

# ECD - Assignment # 3

Pg. 542 - 552

7.21)  $\beta = 100$  ;  $r_o = 100 \text{ k}\Omega$

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

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

$$= 0.9998$$

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

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

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

$$= 0.98039$$

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

→ Output Resistance  $R_o$

Wilson

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

$$R_o = \frac{(100)(100\text{k})}{2}$$

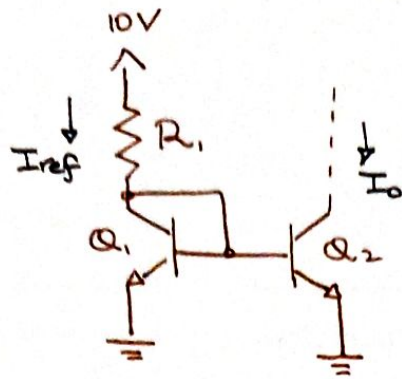
$$= \boxed{5 \text{ M}\Omega}$$

Simple

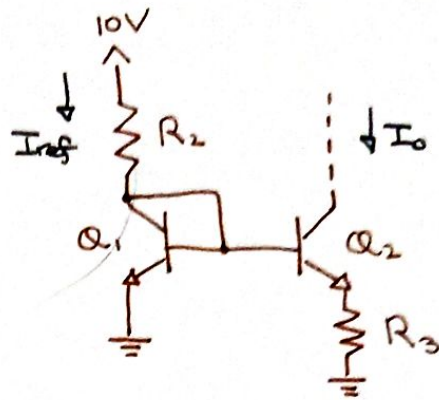
$$\Rightarrow R_o = r_o$$

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

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



Simple



Widlar

• Simple :

$$V_{BE1} = 0.7 + V_T \ln \left( \frac{10\mu}{1m} \right) = 0.584V$$

$$R_1 = \frac{V_{CC} - V_{BE1}}{I_O} = \frac{10 - 0.584}{10\mu} = \boxed{941.6k} \Omega$$

• Widlar:

$$I_{ref} = 1mA ; V_{BE1} = 0.7V$$

$$R_2 = \frac{V_{CC} - V_{BE1}}{I_{ref}} = \frac{10 - 0.7}{1m} = \boxed{9.3k} \Omega$$

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

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

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

7.22)  $R_O = ?$   $\longrightarrow$  ;  $I_O = 10\mu A$

• Simple :

$$R_O = r_O = \frac{V_A}{I_O} = \frac{100}{10\mu} = \boxed{10M} \Omega$$

• Widlar :

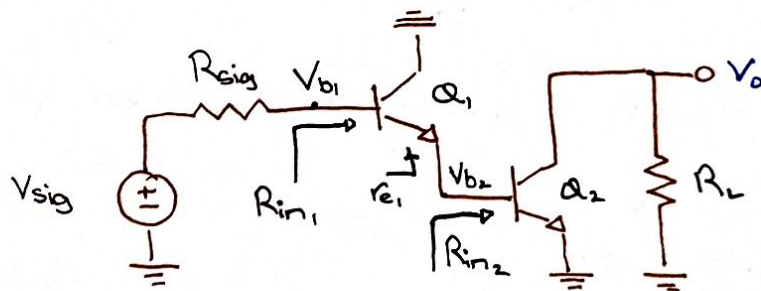
$$R_o = r_o + (1 + g_m r_o) (R_e \parallel r_\pi)$$

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

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

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

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



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

$$r_\pi = \beta / g_m = 2.5 \text{ k } \Omega$$

$$\bullet R_{in2} = r_\pi = 2.5 \text{ k}$$

$$\bullet R_{in} = R_{in1} = (1 + \beta)(r_{e1} + R_{in2}) = \boxed{255 \text{ k } \Omega}$$

$$\rightarrow \frac{V_{b1}}{V_{sig}} = \frac{R_{in}}{R_{sig} + R_{in}} = 0.98 \text{ V/V}$$

$$\rightarrow \frac{V_o}{V_{b2}} = -g_{m2} R_L = -160 \text{ V/V}$$

$$\rightarrow \frac{V_{b2}}{V_{b1}} = \frac{R_{in2}}{R_{in2} + r_{e1}} = 0.99 \text{ V/V}$$



$$G_v = \frac{V_{b1}}{V_{sig}} \cdot \frac{V_{b2}}{V_{b1}} \cdot \frac{V_o}{V_{b2}} = \frac{V_o}{V_{sig}} = (-160)(0.98)(0.99) = \boxed{-155 \text{ V/V}}$$

→ Comparison

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

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



7.23)

Replacing  $Q_1$  with CD results in;

$$R_{in1} = \boxed{\infty}$$

• Gain of  $Q_1 = \frac{R_L}{R_L + 1/g_m}$  ( $R_L$  is  $R_{in2}$ )

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

$$A_{v1} = \frac{2.5\text{k}}{2.5\text{k} + 1/4\text{m}} = 0.909$$

$$A_{v2} \rightarrow \text{From example ; } -160 \text{ V/V}$$

$$G_v = A_{v1} A_{v2} = \boxed{-145 \text{ V/V}}$$

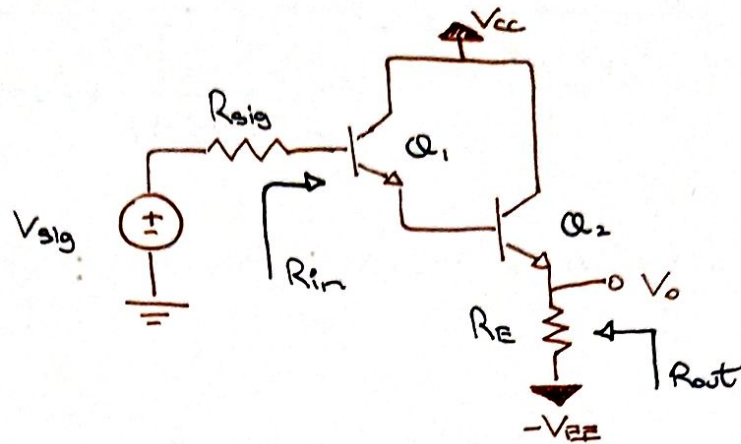
→ For  $R_{sig} = 400 \text{ k}\Omega$ , there is no effect on  $G_v$  of CD-CE configuration.

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

$$\frac{V_{b1}}{V_{sig}} = \frac{R_{in}}{R_{in} + R_{sig}} = \frac{255\text{k}}{255\text{k} + 400\text{k}} = 0.389 \text{ V/V}$$

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

7.24)



• Rin

$$\rightarrow R_{in} \text{ (of } Q_2) = (\beta_2 + 1)(r_{e2} + R_E)$$

$$\begin{aligned} \rightarrow R_{in} \text{ (of } Q_1) &= R_{in} = (\beta_1 + 1)(r_{e1} + R_{in} \text{ (of } Q_2)) \\ &= \boxed{(\beta_1 + 1)[r_{e1} + (\beta_2 + 1)(r_{e2} + R_E)]} \end{aligned}$$

• Rout

$$\rightarrow \text{Resistance in Emitter of } Q_1 = R_{out1} = r_{e1} + \frac{R_{sig}}{(\beta_1 + 1)}$$

$$\rightarrow \text{Similarly, } R_{out2} = r_{e2} + \frac{R_{sig}}{\beta_1 + 1} = r_{e2} + \frac{\left[ r_{e1} + \frac{R_{sig}}{\beta_1 + 1} \right]}{\beta_2 + 1}$$

$$\rightarrow R_{out} = \boxed{R_E \parallel \left[ r_{e2} + \frac{r_{e1} + R_{sig}/\beta_1 + 1}{\beta_2 + 1} \right]}$$

• Vo / Vsig

$$\rightarrow \frac{V_o}{V_{sig}} = \frac{R_{out}}{r_{e2} + R_{in2}} = \frac{R_{out_L}}{R_{out_L} + r_{e2} + R_{sig}/\beta_2 + 1}$$

$$\therefore R_{out_L} = R_E$$



$$\frac{V_o}{V_{sig}} = \frac{R_E}{R_E + r_{e2} + \left[ r_{e1} + \frac{R_{sig}}{\beta_1 + 1} \right] / (\beta_2 + 1)}$$

→ Evaluate :  $I_{E2} = 5 \text{ mA}$  ;  $\beta = 100$  ;  $R_E = 1 \text{ k}\Omega$   
 $R_{sig} = 100 \text{ k}\Omega$

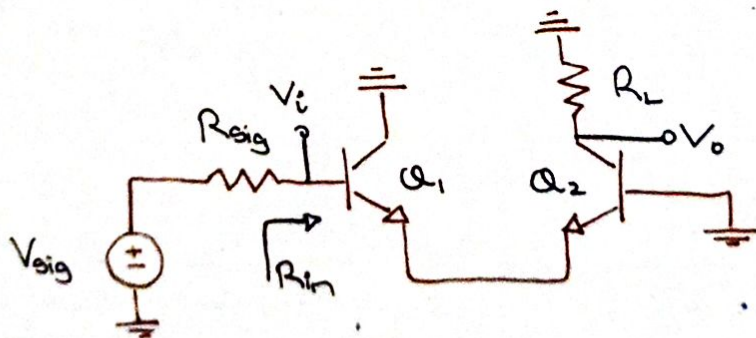
$$r_e = \frac{V_T}{I_E} = \frac{25 \text{ mV}}{5 \text{ mA}} = 5 \Omega$$

$$\begin{aligned} \rightarrow R_{in} &= (101) [5 + (101)(5 + 1 \text{ k})] \\ &= 10.25 \text{ M}\Omega \end{aligned}$$

$$\begin{aligned} \rightarrow R_{out} &= 1 \text{ k} \parallel \left[ 5 + \frac{5 + [100 \text{ k} / 101]}{101} \right] \\ &= 20 \Omega \end{aligned}$$

$$\begin{aligned} \rightarrow \frac{V_o}{V_{sig}} &= \frac{1 \text{ k}}{1 \text{ k} + 5 + \frac{5 + [100 \text{ k} / 101]}{101}} \\ &= 0.98 \text{ V/V} \end{aligned}$$

Example 7.8)

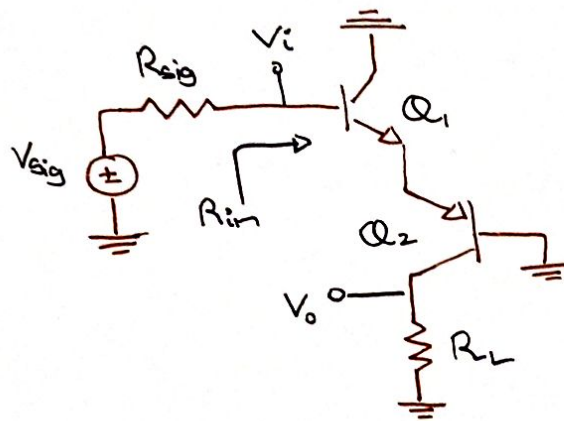


$$\rightarrow R_{in} = (\beta_1 + 1)(2r_e)$$

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

$$\therefore \text{where } g_m = \alpha / 2r_e$$

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



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

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

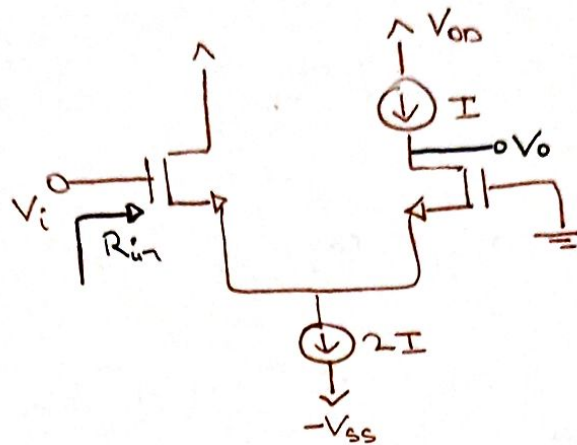
$$\rightarrow R_{in} = (101)(2 \times 25) = \boxed{5.05 \text{ k}\Omega}$$

$$\therefore r_e = \left( \frac{I}{V_T} \right)^{-1} = 25 \Omega$$

$$\rightarrow A_v = \left( \frac{1}{2(25)} \right) (5 \times 10^3) = \boxed{100 \text{ V/V}}$$

$$\rightarrow G_v = \frac{R_{in}}{R_{sig} + R_{in}} A_v = \frac{5.05 \text{ k}}{5 \text{ k} + 5.05 \text{ k}} (100) = \boxed{50 \text{ V/V}}$$

7.26)



•  $A_v$

$$\rightarrow \frac{V_o}{V_i} = g_m R_L$$

$$\therefore (g_m = 1/2r_e)$$

$$\therefore (r_e = V_{ov}/2I)$$

$$= \frac{1}{2r_e} R_L$$

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

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

$$\rightarrow I = 0.1 \text{ m}; R_L = 20 \text{ k}\Omega; (W/L)_1 = ?; A_v = 10 \text{ V/V}$$

$$(W/L)_2 = ? \quad k_n' = 200 \mu\text{A/V}^2$$

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

$$V_{ov} = 0.2 \text{ V}$$

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

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