Problem Set 2 Solutions

6.101 Analog Electronics Lab

Spring 2007

Problem 1 (a) (6pts)

$$V_B = 0V \Rightarrow I_B = 0$$

$$I_C = \beta + 0 = 0$$

$$V_C = 6 - I_C \cdot R_C = 6.0 - (0 \cdot 10K\Omega) = 6.0V$$

(b) (6pts)

$$V_B = 1V \Rightarrow V_E = V_B - 0.7V = 0.3V$$

$$I_E = \frac{V_E}{R_E} = \frac{0.3V}{1K\Omega} = 0.3mA \approx I_C$$

$$V_C = 6 - I_C \cdot R_C = 6.0 - (.3mA \cdot 10K\Omega) = 3.0V$$

(c) (6pts)

$$V_B = 2V \Rightarrow V_E = V_B - 0.7V = 1.3V$$

$$I_E = \frac{V_E}{R_E} = \frac{1.3V}{1K\Omega} = 1.3mA \approx I_C$$

$$V_C = 6 - I_C \cdot R_C = 6.0 - (1.3mA \cdot 10K\Omega) = -7.0V < V_{CE_{sat}} \approx 0.2V$$

The transistor is on because of the large base voltage, but it must be in saturation and at the edge of the saturation region. Thus $V_{CE} = 0.2V$.

$$V_C = V_E + V_{CE_{sat}} \approx V_E + 0.2V = 1.3V + 0.2V = 1.5V$$

Problem 2 (12pts)

$$I_D = I_R = \frac{50mV}{4\Omega} = 12.5mA$$

$$r_d \approx \frac{V_T}{I_D} = \frac{26mV}{12.5mA} = 2.1\Omega$$

$$v_{out} = 6\sin(100t)mV \left(\frac{4\Omega}{2.1\Omega + 4\Omega}\right) = 3.9\sin(100t)mV$$

$$v_{OUT} = V_{OUT} + v_{out} = 50mV + 3.9sin(100t)mV$$

Problem 3 (a) (15pts)

$$I_E \approx I_C = 4mA$$
$$V_E = I_E R_E = 4mA * 100\Omega = 0.4V$$
$$V_B = V_E + 0.6V = 0.4V + 0.6V = 1.0V$$

Make the resistor divider voltage equal the desired base voltage:

$$V_B = \frac{1K\Omega}{1K\Omega + R} 15V = 1.0V \rightarrow R = 14K\Omega$$

Use standard values, either $13K\Omega$ or $15K\Omega$.

(b) (15pts)

$$V_B = 15\frac{1000\Omega}{1000\Omega + R} - (1000\Omega||R)I_B$$

Both $13K\Omega$ and $15K\Omega$ are much greater than 1000Ω so $(1000\Omega||R) \approx 1K\Omega$.

$$V_B \approx 1.0V - 1000I_B$$
$$I_C = \frac{\beta}{\beta+1}\frac{V_B - 0.6V}{100}$$
$$I_B = \frac{I_C}{10} = \frac{10}{11}\frac{V_B - 0.6V}{1000\Omega}$$
$$V_B = 1 - \frac{10}{11}(V_B - 0.6V)$$
$$V_B \approx 0.81V$$
$$I_C \approx 1.9mA$$

Problem 4 (20pts)

$$R_{TH} = R_1||R_2 = 20K\Omega||15K\Omega = 8.57K\Omega$$
$$V_{TH} = \frac{R_1}{R_1 + R_2}V_{CC} = \frac{15K\Omega}{15K\Omega + 20K\Omega}10 = 4.29V$$
$$V_{CC} = I_{EQ}R_E + V_{EB} + \frac{I_{EQ}}{1+\beta}R_{TH} + V_{TH}$$
$$10 = I_{EQ}\left(1K\Omega + \frac{8.57K\Omega}{101}\right) + 0.7V + 4.29V$$
$$I_{EQ} = \frac{(10 - 0.7 - 4.29)V}{1K\Omega + \frac{8.57K\Omega}{101}} = \frac{5.01V}{1.085K\Omega} = 4.62mA$$
$$V_B = \frac{I_{EQ}}{1+\beta}R_{TH} + V_{TH} = \frac{4.62mA}{101}8.57K\Omega + 4.29 = 4.68V$$

Problem 5 (a) (10pts) A large capacitor, often lovingly referred to as a Big Fat Capacitor (BFC), can be placed in parallel with the emitter resistor. This does not affect the DC bias stability of the amplifier, but does drastically increase the AC gain.

(b) (10pts) The Q point is the operating point of circuit. It is determined by the bias currents and voltages that result from resistor values chosen in the design of a circuit. On a load line graph, the Q point illustrates the operating collector current, base current, and voltage difference between the collector and the emitter of a transistor.

Choose a Q point that allows for sufficient output swing, reasonable current levels, and keeps the amplifier in the desired region of operation (usually the forward active region, VCE¿ 0.2V). The x intercept of a load line is the open circuit voltage (i.e., take out the transistor) between the collector and emitter nodes of the transistor. The y intercept of a load line is the short circuit current between the collector and the emitter of the transistor (i.e. the current through the collector if you placed a wire between the collector and the emitter).