Design I

Initial Assumptions :-

$I_{ref} = 10\ \mu A$

So $I_{tail} = 10\ I_{ref} = 100\ \mu A$

$\lambda_n = \lambda_p = 0.1$

$V_{thn} = 0.37\ V$

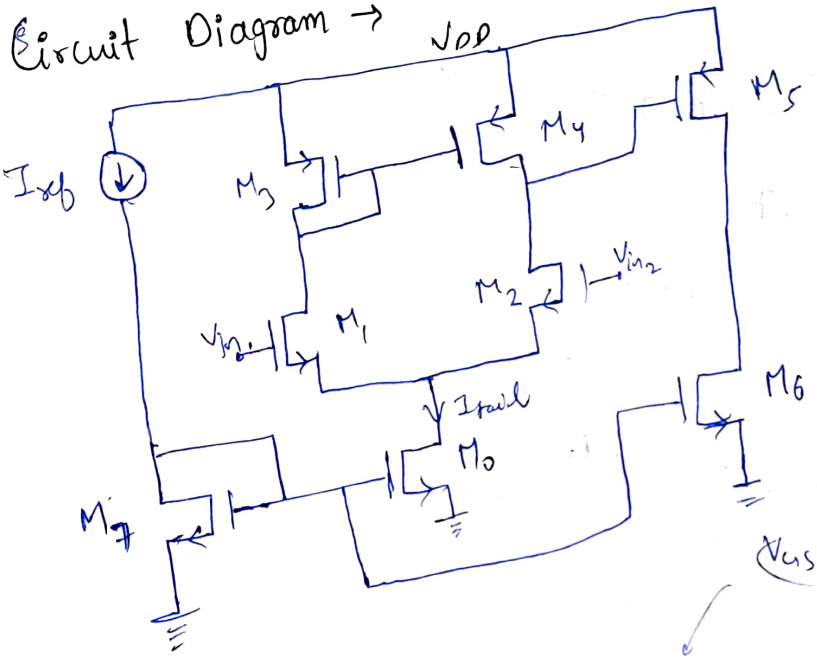
$V_{thp} = 0.39\ V$

$V_{DD} = 1.8\ V$

$\mu_n C_{ox} = 230\ \mu A/V^2$

$\mu_p C_{ox} = 100\ \mu A/V^2$

Circuit Diagram →



$(V_{GS} - V_{th}) \Rightarrow 200\ mV$

For M_7 :-

$I_{ref} = \frac{1}{2} \mu_n C_{ox} \left(\frac{W}{L}\right)_7 (V_{GS} - V_{th})^2$

$\left(\frac{W}{L}\right)_7 \Rightarrow \frac{10 \times 10^{-6} \times 2}{230 \times 10^{-6} \times (200 \times 10^{-3})^2}$

$\boxed{\left(\frac{W}{L}\right)_7 = 2.17}$

For M_0 → $I_{tail} = 100\ \mu A$, $(V_{GS} - V_{th}) \rightarrow 200\ mV$

$I_{tail} = \frac{1}{2} \mu_n C_{ox} \left(\frac{W}{L}\right)_0 (V_{GS} - V_{th})^2$

$\left(\frac{W}{L}\right)_0 = \frac{2 \times 100 \times 10^{-6}}{230 \times 10^{-6} \times (200 \times 10^{-3})^2}$

$\boxed{\left(\frac{W}{L}\right)_0 = 2.17}$

For M_1, M_2 $\quad I = \frac{I_{tail}}{2} = 50\mu A$

$$I = \frac{1}{2} \mu_n C_{ox} \left(\frac{W}{L}\right)_1 (V_{GS} - V_{th})^2$$

$(V_{GS} - V_{th})_1 \Rightarrow$ 5% of $V_{DD} \Rightarrow \frac{5}{100} \times 1.8 \Rightarrow \frac{9}{100}$

$\Rightarrow 0.09\ V$

$$50 \times 10^{-6} = \frac{1}{2} \times 230 \times 10^{-6} \left(\frac{W}{L}\right)_1 (0.09)^2$$

$$\left(\frac{W}{L}\right)_1 = \frac{50 \times 2}{230 \times (0.09)^2}$$

$$\left(\frac{W}{L}\right)_1 = 53.67$$

$$\boxed{\left(\frac{W}{L}\right)_2 = \left(\frac{W}{L}\right)_1 = 53.67}$$

For M_3, M_4 $\rightarrow$ $I = 50\mu A$

$(V_{GS} - V_{th}) = 200\ mV$

$$I = \frac{1}{2} \mu_p C_{ox} \left(\frac{W}{L}\right)_3 (V_{GS} - V_{th})^2$$

$$\left(\frac{W}{L}\right)_3 = \frac{2 \times 50 \times 10^{-6}}{100 \times 10^{-6} \times (200 \times 10^{-3})^2}$$

$$\boxed{\left(\frac{W}{L}\right)_3 = 25}$$

$$\boxed{\left(\frac{W}{L}\right)_4 = \left(\frac{W}{L}\right)_3 = 25}$$

For gain of 1^{st} stage $\rightarrow$

$$(g_m)_{M_1} = \frac{2 I_{d_1}}{(V_{GS} - V_{th})_1}$$

$2 I_{d_1} = 50\mu A$

$(V_{GS} - V_{th})_1 = 0.09$

$$(g_m)_{M_1} = \frac{2 \times 50 \times 10^{-6}}{0.09} = \frac{100}{9} \times 10^{-4}$$

$$\boxed{(g_m)_{M_1} = 11.11 \times 10^{-4}}$$

$(r_o)_n = \frac{1}{\lambda I_d} \Rightarrow \frac{1}{0.1 \times 50 \times 10^{-6}} = 2 \times 10^5$

of M_1

$(r_o)_p = \frac{1}{\lambda I_d} = \frac{1}{0.1 \times 50 \times 10^{-6}} = 2 \times 10^5$

of M_3

$r_{oN} \| r_{op} = 10^5$

Gain of 1st stage $\Rightarrow g_{m_1} (r_{oN} \| r_{op})$

$\Rightarrow 11.11 \times 10^{-4} \times 10^5$

$A_{v_1} \Rightarrow 111.11$

For 2nd stage let take $I = 100\mu A$

$V_{GS} - V_{th} = 0.2\ V$

For $M_5 \rightarrow$ (PMOS)

$I = \frac{1}{2} \mu_p C_{ox} \left(\frac{W}{L}\right)_5 (V_{GS} - V_{th})^2$

$\left(\frac{W}{L}\right)_5 = \frac{100 \times 10^{-6} \times 2}{100 \times 10^{-6} \times (0.2)^2}$

$\left(\frac{W}{L}\right)_5 = 50$

For $M_6 \rightarrow$ NMOS $\quad I = 100\mu A$, $V_{GS} - V_{th} = 200\ mV$

$I = \frac{1}{2} \mu_n C_{ox} \left(\frac{W}{L}\right)_6 (V_{GS} - V_{th})^2$

$\left(\frac{W}{L}\right)_6 = \frac{2 \times 100 \times 10^{-6}}{230 \times 10^{-6} \times (0.2)^2}$

$\left(\frac{W}{L}\right)_6 = 21.74$

For gain of 2nd stage ↓

$$g_{m5} = \frac{2 I_d}{(V_{GS} - V_{th})} \Rightarrow \frac{2 \times 100 \times 10^{-6}}{0.2} = 10^{-3}$$

$$(r_o)_{p5} = \frac{1}{\lambda I_d} = \frac{1}{0.1 \times 100 \times 10^{-6}} \Rightarrow 10^5$$

$$(r_o)_{n6} = \frac{1}{\lambda I_d} = \frac{1}{0.1 \times 100 \times 10^{-6}} = 10^5$$

$$\text{Gain} = A_{V_2} = g_{m5} (r_{op} \| r_{on})$$

$$\Rightarrow 10^{-3} \times \frac{10^5}{2} \Rightarrow 50$$

$$\boxed{A_{V_2} = 50}$$

$$\text{Total gain} = A_{V_1} \times A_{V_2}$$

$$111.11 \times 50$$

$$\boxed{\text{Total Gain} = 5555.5}$$

$$20 \log(\text{gain}) \Rightarrow 20 \log(5555.5)$$

$$\Rightarrow 74.89 \text{ dB}$$