Name: ______________________________ (please print)

Signature: ___________________________

ECE 3355 – Exam #2
November 2, 2019

Keep this exam closed and face up until you are told to begin.

1. This exam is closed book, closed notes. You may use one 8.5" x 11" crib sheet, or its equivalent.
2. Show all work on these pages. Show all work necessary to complete the problem. A solution without the appropriate work shown will receive no credit. A solution which is not given in a reasonable order will lose credit.
3. Show all units in solutions, intermediate results, and figures.
4. If the grader has difficulty following your work because it is messy or disorganized, you will lose credit.
5. Do not use red ink. Do not use red pencil.
6. You will have 90 minutes to work on this exam.

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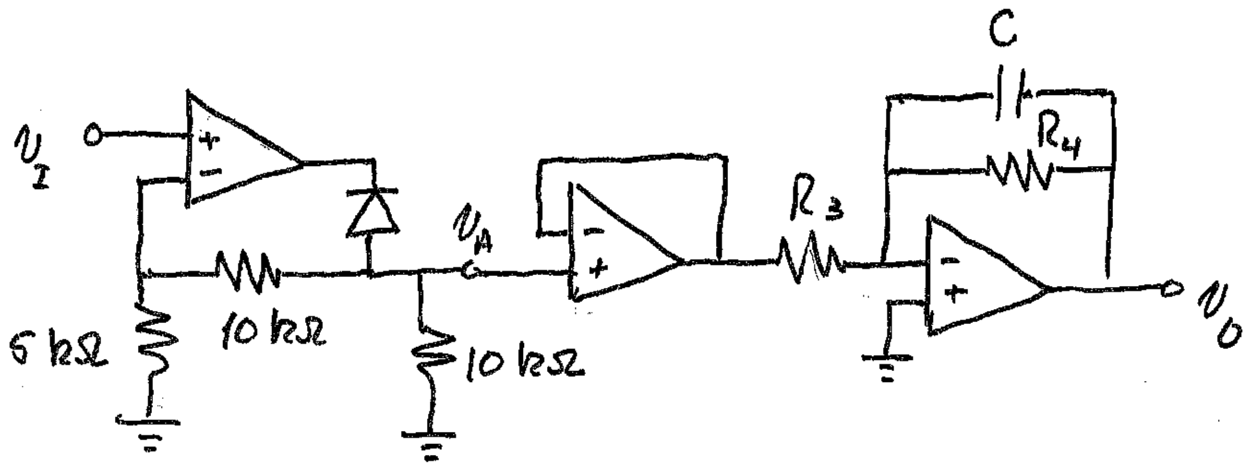
In this exam, you are asked to draw several graphs. To receive any credit at all for these graphs, they must be neat and easily readable. The axes must clearly labeled, and must include tick-marks and units. High precision is not necessary, but they should be accurate. Hint: graphs that occupy a 1 in. x 1 in. space are not likely to be readable.

Room for extra work

1. (30 points) The circuit below is intended to be an ac voltmeter. It uses a modified super-diode, a buffer amplifier, and an active filter. The diode model is $V_{th} = 0.7$ V, $r_d = 0$, $I_S = 0$. The input signal $v_I = 1.5 \sin(1000\, t)$ [V]. The average value of the waveform v_A is given as $\langle v_A \rangle = -3.0/\pi$.

a) Make a sketch of the voltage v_A as a function of time for at least one cycle. Be sure to clearly indicate the amplitude.
b) Choose values for the capacitor C and resistors R_3, R_4 so that (i) only the dc component of the waveform v_A appears at the output v_O, and ii) the gain of the filter stage is 20 dB.



Room for extra work

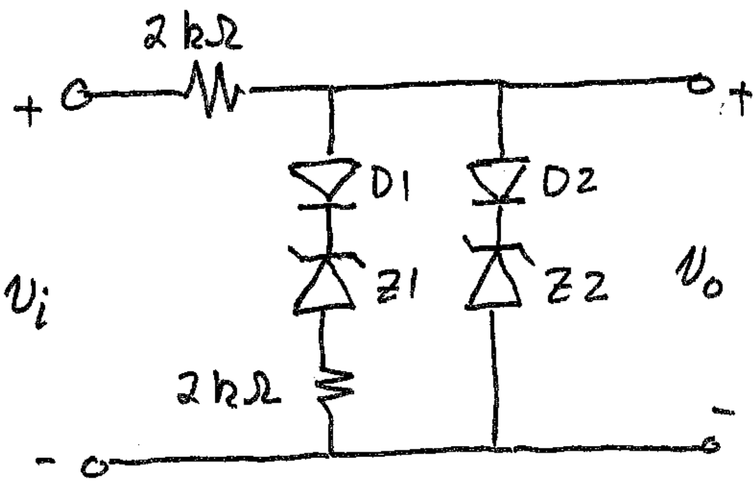
2. (35 points)

a) Draw the transfer characteristic (v_O as a function of v_i) for the circuit shown below. Only $v_i > 0$ needs to be considered. The diodes are characterized as follows.

D1, D2: $V_{th} = 0.6$ V, $I_S = 2.55$ mA, $r_d = 0$
Z1: Vth = 0.6 V (forward bias); $V_{Z1} = 2.4$ V (reverse bias), $r_Z = 0$
Z2: Vth = 0.6 V (forward bias); $V_{Z2} = 5.9$ V (reverse bias), $r_Z = 0$

b) A sinusoidal signal with a dc component of 4.0 V and an ac amplitude of 1 V is applied to the circuit at the input. Sketch the output as a function of time for at least one cycle. Is the output a reproduction of the input, or is there distortion in the output? How do you know?

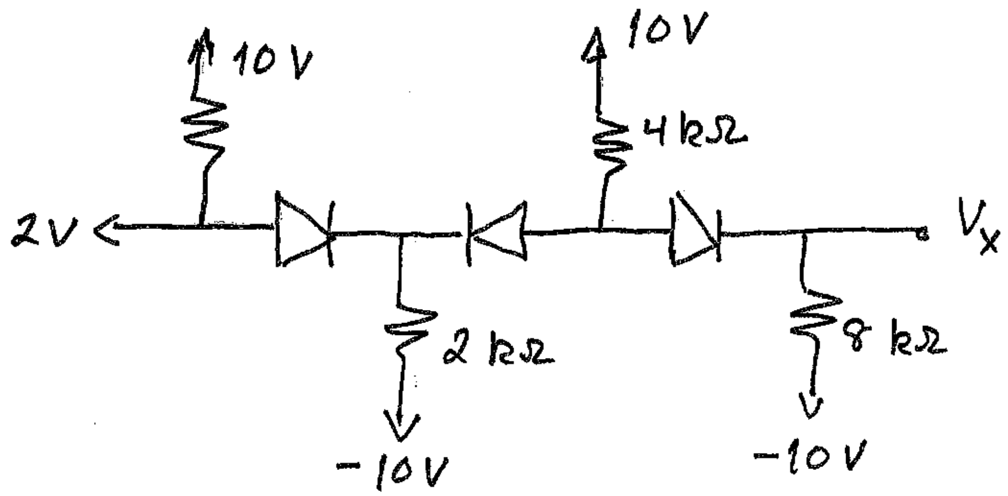
c) A sinusoidal signal with a dc component of 6 V and an ac amplitude of 1 V is applied to the circuit at the input. Sketch the output as a function of time for at least one cycle. Is the output a reproduction of the input, or is there distortion in the output? How do you know?



Room for extra work

3. (35 points) The diodes in the circuit below are modeled with $V_{th} = 1$ V, $r_d = 1$ kΩ, and $I_S = 1$ mA. Find V_X.

Clearly state your guesses as to which regions the diodes are in. Partial credit will be given for incorrect guesses if your tests make it clear that the guesses are incorrect. It is expected that you will get through at least two guesses.

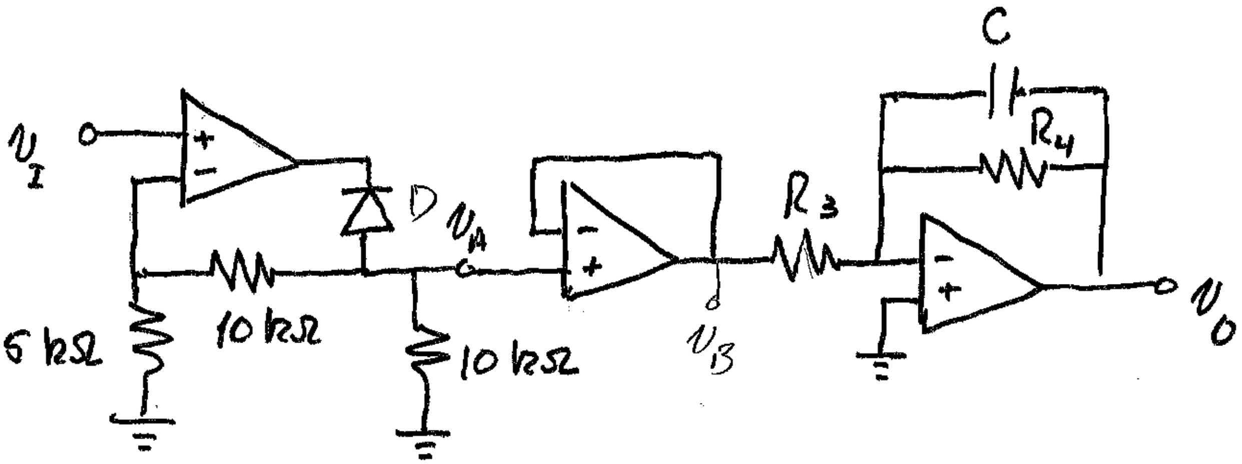


Room for extra work

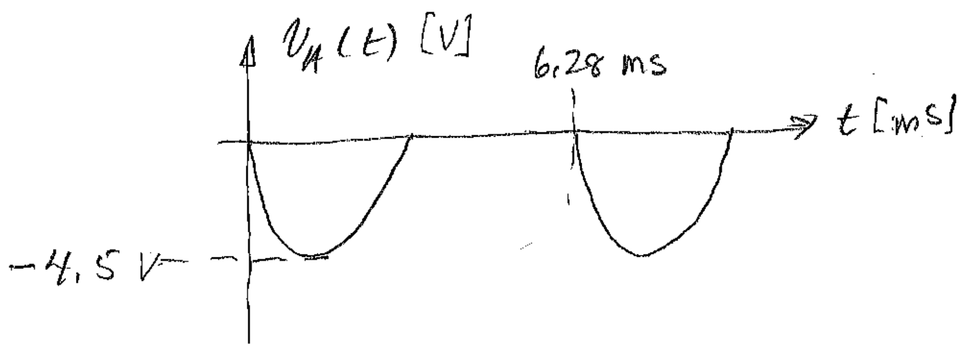
1. (30 points) The circuit below is intended to be an ac voltmeter. It uses a modified super-diode, a buffer amplifier, and an active filter. The diode model is $V_{th} = 0.7$ V, $r_d = 0$, $I_S = 0$. The input signal $v_I = 1.5 \sin(1000\, t)$ [V]. The average value of the waveform v_A is given as $\langle v_A \rangle = -3.0/\pi$.

a) Make a sketch of the voltage v_A as a function of time for at least one cycle. Be sure to clearly indicate the amplitude.

b) Choose values for the capacitor C and resistors R_3, R_4 so that (i) only the dc component of the waveform v_A appears at the output v_O, and ii) the gain of the filter stage is 20 dB.



a) The first stage is a "superdiode". With the diode polarity indicated, D will be ON when $v_I < 0$ and OFF when $v_I > 0$. So v_A is a negative-going half wave,



The gain is $\frac{v_A}{v_I} = 1 + \frac{10\,k\Omega}{5\,k\Omega} = 3$, so $v_{A,max} = -4.5$ V.

The period is $T = \frac{1}{f} = \frac{2\pi}{\omega} = \frac{2\pi}{1000} \approx 6.28$ ms

Note that r_d & V_{th} are not relevant! ↗

Room for extra work

b) $\langle v_A \rangle = -3.0/\pi$ is the dc value, and v_A has harmonics 1000 rad/s and above, so we need to create a low pass filter with a cut-off of less than 1000 rad/s and a gain of 20 dB = 10 V/V.

The second stage is a buffer amplifier so $v_B = v_A$.

Then

$$T(\omega) = \frac{\bar{V}_o}{\bar{V}_b} = \frac{R_4/R_3}{1 + j\omega C R_4}$$

Set $1/CR_4 = 500$ rad/s. Also we need $R_4/R_3 = 10$.

Choose $R_4 = 10\ k\Omega \Rightarrow R_3 = 1\ k\Omega$

$$C = \frac{1}{500(R_4)} = 0.2\ \mu F$$

2. (35 points)

a) Draw the transfer characteristic (v_O as a function of v_i) for the circuit shown below. Only $v_i > 0$ needs to be considered. The diodes are characterized as follows.

D1, D2: $V_{th} = 0.6$ V, $I_S = 2.55$ mA, $r_d = 0$
Z1: Vth = 0.6 V (forward bias); $V_{Z1} = 2.4$ V (reverse bias), $r_Z = 0$
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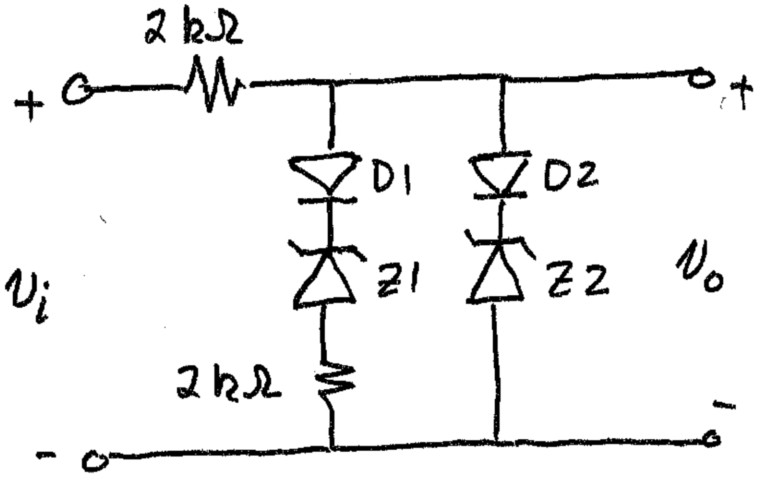
b) A sinusoidal signal with a dc component of 4.0 V and an ac amplitude of 1 V is applied to the circuit at the input. Sketch the output as a function of time for at least one cycle. Is the output a reproduction of the input, or is there distortion in the output? How do you know?

c) A sinusoidal signal with a dc component of 6 V and an ac amplitude of 1 V is applied to the circuit at the input. Sketch the output as a function of time for at least one cycle. Is the output a reproduction of the input, or is there distortion in the output? How do you know?



a) To have D1 and Z1 conducting, we need

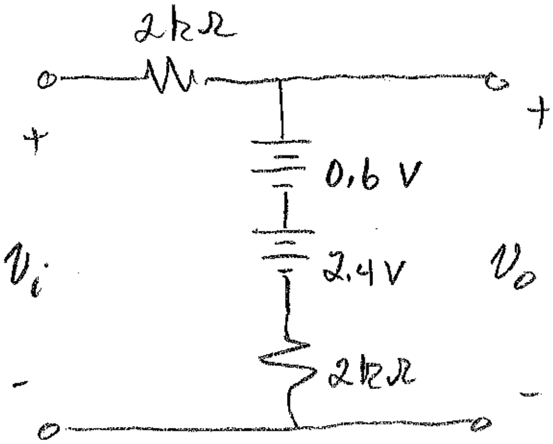
$v_O > V_{th} + V_{Z_1} = 0.6 + 2.4 = 3.0$ V

To have D2 and Z2 conducting, we need

$v_O > V_{th} + V_{Z_2} = 6.5$ V.

So D1, Z1 will come on first. This will happen at $v_i = 3.0$V.

Room for extra work



- For $0 < v_i < 3.0V$, $v_o = v_i$
- For $3.0V < v_i < v_i^{max}$,

$$v_o = 3.0 + \frac{v_i - 3.0}{4k} \cdot 2k \quad (1)$$

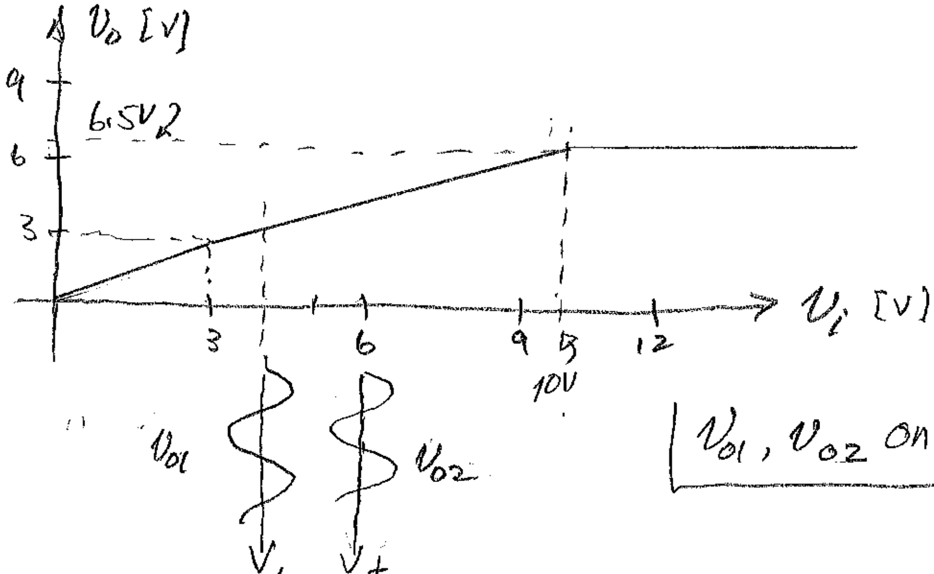
So the slope of v_o vs. v_i will be 1/2,

When D2 and Z2 come on, v_o is clamped at 6.5 V.

- For $v_o = 6.5V$, $v_i = (v_o - 3.0) \cdot 2 + 3.0$ from (1)

$$v_i^{max} = (6.5 - 3.0) \cdot 2 + 3.0 = 10\ V.$$

So our transfer characteristic is...



b)

v_{o1}, v_{o2} on p. 2 →

total signal

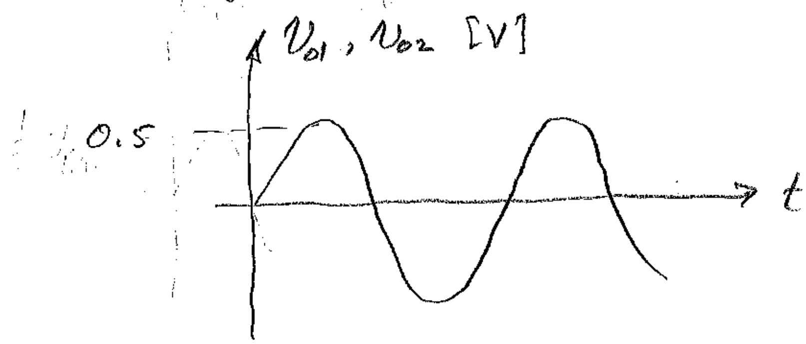
$v_{o1} = 4V + 1\sin(\omega t)$ will lie in the 2nd region and will not be distorted.

$v_{o2} = 6V + 1\sin(\omega t)$ will also lie in the 2nd region and will not be distorted.

Room for extra work

v_{o1}, v_{o2} are sinusoids with amplitudes ½ the input, or 0.5 V. The problem statement suggests ac components are of interest, so we will plot only ac components.

(ω not given)



3. (35 points) The diodes in the circuit below are modeled with $V_{th} = 1$ V, $r_d = 1$ kΩ, and $I_S = 1$ mA. Find V_X.

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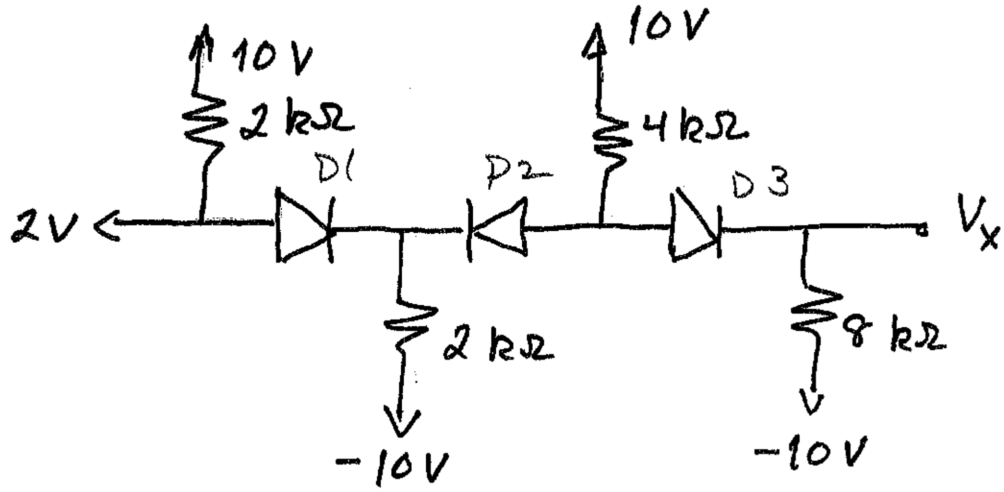
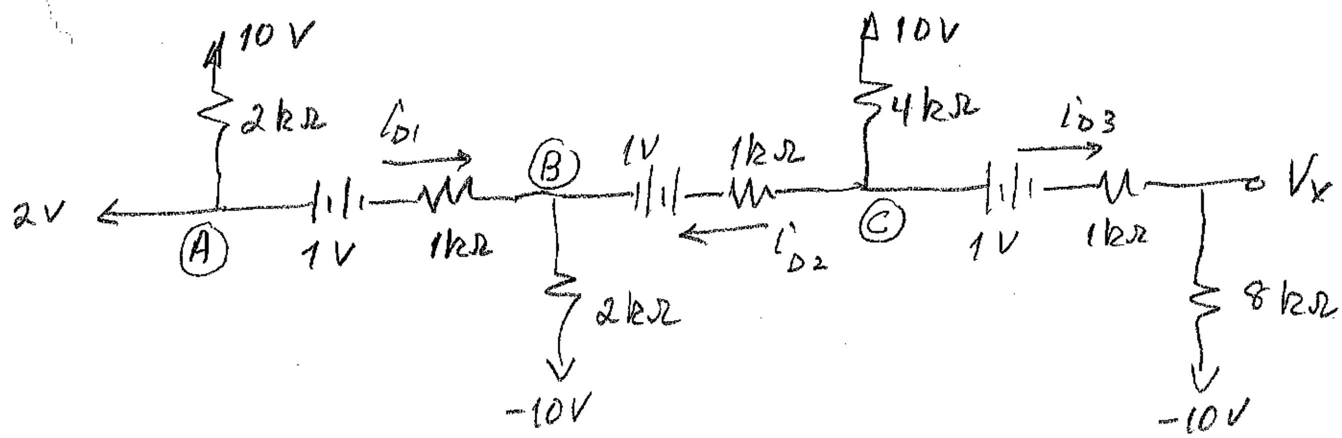


The -10 V sources and the 10 V sources are in a position to forward bias all diodes. Let's try that:



Need to prove i_{D1}, i_{D2}, i_{D3} are positive.

Node Voltage Method to the rescue!

Room for extra work

$V_A = 2V$

$$\frac{V_B - 2 + 1}{1} + \frac{V_B + 10}{2} + \frac{V_B - V_C - 1}{1} = 0$$

$$\frac{V_C - 10}{4} + \frac{V_C - V_B - 1}{1} + \frac{V_C + 10 - 1}{1} = 0$$

We have written resistances in units of kΩ so currents will be in mA.

Solve: $V_B = -1.792V$ $V_C = 0.5202\ V$

$i_{D1} = \frac{2 - V_B}{1} = 3.792\ mA$ ✓

$i_{D2} = \frac{V_C - V_B}{1} = 2.312\ mA$ ✓

$i_{D3} = \frac{V_C + 10 - 1}{9} = 1.058\ mA$ ✓

$V_X = 8 \cdot i_{D3} - 10 = -1.538\ V$