National Exams May 2013

07-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. FIVE (5) questions constitute a complete exam paper.
The first five questions as they appear in the answer book will be marked.

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).

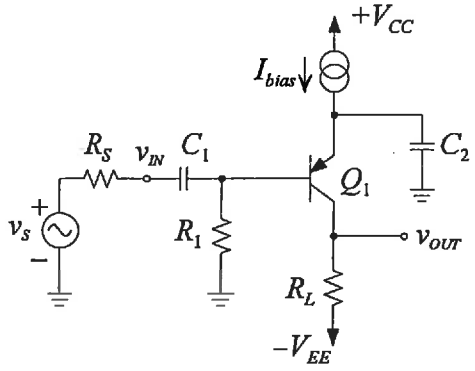
6. In schematics, ground and chassis may be assumed to be common, unless specifically stated otherwise.

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)

In the following circuit, assume that $\beta = 100$, $V_{EB} = 0.7$ V, $V_{EC(sat)} = 0.3$ V, $V_A = 100$ V, $C_\mu = 2$ pF for all transistors. Neglect r_x and r_o in the hybrid-π model.



Given: $R_S = 600\ \Omega$
$R_L = 5\text{k}\ \Omega$
$R_1 = 1\text{k}\ \Omega$
$C_1 = 10\ \mu\text{F}$
$C_2 = \infty$
$|V_{CC}| = |V_{EE}| = 10$ V
$I_{bias} = 1$ mA
$V_T = 25$ mV

a) Estimate the mid-band gain v_{OUT}/v_S in (V/V). (4 points)

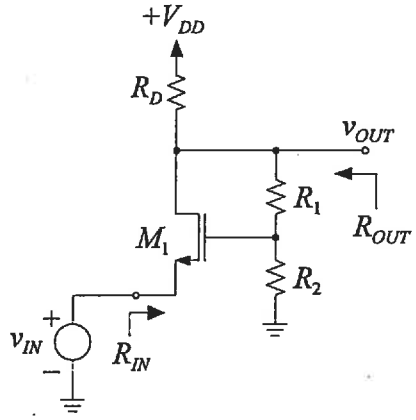
b) Find the lower 3dB frequency f_L in (Hz). (4 points)

c) Find the upper 3dB frequency f_H in (Hz). (6 points)

d) Find the 2nd high frequency dominant pole in (Hz). (6 points)

QUESTION (2)

In the following amplifier can be considered as a feedback circuit.



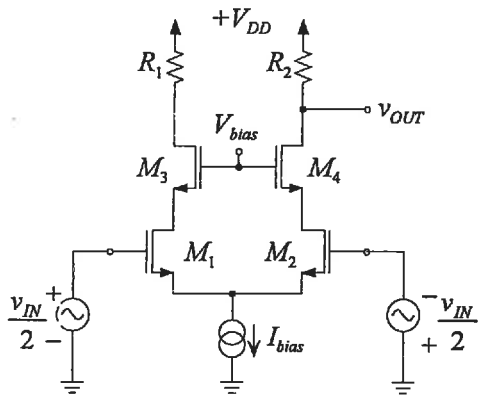
a) Determine the input and output resistance (R_{IN} and R_{OUT}) if there is no feedback network (i.e. $R_1 = \infty$, and $R_2 = 0\ \Omega$). (8 points)

b) Derive the input and output resistance (R_{IN} and R_{OUT}) if the feedback network has finite values for R_1 and R_2. (12 points)

Express you answer in terms of g_m, R_D, R_1 and R_2.

QUESTION (3)

In the following circuits, assume all transistors have the following parameters:



$K = 0.5$ mA/V^2, $V_{TH} = 1$ V and $\lambda = 0.02$.

Given:

$I_{bias} = 1$ mA

$V_{bias} = 6$ V

$V_{DD} = 10$ V

$R_1 = R_2 = 2$ kΩ

a) Estimate the differential gain v_{OUT}/v_{IN} in (V/V). (6 points)

b) Find the common mode input resistance R_{icm}. (4 points)

c) Find the common mode input range. (4 points)

d) Estimate the common mode rejection ratio, CMRR. Express your result in dB. (6 points)

Useful formulae: for n-channel MOSFET

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

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

QUESTION (4)

An analog signal in the range 0 to +10 V is to be converted to an 8-bit digital signal.

a) What is the resolution of the conversion in volts? (4 points)

b) What is the digital representation of an input of 6 V? (4 points)

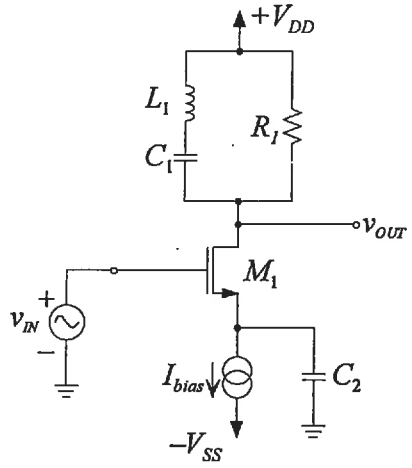
c) What is the representation of an input of 6.2 V? (4 points)

d) What is the error made in the quantization of 6.2 V in absolute terms and in percentage of the input? And as a percent of full scale? (4 points)

e) What is the largest possible quantization error as a percentage of full scale? (4 points)

QUESTION (5)

In the following tuned amplifier circuit, transistor M_1 is biased with I_{bias} =2 mA. The transistor parameters are given as K= 1 mA/V^2, V_{TH} = 1 V, C_{gs} = 10 pF, C_{gd} = 1 pF, and $\lambda = 0$.



For: V_{DD} = 10 V, V_{SS} = −10V
L_1 = 1 μH
C_1 = 200 pF, $C_2 = \infty$
R_S = 1 kΩ, R_L = 2 kΩ

a) What is the center frequency, ω_o of this amplifier? (4 points)

b) What is the gain v_{OUT}/v_S at $\omega = \omega_o$? (8 points)

c) What is the gain at very high frequencies? (4 points)

d) What is the gain at very low frequencies? (4 points)

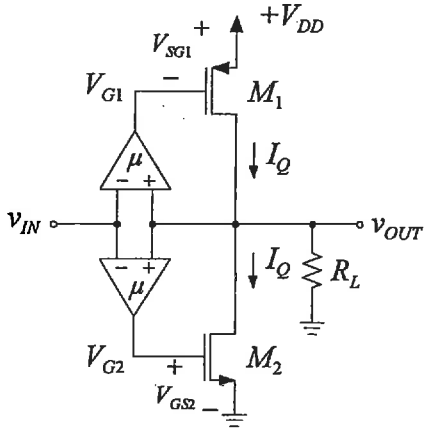
Useful formulae: for n-channel MOSFET

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

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

QUESTION (6)

The following circuit is a class AB power amplifier. The output stage is essentially comprised of two common source amplifiers. The two error amplifiers are used to provide negative feedback to lower the output resistance of this output stage.



Given the followings:

i) Transistors M_1 and M_2 are matched such that $K_n = K_p$, and $V_{Tn} = |V_{Tp}|$

ii) I_Q is the quiescent current for transistors M_1 and M_2 with zero input.

iii) μ is the finite gain of the error amplifiers.

iv) R_L is the load resistance

a) Derive an expression for the voltage gain v_{OUT}/v_{IN} of this amplifier? (12 points)

b) What would be the expected gain? (2 points)

c) What would be the gain error? (6 points)