Solution & Marking scheme

Ryerson University

Department of Electrical and Computer Engineering

ELE404 (Electronic Circuits I)

Midterm Examination (P2013)

May 2013

Duration: 120 minutes

Examiner: Prof. A. Yazdani

Name:...

[Print Last Name] [Print First Name]

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

NOTES

1. This is a closed-book examination. No aids other than basic calculators are permitted.

2. The examination paper is comprised of **FOUR QUESTIONS**, *each* question worth as indicated in the following Table. The entire examination is worth *100* marks.

Question #	Maximum Mark	Mark Earned
1	**30**	
2	**30**	
3	**10**	
4	**30**	
Total	100	

3. Answer all questions in the booklet, within the blank spaces provided under each question in this booklet. Use the reverse if needed.

4. ***No Questions to be asked during the examination***. *If in doubt about any question, clearly state your assumptions in answering the question.*

5. Part marks for an answer will only be given if the *correct methodology* is clearly shown.

6. **DO NOT DETACH** any pages from this booklet.

Q1: In the diode circuit of **Fig. 1**, the diodes assume a constant voltage drop of 0.7 V if they conduct, and $R_1 = 1.2\ k\Omega$, $R_2 = 2.7\ k\Omega$, $R_3 = 1.8\ k\Omega$, and $R_4 = 3.3\ k\Omega$. Showing all the work, determine the conduction states ("on" or "off") of the diodes, and calculate the voltages V_1 through V_3. Summarize your findings in **Table 1**.

Each answer worth 5 marks provided that they are supported by the calculations of the next page, especially the checkings. Otherwise, deduct considerable mark

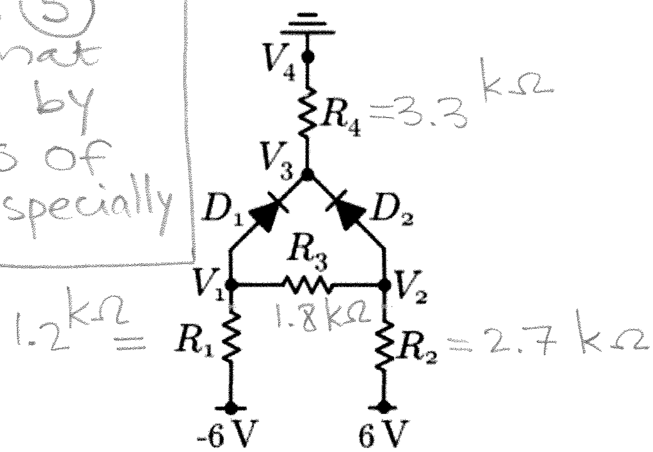

Fig. 1: Diode circuit of Q1.

Table 1: Results of the diode circuit of Q1. [each five marks]

D_1	D_2	V_1 [V]	V_2 [V]	V_3 [V]	V_4 [V]
OFF	OFF	−3.47	0.316	0	0

Systematically, we would solve the circuit for each of the following assumed states, and check the corresponding conditions, until we found the correct state:

State#	D1	D2
1	ON	ON
2	ON	OFF
3	OFF	ON
4	OFF	OFF

However, we show here that state #4 is the right state and consistent with the conditions:

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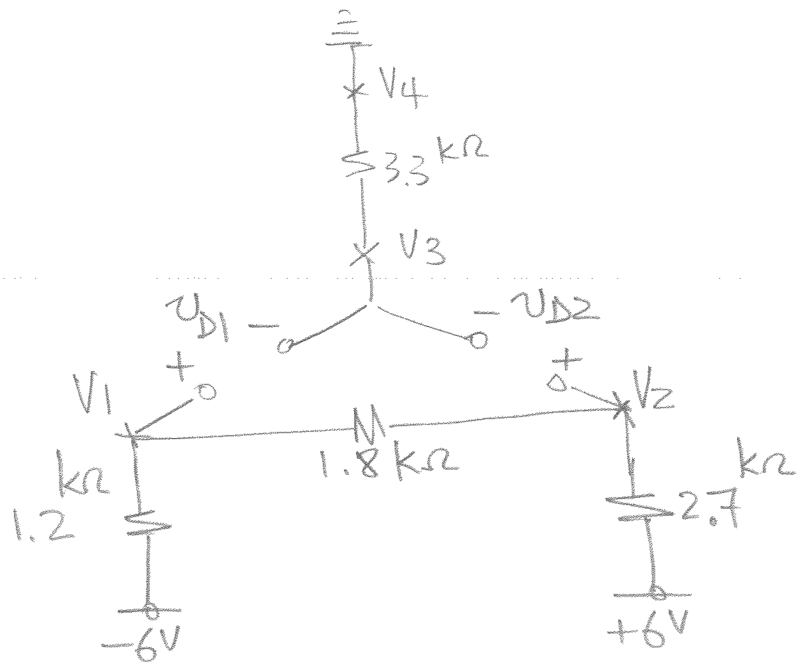
State #4

D1: OFF, D2: OFF



$V_4 = 0$ (the ground)

$V_3 = V_4 = 0$ due to zero current in R_4

$$V_1 = \frac{-6}{1.2+1.8+2.7} \times (1.8+2.7) + \frac{6}{1.2+1.8+2.7} \times 1.2 = -3.47^V$$

$$V_2 = \frac{6}{1.2+1.8+2.7} \times (1.8+1.2) + \frac{-6}{1.2+1.8+2.7} \times 2.7 = 0.316^V$$

Checking

$v_{D1} = V_1 - V_3 = -3.47 - 0 = -3.47^V < 0.7^V$ ✓ diode "off"

$v_{D2} = V_2 - V_3 = 0.316 - 0 = 0.316^V < 0.7^V$ ✓ diode "off"

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Q2: Assuming ideal diodes, derive and mathematically express the transfer characteristic ($v_I - v_O$ characteristic) of the diode circuit of **Fig. 2a**. Then, plot the transfer characteristic on **Fig. 2b**.

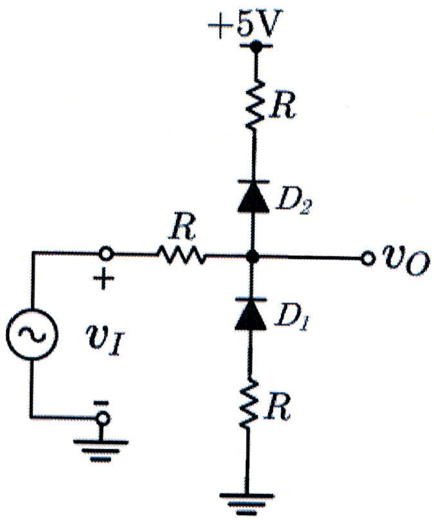

Fig. 2a: Diode circuit of Q2.

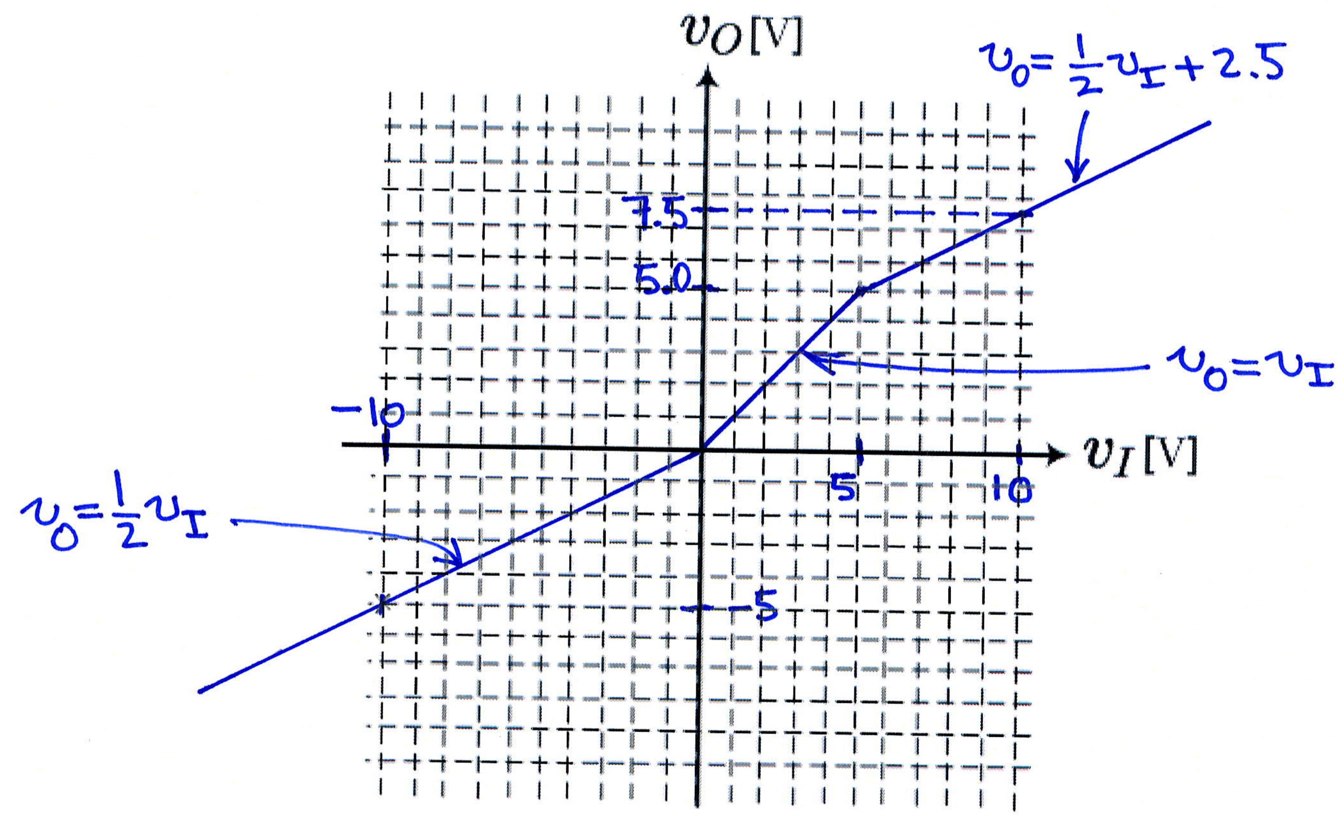

Fig. 2b: Transfer characteristic of the diode circuit of Fig. 2a.

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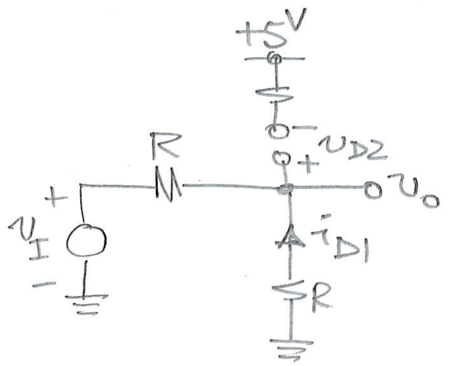
start with $v_I \to -\infty$ (very negative)

D1: ON D2: OFF



$$v_O = \frac{v_I}{R+R} \times R = \boxed{\frac{1}{2} v_I}$$

$$i_{D1} = -\frac{v_I}{R+R} \quad (1)$$

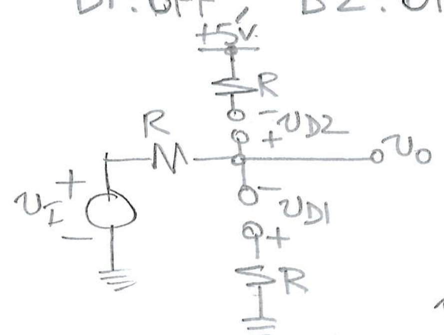
$$v_{D2} = v_O - 5 = \frac{1}{2} v_I - 5 \quad (2)$$

$$\left.\begin{array}{l} i_{D1} > 0 \xrightarrow{(1)} \frac{-v_I}{R+R} > 0 \Rightarrow v_I < 0 \checkmark \\ v_{D2} < 0 \xrightarrow{(2)} \frac{1}{2} v_I - 5 < 0 \Rightarrow v_I < 10 \end{array}\right\} \Rightarrow \boxed{-\infty < v_I < 0}$$

5

Then, if $v_I > 0$

D1: OFF, D2: OFF



$$\boxed{v_O = v_I}$$

$$v_{D1} = 0 - v_O = -v_O = -v_I \quad (3)$$

$$v_{D2} = v_O - 5 = v_I - 5 \quad (4)$$

$v_{D1} < 0 \xrightarrow{(3)} -v_I < 0 \Rightarrow v_I > 0$ (which holds)

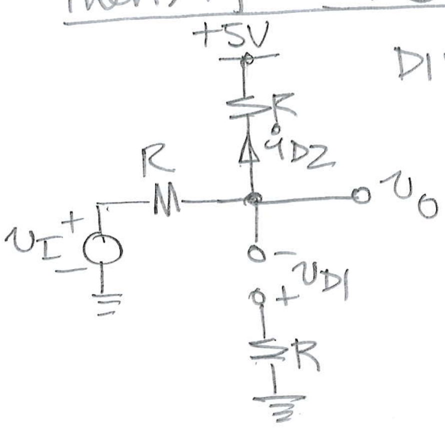
$v_{D2} < 0 \xrightarrow{(4)} v_I - 5 < 0 \Rightarrow v_I < 5$

Therefore, $v_O = v_I$ if $\boxed{0 < v_I < 5}$

5

Then, if $v_I > 5$

D1: OFF, D2: ON



$$v_O = \frac{v_I}{R+R} \times R + \frac{5}{R+R} \times R$$

$$\Rightarrow \boxed{v_O = \frac{1}{2} v_I + 2.5}$$

$$v_{D1} = 0 - v_O = -\frac{1}{2} v_I + 2.5 \quad (5)$$

$$i_{D2} = \frac{v_O - 5}{R} = \frac{v_I - 5}{2R} \quad (6)$$

5

$v_{D1} < 0 \overset{(5)}{\Rightarrow} -\frac{1}{2}v_I + 2.5 < 0 \Rightarrow v_I > 5$ (which holds)

$i_{D2} > 0 \overset{(6)}{\Rightarrow} \frac{v_I - 5}{2R} > 0 \Rightarrow v_I - 5 > 0 \Rightarrow v_I > 5$ (which hods)

So, $v_O = \frac{1}{2}v_I + 2.5$ if $\boxed{v_I > 5}$

The characteristic, then, is

$$v_O = \begin{cases} \frac{1}{2}v_I & \text{if} \quad v_I < 0 \\ v_I & \text{if} \quad 0 < v_I < 5 \\ \frac{1}{2}v_I + 2.5 & \text{if} \quad v_I > 5 \end{cases}$$

The plot consists of 3 lines; as depicted on Fig. 2b.

Mark breakdown

- Each region with the corresponding expression for v_O worth 5 marks — 3×5
- Each line on the plot of Fig. 2b worth 5 marks. — 3×5

total 30 marks

Q3: For the clamping circuit of **Fig. 3a**, assume that the diode exhibits a constant forward voltage drop of 0.7 V, the capacitor has no initial charge, and the input signal v_I is zero until the instant $t = t_0$. Thereafter, v_I is given the voltage waveform shown by the topmost graph of **Fig. 3b**. Plot the waveforms of the voltages v_O and v_C, on **Fig. 3b**.

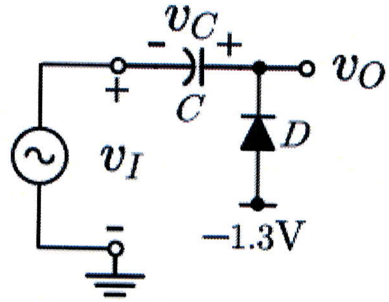
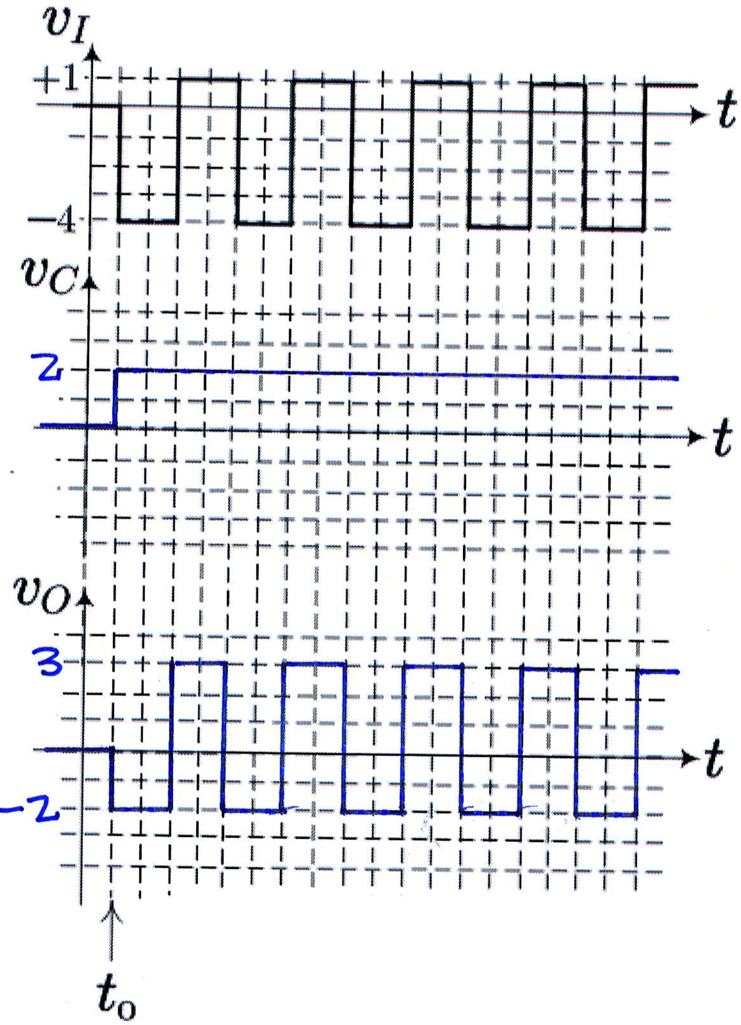


Fig. 3a: Clamping circuit of Q3.

Explanations are not required; only the waveforms are to be marked.

Explanations are, however, given on the next page.



(5) marks

(5) marks

Fig. 3b: Voltage waveforms of the clamping circuit of Fig. 3a.

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Explanation of the waveforms

Initially, the input, the capacitor voltage, and the output are all zero. At $t=t_0$, the input jumps down by 5^V (to -4^V), and, since the capacitor's voltage tends to remain at its initial value, the output also jumps down. Once this happens, the diode turns on and clamps the output voltage to -2^V ($-1.3^V - 0.7^V$). Therefore, the capacitor voltage jumps to $v_O - v_I = -2-(-4)$ or $+2^V$. Thereafter, the capacitor voltage remains constant at 2^V (Since it neither charges nor gets discharged, and the output voltage will always be 2^V more than the input voltage. That is why from $t=t_0$ onwards, v_O is shifted-up version of v_I, by 2^V.

Q4: In the bridge rectifier of **Fig. 4**, the source voltage v_I is a 60-Hz, 24-Vrms sinusoid. Determine the ***reading of a DC voltmeter*** of the output voltage v_O, under each of the following conditions:

(4a) Only the load R_L is connected (the smoothing capacitor C has been removed);
(4b) Only C is connected (R_L has been removed);
(4c) $R_L = 1.0\ k\Omega$ and $C = 100\ \mu F$;
(4d) $R_L = 1.0\ k\Omega$ and $C = \infty$;
(4e) Same as **(4a)** but with D_3 and D_4 removed; and
(4f) Same as **(4b)** but with D_3 and D_4 removed.

Assume that the diodes are ideal and the meter does not draw any current. Support your answers by calculations and/or explanations. Summarize your results in **Table 4**.

Table 4: results of the circuit of Q4.

Answer of (4a)	Answer of (4b)	Answer of (4c)	Answer of (4d)	Answer of (4e)	Answer of (4f)
21.6	33.9	32.5	33.9	10.8	33.9

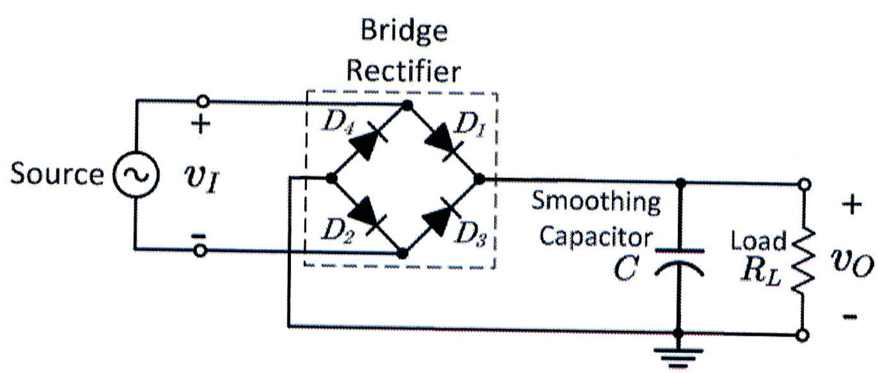

Fig. 4: Bridge rectifier of Q4.

Each item worth 5 marks if supported by the analyses of the next page. 6×5 = 30 marks total

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4a) C: out R_L: in

The circuit is a full-wave rectifier with pure resistive load:

$$V_m = 24 \times \sqrt{2} = 33.9^V \text{ (peak value of } v_I\text{)}$$

A DC voltmeter shows the average voltage:

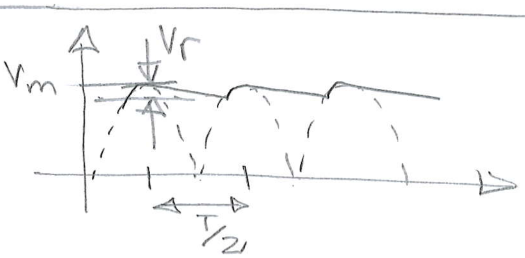
$$\overline{v_O} = \frac{2V_m}{\pi} = \frac{2 \times 33.9}{\pi} = \boxed{21.6^V}$$

4b) C: in R_L: out

The circuit turns into a peak detector; that is, the capacitor gets charged to the peak voltage V_m:

$$\overline{v_O} = V_m = \boxed{33.9^V}$$

4c) C=100μF, R_L=1.0kΩ



V_m: peak voltage

V_r: peak-to-peak ripple

$\overline{v_O} = V_m - \frac{1}{2}V_r$ (average)

Use equation (4.33) to calculate V_r:

$$V_r = \frac{V_m}{2fCR} = \frac{33.9}{2 \times 60 \times 100 \times 10^{-6} \times 1000} = 2.83^V$$

$$\overline{v_O} = V_m - \frac{1}{2}V_r = 33.9 - \frac{1}{2} \times 2.83 = \boxed{32.5^V}$$

4d) C=∞, R_L=1.0kΩ

Based on Eq. (4.33), if C=∞, then V_r=0 (no ripple). Hence,

$$\overline{v_O} = V_m = \boxed{33.9^V}$$

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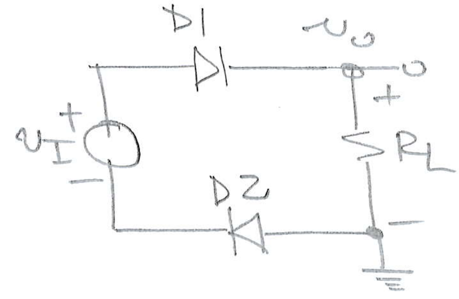
4e) C: out, R_L: in, D3 & D4: out

This turns the rectifier to a half-bridge rectifier



$$\bar{v}_O = \frac{V_m}{\pi} = \frac{33.9}{\pi} = \boxed{10.8^V}$$

4f) C: in, R_L: out, D3 & D4: out

The circuit becomes a half-wave peak detector, still capturing the peak

$$\bar{v}_O = V_m = \boxed{33.9^V}$$