Two stage OPAMP using SKY130PDK

-By

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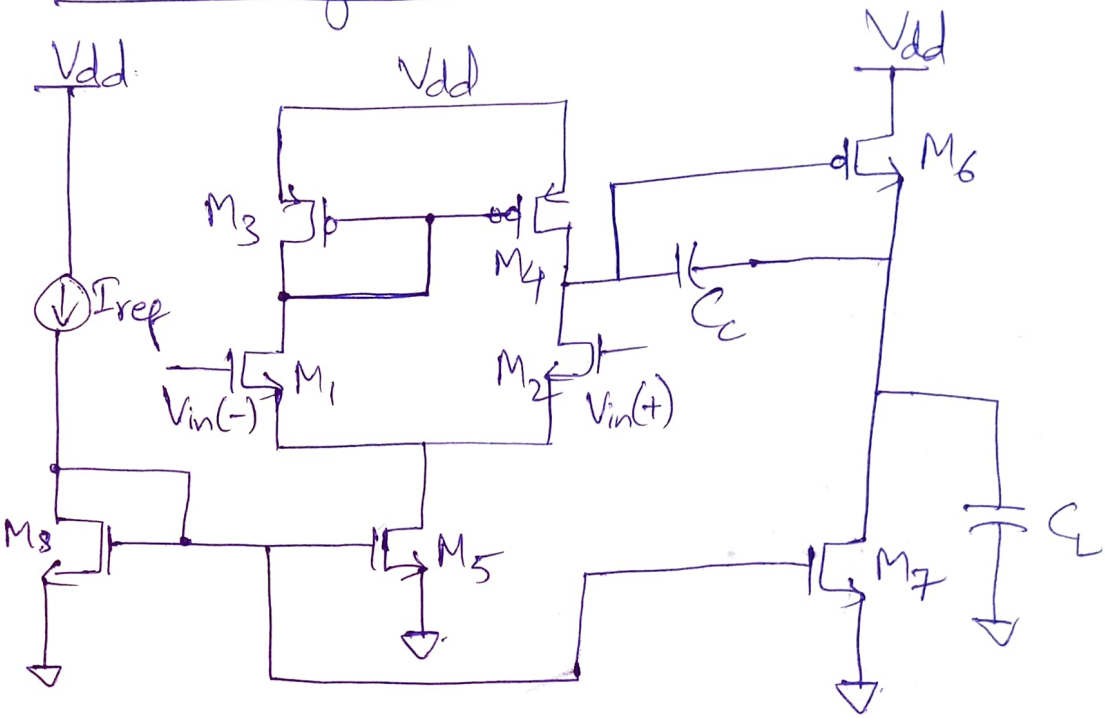
Specification:

- PDK:- SKY130PDK
- VDD: 1.8V
- C_L: 10pf
- DC Gain: 60dB
- GBW(Gain B.W): 5MHz
- Phase Margin: >= 60°
- Slew Rate: 10V/μsec
- ICMR (+): 1.2V
- ICMR (-): 0.8V
- C_c: 3pf
- Power dissipation: ≤ 300μW(max)

Circuit Diagram



Calculations

For a P.M $\geq 60^\circ$

$$C_c \geq 0.22 C_L$$

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

M_1 & M_2

$$g_{m_1} = g_{m_2} = GBW \times C_c \times 2\pi$$

$$\Rightarrow g_{m_1} = 5\times10^6 \times 3\times10^{-12} \times 2\pi$$

$$\Rightarrow \underline{g_{m_1} = 94.2478\mu S}$$

WKT

$$\left(\frac{W}{L}\right)_{1,2} = \frac{g_{m_1}^2}{\mu_n C_{ox} \cdot 2I_D} = \frac{(94.247\mu S)^2}{240\mu \times 30\mu}$$

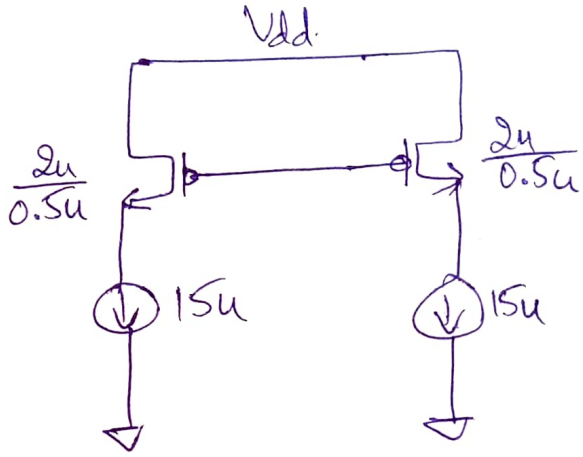
$$\left(\frac{W}{L}\right)_{1,2} \simeq 1.5$$

M_3, M_4

$$\Rightarrow V_{SG_3} = V_{DD} - V_{IC(max)} + V_{TN1(min)}$$

$$\Rightarrow I_3 = \frac{1}{2}\mu_p C_{ox}\left(\frac{W_3}{L_3}\right)\left(V_{SG_3} - V_{TP3(max)}\right)^2$$

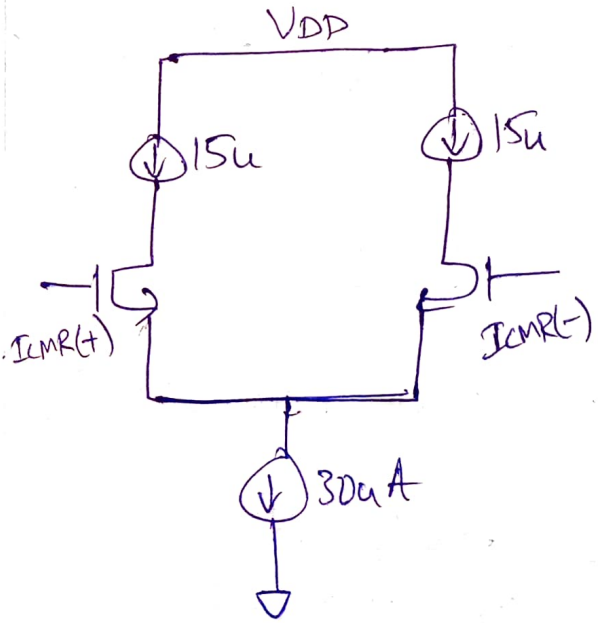
To get $V_{TP3(max)}$



We get $V_{TP3(max)} = 0.62024V \simeq 0.65V$

For $V_{TN1(min)}$ & $V_{TN1(max)}$, We need $\left(\frac{W}{L}\right)_{1,2}$ for $L = 0.5u$

$$\left(\frac{W}{L}\right)_{1,2} \simeq 1.5 \Rightarrow W = 1.5 \times 0.5 = 0.75u$$



⇒ for simulation we get

$V_{TN1(max)} = 0.615934 \simeq 0.62V$

[Put ICMR(+), ICMR(-) = 1.2V]

$V_{TN1(min)} = 0.59764 \simeq 0.6V$

[Put ICMR(+), ICMR(-) ≃ 0.6V]

$$V_{SG_3} = V_{DD} - ICMR_{max} + V_{TN_1}(min)$$

$$= 1.8 - 1.2 + 0.6$$

$$V_{SG_3} = 1.2V$$

$$I_3 = \frac{1}{2}\mu_p C_{ox}\left(\frac{W_3}{L_3}\right)(V_{SG_3} - V_{TP_3(max)})^2$$

or

$$\left(\frac{W_3}{L_3}\right) = \frac{2I_3}{\mu_p C_{ox}(V_{SG_3} - V_{TP_3(max)})^2}$$

$$\left(\frac{W}{L}\right)_{3,4} = \frac{30}{70\mu \times (1.2 - 0.65)^2} = 1.416 \simeq 1.5$$

$$\left(\frac{W}{L}\right)_{3,4} \simeq 1.5$$

M_5, M_8

WKT

$$(V_{Dsat})_5 = ICMR(-) - V_{SS} - \sqrt{\frac{I_5}{\beta}} - V_{TN_1(max)}$$

or

$$V_{GS_1} = \sqrt{\frac{2I_3}{\beta}} - V_{TN_1(max)} = \sqrt{\frac{2I_3}{\mu_n C_{ox}\frac{W_1}{L_1}}} - V_{TN_1(max)}$$

$$V_{GS_1} = \sqrt{\frac{30\mu}{240\mu \times 1.5}} - 0.62 \simeq 0.331V$$

$$(V_{Dsat})_5 = ICMR(-) - V_{GS_1} = 0.8 - 0.331 = 0.468 \simeq 0.47$$

$$\left(\frac{W_5}{L_5}\right) = \frac{2I_5}{\mu_n C_{ox}(V_{Dsat})^2} = \frac{30\mu \times 2}{240\mu \times (0.47)^2}$$

$$\left(\frac{W}{L}\right)_{5,8} \simeq 1.13 \simeq \underline{1.5}$$

M_6

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

$$g_{m4} = \left(2I_4 \times \mu_p C_{ox} \times \left(\frac{W}{L}\right)_4\right)^{1/2} = (30 \times 70 \times 1.5)^{1/2}$$

$$g_{m4} = 56.124\mu$$

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

$$= \frac{942.4\mu}{56.124\mu} \simeq \underline{26}$$

$$\left(\frac{W}{L}\right)_6 \simeq 26$$

But when simulated the best value for $\left(\frac{W}{L}\right)_6$ turns out to be 34, so

$$\underline{\left(\frac{W}{L}\right)_6 \simeq 34} \quad \underline{(\text{Tuning})}$$

M_7

$$I_6 = \frac{\left(\frac{W}{L}\right)_6 I_4}{\left(\frac{W}{L}\right)_4} = \frac{26 \times 15\mu}{1.5} = \underline{260\mu A}$$

$$\left(\frac{W}{L}\right)_7 = \frac{I_6 \times \left(\frac{W}{L}\right)_5}{I_5} = \frac{260 \times 1.5}{30} \simeq 13$$

$$\left(\frac{W}{L}\right)_7 \simeq 13$$

Data:

→ $I_{dc} = 30\mu A$

→ $C_L = 3pF$

→ $C_L = 10pF$

For simplicity $L = 500nm$ & $0.5u$

$$M_1, M_2 = \begin{cases} W = 750n \\ L = 500n \end{cases}$$

$$M_3, M_4 = \begin{cases} W = 0.75u \\ L = 0.5u \end{cases}$$

$$M_{5,8} = \begin{cases} W = 0.75u \\ L = 0.5u \end{cases}$$

$$M_6 = \begin{cases} W = 17u \\ L = 0.5u \end{cases}$$

$$M_7 = \begin{cases} W = 6.5u \\ L = 0.5u \end{cases}$$