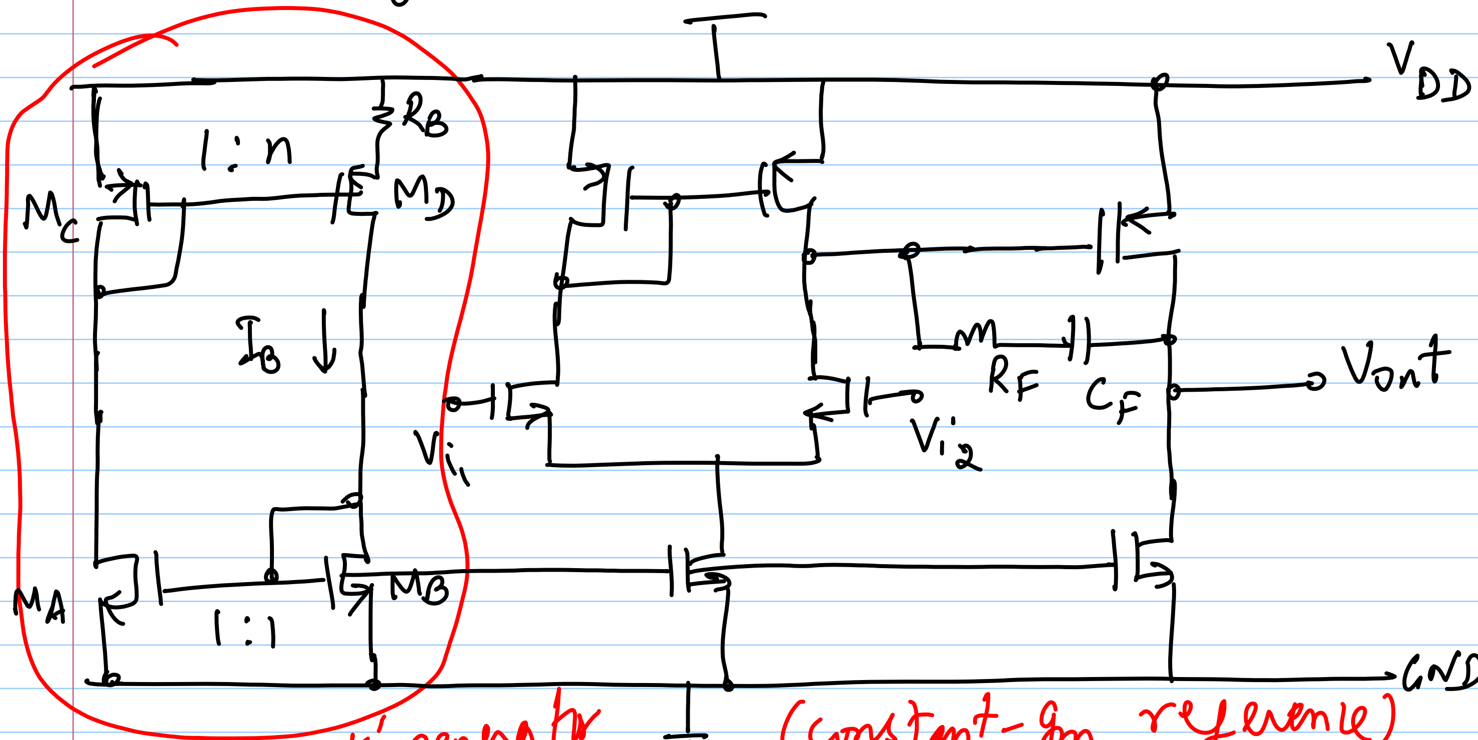
13-3-2012

Lec 27

2) Using a real resistor



K' generator (constant-g_m reference)

* requires a starting ckt (all $I = 0$ is a stable state)

$$V_{SG_C} = V_{SG_D} + I_B R_B$$

$$\Rightarrow V_{ov_C} = V_{ov_D} + I_B R_B \quad \text{—— (1)}$$

$$(W/L)_D = n\,(W/L)_C \Rightarrow V_{ov_D} = \frac{V_{ov_C}}{\sqrt{n}}$$

we also know $g_m = \dfrac{2 I_D}{V_{ov}}$

$$\therefore (1) \Rightarrow V_{ov_C} = \frac{V_{ov_C}}{\sqrt{n}} + I_B R_B$$

$$\Rightarrow \quad \frac{2I_B}{g_{m_C}} = \frac{2I_B}{\sqrt{n}\, g_{m_C}} + I_B R_B$$

$$\Rightarrow \quad g_{m_C} = \frac{2\left(1 - 1/\sqrt{n}\right)}{R_B}$$

$$\sqrt{2K_p' \left(\frac{W}{L}\right)_C \cdot I_B} = \frac{2\left(1 - 1/\sqrt{n}\right)}{R_B}$$

$$I_B = \frac{2}{K_p' R_B^2}\left(\frac{1}{\sqrt{(W/L)_C}} - \frac{1}{\sqrt{(W/L)_D}}\right)^2$$

$$= \frac{2}{K_p' R_B^2} \cdot \alpha$$

* I_B is mirrored into opamp 1st & 2nd stages

$$I_2 = m I_B$$

$$g_{m_6} = \sqrt{2K_p' (W/L)_6 I_2}$$

$$= \sqrt{2K_p' (W/L)_6 \cdot m I_B}$$

$$= \sqrt{2K_p' (W/L)_6 \cdot m \cdot \frac{2}{K_p' \cdot R_B^2} \cdot \alpha} = \underline{\underline{\frac{\beta}{R_B}}}$$

For accurate pole-zero cancellation,
we want

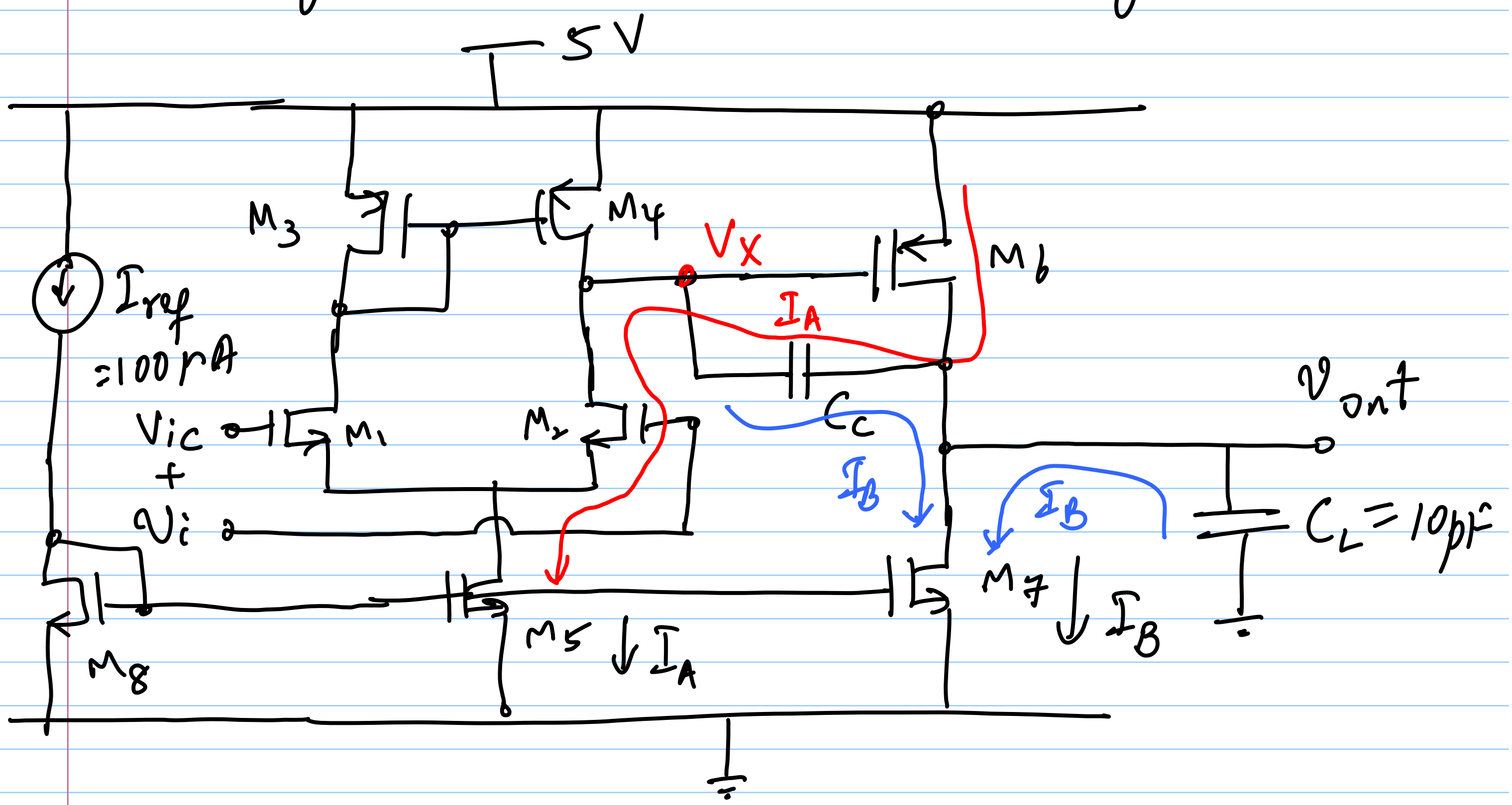
$$R_F = \frac{1}{g_{m6}}\left(1+\frac{C_L}{C_F}\right) = \frac{R_B}{\beta}\left(1+\frac{C_L}{C_F}\right)$$

$$\Rightarrow \frac{R_F}{R_B} = \frac{1}{\beta}\left(1+\frac{C_L}{C_F}\right)$$

* R_B & R_F are of same type

$\Rightarrow$ very well controlled //

Design Example - pole-splitting comp.



DC gain

Specs $\begin{cases} \underbrace{a_0}_{} \geq 80\,dB \; ; \; f_u \geq 5\,MHz \; ; \; V_{o_{p\text{-}p}} = 4V \\ SR \geq 10\,V/\mu s \; ; \; \text{phase margin} = 60^\circ \end{cases}$

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

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

$V_{Tn} = |V_{Tp}| = 1.0\,V \; ; \; L_{min} = 2\mu m$

$(\lambda L)_n = 0.04\,\mu m/V \; ; \; (\lambda L)_p = 0.1\,\mu m/V$

$G_{m_1} = g_{m_1} \; ; \; G_{m_2} = g_{m_6}$

1) <u>60° PM</u> : other p/z are $> 10\omega_u$

$$\omega_z = \frac{g_{m6}}{C_c} \; ; \; \omega_u = \frac{g_{m1}}{C_c}$$

we want $\omega_z \geq 10 \cdot \omega_u \Rightarrow g_{m6} \geq 10 g_{m1}$

$$C_c \geq 2.2\left(\frac{g_{m_1}}{g_{m_6}}\right) \cdot C_L$$

<u>choose $C_c \simeq 0.25\, C_L$</u>

2) Slew rate – decides I_A & I_B

(i) Input-stage limited SR (–)

Since g_{m6} is very large,

$V_x \sim$ virtual ground

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

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

(ii) Output stage limited SR (–)

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

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

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

2) Output swing – decides (W/L) ratios

$V_{out} \geq 4V_{p\text{-}p} \Rightarrow V_{DSAT6} \leq 0.5V$

$V_{DSAT7} \leq 0.5V$

to minimize area, choose

$$V_{DSAT_6} = V_{DSAT_7} = 0.5V$$

$$= V_{DSAT_5} = V_{DSAT_8}$$

$$I_7 = \frac{K_n'}{2}\left(\frac{W}{L}\right)_7 (V_{GS_7} - V_T)^2$$

$$\Rightarrow \left(\frac{W}{L}\right)_7 = 20$$

$$I_5 = 25\mu A \Rightarrow (W/L)_5 = 4$$

$$I_8 = 100\mu A \Rightarrow (W/L)_8 = 16$$

$$I_6 = 125\mu A \Rightarrow (W/L)_6 = 40$$

$$I_3 = I_4 = I_A/2 = 12.5\mu A$$

$$\Rightarrow (W/L)_3 = (W/L)_4 = 4$$

3) $\underline{W_u}$ (VGF) — sets input stage (W/L)

$$W_u \simeq \frac{g_{m_1}}{C_c} \geq 5\,MHz \times 2\pi$$

$$\Rightarrow g_{m_1} \geq 78.5\mu S$$

$$g_{m_1} = \sqrt{2k_n' \left(\frac{W}{L}\right)_1 (I_A/2)}$$

$$\Rightarrow \left(W/L\right)_1 = 4.93$$

choose $(W/L)_{1,2} = 5$

4) DC gain — decides lengths

$$a_0 = a_1 \cdot a_2$$

$$= \frac{g_{m1}}{g_{ds_2} + g_{ds_4}} \cdot \frac{g_{m6}}{g_{ds_6} + g_{ds_7}}$$

$$a_1 = \frac{g_{m_1}}{g_{ds_2} + g_{ds_4}} = \frac{\sqrt{k_n' (W/L)_1}}{(\lambda_2 + \lambda_4)} \cdot \frac{1}{\sqrt{\frac{I_A}{2}}}$$

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

$$a_2 = \frac{g_{m6}}{g_{ds_6} + g_{ds_7}} = \frac{\sqrt{k_p' (W/L)_6}}{\lambda_6 + \lambda_7} \cdot \frac{1}{\sqrt{I_B}}$$

$$= \frac{4.00}{\lambda_6 + \lambda_7}$$

Let us choose all λ's to be equal

$$a_0 = \frac{25.28}{4\lambda^2} = 10{,}000$$

$$\Rightarrow \quad \lambda = 2.514 \times 10^{-2} \ V^{-1}$$