

1. a) By the symmetry $V_D = V_{D_gnd} = 0$ which can be checked by setting $I_{D_{Mn1}} = -I_{D_{Mp1}}$. By the virtual connection of +2- of the op-amp, $V_{DS_{Mno}} = V_{ref} + (-V_{ref}) = V_{dd} - V_{ref} = 2V_{dd} = 10V$.
 by KVL, $V_{GS_{Mno}} = 0 - V_{ref} = V_{dd} = 5V$; for M_{no}
 $V_{GS} = 10 > 5 - 1.5 = 3.5 = V_{GS} - V_{TO_n} \Rightarrow M_{no}$ in saturation;

to find W_{no} :

$$I_{D_{no}} = 200 \times 10^{-6} = \frac{K_{Pn}}{2} \frac{W_{no}}{L_{no}} (V_{GS_{no}} - V_{TO_n})^2 = 2.5 \times 10^{-4} \frac{W_{no}}{10 \times 10^{-6}} (3.5)^2$$

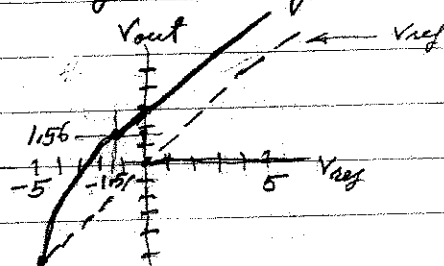
$$\Rightarrow W_{no} = \frac{200 \times 10^{-6} \times 10 \times 10^{-6}}{2.5 \times 10^{-4} \times (3.5)^2} = 65.31 \times 10^{-8} \Rightarrow W_{no} = 0.653 \mu$$

(to make this work, probably scale $\times 10 \Rightarrow W_{no} = 6.53 \mu, L_{no} = 100 \mu$)

- b) The transition point (ohmic) (saturation) is
 for $V_{DS_{Mno}} = V_{GS_{Mno}} - V_{TO_n} = 3.5V = V_{ref} + 5$ or $V_{ref} = -1.5$
 or $V_{GS_{Mno}} = 5V > V_{TO_n} = 1.5$ for all V_{ref} , M_{no} is always "on"
 for $V_{ref} \leq V_{ref} \leq -1.5$, $I_{no} = 2.5 \times 10^{-4} (2 \times 3.5 - [V_{ref} + 5]) [V_{ref} + 5]$
 for $-1.5 \leq V_{ref} \leq V_{dd}$, $I_{no} = 2.5 \times 10^{-4} (3.5)^2 = 30.63 \times 10^{-4}$
 in both cases $V_{out} = R_L I_{no} + V_{ref}$, $\therefore$ for $R_L = 1k\Omega$

$$V_{out} = \begin{cases} 0.25(7 - [V_{ref} + 5]) [V_{ref} + 5] + V_{ref}, & -5 \leq V_{ref} \leq -1.5 \\ 3.06 + V_{ref}, & -1.5 \leq V_{ref} \leq 5 \end{cases}$$

sketched

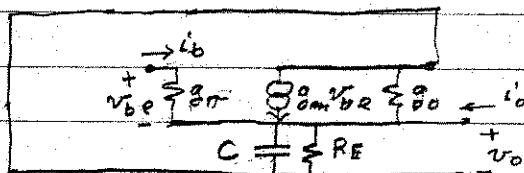


EE 303 final solution

05/09/07

$$\begin{aligned}
 2. \quad I_C &= -\alpha I_E = -\frac{\beta}{\beta+1} I_E = \frac{199}{200} \times 2 \times 10^{-3} = 1.99 \text{ mA} = I_C \\
 I_B &= I_C / \beta = -\frac{1}{\beta+1} I_E = \frac{2 \times 10^{-3}}{200} = 10 \times 10^{-6} = 10 \mu\text{A} \\
 V_{R2} &= R_2 (-I_E) = 1.15 \times 2 = 2.3 \text{ V}, \quad V_{R2} = V_{R1} + V_{R2} = 3 \text{ V} \\
 V_{R2} &= R_2 I_2 = 10^6 I_2 = 3 \text{ V} \Rightarrow I_2 = 3 \mu\text{A} \\
 V_{R1} &= V_{CC} - V_{R2} = 9 - 3 = 6 \text{ V} = R_1 (I_2 + I_B) = R_1 (3 + 10) \times 10^{-6} \\
 \Rightarrow R_1 &= 6 / [13 \times 10^{-6}] = 0.462 \times 10^6 = 462 \text{ k}\Omega = R_1 \\
 g_m &= \frac{I_C}{V_T} = \frac{1.99 \times 10^{-3}}{26 \times 10^{-3}} = 76.5 \text{ mS} = g_m \\
 g_{\pi} &= g_m / \beta = 0.384 \text{ mS} = 384 \mu\text{S} = g_{\pi} \\
 g_o &= \frac{I_C}{V_A} = \frac{1.99 \times 10^{-3}}{100} = 19 \mu\text{S} = g_o
 \end{aligned}$$

b)



c) as $I_b = 0$, $v_{be} = 0$ so the transistor becomes g_o

$$\begin{aligned}
 \Rightarrow & \text{Circuit diagram showing } g_o \text{ in parallel with } C \text{ and } R_E. \\
 g_o & \parallel C \parallel R_E \Rightarrow Y_o = (g_o + g_E) + sC \\
 &= (19 \times 10^{-6} + 1.15 \times 10^{-3}) + sC \\
 \Rightarrow Y_o &= 1.17 \times 10^{-3} + sC \Rightarrow Z_o(s) = \frac{1}{1.17 \times 10^{-3} + sC} \\
 \text{for } Z_o(j\omega) &= \frac{1}{1.17 \times 10^{-3} + j\omega C} = \frac{854.7}{1 + j\omega C \times 854.7}
 \end{aligned}$$

The 3dB point is where $\omega C \times 854.7 = 1$, where

$$\begin{aligned}
 \omega &= 2\pi \times 10^6 \Rightarrow C = \frac{1}{854.7 \times 2\pi \times 10^6} = 1.86 \times 10^{-4} \times 10^{-6} \\
 &= 186 \text{ pF} = C
 \end{aligned}$$