Problem Set 9  (Solutions are due Fri. 11-04-11)

Note: For all problems you have to explain how you arrived at the solution legibly and in a logical order. This includes (i) Statement of problem, (ii) strategy(s) for solution, (iii) execution of the strategy, identifying each step and including a check of the solution(s), and (iv) logical and legible presentation and clear identification of the solution.

1) Problem 4-14 in the book.

2) Consider the following bipolar junction transistor circuits. Assume that the transistors are in active mode \(v_{CE} > 0.4\) V and \(i_C > 0\) and use the non-linear transistor model (based on the Shockley equation) unless stated otherwise.

(a) The transistor in circuit (a) has \(\beta = 120\) and \(v_{BE}\) was measured as 0.7 V at \(i_C = 5\) mA. Select \(R_C\) and \(R_E\) such that \(i_C = 100\) mA and \(v_C = 8\) V. What is the value of \(v_E\) in this case?

(b) Determine the voltage gain \(dv_O/dv_S\) in terms of \(R, i_C\) and \(v_T\) for the (b) circuit.

(c) The circuit in (c) sinks a constant current \(i_C\) as long as the transistor is in active mode. Determine \(i_C\) in terms of \(V_{CC}, R_1, R_2, R_E, v_{BE},\) and \(\beta\). Use the linear current-controlled current source model for this circuit.

3) Consider the pnp transistor circuits shown below. Assume that the transistors are in active mode and use the linear transistor model with \(v_{EB} = 0.7\) V unless otherwise stated.
(a) For $V_{CC} = 15$ V and $\beta = 80$, find values for $R_B$ and $R_C$ in circuit (a) such that $i_E = 10$ mA and $v_C = 5$ V.

(b) For the circuit and values you found in (a), determine $v_C$ and $i_E$ as $\beta \to \infty$ and $i_B \to 0$ (while keeping $v_{EB} = 0.7$ V so that the transistor is in the active mode).

(c) To improve the situation that you saw in part (b) for the case when a transistor has a high $\beta$, the circuit in figure (b) is proposed. Choose $i_x \approx i_B$ and determine $R_x$, $R_B$, and $R_C$ such that $i_E = 10$ mA and $v_C = 5$ V. Now, what happens to $v_C$ and $i_E$ as $\beta \to \infty$ and $i_B \to 0$ (while keeping $v_{EB} = 0.7$ V so that the transistor is in the active mode).

4) Use the following circuit in LTspice to determine the parameters $i_S$, $\alpha$ and $\beta$ of the default npn bipolar junction transistor model $NPN$ (i.e., without choosing a particular transistor type).

Assume that $i_E = i_S \left( e^{v_{BE}/v_T} - 1 \right) \approx i_S e^{v_{BE}/v_T}$, where $i_E$ is the emitter current, $v_{BE}$ is the base-emitter voltage, $i_S$ is the reverse saturation current, and $v_T = 25.7$ mV (at $25^\circ$C) is the thermal voltage. For $\alpha$ use $\alpha = i_C/i_E$ and for $\beta$ use $\beta = i_C/i_B$. 