EECS 240 FINAL SPRING 199

B. E. BOSER SOLUTION

1. $R_{on} = \left(\mu C_{ox} \frac{W}{L} \cdot (V_{GS} - V_{TH})\right)^{-1} = \frac{1}{g_m}$ 2

$B = \left(2\pi R_{on} \cdot C_H\right)^{-1}$ 3

$\Rightarrow C_H = g_m / 2\pi B$

$\Delta V = \frac{Q_{CHAN}}{C_H}$ 5 $= \frac{W L C_{ox} (V_{GS} - V_{TH})}{C_H}$ 5

$= \frac{1.5 C_{GS} \cdot (V_{GS} - V_{TH})}{g_m} \cdot 2\pi B$

$= \frac{1.5 (V_{GS} - V_{TH}) \cdot \cancel{2\pi} B}{\cancel{2\pi} f_T}$

$$\therefore \boxed{\begin{aligned} f_T &= B \cdot \frac{1.5 (V_{DD} - V_{in} - V_{TH})}{\Delta V} \\ &= 50\,MHz \cdot 1.5 \cdot \frac{3 - 1 - 1}{0.02} \\ &= 3.75\,GHz \cong 4\,GHz. \end{aligned}}$$ 10

Reference:D:\Users\Bernhard\Lib\MathCAD\Default\defaults.mcd **corrected**

Thermal Noise in 2-Stage OTA

Unilateral Feedback through Cc

given

$$s \cdot C_c \cdot (v_x - v_o) + i_1 - v_o \cdot g_{m1} \cdot F = 0$$

$$g_{m2} \cdot v_x + s \cdot C_L \cdot v_o + i_2 = 0$$

$$v_o = \frac{1}{F \cdot g_{m1}} \cdot \frac{1}{1 + \frac{s \cdot C_c}{F \cdot g_{m1}} + \frac{s^2 \cdot C_c \cdot C_L}{F \cdot g_{m1} \cdot g_{m2}}} \cdot \left(i_1 - i_2 \cdot \frac{s \cdot C_c}{g_{m2}}\right)$$

$$v_o = \frac{1}{F \cdot g_{m1}} \cdot \frac{\omega_o^2}{s^2 + s \cdot \frac{\omega_o}{Q} + \omega_o^2} \cdot \left(i_1 - i_2 \cdot \frac{s \cdot C_c}{g_{m2}}\right)$$

with $\omega_o = \sqrt{\frac{F \cdot g_{m1} \cdot g_{m2}}{C_c \cdot C_L}}$ $\quad Q = \frac{1}{\omega_o} \cdot \frac{F \cdot g_{m1}}{C_c}$

Noise from M2:

$$N_2 = \int_0^{\infty} 4 \cdot k_B \cdot T_r \cdot \frac{2}{3} \cdot g_{m2} \cdot \left(\frac{1}{F \cdot g_{m1}}\right)^2 \cdot \left(\frac{\omega_o \cdot C_c}{g_{m2}}\right)^2 \cdot \left|\frac{s \cdot \omega_o}{s^2 + s \cdot \frac{\omega_o}{Q} + \omega_o^2}\right|^2 df$$

RESULT: $N_2 = \frac{k_B \cdot T_r}{C_c} \cdot \frac{C_c}{C_L} \cdot \frac{2}{3}$

FYI: $\frac{N_2}{N_1} = F \cdot \frac{C_c}{C_c + C_L} \cdot \frac{g_{m1}}{g_{m2}}$ (usually < 1, esp. for small F)

3. $\Delta i_{1-2} = \underbrace{\frac{v_{dd}}{R_{ss}}}_{\text{tail C.S.}} \cdot \underbrace{\frac{\Delta g_m}{g_m}}_{\text{current divider}}$

$$\Delta i_{3-4} = v_{dd} \cdot \Delta g_m$$

$$A_{dm} = g_m \cdot R_o$$

$$A^{++} = \frac{v_{od}}{v_{dd}} = \frac{\Delta i \cdot R_o}{v_{dd}}$$

$$\therefore \; PSRR = g_m / \Delta i / v_{dd}$$

$$\frac{\Delta i}{v_{dd}} = \Delta g_m \cdot \left(1 + \frac{1}{R_{ss} \cdot g_m} \right)$$

$$\boxed{PSRR = \frac{g_m}{\Delta g_m} \cdot \frac{1}{1 + \frac{1}{R_{ss} \cdot g_m}}} \cong \underline{\underline{31.6}}$$

contribution from M_{3-4} dominates since V_{bias} is connected "WRONG"

$$\Delta g_m = g_m \cdot \frac{\Delta V_{TH}}{V_d^{sat}}$$

$$\Rightarrow \quad \frac{g_m}{\Delta g_m} = \frac{V_d^{sat}}{\Delta V_{TH}} = 31.6$$

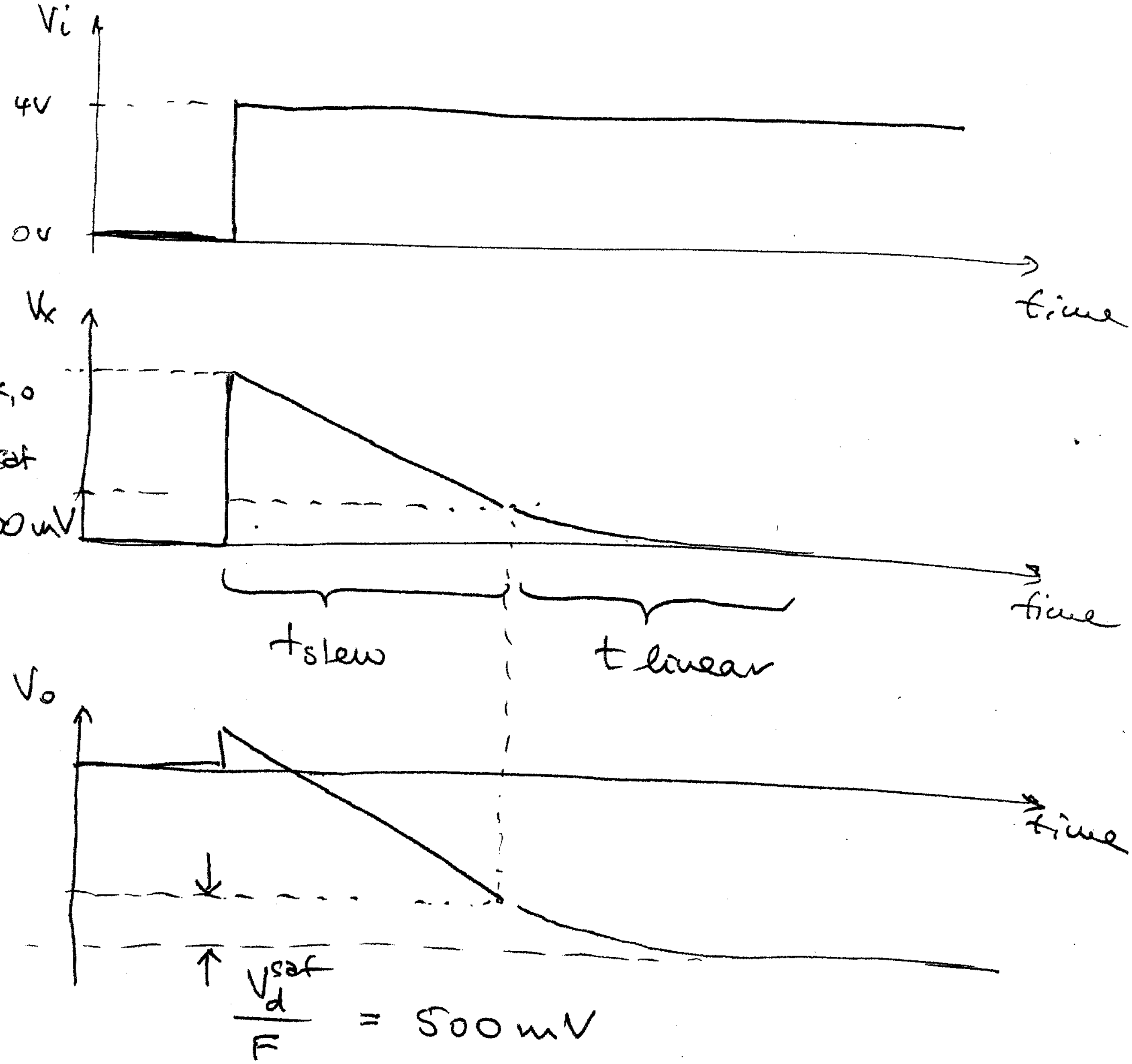
$$g_m \cdot R_{ss} = 15.8$$

using $g_m = 316\,\mu S$

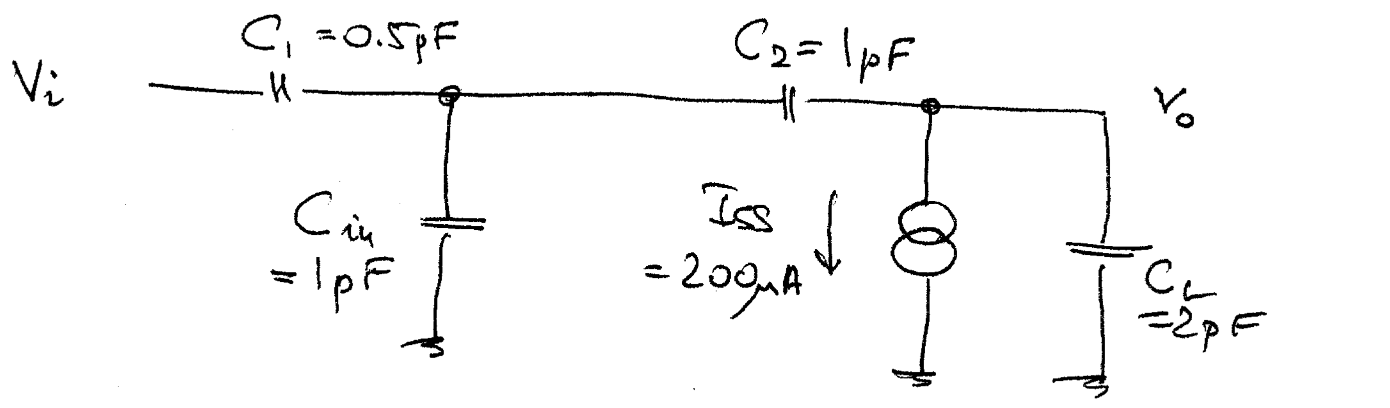
$V_d^{sat} = 316\,mV$

a) $\varepsilon \cong \frac{1}{A_0 F} = \underline{\underline{0.25\%}}$ 5pts

4.
b)



model during slewing:



$$c = \frac{C_1}{C_2} = 0.5$$

$$F = \frac{C_2}{C_1 + C_2 + C_{in}} = \frac{1}{2.5} = 0.4$$

$$V_d^{sat} = \frac{2 I_D}{g_m} = \frac{I_{SS}}{g_m} = 200\,mV$$

A) Calculate initial step:

$$V_{x,0} = V_{step} \cdot \frac{C_1}{(C_2 \| C_L) + C_{in} + C_1} = 923\,mV$$

B) Slew rate:

$$C_L^* = C_L + C_2 \| (C_1 + C_{in}) = 2.6\,pF$$

$$= C_L + F \cdot (C_1 + C_{in}) = C_L + C_2(1-F)$$

$$SR = \frac{I_{SS}}{C_L^*} = 77\,V/\mu sec.$$

$$\boxed{t_{slew} = \frac{\Delta V_0}{SR} = 23.5\,nsec.}$$ 10 pts

$$\Delta V_o = \frac{V_{x0} - V_d^{sat}}{F} = 1808\,mV$$

c) linear settling

$$V_{error} = \varepsilon \cdot 2V$$

$$\varepsilon^* = \frac{V_{error}}{0.5V} = \varepsilon \cdot \frac{2V}{0.5V} = 0.4\,\%$$

$$= \varepsilon / F$$

0.5 V ← final change of output after slewing

$$\tau = \frac{C_L + (1-F)\cdot C_2}{F \cdot g_m} = \frac{2.6\,pF}{0.4\,mS} = 6.5\,ns$$

$$\boxed{t_{linear} = -\tau \cdot \ln \varepsilon^* = 36\,usec.}$$ 10pts

$$\boxed{t_{settle} = t_{slew} + t_{lin} \cong 60\,nsec.}$$