National Exams May 2009

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.
   Any non-communicating calculator is permitted.
3. Any 5 (FIVE) questions constitute a complete 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. Some questions require an answer in essay format. Clarity and organization of the answer are important. Provide block diagrams and circuit schematics whenever necessary.

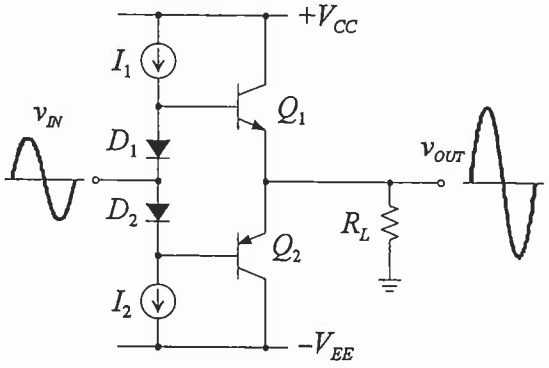
QUESTION (1)

In the following push-pull output stage, assume that each transistors conducts a negligible amount of current around $v_{IN} = 0$V. Q_1 conducts for the positive half of the input voltage and Q_2 conducts for the negative half. Assuming that $V_{CC} = |V_{EE}| = 10$V, $R_L = 8\Omega$, and the input voltage is sinusoidal, determine the followings:

a) The maximum power that can be delivered to the load, R_L. (5 points)

b) The maximum power dissipated by transistor Q_1. Assume that the base current is negligible. (10 points)

c) The maximum power efficiency of this push-pull stage? Neglect the power drawn by the bias current sources I_1 and I_2. (5 points)

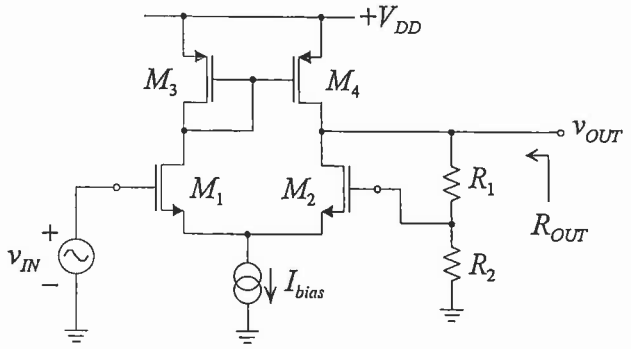


QUESTION (2)

The following differential amplifier can be considered as a voltage-voltage feedback circuit. All the MOSFETs are properly biased to operate in the saturation region. Provide expressions that describe:

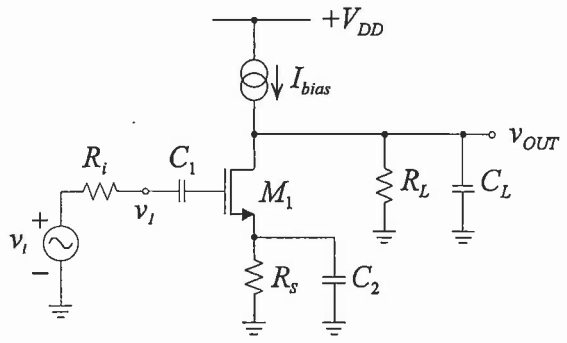
a) The small signal gain, v_{OUT}/v_{IN} of this circuit. (10 points)

b) The output resistance R_{OUT} of this circuit. (10 points)



QUESTION (3)

The following common source amplifier is already biased properly.



Given:

$g_m = 2$ mA/V	$r_o = 20$ kΩ
$R_i = 20$ kΩ	$R_L = 20$ kΩ
$C_{gs} = 20$ fF	$C_{gd} = 5$ fF
$C_L = 5$ fF	$C_1 = \infty$
$C_2 = \infty$	

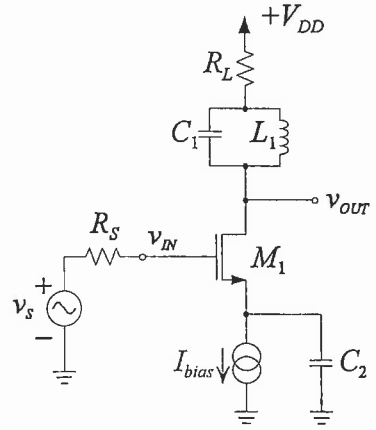
a) Find the mid-band voltage gain v_{OUT}/v_i. (6 points)

b) What is the new mid-band voltage gain, v_{OUT}/v_i if capacitor C_2 is removed? (6 points)

c) What is the new 3dB frequency f_H if capacitor C_2 is removed? (8 points)

QUESTION (4)

In the following tuned amplifier circuit, the transistor M_1 is biased such that V_{DD} = 10 V, 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: $L_1 = 1$ 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 3dB bandwidth of this tuned amplifier? (8 points)

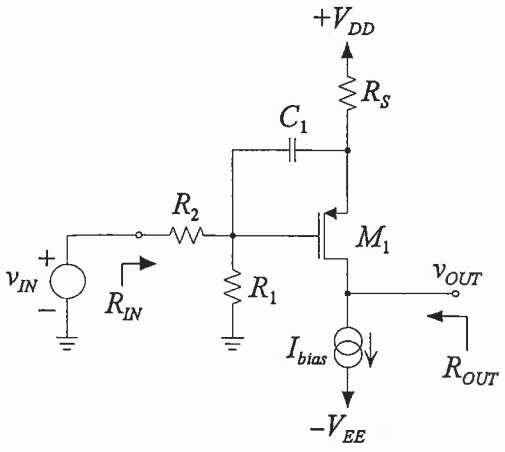
Useful formulae: for *n*-channel MOSFET

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

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

QUESTION (5)

Consider the following amplifier circuit.



Given:

$V_{CC} = 10$ V	$V_{EE} = 10$ V
$I_{bias} = 1$ mA	$C_1 = 20$ pF
$R_1 = 20$ kΩ	$R_2 = 20$ kΩ
$R_S = 2$ kΩ	
$C_{gs} = 10$ pF	$C_{gd} = 1$ pF
$K = 1$ mA/V^2	$\lvert V_{TH}\rvert = 1$ V
$\lambda = 0.01$ V^{-1}	

a) Determine the mid-band voltage gain, v_{OUT}/v_{IN} (8 points)

b) Determine the upper 3dB cut off frequency, f_H. (12 points)

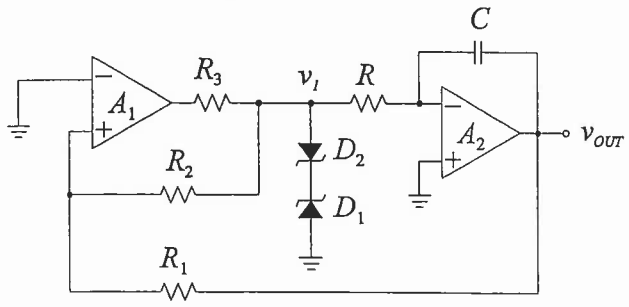
Useful formulae: for p-channel MOSFET

$$i_{SD} = K\left[(v_{SG} - |V_{TH}|)v_{SD} - \frac{1}{2}v_{SD}^2\right] \qquad \text{triode region}$$

$$i_{SD} = \frac{1}{2}K\left(v_{SG} - |V_{TH}|\right)^2\left(1 + \lambda v_{SD}\right) \qquad \text{saturation region}$$

QUESTION (6)

The op amps in the following circuit are ideal and are supplied by ±15V. The zener diodes, D_1 and D_2 have a zener voltage of $V_Z = 10$V and forward voltage of 0V. Sketch **accurately** in your answer book the voltage waveform for v_{OUT} as a function of time. Provide accurate voltage leveling and timing information. (20 points)



Given:

$R_1 = 10$ kΩ	$R_2 = 10$ kΩ
$R_3 = 10$ kΩ	
$R_3 = 10$ kΩ	$C = 100$ pF