National Exams May 2017

16-Elec-B5, Advanced Electronics

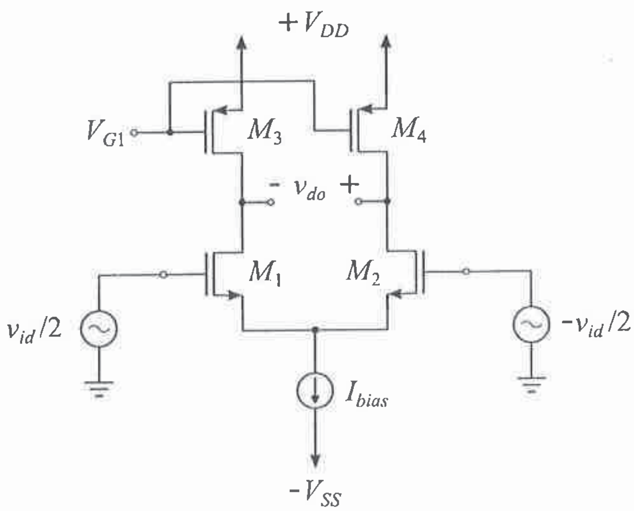
3 hours duration

Notes:

1. If any doubt exists as to the interpretation of any question, the candidate is urged to submit, within their answer, a clear statement of any assumptions made.
2. This is a **CLOSED BOOK EXAM**.
   One of two calculators is permitted; any Casio or Sharp approved model.
3. Answer all **FIVE** (5) questions.
4. All questions are worth 20 marks each.
5. Please start each question on a new page and clearly identify the question number and part number, e.g. Q4(a).
6. In schematics, ground and chassis may be assumed to be common, unless specifically stated otherwise.
7. Unless otherwise specified, assume that Op-Amps are ideal and that supply voltages are ±15V.
8. If questions require an answer in essay format, clarity and organization of the answer are important. Provide block diagrams and circuit schematics whenever necessary.

QUESTION (1)

The following single stage differential amplifier circuit is designed for a 0.18 µm CMOS technology.



Given: $V_{DD} = |V_{SS}| = 1.5$ V, $|V_{TH}| = 0.5$ V, $L = 0.36$ µm (for all transistors), $\mu C_{ox} = 4\mu C_{ox} = 400$ µA/V^2, and $\lambda = 0.2$

a) For a bias current of $I_{bias} = 200$ µA and over drive voltage $|V_{ov}| = 0.2$ V for all transistors, determine the W/L ratios for M_1, M_2, M_3, and M_4. (10 points)

b) Determine the small signal differential gain v_{do}/v_{id} for this design. (10 points)

Useful formulae: for n-channel MOSFET

$$i_{DS} = K\left[(v_{GS} - V_{TH})v_{DS} - \frac{1}{2}v_{DS}^2\right] \quad \text{triode region}$$

$$i_{DS} = \frac{1}{2}K(v_{GS} - V_{TH})^2(1 + \lambda v_{DS}) \quad \text{saturation region}$$

$$V_{ov} = V_{GS} - V_{TH} \quad \text{overdrive voltage}$$

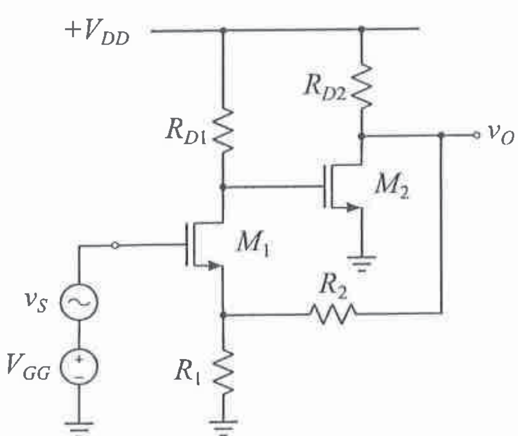
where

$$K = K'\left(\frac{W}{L}\right) = \mu C_{ox}\left(\frac{W}{L}\right)$$

$$V_A = \frac{1}{\lambda}, \text{ and } V_A = V_A' L, \; r_o = \frac{1}{\lambda I_D}$$

QUESTION (2)

The following series–shunt feedback amplifier is already biased properly.



a) Identify the feedback network (β circuit) and provide an expression for β. Also give an expression for the ideal or upper-bound value of the closed-loop gain A_f. You can neglect the output resistance r_o for M_1 and M_2. (6 points)

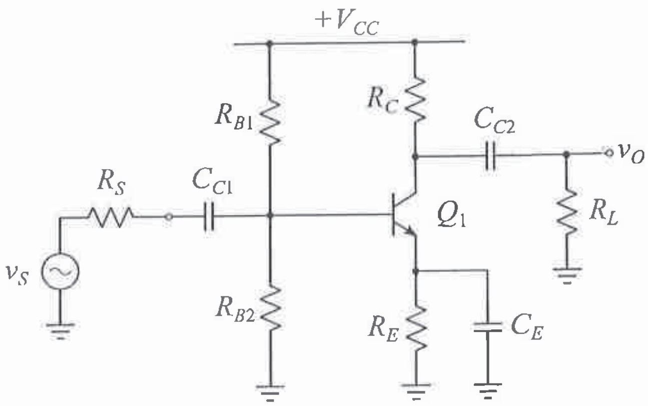
b) Determine the ratio R_2/R_1 that will provide an ideal closed-loop gain of 10 V/V. If $R_1 = 1$ kΩ, what should be the value for R_2? (4 points)

c) Provide an expression for the open-loop gain $A\beta$ (6 points)

d) For $g_{m1} = g_{m2} = 4$ mA/V, and $R_{D1} = R_{D2} = 10$ kΩ, determine the values of $A\beta$, A, and A_f. (4 points)

QUESTION (3)

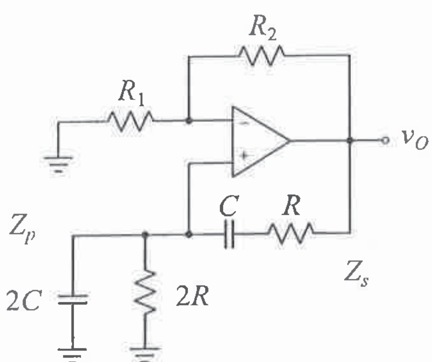
The following common emitter amplifier is already biased properly. Determine the appropriate values for C_{C1}, C_{C2}, C_{CE} to provide a lower cutoff frequency of f_L = 100 Hz. Which capacitor dominates this corner frequency? (20 points)



Given: R_{B1} = 180 kΩ,
R_{B2} = 270 kΩ,
R_S = 5 kΩ,
R_C = 8 kΩ,
R_E = 2 kΩ,
R_L = 5 kΩ,
β = 100,
g_m = 40 mA/V, and
r_π = 2.5 5 kΩ.

QUESTION (4)

For the following circuit, determine the oscillation frequency as a function of R, C, R_1 and R_2. What condition must be satisfied in order to ensure that oscillation will start? What is the main limitation of this circuit? How can you remedy this problem? (20 points)



QUESTION (5)

The bipolar circuit is biased with a current of I_1 = 1mA. Determine the voltage gain v_{OUT}/v_{IN}. (20 points)

Given:

β = 100
V_A = 5 V