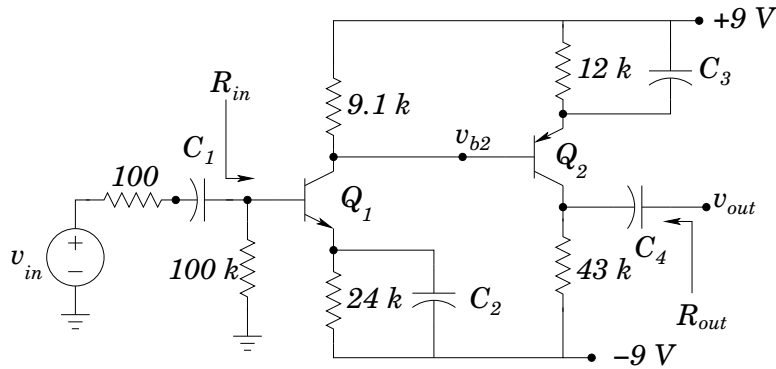


ECE-342 Test 3, Dec 4, 2007
6:00-8:00pm, Closed Book (one page of hand-written notes allowed)

Please use $V_T = kT/q = 25.8 \text{ mV}$ at 300K for your calculations

1. Consider the 2-stage amplifier shown below. Assume that all capacitors are large, so that at “midband” frequencies they have negligible impedance. Draw the small-signal model appropriate for finding the amplifier gain at midband frequencies. Assume that all transistors have $\beta = 80$ and $V_A = 120 \text{ V}$. Carefully label all control voltages/currents, and give the values of all applicable small-signal parameters.



2. For the amplifier of problem 1, assume that a small-signal analysis has provided signal gains as follows:

$$\frac{v_{b2}}{v_{in}} = 60 \qquad \frac{v_{out}}{v_{b2}} = 250$$

The input and output resistances of the amplifier are estimated as

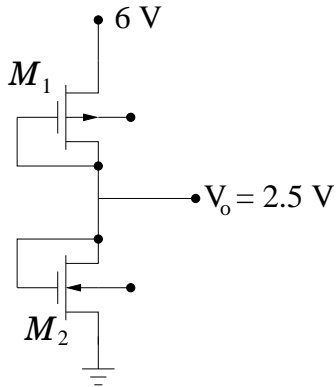
$$R_{in} = 5 \text{ k}\Omega \qquad R_{out} = 40 \text{ k}\Omega$$

(Note that these are not the correct results. Use these numbers to work only this problem!) Find a bound on $|v_{in}|$ which is required so that all assumptions required by the small-signal amplifier model remain valid.

3. The circuit shown below is used to generate a reference voltage of $V_o = 2.5$ V. Neglect channel-length modulation, and assume values of

$$V_{tn} = 1 \text{ V} \quad V_{tp} = 1.3 \text{ V} \quad \mu_n C_{ox} = 75 \mu\text{A}/\text{V}^2 \quad \mu_p C_{ox} = 25 \mu\text{A}/\text{V}^2$$

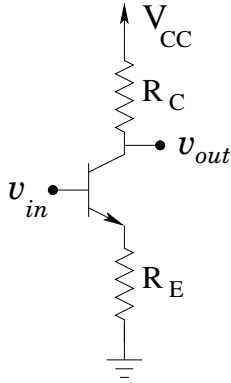
- Identify the type of MOSFET of M_1 and M_2 .
- Label the source and drain terminals of each device.
- Complete the circuit diagram by connecting the body connections to the appropriate locations.
- Assuming that the circuit is to dissipate 2 mW, determine the aspect ratio (W/L) for each of the devices.



4. A common emitter amplifier with emitter degeneration resistor is shown below. The “Single Transistor BJT Amplifiers” handout provided in class incorrectly gave the amplifier output impedance as $R_{out} = R_C \parallel r_o$. This expression does not correctly include the effect of R_E . At least one text lists the output impedance as

$$R_{out} = R_C \parallel r_o (1 + g_m(R_E \parallel r_\pi))$$

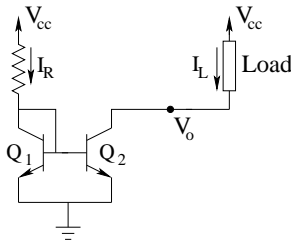
Use a small-signal analysis of the amplifier to show where this expression comes from. Assume that the bias network (not shown) is correctly designed so that the BJT is in the forward active region of operation. List any other assumptions that you need to make.



5. Short Answer:

- (a) The following condition defines the saturation region of operation of an NMOS transistor: (circle all that apply)
- i. $V_{GS} > V_T$ and $V_{DS} < V_{GS} - V_T$
 - ii. $V_{GS} < V_T$ and $V_{DS} < V_{GS} - V_T$
 - iii. $V_{GS} > V_T$ and $V_{DS} > V_{GS} - V_T$
 - iv. Inversion region extends entirely from the source to the drain.
 - v. Inversion region extends from the source toward the drain, but does not reach the drain.
 - vi. Inversion region extends from the drain toward the source, but does not reach the source.
- (b) A PMOS transistor has $k' = 50 \mu\text{A}/\text{V}^2$, $|V_t| = 1 \text{ V}$, and $W/L = 20$. Determine values for V_G and V_S so that (for small v_{DS}) the channel resistance is 600Ω . Give the range of values for v_D for these gate and source voltages that define operation in the triode and saturation regions.

- (c) The circuit below shows one of the current sink configurations that you investigated in lab. Assuming that the transistor is not changed, how will doubling the output current change the output impedance of the current sink? Justify your answer.



For the following, either circle the underlined word to indicate that you think it is correct as written, or cross it out and replace it with the correct word or phrase.

- (d) In an NMOS transistor, the body of the device is a p-type semiconductor, current between the source and drain terminals is supported by the movement of holes.
- (e) Assuming equal terminal voltages, increasing both W and L for a MOSFET by the same factor will increase the current through the device, and will decrease the Early voltage.