ECE 137 A Mid-Term Exam

Thursday February 9, 2017

Do not open exam until instructed to.

Closed book: Crib sheet and 1 page personal notes permitted

There are 3 problems on this exam, and you have 75 minutes.

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

Name: _______________________

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Problem 1, 30 points

You will be working on the circuit below:

The transistor has
\( L_g = 22 \text{nm} \), \( \mu = 180 \text{ cm}^2/\text{V} \cdot \text{s} \), \( e_{r,ox} = 3.8 \), \( T_{ox} = 1 \text{nm} \), \( v_{sat} = 10^7 \text{cm/s} \), \( V_{th} = 0.3 \text{V} \), \( 1/\lambda = 10 \text{V} \),
From which we calculate:
\( c_{ox} v_{sat} = 3.36 \text{ mA/V/}\mu \text{A} \), \( \mu c_{ox} / 2L_g = 13.8 \text{ mA/V}^2/\mu \text{A} \), \( \Delta V = L_g v_{th} / \mu = 0.122 \text{V} \),

The supplies are +1V and -1 V
You are to bias the transistor at 1.5mA drain current, and with -0.40 V DC source voltage.
\( R_{gg} = 10 \text{ M}\Omega \), \( R_{gen} = 100 \text{ k}\Omega \), \( R_L = 1 \text{k}\Omega \)

\( C_{out} \) are very large (AC short-circuit)
Part a, 10 points
DC bias.
Use this approximation: Ignore (i.e. set to zero) the FET $\lambda$ parameter in the DC bias calculation.
Find the following:
FET gate width $W_g =$ __________ $\quad R_{ss} =$ ______________
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

Using the actual (nonzero) FET parameter, find the FET small signal parameters

\( g_m = \_\_\_\_\_ \quad R_{ds} = \_\_\_\_\_ \)
Part d, 10 points.

Find the small signal voltage gain $\frac{V_{out}}{V_{in}}$ and the amplifier small-signal input resistance.

$\frac{V_{out}}{V_{in}} = $

$R_{in, amplifier} = $
Problem 2, 50 points

You will be working on the circuit below:

Q1: $\beta = 100$, $V_A = \infty$ V
The supplies are +15V and -15 V.
You will bias the transistor with 2mA collector current.
The DC collector bias voltage is 0V.
$R_L$ is 1000 $\Omega$, $R_{gen}$ is 100 $\Omega$, $R_b$ is 1 k$\Omega$, $R_{EAC}$ is 25 $\Omega$
$C_{EE}$ is very large. Assume that it is an AC short-circuit.
Part a, 10 points
DC bias.
Find the following:

\[ R_{EE} = \quad R_c = \quad R_{EDC} = \]
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.

\( g_m = \_ \_ \_ \_ \_ \_ \) \( R_{ce} = \_ \_ \_ \_ \_ \_ \) \( R_{be} = \_ \_ \_ \_ \_ \_ \)
Part d, 10 points.

Find the small signal voltage gain \( \frac{V_{out}}{V_{in}} \) of Q1 and the amplifier small-signal input resistance.

\[ \frac{V_{out}}{V_{in}} = \]  

\[ R_{in, amp} = \]
Part e, 5 points

Find \((\text{Vin}/\text{Vgen})\) and \((\text{Vout}/\text{Vgen})\)

\((\text{Vin}/\text{Vgen}) = \) ______________________________

\((\text{Vout}/\text{Vgen}) = \) ______________________________
Part f, 15 points

Now you must find the maximum signal swings. Find the output voltage due to saturation and cutoff in Q2. *Give the sign (+ or -) in your answers below.*

Cutoff of Q1; Maximum $\Delta V_{out}$ resulting = ______________________

Saturation of Q1; Maximum $\Delta V_{out}$ resulting = ______________________
Problem 3, 20 points

You will be working on the circuit to the left.

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

The transistor has transconductance $g_m$.

The drain-source resistance $R_{ds}$ of the transistor is infinity (so you don’t need to draw it!)

Part a, 8 points

Draw the small-signal equivalent circuit
Part b, 8 points

Find, by nodal analysis, a small-signal expression for Rin.

Rin= ________________
Part c, 4 points

gm = 1 mS, \( R_L = 3 \text{kOhm} \), \( R_f = 2 \text{kOhm} \).

Give a numerical value for Rin.

Rin = __________________