

ENGR-2300  
Electronic Instrumentation  
Quiz 4  
Fall 2012

Name \_\_\_\_\_



Question I (25 points) \_\_\_\_\_

Question II (25 points) \_\_\_\_\_

Question III (25 points) \_\_\_\_\_

Question IV (25 points) \_\_\_\_\_

Total (100 points) \_\_\_\_\_

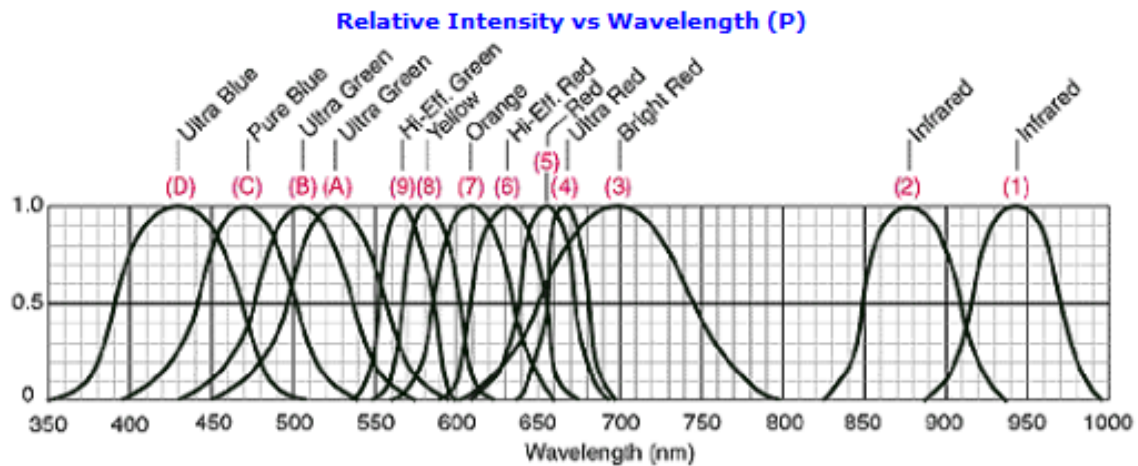
On all questions: SHOW ALL WORK. BEGIN WITH FORMULAS, THEN SUBSTITUTE VALUES AND UNITS. No credit will be given for numbers that appear without justification. Read the entire quiz before answering any questions. Also it may be easier to answer parts of questions out of order.

### Some Additional Background

Some Typical LED Operating Info:

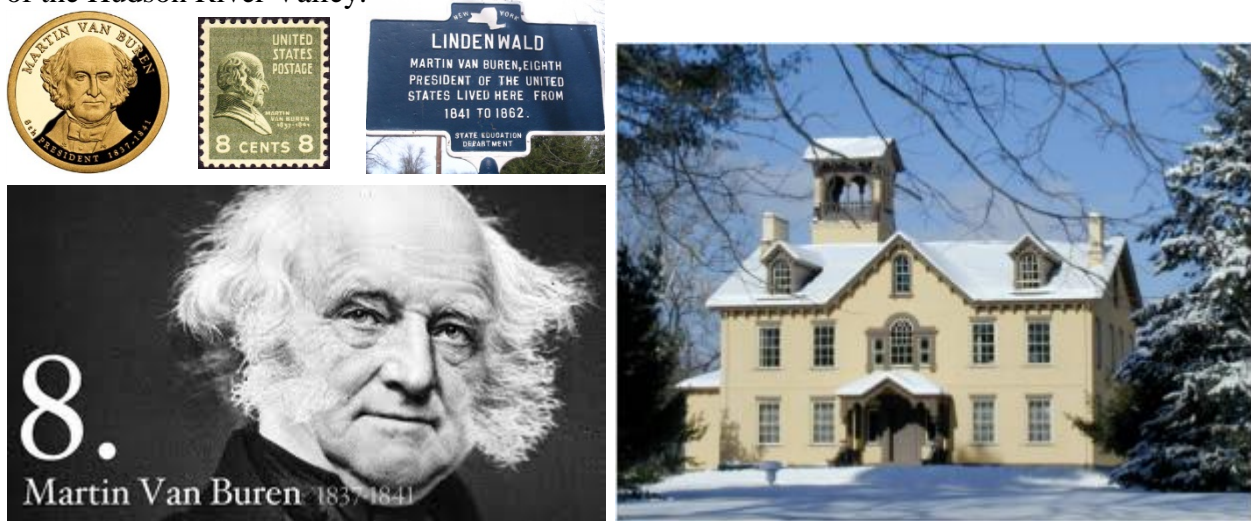
	Wavelength (nm)	Color Name	Fwd Voltage (Vf @ 20ma)	Intensity 5mm LEDs	Viewing Angle	LED Dye Material
	940	Infrared	1.5	16mW @50mA	15°	GaAIAs/GaAs -- Gallium Aluminum Arsenide/Gallium Arsenide
	880	Infrared	1.7	18mW @50mA	15°	GaAIAs/GaAs -- Gallium Aluminum Arsenide/Gallium Arsenide
	850	Infrared	1.7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

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



## 5 December

Martin Van Buren, the 8<sup>th</sup> US President, was born on 5 December, 1782 (making him the first to be born in the US) in the then predominantly Dutch community of Kinderhook, NY. His elegant house in Kinderhook is barely 30 miles from the RPI campus and one of the many great houses of the Hudson River Valley.



There are many wonderful historic sites and great little towns to visit on the Hudson, but one of interest to engineers is Locust Grove, Samuel F. B. Morse's home in Poughkeepsie.



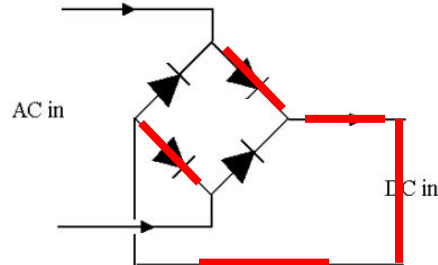
If you have an interest in patents, reading about Morse and his many battles to secure the intellectual property of the telegraph is quite fascinating. Today, only his name is associated with the telegraph but there were many others involved in its development. The history of the telegraph makes very interesting reading for any future and present inventors. One of the key figures in the development of the telegraph was Joseph Henry (originally from Albany and educated at Albany Academy), for whom the units of inductance were named.

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

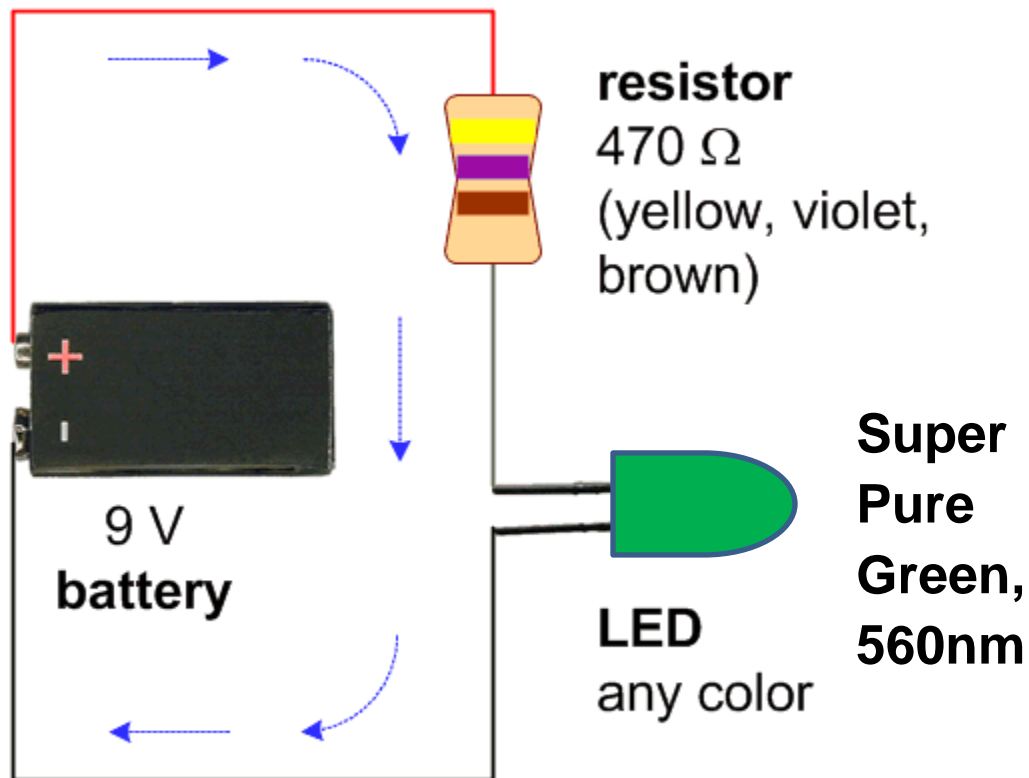
For these multiple choice questions, circle the correct answer. All questions are 3pts, except g, which is worth 1pt. Be sure to explain your answer.

- a. The dc current through each forward-biased diode in a full wave bridge rectifier equals:

- a. The load current  
 b. Near zero current  
 c. Twice the dc load current  
 d. Near infinite current



- b. What is the current through the LED, if we use the specified green LED?



*An LED schematic with a 9V battery, 470 ohm resistor, and a single LED of any color.*

- a. 0 mA  
 b. 4.5 mA  
 c. 12 mA  
 d. 15 mA  
 e. 16.5 mA

For the super pure green LED, the forward voltage is 2.1V. The current is  $6.9/470 = 14.7\text{mA}$  or about 15mA

**Question I Multiple Choice & Short Answer Questions (continued)**

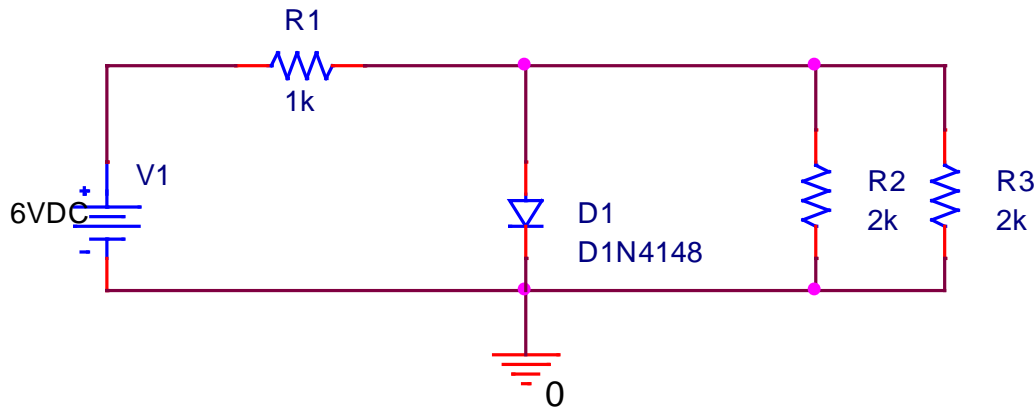
- c. If the frequency of a sinusoidal voltage is lowered, will the ripple for a filtered full-wave rectifier voltage (for the same load resistance and capacitor values):
- Become smaller.
  - Become larger. **Because the time for decay gets larger**
  - Stay the same.
  - None of the above.
- d. A full-wave bridge rectifier is built using four orange LEDs rather than conventional diodes (like the 1N4148). For a given AC input voltage, will the voltage across the load be
- Smaller **Because the drop across the diodes is larger**
  - Larger
  - The same
  - None of the above
- than it was with the 1N4148 diodes?
- e. The magnitude of the peak reverse voltage across a diode in a half-wave bridge rectifier equals approximately:
- Twice the on voltage for the diode
  - Twice the peak value of the **primary (input) voltage**
  - The peak value of the **primary (input) voltage**
  - The on voltage for the diode

**Because no voltage appears across the load (try PSpice if you doubt the answer).**

- f. What is the magnitude of a typical reverse breakdown voltage for a 1N4148 diode?
- |         |                             |          |
|---------|-----------------------------|----------|
| a. 0V   |                             | e. 100V  |
| b. 0.7V | <b>You either know this</b> | f. 400V  |
| c. 4.7V | <b>or you do not.</b>       | g. 1000V |
| d. 10V  |                             |          |
- g. Which number is largest?
- |         |                         |          |
|---------|-------------------------|----------|
| a. Zero | <b>This is one free</b> | d. Three |
| b. One  | <b>point.</b>           | e. Four  |
| c. Two  |                         | f. Five  |

### Question I Multiple Choice & Short Answer Questions (continued)

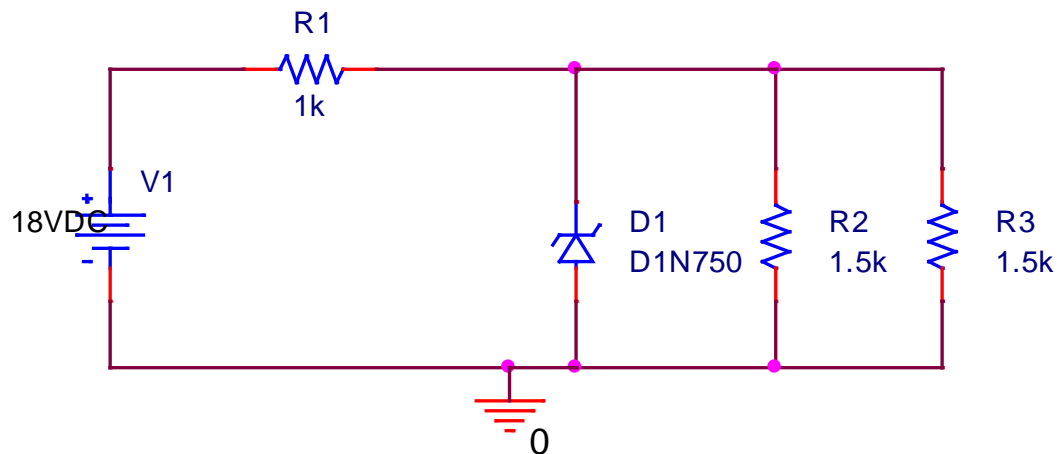
h. What is the approximate current through the diode?



- a. 2.5 mA
- b. 3 mA
- c. 4.5 mA
- d. 6 mA

The two 2k resistors add to 1k. The voltage across the diode is 0.7V (can also use 0.6V). Thus,  $(5.3/1k)$  is the current through the first 1k resistor. The current through the 1k in parallel with the diode is  $0.7/1k = .7mA$  so  $I_D = 4.6mA$  or about 4.5mA.

i. What is the approximate current through the resistor R2?  $V_Z = 4.7V$



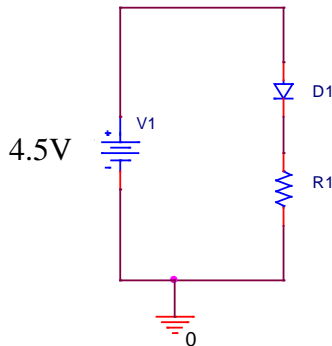
- a. 1 mA
- b. 2 mA
- c. 3 mA
- d. 4 mA
- e. 0 mA

The voltage across R2 is 4.7 because the Zener is on. Thus, the current is  $I = 4.7/1.5k$  which is very close to 3mA.

**Question II - LEDs and Phototransistor Circuits (25 points)**

A green LED is driven by a standard DC source. The source we have is a combination of three 1.5 Volt batteries. We need a forward bias voltage of 3.5V and a current of 50 mA.

- a) (8pts) Using the three 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 across the resistor is  $4.5 - 3.5$  or 1V. The current is to be 50mA or  $R = 1/.05=20\text{Ohms}$ . The total power is just 4.5 time 50mA or 225mW or .225W

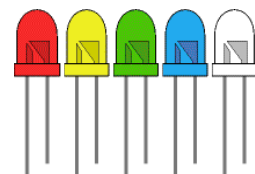
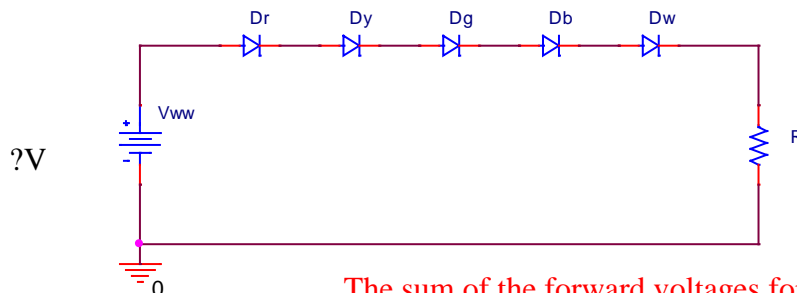
We now want multiple LEDs like a short string of Holiday lights. For this purpose, we will use five different color LEDs: Red, Yellow, Green, Blue and White. We will use the green LED from part a) and the four LEDs marked with a ★ in the table above. For the power supply, we will use one of two universal 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, you must select the minimum voltage from one of the power supplies.

- b) (8 pt) **Determine the voltage V<sub>vw</sub> 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.

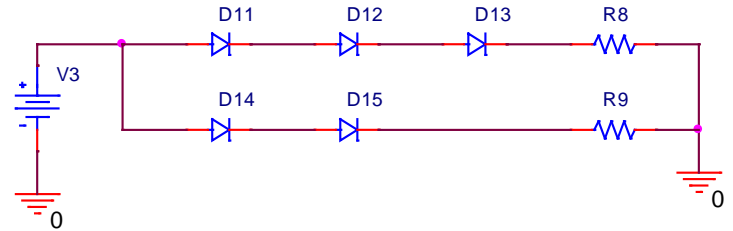
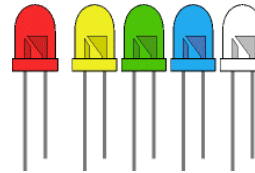
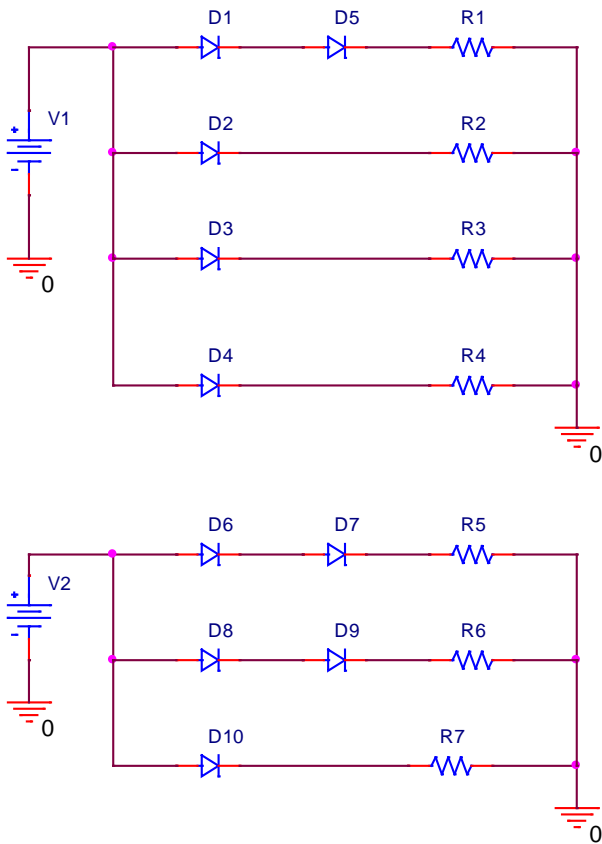


The sum of the forward voltages for the LEDs will be  $3.5 + 2.2 + 2.2 + 3.6 + 3.6 = 15.1\text{V}$  or we have to use the 16V supply. For the resistance then, the voltage across R is  $16 - 15.1 = .9\text{V}$  so R is  $.9/.02=45\text{ Ohms}$ .



### Question II - LEDs and Phototransistor Circuits (Cont)

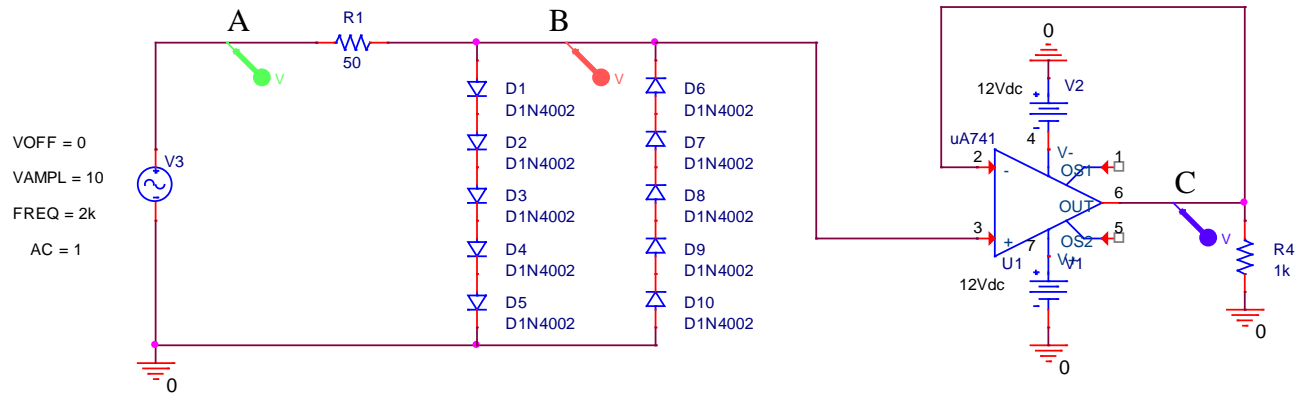
- c) (9 pt) Determine the configuration and resistances to achieve the desired operating conditions for the series/parallel combination of 5 LEDs if we are limited to only the 9V source and you are to use the minimum number of components required to light up all five LEDs. Assume that the current in 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.



The minimum configuration is the one at the right because it has the fewest components. To keep under 9V, combine  $3.6 + 3.6$  and  $3.5 + 2.2 + 2.2$  in the two legs. For the first, the R will be  $1.8V/.02 = 90\Omega$  and for the second R will be  $1.1/.02 = 22\Omega$ . Since we can get the minimum configuration to work, we only need to do one case.

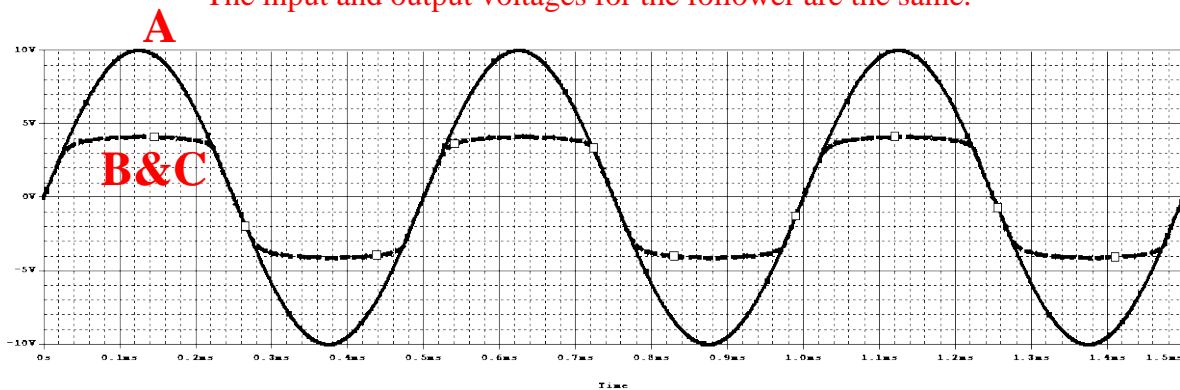
**Question III – Diode Circuits (25 Points)**

- a. Voltage Limiter Circuit (10 Points) – 1N4002 diodes are used to limit the voltage at the input of a voltage follower. (Protection like this keeps the Mobile Studio board working even when you build your circuit incorrectly.) In the circuit below, a total of 10 diodes are used to limit the input voltage. As you can see from the probe markers, the voltage was determined at three points in the circuit.



Label the three voltage signals shown below with the letters given above.

The input and output voltages for the follower are the same.

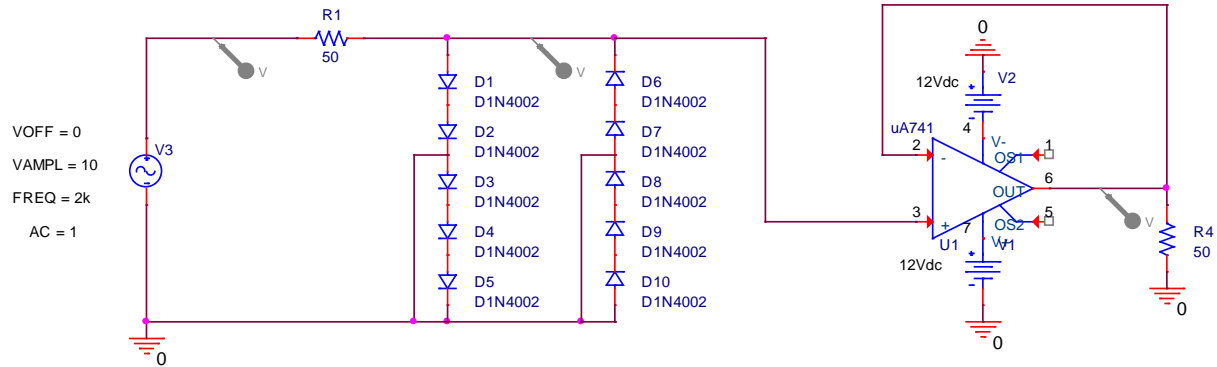


From the information given in the plot, what is the approximate forward voltage of the 1N4002? (5 Pts)

There are 4 diodes with a total forward voltage of 4V or 0.8V for each diode.

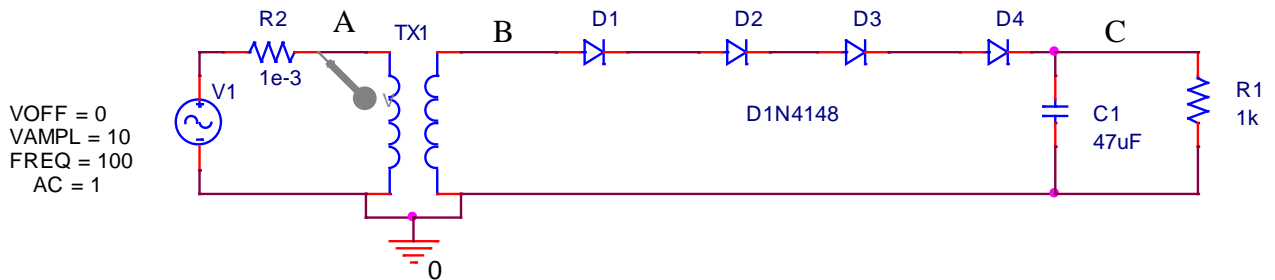
The 1kΩ load is replaced by a 50Ω load (very common in instrumentation). From Experiment 4, you should recall that there is a limit to the amount of current that an op-amp can provide to a load. Assume that this limit is 40mA. How many voltage limiting diodes would you use to limit the input voltage to the voltage follower so that the output current of the 741 is kept below 40mA? Draw the new configuration on the next page. (5 Pts)

**Question III – Diode Circuits (Cont)**

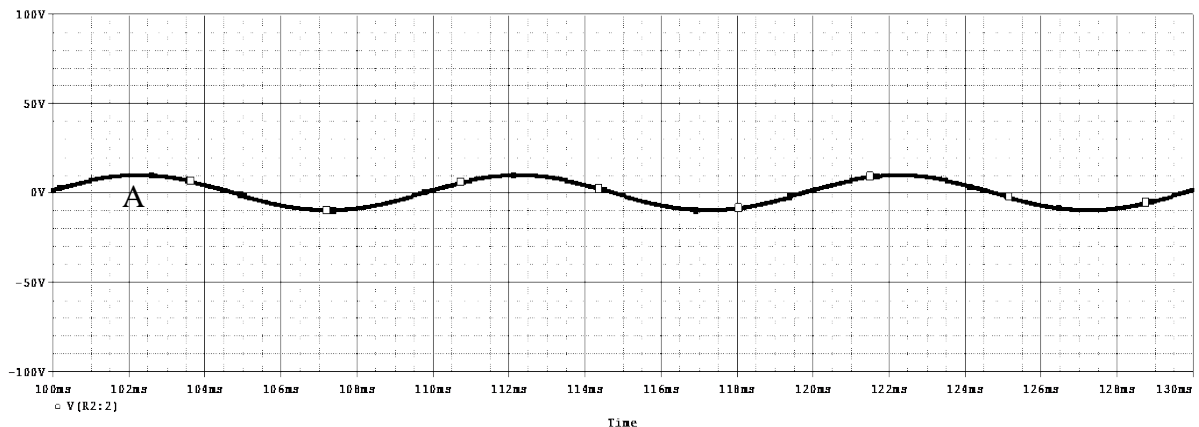


Only two diodes in each direction for a total of four. The circuit above shows three diodes shorted out in each direction. Each diode has a forward voltage of 0.8V for a total of 1.6V which is smaller than 2V. The output voltage has to be kept lower than 2V or the current will exceed  $2/50 = 40\text{mA}$

- b. Half-wave rectifier (15 Points) – A smoothed half-wave rectifier, configured with four 1N4148 diodes, is driven by a 10V, 100Hz sinusoidal source and a transformer. The primary inductance of the transformer is 10uH and the secondary inductance is 1mH. The load resistor R1 is 1kΩ.

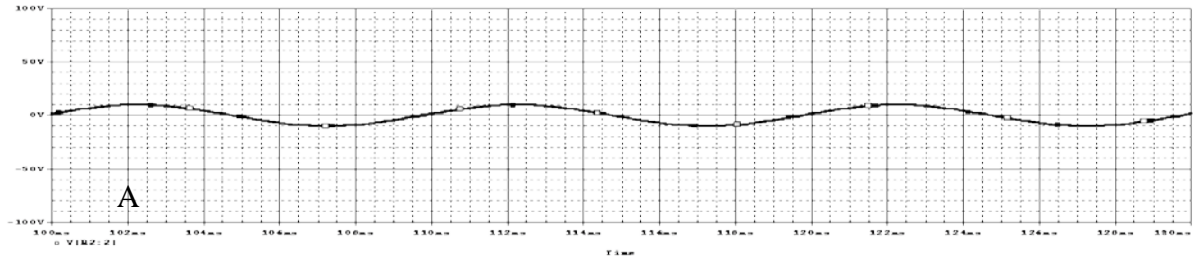


Sketch the voltage signals at points B and C. The signal at A is shown in the figure. (10 Pts)

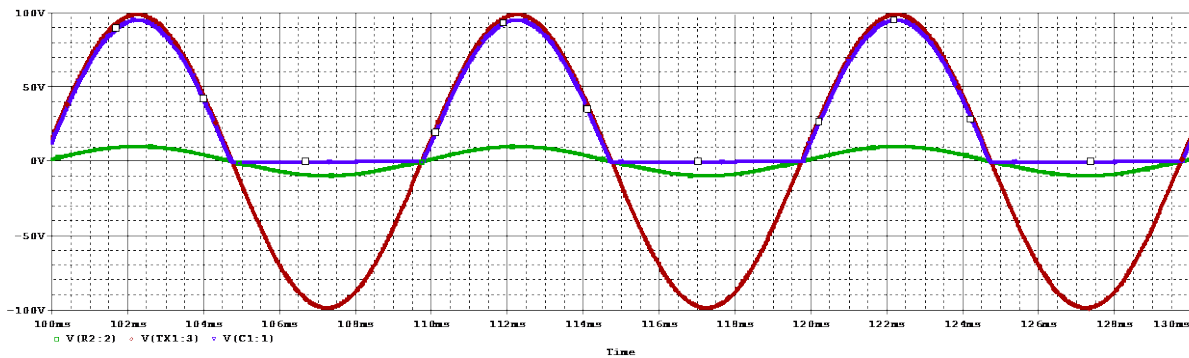
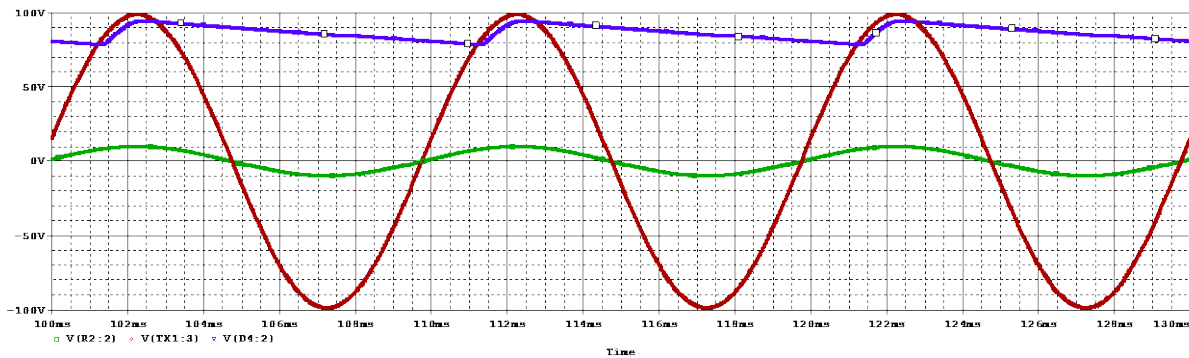


**Question III – Diode Circuits (Cont)**

For reference purposes, also sketch the signals at points B and C for the case where there is no smoothing capacitor. (5 Pts)



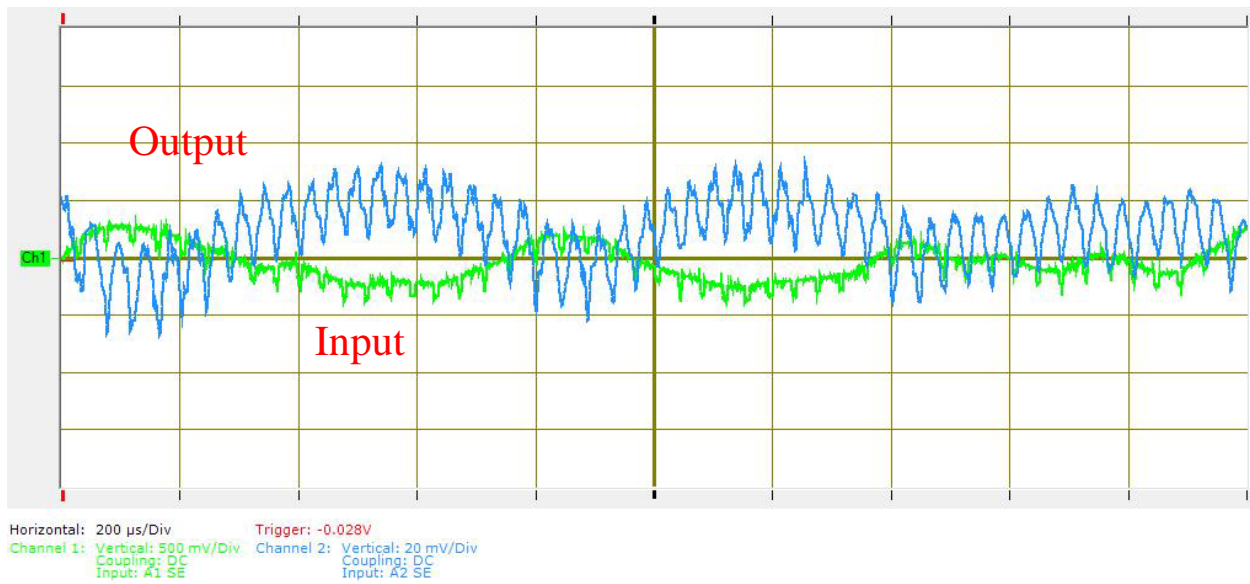
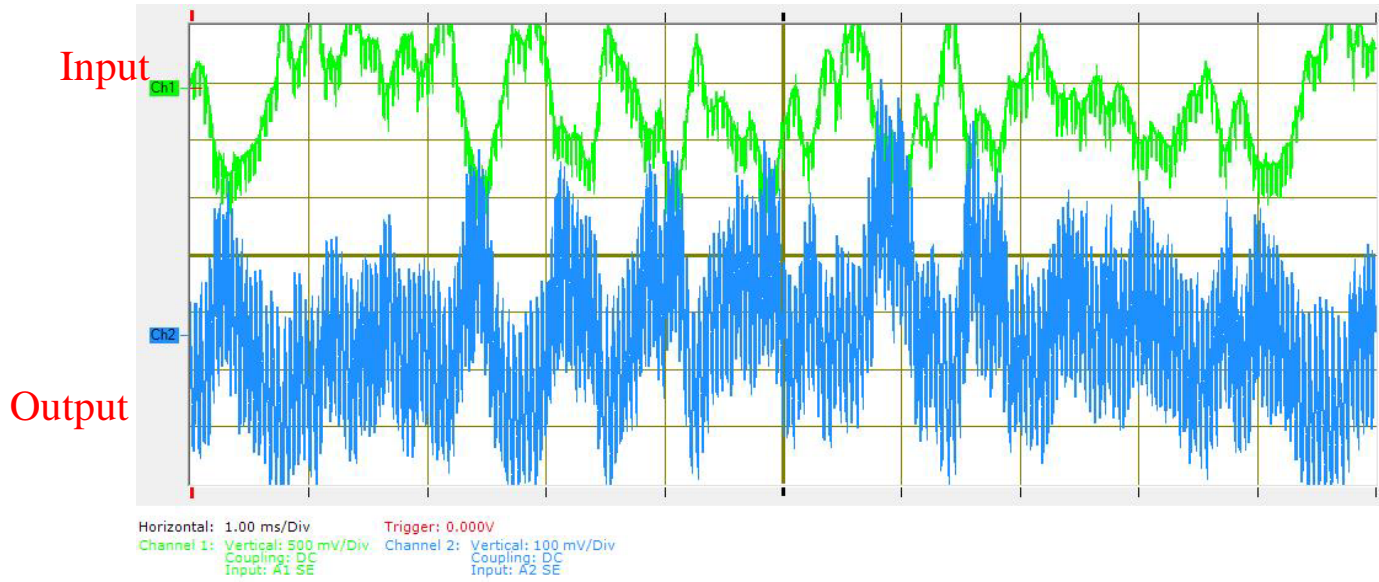
Be sure to show all of your work in determining the two voltages for both cases.



The ratio of the inductances is 100:1 so the turns ratio is 10. The transformer output will be 100V. The forward voltage across 4 diodes is about 3.6V so the peak output voltage after the diodes is  $100 - 3.6$  or about 96V. With no smoothing, the forward voltage tracks the transformer output  $- 3.6$ V. The reverse voltage is zero. With smoothing, the droop will be  $100(10\text{ms}/RC) = 100(10\text{ms}/47\text{ms}) =$  about 20V which is what is shown on the plot.

### Question IV – Complex Circuits (25 Points)

- a. Optical Transmitter-Receiver Project – Shown below are two examples of measurements taken with the transmitter and receiver. One of the signals is the audio input to the transmitter and one is the output at the speaker attached to the receiver. For both cases, label which signal is the input (location A) and which is the output (location H). (5 Pts)



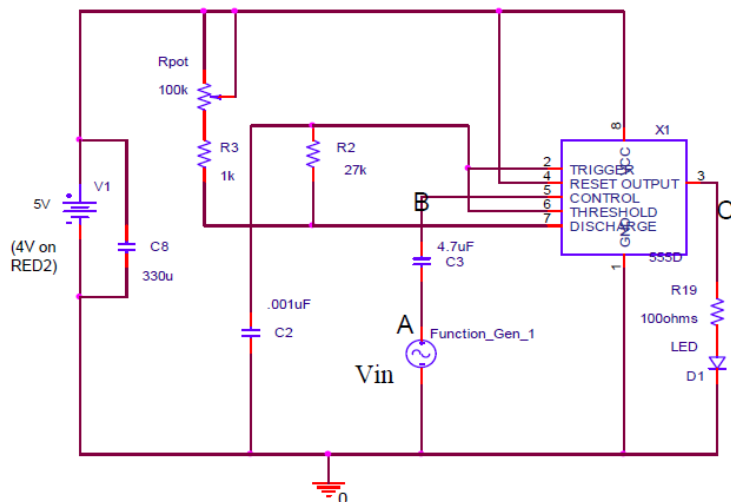
- b. Identify the main characteristics of each signal and use this information to explain your choice of labels and to explain why this data shows that the circuits are working as they should. Be as complete as possible with your explanation. The two circuit diagrams are on the following page. (8 Pts)

**Question IV – Complex Circuits (Cont)**

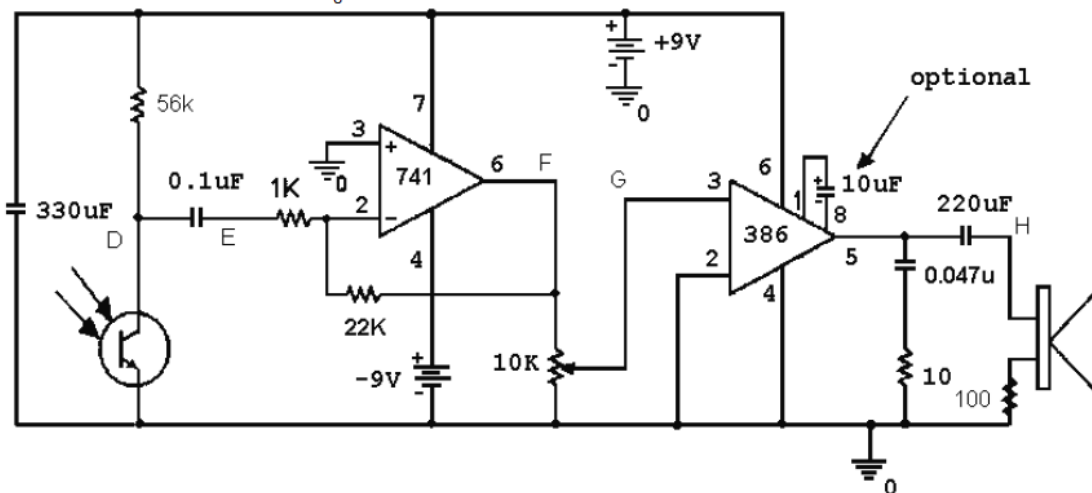
The entire scan is 1ms/div times 10 divisions or 10ms. Thus, the frequencies shown are generally in the lower audio range. For the upper plot, there are about 12 peaks in the 10ms for the main frequency which is about 1.2kHz. There is also a frequency that is much higher, probably too high to read from this plot. In the lower plot, the main signal is 3 cycles in 10 times 200μs/Div or about 1.5kHz (similar to the top). The higher frequency can be read in this case. There are about 50 peaks in 2ms for a frequency of about 25kHz.

Thus, we see that input is a relatively clean audio signal while the output looks similar except that it has a large 25kHz signal on top of it. This latter signal is from the 555 timer in the transmitter and is at a frequency that is generally too high to hear.

The proof that the system is working as expected is that the low frequency part of the output signal is similar to the input signal (inverted). Thus the output contains the input along with something we cannot hear.



The basic idea behind this question is to check for any level of understanding of how the transmitter-receiver works. The key characteristics to identify are the original audio signal and the modulation due to the 555 timers seen on the output. The low freq part of the output should track the input.



**Question IV – Complex Circuits (Cont)**

- c. What are the purposes the  $0.1\mu\text{F}$  capacitor at point E and the  $330\mu\text{F}$  capacitor at the far left in the receiver circuit? (6 Pts)

The cap at E is to block the DC bias voltage required by the phototransistor

The  $330\mu\text{F}$  cap at the left is to stabilize the DC voltage source. It can also be thought of as an AC short that eliminates AC or noise signals or as a smoothing capacitor. Basically, it reduces the noise on the DC bus.

- d. We have considered a variety of circuits in the four projects in this course. Describe an application of any of these circuits, individually or in combination, that was not addressed in the projects? That is, how could you use what you have learned in a new application? Any reasonable answer will be accepted. Explain why you think your idea will work? Note that we have made several suggestions from time-to-time in discussions in class. You are free to use an idea from these discussions. (6 Pts)

The optical receiver can be used to detect IR signals from remote controls. It can also be used to create a popping noise when detecting a flashing light. Anything reasonable will be accepted.