

ENGR4300 Test 4A

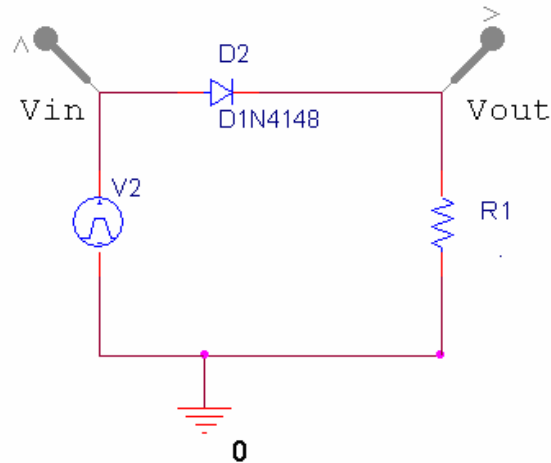
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Question 1 – Diodes

Assume that the forward bias threshold voltage for the diode in the circuit is 0.7V.

A. Consider the following circuit



a) What type of diode circuit is the circuit above? (1 pt)

half wave rectifier

b) What will be the voltage at Vout be when the input voltage is at the following levels:
(1 pt each = 7 pt)

Vin = 0V **0V**

Vin = 0.5V **0V**

Vin = -0.5V **0V**

Vin = 3V **3-0.7 = 2.3V**

Vin = -3V **0V**

Vin = 5V **5-0.7 = 4.3V**

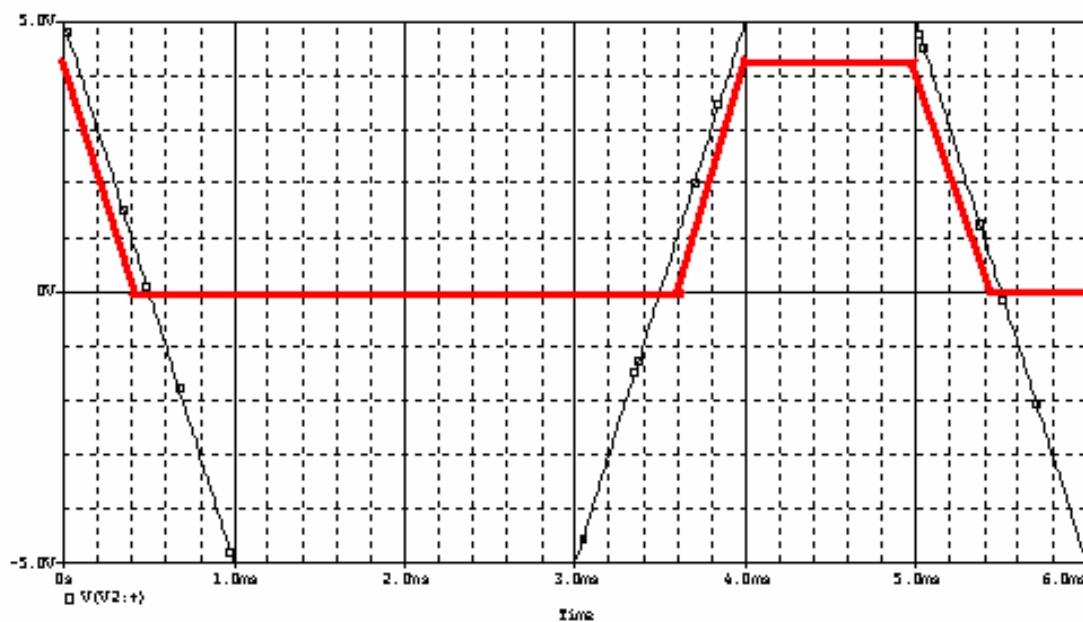
Vin = -5V **0V**

c) If $R1=900\Omega$, what will be the current through the circuit when V_{in} has the following values: (2 pt each = 4 pt)

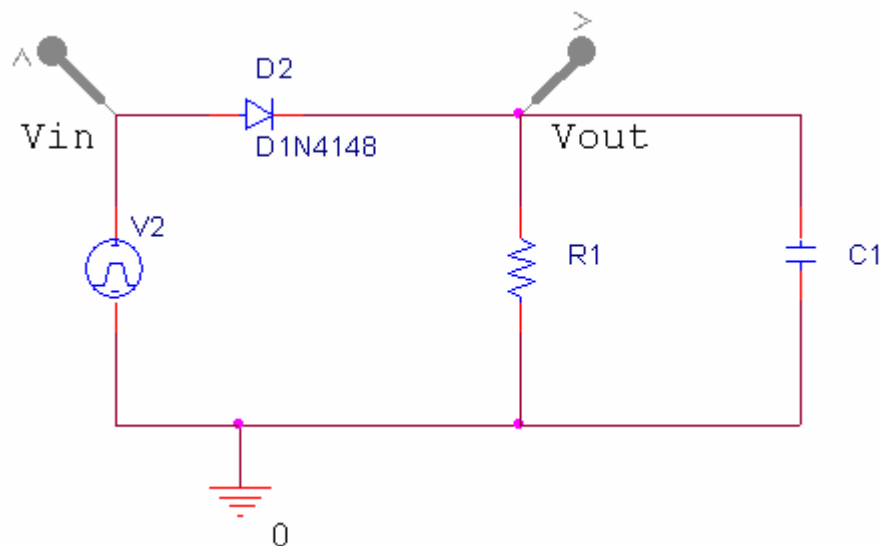
$V_{in} = 3V$ $I = V/R = (2.3)/(.9) = 2.55mA$

$V_{in} = -0.5V$ $I = V/R = (0)/(.9) = 0A$

d) Sketch the output of the above circuit for the following input. (4 pt)



B. Now we add a capacitor in parallel with the load resistor, as shown below:



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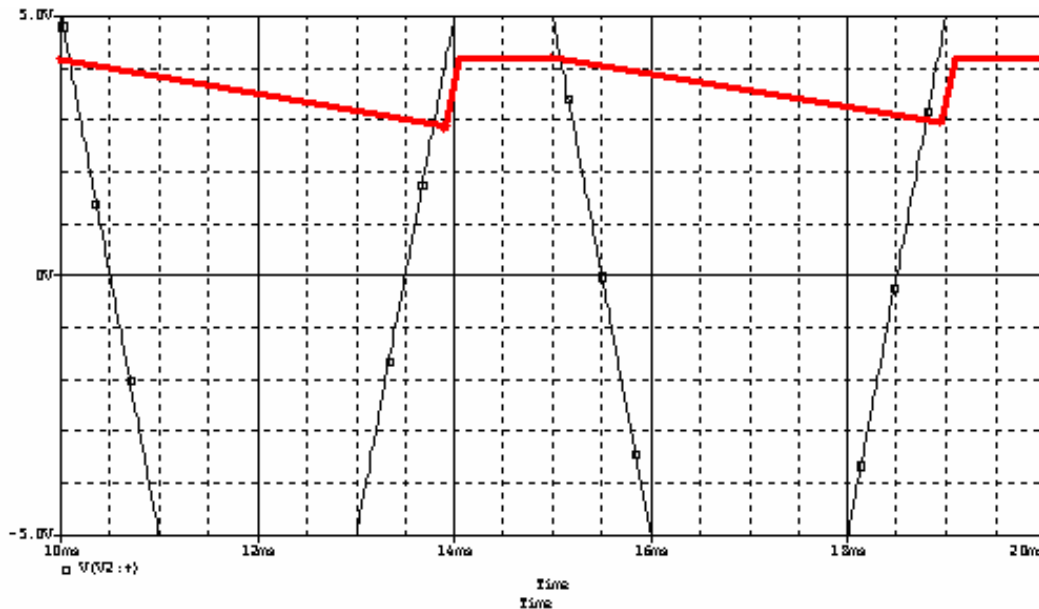
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a) If C2 is 10 μ F and R1=900 Ω , what is the time constant, τ , of the RC circuit combination R1-C2? (3 pt)

$$\tau = (R1)(C2) = (0.9K)(10\mu) = 9ms$$

b) Assume that the capacitor discharges at a linear rate of 3/ τ V/s at the beginning of its discharge cycle. (In other words, assume a linear rate of discharge of 3/ τ .) Plot the output of the circuit with the smoothing capacitor. (Note that this plot does not start at time t=0, so you can assume the signal has already reached steady state.) (6 pt)



Show work here:

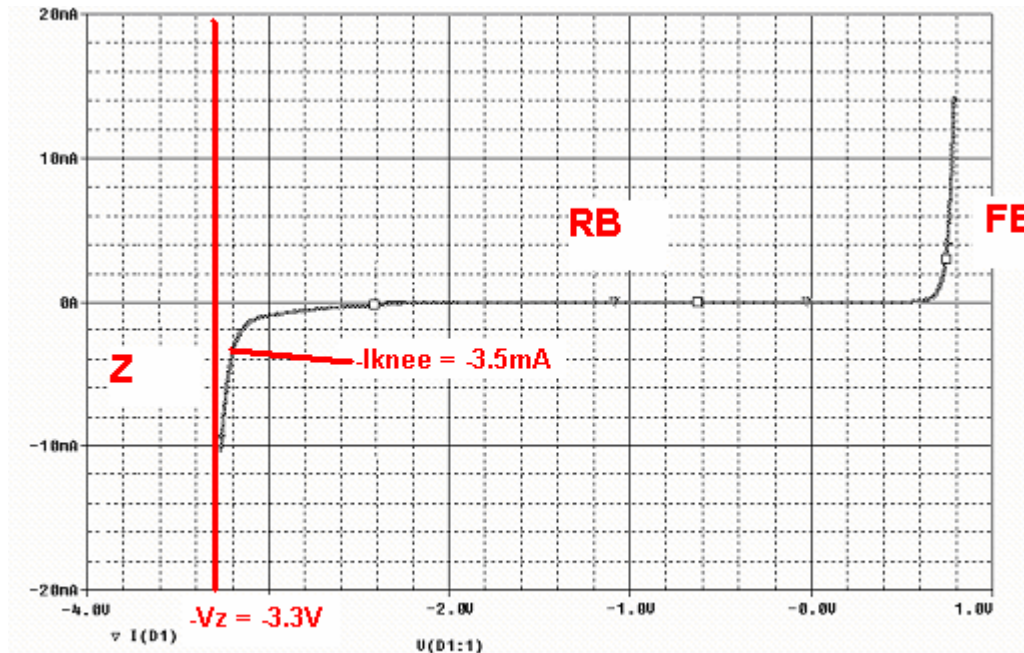
$$3/\tau = 3/9m = 0.33V/ms \text{ It should decay } 0.33 \text{ volts every millisecond.}$$

$$-.33 V/ms = (x-4.3) / (14-10) \quad x=2.97V$$

Between 10 and 14 ms it will decay to about 3 volts.

Question 2 – Zener diodes

Part A: Characteristic curve -- The following plot shows the characteristic curve for a Zener diode.



a) Mark the following regions on the plot: (6 pt)

The forward bias region (FB) The reverse bias region (RB) The Zener region (Z)

b) Estimate the Zener voltage for this diode to the nearest 0.1 of a volt. (2 pt)

$$V_z = 3.3V \text{ (} V_z \text{ is positive by convention.)}$$

c) If the knee current of this diode is the current at the point where the voltage across the diode is within 0.1V of the Zener voltage, what is the knee current of this diode? (3 pt)

$$3.3 - 0.1 = 3.2V \quad V_d = -3.2 \text{ when } I_d = -3.5mA \text{ (from the plot).}$$

Therefore, I_{knee} is $+3.5mA$ (I_{knee} is also given as positive -- see cribsheet)

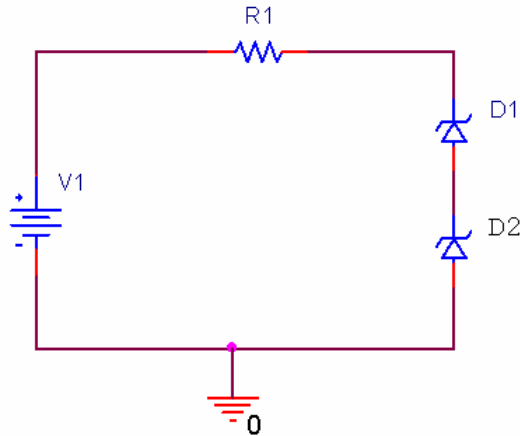
d) Mark the knee current and the Zener voltage on the plot of the characteristic curve. (2 pt)

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Part B – Zener diode circuit -- We place two of these Zener diodes in a circuit as shown below.



a) What region will the Zener diodes be in, forward bias (FB), reverse bias (RB), or Zener (Z), when the input voltage at V1 is each of the following? (1 pt each = 6 pt)

(upper limit is $2(3.3)=+6.6V$, lowerlimit is $2(-0.7)=-1.4V$. The Zener diodes are upside down, so it is forward biased for negative voltages.)

-7.5V	D1: FB	D2: FB
-3.5V	D1: FB	D2: FB
-1.0V	D1: RB	D2: RB
1.0V	D1: RB	D2: RB
3.5V	D1: RB	D2: RB
7.5V	D1: Z	D2: Z

b) What will the current through the circuit be if $R1=2K$ and the voltage at the input is each of the following? (2 pt each = 6 pt)

-7.5V: $(-7.5+1.4)/2k = -3.05mA$

3.5V: $I=0A$

7.5V: $(7.5-6.6)/2k = 0.45mA$

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In the circuit on the previous page, the circuit blocks are identified by capital letters. The voltage levels between the blocks (measured relative to ground) are identified by the notation V_x .

Part A: Identify each of the blocks in the circuit

A (1 pt): *function generator (or source)*

B (1 pt): *DC blocking capacitor*

C (1 pt): *inverting amplifier*

D (1 pt): *high pass filter*

E (1 pt): *miller integrator*

F (1 pt): *voltage divider*

G (1 pt): *buffer*

Part B: Analyze circuit blocks.

a) What does resistor R3 represent? (1 pt)

the internal impedance of the function generator

b) What is the gain of block C (include the sign)? (1 pt)

$$-10k/2k = -5$$

c) What is the corner frequency in Hertz of block D? (2 pt)

$$f_c = 1/(2\pi RC) = 1/(2\pi(20k)(1\mu)) = 7.96\text{Hz}$$

d) What is the corner frequency in Hertz of block E ? (2 pt)

$$f_c = 1/(2\pi R_f C_f) = 1/(2\pi(5k)(0.047\mu)) = 677\text{Hz}$$

e) What is the gain of block E at frequencies significantly below the corner frequency (include the sign)? (1 pt)

$$-R_f/R_i = 5k/1k = -5$$

f) What is the gain of block E at frequencies significantly above the corner frequency (include the sign)? (1 pt)

$$-1/\{(R_i)(C_f)\} = -1/\{(1k)(0.047\mu)\} = -21,300 \quad (\omega \text{ is not part of the gain})$$

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g) If the voltage at V_e is 10V, what will the voltage at V_f be? (1 pt)

$$10(4k/5k) = 8V$$

h) If the voltage at V_f is 5V, what will the voltage at V_g be? (1 pt)

$$5V$$

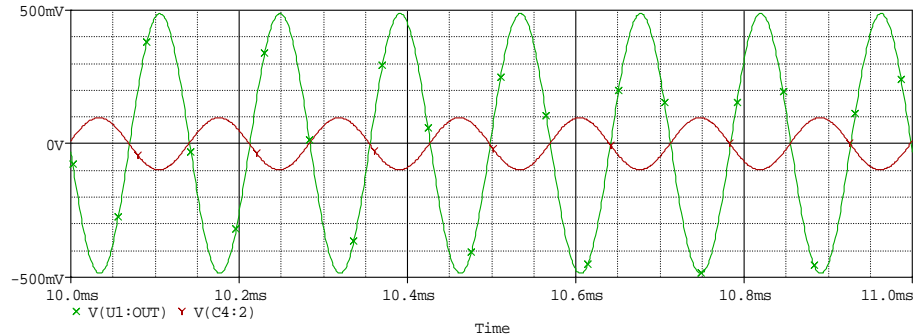
i) If the voltage at V_g is 3V, what will the current through R_8 be? (1 pt)

$$I = V/R = 3/1k = 3mA$$

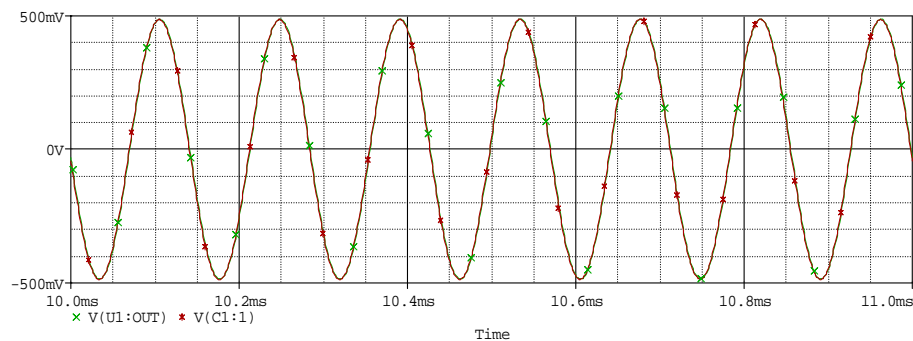
Part C – Block input and output (6 pt)

The following 6 plots show the input and output to blocks B, C, D, E, F and G when the input at block A is set to the values shown in the circuit diagram. All show two traces. Identify which is which.

C:



D:

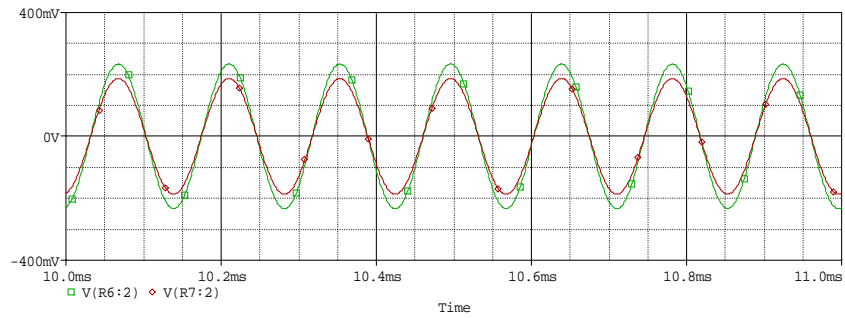


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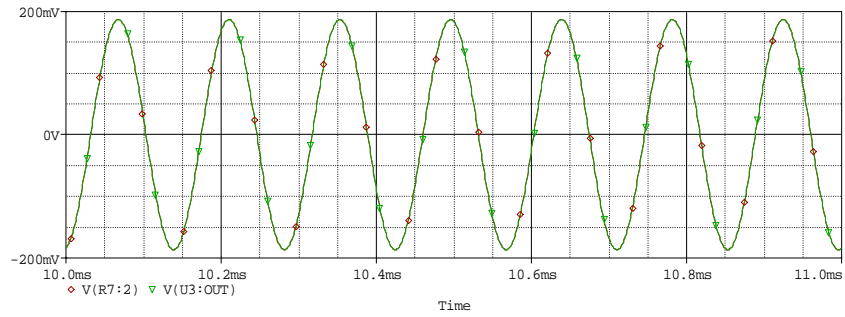
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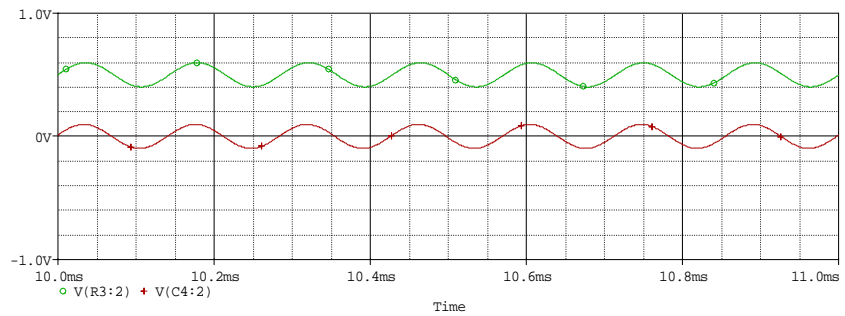
F:



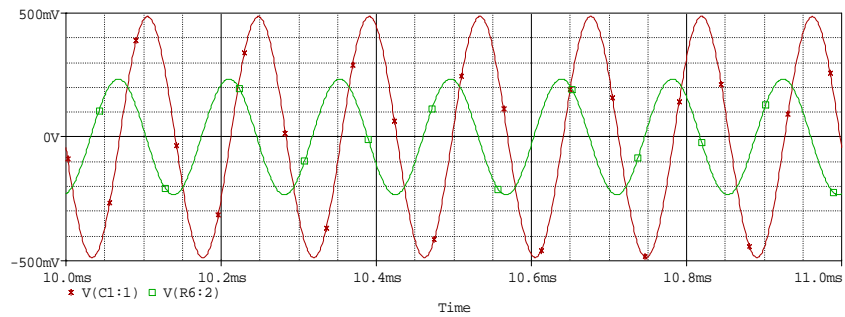
G:



B:

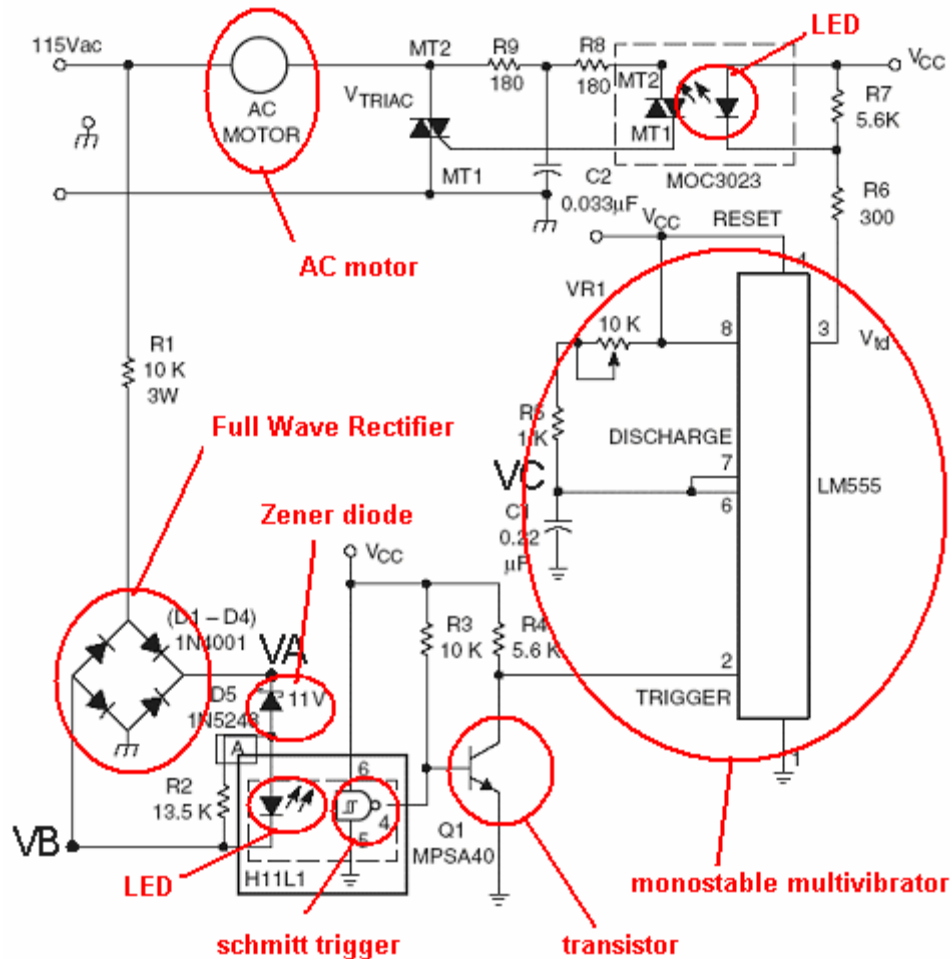


E:



Question 4 – Circuit Functionality

Having just been hired as the only engineer in a new start-up company, your supervisor has provided the following circuit from an applications note that she thinks might work for controlling a motor on your first project. It has some symbols/components you are not familiar with, but you recognize most of the components from your experience in EI.



From a quick web search, you learn that an MOC3023 is an optically isolated triac driver, and a triac is a solid state device for controlling AC power. The Triac looks like this



. The machine will be used in the US, which you know has AC power that is nominally 115V oscillating at 60Hz.

a) Circle and label the following circuit blocks in the diagram. (1 pt each = 7 pts)

- | | | |
|----------------|-------------------------|------------------------------|
| 1 – 2 LEDs | 2 – Full Wave rectifier | 3 – Monostable multivibrator |
| 4 – transistor | 5 – Schmitt trigger | 6 – Zener diode |
| 7 – AC Motor | | |

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b) The Zener diode is used to (select one): (2 pts)

Thermally protect the circuit

Limit Current

Rectify the input signal

Limit Voltage

c) The Zener voltage of the Zener diode is: (2 pts)

$$11V$$

d) The LED in the H11L1 has a forward bias voltage drop of 1.2V. When the diode is lit, what is the current through R2? (3 pts)

$$I = 1.2/13.5K = 0.089mA$$

e) What is the maximum voltage between test points VA and VB? (2 pts)

$$1.2V + 11V = 12.2V$$

f) After searching the web for the H11L1 data sheet, you confirm that when the LED is on, the Schmitt trigger output is low, and when it's off, the output is high. The 555 timer begins capacitor charging when the trigger signal falls from logic high to logic low. How frequently does this occur? (2 pts)

The input is sixty hertz. It is full wave rectified, so the voltage goes high twice in every cycle. $\rightarrow 120 \text{ times per second}$

g) Based on your knowledge of the 555 timer, what is the charging time constant for capacitor C1 when potentiometer VR1 is set in the middle of its range of adjustment? (3 pts)

$$\tau = RC = (1k+5k)(0.22\mu) = 1.32 \text{ ms}$$

h) Pin 7 of the 555-timer is the discharge pin, what device is this connected directly to inside the 555 timer based on the model from project 3? (2 pts)

Flip-Flop ***transistor*** comparator NAND gate (or equivalent)

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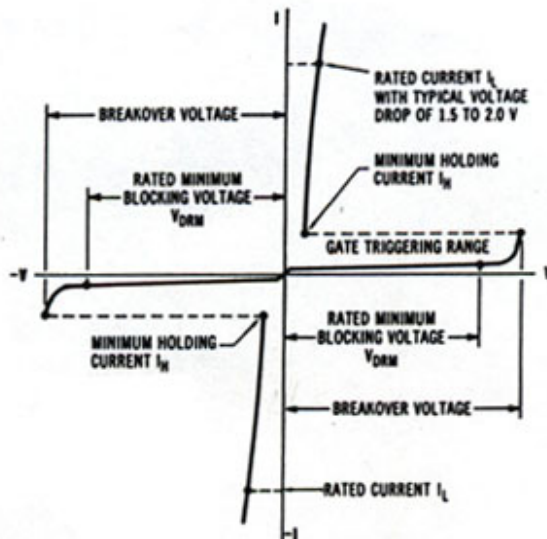
i) Approximately how long will it take for this capacitor to discharge once the threshold has been reached? (1 pt)

0ms (It is a monostable, the capacitor is attached directly to ground as soon as the transistor at pin 7 closes, so it takes no time to discharge.)

j) If you didn't have R1 as specified when you had to build this circuit, which of the following could you most likely safely replace it with (1 pt)

1. A 30k 1/4W carbon film resistor from your EI parts kit
2. A 1k, 30W wire wound resistor
3. **A 12k, 4W resistor of unknown construction (R1 is 10k, 3W is less than 4W)**
4. A zener diode with at least a 115V zener voltage

Extra Credit (1pt): What does the circuit do? The i-v characteristic curve of a triac, shown below, will help you understand what it does.



Typical triac VI characteristic curves.

The triac turns on after a certain threshold voltage is reached in either direction. This is necessary since the motor is AC. The input is 60 hertz. It is full wave rectified, so there are 120 voltage pulses every second. Each of these pulses triggers a pulse on the one-shot. These pulses allow the motor to spin by connecting it to ground. Since the 10K pot in the astable allows you to adjust the width of the pulses, the circuit allows you to control the speed of the AC motor.