Tutorial-12: Solutions

Q2.

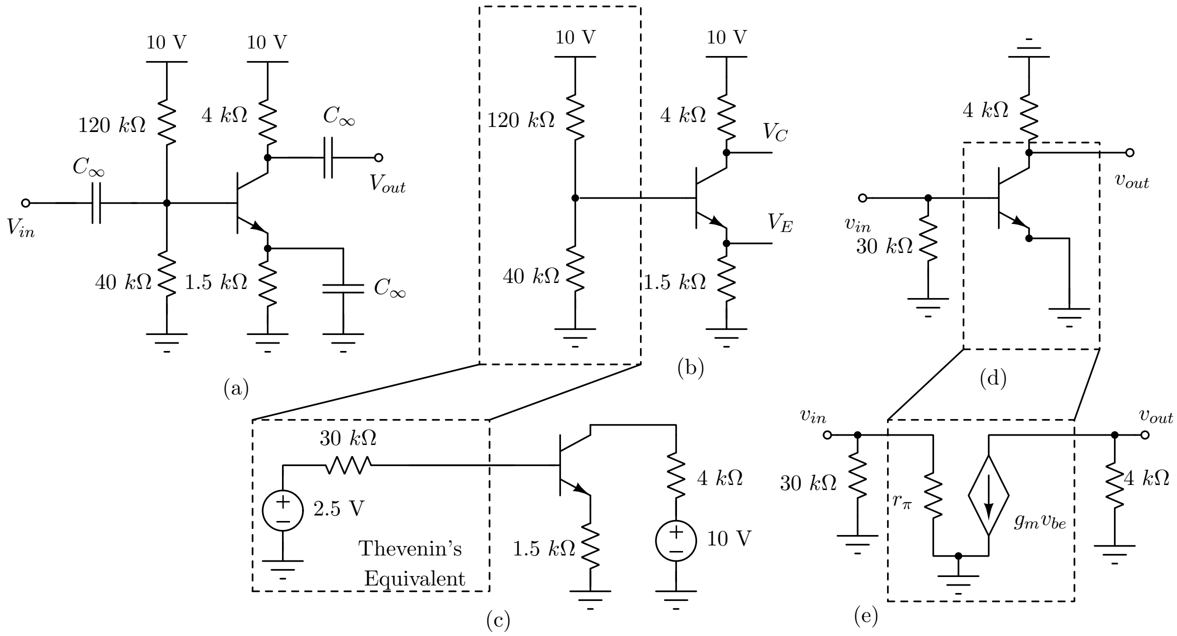

Figure 1: (a) The CE amplifier. (b) and (c) are the DC equivalent circuits. (d) and (e) are the AC equivalent circuit.

1. Fig. 1(b) shows the DC equivalent circuit of the CE amplifier shown in Fig. 1(a). Note that the capacitors have been replaced by open-circuits.

2. In Fig. 1(c), the input voltage divider has been replaced by Thevenin's equivalent circuit. The open-circuit voltage is $\frac{40}{160} \times 10$ V and the open-circuit impedance is $\frac{40*120}{160}$ $k\Omega$.

3. From Fig. 1(c), applying the KVL around the input loop gives

$$
\begin{aligned}
2.5 &= I_B \times 30k\Omega + V_{BE} + I_E \times 1.5k\Omega \\
&= \frac{I_E}{100+1} \times 30k\Omega + 0.7 + I_E \times 1.5k\Omega \\
2.5 - 0.7 &= I_E \times (1.5 + 30/101) \times 10^3 \\
I_E &\approx 1 \text{ mA}
\end{aligned}
$$

4. All other currents and node voltages can be found from I_E and are given below.

$$\begin{aligned}
I_C &= \frac{\beta I_E}{1+\beta} \approx 0.99 \text{ mA} \\
I_B &= \frac{I_C}{\beta} \approx 9.9 \ \mu\text{A} \\
V_E &= I_E \times 1.5k\Omega \approx 1.5 \ V \\
V_C &= 10V - I_C \times 4k\Omega \approx 6 \ V \\
V_B &= 0.7 + V_E \approx 2.2 \ V
\end{aligned}$$

5. Cross verify the inherent assumption that the collector-base junction is reverse biased: $V_C > V_B > V_E$

6. The AC equivalent circuit is shown in Fig. 1(d). Note that the DC voltage sources are short circuited in the AC equivalent circuit. Moreover, the capacitors C_∞ are also replaced with short-circuits.

7. Transconductance of the transistor is $g_m = \frac{I_C}{V_T} \approx \frac{0.99 \ mA}{25 \ mV} \approx 39.6 \ mA/V$.

8. $r_\pi = \frac{\beta}{g_m} \approx 2.53 \ k\Omega$.

9. Voltage gain of the amplifier is $\approx g_m \times 4k\Omega \approx 158.4$

Q3. $Z_{in} = \frac{-j500}{5\omega - j100} + 2 + \frac{j5\omega}{500 + j\omega}$

(a) At resonance $I_m(Z_{in}) = 0$

$$\Rightarrow \frac{-2500\omega_0}{25\omega_0^2 + 10^4} + \frac{2500\omega_0}{25\times10^4 + \omega_0^2} = 0$$

$$\Rightarrow -25\times10^4 - \omega_0^2 + 25\omega_0^2 + 10^4 = 0$$

$$\Rightarrow \omega_0^2 = 10^4 \Rightarrow \omega_0 = 100 rad/s$$

$$(b) Z_{in}(j\omega_0) = Re\{Z_{in}(j\omega_0)\} = 2 + \frac{5\times10^4}{25\omega_0^2 + 10^4} + \frac{5\omega_0^2}{\omega_0^2 + 500^2}$$

$$= 2 + \frac{5}{26} + \frac{5}{26} = 2.385\Omega$$

Q4. $\omega_0 = \frac{1}{\sqrt{LC}} = 50 krad/s$

$$f_0 = \frac{\omega_0}{2\pi} = 7.96 kHz$$

$$Q_0 = \omega_0 L / R = 4$$

Bandwidth $B = \frac{\omega_0}{Q_0} = 12.5 krad/s$

$$\boldsymbol{\omega_2, \omega_1 = \omega_0\left[\sqrt{1 + \left(\frac{1}{2Q_0}\right)^2} \pm \frac{1}{2Q_0}\right]}$$

$$\boldsymbol{\omega_2 = 56.65\ krad/s}$$

$$\boldsymbol{\omega_2 = 44.15\ krad/s}$$

$$Z_{in} = R_s + j\left(\omega L_s - \frac{1}{\omega C_s}\right)$$

At $\omega = 45 krad/s$, $\quad Z_{in} = 65.4\angle -40.2^\circ$

$$\frac{Z_c}{R} = \frac{1}{\omega CR} = \frac{1}{45\times10^{-4}\times50} = 4.44$$