ECE 137 A Mid-Term Exam

February 7, 2005

Do not open exam until instructed to.

Closed book: Crib sheet and 1 page personal notes permitted

There are 2 problems on this exam, and you have 50 minutes.

Use any and all reasonable approximations (5% accuracy is fine.), AFTER STATING and approximately Justifying them.

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Problem 1, 70 points

You will be working on the circuit below:

Q1: $|V_{th}| = 1$ Volts. $v_{sat} C_{gs} W = 2$ mA/V, $\lambda = 0$ (P-channel enhancement mode device)
Q2: $\beta = 200$, $V_A = 75$ V
+Vss=+10 volts. -Vdd=-10 volts Rgen=1 MOhm RL=500 Ohm
Rg1=2 MOhm Reac2=50 Ohm Rss1= ?? Reac2= ??
Rc2= ??

$C_E$ and $C_{out}$ are very big and have negligible AC impedance.
Part a, 5 points
DC bias.
Q1 is to be biased with 3 mA source current.
Q2 is to be biased with 10 mA emitter current.
The circuit is to be biased such that the DC collector voltage of Q2 is -3 Volts.

Find: \( R_{ss1} = \) ____________ \( R_{ee2} = \) ____________ \( R_{c2} = \) ____________
Part b, 5 points

DC bias

On the circuit diagram above, label the DC voltages at **ALL nodes** and the DC currents through **ALL resistors**
Part c, 5 points

Find the small signal parameters of Q1 and Q2.

Transistor Q1: \( gm = \underline{\quad} \quad R_{ds} = \underline{\quad} \)

Transistor Q2: \( gm = \underline{\quad} \quad R_{ce} = \underline{\quad} \quad R_{be} = \underline{\quad} \)
Part d, 15 points.

Find the small signal voltage gain \((V_{c2}/V_{b2})\) of Q2 and Q2's small-signal input resistance.

\[ V_{c2}/V_{b2}= \] ________________

\[ R_{in,q2}= \] ________________
Part d, 15 points

Find the small signal voltage gain (V_{s1}/V_{g1}) of Q1 and the amplifier input resistance.

\[
V_{s1}/V_{g1} = \underline{\quad} \\
R_{in,\text{amplifier}} = \underline{\quad}
\]
Part f, 5 points

Find \([V_{\text{out}}/V_{\text{in}}]\), \([V_{\text{in}}/V_{\text{gen}}]\) and \([V_{\text{out}}/V_{\text{gen}}]\)

\([V_{\text{out}}/V_{\text{in}}]\) = ______________________________

\([V_{\text{in}}/V_{\text{gen}}]\) = ______________________________

\([V_{\text{out}}/V_{\text{gen}}]\) = ______________________________
Part g, 20 points

Find the maximum peak-peak output voltage (show all your work, specifically show the limits of the output swing arising from cutoff and saturation of Q1 and Q2)

Cutoff of Q1; Maximum $\Delta V_{out}$ resulting $= \underline{\text{_________________________}}$

Knee voltage of Q1; Maximum $\Delta V_{out}$ resulting $= \underline{\text{_________________________}}$

Cutoff of Q2; Maximum $\Delta V_{out}$ resulting $= \underline{\text{_________________________}}$

Saturation of Q2; Maximum $\Delta V_{out}$ resulting $= \underline{\text{_________________________}}$

Maximum Undistorted Sinusoidal Peak-Peak output $= \underline{\text{_________________________}}$
Problem 2, 30 points

nodal analysis

You will be working on the circuit to the left.

Ignore DC bias analysis. You don’t need it.

The two transistors have transconductance $gm_1$ and $gm_2$ respectively. Their output resistances $R_{ds1}$ and $R_{ds2}$ are both infinity.

Part a, 12 points

Draw a small-signal equivalent circuit of the circuit
Part b. 13 points

Find, by nodal analysis, a small-signal expression for $V_{out}/V_{in}$.

$V_{out}/V_{in} =$ ________________
Part c, 5 points

$g_{m1} = 10 \, \text{mS}$  $g_{m2} = 11 \, \text{mS}$

Give a numerical value for $V_{out}/V_{in}$.

$V_{out}/V_{in} = \underline{\phantom{1/2}}$