PROBLEM SET #1

Issued: Tuesday, Jan. 24, 2012

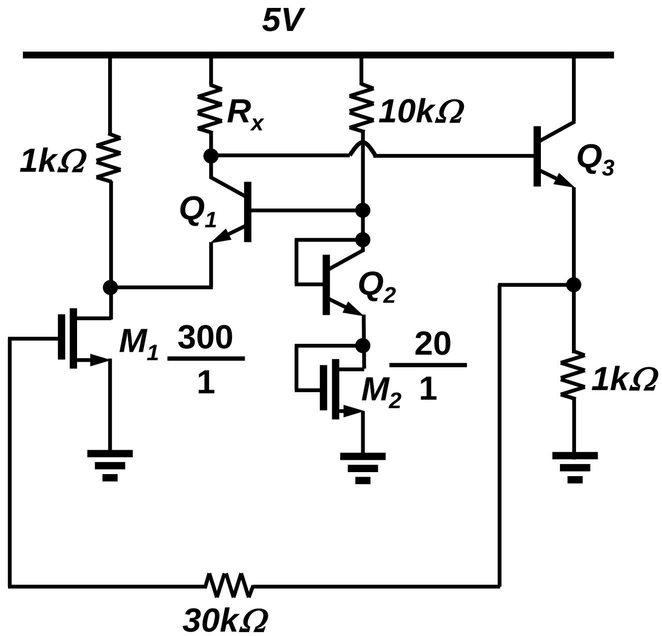
Due: Tuesday, Jan. 31, 2012, 5:00 p.m. in the EE 140 homework box in 240 Cory

1. Consider a *pn* junction diode in silicon with doping densities N_A=10^{17}/cm^3 and N_D=10^{20}/cm^3. (assume n_i=10^{10}/cm^3, junction area = 1×10^{-5}cm^2)
   (a) Calculate the built-in potential, depletion-layer depths and maximum field for a reverse bias of 5V.
   (b) Repeat (a) for zero external bias and 0.3V forward bias.
   (c) Calculate the junction capacitance at zero bias, 3V reverse bias and 0.5V forward bias.

2. Gray & Meyer, Chapter 1: Problem 1.9. (As in the text, assume n_c=n_s=0.3.)

3. An NMOS transistor has parameters W=10μm, L=1μm, k'=200μA/V^2, λ=0.02V^{-1}, t_{ox}=100Å, ϕ_f=0.3V, V_{t0}=0.7V, substrate doping concentration =10^{15}/cm^3, relative permittivity of Si = 11.8 and of gate oxide = 3.9. Ignore velocity saturation effects.
   (a) Sketch the I_D-V_{DS} characteristics for V_{DS} from 0 to 3V and V_{GS}=0.5V, 1.5V, and 3V. Assume V_{SB}=0V.
   (b) Sketch the I_D-V_{GS} characteristics for V_{DS}=2V as V_{GS} varies from 0 to 2V with V_{SB}=0V, 0.5V, and 1V.
   (c) Derive and sketch the *complete* small-signal equivalent circuit for the device with V_{GS}=1V, V_{DS}=3V and V_{SB}=1V. Use ψ_0=0.7V, C_{sb0}=C_{db0}=20fF, and C_{gb}=5fF. Overlap capacitance from gate to source and gate to drain is 2fF.
   (d) Under the bias condition in (c), calculate the frequency of unity current gain of this device.

4. Refer to the circuit shown below: (β_f=100, $V_A\rightarrow\infty$, r_b=0, $V_{BE(on)}$=0.7V, $V_{CE(sat)}$=0.2V, k'=200μA/V^2, V_t=0.6V, λ=0)
   (a) Assume R_x =10kΩ, calculate the DC operating points including the current flowing along each branch and DC voltage at each node. (You can assume $\beta_f\rightarrow\infty$ for part(a).)
   (b) What is the maximum value for R_x that ensures all the BJT's are in forward active region?



5. Consider a bias circuit shown below. Calculate the output voltage V_{out} and output current I_{out}. Assume $V_{BE(on)}$=0.7V and $V_{CE(sat)}$=0.2V.