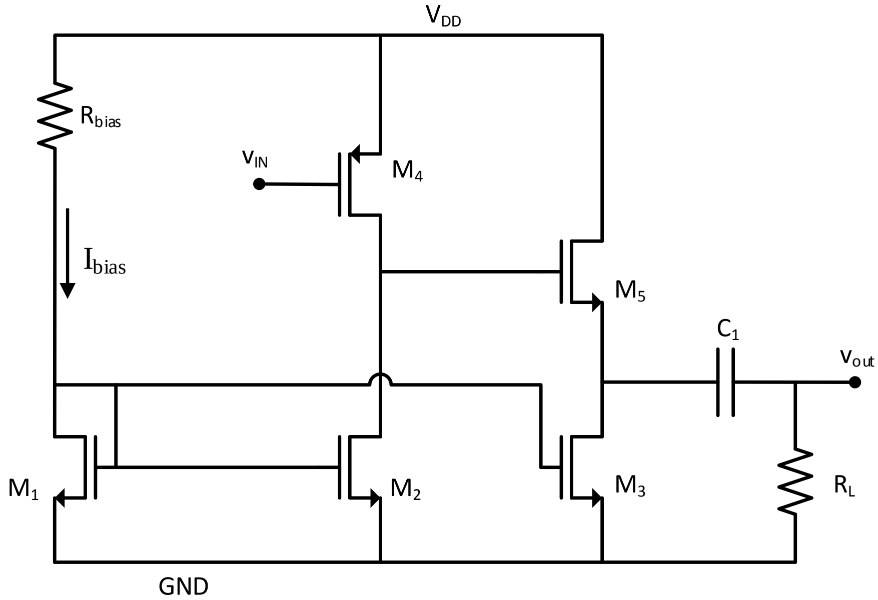
Q1. Consider the multi-stage amplifier given below.



NMOS: V_{TN}=0.5 V
$\mu_n C_{ox}$=2 mA/V^2
λ=0.01 V^{-1}
PMOS: V_{TP}=-0.5 V
$\mu_p C_{ox}$=1 mA/V^2
λ=0.01 V^{-1}

VDD=5 V
RL=100 Ω
C1 is very large

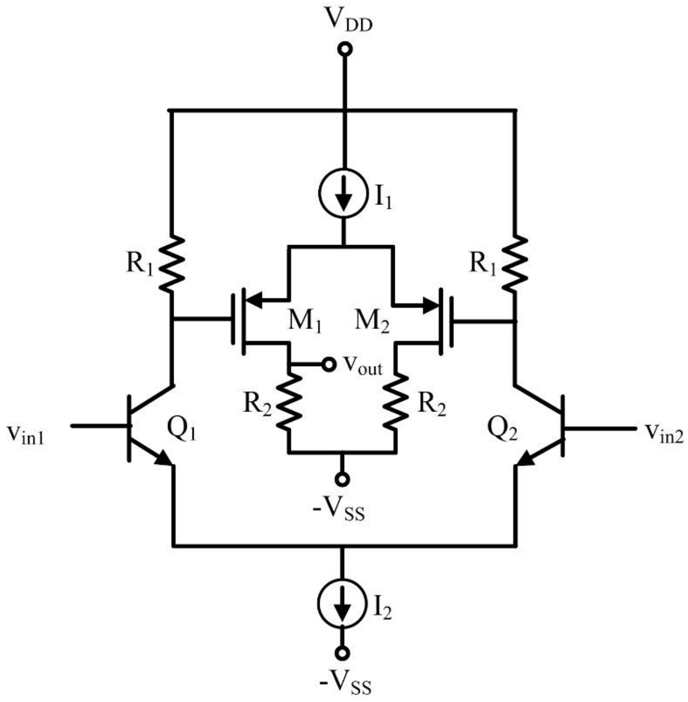
W/L Ratios:
M_1=1/1
M_2=10/1
M_4=500/1
M_5=100/1

a. Calculate the value of R_{bias} to generate 10μA I_{bias} current. You can ignore the effect of the channel length modulation when solving this part (i.e. λ=0).

b. If a total gain of more than 2500 V/V is required (i.e. $|v_{out}/v_{in}| \geq 2500$ V/V), calculate the W/L ratio of M_3 while keeping the DC power dissipation of the circuit at the minimum (Hint: P=IV). If you make any approximations, quantitatively validate your approximations after your solution.

c. Calculate the DC power dissipation of the circuit with the values you calculated in part b.

Q2. For the differential amplifier given in the figure, the output resistances (r_{I1}, r_{I2}) of current sources I_1 and I_2 are given as 50 kΩ. You can neglect the DC base currents in your calculations.



For Q_1-Q_2 matched pair
β = 250
$V_A = \infty$
V_T = 25 mV
$V_{BE(on)}$ = 0.7 V
$V_{CE(sat)}$ = 0.2 V

For M_1-M_2 matched pair
K_P = 2 mA/V^2
V_{TP} = -1 V
λ = 0 V^{-1}

Current sources
I_1 = 8 mA, r_{I1} = 50 kΩ
I_2 = 2 mA, r_{I2} = 50 kΩ
r_{I1} & r_{I2} are internal resistances of the current sources.

R_1 = 4 kΩ
R_2 = 3 kΩ
$V_{DD} = V_{SS}$ = 10 V

a. Draw the half-circuit for the differential mode. Determine the differential mode gain $A_{dm}=v_{out}/(v_{in1}-v_{in2})$

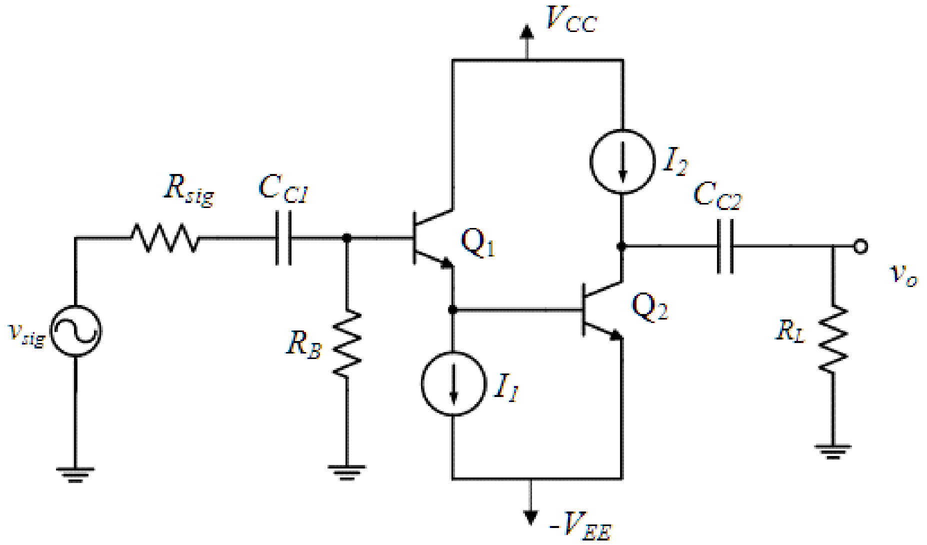
b. Find the common mode gain $A_{cm}=v_{out}/v_{cm}$, $v_{cm}=v_{in1}=v_{in2}$.

c. Find the differential mode input resistance R_{idm} and the common mode input resistance R_{icm}.

d. Find the common mode input signal range, assuming that a minimum voltage drop of 0.2 V across the current sources is required.

e. If $v_{in1} = A\cos(\omega_A t) + B\sin(\omega_B t)$ and $v_{in2} = A\cos(\omega_A t) - B\sin(\omega_B t)$, find v_{out}.

Q3.



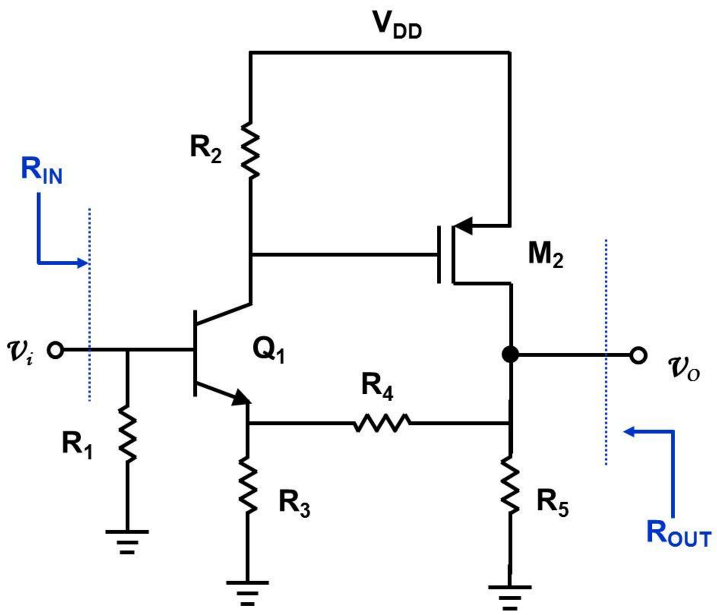
$I_1 = I_2 = 1$ mA
$R_{sig} = R_L = 4$ kΩ
$R_B = 100$ kΩ
$C_{C1} = C_{C2} = \infty$
Transistor parameters:
$\beta_1 = \beta_2 = 100$
$C_{\pi1} = C_{\pi2} = 13.9$ pF
$C_{\mu1} = C_{\mu2} = 2$ pF
$r_{x1} = r_{x2} = 0$
$r_{o1} = r_{o2} = \infty$

Consider the above given CC-CE amplifier circuit.

a. Apply Miller theorem to the second transistor and estimate the upper 3-dB frequency f_H of the complete amplifier using the open-circuit time-constant (OCTC) method.

b. Calculate the upper 3-dB frequency f_H without the first stage and compare it with the one calculated in part a). Which one is better? Why?

Q4. For the series-shunt feedback amplifier given below.



a. Show the feedback network and determine the parameters of the feedback circuitry.

b. Draw the modified A-circuit, including the loading effect of the feedback network.

c. Determine A, R_{IN}^A, and R_{OUT}^A of the modified A-circuit.

d. Determine the closed-loop voltage gain $A_v=v_o/v_i$.

e. Determine the closed-loop input and output resistances (i.e., R_{IN}, R_{OUT}).

Q5. Consider an amplifier with the following open loop transfer function.

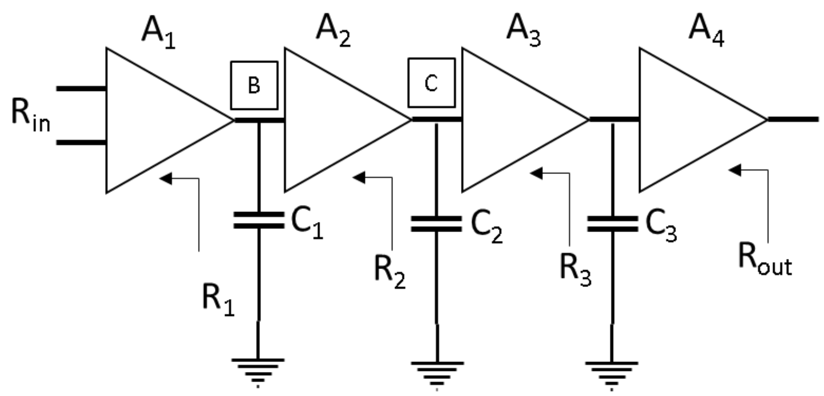
$$A = \frac{10^5}{\left(1+\frac{jf}{10^5}\right)\left(1+\frac{jf}{10^6}\right)\left(1+\frac{jf}{10^7}\right)}$$

a. Construct the Bode plots for magnitude and phase using the empty plots provided on the next page.

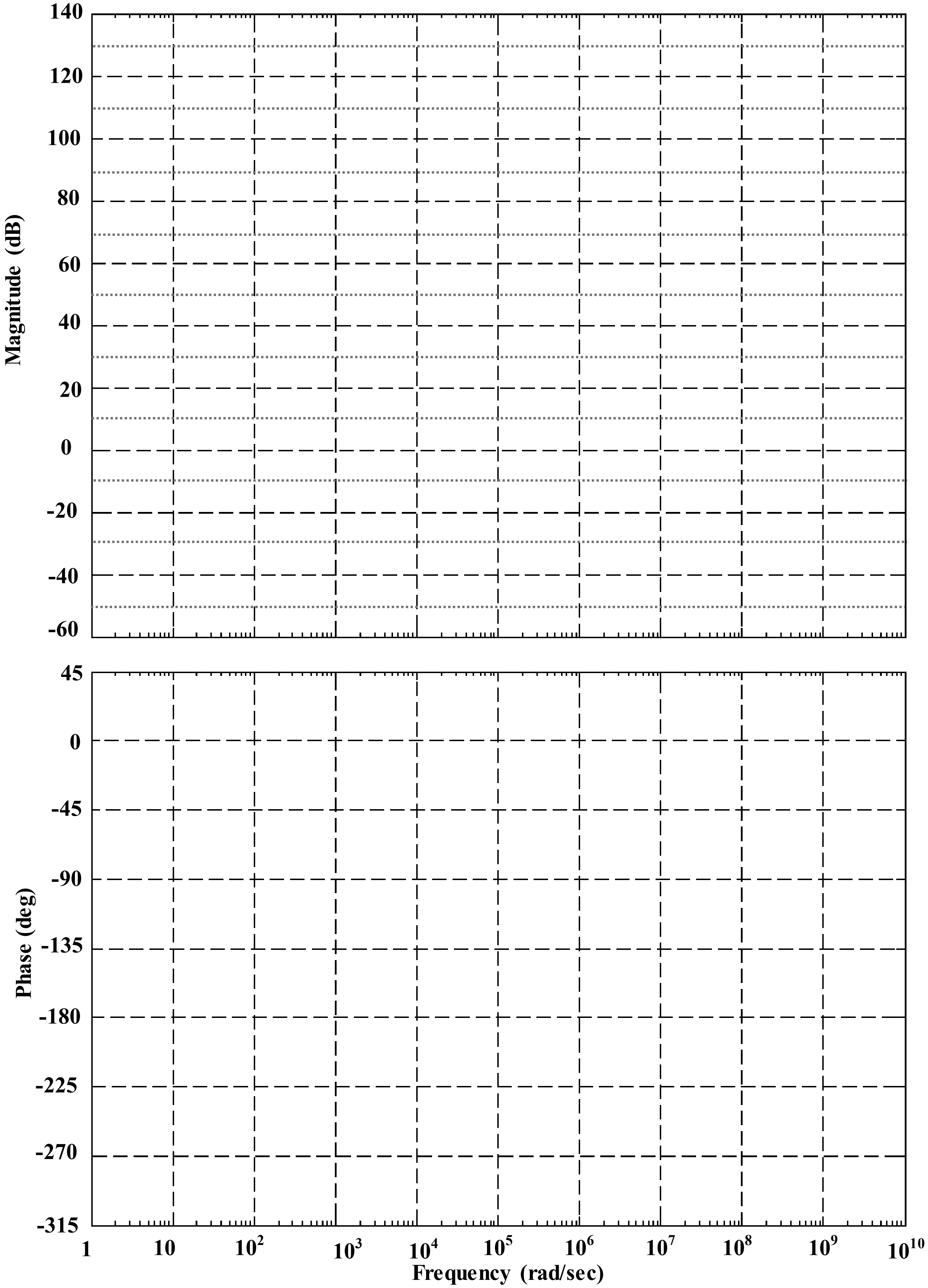
b. Assuming feedback factor (β) is independent of frequency, check if the closed loop amplifier is stable with the following values. Calculate phase and gain margin if applicable.

- $\beta=3.16\text{x}10^{-5}$
- $\beta=1\text{x}10^{-2}$

c. Assuming internal structure of this amplifier is as below, calculate R_3 and A_2. What would be the C_c (connected between nodes B and C) value that makes the closed loop amplifier stable for $\beta<0.1$.



$C_1=0.5\text{nF}$
$C_2=20\text{nF}$
$C_3=0.01\text{nF}$
$R_1=20\text{k}\Omega$
$R_2=50\Omega$
$R_{in}=\infty$
$R_{out}=0$
$A_1=5$
$A_3=-2$
$A_4=1$


140
120
100
80
60
40
20
0
-20
-40
-60
Magnitude (dB)
45
0
-45
-90
-135
-180
-225
-270
-315
Phase (deg)
1
10
10^2
10^3
10^4
10^5
10^6
10^7
10^8
10^9
10^{10}
Frequency (rad/sec)