National Exams May 2009

07-Elec-A5, Electronics

3 hours duration

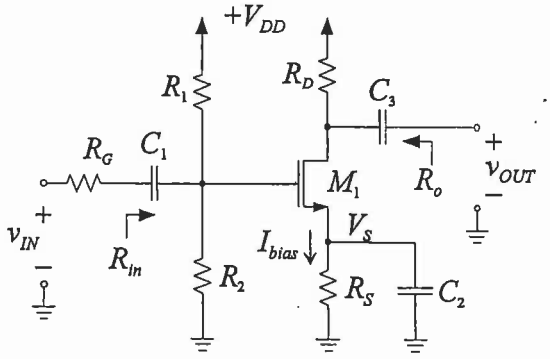
Notes:

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.
   calculator is permitted.
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. 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)

Design a common source amplifier circuit with the following specifications:

Voltage gain	v_{OUT}/v_{IN}	= 5 V/V
Input impedance	R_{IN}	= 50 kΩ
Power budget	P_{max}	= 5mW.



Given:

V_{TH} = 0.5 V
$\mu_n C_{ox}$ = 100 μA/V^2
λ = 0 V^{-1}
V_{DD} = 1.8 V
I_{bias} = 2.7 mA
V_S = 0.4V
R_G = 0Ω

Determine possible values for the following components:

W/L for M_1, R_1, R_2, R_S *and* R_D (20 points)

Note: the value for *W/L* may not be unique. You must double check to make sure that M_1 is biased to operate in saturation mode.

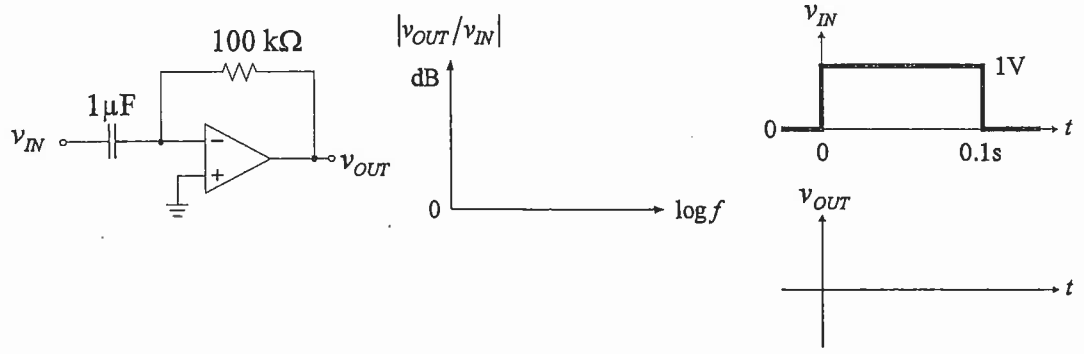
Useful formulae: for *n*-channel MOSFET

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

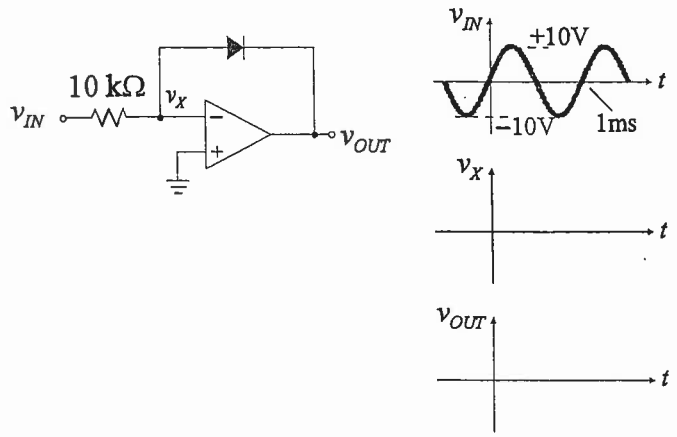
$$i_{DS} = \frac{1}{2}\mu_n C_{ox} \frac{W}{L}(v_{GS} - V_{TH})^2(1 + \lambda v_{DS}) \quad \text{saturation region}$$

QUESTION (2)

a) The op amp in the circuit below is ideal. It is powered by a ±15V supply. Sketch **accurately** in your answer book the frequency response for $|v_{OUT}/v_{IN}|$ and the voltage waveform for v_{OUT}. Remember to provide accurate values in both plots. (10 points)



a) The op amp and the diode in the circuit below are ideal. The op amp is powered by a ±15V supply. The diode has a forward voltage of 0.7V. Sketch **accurately** in your answer book the voltage waveforms for v_X, and v_{OUT}. Remember to provide accurate amplitudes in both plots. (10 points)

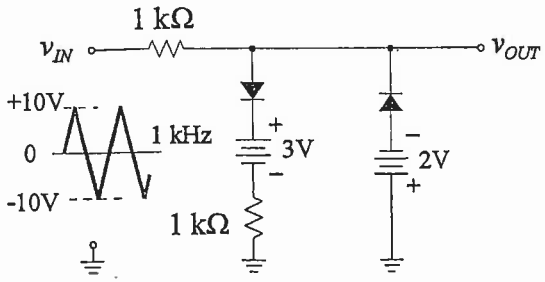


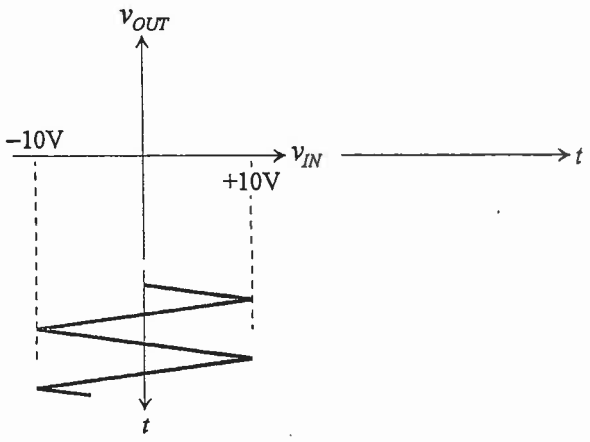
QUESTION (3)

Assuming that the diodes in the following circuit are ideal and with a forward voltage drop of 0.7V.

a) Sketch **accurately** in your answer book the transfer characteristics of this circuit. Include the values for v_{IN} and v_{OUT} at each break-point. (12 points)

b) Sketch **accurately** in your answer book output voltage waveform, v_{OUT}. (8 points)





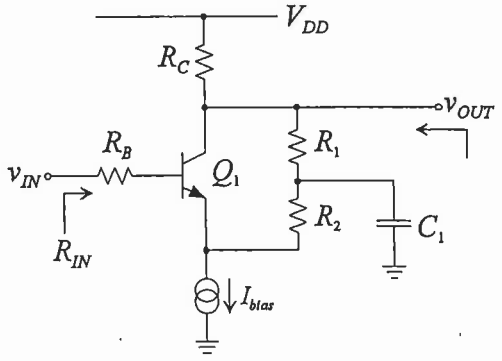
QUESTION (4)

Assuming that transistor Q_1 in this circuit is properly biased to be operating in active mode. You can assume that the value of C_1 is sufficiently large. Determine the expressions for:

(a) The mid-band voltage gain, v_{IN}/v_{OUT}. (10 points)

(b) The input resistance, R_{IN}. (5 points)

(c) The output resistance, R_{OUT}. (5 points)



QUESTION (5)

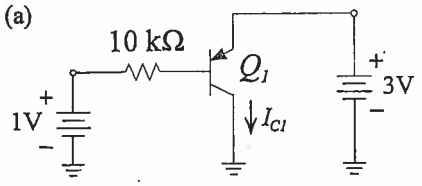
In the following circuits, assume that the BJTs are ideal and have the following characteristics:

$\beta = 100$
$V_{BE(on)} = 0.7$ V
$V_{CE(sat)} = 0.3$ V
$V_A = 100$ V
$V_T = 25$ mV

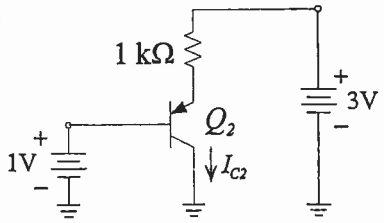
Determine the values of V_E, V_B, V_C and I_C for each circuit. Also specify the mode of operation for all the BJTs.

(20 points)

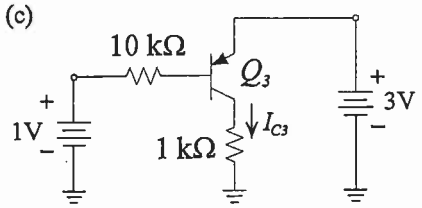
(a)



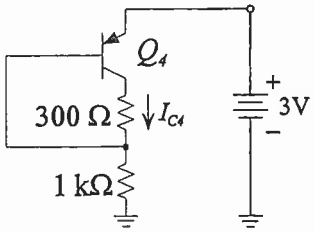
(b)



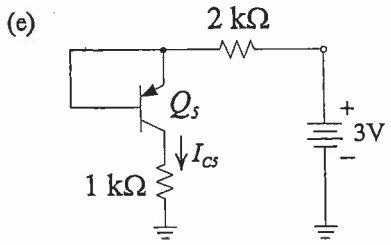
(c)



(d)

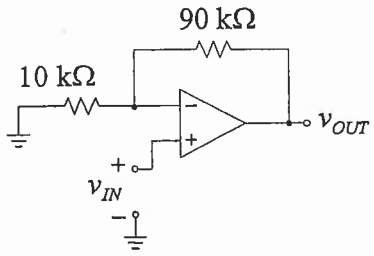


(e)



QUESTION (6)

The op amp in the following is internally compensated and draws an input bias current of 200nA from each input terminal. The non-inverting gain amplifier must be designed to provide a closed-loop gain of 10 and a bandwidth of 10 MHz.



a) What is the minimum open-loop gain, A_v and open-loop bandwidth, f_{3dB} that this op amp must have in order to meet the proposed specifications. (10 points)

b) What is the gain error (from the desired gain of 10) in percentage? (10 points)