ENGR-2300

Electronic Instrumentation

Quiz 4

Spring 2013

Solution

Question I (25 points) _____

Question II (25 points) _____

Question III (25 points) _____

Question IV (25 points) _____

Total (100 points) _____

On all questions: SHOW ALL WORK. BEGIN WITH FORMULAS, THEN SUBSTITUTE VALUES <u>AND UNITS</u>. No credit will be given for numbers that appear without justification. Read the entire quiz before answering any questions. Also it may be easier to answer parts of questions out of order.

Some Additional Background

Some Typical LED Operating Info:

	Wavelength (nm)	Color Name	Fwd Voltage (Vf @ 20ma)	Intensity 5mm LEDs	Viewing Angle	LED Dye Material
	940	Infrared	1.5	16mW @50mA	15º	GaAIAs/GaAs -- Gallium Aluminum Arsenide/Gallium Arsenide
	880	Infrared	1.7	18mW @50mA	15º	GaAIAs/GaAs -- Gallium Aluminum Arsenide/Gallium Arsenide
	850	Infrared	1.7	26mW @50mA	15º	GaAIAs/GaAs -- Gallium Aluminum Arsenide/Gallium Aluminum Arsenide
★	660	Ultra Red	1.8	2000mcd @50mA	15º	GaAIAs/GaAs -- Gallium Aluminum Arsenide/Gallium Aluminum Arsenide
	635	High Eff. Red	2.0	200mcd @20mA	15º	GaAsP/GaP - Gallium Arsenic Phosphide / Gallium Phosphide
	633	Super Red	2.2	3500mcd @20mA	15º	InGaAIP - Indium Gallium Aluminum Phosphide
	620	Super Orange	2.2	4500mcd @20mA	15º	InGaAIP - Indium Gallium Aluminum Phosphide
★	612	Super Orange	2.2	6500mcd @20mA	15º	InGaAIP - Indium Gallium Aluminum Phosphide
	605	Orange	2.1	160mcd @20mA	15º	GaAsP/GaP - Gallium Arsenic Phosphide / Gallium Phosphide
	595	Super Yellow	2.2	5500mcd @20mA	15º	InGaAIP - Indium Gallium Aluminum Phosphide
★	592	Super Pure Yellow	2.1	7000mcd @20mA	15º	InGaAIP - Indium Gallium Aluminum Phosphide
	585	Yellow	2.1	100mcd @20mA	15º	GaAsP/GaP - Gallium Arsenic Phosphide / Gallium Phosphide
	4500K	"Incan-descent" White	3.6	2000mcd @20mA	20º	SiC/GaN -- Silicon Carbide/Gallium Nitride

	6500K	Pale White	3.6	4000mcd @20mA	20º	SiC/GaN -- Silicon Carbide/Gallium Nitride
⭐	8000K	Cool White	3.6	6000mcd @20mA	20º	SiC/GaN - Silicon Carbide / Gallium Nitride
	574	Super Lime Yellow	2.4	1000mcd @20mA	15º	InGaAlP - Indium Gallium Aluminum Phosphide
	570	Super Lime Green	2.0	1000mcd @20mA	15º	InGaAlP - Indium Gallium Aluminum Phosphide
	565	High Efficiency Green	2.1	200mcd @20mA	15º	GaP/GaP - Gallium Phosphide/Gallium Phosphide
	560	Super Pure Green	2.1	350mcd @20mA	15º	InGaAlP - Indium Gallium Aluminum Phosphide
	555	Pure Green	2.1	80mcd @20mA	15º	GaP/GaP - Gallium Phosphide/ Gallium Phosphide
⭐	525	Aqua Green	3.5	10,000mcd @20mA	15º	SiC/GaN - Silicon Carbide / Gallium Nitride
	505	Blue Green	3.5	2000mcd @20mA	45º	SiC/GaN - Silicon Carbide / Gallium Nitride
	470	Super Blue	3.6	3000mcd @20mA	15º	SiC/GaN - Silicon Carbide / Gallium Nitride
	430	Ultra Blue	3.8	100mcd @20mA	15º	SiC/GaN - Silicon Carbide / Gallium Nitride

Relative Intensity vs Wavelength (P)

*K. A. Connor*
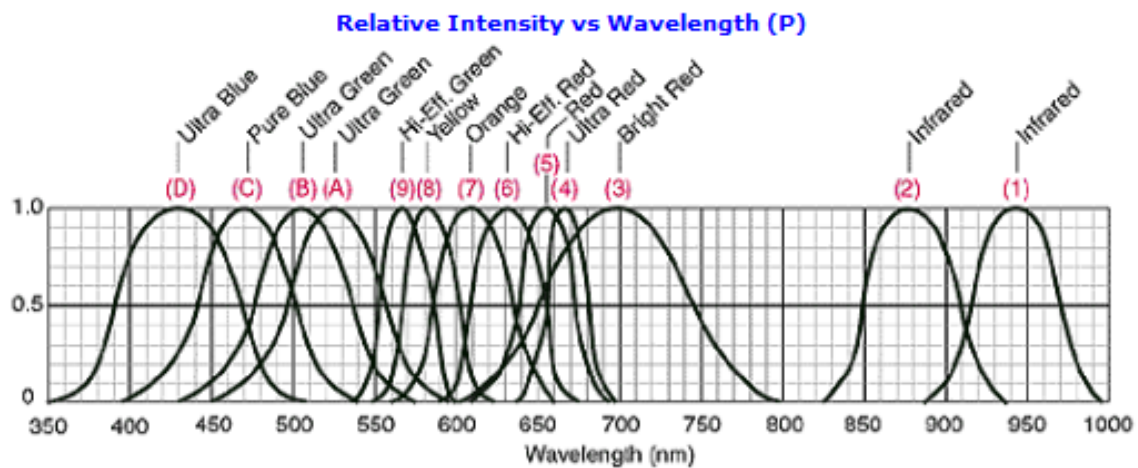
8 May – VE Day

Question I Multiple Choice & Short Answer Questions (25 points)

For these multiple choice questions, circle the correct answer or, for the first question, fill in the blanks. All questions are 3pts, except h, which is worth 4pts. Be sure to explain your answer. *Hint: if there is no figure with the question, it is a good idea to draw one.*

a. There are three voltage ranges shown in the diode I-V curve below. Write the letter from the figure in the blank next to the name for the range.
   a. Forward Bias Region **_C_**
   b. Reverse Bias Region **_B_**
   c. Breakdown Region   **_A_**
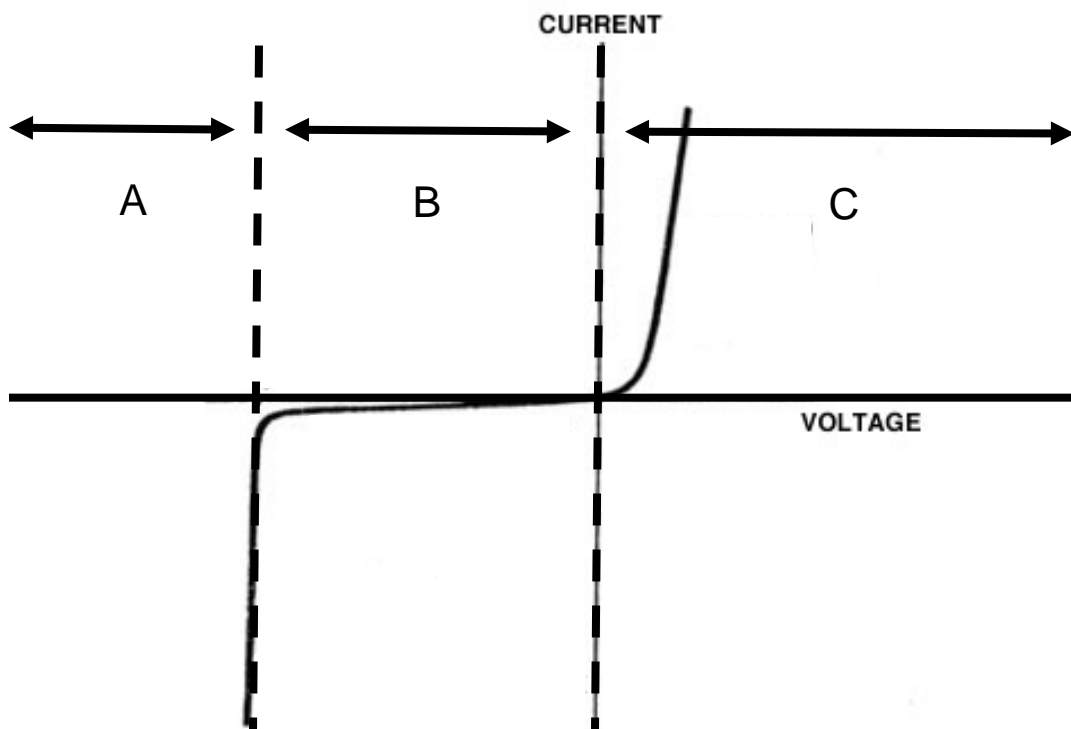
b. The DC voltage across each reverse-biased diode in a typical full wave bridge rectifier is:
   a. Near the source voltage
   b. Near twice the source voltage
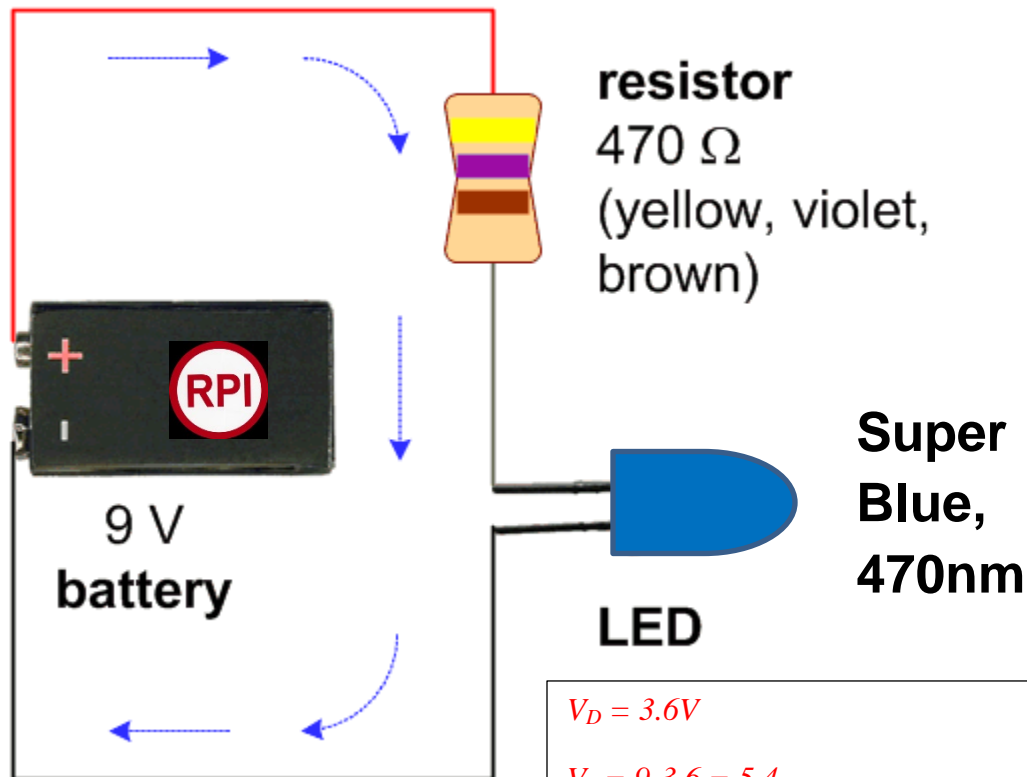   c. Near half the source voltage
   d. Near zero volts

Forward-biased diodes have small voltage.

Thus reverse-biased diodes must have nearly all of the voltage from the source.

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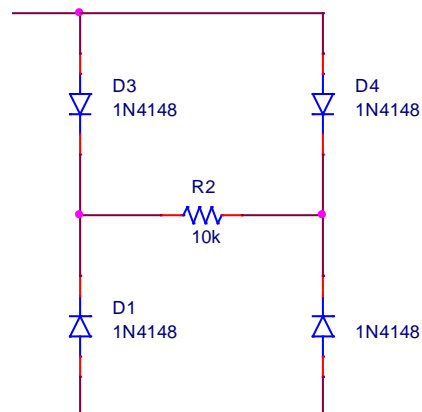
Question I Multiple Choice & Short Answer Questions (continued)

c. What is the current through the LED, if we use the specified blue LED?

**resistor
470 Ω
(yellow, violet,
brown)**

**9 V
battery**

**Super
Blue,
470nm**

LED

$V_D = 3.6V$

$V_R = 9-3.6 = 5.4$

5.4/470=11.5mA or 12mA is closest

a. 4.5 mA
b. 9 mA
c. 12 mA
d. 18 mA
e. 20 mA

d. A full-wave bridge rectifier is built using four green LEDs rather than conventional diodes (like the 1N4148). For a given AC input voltage, will the voltage across the load be

a. Smaller
b. Larger
c. The same
d. None of the above

The voltage drop across the diodes is larger so there is less voltage across the load

than it was with the 1N4148 diodes?

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Question I Multiple Choice & Short Answer Questions (continued)

e. If the frequency of a sinusoidal voltage is raised, will the ripple for a filtered half-wave rectifier voltage (for the same load resistance and capacitor values):

    a. Become smaller.

    b. Become larger.

    c. Stay the same.

    d. None of the above.

*Becomes smaller because there is less time for the voltage to decay between charging cycles.*

f. What is the magnitude of a Zener breakdown voltage for a typical 1N750 diode?

    a. 0V   e. 47V

    b. 0.7V   f. 100V

    c. 4.7V   g. 470V

    d. 10V

g. What is the approximate current magnitude through the resistor R1 in the circuit below?

    a. 0 mA

    b. 1.5 mA

    c. 2 mA

    d. 3 mA

Note that the battery is backwards, so the diode is not on. Thus, this is just a simple voltage divider problem. 8V across R1 gives 2mA
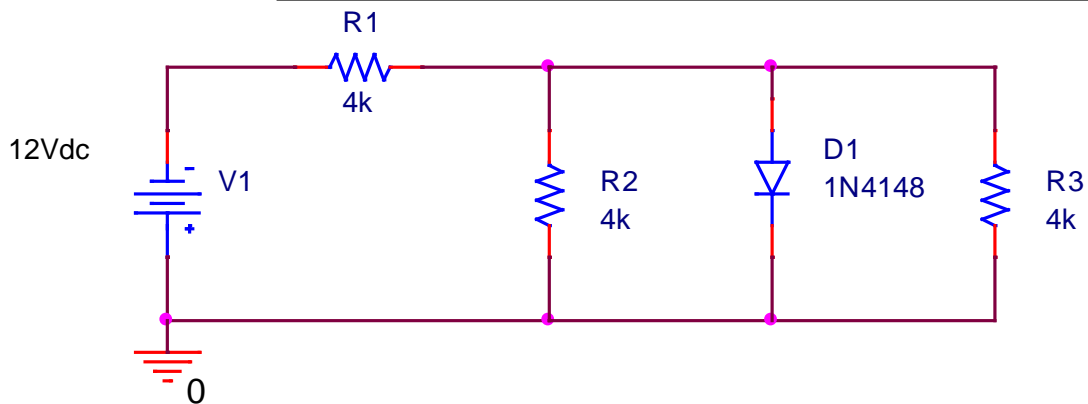
Question I Multiple Choice & Short Answer Questions (continued)

h. What is the approximate power dissipated by the Zener diode? (4pts)
   a. 0 mW
   b. 6 mW
   c. 12 mW
   d. 18 mW
   e. 36 mW
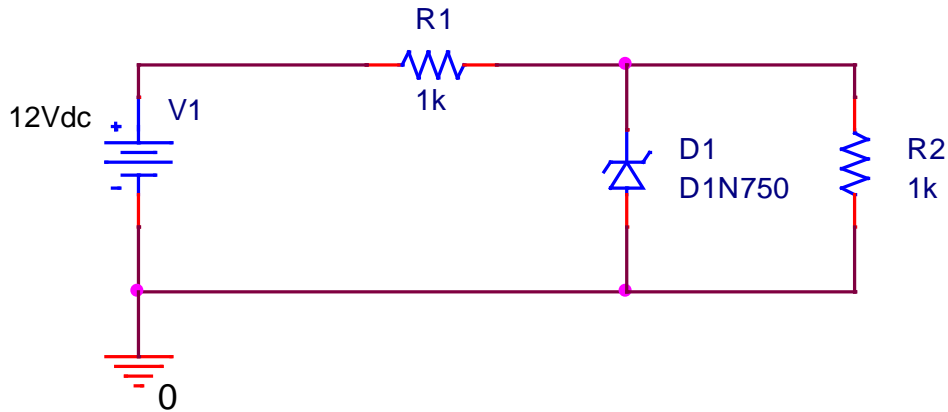
The voltage across the Zener is 4.7V. The voltage across R1 is 12 – 4.7 = 7.3

The current through R1 is 7.3/1k = 7.3mA

The current through R2 is 4.7/1k = 4.7mA
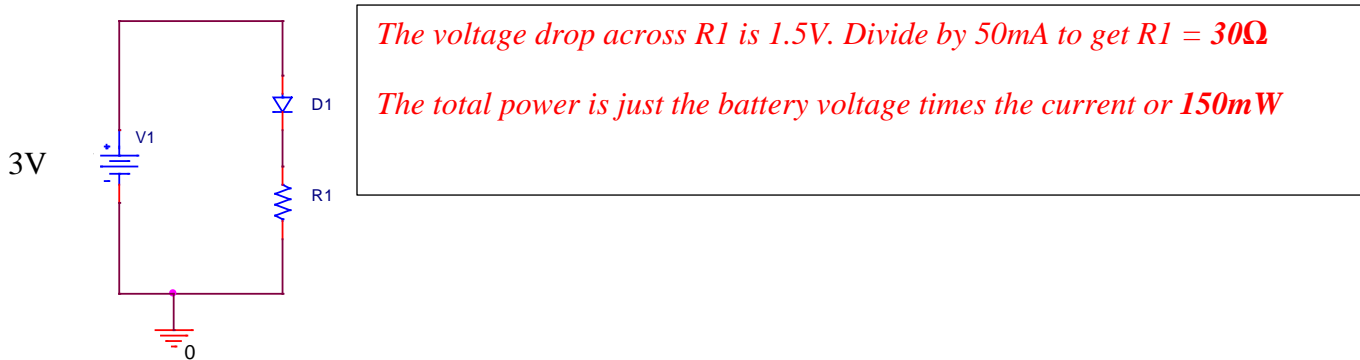
The current through the diode is 7.3 – 4.7 = 2.6mA

*The power is 4.7 * 2.6 mW = 12mW*

Note that it is OK to assume that V_Z = 4.6 or even slightly less. Then the answer will be a little bigger, but 12mW is the closest.

Question II - LEDs Circuits (25 points)

A 940nm infrared LED (like the ones used in a TV remote control) is driven by a standard DC source. The source we have is a combination of two 1.5 Volt batteries. From the chart provided at the beginning of the quiz, we need a forward bias voltage of 1.5V and a current of 50 mA.

a) (*8pts*) Using the two 1.5 Volt batteries in series, **determine the resistance R1** necessary to achieve the desired operating conditions for the diode. Also determine the total power dissipated in the circuit.

*The voltage drop across R1 is 1.5V. Divide by 50mA to get R1 = **30Ω***

*The total power is just the battery voltage times the current or **150mW***

We now want to use multiple LEDs like a short string of holiday lights. For this purpose, we will use five different color LEDs: Red, Orange, Yellow, Aqua Green and White. We will use the five LEDs marked with a ★ in the table above. For the power supply, we will use one of two universal AC adapters available online that can output one of the following voltages (switch selectable):
Universal AC Adapter 15V 16V 18V 18.5V 19V 19.5V 20V 22V 24V 70W

Universal AC Adapter 3V 4.5V 6V 7.5V 9V 12V 10W

For the next two questions, select the minimum voltage from one of the power supplies.

b) *(8 pt)* **Determine the voltage Vww and resistance R** to achieve the desired operating conditions for the series combination of 5 LEDs shown below. Assume that the current is 20mA, since we have to be limited to the smallest maximum current for any of our five LEDs. Use the typical forward bias voltages from the table. The power supply voltage should be the minimum value that will turn on all of the LEDs.


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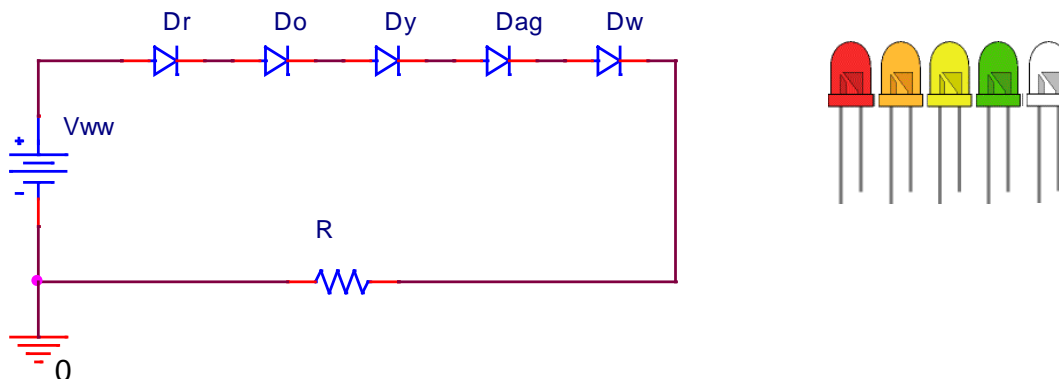
Question II - LEDs Circuits (Cont)

The sum of the five diode voltages is 1.8+2.2+2.1+3.6+3.5 = 13.2

The smallest wallwart voltage is 15V. To get 20mA, we need R = (15-13.2)/.02 = 90Ω

c) *(9 pt)* **Determine the configuration and resistances** to achieve the desired operating conditions for the series/parallel combination of 5 LEDs if we are limited to only the 9V source and you are to use the minimum number of components required to light up all five LEDs. Assume that the current in each of the LEDs is 20mA, since we have to be limited to the smallest maximum current for any of our LEDs. Use the typical forward bias voltages from the table. Note, two options have been eliminated (all in series and each diode in its own parallel leg), so you only have to consider 3 possibilities.
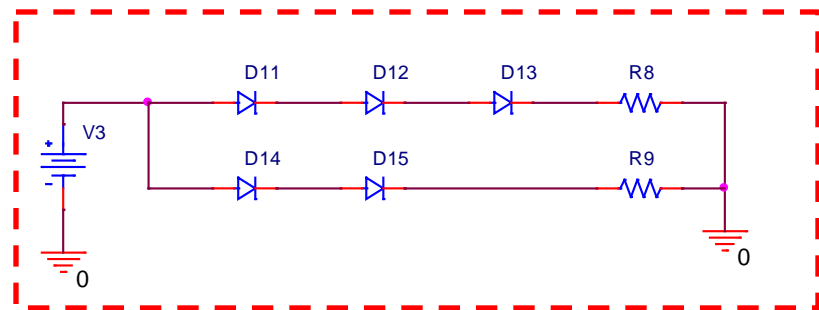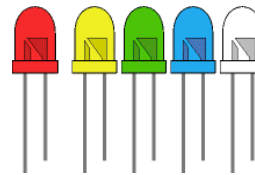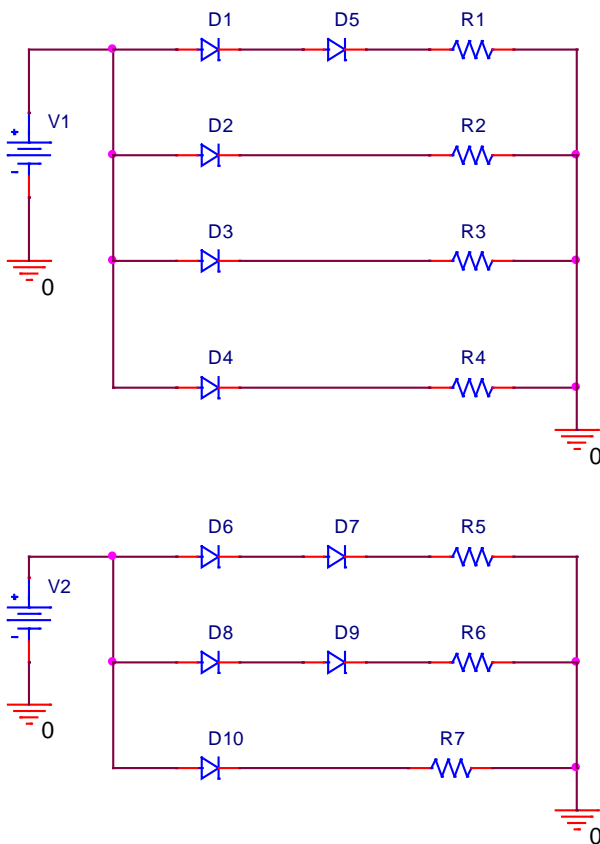

Begin with the smallest configuration (with two legs). The 3 smallest LEDs add up as (1.8 + 2.2 + 2.1) = 6.1V and the 2 largest LEDs add up as (3.5 + 3.6) = 7.1V. Both are less than 9V so the simplest configuration works. The resistances needed are (9-6.1)/.02 = 145Ω for R8 and (9-7.1)/.02 = 95Ω for R9

Question III – Diode Circuits (25 Points)

Note – There are three parts to this question, each involving an application of diodes. One circuit does not work. You should first identify which is the bad circuit and explain thoroughly why it does not work. Then address the other two parts. The bad circuit is worth 9pts.
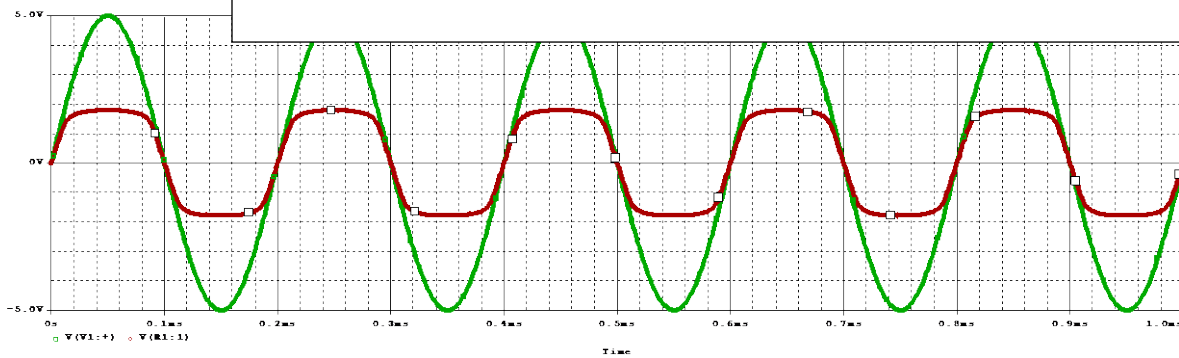
    a. Limiter Circuit (8 or 9pts) – 1N4148 diodes are used to limit the voltage at a resistive load. (Protection like this keeps the Mobile Studio board working even when you build your circuit incorrectly.) In the circuit below, a total of 6 diodes are used to limit the input voltage. Shown below are the voltage observed at point A for three different input signals. Sketch and label the output voltage at B for each case.
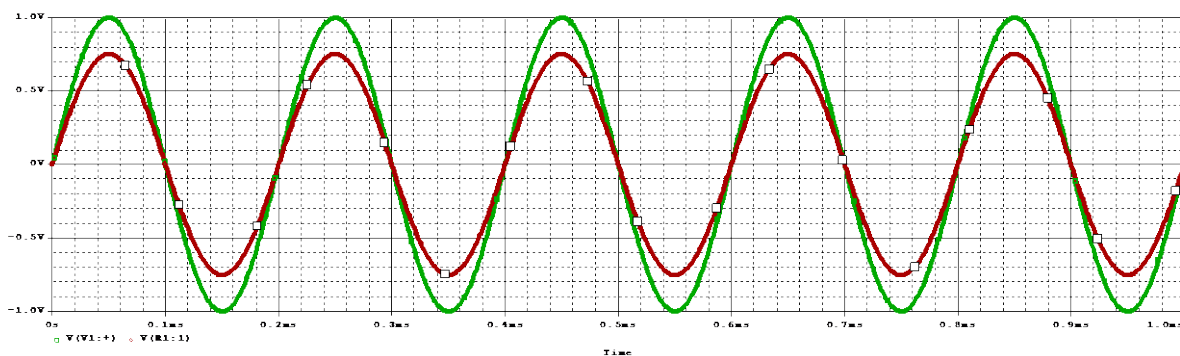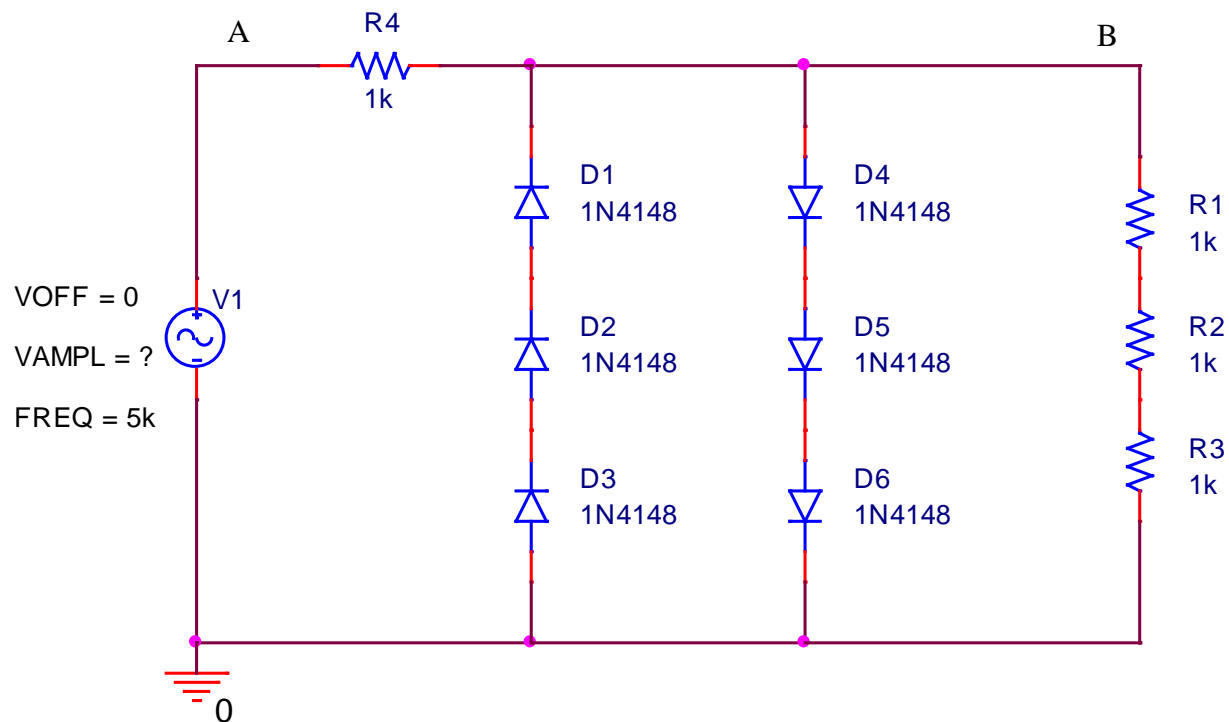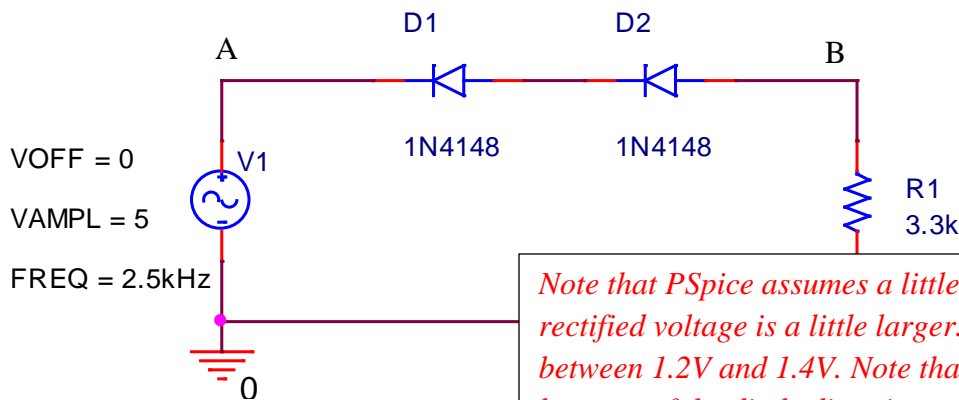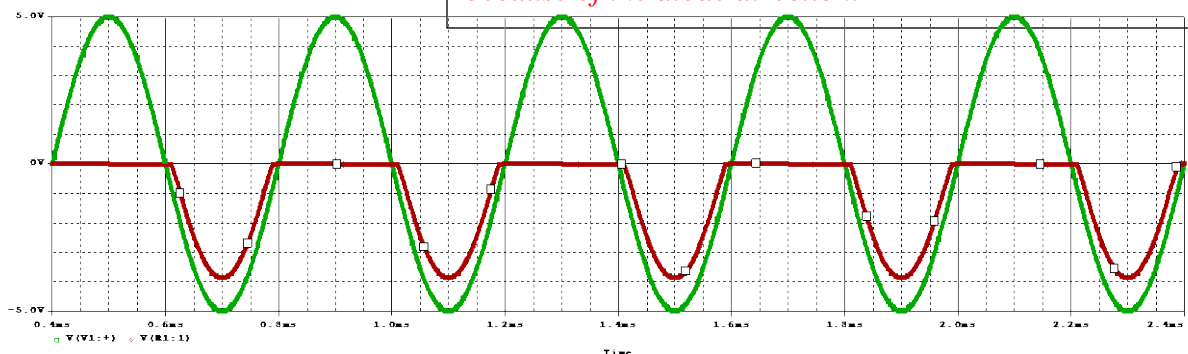
Question III – Diode Circuits (Cont)
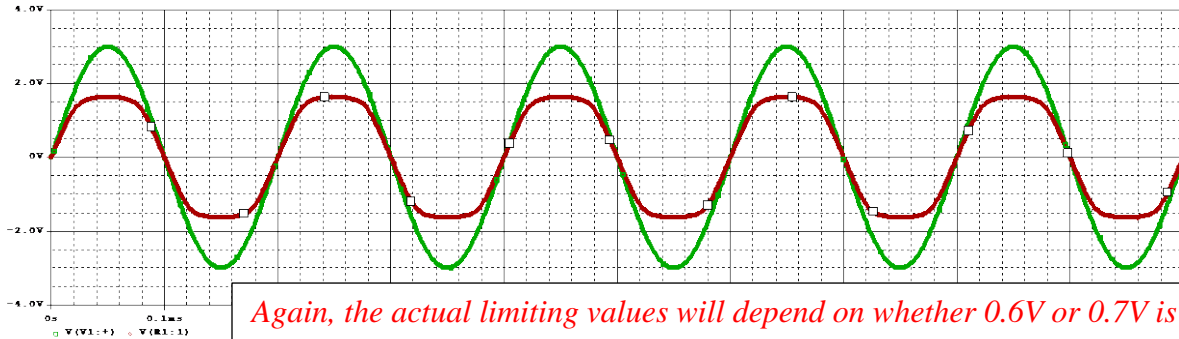
Again, the actual limiting values will depend on whether 0.6V or 0.7V is used for the on voltage of the diode.

b. Rectifier Circuit (8 or 9pts) – Two 1N4148 diodes are used to rectify an AC signal. The input signal at A is shown. Sketch the output signal at B.
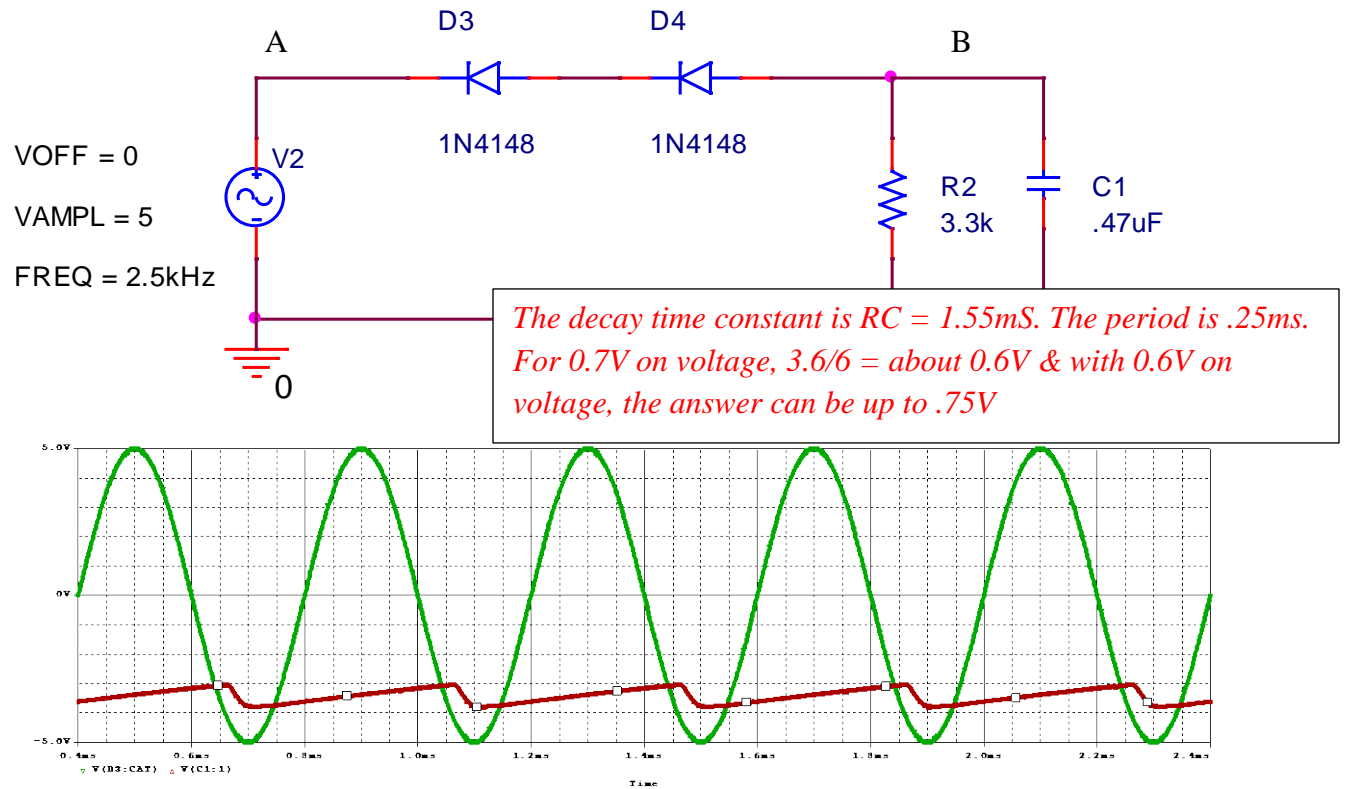

Note that PSpice assumes a little smaller on voltage so the rectified voltage is a little larger. The difference should be between 1.2V and 1.4V. Note that plot is upside down because of the diode direction.
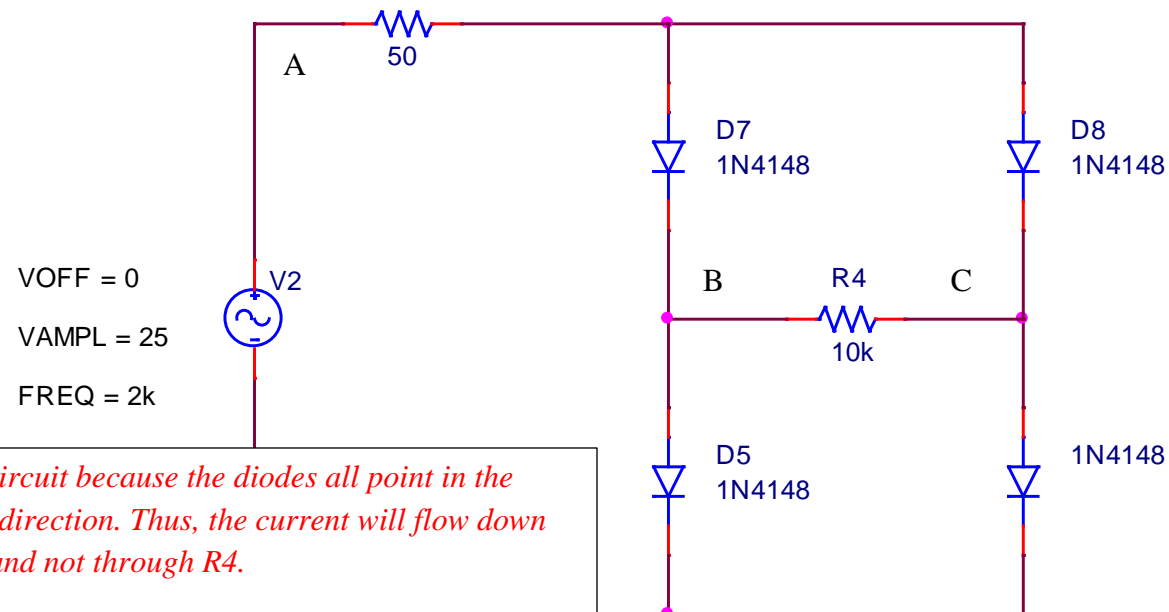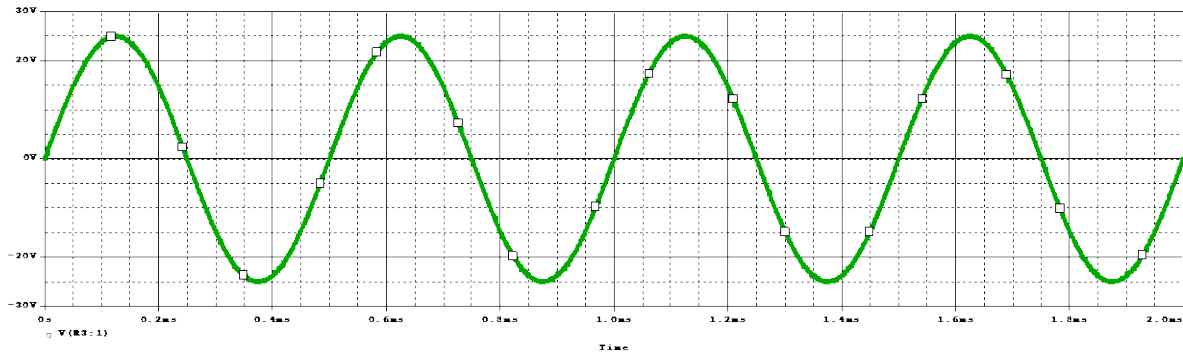
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Question III – Diode Circuits (Cont)

A smoothing capacitor is added to the circuit, as shown below. Calculate the droop (the capacitor voltage decay between charging cycles) and sketch the output voltage with the capacitor in place.

The decay time constant is RC = 1.55mS. The period is .25ms. For 0.7V on voltage, 3.6/6 = about 0.6V & with 0.6V on voltage, the answer can be up to .75V

c. Rectifier Circuit (8 or 9pts) – 1N4148 diodes are used to rectify an AC signal. The input signal at A is shown. Sketch the output signal between B and C.

Bad circuit because the diodes all point in the same direction. Thus, the current will flow down only and not through R4.

Question III – Diode Circuits (Cont)

A smoothing capacitor is added to the circuit, as shown below. Calculate the droop (the capacitor voltage decay between charging cycles) and sketch the output voltage with the capacitor in place.
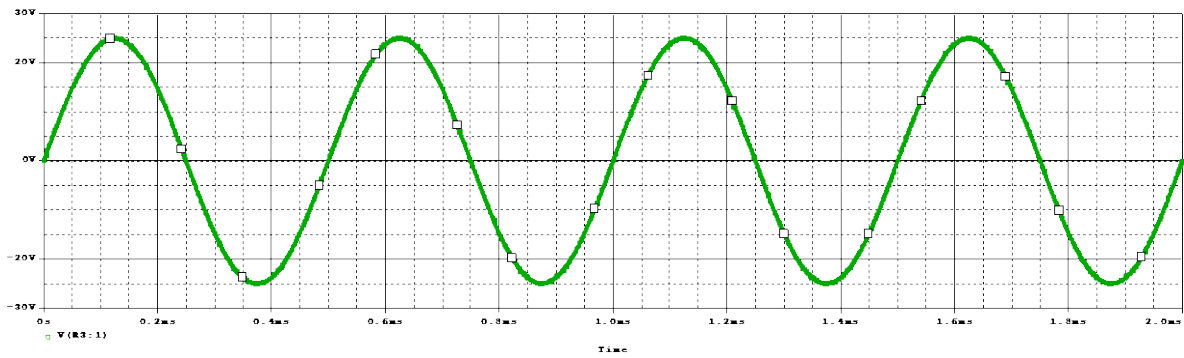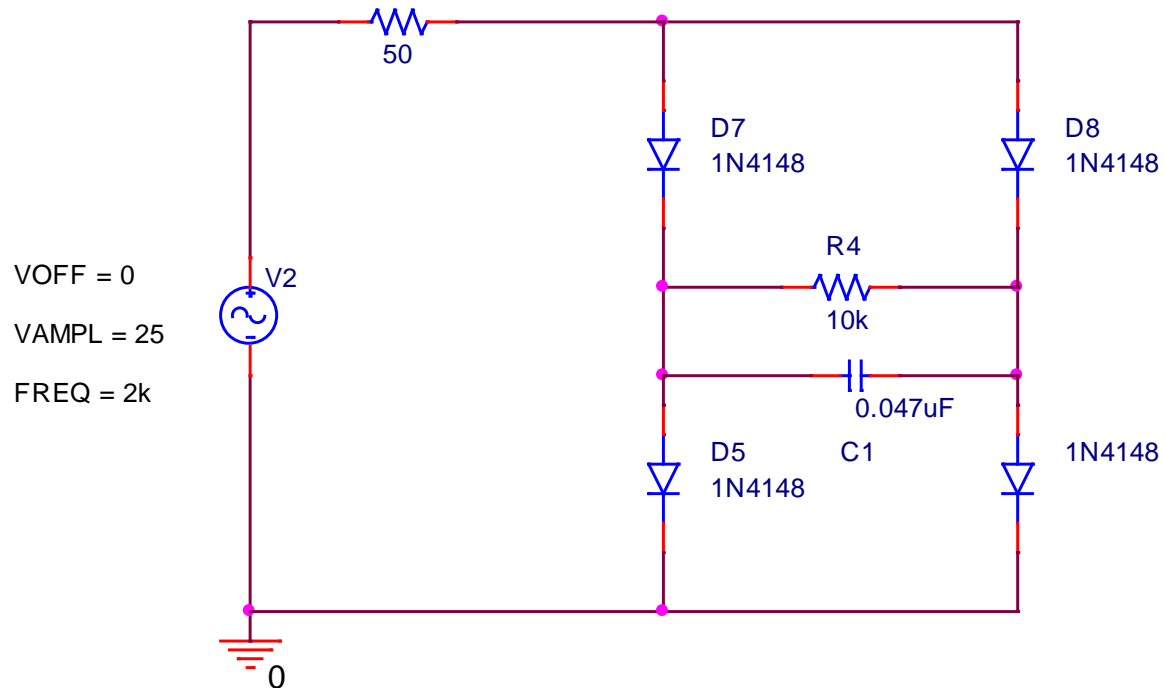
VOFF = 0

VAMPL = 25

FREQ = 2k

*K. A. Connor*

Question IV – Complex Circuits (25 Points)

a. Optical Transmitter-Receiver Project – Shown below is the general diagram of the functional blocks for Project 4. Begin by labeling the speaker, the LED and the phototransistor. Then add in the audio source using the appropriate circuit element or elements. That is, draw in what you would see in a circuit diagram that represents the audio source. (4pts)

Functional Blocks for the Optical Communications Link
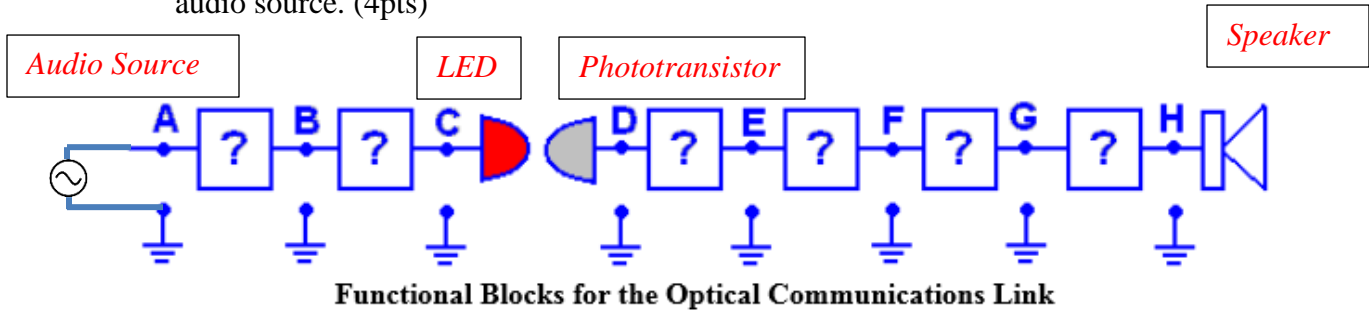
b. Next, identify each block below by indicating the node letters on either side. For clarity, one of the elements has already been identified. (6pts)

    a. Audio Amplifier **G-H**
    b. DC Blocking Capacitor **A-B**
    c. Pre-amplifier **E-F**
    d. Astable Multivibrator **B-C**
    e. Matching Network **assume part of audio amp output stage.**
    f. Volume Control **F-G**
    g. Bias Resistor & DC Blocking Capacitor **D – E**

c. In the project, you were asked to add an integrator to smooth out the spikes in the detected signal. Assume that you are to use a passive RC integrator. Draw the integrator circuit below. At what point (A-H) should the integrator be added? _____**E**__ If the resistor is 500Ω, which of the following capacitor values would be the most reasonable choice for the integrator? Explain your answer. (6pts) *Hint – there may be more than one acceptable answer, depending on your explanation. You only need one answer.*

$$C = \quad 1nF \quad 10nF \quad 100nF \quad \color{red}{1\mu F} \quad 10uF \quad 100uF$$
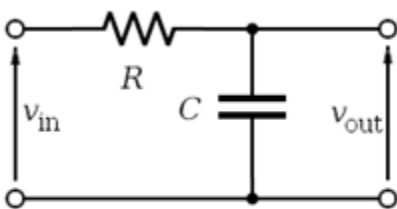
To integrate well, $\omega_c = 1/RC$ should be a lot less than the frequencies of interest. For the given C, $f_c = 318Hz$, so all the high frequencies are really averaged out. The next two smaller values are also OK, but do not produce as clean a signal. They do keep the magnitude of the signal up however.

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Question IV – Complex Circuits (Cont)

   d. A student team decides to add the circuit below after the audio source. Give two reasons why this may add to the performance of the transmitter-receiver system? (4pts)
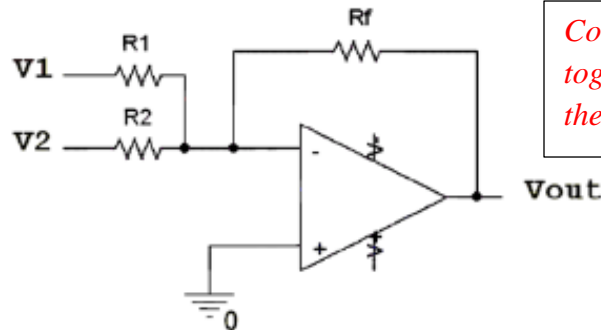
Combine the two stereo channels together and add some gain to get the input levels up.

   e. Answer any one of the following questions (be specific) (5pts):

      a. The receiver circuit incorporates both a pre-amplifier based on the 741 op-amp and the 386 audio amplifier. Why do we use the 386 instead of two 741 amplifiers?

The audio amplifier is designed to drive speakers with some fidelity, which the 741 is not.

      b. What is a reasonable value for the astable multivibrator pulsing frequency? Why?

22-30kHz because we cannot hear it. Also, that will sample frequencies over 2kHz at least 10X per cycle, which will reproduce the signal well.

      c. Based on what you know about diodes, how would you design a simple circuit that will amplitude modulate (AM) the transmitter LED rather than use the pulse position modulation (PPM) as in Project 4.

Add a DC bias near the on voltage for the LED to the audio signal and then the LED will flicker with the audio levels going up and down. The key issue is the bias voltage.