National Exams December 2017

16-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**.
   Approved Casio or Sharp calculator is permitted.
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.

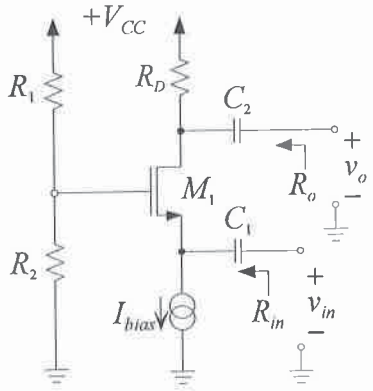
QUESTION (1)

Transistor M_1 in this common base amplifier circuit has the following characteristics:

$V_{TH} = 1$ V

$K = 1$ mA/V^2 $\lambda = 0.1$

Given: $V_{CC} = 10$ V, $I_{bias} = 2$ mA,
$C_1 = C_2 = \infty$,
$R_1 = 10$ kΩ, $R_2 = 5$ kΩ, $R_D = 2$ kΩ



a) Determine the small signal gain, v_o/v_{in}. (12 points)

b) Determine the input resistance, R_{in}. (4 points)

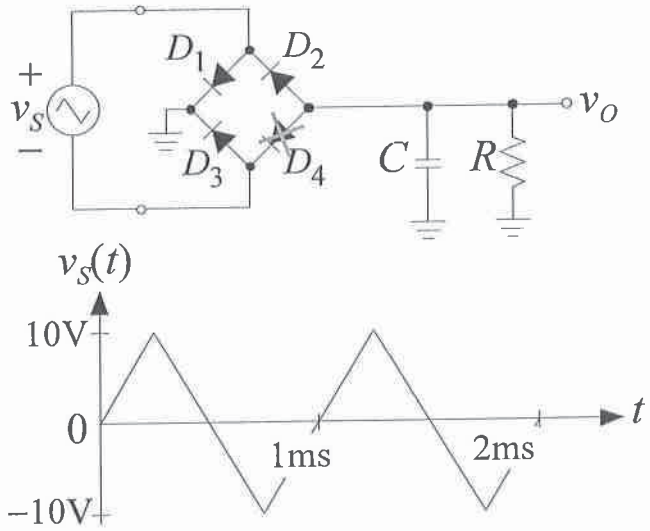
c) Determine the output resistance, R_o. (4 points)

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 (2)



Due to an abnormal operating condition, Diode D_4 in this full-wave rectifier circuit was suddenly destroyed, and stopped conducting in both forward and reverse directions (i.e. open circuit).

Assume that all other diodes are ideal with zero forward voltage drop and that the time constant $RC = 5$ ms.

For a 1 kHz triangular input waveform with a peak amplitude of 10V,

a) Sketch accurately in your answer book the output voltage waveform, v_O in steady state (5 points)

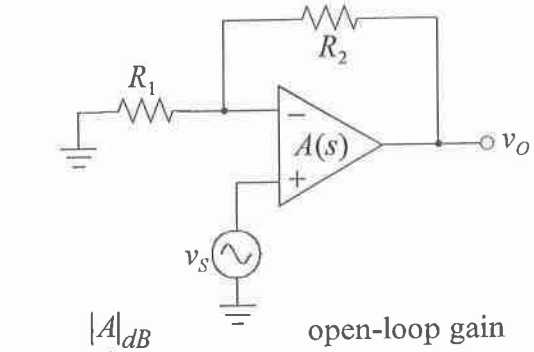
b) What are the peak voltage, V_p and the ripple voltage V_r at the output? (5 points)

c) What is the average DC output voltage at v_o? (5 points)

d) Estimate the time interval, t_{on} during which the diodes conduct during each period. (5 points)

QUESTION (3)

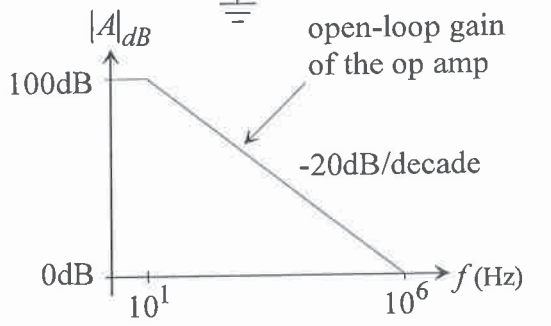
The op amp in the following non-inverting configuration is internal compensated with an open-loop gain as shown. It has a slew rate of 0.5 V/μs. Given that R_1 = 1 kΩ, and R_2 = 100 kΩ.



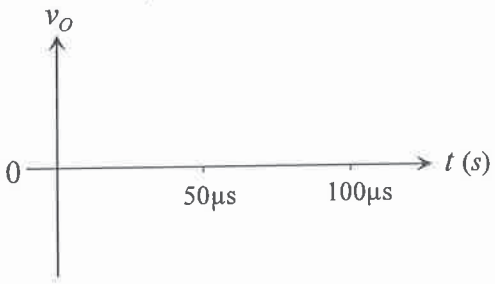
a) What is the f_{3dB} of this non-inverting amplifier? Sketch **accurately** the resulting frequency response. (6 points)

b) If the input is a sinusoidal wave at 10 kHz with an amplitude of 20 mV peak to peak, sketch accurately the output waveform v_O. What is the resulting peak to peak output amplitude? (8 points)

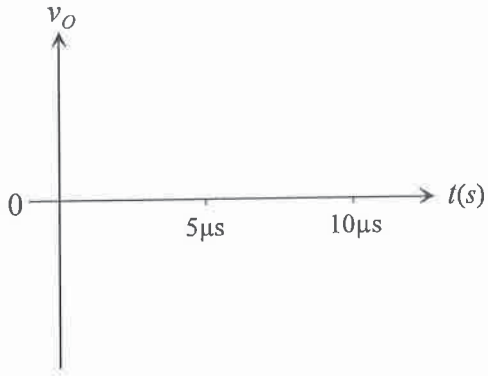
c) If the input is a sinusoidal wave at 100 kHz with an amplitude of 5 V peak to peak, sketch accurately the output waveform v_O. Provide an estimate for the resulting peak to peak output amplitude. (8 points)



(b)



(c)

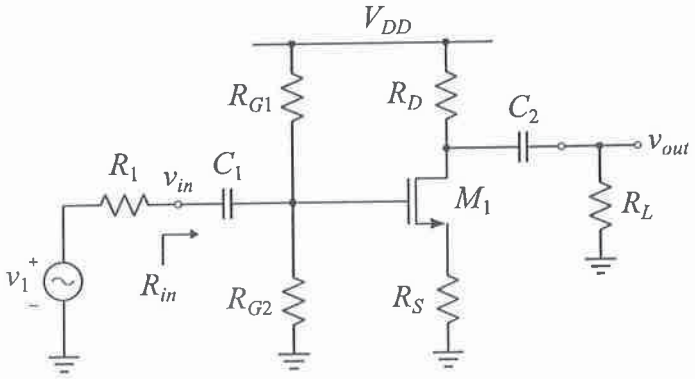


QUESTION (4)

The following is a single stage common source amplifier circuit.
Given: $V_{TH} = 1\text{V}$, $K = 4\ \text{mA/V}^2$, and $\lambda = 0$

a) For a supply voltage $V_{DD} = 15$ V, design the bias circuit such that $I_D = 0.5$ mA, $V_S = 3.5$ V, and $V_D = 6$ V. Please specify the values for R_{G1}, R_{G2}, R_S and R_D. (10 points)

b) Assuming that the equivalent input resistance $R_{in} = 1.67\ \text{M}\Omega$, $R_1 = 100\ \text{k}\Omega$, $R_L = 200\ \text{k}\Omega$, determine the overall small signal voltage gain v_1/v_{out}. (10 points)



Useful formulae: for n-channel MOSFET

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

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

QUESTION (5)

For the transistor circuit below, determine the DC bias voltages and currents V_{B1}, V_{E1}, V_{C1}, V_{B2}, V_{E2}, V_{C2}, I_{C1}, I_{B1}, I_{C2}, and I_{B2}.

Given: $R_{B1} = 100\ \text{k}\Omega$, $R_{B2} = 50\ \text{k}\Omega$, $R_{C1} = 5\ \text{k}\Omega$, $R_{E1} = 3\ \text{k}\Omega$, $R_{C2} = 2.7\ \text{k}\Omega$, $R_{E2} = 2\ \text{k}\Omega$
$V_{CC} = +15\text{V}$
The current gain for both transistors is $\beta = 100$ (20 points)