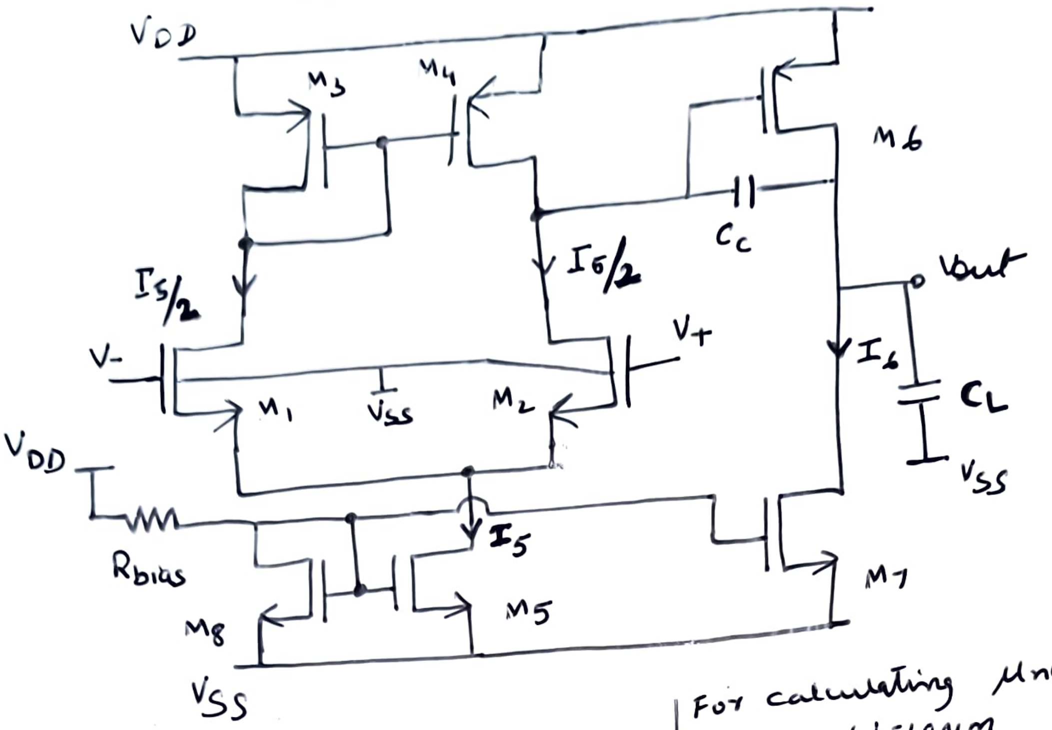


M_3, M_4 (ICMR +) i.e ICMR max

M_1, M_2 GBW

I_5 Slew Rate

M_5, M_8 (ICMR −) i.e ICMR min.
M_7

Specifications

DC gain = 225 = 47 dB

GBW = 30 MHz

PM ≥ 60°

Slew Rate = 20 V/µs

ICMR (+) = 1.6 V

ICMR (−) = 0.8 V

C_L = 2 pF

Power consumption ≤ 200 µW

For calculating $\mu_n C_{ox}$ & $\mu_p C_{ox}$

L = 1µm, W = 10µm

DC operating point, print in ADE

$\beta_{eff_p} = 1.6993 \times 10^{-3} \rightarrow 1700\mu$

$\therefore \mu_p C_{ox}\left(\frac{W}{L}\right) \simeq 1600\mu$ | V_t −0.18V

$\therefore \mu_p C_{ox} = 1600 \times 10^{-6} \times \left(\frac{1}{10}\right)$

$= \boxed{160\mu\ A/V^2}$

$\mu_n C_{ox}\left(\frac{W}{L}\right) \simeq 3150\mu$ | V_t 0.2 V

$\therefore \mu_n C_{ox} = \boxed{315\mu A/V^2}$

$V_{DD} = 1.8V$

process = 90 nm

L_{min} = 90 nm

$L \geq 2 \cdot L_{min}$ (λ - channel length mod)

$\therefore L = 180\,nm$

Let us consider $\boxed{L = 240\,nm}$

$C_c \geq 0.22\,C_L$

$\therefore C_c \geq 440\,fF$

Let us consider $C_c = 600\,fF$

Slew rate $= \dfrac{I_5}{C_c}$

$$I_5 = \frac{20}{1\times10^{-6}} \times 600\times10^{-15}$$

$$I_{5_{min}} = 12\,\mu A$$

Let $\boxed{I_5 = 20\,\mu A}$

M1, M2 Design

$$g_{m_1} = G.B \times C_c \times 2\pi$$

$60\times10^{6} \times 450\times10^{-15} \times 2\pi$

$$= 30\times10^{6} \times 600\times10^{-15} \times 2\pi$$

$$\therefore g_{m_1} = 113.1\,\mu S$$

$170\,\mu S$

Let $\boxed{g_{m_1} = 120\,\mu S}$

$135\times10^{-6} = 45\times10^{6} \times x \times 2\pi$

$480\,fF$

wkt

$$I_D = \mu_n C_{ox}\left(\frac{W}{L}\right) \cdot \frac{(V_{GS}-V_T)^2}{2}$$

$$g_m = \frac{\partial I_{DS}}{\partial V_{GS}} = \mu_n C_{ox}\left(\frac{W}{L}\right)(V_{GS}-V_T)$$

squaring on both sides & x/. by 2

$$g_m^2 = \left[\mu_n C_{ox}\left(\frac{W}{L}\right)\right]^2 \frac{(V_{GS}-V_T)^2}{2} \times 2$$

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

$$\therefore = \left\{\frac{g_m^2}{2 I_D \cdot \mu_n C_{ox}}\right\}$$

From the circuit wkt $2I_D = I_5$

$200\ \mu A/V^2$

$140\ \mu A/V^2$

$$\left(\frac{W}{L}\right) = \left\{\frac{g_m^2}{I_5 \cdot \mu_n C_{ox}}\right\}$$

$2\times10^{-2}\ \frac{m^2}{V.s}$

$3.45\times10^{-11}\ \frac{F}{m^2}$

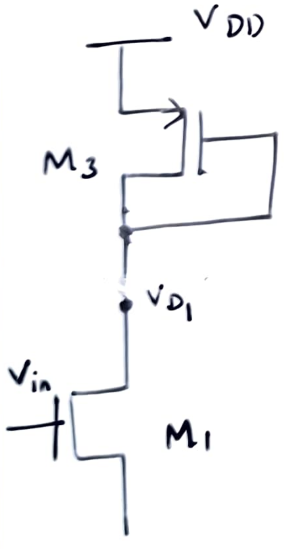
$$= \frac{(120\times10^{-6})^2}{(20\times10^{-6})\times(315\times10^{-6})}$$

$= 2.2857$

$\therefore$ consider $\boxed{\left(\frac{W}{L}\right)_{M_1, M_2} = 3}$

M3, M4 Design

consider



$$V_{D1} = V_{DD} - V_{SG3}$$

$$I_3 = \mu_p C_{ox}\left(\frac{W}{L}\right)\frac{(V_{GS} - V_t)^2}{2}$$

$$V_{GS} = \sqrt{\frac{2I_3}{\mu_p C_{ox}}} + |V_{t3}|$$

$$\therefore V_{D1} = V_{DD} - \left(\frac{2I_3}{\beta_p}\right)^{1/2} - |V_{t3}|$$

wkt

$$V_{in_{max}} \leq V_{D1} + V_{t1}$$

$$ICMR^+ \leq V_{D1_{min}} + V_{t1_{min}}$$

$$ICMR^+ \leq V_{DD} - \sqrt{\frac{2I_3}{\beta_3}} - |V_{t3}|_{max} + V_{t1_{min}}$$

Rearranging for $\left(\frac{W_3}{L_3}\right)$

$$\left(\frac{W}{L}\right)_3 = \frac{2 I_{D3}}{\mu_p C_{ox}\left[V_{DD} - ICMR^{+} - |V_{t3}|_{max} + V_{t1,min}\right]^2}$$

Simulating the circ of diff amp only

for $1.6V \rightarrow ICMR^{+} \rightarrow V_{in_{CM}} \rightarrow M_1$ & M_3

$V_{t_{1,max}} = 185.214 mV$

$\boxed{V_{t3_{max}} = -227.588 mV}$ $\therefore$ consider $\boxed{V_{t3_{max}} = -240 mV}$

for $0.8V \rightarrow ICMR^{-} \rightarrow V_{in_{CM}} \rightarrow M_1$ & M_3

$\boxed{V_{t1min} = 178.886 mV}$ $\therefore$ consider $\boxed{V_{t1min} = 160 mV}$

$V_{t3min} = -231.506 mV$

$I_{D3} = \frac{I_{D5}}{2} = 10 \mu A$

$\mu_p C_{ox} = 160 \mu A/V^2$

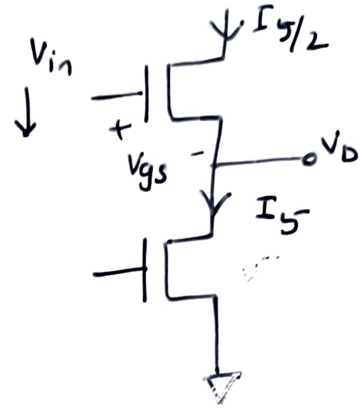
$$\therefore \left(\frac{W}{L}\right)_3 = \frac{2 \times 10 \times 10^{-6}}{160 \times 10^{-6}\left[1.8 - 1.6 - 0.24 + 0.16\right]^2}$$

$$= 8.681$$

$$\boxed{\therefore \left(\frac{W}{L}\right)_{3,4} = 9}$$

Design of M_5 & M_8

ICMR$^-$



$I_5 = 20\mu A$

$V_{D5} > V_G - V_t$ (for sat) ... but

$M_5 \rightarrow$ Triode as $V_{in} \downarrow$

For M_5 to be in sat

$$\underset{(ICMR^-)}{V_{in}} \geq V_{gs1_{max}} + V_{Dsat5}$$

$$ICMR^- \geq \left[\sqrt{\frac{2I_{D1}}{\beta_1}} + V_{t1}\right]_{max} + V_{Dsat}$$

$$ICMR^- \geq \sqrt{\frac{2I_{D1}}{\beta_1}} + V_{t1_{max}} + V_{Dsat}$$

$$V_{Dsat} \leq ICMR^- - \sqrt{\frac{2I_{D1}}{\beta_1}} - V_{t1\,max}$$

$$V_{Dsat} \leq 0.8 - \sqrt{\frac{2\times 10\mu}{315\mu \times 3}} - 186\times10^{-3}$$

$\therefore V_{Dsat} = 468.521$ mV

But V_{Dsat} Minimum is 184mV $\therefore$ Let us take $\underline{\underline{200\,mV}}$

$\therefore V_{Dsat} = 200$mV

$$\left(\frac{W}{L}\right)_5 = \frac{2I_{D5}}{\mu_n C_{ox}\,(V_{Dsat})^2} = \frac{2\times 20\mu}{315\mu \times (200\times10^{-3})^2}$$

$$\boxed{\therefore \left(\frac{W}{L}\right)_5 = 3}$$

Design of M6

$V_{DS} \geq V_{GS} - V_t$

for 60° PM

2367.913
184.822
183.091

$$g_{m6} \geq 10 \cdot g_{m1}$$

$$g_{m6} \geq 10 \cdot 120\mu$$

$$g_{m6} \geq 1200\mu.$$

1350μ

$$\frac{\left(\frac{W}{L}\right)_6}{\left(\frac{W}{L}\right)_4} = \frac{I_6}{I_4} = \frac{g_{m6}}{g_{m4}}$$

$\left(\frac{W}{L}\right)_4 \rightarrow 9$

$$g_{m4} = \sqrt{\mu_p C_{ox} \left(\frac{W}{L}\right)_4 \cdot 2 I_D}$$

$$g_{m4} = \sqrt{160 \times 10^{-6} \times 9 \times 2 \times 10 \times 10^{-6}}$$

$$g_{m4} = 169.71\mu$$

$$\therefore \left(\frac{W}{L}\right)_6 = \frac{1200}{169.71} \times 9$$

$$\therefore \boxed{\left(\frac{W}{L}\right)_6 = 64}$$

Design of M7

$$\frac{I_6}{I_4} = \frac{(W/L)_6}{(W/L)_4}$$

$$I_6 = \frac{64}{9} \times 10\mu = 71.11\,\mu A \simeq \underline{\underline{72\mu A}}$$

$$\frac{\left(\frac{W}{L}\right)_7}{\left(\frac{W}{L}\right)_5} = \frac{I_7 \to I_6}{I_5}$$

$$\therefore \left(\frac{W}{L}\right)_7 = \frac{72}{20} \times 3.2$$

$$\boxed{\therefore \left(\frac{W}{L}\right)_7 = 12}$$

Manual gain calculation:

First stage gain M_1 & M_4 at V_{in} $V_{cm} = 800mV$ $\quad r_{o} = \frac{1}{g_{ds}}$

$gm_1 = 124.439\mu A/V$

$gds_1 = 9.03594\,\mu$ $\quad gds_4 = 4.9529\mu$

$$\text{gain} = gm\,(r_{o1} \parallel r_{o4})$$

$$= \frac{gm_1}{gds_1 + gds_4}$$

$$= 8.8956$$

gain (dB) = 18.9835 dB

Second stage gain

$g_{m_6} = 1.07748m$

$g_{ds_6} = 36.2053\mu$ $g_{ds_7} = 6.2731\mu$

$\frac{1}{r_{on}} = g_{ds}$

$$\text{gain} = \frac{g_{m6}}{g_{ds6} + g_{ds7}}$$

$$= \frac{1.07748 \times 10^{-3}}{(36.2053 + 6.2731) \times 10^{-6}} = 25.3653$$

gain (dB) = 28.084 dB

totalgain = 47 dB