ECE 137 A Mid-Term Exam

February 7, 2007

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 your have 50 minutes.

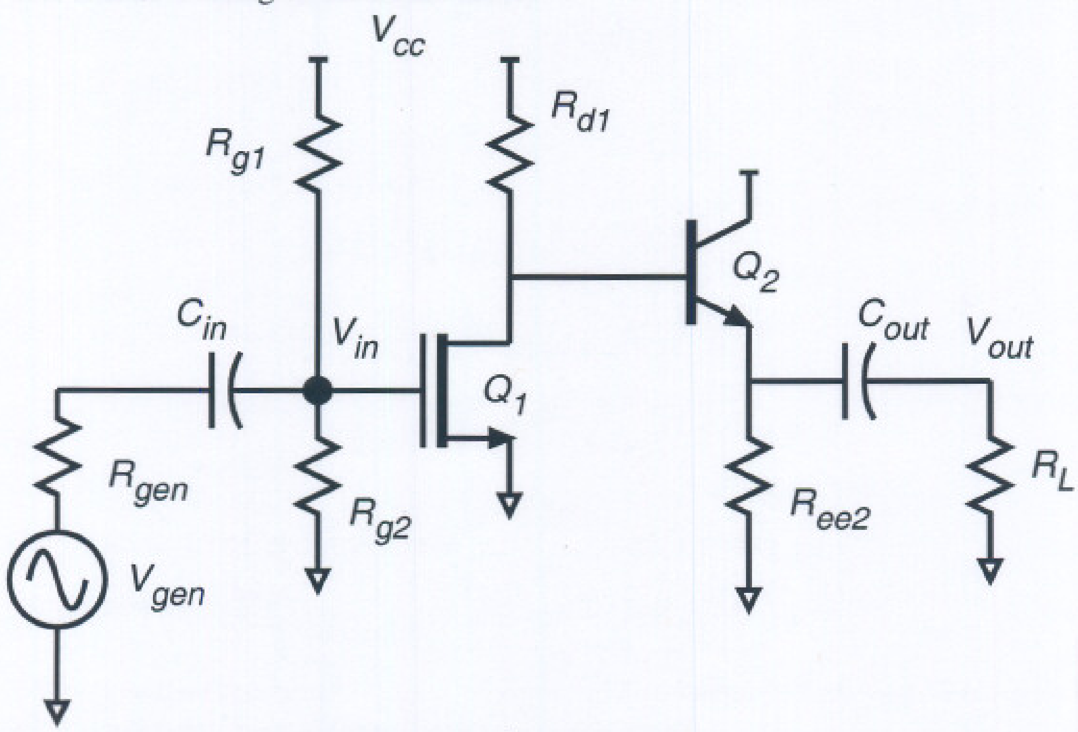
Use any and all reasonable approximations (5% accuracy is fine.) , ***AFTER STATING and approximately Justifying them.***

Name: Solution

Problem	Points Received	Points Possible
1a		7
1b		7
1c		6
1d		15
1e		15
1f		6
1g		14
2a		12
2b		13
2c		5
total		100

Problem 1, 70 points

You will be working on the circuit below:



Q1: V_{th} =0.3 V, $v_{sat}c_{ox}W_g = 10$ mA/V, $\lambda = 0$ 1/Volts

Q2 : β =200, V_A =infinity V

+Vcc= +3.0 volts. Rgen=100 kOhm RL=1 kOhm

Ree2=????? Rd1=??? Rg1=????

Rg2= 500 kOhm

Cin1 and Cout are very big and have negligible AC impedance.

Part a, 7 points

DC bias.

Q1 is to be biased with 1 mA drain current.

Q2 is to be biased with 2 mA emitter current.

The DC emitter voltage of Q2 is +1.3 Volts.

Find: Ree2= $650\,\Omega$ Rd1= $990\,\Omega$ Rg1= $3.25\,M\Omega$

(1) $R_{EE2} = 1.3V / 2mA = 650\,\Omega$

(1) $V_{b2} = 1.3V + \phi = 2V$

(2) $I_{b2} = 2mA/\beta = 2mA/200 = 10\mu A$

$R_{d1} = \dfrac{(3V - V_{E2})}{I_{d1} + I_{B1}} = \dfrac{3V - 2V}{1mA + .01mA} = 990\,\Omega$

(1) $R_{g1} = ?$

$V_{g1} = V_{th} + I_d/g_m = 0.3V + 1mA/10mS$

$= 0.4V$

(2) current ∴ $R_{g1}, R_{g2} = V_{g1}/R_{g2} = 0.4V / 0.5M\Omega$

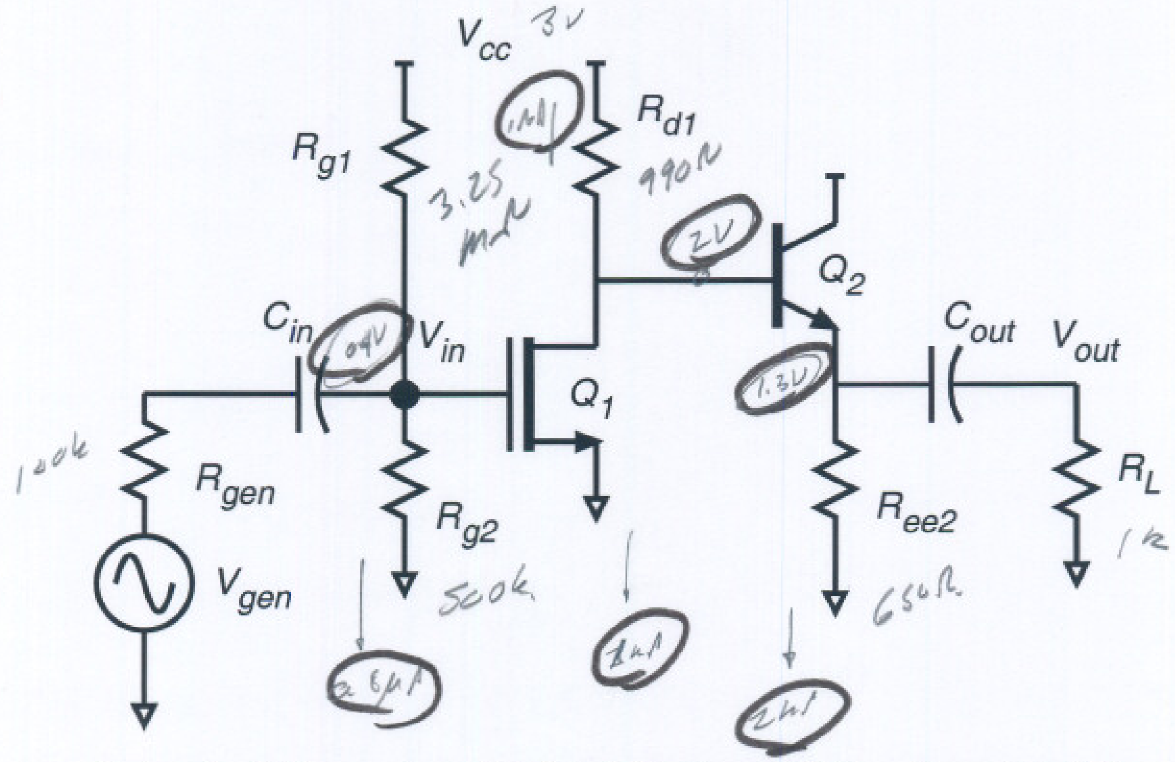
$= \underline{0.8\,\mu A}$

$R_{g1} = \dfrac{3V - 0.4V}{0.8\mu A} = 3.25\,M\Omega$

Q1 $V_{th} = 0.3V$ $k = 10mA/V^2$, $\lambda = 0$
Q2: $\beta = 200$, $V_A = \infty$

Part b, 7 points

DC bias



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

Part c, 6 points

Find the small signal parameters of Q1 and Q2.

Transistor Q1: gm= 10mS Rds= ∞

Transistor Q2: gm= 76.9mS Rce= ∞ Rbe= 2.6 kΩ.

Q1: $g_m = \mu_n C_{ox} \frac{W}{L} = 10mS$] 2

$R_{ds} = 1/\lambda I_d = \infty$] 1

Q2: $g_m = 1/r_E = I_E/V_T = 1/13\Omega = 76.9mS$] 1

$R_{CE} = \frac{V_A + V_{CE}}{I_C} = \infty$] 1

$R_{BE} = \beta r_E = 200 \cdot 13\Omega = 2.6k\Omega$] 1

Part d, 15 points.

Find the small signal voltage gain (Ve2/Vb2) of Q2 and Q2's small-signal input resistance.

Ve2/Vb2= 0.968

Rin,q2= 81.4 kΩ

Q2: CF

5 $R_{Leq} = R_{EE2} \parallel R_L = 650\Omega \parallel 1k\Omega$

$= 394\Omega.$

5 $A_v = \frac{R_{Leq}}{R_{Leq} + r_e} = \frac{394}{394 + 13} = 0.968$

5 $R_{i2} = \beta(R_{Leq} + r_e) = 200(394\Omega + 13\Omega)$

$= 81.4\ k\Omega$

Part e, 15 points

Find the small signal voltage gain (Vd1/Vg1) of Q1 and the *** amplifier *** input resistance.

Vd1/Vg1= -9.78

Rin,amplifier = $433\ k\Omega$

5

Q1 : $R_{eq} = R_{o1} \| R_{i2}$

$= 990\Omega \| 81k\Omega$

$= 978\Omega$

5

$A_v = -g_m R_{eq} = -10mS \cdot 978\Omega$

$= -9.78$

5.

$R_{i\,g1} = \infty$

$R_{i\,amp} = R_{g1} \| R_{g2} = 500k\Omega \| 3.28M\Omega$

$= 433\ k\Omega$

Part f, 6 points

Find (Vout/Vin), (Vin/Vgen) and (Vout/Vgen)

(Vout/Vin) = -9.46

(Vin/Vgen) = 0.81

(Vout/Vgen) = -7.69

2 $v_o/v_i = A_{v1} \cdot A_{v2} = 0.968 \cdot (-9.78)$

$= -9.46$

2 $v_i/v_{gen} = \dfrac{R_{iA}}{R_{iA} + R_{gen}} = \dfrac{437k\Omega}{437k\Omega + 100k\Omega} = 0.81$

2 $v_o/v_g = \dfrac{v_o}{v_i} \cdot \dfrac{v_i}{v_g} = (-9.46)(0.81) = -7.69$

Part g, 14 points

Now you must find the maximum signal swings. Find the output voltage due to saturation and cutoff in Q2. ***To save time, we are going to ignore the saturation and the keen voltage cutoff of Q1, even though it might be important. Give the sign (+ or -) in your answers below.***

Cutoff of Q2; Maximum ΔVout resulting = - 788 mV

Saturation of Q2; Maximum ΔVout resulting = + 500 mV.

Q2 cutoff

3 [I_{CQ} = 2 mA
$\Delta I_{C max}$ = 2 mA decrease
R_{eq} = 394 Ω

4 [ΔV_{out} = 394 Ω · 2 mA = 788 mV negative

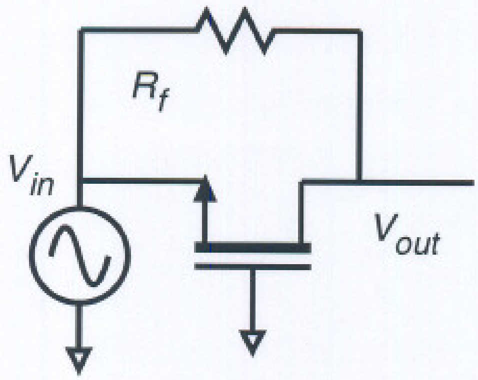
Q2 sat

2 [$V_{CE, BIAS}$ = 3V - 1.3V = 1.7V

1 [$V_{CE sat}$ ≅ 1/2 V

4 [ΔV_{out} = 1.7V - 0.5V = 1.2V positive

Problem 2, 30 points
nodal analysis



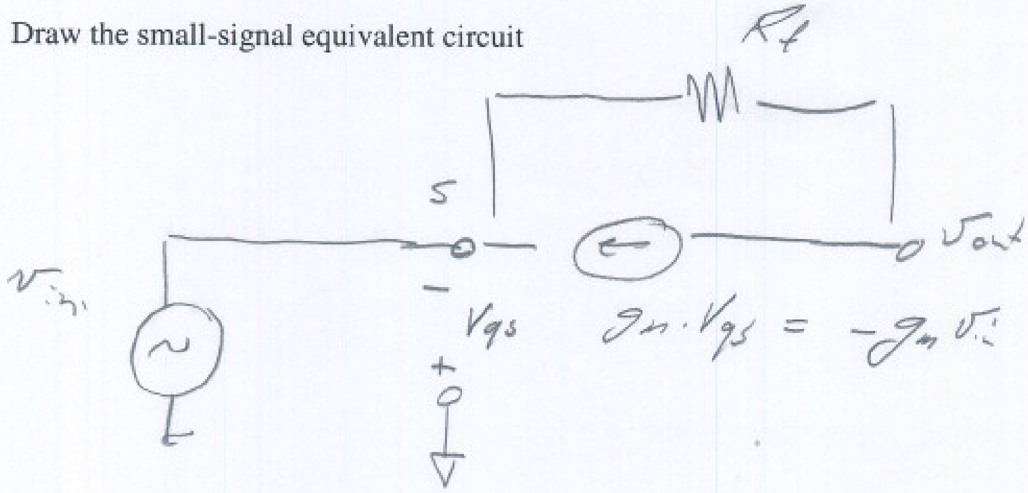
You will be working on the circuit to the left.

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

The transistor has transconductance gm. Its drain-source resistance Rds is infinity (so you don't need to draw it!)

Part a, 12 points

Draw the small-signal equivalent circuit



Hard to give partial credit.

Part b,13 points

Find, by nodal analysis, a small-signal expression for Vout/Vin.

Vout/Vin= ___________________

$\Sigma I = 0$ @ v_{out}:

6 $-g_m \cdot v_{in} + (v_o - v_{in})/R_f = 0$

$v_o/R_f = v_{in}(g_m + 1/R_f)$

7 $\boxed{\dfrac{v_o}{v_{in}} = (1 + g_m R_f)}$

Part c, 5 points

gm= 10 mS Rf= 2~~0~~000 Ohms
Give a numerical value for Vout/Vin.

Vout/Vin= +21.

$$\frac{v_o}{v_i} = 1 + g_m R_f = 1 + 10mS \cdot 2000\,\Omega$$

$$= 1 + 20$$

$$= 21$$

5