Single Stage Differential Amplifier Design

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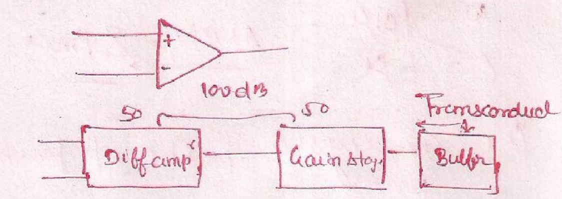
Opm Design

Differential amplifier



Parameter Requirement

UMC 180 nm

$V_{DD} = 1.8$

$A \geq 100 = 40dB$

$C_L = 10PF$

$ICMR^+ = 1.6V$

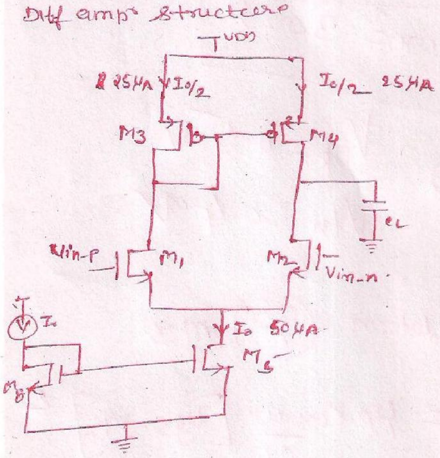
$ICMR^- = 0.8$

$SR = 5V/\mu sec$

Power diss < 0.3mW

GBP ≥ 5MHZ

Diff amp structure



$M_1 = M_2$ $M_3 = M_4$

– All the MOSFET are in saturation

find W/L ratio of all the transistor

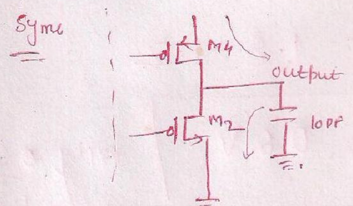
1. first find I_0 from S.R.
2. M_3 & M_4 (W/L) from $ICMR^+$
3. (W/L) of M_1 & M_2 from Gain Bandwidth product
4. M_5 (W/L) from $ICMR^-$
5. M_8 $\left(\frac{W}{L}\right)$ derived from I_0 & M_5

Start

Slew rate :- rate of change of voltage per unit time → maximum rate of change of output voltage.

Charging of capacitor from M4 &

Sym



Slew rate happen / measure when one branch is completely off and other is completely ON.

$$\frac{dv}{dt} = \frac{I}{C}$$

$$Q = CV$$

$$I = \frac{dQ}{dt} = C\frac{dv}{dt}$$

$$\Rightarrow SR = \frac{I_0}{C_L}$$

$SR = 5V/\mu sec$

$C_L = 10PF$

$$I_0 = 5V \times 10^6 \times 10PF = 50\mu A$$

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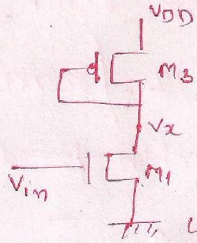
TLFBK5

For Pmos $V_{DS} = (V_{SD})$ consider $V_{GS} = V_{SG}$

$\left(\frac{W}{L}\right)_{M_3, M_4}$ Calculation



If Vin ↑↑
→ M_1 → triode
avoid

$V_{DS} = V_{GS1} - V_{th}$

$V_D > V_G - V_{th}$

maximum input 1.6 (MOSFET not goes to triode)

$V_x > V_{in} - V_{t1}$

$V_x > 1.6 - 0.45$ (Assume)

$V_x > 1.15$ ≈ 1.2 V

$V_{DS\,M_3} = V_{DD} - V_x$

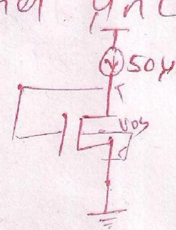
$V_{DS_{M_3}} = 1.8 - 1.2$

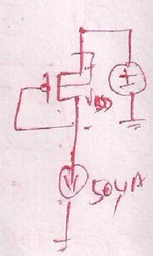
$V_{DS\,m_3} = 0.6\ V$
$= V_{GS3}$

only 0.6V drop across M3

$I_{m3} = 25\ \mu A$

So find $\mu_n C_{ox}$





for approx avoid λ

$L = 1\mu$

$L_{min} = 0.18\,\mu$

$L = 1\mu$

for simulation purpose

$W = 10\mu$
$L = 1\mu$

Nmos & Pmos

D.C analysis, D.C op point

See for Pmos

$\beta_{eff} = 600\mu$ $\left(\frac{W}{L}\right) = 10$

$\mu_p C_{ox} \left(\frac{W}{L}\right) = 600\ \mu$

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

For Nmos

$\beta_{eff} = 2.98m$ $\left(\frac{W}{L}\right) = 10$

$\mu_n C_{ox} \approx 300\ \mu$

$V_{tp} = 0.5\ V$

$V_{tn} = 0.4\ V$

Calculation $\left(\frac{W}{L}\right)_{m_3}$

$$I_3 = \frac{\mu_p C_{ox} W}{2L}\left[V_{gs} - V_{t_p}\right]^2$$

$$25\mu = \frac{60\mu}{2}\left(\frac{W}{L}\right)_3 \left[0.6 - 0.5\right]^2$$

$$25 = 30\left(\frac{W}{L}\right)_3 [0.01]$$

$$\left(\frac{W}{L}\right)_3 = 83 \approx 84 \text{ (approx)}$$

$$\left(\frac{W}{L}\right)_3 = \left(\frac{W}{L}\right)_4 = 84$$

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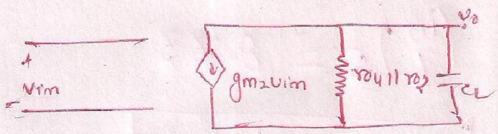
Calculation of M_1 & M_2

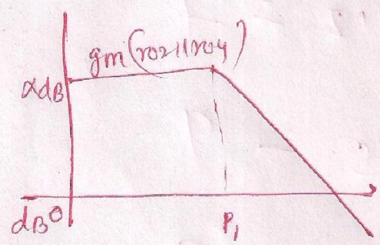
GBP = 5 MHZ



$$\frac{V_o}{r_{o4}\|r_{o2}} + \frac{V_o}{1/sC_L} + g_{m2} v_{in} = 0$$

$$\frac{V_o}{V_{in}} = \frac{-g_m (r_{o2}\|r_{o4})}{1 + sC_L (r_{o2}\|r_{o4})}$$

Single pole System



DC gain $g_m (r_{o2}\|r_{o4})$

$$P_1 = \frac{1}{(r_{o4}\|r_{o2}) C_L}$$

GBP = DC gain × P_1

$$GB = \frac{g_m}{sC_L}$$

$$GB = \frac{g_{m1,2}}{2\pi C_L}$$

$$5\,MHz = \frac{g_{m1,2}}{2\pi \times 10\,pF}$$

$$g_{m1,2} = 314.16\ \mu A/V$$

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

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

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

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

$$\left(\frac{W}{L}\right)_{1,2} = \frac{g_m^2}{2 I \mu_n C_{ox}}$$

$$\left(\frac{W}{L}\right)_{1,2} = \frac{(314.16)^2}{2 \times 50\mu \times 300}$$

$$\left(\frac{W}{L}\right)_{1,2} = 6.57$$

$$\left(\frac{W}{L}\right)_{1,2} = 7$$

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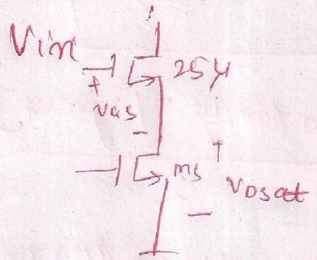
Summary

$(W/L)_{3,4}$, $(W/L)_2$ got

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

$ICMR^- = 0.8$



$V_{in} > V_{GS1} + V_{Dsat}$

$0.8 > V_{gs1} + V_{Dsat5}$

$V_{gs1} = ??$

$I_D = \frac{\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)_1 [V_{gs1} - V_t]^2$

$25\mu = \frac{300\mu \times 7}{2} [V_{gs1} - 0.45]^2$

$0.154 = V_{gs1} - 0.45$

$V_{gs1} = 0.154 + 0.45$

$V_{GS1} = 0.6$

$\Rightarrow$

$0.8 > 0.6 + V_{Dsat}$

$V_{Dsat} \leq 0.2$

I_{DS}, V_{Dsat}

$50\mu = \frac{300\mu}{2}\left(\frac{W}{L}\right)_5 (0.2)^2$

$\left(\frac{W}{L}\right)_5 = 8.33$

$\left(\frac{W}{L}\right)_5 \simeq 9$

$\left(\frac{W}{L}\right)_{3,4} = 84$

$\left(\frac{W}{L}\right)_{1,2} = 7$

$\left(\frac{W}{L}\right)_5 = 9$

$\left(\frac{W}{L}\right)_8 = 9$

current mirror.

40dB difficult to get let do some tuning in Simulation

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