(1) The dc collector voltage for our CE amp is given by

\[ V_C = V_C - I_C R_C = V_{CC} - V_C \]

\[ V_C = V_{CC} - I_C R_C \]

w/ the signal \( V_{in} \) applied to the base, the total collector voltage (i.e. large signal + small signal) is

\[ V_{C, \text{total}} = V_C \left( 1 + \frac{I_C}{I_R} \right) \]

\[ \text{small-signal gain} \]

but,

\[ g_m = \frac{I_C}{V_T} \]

\[ V_C = V_{CC} - I_C R_C \]

Now, the transistor is on the brink of leaving the active region when

\[ V_{CC, \text{total}} = 0 \]

\[ \frac{(V_{be} + V_{in}) - (V_C - \frac{I_C}{V_T} R_C V_{in})}{V_{be, \text{total}}} = 0 \]

\[ g_m R_C = \frac{(V_{CC} - V_{be} - V_{in})}{(1 + \frac{I_{in}}{V_T})} \]

Rearranging the above equation yields

\[ I_C R_C = \frac{(V_{CC} - V_{be} - V_{in})}{(1 + \frac{V_{in}}{V_T})} \]

For \( V_{CC} = 10 \text{ V}, V_{be} = 0.7 \text{ V}, \) and \( V_{in} = 5 \text{ mV} \)

\[ I_C R_C = 9.7958 \Rightarrow \text{dc voltage @ collector} = \frac{V_C - I_C R_C}{22002 \text{ V}} \]

\[ |A_I| = \text{small-signal gain} = \frac{I_C}{V_T} \]

\[ |A_I| = 399.34 \text{ V/V} \]

\[ \text{amp of output signal} = |A_I| |V_{in}| = 1.5 \text{ V} | \]

For the small-signal (ss) equiv ckt for obtaining \( A_v = \frac{V_{out}}{V_{in}} \)

\[ V_{in} = \frac{V_{out}}{g_m} \]

KCL at the output node yields

\[ \frac{V_{out}}{r_{oi}} = g_m (V_{in} - V_{in}) \Rightarrow V_{out} \left( \frac{1 + g_m R_C}{r_{oi}} \right) = g_m V_{in} \]

\[ \frac{V_{out}}{V_{in}} = \frac{1 + g_m R_C}{r_{oi}} \]

The ss equiv ckt for obtaining \( R_{oi} \) is

\[ KCL \text{ at the output node yields} \]

\[ \frac{V_{out}}{r_{oi}} + g_m V_{test} = V_{test} \]

\[ \frac{V_{test}}{V_{test}} = \frac{1 + g_m R_C}{r_{oi}} \]

\[ R_{oi} = \frac{V_{test}}{V_{test}} = \frac{61}{1 + g_m R_C} \]
(b) The ss equiv ckt for $A_{ss} = \frac{v_{s2}}{v_{in}}$ is:

$$\frac{v_{s2}}{v_{in}} = \frac{R_2}{R_2 + R}$$

KCL at the output node yields:

$$\frac{(v_{s2} - v_{in})}{R_2} - \beta_{s2} v_{s2} + \frac{v_{s2}}{R} = 0$$

$\Rightarrow v_{s2} \left( \frac{R + R_2}{R_2 R} \right) = v_{in} \left( \frac{\beta_{s2}}{R_2 R} \right)$

$$A_{ss} = \frac{v_{s2}}{v_{in}} = \frac{(\beta_{s2} R_2 + 1)R}{R_2 + R}$$

The ss equiv ckt for obtaining $R_{s2}$ is:

$$\frac{v_{s2}}{v_{in}} = \frac{R_2}{R_2 + R}$$

KCL at the input yields:

$$\frac{v_{in} - v_{s2}}{R_2} + \beta_{s2} \frac{v_{s2}}{R_2} = \frac{v_{test}}{R_2}$$

Using $A_{ss}$, however, $v_{s2} = \frac{(\beta_{s2} R_2 + 1)R}{R_2 + R} \cdot v_{test}$.

(c) w/ $\lambda = \lambda_2 = 0$, the derived eqns simplify to the following ($r_{s1} = r_{s2} = \infty$):

$$A_{01} = \frac{v_{in}}{v_{in}} = 1$$

$$R_{01} = \frac{1}{\beta_{in}}$$

$$A_{02} = \frac{v_{s2}}{v_{in}} = \beta_{s2} R$$

$$R_{02} = \frac{1}{\beta_{s2}}$$

(d) The 2-port representation of our ckt is:

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SF stage            CG stage
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\[
\frac{\nu_{2}}{\nu_{1}} = \frac{A_{n}}{R_{1} + R_{2}} \cdot \frac{R_{1}}{R_{2}} \cdot \frac{\nu_{2}}{\nu_{1}}
\]

\[
\frac{R}{j \omega L} = \frac{j \omega L}{R} \quad \text{if} \quad j \omega L \gg R
\]

(e) \[\frac{S}{R} = \frac{50 \mu}{R} \]  
if \[V_{o} = 0 \Rightarrow \frac{R}{R} = 100 \text{ k}\Omega\]

(f) \[\frac{\nu_{2}}{\nu_{1}} = \frac{\frac{R_{1} R}{2}}{R_{2}} = 25 \]

\[\Rightarrow \frac{R_{1}}{R_{2}} = 500 \mu \text{s} \]

Since \[j_{n} = \sqrt{2 \mu_{n} C_{ox} \frac{V_{t}}{L}} \Rightarrow \frac{V_{t}}{L} = 41.67 \approx 42\]
small-signal transfer characteristics

V(out)/vgl = 25.0998
input resistance at vgl = 1.0006e+20
output resistance at V(out) = 100.0000k

job concluded

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