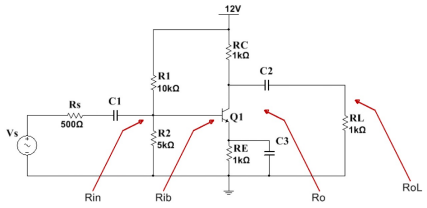
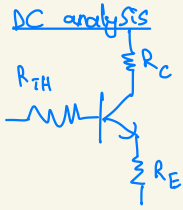
1. Consider the following common emitter amplifier circuit where β = 70, $V_{BE(ON)}$ = 0.7 V, V_A = 100 V, v_s = 10 mV and $V_{CE(Sat)}$ = 0.2 V. Determine: small-signal parameters (r_π, r_e, r_o and g_m), R_{in}, R_{ib}, R_o, R_{oL}, signal current in collector (i_c), signal voltage at collector (v_c). Use π model and do not ignore output resistance r_o. Assume that the capacitors are large enough for the signal frequency.



DC analysis



$R_{th} = 10k\Omega \,//\, 5k\Omega$
$= 3.33\,K\Omega$

$V_{th} = \frac{R_2}{R_1+R_2} V_{cc}$
$= \frac{5}{10+5} \times 12$
$= 4V$

$I_B = \frac{V_{TH} - V_{BE}}{R_{TH} + R_E(\beta+1)}$ where $I_B = 44.4mA$

$I_C = \beta i_B = 3.100mA$

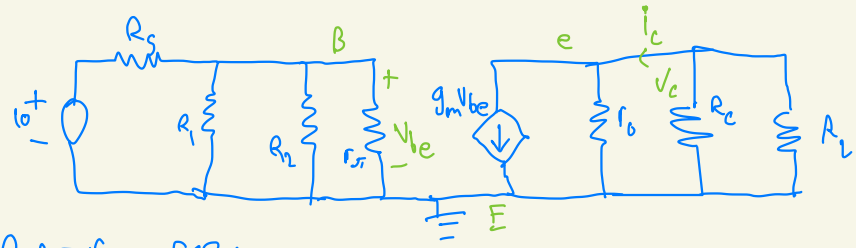
$I_C + I_B = I_E = 3.15mA$

small signal analysis

$r_\pi = \frac{V_T}{I_B} = 563.1$ $\quad r_e = \frac{V_T}{I_E} = 7.94\,\Omega$

$r_o = \frac{V_A}{I_C} = 32.15K\Omega$ $\quad g_m = \frac{I_C}{V_T} = 124.3mA$

small signal model



$R_{ib} = r_\pi = 563.1\,\Omega$

$R_{in} = R_1 \,//\, R_2 \,//\, r_\pi$
$= 481.6\,\Omega$

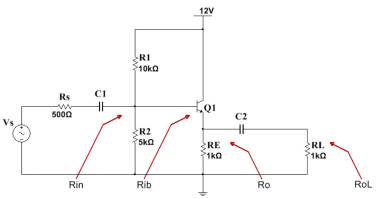
$\therefore V_{be} = \frac{V_s R_{in}}{R_s + R_{in}} = 4.91mV$

$\therefore V_c = -g_m V_{be} (r_o \,//\, R_c \,//\, R_L)$
$= -300.7mV$

$i_c = V_c / (R_c \,//\, R_L) = 601.4\mu A$

2. q4 is their q8

2. Consider the following common collector amplifier circuit where $\beta = 70$, $V_{BE(ON)} = 0.7\ V$, $V_A = 100\ V$, $v_s = 10\ mV$ and $V_{CE(Sat)} = 0.2\ V$. Determine: the small-signal parameters (r_π, r_e, r_o and g_m), R_{in}, R_{ib}, R_i, R_{oL}, voltage across the load R_L. Use T model and do not ignore output resistance r_o. Assume that the capacitors are large enough for the signal frequency.



similar to q1

$R_{th} = 3.33\ k\Omega$ $\quad V_{CE} = 12 - I_E R_E = 8.85V$

$V_{Th} = 4V$

$V_{th} - I_B R_{th} - V_{be} - I_E R_E = 0$

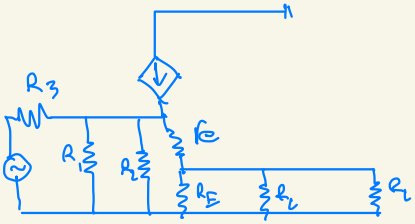
$I_E = 3.1522\ mA$

so, $I_C = \frac{\beta}{\beta+1} I_E = 3.11\ \mu A$

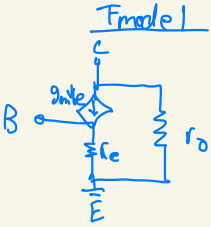
small signal parameters

$g_m = \frac{I_C}{V_T} = 124.3\ mA/V$ $\quad r_e = \frac{V_T}{I_E} = 7.73\Omega$ $\quad r_\pi = \frac{V_T}{I_B} = 563.1\Omega$ $\quad r_o = \frac{V_A}{I_C} = 32.2\ k\Omega$

AC analysis



Fmodel



left side

$R_{ib} = (\beta+1)[r_e + (R_E // r_o // R_L)]$
$= 36\ k\Omega$

$R_{in} = R_1 // R_2 // R_{ib} = 3.1\ k\Omega$

right

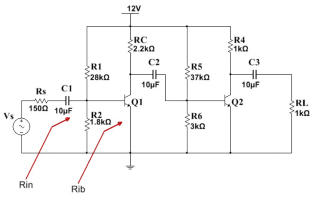
$R_o = \left[r_e + \frac{R_1 // R_2 // R_3}{\beta+1}\right]$
$= 14\Omega$

$R_{oL} = R_o // R_L = 13.8\Omega$

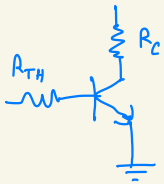
AC

$V_i = V_s \cdot \frac{R_{in}}{R_s + R_{in}} = 8.7mV$ $\quad i_c = \frac{V_i}{r_e + R_E // r_o // R_L} = 17.4\mu A$ $\quad V_o = i_c (R_E // r_o // R_L)$
$= 8.6mV$

3. Consider the following two-stage common emitter amplifier circuit where the transistors are identical. Given that $\beta = 70$, $V_{BE(ON)} = 0.7$ V, $V_A = 100$ V, $v_s = 10$ mV and $V_{CE(Sat)} = 0.2$ V. Determine: small-signal parameters ($r_{\pi 1}$, $r_{\pi 2}$, r_{e1}, r_{e2}, r_{O1} r_{O2} and g_{m1}, g_{m2}), R_{in}, R_{ib} signal currents flowing in both collectors (i_{c1}, i_{c2}) signal voltage at both collectors (v_{c1}, v_{c2}). Do not ignore output resistance r_o. Assume that the capacitors are large enough for the signal frequency.



DC analysis



$R_{th} = 28K \,//\, 1.8K = 1.69K\Omega$

$V_{th} = \frac{R_2}{R_1+R_2} V_{CC} = 0.72V$

$I_B = \frac{0.72-0.7}{R_{th}} = 14.67\mu A$

$I_C = 1.03\,mA \qquad I_E = 1.04\mu A$

$r_{\pi 1} = 1.7K\Omega \qquad r_{e1} = 24\Omega \qquad r_{o1} = 97.4K\Omega$

$g_{m_1} = 41.1\,mA/V$

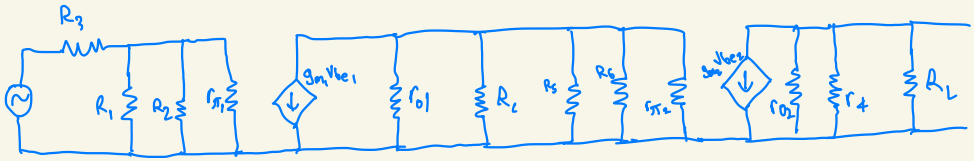
DC analysis Q_2

$R_{th_2} = R_5 // R_6 = 2.78K\Omega \qquad V_{th_2} = \frac{R_6}{R_6+R_5} \cdot 12 = 0.9V \qquad I_{B2} = \frac{0.9-0.7}{2.78K} = 72.1\mu A$

$I_{C2} = 5.05mA \qquad I_{E2} = 5.12mA$

$g_{m_2} = 201.9\frac{mA}{V} \qquad r_{e_2} = 4.9\Omega \qquad r_{\pi_2} = 346.8\Omega \qquad r_{O_2} = 19.81K\Omega$

AC analysis



$V_4 = -g_{m_1} V_{be_1} \underbrace{(r_{O_1} // R_C // R_5 // R_6 // r_{\pi_2})}_{269.8\Omega} = -41.1e^{-3} \cdot 8.5e^{-3} \cdot 269.8 = -94.2mV$

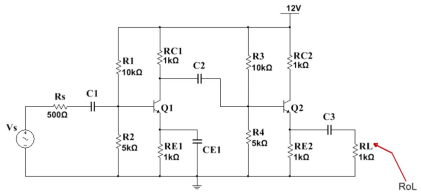
$I_{C_1} = \frac{V_{C_1}}{\underbrace{(R_C // R_5 // R_6 // R_{\pi_2})}_{270.5\Omega}} = 348.2\mu A$

$V_{C_2} = g_{m_2} V_{bc_2} \underbrace{(r_{O_2} // R_4 // R_L)}_{487.7\Omega} = 201.9e^{-3} \cdot 94.2e^{-3} \cdot 487.7 = 9.3V$

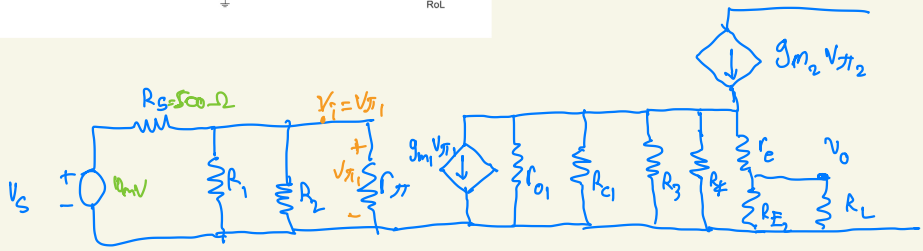
finally

$I_{C_2} = \frac{V_{C_2}}{R_4 // R_2} = \frac{9.3}{500} = 18.6\,mA$

4. Consider the following two-stage amplifier circuit where the transistors are identical. Given that $\beta = 70$, $V_{BE(ON)} = 0.7$ V, $V_A = 100$ V, $v_s = 10$ mV and $V_{CE(Sat)} = 0.2$ V. Determine: the voltage across load resistor RL and output resistance R_{OL} as indicated in the circuit below. Do not ignore output resistance r_o. Assume that the capacitors are large enough for the signal frequency.



Biasing and small signal are same as before



$R_{OL} = R_L // R_o = 18.2\Omega$

$R_o = R_{E_2} // [r_e + R_x(\beta+1)] = 18.5\Omega$

$R_x = R_4 // R_3 // R_{C_1} // R_{21} = 750\Omega$

$V_i = V_s \cdot \frac{R_{in1}}{R_s + R_{in1}}$ .... $R_{in_1} = R_1 // R_2 // r_\pi$

$R_Y = r_{o_1} // R_{E_1} // R_3 // R_4 // [(r_e + R_{E_2} // R_L)\cdot(\beta+1)]$

$V_{o1} = -g_{m_1} V_i R_y$

$V_o = i_{c_2}(R_{E_2} // R_L)$

$i_{c_2} = \frac{V_{o1}}{r_e + R_{E_2} // R_L}$ $\therefore V_o = \frac{V_{o1}}{r_e + R_{E_2} // R_L}$

$(R_{E_2} // R_L) \approx V_{o1}$

$[\because R_{E_2} // R_L \gg r_e]$