ECE137B Final Exam

There are 5 problems on this exam and you have 3 hours
There are pages 1-19 in the exam: please make sure all are there.

Do not open this exam until told to do so
Show all work:
Credit will not be given for correct answers if supporting work is not shown.
Class Crib sheets and 2 pages (front and back→ 4 surfaces) of your own notes permitted.
Don't panic.

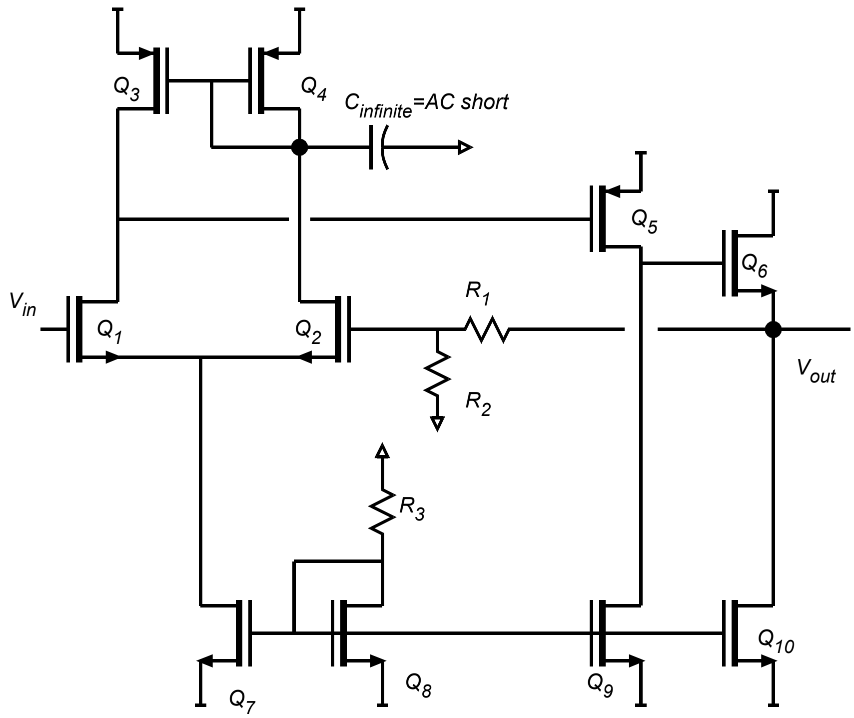
Time function	LaPlace Transform
$\delta(t)$	1
U(t)	1/s
$e^{-\alpha t}\cdot U(t)$	$\frac{1}{s+\alpha}$ or $\frac{1/\alpha}{1+s/\alpha}$
$e^{-\alpha t}\cos(\omega_d t)\cdot U(t)$	$\frac{s+\alpha}{(s+\alpha)^2+\omega_d^2}$
$e^{-\alpha t}\sin(\omega_d t)\cdot U(t)$	$\frac{\omega_d}{(s+\alpha)^2+\omega_d^2}$

Name: ___________________________________

Problem	points	possible	Problem	points	possible
1a		3	2		10
1b		8	3a		7
1c		5	3b		13
1d		12	4a		10
1e		7	4b		5
1f		5	5a		5
			5b		5
			5c		5

Problem 1, 40 points
method of first-order and second-order time constants, some feedback theory

The circuit below is an op-amp



<u>Part a, 3 points</u>
DC analysis

Find all transistor DC emitter currents, find all node voltages. Make these on the circuit diagrm.

λ=1/50 V for Q3 and Q9.	λ=0 for all other transistors
$\lvert V_{th}\rvert$=0.3 V for all transistors, g_m=2 mS for all transistors.	
Q5 : C_{gs} = 5 fF, C_{gd}=0.5 fF.	Q6 : C_{gs} = 0 fF, C_{gd}=0.5 fF.
All other transistors: C_{gs} = C_{gd}=0 fF.	
The DC component of Vin is zero volts	
The supplies are +/- 2 Volts.	
Pick R3 so that the DC drain current of Q8 is 0.5 mA	
R1=1 MegOhm R2=100 kOhm	

b

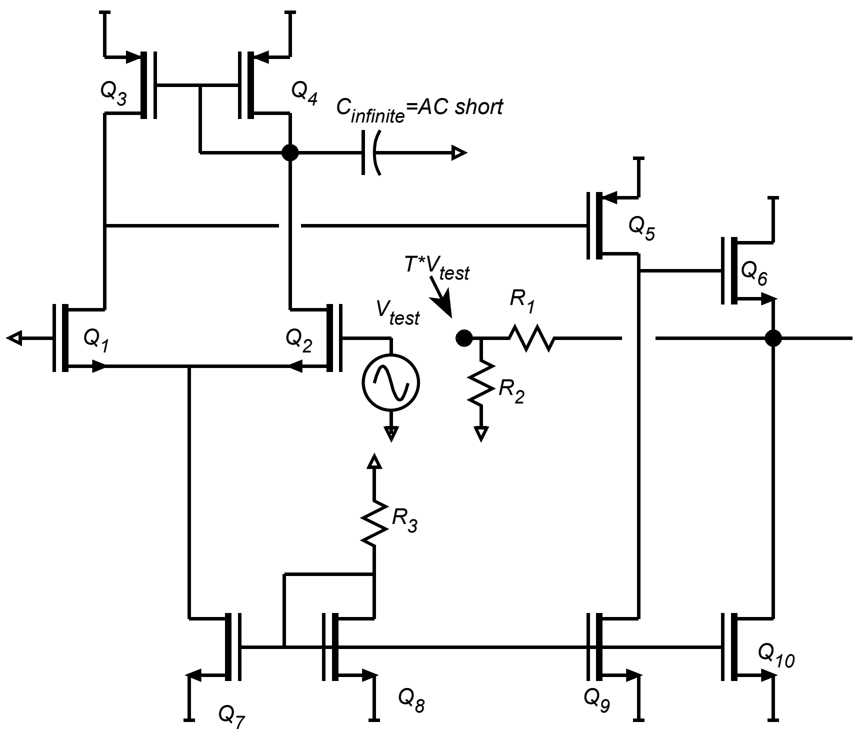
Part b, 8 points

mid-band analysis

Find the low-frequency loop transmission:

T(f=0 Hz) =________________________

To do this, you need to cut the feedback loop, thus, to find the loop transmission



b

Part c, 5 points
feedback theory

At low frequencies, what is the closed-loop gain V_{out} / V_{in} ?

Treat $C_{infinite}$ as an AC short (not a capacitor) in the MOTC analysis.

$V_{out} / V_{in} =$ __________________________

b

Part d, 12 points

motc

Using MOTC, you will find the frequency, in Hz (not rad/sec), of the ***two*** major poles in the transfer function.

capacitor 1: Cgs of Q5	capacitor 2: Cgd of Q5	capacitor 3: Cgd of Q6
$R_{11}^{0} =$	$R_{22}^{0} =$	$R_{33}^{0} =$
$R_{22}^{1} =$	$R_{33}^{1} =$	$R_{33}^{2} =$
$f_{p1} =$	$f_{p2} =$	

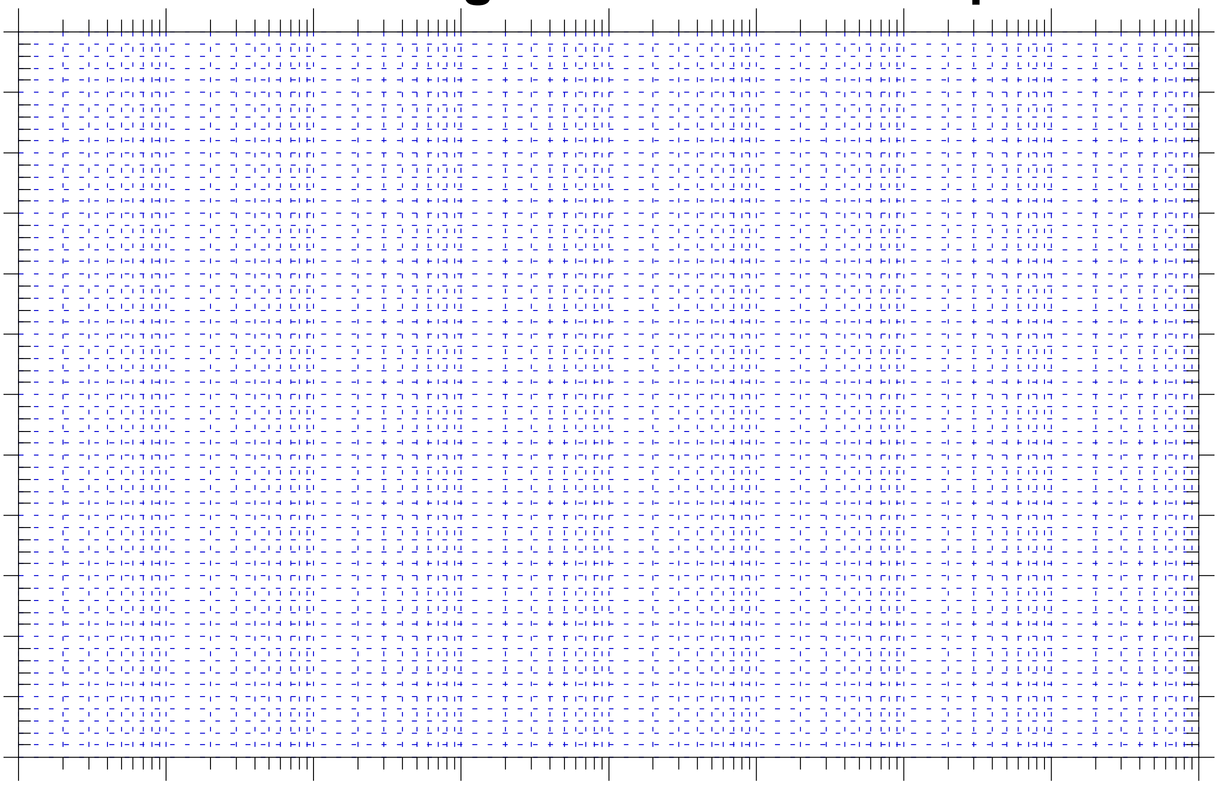
Remember to treat $C_{infinite}$ as an AC short (not a capacitor) in the MOTC analysis.

Part e, 7 points

Make accurate asymptotic plots of T. Find the phase margin and the loop bandwidth.

Phase margin =______________ Loop bandwidth =_______________

Draw the magnitude of T on this plot



Frequency, Hz

b

Part f, 5 points

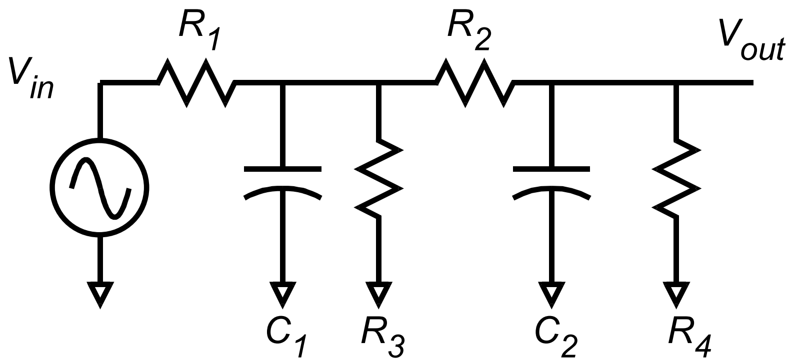
What is the gain and bandwidth of the closed-loop amplifier ?

low frequency Vout/Vgen=_____________ bandwidth of Vout/Vgen=___________

b

Problem 2: 10 points

method of time constants analysis

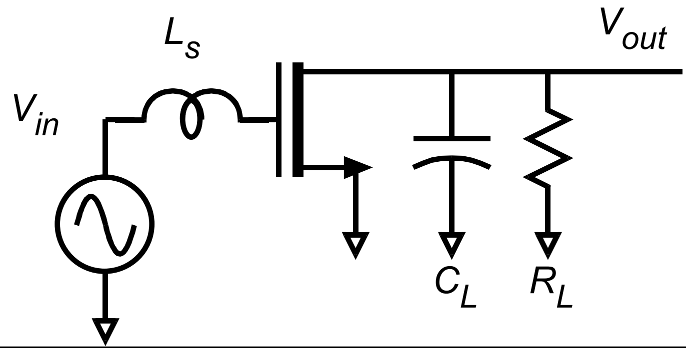


R1=1 KOhm, R2=2kOhm, R3=3kOhm, R4=4 kOhm, C1= 1 fF C2=2 fF
Using MOTC, find the coefficients a1 and a2 of transfer function Vout(s)/Vgen(s), given a tranfer function in the standard form $\frac{V_{out}(s)}{V_{gen}(s)} = \left.\frac{V_{out}}{V_{gen}}\right|_{DC} \frac{1+b_1 s + b_2 s^2 + \ldots}{1+a_1 s + a_2 s^2 + \ldots}$

$R_{11}^0 =$____________________ $R_{22}^0 =$____________________ $R_{22}^1 =$____________________

$\left.\frac{V_{out}}{V_{gen}}\right|_{DC} =$____________________ $a_1 =$____________________ $a_2 =$____________________

Problem 3: 20 points
Nodal analysis and transistor circuit models



Ignore DC bias; you don't need it.
C_{gs} = 0 fF C_{gd} =100 fF, g_m = 10 mS,
$R_{ds} = \infty$, so you don’t need to draw it.
R_L =10 kOhm, C_L =100 fF, L_S =100 nH

<u>Part a, 7 points</u>
Draw an accurate small-signal equivalent circuit model of the circuit above.

Part b, 13 points

Using NODAL ANALYSIS, find the transfer function Vout(s)/Vin(s)

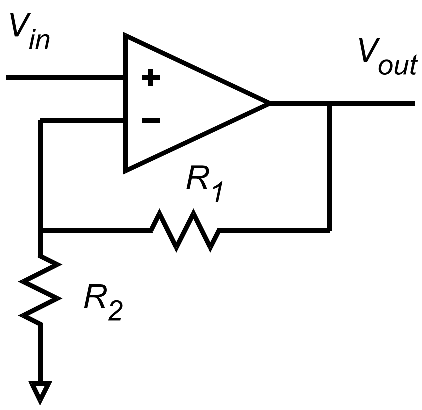
The answer must be in standard form $\frac{V_{out}(s)}{V_{in}(s)} = \left.\frac{V_{out}}{V_{in}}\right|_{midband} \times \frac{1 + b_1 s + b_2 s^2 + \ldots}{1 + a_1 s + a_2 s^2 + \ldots}$,

Vout(s)/Vin(s)=________________________________

b

Problem 4, 15 points
negative feedback

part a, 10 points



The amplifier has a differential gain of 10^5. R1=99 kOhm, R2=1 kOhm. The op-amp has infinite differential input impedance and zero differential output impedance.

The differential amplifier has 2 poles in its open-loop transfer function.

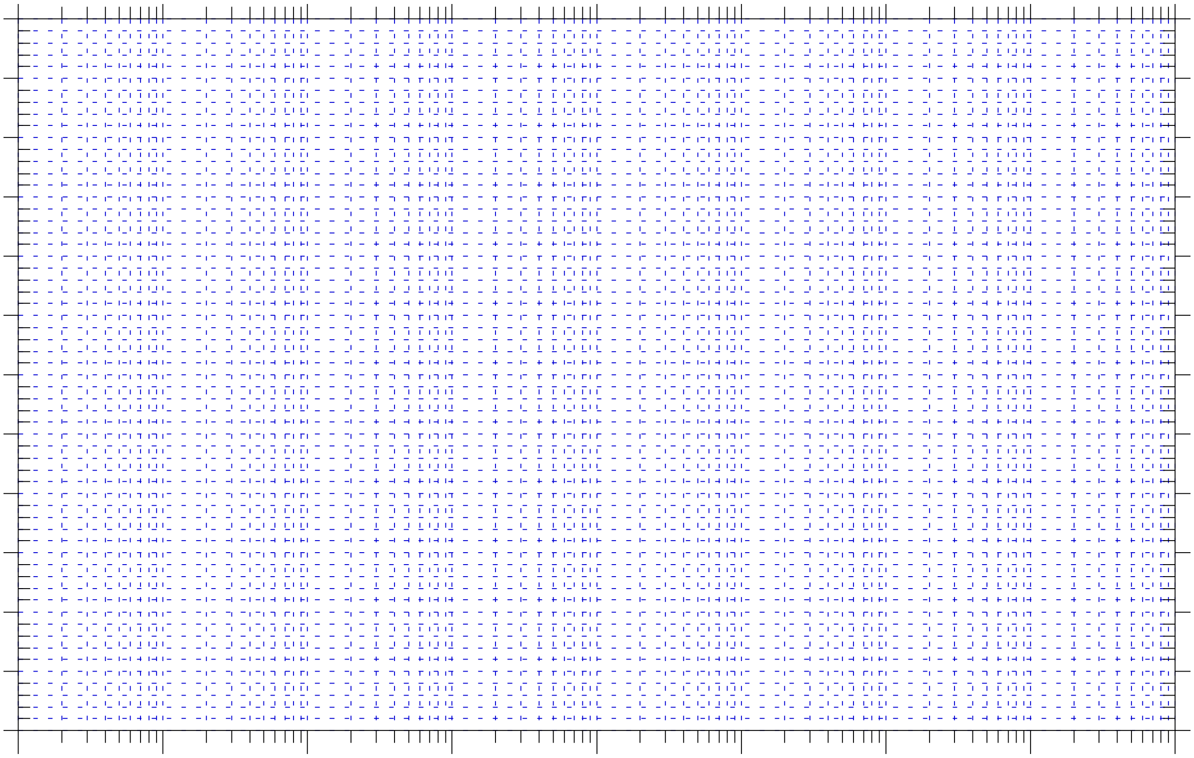
One, the dominant pole, is at a low frequency, and can be adjusted by appropriately adjusting a compensation capacitor internal to the op-amp. The second one is at 500 MHz

To repeat:
f_{p1} = dominant pole frequency= you must find the required value
f_{p2} = second pole frequency= 500 MHz

PICK f_{p1} ***so that the phase margin is 168.7 degrees.***

Using the Bode plot on the next page, plot the open-loop gain (A_d or A_{ol}), the inverse of the feedback factor ($1/\beta$) , closed loop gain (A_{CL}). ***Label all axes, slopes, pole/zero frequencies, etc***. Determine the following:

f_{p1}=____________________ Loop bandwidth=________________
Vout/Vgen at DC=_____________________



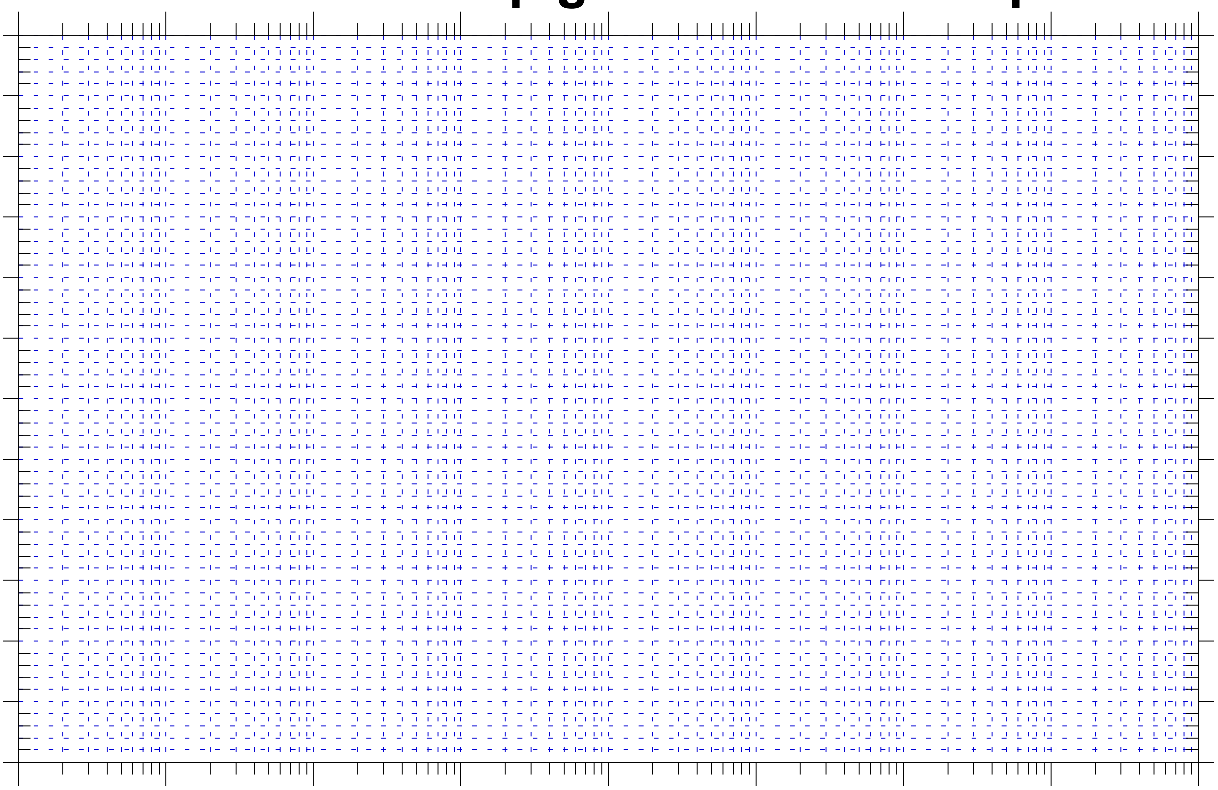
Frequency, Hz

b

part b, 5 points
What is the gain and bandwidth of the closed-loop amplifier ?

low frequency Vout/Vgen=_____________ bandwidth of Vout/Vgen=___________
Draw a plot of the closed loop gain, labeling all axes, slopes, pole/zero frequencies, etc.

draw closed loop gain on this bode plot



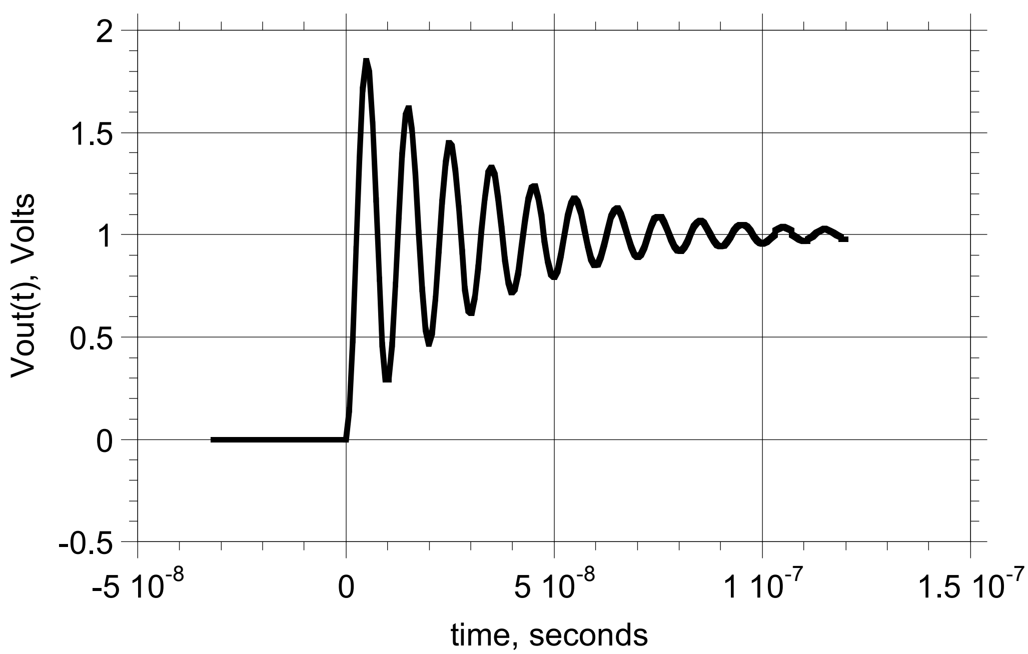
Frequency, Hz

b

Problem 5: 15 points
transfer functions

<u>Part a, 5 points</u>

A transistor circuit has a step response (input is a 1-V step function) as shown.



Determine the frequency and damping factor of the dominant poles of the transfer function.

b

Part b, 5 points

Give the transfer function

Vout(s)/Vgen(s). Give the answer in standard form $\frac{V_{out}(s)}{V_{gen}(s)} = \left.\frac{V_{out}}{V_{gen}}\right|_{DC} \frac{1+b_1 s+b_2 s^2+\ldots}{1+a_1 s+a_2 s^2+\ldots}$

Vout(s)/Vgen(s)= ________________________

b

Part c, 5 points

Draw an ***accurate*** Bode plot of the transfer function. LABEL AXES precisely