**Mid-Term Exam, ECE-137B**
Tuesday, April 28, 2015


**Closed-Book Exam**

There are 2 problems on this exam , and you have 75 minutes.
*1) show all work. Full credit will not be given for correct answers if supporting work is not shown.*
2) please write answers in provided blanks
3) Don't Panic !
4) 137a, 137b crib sheets, and 2 pages personal sheets permitted.
Use any, all reasonable approximations. 5% accuracy is fine if the method is correct.
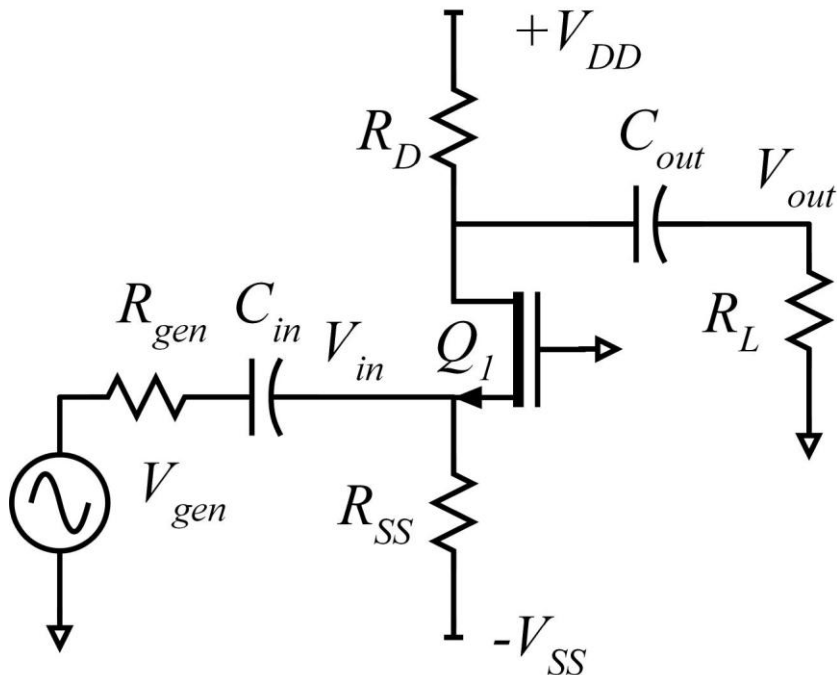
# Do not turn over the cover page until requested to do so.


Name: _____

| Time function | LaPlace Transform |
|---|---|
| $\delta(t)$ | 1 |
| $U(t)$ | $1/s$ |
| $e^{-\alpha t}U(t)$ | $\dfrac{1}{s+\alpha}$ |
| $e^{-\alpha t}\cos(\omega_d t)U(t)$ | $\dfrac{s+\alpha}{(s+\alpha)^2+\omega_d^2}$ |
| $e^{-\alpha t}\sin(\omega_d t)U(t)$ | $\dfrac{\omega_d}{(s+\alpha)^2+\omega_d^2}$ |

| Problem | Points Received | Points Possible |
|---|---|---|
| 1a | | 6 |
| 1b | | 8 |
| 1c | | 8 |
| 1d | | 14 |
| 1e | | 14 |
| 1f | | 10 |
| 2a | | 10 |
| 2b | | 10 |
| 2c | | 10 |
| 2d | | 10 |
| total | | 100 |

a

**Problem 1, 60 points**



Q1 has 1.0 nm oxide thickness, $\varepsilon_r$ =3.8, 22 nm gate length, and a 0.2 V threshold.
Mobility is 400 cm^2/(V-s), saturation drift velocity is 1E7 cm/s, $\lambda = 0\,\text{Volts}^{-1}$,
$C_{gs} = \varepsilon_r \varepsilon_{ox} L_g W_g / T_{ox} + (0.5\text{fF}/\mu\text{m}) \cdot W_g$ and $C_{gd} = (0.5\text{fF}/\mu\text{m}) \cdot W_g$.

Hints:

$\varepsilon_r \varepsilon_{ox} / T_{ox} = 3.36 \cdot 10^{-2}\,\text{F/m}^2$, $(\mu c_{ox} W_g / 2L_g) = (3.06 \cdot 10^{-2}\,\text{A/V}^2) \cdot (W_g / 1\mu\text{m})$

$(c_{ox} v_{sat} W_g) = (3.36 \cdot 10^{-3}\,\text{A/V}^1) \cdot (W_g / 1\mu\text{m})$, $(v_{sat} L_g / \mu) = 55\text{mV}$.

The power supplies are +2V and -2V. The drain currents of Q1 is 2 mA.
$V_{gs}$ of Q1 is 0.30 V. The drain of Q1 is at +1.0V.

$R_{gen}$=50Ohm. $R_L = 3 \cdot R_D$

$C_{in} = 1\,\text{nF}$, $C_{out} = 2\,\text{nF}$
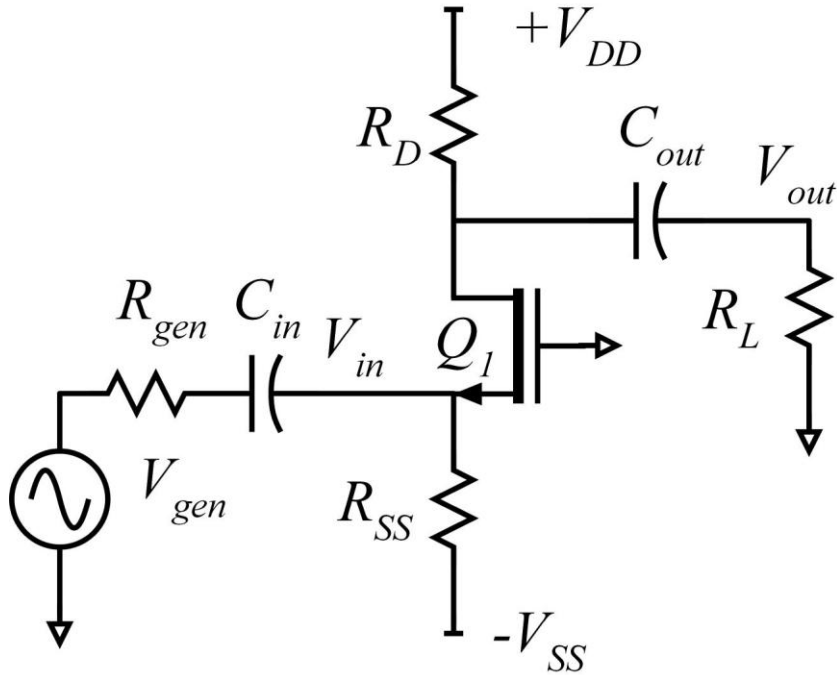
Part a, 6 points
Find the following:

$R_{ss} =$_____     $R_D =$_____

$W_g =$_____     $R_L =$_____

Draw all DC node voltages on the circuit diagram below.

a

Part b,  8  points
*small-signal parameters*
Find the following

$C_{gs} = $ _____     $C_{gd} = $ _____

$g_m = $ _____     $f_\tau = $ _____

a

Part c: 8 points
*Mid Band Analysis:*
Find the following:

$R_{in, Amplifier} = $_____     $R_{L,eq} = $_____

$V_{out} / V_{in} = $_____     $V_{in} / V_{gen} = $_____

a

a

Part d: 14  points
*High-Frequency Analysis:*
Find the frequencies, in Hz, of the two poles limiting the high-frequency response of the amplifier. Show your analysis (do not simply state that the input pole of a common-gate amplifier is approximately at $f_\tau$ )

$f_{p1,HF} =$_____     $f_{p2,HF} =$_____.
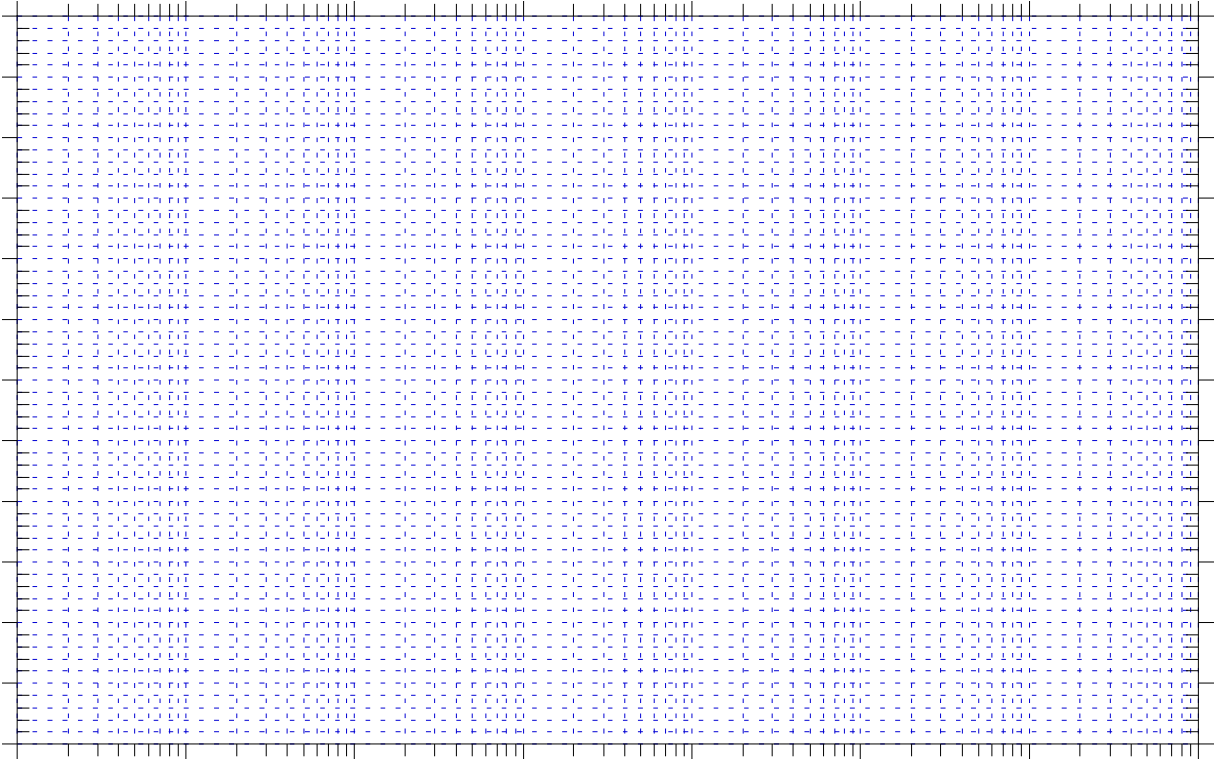
a

a

Part e: 14 points

*Low-Frequency Analysis:*

Find the frequencies, in Hz, of the two poles limiting the low-frequency response of the amplifier. Show your analysis.

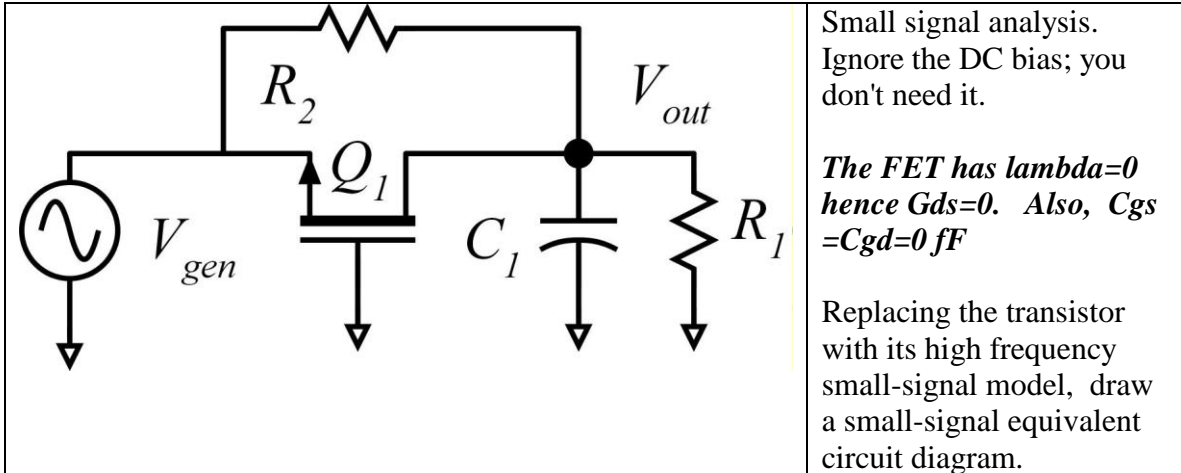$f_{p1,LF} =$_____     $f_{p2,LF} =$_____.

a

a

Part f: 10 points

Draw a clean asymptotic Bode Magnitude plot of $V_{out}/V_{gen}$ as a function of frequency in Hz. Be sure to label and dimension the axes clearly, label pole and zero frequencies and gain slopes.  Be sure to use the semi-log paper correctly

a

## Problem 2, 40 points

Part a 10 points



Small signal analysis. Ignore the DC bias; you don't need it.

***The FET has lambda=0 hence Gds=0. Also, Cgs =Cgd=0 fF***

Replacing the transistor with its high frequency small-signal model, draw a small-signal equivalent circuit diagram.

a

Part b, 10 points

*USING NODAL ANALYSIS,* compute Vout(s)/Vgen(s) in ratio-of-polynomials form:

$$\frac{V_{out}(s)}{V_{gen}(s)} = \frac{V_{out}}{V_{gen}}\bigg|_{mid-band} \times (s\tau)^m \times \frac{1+b_1 s+b_2 s^2+...}{1+a_1 s+a_2 s^2+...} = \underline{\hspace{5cm}}$$

***here m, an integer, can be positive or negative or zero***

a

Part c, 10 points
$g_m = 10$ mS.   $R_1 = 1$ kOhm, $R_2 = 3$ kOhm, $C_1 = 1$pF

Find the frequencies of any zeros (there may be zero, one or two present ) in the transfer function:
$f_{z1} = $_____, $f_{z2} = $_____, ....

There may be either 1 or 2 poles of the transfer function.

If the poles are real, give the 1 or 2 pole frequencies in Hz:
$f_{p1} = $_____ , $f_{p2} = $_____

If there are 2 poles, and they are complex, give $f_n = \omega_n / 2\pi$ and the damping factor $\zeta$ :
$f_n = \omega_n / 2\pi = $_____, $\zeta = $_____

16

a

Part d, 10 points

If Vin(t) is a 100mV step-function, find and plot Vout(t).   Be sure to label and dimension the axes clearly, and to clearly label key features of the time waveform.

a

a