Design for Particular Specification:- [180nm Tech]

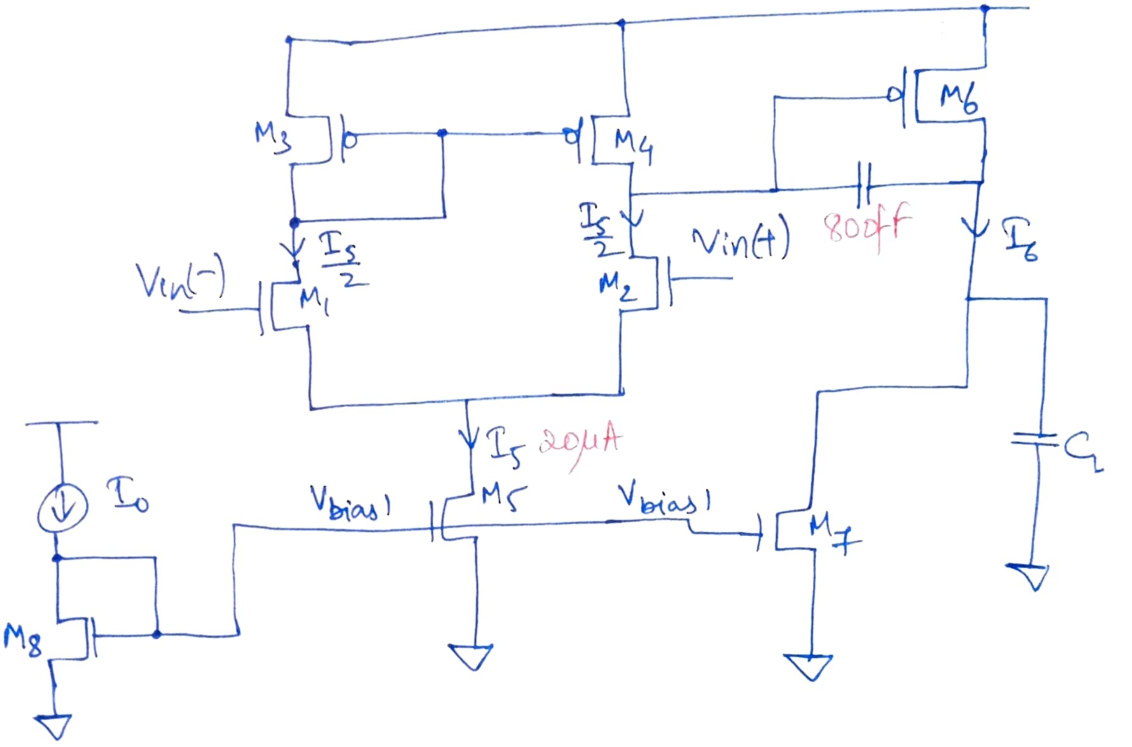
for

- DC gain = 1000 => $20\log_{10} 10^3 = 60\,dB$
- GBW = 30MHz
- PM ≥ 60°
- Slew Rate = 20 V/μsec
- ICMR(+) = 1.6V
- ICMR(−) = 0.8V
- C_L = 2pF
- Power dissipation ≤ 300μW

- V_{DD} = 1.8V
- process = 180nm Tech

L_{min} = 180nm
L ≥ 2.L_{min}
L = 500nm

To avoid channel length Modulation



$I_5 \simeq I_0$

$M_5 = M_8$

W/L ratio of M_3, M_4 is found using ICMR(+)

W/L —"— of M_1, M_2 is found using GBW

I_5 is found using Slew rate

W/L ratio of M_5 is found using ICMR(−)

—"— of M_6 from Gain & design of M_3 & M_4

M_5 & M_7 are related

C_c is found from Phase Margin :

Design :-

- $L = 500nm$
- $PM \geq 60^\circ$
- $C_c \geq 0.22 C_L$

For C_c

$C_c \geq 0.22(2pF)$

$C_c \geq 0.44 pF$

$C_c \geq 440 fF$

$\boxed{C_c \simeq 800 fF}$

For I_5

$$\text{Slew Rate} = \frac{I_5}{C_c} \Rightarrow \frac{20V}{\mu s} \times 800fF = I_5$$

$$\boxed{I_5 = 16\mu A} \Rightarrow \boxed{I_5 \simeq 20\mu A}$$

For M_1 & M_2

$$g_{m1} = GB \times C_c \times 2\pi$$

$$g_{m1} = 30MHz \times 800fF \times 2\pi$$

$$g_{m1} = 150.79\mu$$

$$\boxed{g_{m1} \simeq 160\mu}$$

WKT

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

$$\left(\frac{W}{L}\right)_1 = \frac{(g_{m1})^2}{\mu_n C_{ox} \cdot 2 I_D} = \cancel{(160\mu)^2}$$

To derive

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

$$g_m = \frac{\partial I_D}{\partial V_{gs}} = \frac{\mu_n C_{ox}}{\cancel{2}}\left(\frac{W}{L}\right) \times \cancel{2}\,(V_{gs}-V_t)$$

$$g_m = \mu_n C_{ox}\left(\frac{W}{L}\right)(V_{gs}-V_t)$$

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

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

$$\boxed{\frac{W}{L} = \frac{g_m^2}{\mu_n C_{ox} \cdot 2I_D}}$$

for M_1 M_2, $2I_D = I_5$

$$I_D = \frac{I_5}{2} = 10\mu A$$

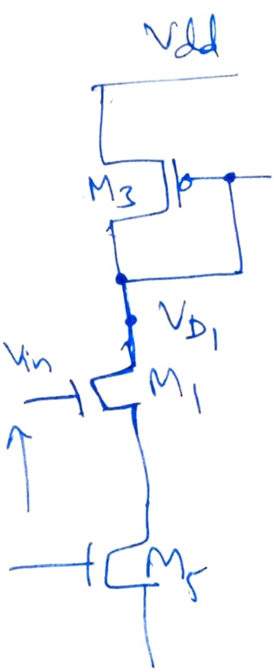
$$\left(\frac{W}{L}\right)_1 = \frac{g_{m1}^2}{\mu_n C_{ox} \cdot 2I_D} = \frac{(160\mu)^2}{30 \times 20\mu}$$

$$\left(\frac{W}{L}\right)_{1,2} = 4.266 \simeq 5$$

$$\boxed{\left(\frac{W}{L}\right)_{1,2} \simeq 5}$$

For M_3 & M_4

when we increase V_{in}, M_1 enters triode Region



$$V_{DS} > V_g - V_{t_1}$$

$$V_g < V_{D_1} + V_{t_1} \quad [V_g = V_{in}] \uparrow$$

$$V_{in} < V_{D_1} + V_t$$

$$V_{inmax} = V_{D_1} + V_{t_1} \quad \text{--- (1)}$$

$$V_{D_1} = V_{DD} - V_{sg3}$$

$$\left[\beta = \mu_n C_{ox} \frac{W}{L}\right]$$

$$V_{D_1} = V_{DD} - \left[\sqrt{\frac{2I_3}{\beta_p}} + |V_{t3}|\right]$$

For V_{sg}

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

$$I_3 = \frac{\beta}{2} (V_{sg} - V_t)^2$$

$$\boxed{V_{gs} = \sqrt{\frac{2I_3}{\beta_p}} + |V_{t3}|}$$

$$V_{in\,max} \leq \underbrace{V_{D1} + V_{t1}}_{min}$$

$$ICMR(+) \leq V_{D1\,min} + V_{t1\,min}$$

$$\boxed{\begin{aligned} \mu_p C_{ox} &= 60\mu \\ \mu_n C_{ox} &= 300\mu \end{aligned}}$$

$$V_{in\,max} \leq V_{D1\,min} + V_{t1\,min}$$

$$ICMR(+) \leq \left[V_{DD} - \left(\sqrt{\frac{2I_3}{\beta}} + |V_{t3}|\right)\right]_{min} + V_{t1\,min}$$

$$ICMR(+) \leq V_{DD} - \sqrt{\frac{2I_3}{\beta_3}} - |V_t|_{3\,max} + V_{t1\,min}$$

$$\frac{2I_3}{\beta_3} = \left(V_{DD} - ICMR_{max} - |V_{t3}|_{max} + V_{t1\,min}\right)^2$$

$$\frac{2I_3}{\mu_p C_{ox} \left(\frac{W}{L}\right)_{3,4}} = \left[V_{DD} - ICMR_{(+)} - |V_{t3}|_{max} + V_{t1\,min}\right]^2$$

$$\left(\frac{W}{L}\right)_{3,4} = \frac{2I_{D_3}}{\mu_p C_{ox}\left[V_{DD} - ICMR_{(+)} - V_{t3\,max} + V_{t1\,min}\right]^2}$$

By simulation find. $V_{t1\,min} \simeq 470\,mV$

$V_{DD} = 1.8$

$V_{th3\,max} \simeq 510\,mV$

$V_{D_3} = \frac{I_{DS}}{2} = 10\mu$

$\mu_p C_{ox} = 60\mu$

$ICMR_{(+)} = 1.6\,V$

$$\left(\frac{W}{L}\right)_{3,4} = \frac{2 \times 10\mu}{368\mu\,[1.8 - 1.6 - 0.51 + 0.47]^2}$$

$$\left(\frac{W}{L}\right)_{3,4} = 13.02$$

$$\boxed{\left(\frac{W}{L}\right)_{3,4} \simeq 14}$$

Data in Cadence

$i_{dc} = 20u$

$C_c = 800f$

$M_3, M_6 \begin{cases} W = 3uM \\ L = 500nM \end{cases}$

$M_2, M_1 \begin{cases} W = 7uM \\ L = 500nM \end{cases}$

$M_8, M_9 \begin{cases} W = 6uM \\ L = 500nM \end{cases}$

$M_4 = \begin{cases} W = 87uM \\ L = 500nM \end{cases}$

$M_{10} = \begin{cases} W = 37uM \\ L = 500nM \end{cases}$

VCM → variable [Value initial → 1.6V } for Higher Range

Analysis:

Results > Print > operating point

(for ICMR = 0.8V)

$V_{in} = 0.8V$

To find gain of 1st Stage

g_{m6}, g_{ds6}, g_{ds1}

$g_{m6} = 143\mu$

$g_{ds6} = 2.17\mu$

$g_{ds1} = 9.125n$ [if small output resistance is high].

To find gain of 2nd Stage

g_{m4}, g_{ds4}, g_{ds10}

$g_{m4} = 1.467m$

$g_{ds4} = 7.47\mu$

$g_{ds10} = 43.02\mu$

1st Stage Gain:

$V_{CM} = 0.8V$

$$\frac{1}{r_{o1}} = g_{ds}$$

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

$$= \frac{g_{m6}}{g_{ds6} + g_{ds1}} = \frac{143\mu}{2.17\mu + 0.912\mu} = 46.39$$

gain = 46.36

$$\text{gain (in dB)} = 20 \log(46.36) = \underline{33.33 dB}$$

2nd Stage Gain

$$\text{gain} = \frac{1.467}{7.475 + 43.02}$$

$\text{gain} = 29.05$

$\text{gain (in dB)} = 20 \log 29.05 = 29.26$

$\text{total gain} = 33.33 + 29.26 = \underline{62.59\,dB}$

Targeted Gain = ~~62.59 dB~~ $\underline{60\,dB}$

Our Gain = $\underline{62.59\,dB}$

[Gain for ICMR = 1.6V] $V_{in} = 1.6V$

$g_{m6} = 158.1\mu$

$g_{ds6} = 5.9\mu$

$g_{ds1} = 1.069\mu$

$g_{m4} = 1.575\mu$

$g_{ds4} = 10.77\mu$

$g_{ds10} = 29.78\mu$

$$\text{1st stage Gain} = \frac{158.1}{5.9+1} = 22.91 \Rightarrow \underline{27\,dB}$$

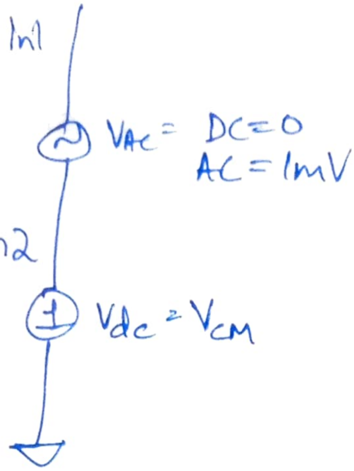
$$\text{2nd stage Gain} = \frac{1575}{10.77+29.75} = 38.84 \Rightarrow \cancel{31.78} \; \underline{31.78\,dB}$$

$\text{Total Gain} = 27 + 31.78 = \underline{58.98\,dB}$

Targeted Gain = $\underline{60\,dB}$

Our Gain = $\underline{58.98\,dB}$

Now to increase gain using simulation:-
So introduce an AC source



To plot bodeplot were introduci-ng a small AC source too

AC analysis > Frequency >
Start-Stop > start - 100
stop - 100M

Calculate for 800mV

Result > Direct plot > AC Gain & Phase

Simulation Gain = 62.5dB

Our Gain = 62.59dB

BW = 24.17MHz

Phase Margin = 65°

GBW = 30MHz got is 24.17MHz

for 1.6V

Gain = 58.85dB

GBW = 26.45MHz

PM = 64°

To get GBW near to wanted value you can change C_c

Power dissipation :-

$P = V_{DD} \times (\text{Total current})$

$= 1.8 \times [125 + 20]$

$\underline{P = 261\ \mu W}$

125 is through second stage

To find Power dissipation

Output < Save all < select power signal to output < All < OK

Run simulation

Tools < Result Browser < dc operating point

$\underline{P = 273\ \mu W}$ } for 0.8V

For V = 1.6V

$\underline{P = 273\ \mu W}$