NATIONAL UNIVERSITY OF SCIENCES & TECHNOLOGY

Electronic Circuit Design (EE-313)

Assignment # 3

Chapter 7: Pg. 542-552 Questions

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ECD - Assignment # 3

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7.21) $\beta = 100$; $r_o = 100\,k\Omega$

- Transfer Ratio (Wilson) $\dfrac{I_o}{I_{ref}} = \dfrac{1}{1 + 2/(\beta(\beta+1))}$

$$= (1.000198)^{-1}$$

$$= 0.9998$$

→ % error (Wilson) $= (1 - I_o/I_{ref}) \times 100 = \boxed{0.02\%}$

- Transfer Ratio (Simple) $\dfrac{I_o}{I_{ref}} = \dfrac{1}{1 + 2/\beta}$

$$= (1.02)^{-1}$$

$$= 0.98039$$

→ % error (simple) $= (1 - I_o/I_{ref}) \times 100 = \boxed{2\%}$

→ Output Resistance R_o

Wilson

$\Rightarrow \dfrac{\beta r_o}{2} = R_o$

$R_o = \dfrac{(100)(100k)}{2}$

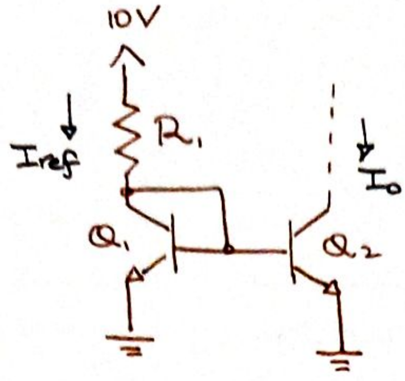
$= \boxed{5\,M\Omega}$

Simple

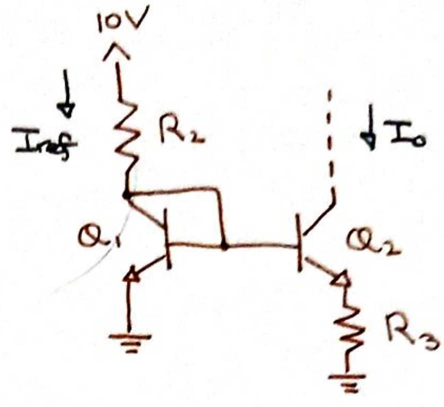
$\Rightarrow R_o = r_o$

$= \boxed{100\,k\Omega}$

Example 7.6) $I_o = 10\,\mu A$; $V_{BE} = 0.7V$ at $1\,mA$



Simple



Widlar

- Simple :

$$V_{BE_1} = 0.7 + V_t \ln\left(\frac{10\mu}{1m}\right) = 0.584V$$

$$R_1 = \frac{V_{cc} - V_{BE_1}}{I_o} = \frac{10 - 0.584}{10\mu} = \boxed{941.6\,k}\,\Omega$$

- Widlar:

$I_{ref} = 1\,mA$; $V_{BE_1} = 0.7V$

$$R_2 = \frac{V_{cc} - V_{BE_1}}{I_{ref}} = \frac{10 - 0.7}{1m} = \boxed{9.3\,k}\,\Omega$$

$$I_o R_3 = V_T \ln\left(\frac{I_{ref}}{I_o}\right)$$

$$(10\mu)\,R_3 = (25m)\ln\left(\frac{1m}{10\mu}\right)$$

$$R_3 = 11512.9 = \boxed{11.5\,k}\,\Omega$$

7.22) $R_o = ?$ $\longrightarrow$; $I_o = 10\mu A$

- Simple :

$$R_o = r_o = \frac{V_A}{I_o} = \frac{100}{10\mu} = \boxed{10\,M}\,\Omega$$

• Widlar :

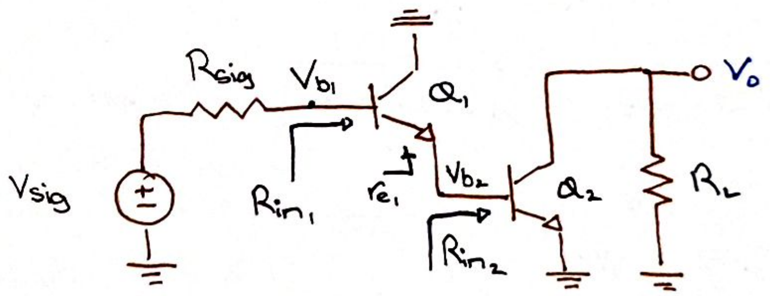
$$R_o = r_o + (1 + g_m r_o)(R_e \parallel r_\pi)$$

$$g_m = \frac{I_c}{V_T} = \frac{I_o}{V_T} = \frac{10\mu}{25m} = 0.4\,mA/V$$

$$r_\pi = \frac{\beta}{g_m} = \frac{100}{0.4m} = 250\,k$$

$$R_o = 10\,M + (1 + (0.4m \times 10M))(11.5k \parallel 250k)$$
$$= 10\,M + (4001)(10994.26)$$
$$= \boxed{54\,M}\,\Omega$$

Example 7.7) $I_c = 1\,mA$; $R_{sig} = 4k\Omega$; $R_L = 4k\Omega$
$\beta = 100$



$$g_m = \frac{I_c}{V_T} = \frac{1m}{25m} = 40\,mA/V \quad ; \quad r_e = \frac{1}{g_m} = 25\,\Omega$$

$$r_\pi = \beta/g_m = 2.5\,k\Omega$$

• $R_{in_2} = r_\pi = 2.5k$

• $R_{in} = R_{in_1} = (1+\beta)(r_{e_1} + R_{in_2}) = \boxed{255\,k}\,\Omega$

$\rightarrow \frac{V_{b_1}}{V_{sig}} = \frac{R_{in}}{R_{sig} + R_{in}} = 0.98\,V/V$ $\rightarrow \frac{V_o}{V_{b_2}} = -g_{m_2} R_L = -160\,V/V$

$\rightarrow \frac{V_{b_2}}{V_{b_1}} = \frac{R_{in_2}}{R_{in_2} + r_{e_1}} = 0.99\,V/V$

$$G_v = \frac{\cancel{V_{b_1}}}{V_{sig}} \cdot \frac{\cancel{V_{b_2}}}{\cancel{V_{b_1}}} \cdot \frac{V_o}{\cancel{V_{b_2}}} = \frac{V_o}{V_{sig}} = (-160)(0.98)(0.99) = \boxed{-155\ V/V}$$

c

→ Comparison

$R_{in} = r_\pi = 2.5\ k\Omega$

$$G_v = \frac{R_{in}}{R_{sig} + R_{in}}(-g_m R_L) = \frac{2.5}{2.5+4}(-40 \times 4) = \boxed{-61.5\ V/V}$$

7.23)

Replacing Q_1 with CD results in;

$R_{in_1} = \boxed{\infty}$

- Gain of $Q_1 = \dfrac{R_L}{R_L + 1/g_m}$ (R_L is R_{in_2})

→ $g_m = \sqrt{2k_n I_D} = \sqrt{2(8m)(1m)} = 4\ mA/V$

$$A_{v_1} = \frac{2.5k}{2.5k + 1/4m} = 0.909$$

A_{v_2} → From example ; $-160\ V/V$

$G_v = A_{v_1} A_{v_2} = \boxed{-145\ V/V}$

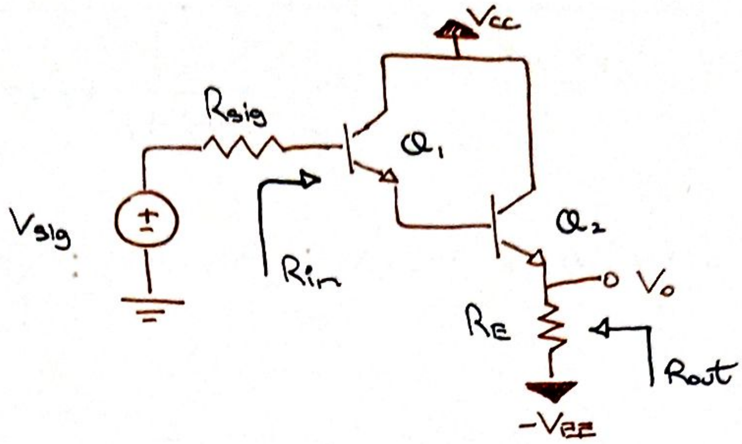
→ For $R_{sig} = 400\ k\Omega$, there is no effect on G_v of CD - CE configuration.

→ For $R_{sig} = 400\ k\Omega$ (CC-CE)

$$\frac{V_{b_1}}{V_{sig}} = \frac{R_{in}}{R_{in} + R_{sig}} = \frac{255k}{255k + 400k} = 0.389\ V/V$$

- $G_v = (-160)(0.99)(0.389) = \boxed{-61.6\ V/V}$

7.24)



• R_{in}

→ R_{in} (of Q_2) $= (\beta_2+1)(r_{e_2}+R_E)$

→ R_{in} (of Q_1) $= R_{in} = (\beta_1+1)(r_{e_1}+R_{in}\text{ (of } Q_2))$

$$= \boxed{(\beta_1+1)\left[r_{e_1}+(\beta_2+1)(r_{e_2}+R_E)\right]}$$

• R_{out}

→ Resistance in Emitter of $Q_1 = R_{out_1} = r_{e_1} + \dfrac{R_{sig}}{(\beta_1+1)}$

→ Similarly, $R_{out_2} = r_{e_2} + \dfrac{R_{sig}}{\beta_1+1} = r_{e_2} + \dfrac{\left[r_{e_1}+\dfrac{R_{sig}}{\beta_1+1}\right]}{\beta_2+1}$

→ $R_{out} = \boxed{R_E \parallel \left[r_{e_2} + \dfrac{\left[r_{e_1}+R_{sig}/\beta_1+1\right]}{\beta_2+1}\right]}$

• V_o/V_{sig}

→ $\dfrac{V_o}{V_{sig}} = \dfrac{R_{out}}{r_{e_2}+R_{in_2}} = \dfrac{R_{out_L}}{R_{out_L}+r_{e_2}+R_{sig}/\beta_2+1}$

$\therefore R_{out_L} = R_e$

$$\boxed{\frac{V_o}{V_{sig}} = \frac{R_E}{R_E + r_{e_2} + \left[r_{e_1} + \frac{R_{sig}}{\beta_1+1}\right] / (\beta_2+1)}}$$

→ Evaluate : $I_{E_2} = 5mA$; $\beta = 100$; $R_E = 1k\Omega$
$R_{sig} = 100k\Omega$

$$r_e = \frac{V_T}{I_E} = \frac{25m}{5m} = 5\,\Omega$$

→ $R_{in} = (101)[5 + (101)(5 + 1k)]$

$= \boxed{10.25\ M}\,\Omega$

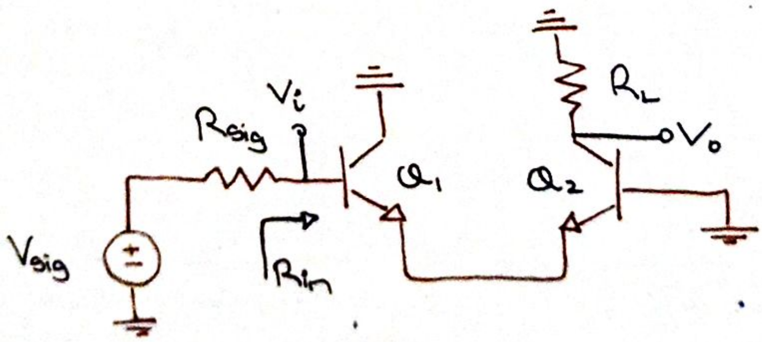
→ $R_{out} = 1k \parallel \left[5 + \frac{5 + [100k/101]}{101}\right]$

$= \boxed{20}\,\Omega$

→ $$\frac{V_o}{V_{sig}} = \frac{1k}{1k + 5 + \frac{5 + [100k/101]}{101}}$$

$= \boxed{0.98}\ V/V$

Example 7.8)

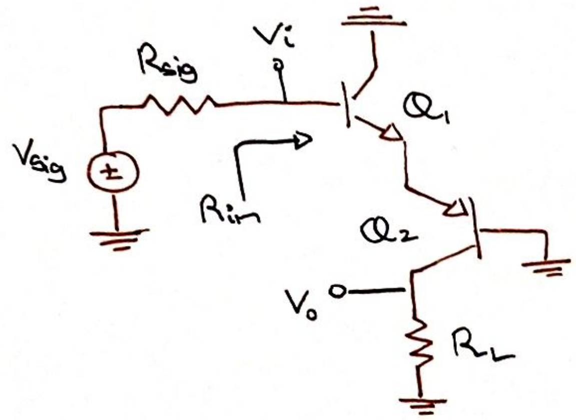


$\rightarrow R_{in} = (\beta_1+1)(2r_e)$

$\rightarrow A_v = \dfrac{V_o}{V_i} = g_m R_L$

$\therefore$ where $g_m = \alpha/2r_e$

$\rightarrow G_v = \dfrac{V_o}{V_{sig}} = \dfrac{R_{in}}{R_{sig}+R_{in}}(g_m R_L)$



- All equations are similar as both are the same configuration (CC - CB)

7.25) $I = 1mA$; $\beta = 100$; $R_L = R_{sig} = 5k\Omega$

$\rightarrow R_{in} = (101)(2\times 25)$ $\quad\therefore r_e = \left(\dfrac{I}{V_T}\right)^{-1} = 25\,\Omega$

$= \boxed{5.05\,k}\,\Omega$

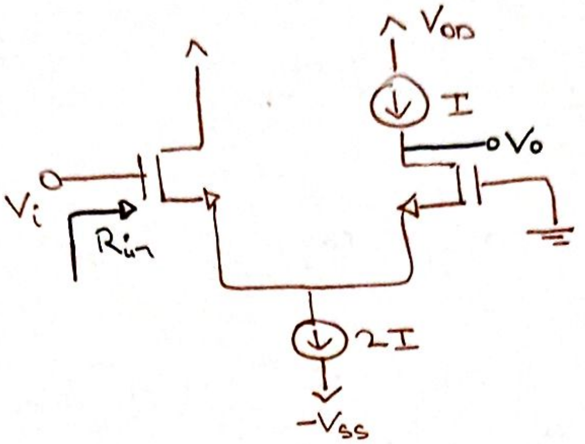
$\rightarrow A_v = \left(\dfrac{1}{2(25)}\right)(5\times 10^3)$

$= \boxed{100\ V/V}$

$\rightarrow G_v = \dfrac{R_{in}}{R_{sig}+R_{in}}A_v = \dfrac{5.05k}{5k+5.05k}(100)$

$= \boxed{50\ V/V}$

7.26)



- A_v

$\rightarrow$ $$\frac{V_o}{V_i} = g_m R_L \qquad \because (g_m = 1/2r_e)$$

$$= \frac{1}{2r_e} R_L \qquad \because (r_e = V_{ov}/2I)$$

$$= \frac{2I}{2V_{ov}} R_L$$

$$= \boxed{\frac{I R_L}{V_{ov}}} \quad a)$$

$\rightarrow$ $I = 0.1m$; $R_L = 20k\Omega$; $(W/L)_1 = ?$; $A_v = 10\,V/V$
$(W/L)_2 = ?$ $k_n' = 200\,\mu A/V^2$

$\rightarrow$ $A_v = \frac{I R_L}{V_{ov}} \Rightarrow 10 = \frac{(0.1m)(20k)}{V_{ov}}$

$V_{ov} = 0.2\,V$

$\rightarrow$ $I_D = \frac{1}{2} k_n' (W/L) V_{ov}^2 \Rightarrow 0.1m = \frac{1}{2}(200\mu)(W/L)(0.2)^2$

$\frac{W}{L} = \boxed{25}$ b) (both Q_1 and Q_2)