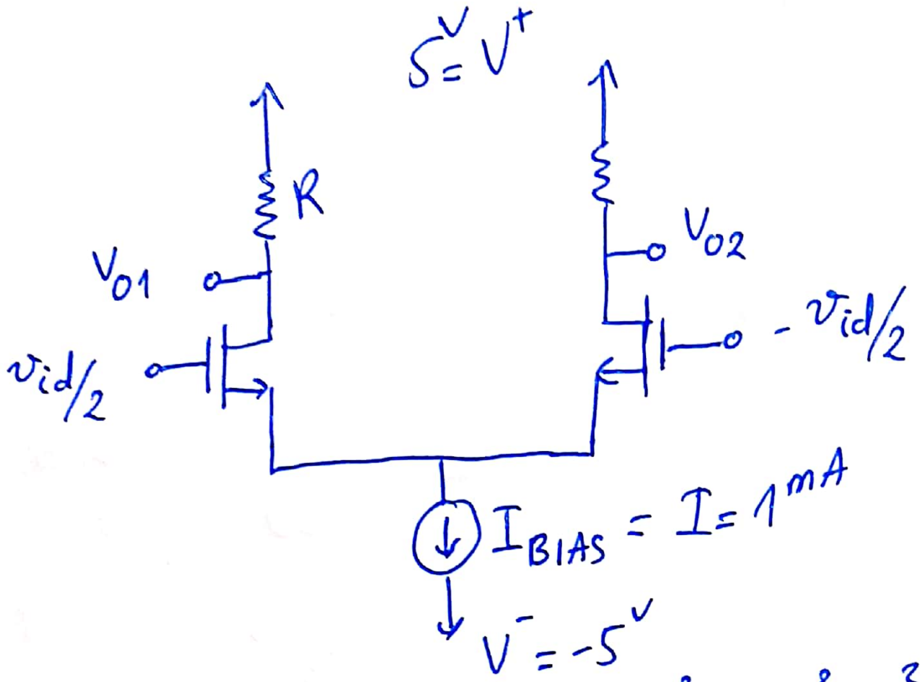
Analog Electronics

QUIZ # 3.3

(a)



i) $I_D = \frac{I}{2} = \frac{1}{2} k_n' \frac{W}{L} V_{ov}^2 \Leftrightarrow 10^{-3} = 10^{-3} V_{ov}^2$

$\Rightarrow V_{ov} = 1^V$

ii) $g_m = \frac{2I_D}{V_{ov}} = \frac{I}{V_{ov}} = \frac{1^{mA}}{1^V} = 1^{mA/V}$

iii) $A_d = \frac{V_{o2} - V_{o1}}{v_{id}} = g_m R = 1^{mA/V} \times 6^{k\Omega} = 6$

iv) $r_o = \frac{V_A}{I_D} = \frac{50^V}{0.5^{mA}} = 100^{k\Omega}$

$A_d = g_m (R // r_o) = 1^{mA/V} \times (6^{k\Omega} // 100^{k\Omega}) \simeq 5.67$

v) $A_c = 0$ (same inputs, two symmetric parts)

$\Rightarrow CMRR = 20 \log \frac{A_d}{A_c} \to \infty$

vi) $\Delta R = 6^{k\Omega} \times 0.4 = 2.4^{k\Omega}$

$$A_{cm1} = \frac{-R}{1/g_m + 2R_{SS}} \approx -\frac{R}{2R_{SS}} \quad (1/g_m << 2R_{SS})$$

$$A_{cm2} = \frac{v_{o2}}{v_{icm}} = -\frac{R}{2R_{SS}}$$

Resistance tolerance $A_{cm1} = -\frac{R + \Delta R}{2R_{SS}}$

$$\Rightarrow |A_c| = \left|\frac{v_{o2} - v_{o1}}{v_{icm}}\right| = \frac{\Delta R}{2R_{SS}} = \frac{2.4}{100} = 0.024$$

$$CMRR = 20\log\left|\frac{A_d}{A_{cm}}\right| = 20\log\frac{6}{0.024} \approx 47.96\ dB$$

b) i) $\frac{I_o}{I_{REF}} = \frac{1}{1 + \frac{2}{\beta}} \approx 1 \Leftrightarrow I_{REF} \approx I_o = 1\ (mA)$

$$\Rightarrow R = \frac{V_{CC} - V_{BE}}{I_{REF}} = \frac{5^V - 0.7^V}{1^{mA}} = 4.3\ (k\Omega)$$

$$r_o = \frac{V_A}{I_C} = \frac{V_A}{I_o} = \frac{50^V}{1^{mA}} = 50\ (k\Omega)$$

ii) $I_{REF} = I_o = 1\ (mA)$

$$I_{REF} = \frac{1}{2}k_n'\frac{W}{L}V_{OV}^2 \Leftrightarrow 1^{mA} = 1^{mA/V^2} \times V_{OV}^2$$

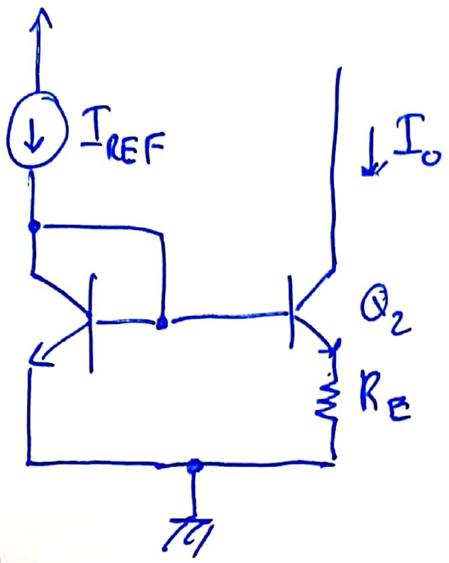
$$\Rightarrow V_{OV} = 1\ (V)$$

npn transistor $\Rightarrow V_{GS} = V_{OV} + V_t = 2\ (V)$

$$R = \frac{V_{DD} - V_{GS}}{I_{REF}} = \frac{5^V - 2^V}{1^{mA}} = 3\,(k\Omega)$$

$$r_o = \frac{V_A}{I_o} = \frac{80^V}{1^{mA}} = 80\,(k\Omega)$$

iii)



$$\begin{cases} I_{REF} \approx I_s e^{V_{BE1}/V_T} \\ I_o = I_s e^{V_{BE2}/V_T} \end{cases}$$

$$\Rightarrow \ln\left(\frac{I_{REF}}{I_o}\right) \approx \frac{V_{BE1} - V_{BE2}}{V_T} \approx \frac{I_o R_E}{V_T}$$

$$\Leftrightarrow \ln 5 \approx \frac{0.2^{mA} R_E}{25^{mV}} \Leftrightarrow R_E \approx 201\,(\Omega)$$

$$g_m = \frac{I_{E_2}}{V_T} \approx \frac{I_o}{V_T} = \frac{1}{125}\,(A/V)$$

$$r_\pi = \frac{V_T}{I_B} = \frac{V_T \beta}{I_o} = \frac{25 \times 100}{0.2} = 12.5\,(k\Omega)$$

$$r_o = \frac{V_A}{I_o} = \frac{50^V}{0.2^{mA}} = 250\,(k\Omega)$$

$$R_o \simeq \left[1 + g_m (r_\pi // R_E)\right] r_o$$

$$= \left[1 + \frac{1}{125} (12.5^{k\Omega} // 0.2^{k\Omega})\right] 250^{k\Omega}$$

$$R_o \simeq 643 \ (k\Omega)$$