ELECTRONICS I
December 8, 2010

1. (20 pts) In the circuit below, a measurement shows that the emitter voltage is 1.2 V. Find $V_B$, $V_C$, $I_E$, $I_B$, $I_C$, and the value of $\beta$ and $\alpha$. Neglect the effect of the Early voltage ($\lambda = 0$).

\[ V_B = 1.2 - 0.7 = 0.5 V \]
\[ I_B = \frac{0.5 - 0}{50 \Omega} = 0.01 mA \]
\[ I_C = I_E - I_B = 0.76 mA \]
\[ B = \frac{I_C}{I_B} = \frac{0.76}{0.01} = 75 \]
\[ \alpha = \frac{B}{B+1} = \frac{75}{76} = 0.987 \]
2. (20 pts) Measurements on the circuit below produce the labeled voltages as indicated. Find the value of $\beta$ for the transistor.

\[ I_E = \frac{10 - 7}{1k} = 3 \, mA \]

\[ I_E = I_C + I_B = 3 \, mA \]

\[ V_C = 3 \, mA \cdot (1k) = 3 \, V \]

\[ I_B = \frac{6.3 - 3}{100 \, k} = 33 \, \mu A \]

\[ \frac{I_E}{I_B} = \beta + 1 = \frac{3 \, mA}{33 \, \mu A} = 90.9 \]

\[ \rightarrow \beta = 89.9 \]
3. (30 pts) The BJT as an amplifier

- (a) In the circuit below, assume $V_{BE} = 0.7 \text{V}$ and calculate the value of the collector current and the voltage at the collector.

- (b) Using the T-model of the BJT and neglecting the effect of $r_o$, draw the small signal equivalent circuit of the amplifier.

- (c) Using the results of part (b), calculate the voltage gain of the amplifier, $v_o/v_i$.
4. (30 pts) The BJT as an amplifier

- (a) Is the amplifier below a (1) common-emitter, (2) common-base, or (c) common-collector configuration? (circle the correct answer)
- (b) Including the effects of $r_o$ and using the T-model of the transistor, draw the small-signal equivalent circuit of the amplifier. Derive the analytical expression for the small-signal voltage gain $A_v = v_o/v_i$ of the amplifier.
- (c) Derive the expression for the input resistance $R_{in}$. 

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[Diagram of the BJT amplifier circuit]
5. (20 pts) In the circuit below, the enhancement-NMOS transistor has a threshold voltage $V_t = 1V$. Furthermore $k_n' (W/L) = 0.4$ mA/V$^2$ and $\lambda = 0$. Find the labeled voltage $V_1$.

\[ \frac{V_1 + 5}{100} = I = \frac{1}{2} (0.4) (5 - V_1)^2 \]

\[ = \frac{1}{2} (0.4) (5 - 100 I - 1) \]

\[ \Rightarrow I = 0.036 \text{ mA} \]

$V_{GS} < V_t$

\[ V_1 = -5 + 100 \times -1.4V \]

$\Rightarrow$ Saturation ($+5$)
6. (20 pts) The transistor below has a threshold voltage $V_t = 0.5V$. Furthermore $k_n' = 0.4 \text{ mA/V}^2$ and $\lambda = 0$. Show that the transistor operates at the edge of saturation if the following condition is satisfied

$$\frac{W}{L} R_D = 1.5k\Omega$$

\[ \frac{I}{I_e} = 0.4 \text{ mA/V}^2 \]

\[ V_t = 0.5V \]

\[ \lambda = 0 \]

**Saturation Boundary**

\[ V_{GD} = 5V = R_D I_D \]

\[ 0.5 = \frac{1}{2} k_n' \frac{W}{L} (1.8 - 0.5)^2 R_D \]

\[ \Rightarrow \frac{W}{L} R_D = 1.48 k\Omega \]
7. (30 pts) For the two amplifiers shown below, draw their small signal equivalent circuit.

- Use the T-model for both transistors in circuit I and neglect the effect of \( r_0 \).
- For circuit II, using the hybrid-\( \pi \) model of the transistor and neglect the effect of \( r_0 \). Use your small signal equivalent circuit to derive an analytical expression of the input resistance \( R_{in} \).
\[ R_i = \frac{\sqrt{g} m}{i} \]

\[-g m \sqrt{g} s = \left( \frac{1}{R_L} + \frac{1}{R_1 + R_2} \right) N_0 \]

\[ i_i = -g m \sqrt{g} s \]

\[ i_i = \left( \frac{1}{R_L} + \frac{1}{R_1 + R_2} \right) N_0 \]

\[ \frac{i_i}{N_0} = \frac{N_0}{N_0} \left( \frac{1}{R_1 + R_2} + \frac{1}{R_L} \right) \]

\[ \sqrt{i} = \frac{g m}{N} \left[ \frac{g m (R_1 + 1)}{R_1 + R_2} + \frac{1}{R_L} \right] \left[ \frac{1}{R_1 + R_2 + \frac{1}{R_L}} \right] \]

\[ R_i = \frac{\sqrt{i}}{i} = \left[ \frac{g m (R_1 + 1)}{R_1 + R_2} + \frac{1}{R_L} \right] \left[ \frac{1}{R_1 + R_2 + \frac{1}{R_L}} \right] \]
8. (30 pts) For the amplifier shown below with 3 terminals X, Y, and Z, show how to connect to which terminal a signal source $v_{sig}$, load resistance $R_L$, and AC ground to build a common-source, common-gate, and common-drain amplifier. Draw the three separate circuits (10 points each).
Common Drain

[Diagram of a common drain circuit with voltage sources, resistors, and labels for positive and negative voltages.]

\[ +5V \]
\[ -5V \]
\[ R_D \]
\[ R_L \]