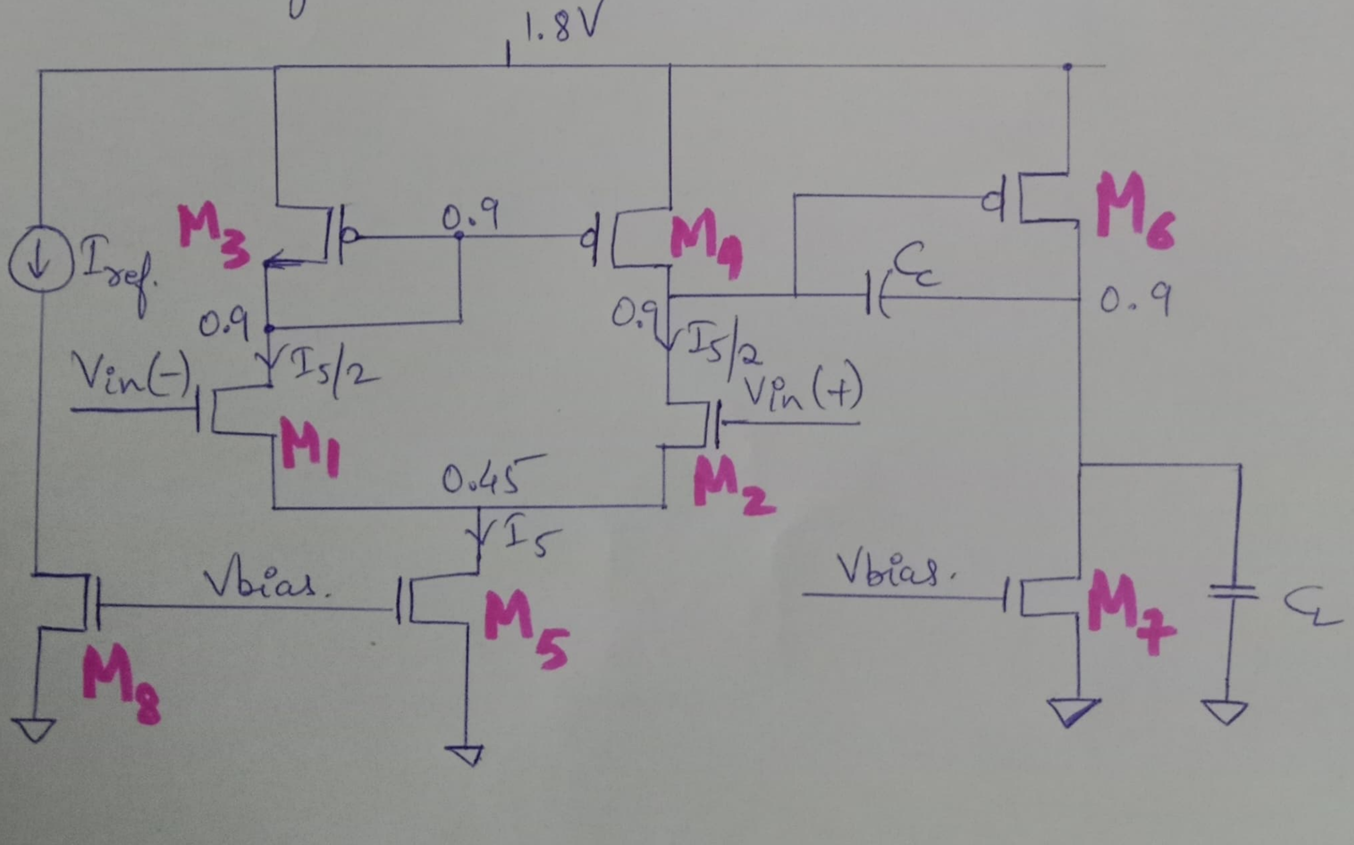
Design for 2 Stage OPAMP

Specification:

- DC Gain = 1000 ⇒ $20 \log_{10} 10^3 = 60dB$
- GBW = 5MHz
- Process = 180nm Tech
- PM ≥ 60°
- Slew Rate ≥ 10V/μsec
- ICMR(+) = 1.6V
- ICMR(−) = 0.8V
- C_L = 10pF
- Power dissipation → as minimum as possible.
- V_{DD} = 1.8V
- $\mu_n C_{ox}$ = 246.74 • $\mu_p C_{ox}$ = 92.75

Circuit diagram:



Method:-

- $\frac{W}{L}$ ratio of M_3 & M_4 is found using ICMR(+)
- $\frac{W}{L}$ ratio of M_1 & M_2 is found using GBW
- I_5 is found using SlewRate
- $\frac{W}{L}$ ratio of M_5 is found using ICMR(-)
- $\frac{W}{L}$ ratio of M_6 is Gain, design of M_3 & M_4
- M_5 & M_7 are related
- C_c is found using Phase Margin

Calculation:-

C_c

for a PM $\geq 60°$

$$\Rightarrow C_c \geq 0.22 C_L$$
$$C_c \geq 0.22(10pF)$$
$$C_c \geq 2.2pF$$
$$\underline{C_c \simeq 3pF}$$

I_5

$$\text{Slew Rate} = \frac{I_5}{C_c}$$

$$I_5 = S.R \times C_c = \frac{10V}{\mu sec} \times 3pF = \underline{30\mu A}$$

For M_1 & M_2

$$g_{m_1} = GBW \times C_L \times 2\pi$$
$$= 5\times10^{6} \times 3\times10^{-12} \times 2\pi$$
$$g_{m_1} = 94.24\mu S$$

WKT

$$\left(\frac{W}{L}\right) = \frac{g_m^2}{\mu_n C_{ox} \cdot 2 I_B}$$

$$\left(\frac{W}{L}\right)_1 = \frac{(94.24\mu S)^2}{(246.79 \times 30\mu)} = 1.2$$

For M_3 & M_4

$$\left(\frac{W}{L}\right)_{3,4} = \frac{2 I_{D3}}{\mu_p C_{ox}\left[V_{DD} - ICMR(+) - V_{t_3 max} + V_{t_1 min}\right]^2}$$

By simulation we get

$V_{t_3} max = 0.433V$

$V_{t_1} min = 0.31V$

$$\left(\frac{W}{L}\right)_{3,4} = \frac{30}{92.75\left[1.8 - 1.6 - 0.433 + 0.31\right]^2} = 54.55$$

$$\left(\frac{W}{L}\right)_{3,4} = 55$$

for M_5, M_8

WKT

$$[V_{D\,sat}]_5 = ICMR(-) - V_{SS} - \sqrt{\frac{I_5}{\beta_1}} - V_{th,max}$$

$$= 0.8 - 1.8 - 0.319 - 0.622 \simeq \underline{0.100\,V}$$

WKT

$$\left(\frac{W}{L}\right)_5 = \frac{2I_5}{\mu_n C_{ox} \cdot (V_{D\,sat5})^2} = \frac{2 \times 30}{246.74 \times (0.100)^2} = 24.31$$

$$\left(\frac{W}{L}\right)_{5,8} \simeq \underline{24}$$

for M_6

$$g_{m6} = 10 g_{m1} = \underline{942.4\mu}$$

$$g_{m4} = \left[2I_4 \times \mu_p C_{ox} \times \left(\frac{W}{L}\right)_4\right]^{1/2} \simeq \sqrt{(30 \times 92.75 \times 55)}$$

$$g_{m4} \simeq 391.20\,\mu$$

$$\left(\frac{W}{L}\right)_6 = \frac{g_{m6} \times \left(\frac{W}{L}\right)_4}{g_{m4}} \simeq 132.49 \simeq \underline{132}$$

for M_7

$$I_6 = \frac{\left[\left(\frac{W}{L}\right)_6 \times I_4\right]}{\left(\frac{W}{L}\right)_4} = \frac{132 \times 15\mu}{55} = \underline{36\mu A}$$

$$\left(\frac{W}{L}\right)_7 = \frac{I_7 \times \left(\frac{W}{L}\right)_5}{I_5} = \underline{\underline{28}}$$

Data in Cadence / LTSpice!

$I_{dc} = 30\mu$

$C_c = 3pF$

$C_L = 10pf$

for simple calculation keep $L = 500n$

$M_1, M_2 = \begin{cases} W = 600n \\ L = 500n \end{cases}$

$M_3, M_4 = \begin{cases} W = 27u \\ L = 500n \end{cases}$

$M_5 = \begin{cases} W = 12u \\ L = 500n \end{cases}$

$M_6 = \begin{cases} W = 66u \\ L = 500n \end{cases}$

$M_7 = \begin{cases} W = 14u \\ L = 500n \end{cases}$

$M_8 = \begin{cases} W = 12u \\ L = 500n \end{cases}$

Analysis:

Total obtained Gain after Simulation = 63dB

Speculated Gain = 60dB

obtained GBW ≃ ~~[illegible]~~ 8 MHz

Speculated ≃ 5MHz

obt PM ≃ 65°

Speculated PM ≃ 60°

Power dissipation is minimum.

Result: The desired specifications are approximately met.