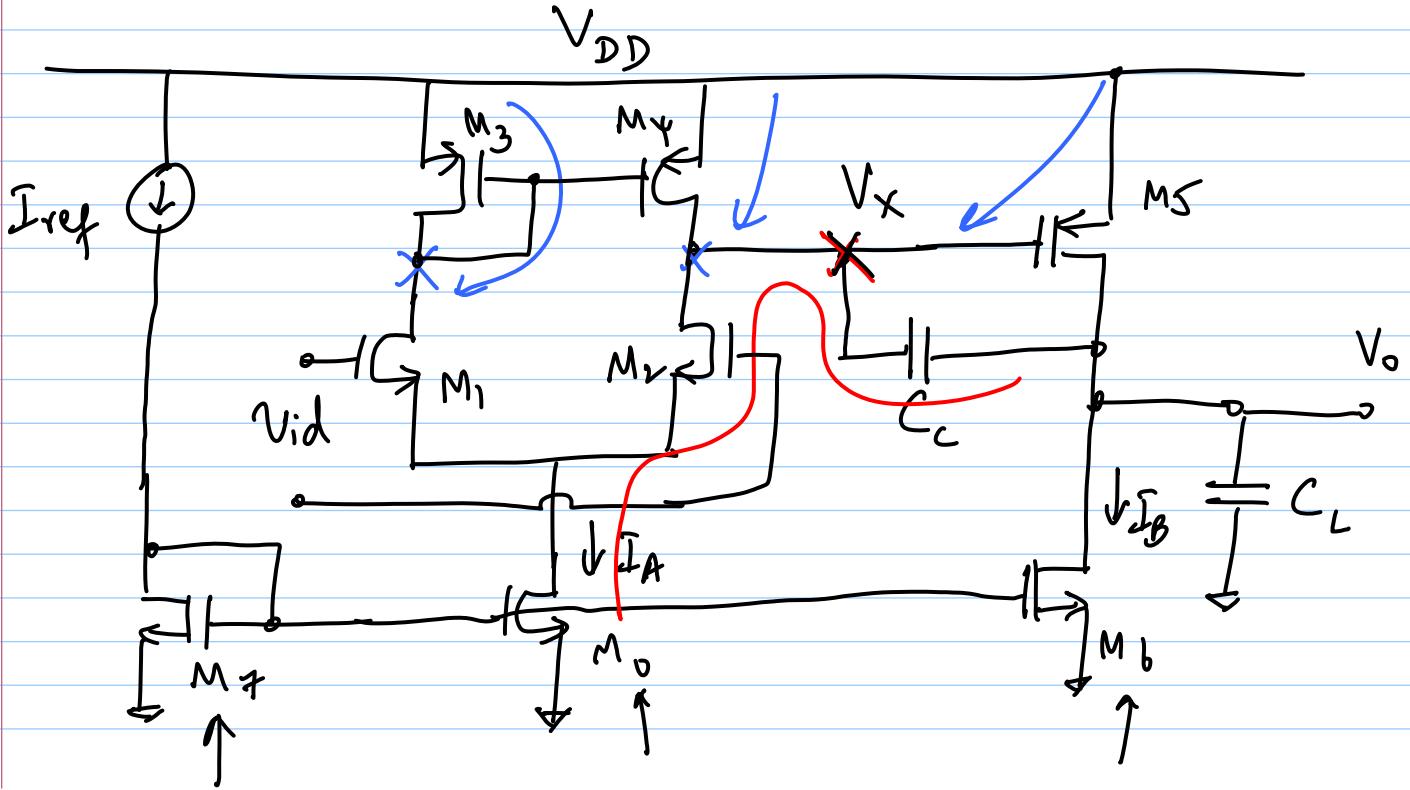


8-3-13

Lec 33

Design Example (pole -splitting)



Specs

$$A_o \geq 80 \text{ dB} ; f_u \geq 5 \text{ MHz} ; V_{op-p} = 4 \text{ V}$$

$$SR \geq 10 \text{ V}/\mu\text{s} ; \rho_M = 60^\circ ; I_{ref} = 100 \mu\text{A}$$

Design parameters

$$V_{DD} = 5 \text{ V} ; C_L = 10 \text{ pF}$$

$$\mu_n \text{Lox} = 50 \mu\text{A}/\text{V}^2 ; \mu_p \text{Lox} = 25 \mu\text{A}/\text{V}^2$$

$$V_{Tn} = |V_{Tp}| = 1 \text{ V} ; L_{min} = 2 \mu\text{m}$$

$$C_{ox} = 1.5 \text{ fF/mm}^2 ;$$

$$(\lambda L)_n = 0.04 \mu\text{m}/\nu ; (\lambda L)_p = 0.1 \mu\text{m}/\nu$$

$$Gm_1 = g_{m1} ; \quad Gm_2 = g_{m5}$$

1) 60° PM : Assume other poles & zeros
are > 10 f_u

$$\omega_z = \frac{g_{m5}}{C_c} ; \quad \omega_u = \frac{g_{m1}}{C_c}$$

a) $\omega_z \geq 10 \omega_u \Rightarrow g_{m5} \geq 10 g_{m1}$

for 60° PM

$$C_c \approx 2 \cdot 2 \left(\frac{g_{m1}}{g_{m5}} \right) \cdot C_L$$

choose $C_c \approx 0.25 C_L = 2.5 \mu\text{F}$

2) Slew rate - divides I_A & I_B

i) Input-stage limited

Since g_{m5} is large,

V_x is a virtual ground

$$I_A = C_c \frac{dV_o}{dt} \Rightarrow \frac{dV_o}{dt} = SR = \frac{I_A}{C_c}$$

$$\frac{I_A}{C_c} \geq 10 \text{ V}/\mu\text{s} \Rightarrow I_A \geq 25 \mu\text{A}$$

ii) Output stage limited SR

$$I_B = (C_C + C_L) \frac{dV_o}{dt}$$

$$\Rightarrow \frac{dV_o}{dt} = \frac{I_B}{C_C + C_L} \geq 10V/\mu s$$

$$\Rightarrow I_B \geq 125 \mu A$$

3) Output swing - decides (w/l) ratios

$$V_{out} \geq 4V_{p-p} \Rightarrow V_{DSAT_5} = V_{DSAT_6} = 0.5V$$

$$I_B = \frac{k_n}{2} \left(\frac{w}{l}\right)_B \left(V_{HSS_6} - V_T\right)^2$$

$$\Rightarrow \left(\frac{w}{l}\right)_B = 20$$

$$V_{DSAT_0} = V_{DSAT_1} = V_{DSAT_6}$$

$$(w/l)_0 = 4$$

$$(w/l)_7 = 16$$

$$I_S = 125 \mu A \Rightarrow (\omega/L)_S = 40 \quad \checkmark$$

$$I_1 = I_2 = I_3 = I_4 = 12.5 \mu A$$

$$(\omega/L)_3 = (\omega/L)_4 = 4$$

4) f_u (VAF) - sets input stage (ω/L)

$$\omega_h = \frac{g_m}{C_C} \geq 2\pi \times 5 MHz$$

$$g_m \geq 78.5 \mu S$$

$$\sqrt{2k_n^f \left(\frac{\omega}{L} \right), \left(\frac{I_A}{2} \right)} \geq 78.5 \mu S$$

$$\Rightarrow (\omega/L)_1 = 4.93$$

$$\text{choose } (\omega/L)_{1,2} = 5$$

5) DC gain - decides lengths

$$A_0 = A_1 \cdot A_2 = \frac{g_m}{g_{ds2} + g_{ds4}} \cdot \frac{g_m}{g_{ds5} + g_{ds1}}$$

$$A_1 = \frac{\cancel{78.5 \mu S}}{\cancel{g_{ds2} + g_{ds4}}} = \frac{\sqrt{k_n^f (\omega/L)_1}}{(x_2 + x_4)} \cdot \frac{1}{\sqrt{\frac{I_A}{2}}}$$

$$= \frac{6.32}{\lambda_2 + \lambda_4}$$

$$A_L = \frac{4}{\lambda_5 + \lambda_6}$$

$$A_0 = \frac{\alpha S \cdot 2\delta}{4\lambda^2} = 10,000$$

$$\Rightarrow \lambda \approx 2.514 \times 10^{-2} \text{ V}^{-1}$$

$$\lambda_n L_n = 0.04 \Rightarrow L_n = 1.59 \mu\text{m}$$

choose NMOS lengths = 2 μm

$$\lambda_p L_p = 0.1 \Rightarrow L_p = 3.98$$

choose PMOS $L_p = 4 \mu\text{m}$

check

$$1) \quad g_{ms} \gtrsim 10 g_{m1} \quad \left. \begin{array}{l} \uparrow (\omega)L \\ \uparrow I \end{array} \right.$$

$$g_{ms} \approx 6.5 g_{m1}$$

2) Other poles $\gtrsim 10 \text{ fm}$ - especially mirror pole

3) V_{icm}