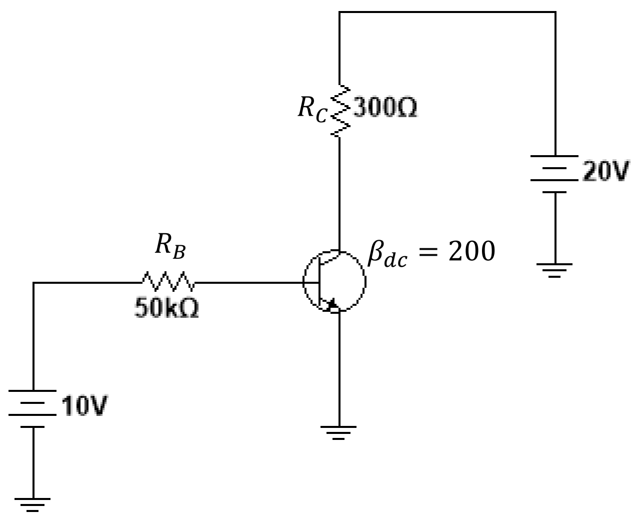
<u>dc Operating Point (Q-Point)</u>



Q-point is defined by I_C and V_{CE}

$$I_B = \frac{V_{BB} - 0.7V}{R_B} = \frac{9.3V}{50k\Omega} = 186\ \mu A$$

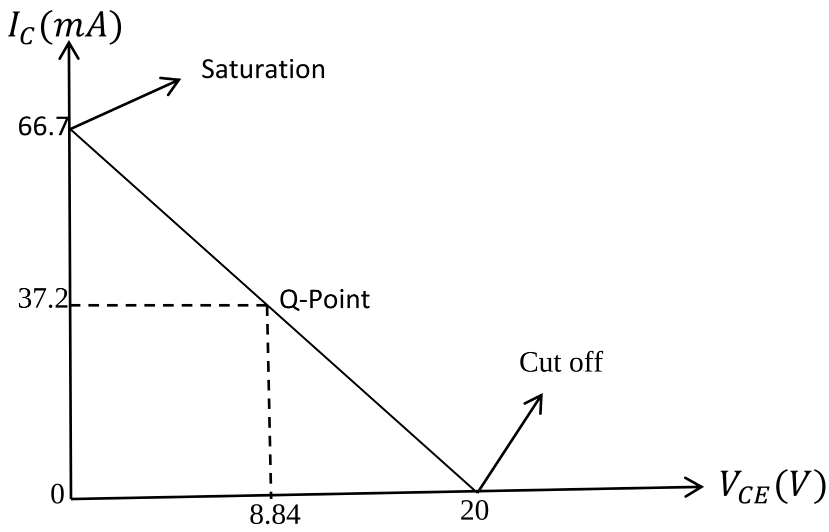
$$I_C = \beta_{dc} I_B = (200)(186\ \mu A) = 37.2\ mA$$

$$V_{CE} = V_{CC} - I_C R_C = 20V - (37.2\ mA)(300\Omega) = 20V - 11.16V = 8.84V$$

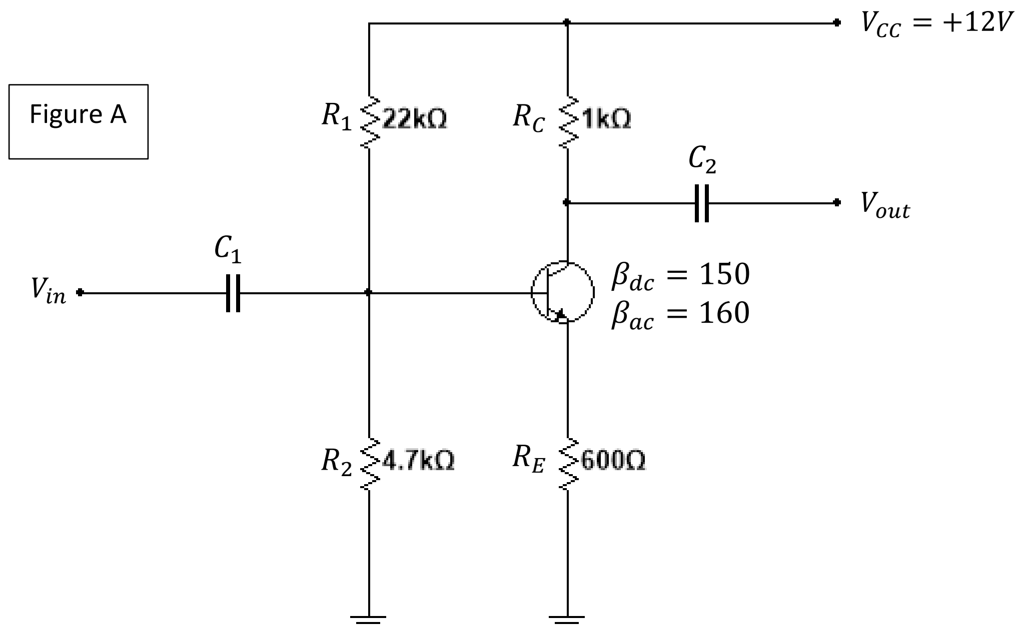
Q-point is at $I_C = 37.2\ mA$, $V_{CE} = 8.84V$

$$I_{C(sat)} = \frac{V_{CC}}{R_C} = \frac{20V}{300\Omega} = 66.7\ mA$$

The load line (dc) is graphically illustrated as:

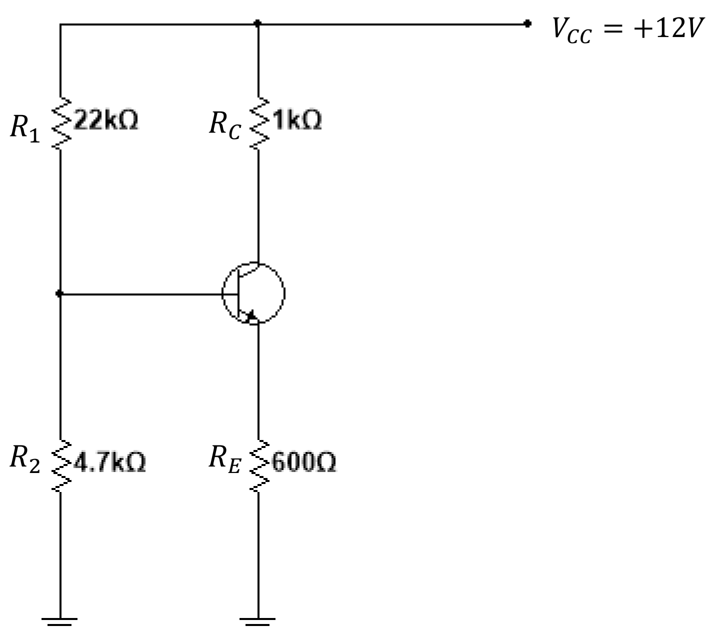


A1: Common-Emitter Amplifier



- The circuit has a combination of ac and dc operation

dc analysis



dc input resistance

$$R_{IN(base)} = \beta_{dc}R_E = 90k\Omega$$

If $R_{IN(base)} > 10R_2$, then

$$V_B = \left(\frac{R_2}{R_1 + R_2}\right)V_{CC}$$

$$= \left(\frac{4.7k\Omega}{26.7k\Omega}\right)12V = 2.11V$$

Since $V_{BE} = V_B - V_E$

$$V_E = V_B - 0.7V = 2.11V - 0.7V = 1.41V$$

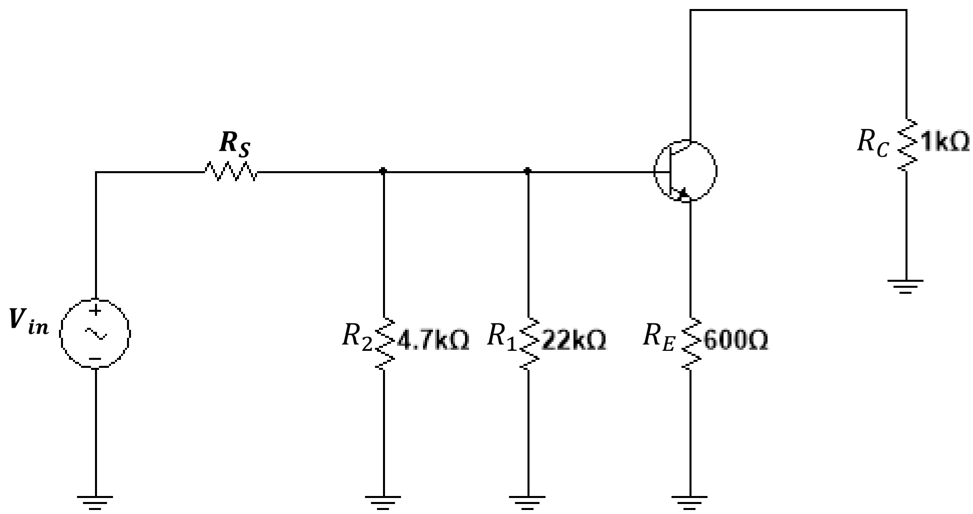
$$I_E = \frac{V_E}{R_E} = \frac{1.41V}{600\Omega} = 2.4mA$$

Since $I_C \approx I_E$

$$V_C = V_{CC} - I_C R_C = 12V - 2.4V = 9.6V$$

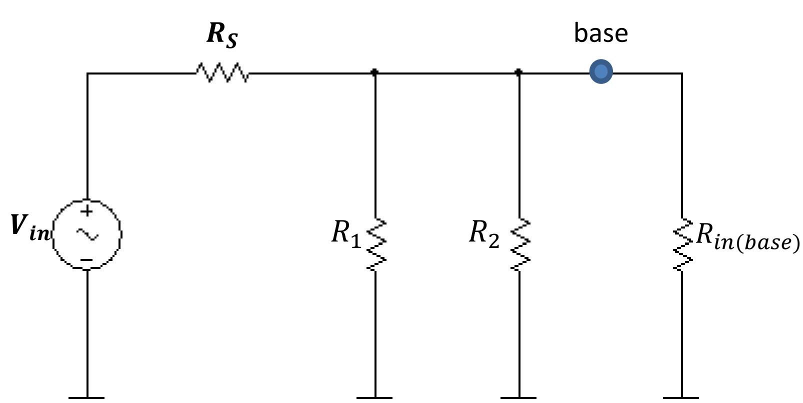
$$V_{CE} = V_C - V_E = 9.6V - 1.41V = 8.19V$$

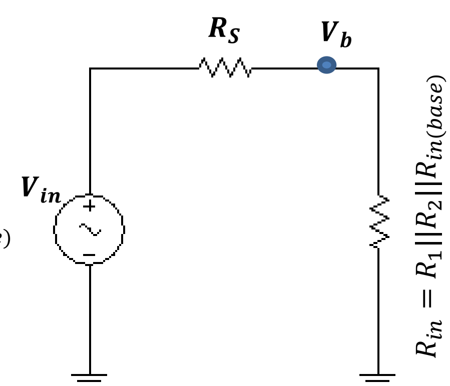
ac Equivalent Circuit



- Capacitors are replaced by effective shorts (assuming $X_C = 0$ at signal frequency)
- dc source is replaced by ground

signal ac at the base



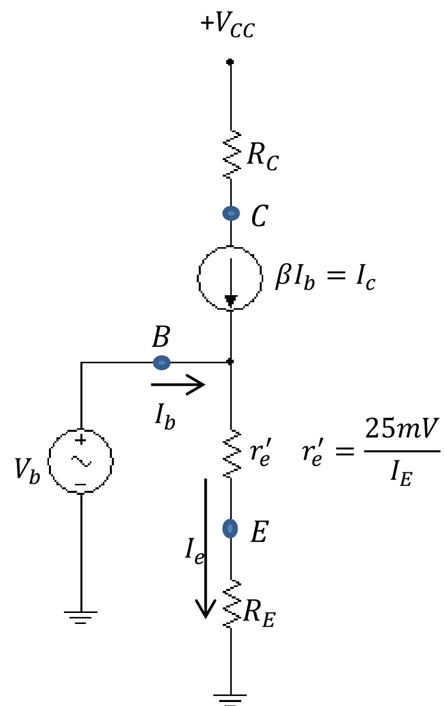


$$V_b = \left(\frac{R_{in}}{R_S + R_{in}}\right) V_{in}$$

R_{in} : Total input impedance at the base

If $R_S \ll R_{in}$, then $V_b = V_{in}$

Input Impedance



$$R_{in(base)} = \frac{V_b}{I_b}$$

$V_b = I_e(r_e' + R_E)$ and $I_b \approx \frac{I_e}{\beta_{ac}}$

$$R_{in(base)} = \beta(r_e' + R_E)$$

The total impedance seen by the ac source

$$R_{in} = R_1 \parallel R_2 \parallel R_{in(base)}$$

Output Impedance

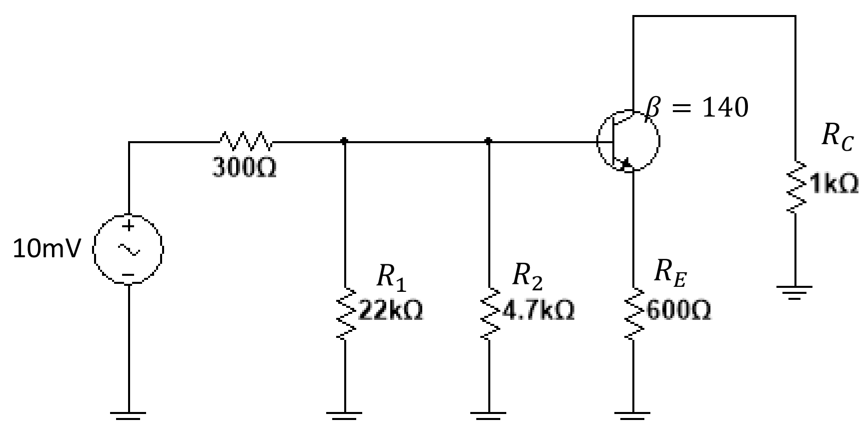
$$R_{out} = R_C || r_C$$

But since the collector resistance r_C is typically much larger than R_C then

$$R_{out} \approx R_C$$

Example: Determine the signal voltage at the base in figure below:

$I_E = 2.4mA$



$$r'_e = \frac{25mV}{I_E} = \frac{25mV}{2.4mA} = 10.4\Omega$$

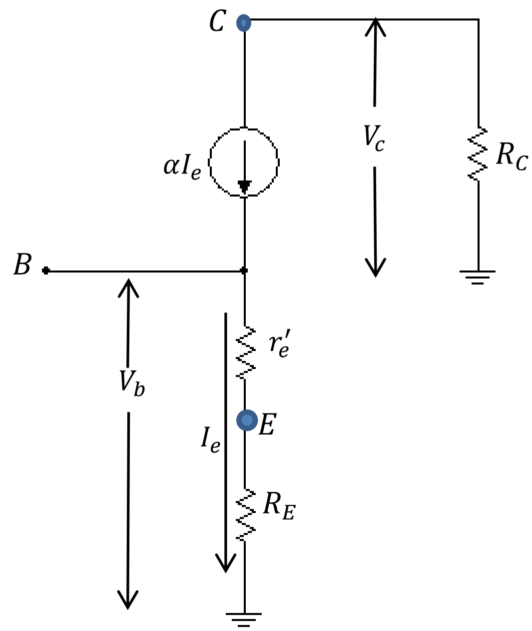
$$R_{in(base)} = \beta(r'_e + R_E) = 140(610.4\Omega) = 85.5k\Omega$$

$$\frac{1}{R_{in}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_{in(base)}} = \frac{1}{22k\Omega} + \frac{1}{4.7k\Omega} + \frac{1}{85.5k\Omega}$$

$$R_{in} = 3.7k\Omega$$

$$V_b = \left(\frac{R_{in}}{R_S + R_{in}}\right) V_{in} = \left(\frac{3.7k\Omega}{4k\Omega}\right) 10mV = 9.25mV$$

Voltage Gain



$$A_v = \frac{V_c}{V_b}$$

Since $V_c = I_e R_C$

$$V_b = I_e(r_e' + R_E)$$

$$A_v = \frac{I_e R_C}{I_e(r_e' + R_E)}$$

$$A_v = \frac{R_C}{(r_e' + R_E)}$$