National Exams December 2012

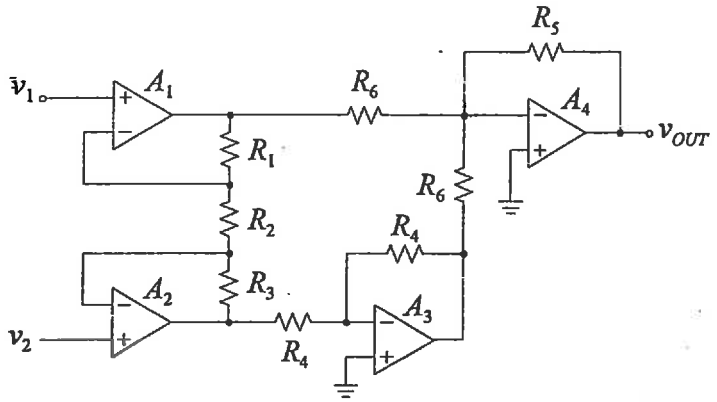
07-Elec-A5, Electronics

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.
   One of two calculators is permitted any Casio or Sharp approved models.
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) a) Derive an expression for the output v_{OUT} as a function of v_1 and v_2 in the following op amp circuit. (12 points)



Given:

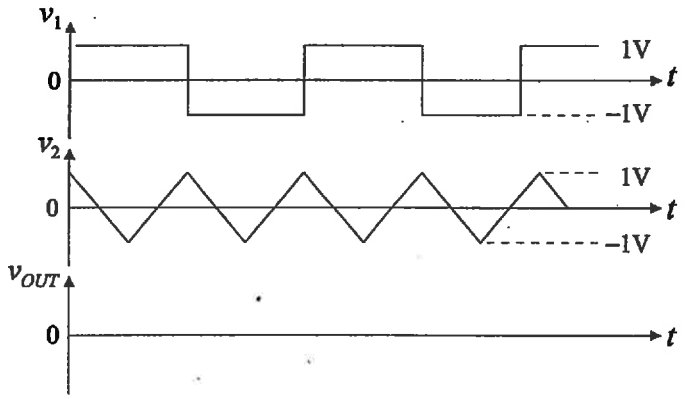
all op amps are ideal,

$R_1, R_2, R_3 = 2\ k\Omega$

$R_4, R_5, = 1\ k\Omega$

$R_6 = 3\ k\Omega$

b) For the input voltages v_1 and v_2 below, sketch accurately (in your answer book) the output waveform for v_{OUT}. (8 points)

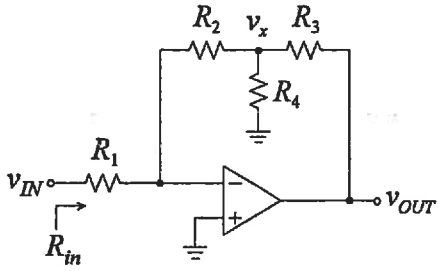


QUESTION (2)

Design this inverting amplifier to have a closed-loop voltage gain of $v_{OUT}/v_{IN} = -100$ V/V, and an input resistance of $R_{in} = 50k\Omega$.

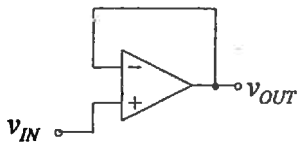
a) Derive and expression for v_{OUT}/v_{IN} (10 points)

b) Provide the resistance values for R_1, R_2, R_3, and R_4. (10 points)



QUESTION (3)

An op amp with a slew rate of 1 V/μs and a unity-gain bandwidth, f_t of 1 MHz is connected in the unity-gain follower configuration.



a) What is the largest possible input voltage step for which the output voltage waveform can still produce an exponential raise and fall waveform? (8 points)

b) For this input voltage, find the 10% to 90% rise time. (6 points)

c) If the input step is 10 times larger than the voltage that you have found in part (a), find the 10% to 90% rise time. (6 points)

Given:

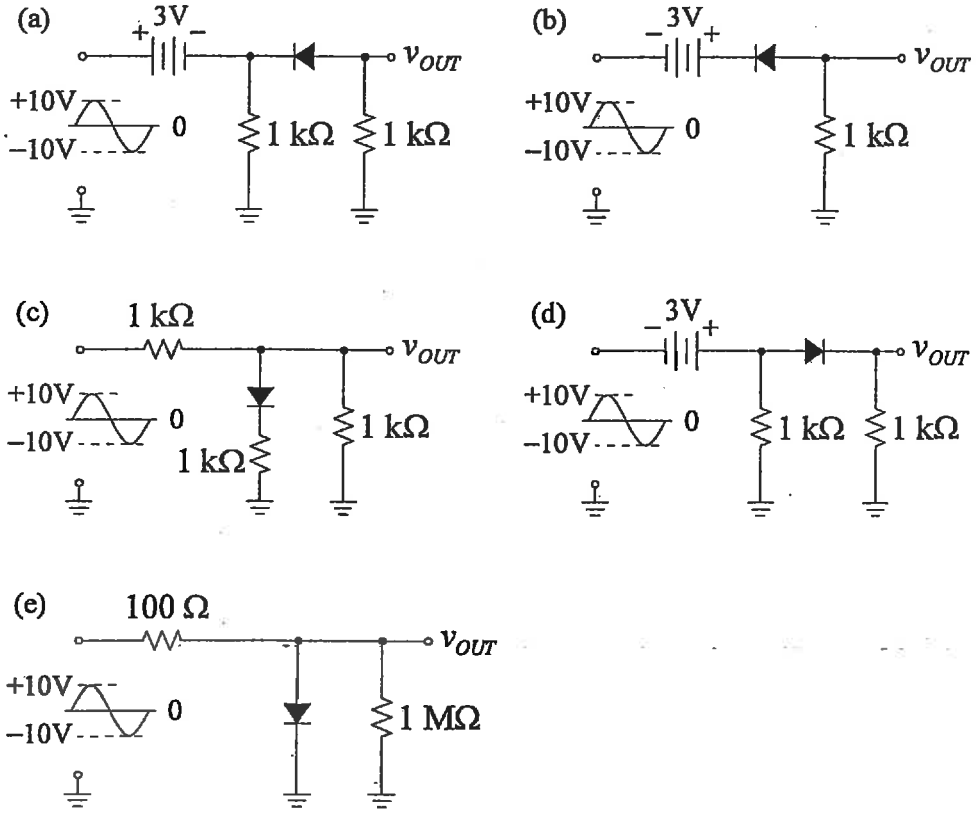
Supply Voltage = ±10 V

Useful Formulae:

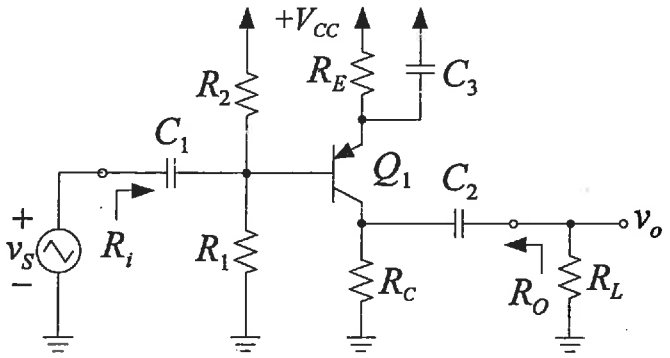
$$\frac{V_{OUT}}{V_{IN}} = \frac{1}{1+s/\omega_t}, \quad v_{OUT}(t) = V\left(1-e^{-\omega_t t}\right)$$

QUESTION (4)

In the following circuits, assume that the diode is ideal and has a forward voltage of 0V. Sketch the output waveform for one complete sine wave input. (20 points)



QUESTION (5)



Assume that the BJT has the following characteristics:

$\beta = 100$
$V_{EB(on)} = 0.7\text{V}$
$V_{EC(sat)} = 0.3\text{V}$
$V_A = \infty$

Given:

$V_{CC} = 10\text{V}$
$R_L = 10\text{k}\Omega$
$R_E = 1\text{k}\Omega$

a) Design this common emitter amplifier circuit to have the following specification:

DC bias current, $I_E = 1$ mA,
A mid-band voltage gain $v_{out}/v_S = 70$ V/V
Provide values for R_1, R_2, and R_C. (15 points)

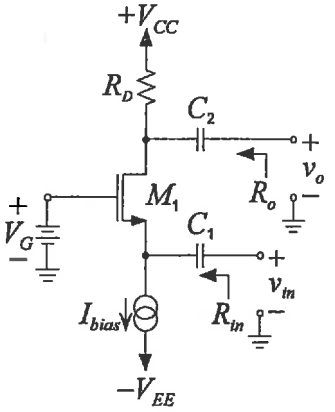
b) What is the equivalent output resistance, R_O? (2 points)

c) What is the maximum undistorted peak to peak output voltage swing at the output? (3 points)

QUESTION (6)

For this circuit,

$V_{TH} = 1$ V
$K = 2$ mA/V^2
$V_{CC} = |V_{EE}| = 10$ V
$R_D = 2$ kΩ
$I_{bias} = 2$ mA
$\lambda = 0.01$ V^{-1}
$V_G = 1$ V
$C_1 = C_2 = \infty$



a) Determine the gain v_O/v_i. (10 points)

b) Determine the input and output resistance, R_{in} and R_o. (5 points)

c) What is maximum peak to peak input voltage that can be applied while still keeping M_1 operating in the saturation region? (5 points)

Useful formulae: for n-channel MOSFET

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

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