ECE137B Final Exam

There are 5 problems on this exam and you have 3 hours
There are pages 1-18 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 4 pages (front and back→ 8 surfaces) of your own notes permitted.
Don't panic.

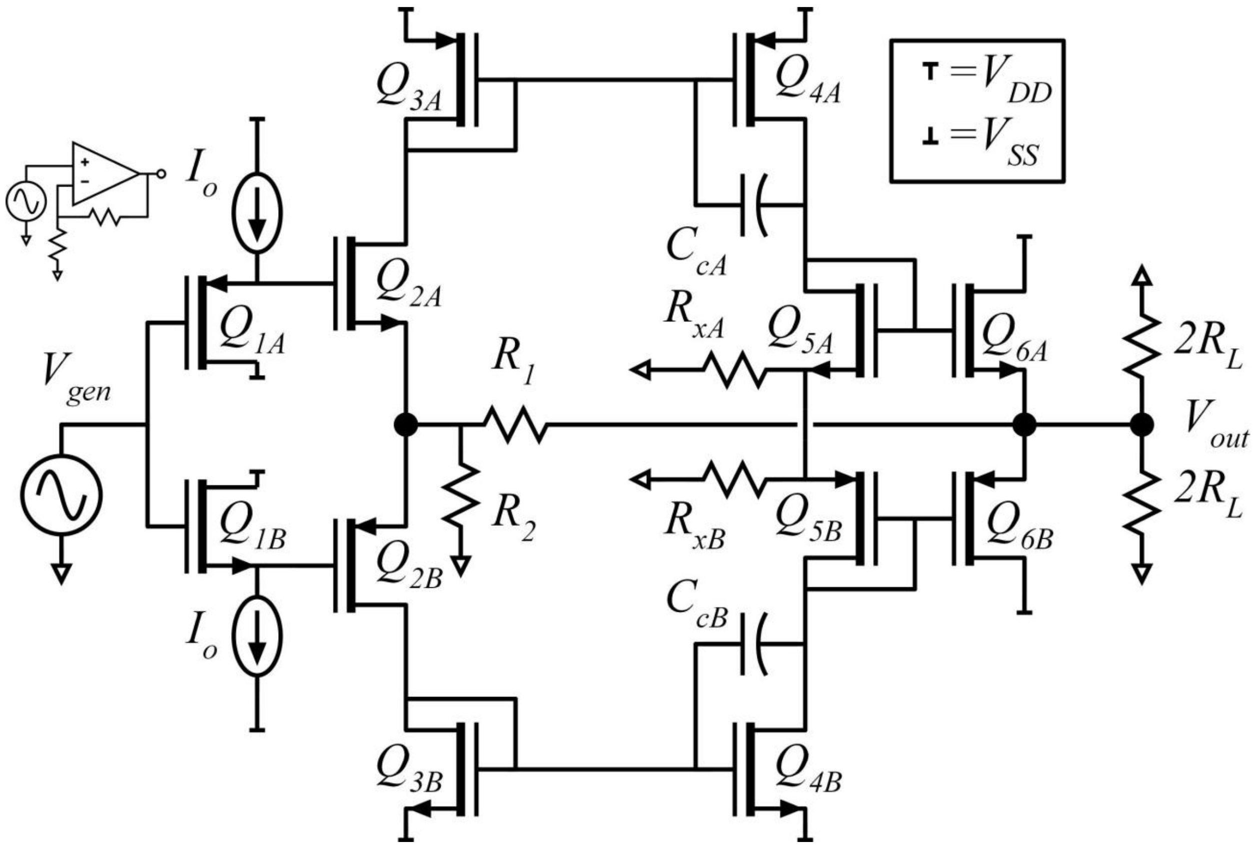
Time function	LaPlace Transform
$\delta(t)$	1
U(t)	1/s
$e^{-\alpha t}\cdot U(t)$	$\frac{1}{s+\alpha}$ or $\frac{1/\alpha}{1+s/\alpha}$
$e^{-\alpha t}\cos(\omega_d t)\cdot U(t)$	$\frac{s+\alpha}{(s+\alpha)^2+\omega_d^2}$
$e^{-\alpha t}\sin(\omega_d t)\cdot U(t)$	$\frac{\omega_d}{(s+\alpha)^2+\omega_d^2}$

Name: ___________________________________

Problem	points	possible	Problem	points	possible
1a		5	5a		10
1b		3	5b		2
1c		10	6a		10
1d		15	6b		10
2		10	6c		3
3		10	7		10
4		10	total		108

b

Problem 1, 33 points
method of first-order and second-order time constants. Some negative feedback



Above is a high-speed op-amp with, by design, a low input impedance to the negative input. It is connected, as the inset image suggests, as a positive voltage-gain stage.

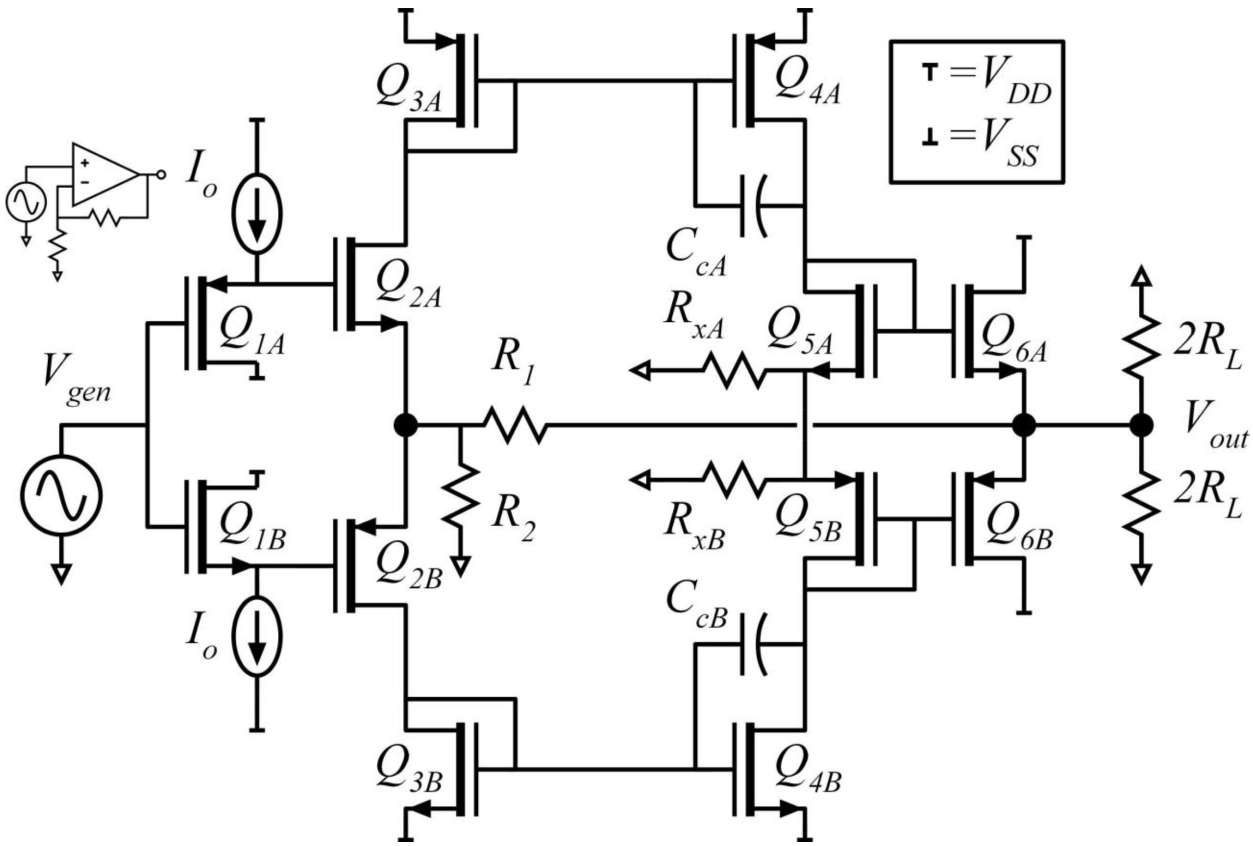
All FETs are short-channel devices:
$I_d \cong v_{sat} c_{ox} W_g (V_{gs} - V_{th} - \Delta V)$ where $v_{sat} c_{ox}$ =1mS/micrometer and $(V_{th} + \Delta V) = 0.3$ Volts.
All FETs have λ =0 V^{-1}, all have W_g =10 micrometers.
Q4a and Q4b have C_{gs} =10fF and C_{gd} =1 fF,
Q6a and Q6b have C_{gs} =10fF and C_{gd} =0 fF,
Q1a, Q1b, Q2a, Q2b, Q3a, Q3b, Q5a, Q5b, have C_{gs} =0fF and C_{gd} =0 fF.

I_o =2 mA, $R_{xa} = R_{xb} = 2\text{M}\Omega$, $2R_L$ =infinity (just to keep the exam simple).
$C_{cA} = C_{cb} =$ 99fF. $R_1 = 1000\Omega$, R_2 =50Ω
The supplies are +1.5V and -1.5V.

b

Part a, 5 points

Draw all DC node voltages and all DC bias currents on the diagram below.

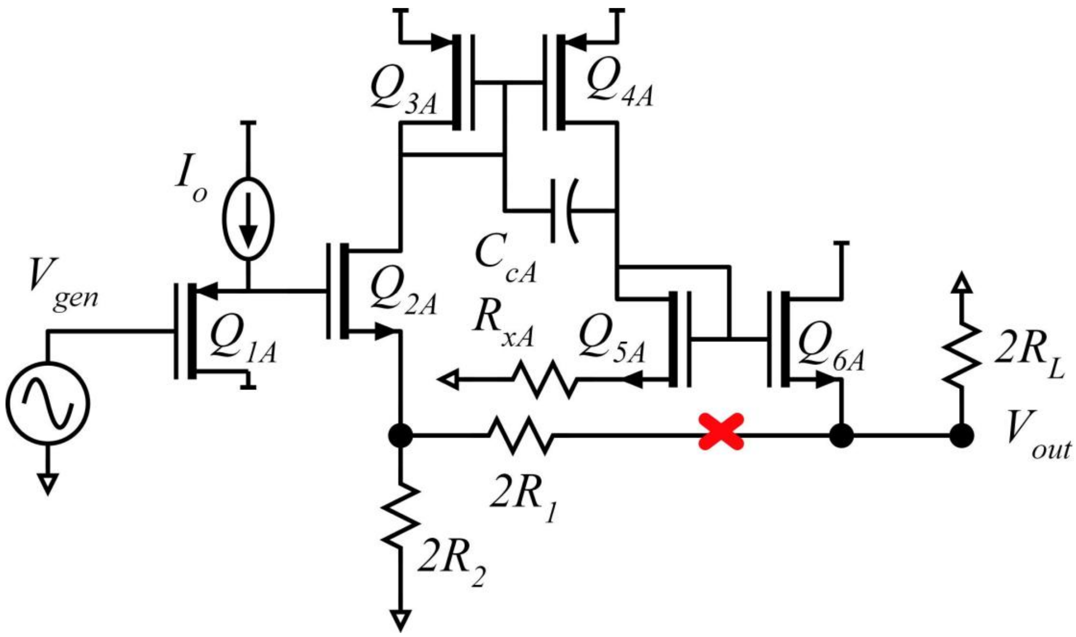


b

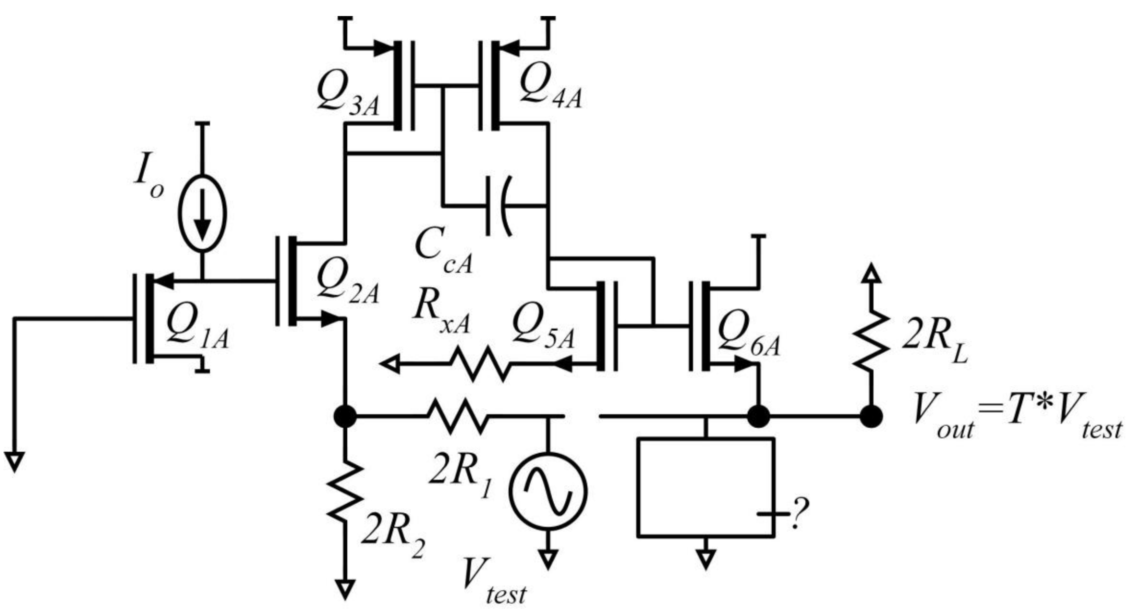
b

Part b, 3 points

Symmetry allows us to analyze bandwidth and gain with the half-circuit below:



To compute the loop transmission you must (1) set Vgen to zero, (2) cut the feedback loop as shown (3) restore the stage loading which has been removed by making the cut, (4) insert an AC voltage generator at the cut point, and (5) compute the voltage gain once around the loop.



Indicate on the drawing above what circuit element must be placed in the box labeled with a "?", and give the value of this element.

b

Part c, 10 points

Working with the circuit diagram of the previous page, determine the DC value of the loop transmission.

T_{DC}=____________

b

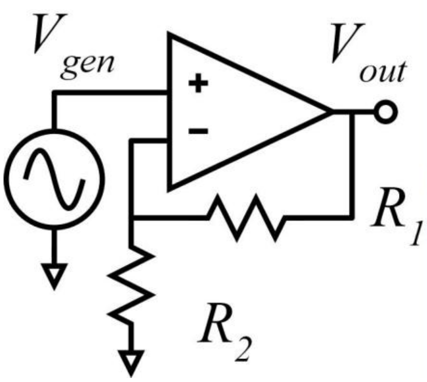
Part d, 15 points

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

Find all the following.

$C_1 = C_{gd4a} + C_{ca}$	$C_2 = C_{gs4a}$:	$C_3 = C_{gs6a}$
$R_{11}^0 =$	$R_{22}^0 =$	$R_{33}^0 =$
$R_{22}^1 =$	$R_{33}^1 =$	$R_{33}^2 =$
$f_{p1} =$	$f_{p2} =$	

Problem 2, 10 points
negative feedback



The amplifier has a differential gain of 10^7.

The op-amp has infinite differential input impedance and zero differential output impedance.

The differential amplifier has pole in its open-loop transfer function at 1 Hz, 10 MHz, and 50MHz.

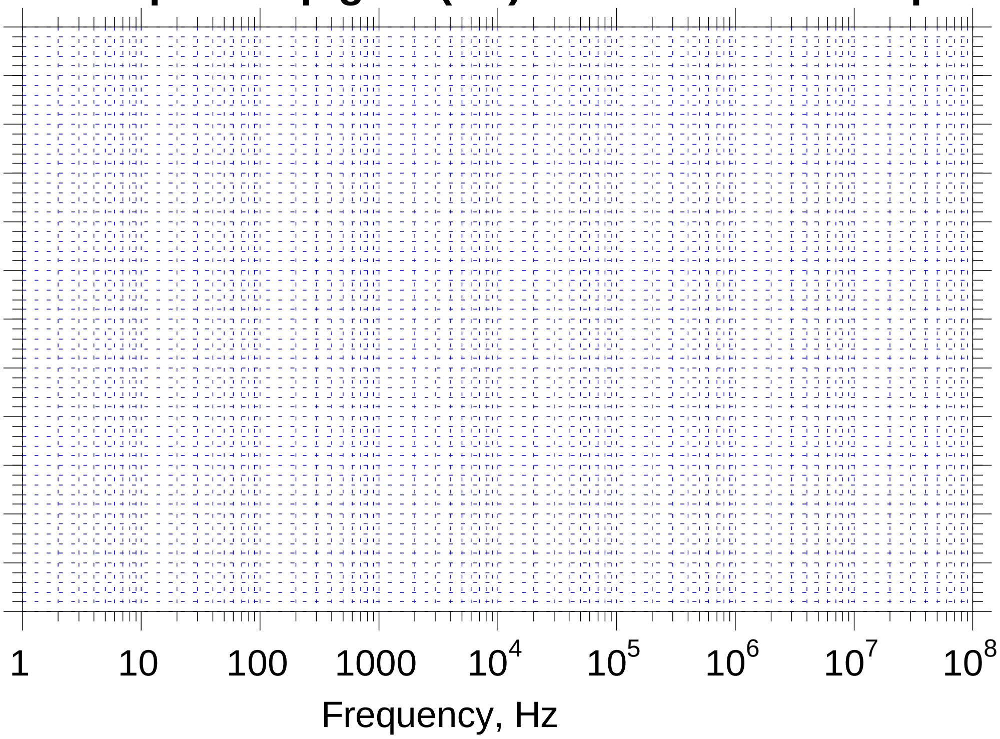
R_1 =4 kOhm, R_2 =1 kOhm,

Using the Bode plots 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}), and determine the following:

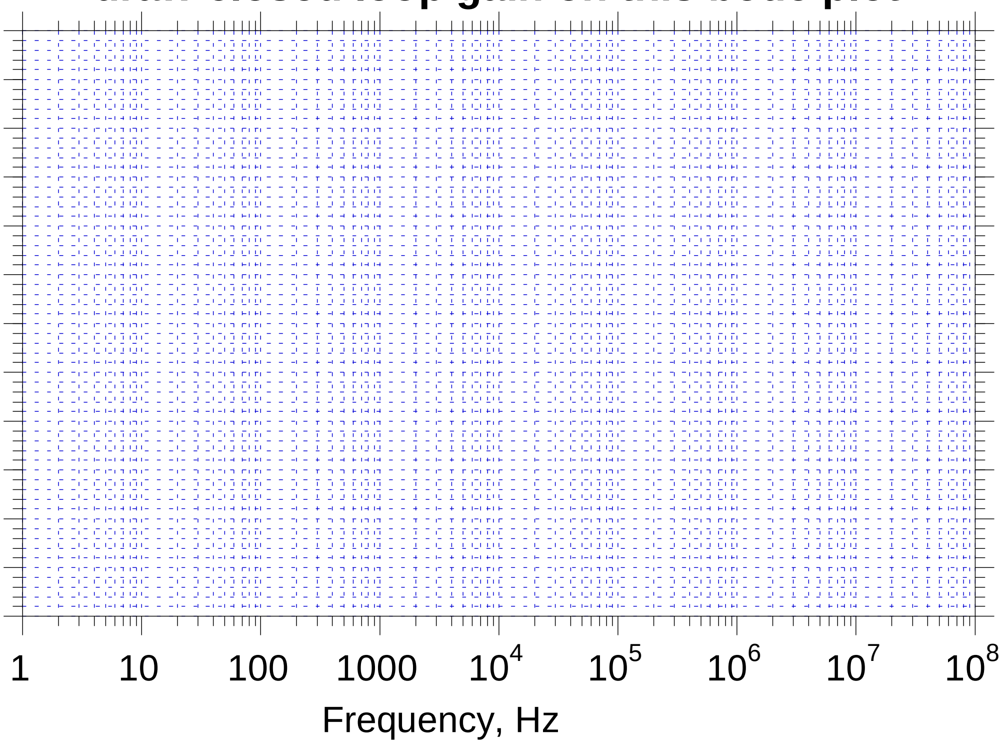
Loop bandwidth=________________ phase margin=____________________
Vout/Vgen at DC=_____________________

Be SURE to ***label*** and ***dimension*** all ***axes*** clearly, and to make clear and ***accurate asymptotic*** plots.

Draw open loop gain (Ad) and 1/beta on this plot

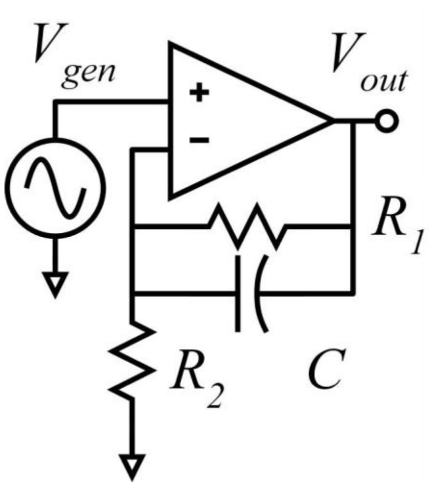


draw closed loop gain on this bode plot



b

Problem 3, 10 points
negative feedback



The amplifier has a differential gain of 10^7.

The op-amp has infinite differential input impedance and zero differential output impedance.

The differential amplifier has pole in its open-loop transfer function at 1 Hz.

R_1 =9 kOhm, R_2 =1 kOhm, C=100nF

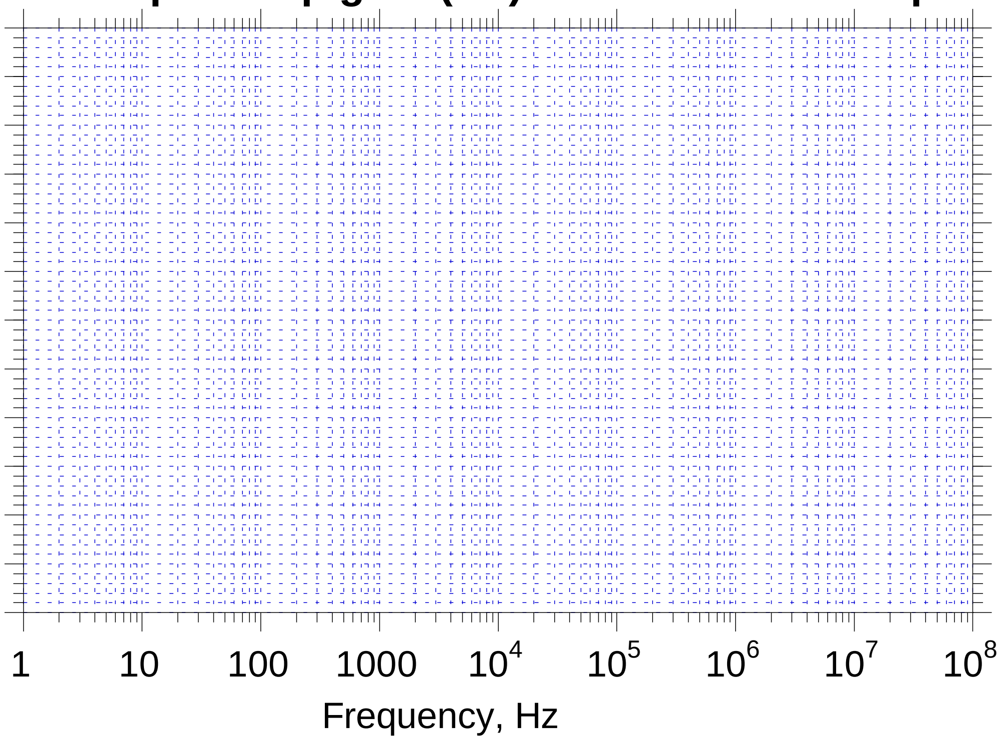
Using the Bode plots on the next page, plot the open-loop gain (A_d or A_{ol}), the inverse of the feedback factor ($1/\beta$) , closed loop gain (A_{CL}), and determine the following:

Loop bandwidth=_______________

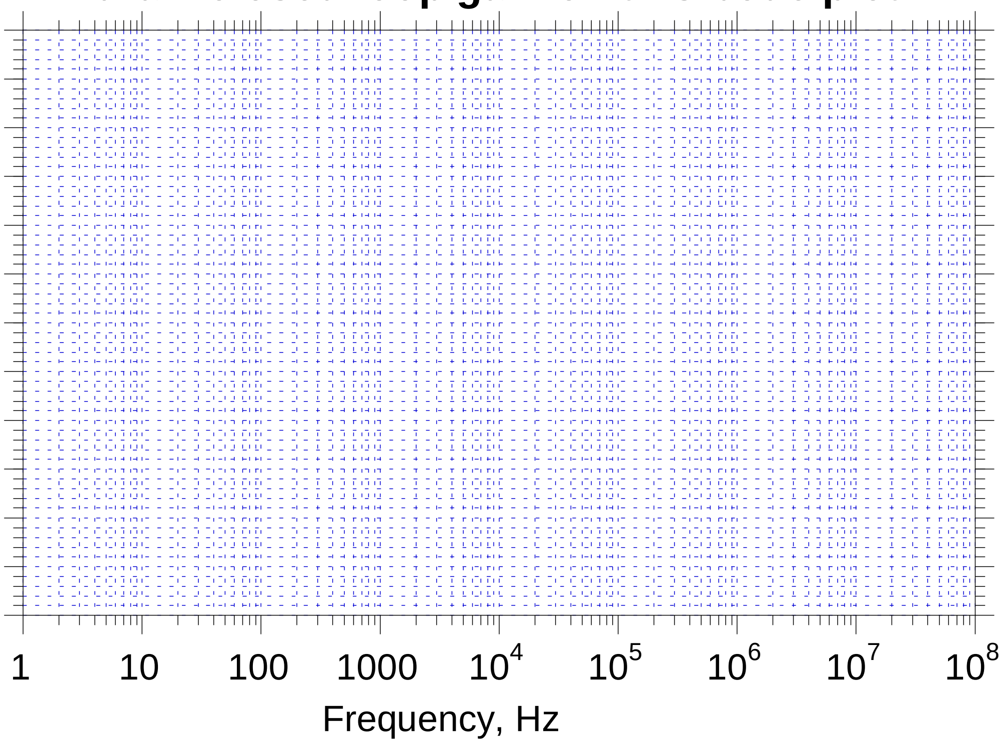
Be SURE to ***label*** and ***dimension*** all ***axes*** clearly, and to make clear and ***accurate asymptotic*** plots.

b

Draw open loop gain (Ad) and 1/beta on this plot

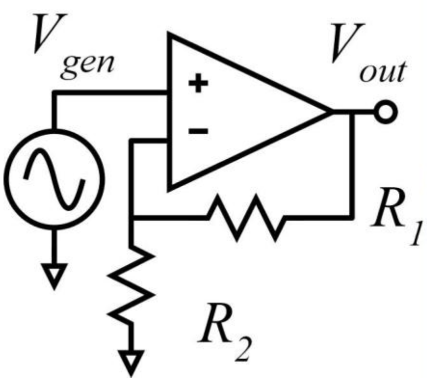


draw closed loop gain on this bode plot



b

Problem 4, 10 points
negative feedback



The amplifier has a differential gain of 10^7.

The op-amp has **100 Ohms differential input impedance** and zero differential output impedance.

The differential amplifier has one pole in its open-loop transfer function at 1 Hz.

R_1 =9 kOhm, R_2 =1 kOhm,

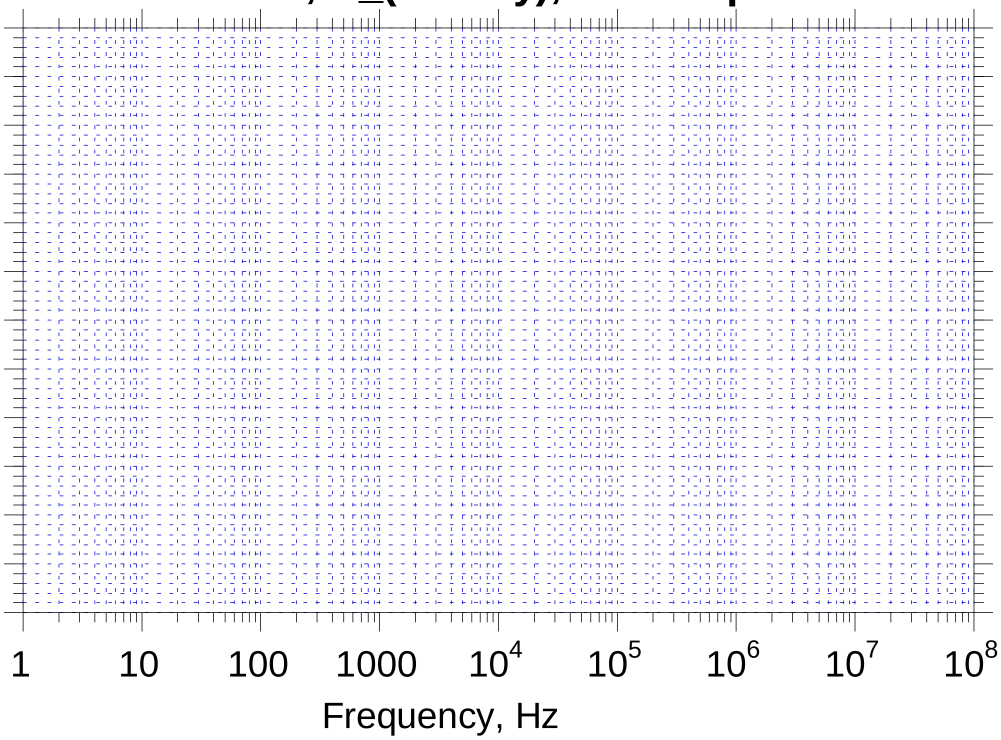
Using the Bode plots on the next page, plot the loop transmission (T), plot A_∞ and plot the closed loop gain (A_{CL} =Vout/Vgen), and determine the following:

Loop bandwidth=________________ . Amplifier 3dB bandwidth=________________

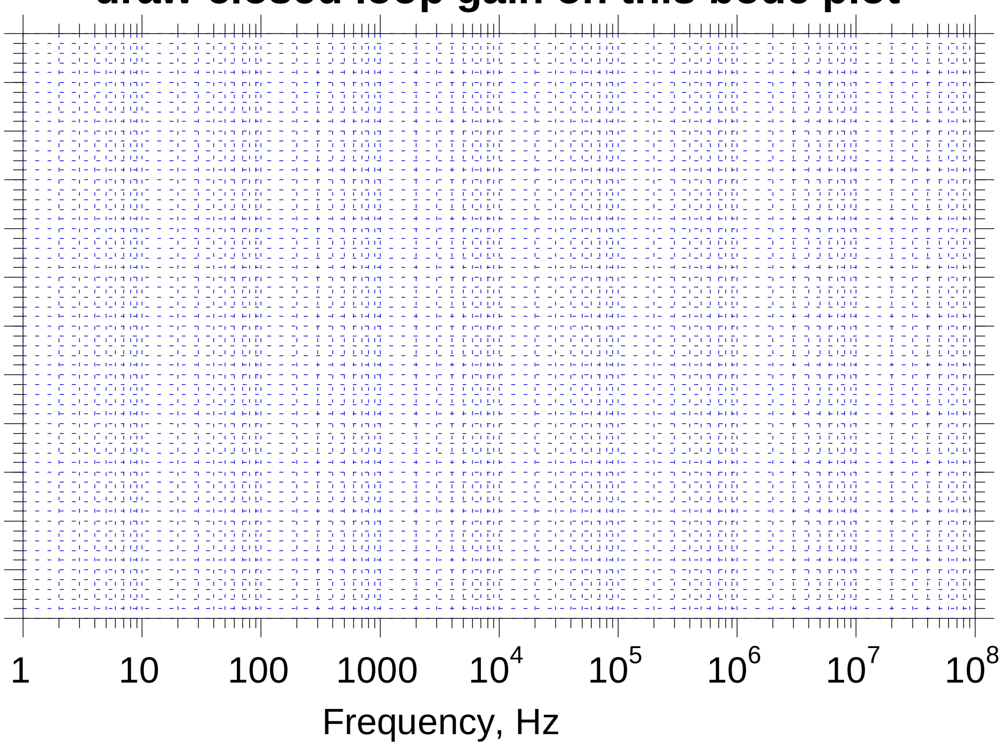
Be SURE to ***label*** and ***dimension*** all ***axes*** clearly, and to make clear and ***accurate asymptotic*** plots.

b

Plot T, A_(infinity), on this plot



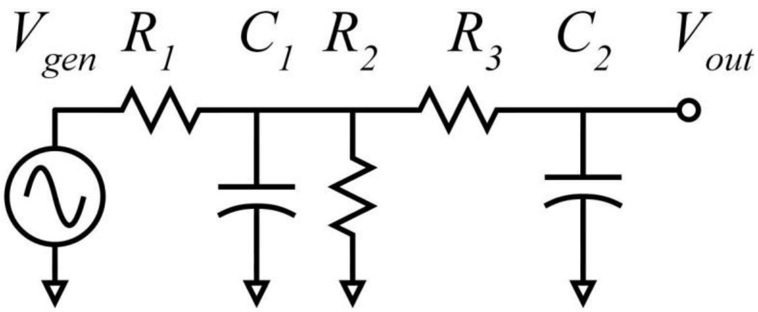
draw closed loop gain on this bode plot



b

Problem 5: 12 points
method of time constants analysis

part a, 10 points



Using MOTC, find the transfer function Vout(s)/Vgen(s). Working with the transfer function in standard form, i.e. $\frac{V_{out}(s)}{V_{gen}(s)} = \left.\frac{V_{out}}{V_{gen}}\right|_{DC} \frac{1+b_1 s+b_2 s^2+...}{1+a_1 s+a_2 s^2+...}$ give algebraic answers in the blanks below

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

$b_1 =$ ______________________ $b_2 =$ ______________________

We will give you that b1 =b2=0 seconds. This can be found without nodal analysis, just by looking at the form of the circuit.

b

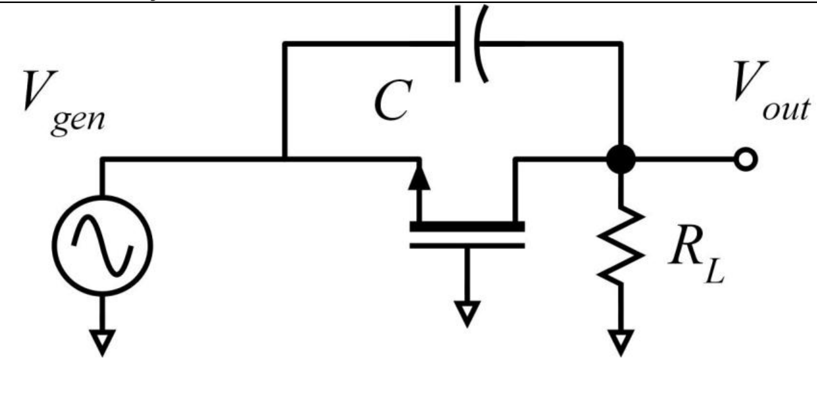
part b, 2 points

Now, R1=1 kΩ, R2=2 kΩ, R3=3 kΩ, C1=1 μF, C2=2 μF. Again find a1 and a2 and Vout/Vgen at DC.

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

b

Problem 6: 23 points
Nodal analysis and transistor circuit models



Ignore DC bias; you don't need it.
FET: C_{gs}=0fF, C_{gd}=0 fF, R_{ds}=infinity.

** g_m is nonzero**

<u>Part a, 10 points</u>
Draw an accurate small-signal equivalent circuit model of the circuit above. Do not show components whose element values are zero or infinity (!).
Important hints:
(1) use a hybrid-pi model, not a T-model, for the FET
(2) Use a Norton model (not a Thevenin model) for the generator.

Part b, 10 points

Using NODAL ANALYSIS, find the transfer function Vout(s)/Vgen(s). The answer must be in standard form $\frac{V_{out}(s)}{V_{gen}(s)} = \left.\frac{V_{out}}{V_{gen}}\right|_{DC} \frac{1+b_1 s+b_2 s^2+...}{1+a_1 s+a_2 s^2+...}$

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

$b_1 =$ ____________________ , $b_2 =$ ____________________

b

Part c, 3 points

Now set: R_L =1000 Ω, g_m = 1mS, C =1 pF. Find numeric values for $\left.\frac{V_{out}}{V_{gen}}\right|_{DC}$, a1, a2, b1 and b2.

Find the frequencies (in Hz) of all pole and zero frequencies

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

$b_1 =$ ____________________, $b_2 =$ ____________________

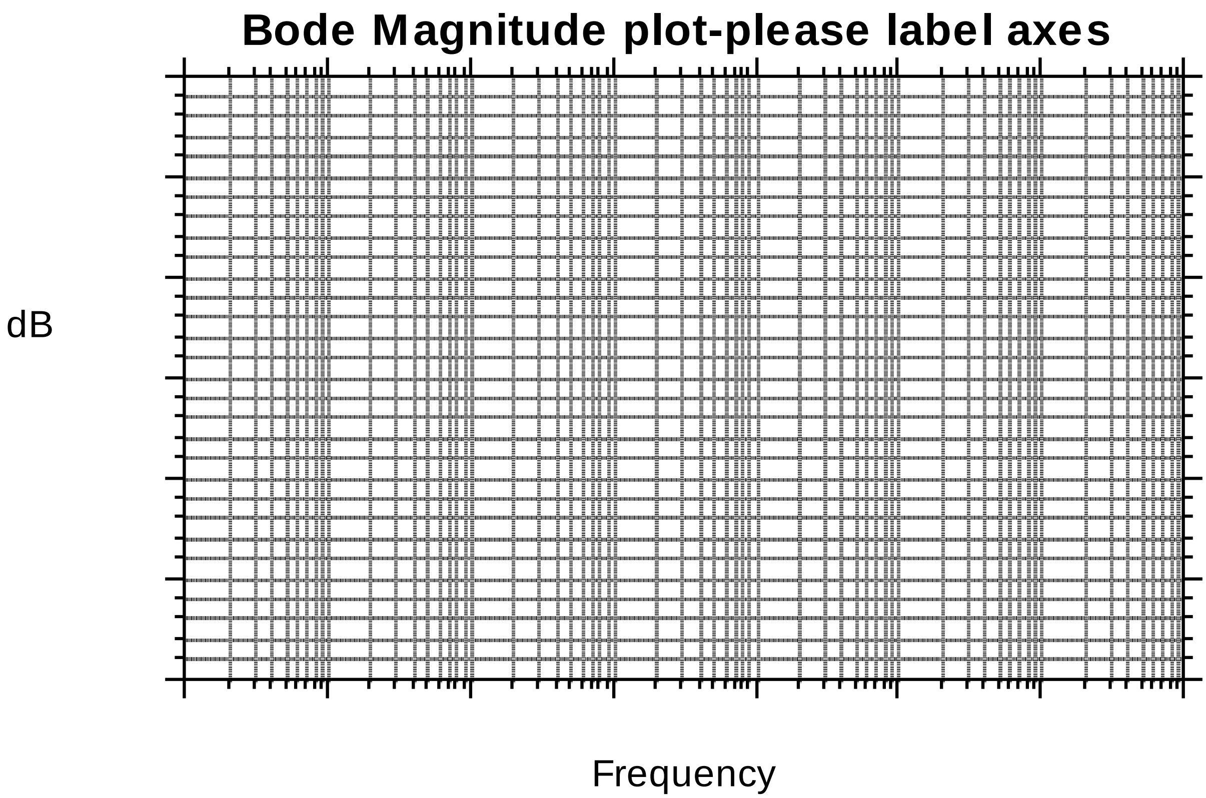
fp1=__________________ fp2=__________________

fz1=_____________________ fz2=_____________________

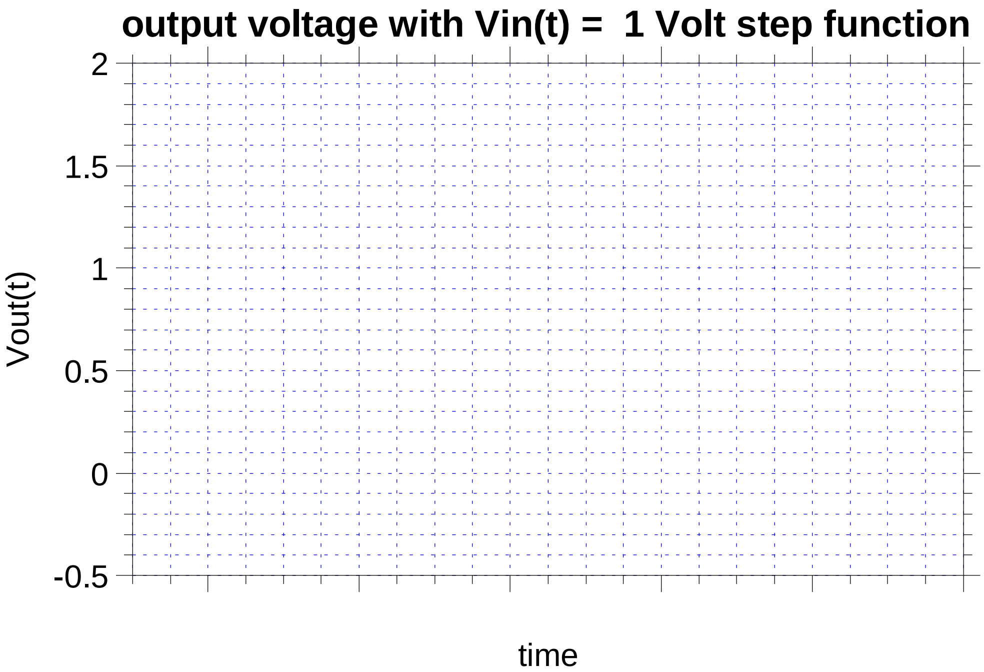
b

Problem 7, 10 points
mental Fourier Transforms

An amplifier has low-frequency and high frequency poles, with an upper -3 dB frequency of 10kHz and a lower -3dB frequency of 2kHz. It has a ****MIDBAND**** voltage gain of 10. Plot below an accurate Bode plot of Vout/Vgen and an accurate plot of its step response with a 1 V step-function input. Label and dimension axes.



b


output voltage with Vin(t) = 1 Volt step function
2
1.5
1
0.5
0
-0.5
Vout(t)
time

b

31

b