National Exams December 2013

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.
   Any non-communicating calculator is permitted.
3. Answer 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)

This is a CMOS inverter. Given that the threshold voltages of the n- and p-channel transistors are V_{Tn} and V_{Tp}, respectively:

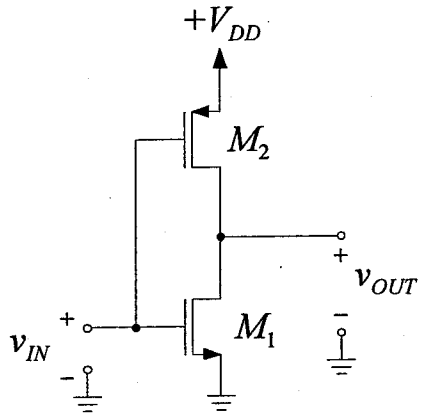
a) Draw the input to output voltage transfer characteristic (VTC) for this inverter. Express and label clearly all voltage levels on the VTC plot. (12 points)

b) Indicate the noise margins NM_L and NM_H on the VTC.

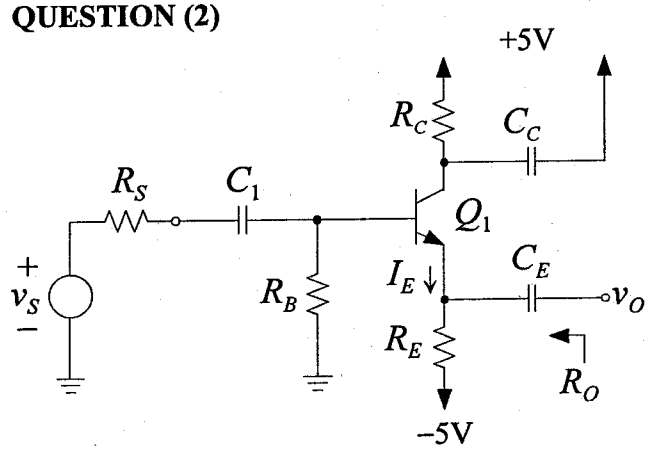
c) Indicate the logic high and low output voltage levels V_{OH}, V_{OL} on the VTC.

d) Indicate the logic high and low input voltage levels V_{IH}, V_{IL} on the VTC.

e) Indicate clearly the mode of operation in each region of the VTC.



QUESTION (2)



Assume that the BJT has the following characteristics:

$\beta = 100$
$V_{EB(on)} = 0.7\text{V}$
$V_{EC(sat)} = 0.3\text{V}$
$V_A = \infty$
$R_S = 100\Omega$
$R_B = 100\Omega$
C_1, C_E, and C_C are large capacitors

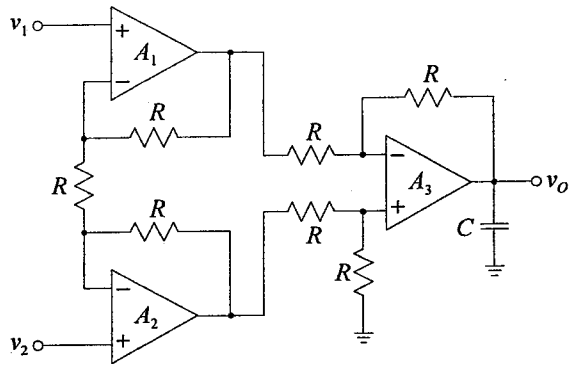
Given: $V_{CC} = 10\text{V}$, $R_L = 10\text{k}\Omega$, and $R_E = 1\text{k}\Omega$,

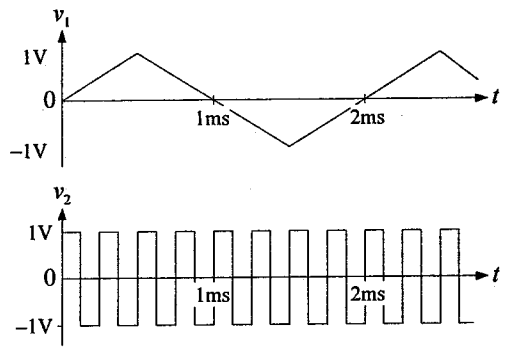
a) Design this common collector amplifier circuit to have DC bias current, $I_E = 2\text{mA}$. Provide values for R_E and R_C. (5 points)

b) What is the equivalent output resistance, R_O? (10 points)

c) What is the maximum undistorted peak to peak output voltage swing at the output? (5 points)

QUESTION (3)





Given that all the op amps are ideal. The op amps' power supply is ±15V. Also, $R = 10\text{k}\Omega$ and $C = 10\mu\text{F}$.

(a) Derive an expression for the output voltage v_O as a function of v_1 and v_2. (10 points)

(b) Sketch the output waveform accurately in your answer book. (10 points)

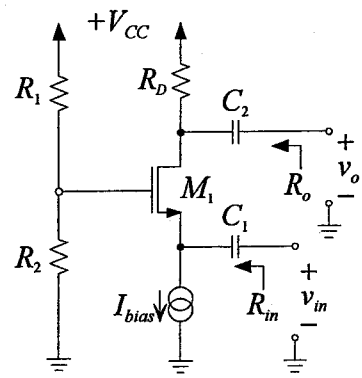
QUESTION (4)

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: $V_{DD} = 10$ 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

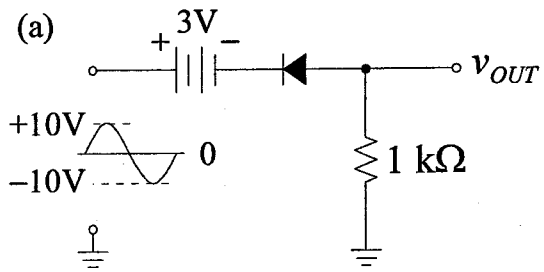
$$i_{DS} = K\left[(v_{GS} - V_{TH})v_{DS} - \frac{1}{2}v_{DS}^2\right] \quad \text{triode region}$$

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

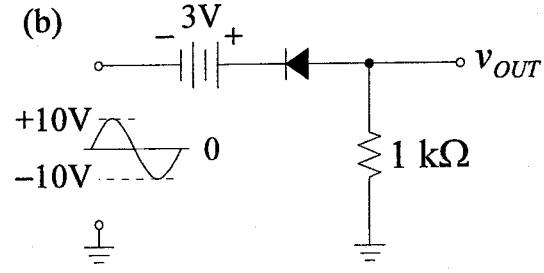
QUESTION (5)

In the following circuits, assume that the diode is ideal and has a forward voltage of 0.7V. Sketch the output waveform for one complete sine wave input. (20 points)

(a)



(b)



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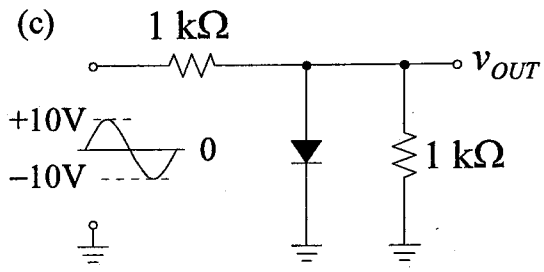

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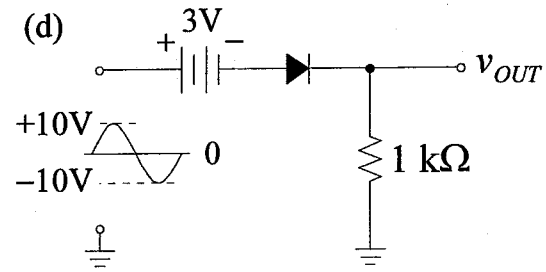

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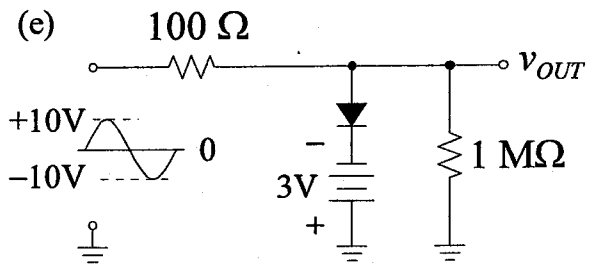
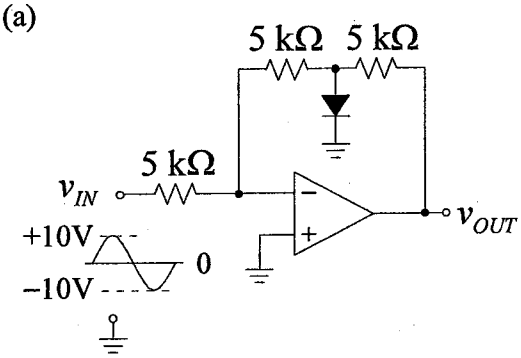


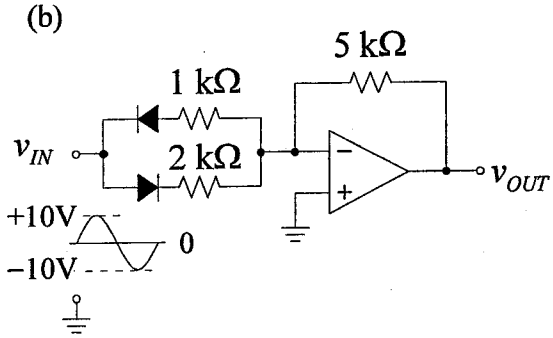
QUESTION (6)

In the following circuits, assume that the diode is ideal and has a forward voltage of 0.7V, and all op amps are ideal and with supply voltages of ±15 V. Sketch the output waveform for one complete sine wave input. (20 points)

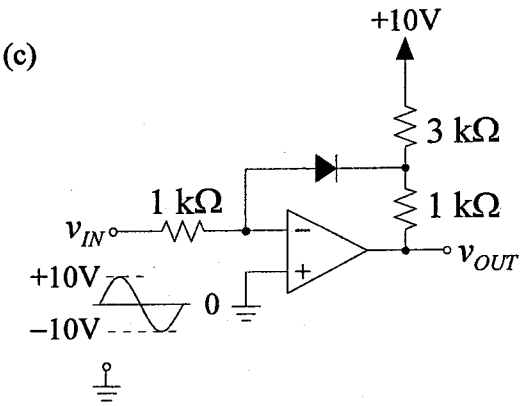
(a)



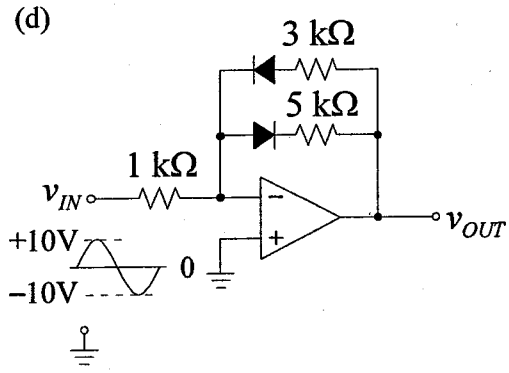
(b)



(c)



(d)



(e)