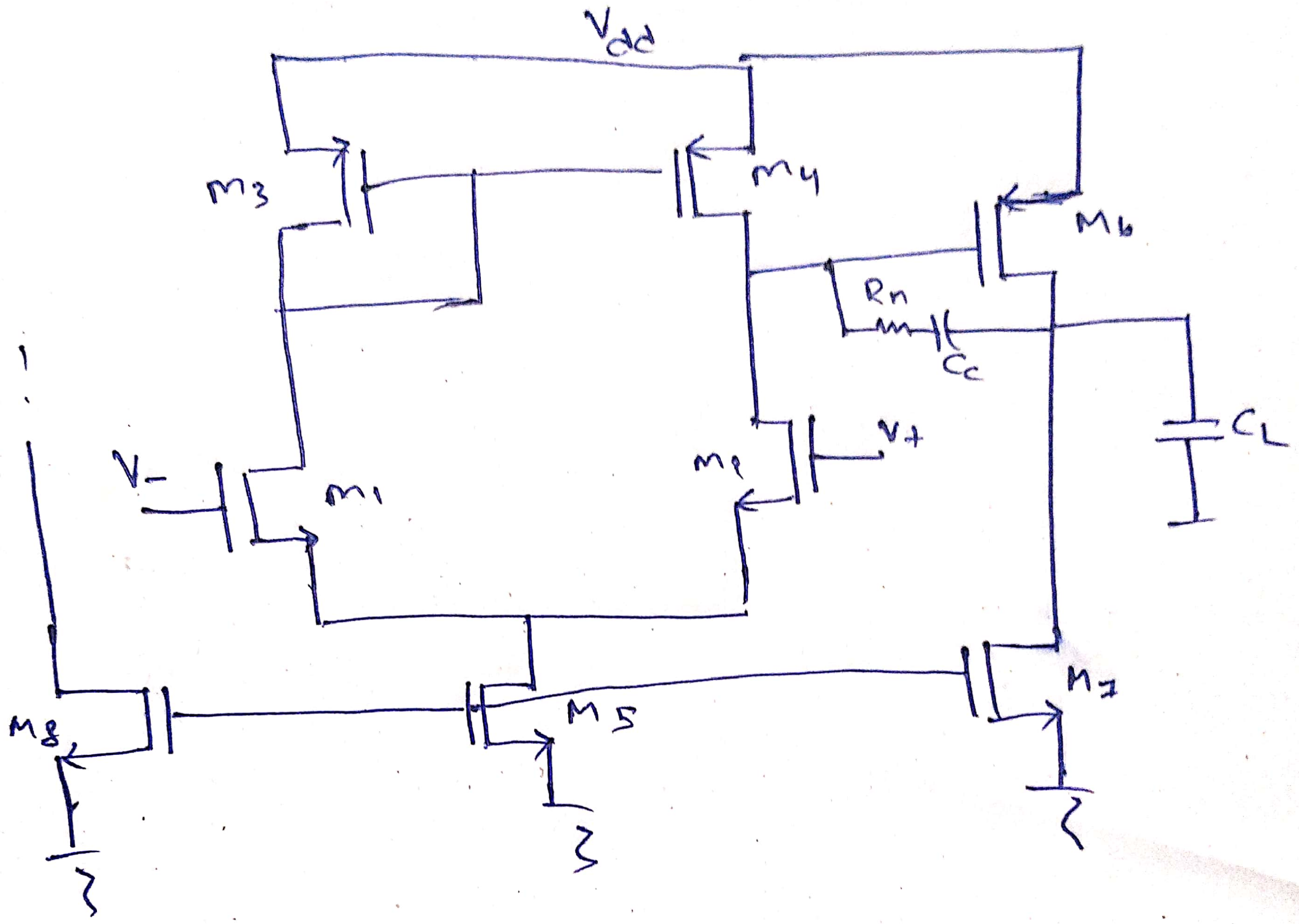
Two-stage-opamp:-



Design constraints,

$C_L = 5pf$

Power consump = < 0.5mW

Unity Gain BW = > 10MHz

Slew rate = 15 V/µs

Gain > 90db

PM > 75°

For M_1 & M_2 :-

$$gm_1 = 2\pi \times GBW \times C_c$$

$$= 2\pi \times 10 \times 2$$

$$gm_1 = 125.6\,\mu$$

$$\left\{ \begin{array}{l} C_L = 5P \\ C_c = 4 C_L \\ C_c = 2\,pf \end{array} \right.$$

Consider ~~[illegible]~~

Slew rate $= 15\,V/\mu s$ $\left(S.R = \frac{I_o}{C_c}\right)$

$$I_{Tail} = 15 \times 2$$

$$= 30\,\mu$$

$$I_{Tail} = 30\,\mu$$

$$\therefore \left(\frac{W}{L}\right)_1 = \frac{gm_1^2}{\mu_n C_{ox} 2 I_{o1}}$$

$$= \frac{(125.6)^2}{3\cancel{25} \times 2 \times .15}$$

$$= 1.78\,\mu$$

$$\left(\frac{W}{L}\right)_{1/2} \simeq 2\,\mu$$

Using Miller Compensation :-

→ Let us assume that due to miller cap the zero which is created due to miller cap is 10 times bigger than GBP

$\therefore Z_1 \geq 10\ GBP$

$$PM = 180 - \tan^{-1}\left(\frac{GBP}{Z}\right) - \underbrace{\tan^{-1}\left(\frac{GBP}{P_1}\right)}_{A_{DC}} - \tan^{-1}\left(\frac{GBP}{P_2}\right)$$

→ Let us assume that gain of the op amp is very high such that $\tan^{-1}(A_{DC})$ can go upto 90°.

$$PM = 180 - 95.17 - \tan^{-1}\left(\frac{GBP}{P_2}\right)$$

$\therefore$ We have considered, $PM = 70°$

$$\therefore \tan^{-1}\frac{GBP}{P_2} = 14.29$$

$$\boxed{P_2 = 4\ GBP}$$

From this, $C_C = 0.4\,C_L$

For M_6:-

we have assumed,

$$z_1 = 10\,GBP$$

$$\frac{g_{m6}}{C_C} \geq 10\frac{g_{m1}}{C_C}$$

$$\boxed{g_{m6} \geq 10\, g_{m1}}$$

$\therefore g_{m6} = 1250\mu$

But from the test circuit g_{m1} was found to be, 117μ

$\therefore g_{m1} = 117\mu$

$\therefore g_{m6} = 1170\mu$

$$\left(\frac{W}{L}\right)_6 = \frac{g_{m6}}{g_{m4}}\left(\frac{W}{L}\right)_4$$

→ Also found from test circuit.

$$= \frac{1170}{208.9} \times 48.5$$

$$= 268.8$$

$$\left(\frac{W}{L}\right)_6 \simeq 269$$

now $I_6 = \frac{269}{41.3} \times 15$ $\Big\}$ $I_6 = \frac{\left(\frac{W}{L}\right)_6}{\left(\frac{W}{L}\right)_4} \times I_4$

$$I_6 = 98.41\,\mu A$$

For M_7 :-

$$\left(\frac{W}{L}\right)_7 = \frac{I_7}{I_5} \times \left(\frac{W}{L}\right)_5$$

$$= \frac{98.41}{30}(20)$$

$$\left(\frac{W}{L}\right)_7 = 65.60$$

→ To increase the PM & GBP, we are using nulling resistor such that it will compensate the non-dominant pole and increase the gap between P_1 & P_3 such that PM will increase.

$$R_N = \left(\frac{C_C + C_L}{C_C}\right)\frac{1}{g_{m6}}$$

$$= \left(\frac{2+5}{2}\right)\frac{1}{1170}$$

$$R_N = 2.99\,k$$

$$\boxed{R_N \simeq 3\,k\Omega}$$

After adding Miller Cap & nulling Res:-

$$\omega_{P1} = \frac{1}{g_{m1} R_1 R_2 C_C}, \quad \omega_{P2} = \frac{g_{m6}}{C_L}$$

$$\omega_{P3} = \frac{1}{R_2 C_1}, \quad \omega_{z1} = \frac{1}{C_C\left(\frac{1}{g_{m3}} - R_Z\right)}$$

$$\boxed{\omega_{z1} = \omega_{P2}} \Rightarrow \text{For inc PM}$$

From this we get, R_N

Tuning the parameters:-

→ Since the square law method is approximate method and we don't get exact results.

→ Tuning the parameters is important to get expected results.

After tuning:

For $M_{1,2}$:-

$\left(\frac{W}{L}\right) = 2$, $W = 4\,\mu m$

$L = 2\,\mu m$

For M_3, M_4 :-

$\left(\frac{W}{L}\right) = 41$ $W = 20.5\mu$

$L = 500n$

For M_5, ~~M6~~ :-

$W = 20\mu$

$\left(\frac{W}{L}\right) = 20$ $L = 1\mu$

For M_6 :-

$W = 134.5\mu$

$\left(\frac{W}{L}\right) = 269$ $L = 500n$

For M_7 :- $W = 65.6\mu$

$\left(\frac{W}{L}\right) = \cancel{84}65.6\mu$ $L = 1\mu.$

For nulling resistor, $R_N = 2.29k$ ohms after tuning.