İZMİR UNIVERSITY OF ECONOMICS
Department of Electrical and Electronics Engineering
EEE 232 Microelectronic Devices and Circuits

Spring 2012/2013

MIDTERM #1
April 6, 2013
120 min

SOLUTIONS

INSTRUCTIONS

- Closed book, closed notes.
- Calculators are allowed, but borrowing is not allowed.
- Your mobile phones must be turned off during the exam.
- You must show your work for all problems to receive full credit; simply providing answers will result in only partial credit, even if the answers are correct.
- Put your name on any additional material that you submit.
- Be sure to provide units.
- Please indicate the number of page where your work is to be continued.
- Do not spend all your time on one problem and on one part and attempt to solve all of them.
- Please sign the honor pledge that is provided below.

Honor Pledge: I have neither given nor received any aid on this exam.

Signed:.....................................

Last Name :........................

Name :........................

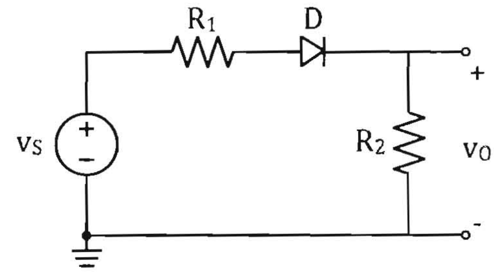
Group :........................

Student No :........................

Q	Points	Grade
1	25	
2	25	
3	25	
4	25	
Total	100	

Q1. (25 pts) Consider the diode circuit given below, with R_1 = 10 kΩ, R_2 = 30 kΩ. Assume that the turn on voltage of the diode is $V_{D(on)}$ = 0.6 V.

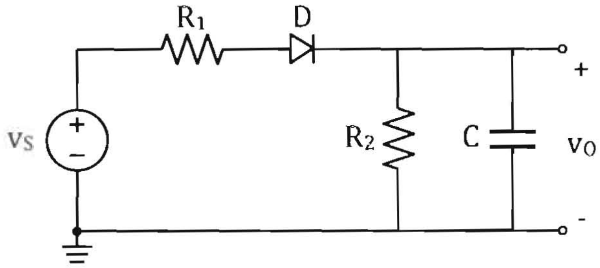
(a) Determine the range of v_s where the diode is ON and the region where the diode is OFF.



(b) Plot the output voltage v_O if

$v_S = 40 \sin 2\pi\cdot 200\, t$ volts $f = 200$ Hz

(c) A capacitor C is added to the output of the circuit given in ***part (a).*** Plot the output voltage waveform. Determine the ripple to peak ratio.



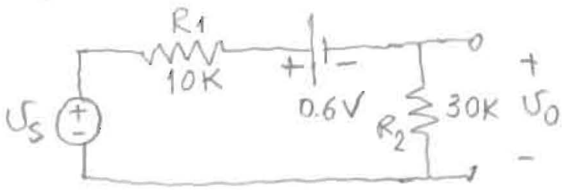
$v_S = 40 \sin 2\pi\cdot 200\, t$ volts

R_1 = 10 kΩ,

R_2 = 30 kΩ.

C = 2 μF

(a) $v_S \geq V_{D(on)}$: D is ON



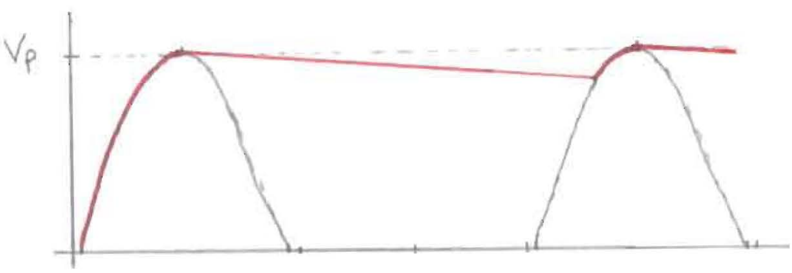
$v_O = (v_S - 0.6)\frac{30}{40}$

$= 0.75\,(v_S - 0.6)$

$v_S < V_{D(on)}$: D is OFF

$v_O = 0$

(b)



— v_O : part(b)

— v_O : part (c)

$V_p = 0.75(40 - 0.6)$

$= 29.55$ V

(c) Plot of v_O is given above. Discharging is over R_2. Then

$$\frac{V_r}{V_p} = \frac{T}{R_2 C} = \frac{1}{f R_2 C} = \frac{1}{(200)(30\times10^3)(2\times10^{-6})} = \frac{1}{12} \simeq 8.33\,\%$$

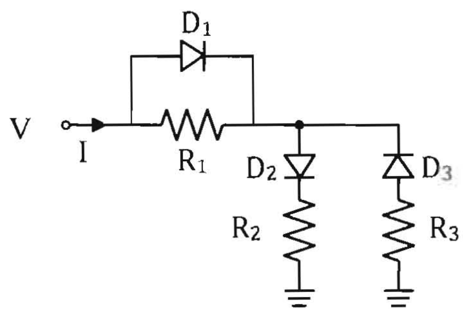
$$V_p = 29.55\text{ V} \Rightarrow V_r = \frac{V_p}{12} = \frac{29.55}{12} = 2.46\text{ V}$$

Q2. (25 pts) Consider the following diode circuits.

(a) Determine and plot the current I as a function of V, i.e., I-V characteristics of the circuit given on the right.

Circuit parameters:

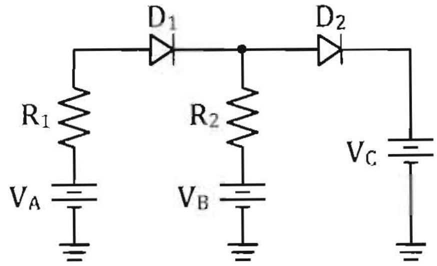
R_1= 150 kΩ
R_2= 150 kΩ
R_3= 300 kΩ



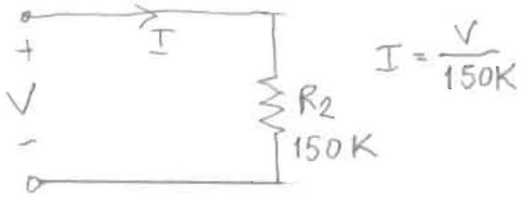
(b) Determine and **verify** the states of the diodes in the circuit given on the right. Assume all diodes are ideal.

Circuit parameters:

V_A= 6 volts
V_B= 2 volts
V_C= 3 volts
R_1= 4 kΩ
R_2= 4 kΩ

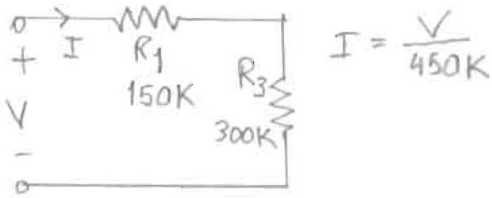


(a) $V \geq 0$: D_1 & D_2 are ON; D_3 is OFF

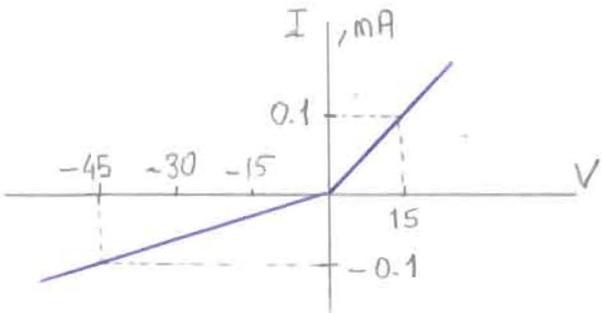


$I = \frac{V}{150K}$

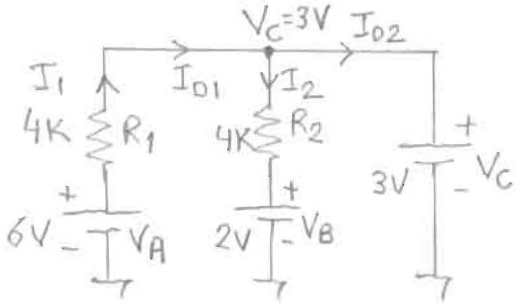
$V < 0$ D_1 and D_2 are OFF; D_3 is ON



$I = \frac{V}{450K}$



(b) Assume D_1 & D_2 are both ON and verify that $I_{D1} \geq 0$ and $I_{D2} \geq 0$.



$I_{D1} = I_1 = \frac{6-3V}{4K} = 0.75\ mA \geq 0$ (1)

$I_2 = \frac{3-2V}{4K} = 0.25\ mA$

$I_{D1} = I_{D2} + I_2 \Rightarrow I_{D2} = I_{D1} - I_2$

$I_{D2} = 0.75 - 0.25\ mA$

$I_{D2} = 0.5\ mA \geq 0$ (2)

(1) & (2) verify that D_1 & D_2 are ON.

Q3. (25 pts) .

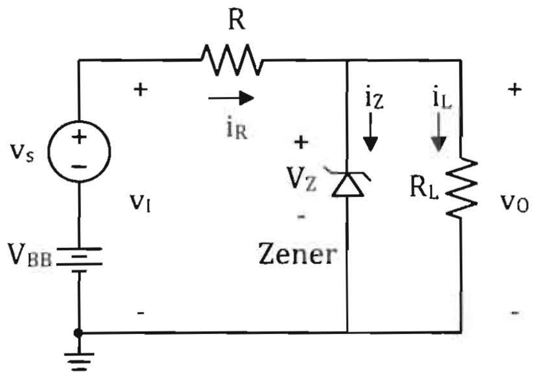
a) Consider the zener diode voltage regulator given below.

Assume the circuit parameters are:

V_{BB} = 12 V, $v_S(t)$ = 1 cos $2\pi 50$ t volts ,

R = 80 Ω, R_L = 300 Ω,

Zener diode: V_Z = 8 V, r_z = 100 Ω.



i. Determine the DC and AC small signal components of the output voltage v_O.

ii. Plot v_I and v_O.

iii. Compare the two terms:

$$\left.\frac{V_{peak(ripple)}}{V_{DC}}\right|_{input} \text{ and } \left.\frac{V_{peak(ripple)}}{V_{DC}}\right|_{output}$$

iv. Determine the minimum value of R_L so that zener diode is still operated in the zener diode region.

v. What is the output voltage v_O when R_L is removed (not connected)? What is the current i_Z then?

b) Consider the circuit given on the right.

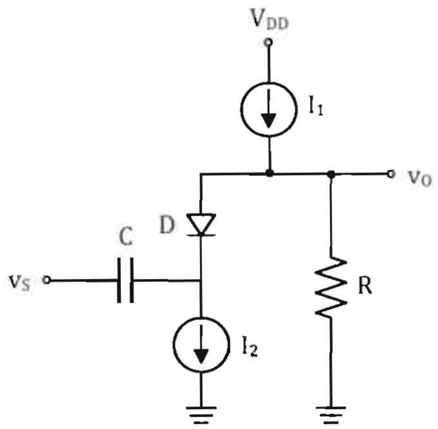
The circuit parameters

I_1 = 10 mA, I_2 = 9 mA, R = 0.25 kΩ

v_s = V_P sin ωt volts

Diode Parameters

$V_{D(on)}$ = 0.7 V, V_T = 26 mV at room temperature



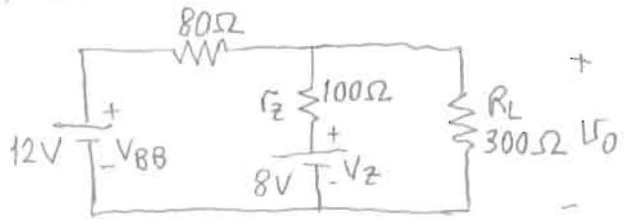
i. Determine the DC component of the output voltage V_O.

ii. Determine the AC small signal component v_o of the output voltage, assuming the capacitor C is short circuit at the frequency ω.

iii. Determine the total output voltage v_O .

iv. Determine the limit on V_p for proper small signal modeling.

(a) DC Analysis : Zener is always operated in zener region

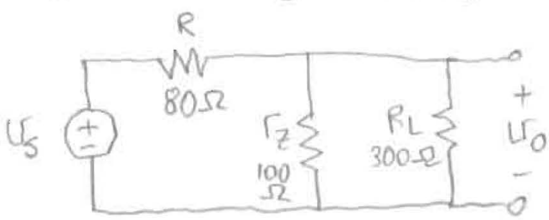


Using superposition

$$V_O = \frac{100//300}{80+100//300}\cdot 12 + \frac{80//300}{100+80//300}\, 8$$

$$= \frac{75}{155}\cdot 12 + \frac{63}{163}\cdot 8 = 8.9\text{ V}$$

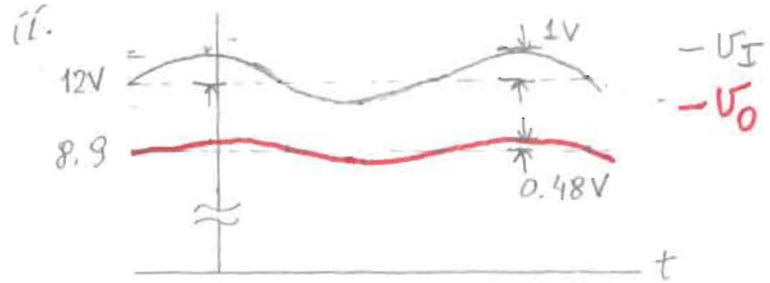
AC small signal analysis



$$v_o = \frac{100//300}{80+100//300} v_s = \frac{75}{155} v_s$$

$$= 0.48 \cos 2\pi 50 t \text{ volts}$$

ii.



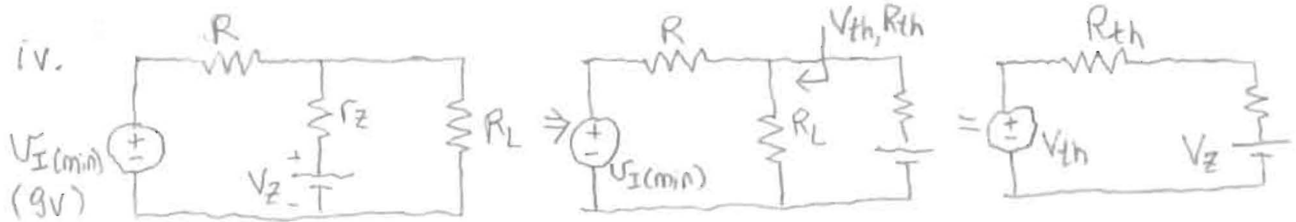
$v_I = V_{BB} + v_s$

$= 12 + 1\cos 2\pi 50t$ volts

$v_O = 8.9 + 0.48\cos 2\pi 50t$ volts

iii. $\left.\frac{V_{peak(ripple)}}{V_{DC}}\right|_{input} = \frac{1}{12} = 8.33\%$; $\left.\frac{V_{peak(ripple)}}{V_{DC}}\right|_{output} = \frac{0.48}{8.9} = 5.4\%$

iv.

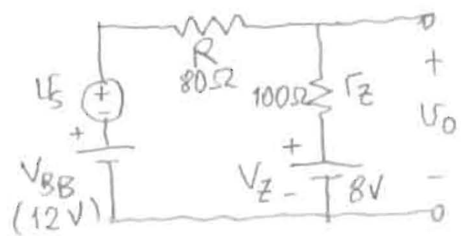


Zener is in zener region if

$V_{th} \geq V_Z \Rightarrow \frac{R_L}{R_L + R} v_{I(min)} \geq V_Z \Rightarrow \frac{R_L}{R_L + 80}(9V) \geq 8V$

$\frac{R_L}{R_L + 80} \geq \frac{8}{9} \Rightarrow 9R_L \geq 8R_L + 640 \Rightarrow R_L \geq 640\Omega$

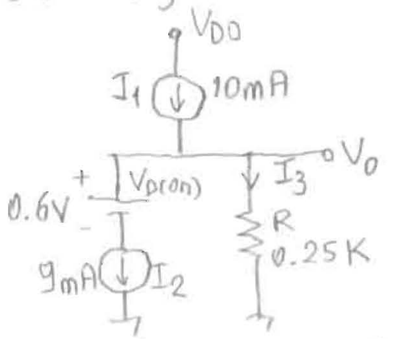
v. When R_L is removed, using superposition



$v_O = \frac{100}{180}(12 + 1\cos 2\pi 50t) + \frac{80}{180} \cdot 8$

$= 10.2 + 0.55\cos 2\pi 50t$ volts

b) i. DC Analysis

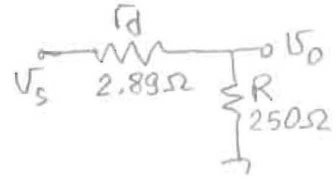


$I_3 = 10 - 9 = 1$ mA

$V_O = I_3 R = 0.25$ V

ii. AC small signal analysis

$r_d = \frac{26\,mV}{I_2} = \frac{26\,mV}{9\,mA} = 2.89\Omega$



$v_o = \frac{250}{252.89} v_s$

$= 0.99 V_p \sin\omega t$ V

iii. $v_O = 0.25 + 0.99 V_p \sin\omega t$ volts

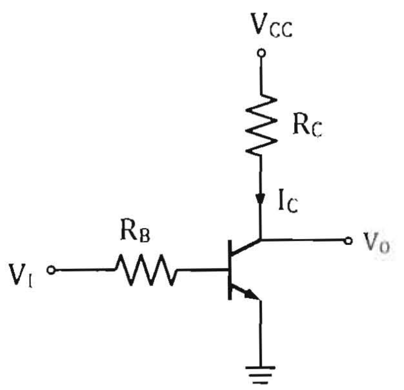
iv. For linear assumption

$v_d << 2V_T = 52$ mV $\Rightarrow v_d \leq 5.2$ mV

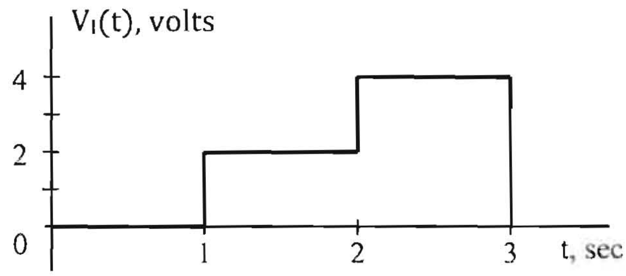
$v_d = \frac{2.89}{252.89} V_p \leq 5.2$ mV

$V_p \leq 455$ mV

Q4. (25 pts) Consider the BJT circuit given below.

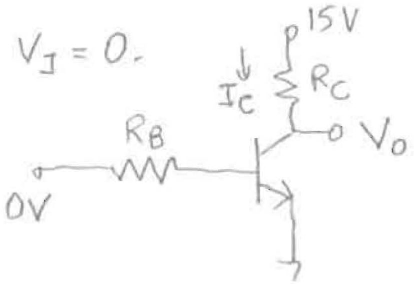


Circuit Parameters	*Transistor Parameters*
$V_{CC} = 15$ V	$V_{BE(on)} = 0.7$ V
$R_B = 100$ kΩ	$\beta = 100$
$R_C = 10$ kΩ	$V_{CE(sat)} = 0.2$ V



(a) Determine the state of the transistor and the currents I_B, I_C and V_O for each input level. Verify your result.
(b) Plot $V_O(t)$.

(a) $V_I = 0$.

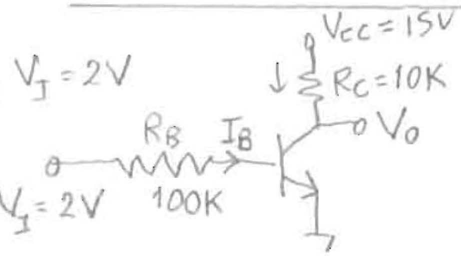


BJT is OFF (both junctions are OFF)

$V_{BE} = 0 < V_{BE(ON)} = 0.7V$
$V_{BC} = 0 - 15 = -15V < V_{BC(ON)}$
} BE and BC junctions are OFF, then BJT is OFF

$I_C = 0 \Rightarrow V_0 = V_{CC} = 15V$

(b) $V_I = 2V$



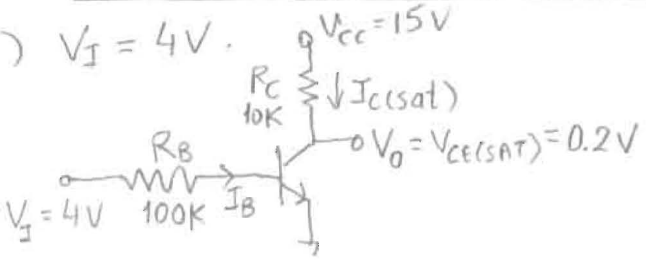
Assume BJT is forward active (FA) and use $I_C = \beta I_B$ and verify $V_{CE} \geq V_{CE(SAT)}$

$$I_B = \frac{V_I - V_{BE(on)}}{R_B} = \frac{2 - 0.7}{100K} = \frac{1.3V}{0.1M} = 13\mu A$$

$$I_C = \beta I_B = (100)(13\mu A) = 1300\mu A = 1.3mA$$

$V_0 = V_{CE} = V_{CC} - R_C I_C = 15 - (10K)(1.3mA) = 2V \geq V_{CE(sat)}$ (FA is OK)

(c) $V_I = 4V$.



Assume BJT is SAT, calculate $I_{C(sat)}$ and show that $\beta I_B \geq I_{C(sat)}$

$$I_B = \frac{V_I - V_{BE(on)}}{100K} = \frac{4 - 0.7}{0.1M} = 33\mu A$$

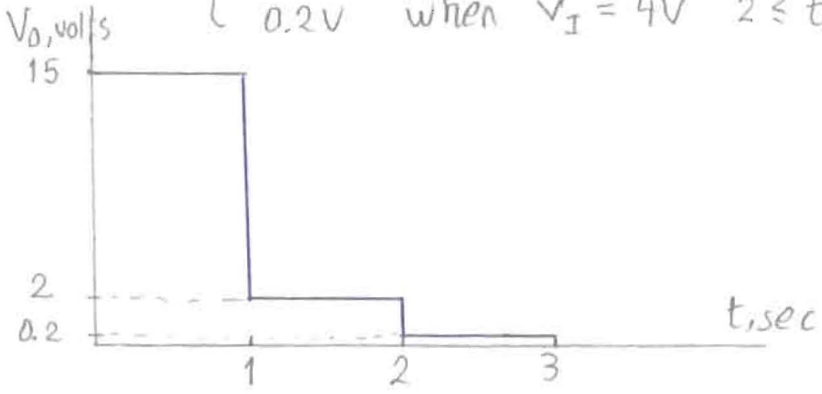
$$I_{C(SAT)} = \frac{V_{CC} - V_{CE(sat)}}{R_C} = \frac{15 - 0.2}{10K} = 1.48 mA$$

$\beta I_B = (100)(33\mu A) = 3300\mu A = 3.3 mA$
$I_{C(SAT)} = 1.48 mA$
} $\beta I_B \geq I_{C(SAT)}$ SAT is verified

Then $V_0 = V_{CE(sat)} = 0.2V$

b) Summary

$$V_O = \begin{cases} 15\,V & \text{when } V_I = 0V \;;\; 0 \leq t < 1\,sec \\ 2\,V & \text{when } V_I = 2V \quad 1 \leq t < 2\,sec \\ 0.2\,V & \text{when } V_I = 4V \quad 2 \leq t < 3\,sec \end{cases}$$



Q1 25

(a) Region ~~5~~ 6

Output

(b) Plot 6

(c) Plot ~~6~~ ~~7~~ 6

$\frac{V_r}{V_p}$ ~~6~~ 7

Q2

(a) Plot

R_2 13

$R_1 + R_3$

(b) D_1 & D_2 ON 12

Q3

(i) V_0 4

(ii) V_0 4

(iii) $\frac{V_{PR}}{V_{DC}}$ 4 (15)

(iv) $R_{L,min}$ 2

(v) V_0 1

~~Q4~~

(b) i. V_0 3

ii. AC 4 (10)

iii. V_0 Total 2

iv. $V_{p,max}$ 1

Q4

a) i. $V_I = 0$ OFF 6

ii. $V_I = ..$ FA 8

iii. $V_I = ..$ SAT 6

b) plot 5