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.

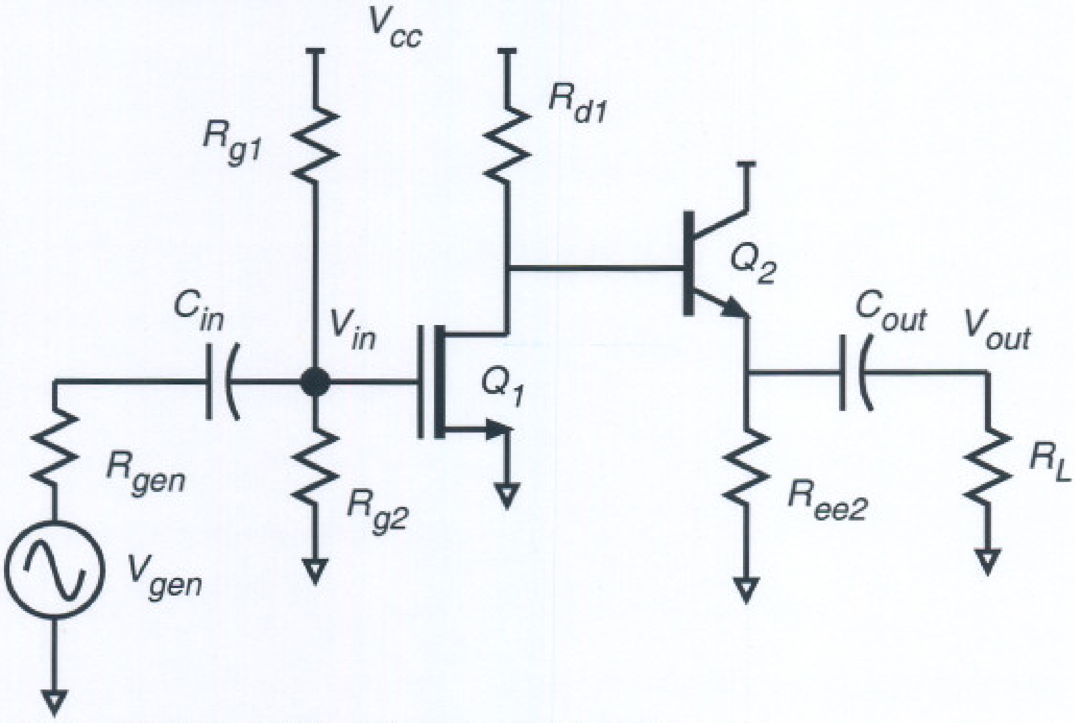
Use any and all reasonable approximations   (5% accuracy is fine.) , ***AFTER STATING and approximately Justifying them.***

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, λ = 0.1/Volts

Q2 : β =100, V_A =infinity V

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

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

Rg2= 400 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 1 mA emitter current.

The DC emitter voltage of Q2 is +2.0 Volts.

Find: Ree2= $2k\Omega$ Rd1= 297Ω Rg1= $2.6M\Omega$

1pt $R_{EE2} = 2V / 1mA = 2k\Omega$

1pt $V_{B2} = 2V + \phi = 2.7V$

2pt $R_{d1} = (V_{CC} - V_{B2}) / (I_{d1} + I_{B2})$

$I_{b2} = 1mA/\beta = 10\mu A$

$= (3V - 2.7V) / (1mA + 10\mu A) = 297\Omega$

$R_{g1} = ?$

1pt Well

$V_{gs1} = V_{th} + I_d / g_m = 0.3V + 1mA/(10mA/V)$

$= 0.4V.$

2pt. current in R_{g1}, R_{g2}: $I = 0.4V/R_{g2} = 1\mu A$

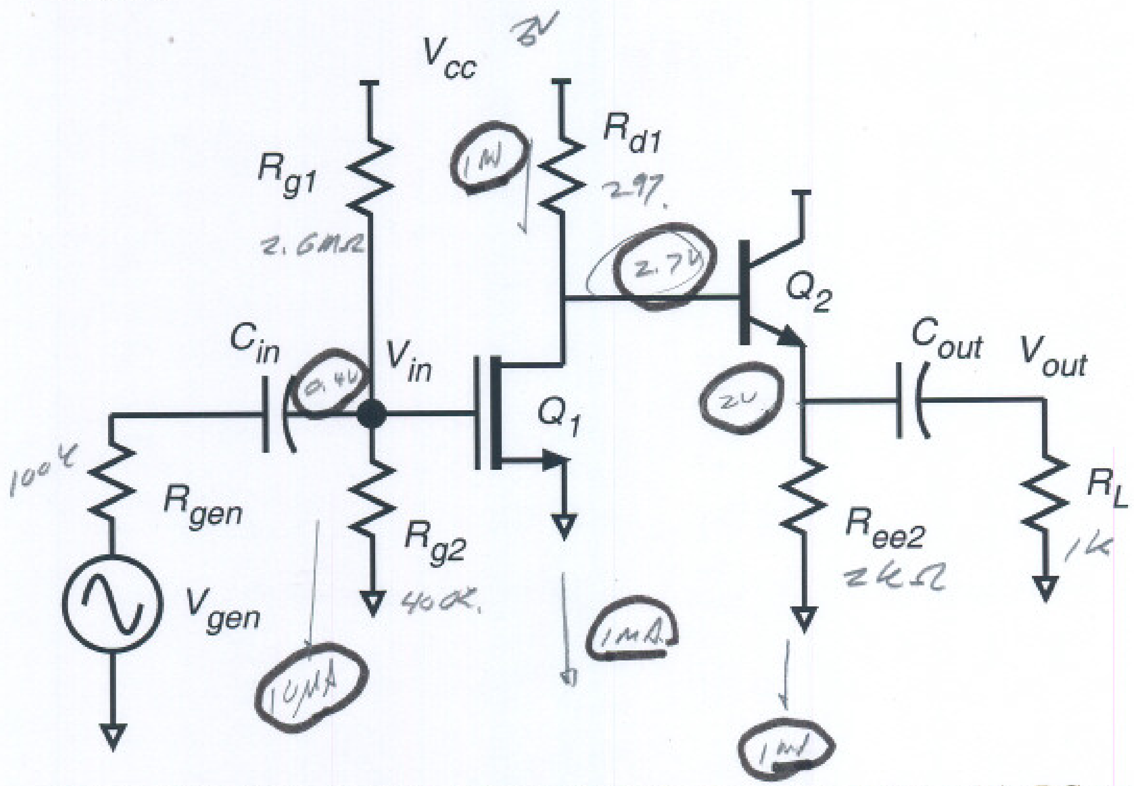
$R_{g2} = (3V - 0.4V)/1\mu A = 2.6V / 1\mu A = 2.6M\Omega$

$V_{th} = 0.3V, \; g_m = 10mA/V$
$\lambda = 0$

Part b, 7 points

$\beta = 100, \; V_A = \infty$

DC bias



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

$Q2 \; g_m = \frac{1}{r_e} = \frac{1}{26\Omega}$

$Q1: \; g_m = 10mS$

Part c, 6 points

Find the small signal parameters of Q1 and Q2.

Transistor Q1: gm= 10 mS Rds= ∞

Transistor Q2: gm= 38.5mS Rce= ∞ Rbe= 2.6kΩ

Q2: $g_m = \frac{1}{r_e} = \frac{I_E}{V_t} = \frac{1mA}{26mV} = 38.5mS$] 2

$R_{BE} = \beta r_e = 100 \cdot 26\Omega = 2.6k\Omega$] 1

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

Q1: $g_m = 2\sqrt{\mu_n C_{ox} W/L \, I_D} = 10mS$] 1

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

Part d, 15 points.

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

Ve2/Vb2= 0.962

Rin,q2= 69.3 kΩ

Q2: EF

5 [$R_{Leq} = 2k \parallel 1k = 667\Omega$

$r_E = 26\Omega$

5 [$A_v = \frac{R_{Leq}}{R_{Leq} + r_E} = \frac{667}{667+26} = 0.962$

5 [$R_{i2} = \beta(r_E + R_{Leq}) = 100(26+667) = 69.3k\Omega$

Part e, 15 points

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

Vd1/Vg1= -2.96

Rin,amplifier = $347\ k\Omega$

Q1: CS:

5 $R_{eq} = R_{d1} \,//\, R_{i2} = 297 \,//\, 69.7k\Omega$

$\cong 298\Omega$

5 $A_v = -g_m R_{eq} = -10mS \cdot 295\Omega = -2.96$

$R_{iQ1} = \infty$

5 $R_{in} = R_{g1} \,//\, R_{g2} = 2.6M\Omega \,//\, 400k\Omega$

$= 347\ k\Omega$

Part f, 6 points

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

(Vout/Vin) = -2.85

(Vin/Vgen) = 0.776

(Vout/Vgen) = -2.21

2 [$v_o/v_i = A_{v1} A_{v2} = 0.962 \cdot (-2.96) = -2.85$

2 [$v_i/v_{ga} = \dfrac{R_{in}}{R_i + R_{ga}} = \dfrac{347k\Omega}{347k\Omega + 1004\Omega} = 0.776$

2 [$v_o/v_{ga} = \dfrac{v_o}{v_i} \cdot \dfrac{v_i}{v_{ga}} = (-2.85)\cdot(0.776) = -2.21$

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 = - 667 mV

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

Q2 cutoff

BIAS: $I_{CQ1,Q} = 1mA$

min $I_{C1} = 0$ mA

3 [$\Delta I_C = 1mA$ max (decrease)

4 [$\Delta V_{out} = 1mA \cdot R_{eq} = 1mA \cdot 667\Omega$

$= 667$ mV negative

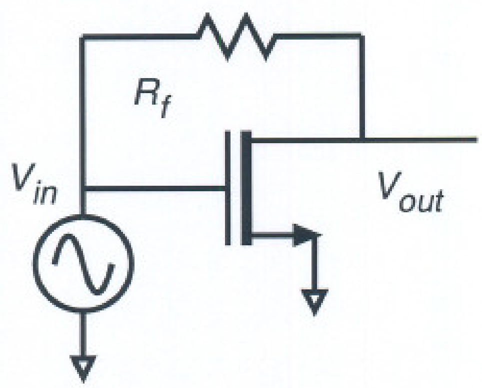
Q2 Saturation

2 [Bias. $V_{CE} = 1V$

1 [Sat $V_{CE} = V_{CEsat} = 1/2\,V$

4 [$\Delta V_{CE} = \Delta V_{out} = 1/2\,V$ positive

Problem 2, 30 points
nodal analysis



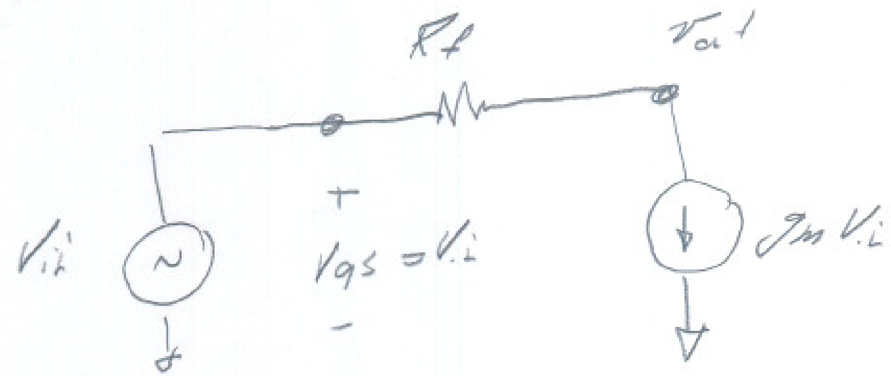
You will be working on the circuit to the left.

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= ____________________

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

6 $$\frac{v_{out} - v_{in}}{R_f} + g_m v_{in} = 0$$

$$v_{out}(1/R_f) = v_{in}[1/R_f - g_m]$$

7 $$\boxed{\frac{v_{out}}{v_{in}} = 1 - g_m R_f}$$

Part c, 5 points

gm= 10 mS   Rf= 1000 Ohms
Give a numerical value for Vout/Vin.

Vout/Vin= -9

5

$$\frac{v_{out}}{v_i} = 1 - g_m R_f$$

$$= 1 - 10\,mS \cdot 1000\,\Omega$$

$$= -9$$