ENGR-4300

Electronic Instrumentation

Quiz 4

Fall 2011

Name ________________________

Section ___

Question I (20 points) ___________

Question II (20 points) ___________

Question III (20 points) ___________

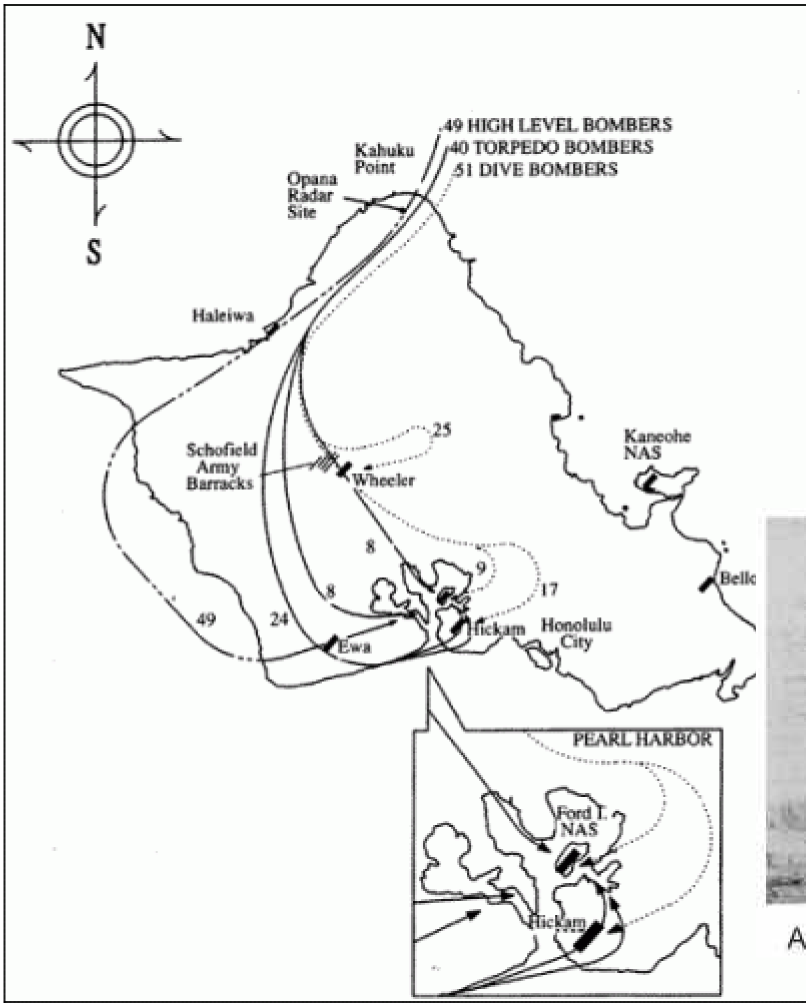
Question IV (20 points) ___________

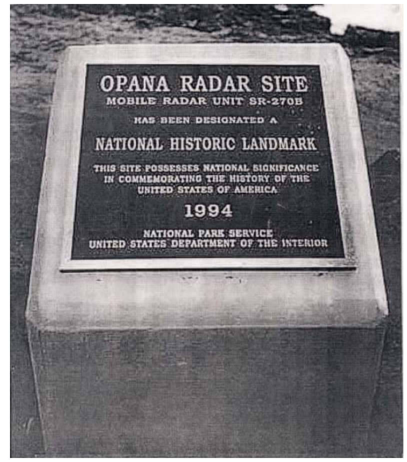
Question V (20 points) ___________

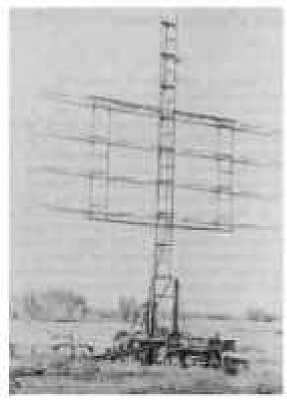
Total (100 points) ______________

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.

7 December 1941





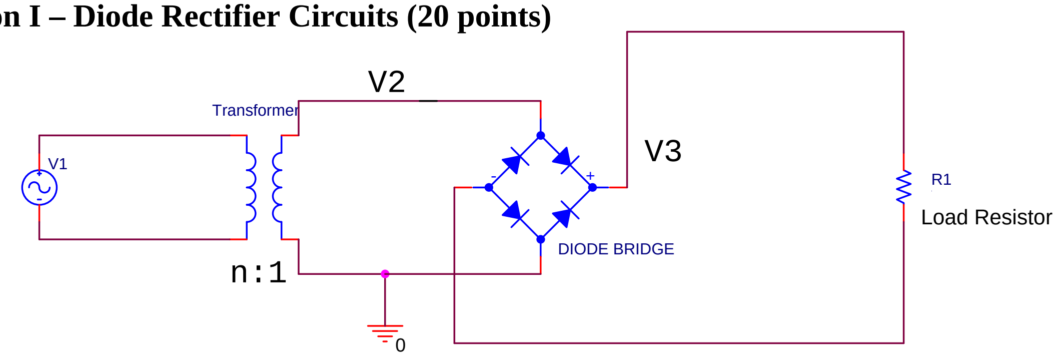

As it was in 1949


As it is now

This map, from the U.S. National Park Service, depicts the location of the Opana Point Radar station. The radar operators working Opana Point, the morning of December 7th, 1941, picked-up signs of incoming planes. They were misinterpreted, however, as planes (which were expected) flying in from mainland America. The original antenna was located in Saskatchewan and moved to the National Electronics Museum in Linthicum, Maryland (near BWI).

USS Anthedon – my dad served on this submarine tender in the Pacific in WWII. Tenders repaired the subs, building most of the parts they needed. It was built in Mississippi and shipped out from New London, CT. He was a pattern maker in the on-board foundry. This boat was sold to the Turkish Navy in 1969, where it may still be in use. The picture of my dad was from when he was home on leave before shipping out.

Question I – Diode Rectifier Circuits (20 points)



The diagram above shows the application of a diode bridge for performing rectification of the voltage from the output of the transformer. The sinusoidal source voltage V1 = $240V_{RMS}$ and R1 = 33kΩ.

1. (5pt) Knowing that the voltage amplitude is $\sqrt{2}$ larger than the RMS voltage, what transformer turns ratio n:1 will give as close as possible to a 24V amplitude at V2? (n should be rounded to an integer.)

The voltage is 1.414(240)=339.4V so that the ratio to 24V is 339.4/24=14.14 or 14 is the integer value.

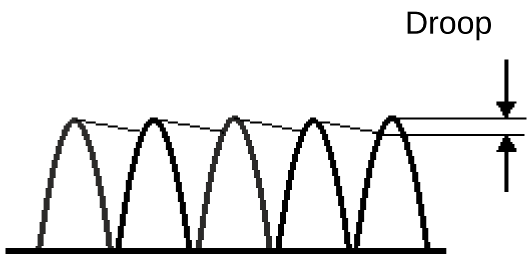
2. (5pt) What will the actual peak voltage be on the output of the full wave bridge (across R1). Let the idealized diodes have V_{on} = 0.7V and V2 is the voltage from the turns ratio in question 1?

The peak voltage is (339.4/14)-(.7+.7)=22.84

Question I – Diode Rectifier Circuits (continued)

3. (5pt) Given R1 above, what is the peak current that will flow through any of the 4 diodes?

The peak current is then the peak voltage divided by 33000 or about 0.7mA



4. (4pt) For a 50Hz input voltage V1 a capacitor is added in parallel with R1 to reduce the ripple in the voltage across the load resistance so that the droop from the peak value is less than 1V. Which of the following values is the minimum capacitance necessary to achieve this?

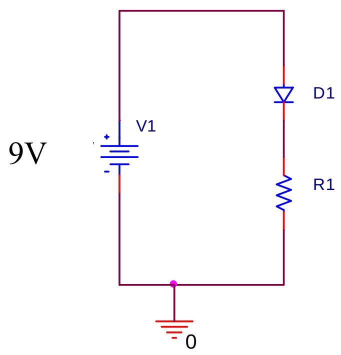
a) 1μF b) 4.7μF c)10μF d) 47μF e) 100μF f) 470μF

The time constant is τ=RC. The droop is 1V in half of the period of the 50Hz source. The peak voltage is about 23V so that the percentage droop is 1/23 or about 4% so that the time constant needs to be 0.01/.04=230ms and C=7uF. The smallest value is 10uF.

Question II - LEDs and Phototransistor Circuits (20 points)

A white LED is driven by a standard DC source. The source we have is a 9 Volt battery. We need a forward bias voltage of 3.5V and a current of 50 mA.

a) (***5pt***) Using the 9 Volt battery, **determine the resistance R1** necessary to achieve the desired operating conditions for the diode. Also determine the total power dissipated in the circuit.



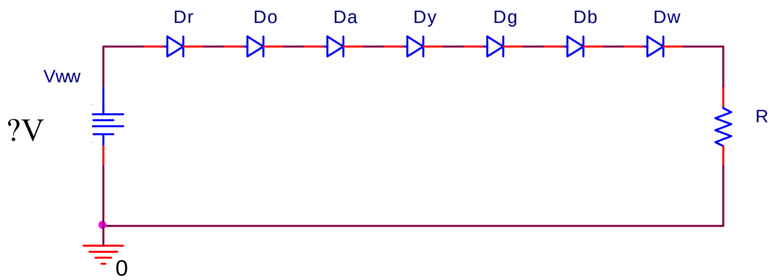
We now want multiple LEDs like a short string of Holiday lights. For this purpose, we will use seven different color LEDs: Red, Orange, Amber, Yellow, Green, Blue and White. The seven LEDs we have are found in the table below. Our Red LED is labeled Super Red in the table and all seven LEDs are indicated in bold letters.

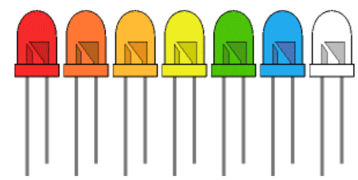
Color	Material	Wavelength (nm)	V-forward
Super Red	GaAlAs	660	1.8
Green	GaP	565	2
Red	GaAsP	645	2
Red	AlInGaP	646	2
Orange	AlInGaP	610	2
Yellow	AlInGaP	590	2
Amber	GaAsP	605	2.1
Red	GaP	700	2.1
Green	GaP	555	2.1
Green	AlInGaP	574	2.2
Blue	SiC	430	3.5
Green	InGaN	505	3.5
Blue	InGaN	470	3.5
White	InGaN		3.5
Green	InGaN	525	3.7
Green	InGaN	525	4
Blue	SiC	430	4.5

Question II - LEDs and Phototransistor Circuits (continued)

For the power supply, we will use a universal AC adapter that can output one of the following voltages (switch selectable): 3V, 6V, 9V, 12V, 15V, 18V, 21V or 24V. Power is limited to 20W. For the next two questions, you must select the minimum voltage from the power supply.

b) ***(5 pt)*** **Determine the voltage Vww and resistance R** to achieve the desired operating conditions for the series combination of 7 LEDs shown below. Assume that the current is 25mA, since we have to be limited to the smallest maximum current for any of our seven 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 7 on voltages is (1.8+2+2+2.1+3.5+3.5+4.5)=19.4V

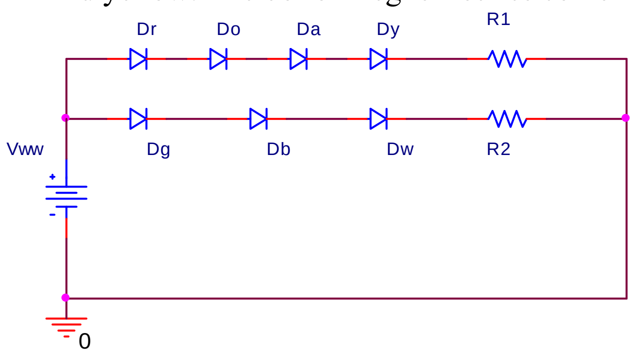
The next larger voltage is 21V so we choose that voltage for Vww.

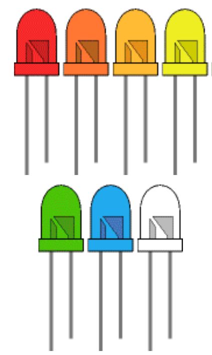
The resistance is determined by the current limit of 25mA=(21-19.4)/R or R=64Ohms

Checking I=(1.6/64)=0.025A so it does check.

Question II - LEDs and Phototransistor Circuits (continued)

c) ***(5 pt)*** **Determine the voltage Vww and resistances (R1 & R2)** to achieve the desired operating conditions for the series/parallel combination of 7 LEDs shown below. Assume that the current in each of the LEDs is 25mA, since we have to be limited to the smallest maximum current for any of our seven 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 in both legs of the circuit. The top leg is a series combination of red, orange, amber, and yellow. The bottom leg is a series combination of green, blue and white.





The sum of the top leg voltages is (1.8+2+2+2.1)=7.9

The sum of the bottom leg voltages is (3.5+3.5+4.5)=11.5

Thus, we choose Vww=12V

The top resistor R1=(12-7.9)/.025=164Ohms

The bottom resistor R2=(12-11.5)/.025=20Ohms

d) (5pts) Determine the total power dissipated in both circuits.

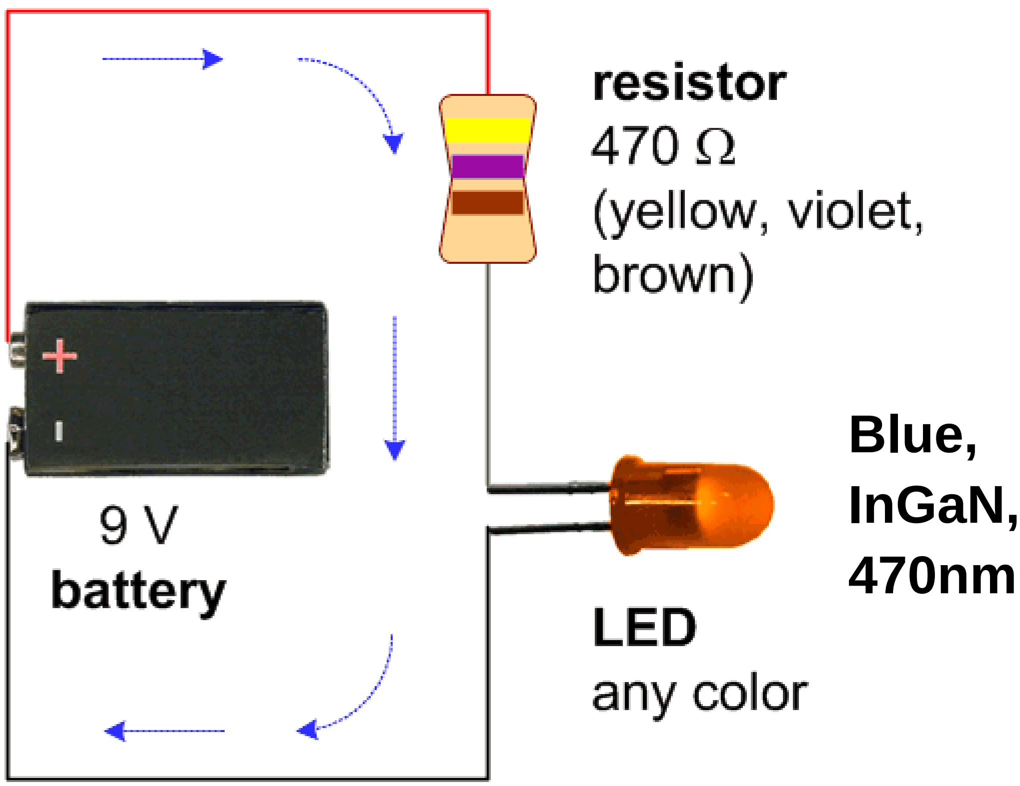
The power in each circuit is the voltage Vww times the current. We do not have to calculate the power to the resistors and LEDs. Thus, for the first circuit, the power is 21(.025)=525mW and for the second circuit, the power is 12(.050)=600mW so they are quite similar. This is to be expected because most of the power does go to the LEDs.

Question III Multiple Choice & Short Answer Questions (20 points)

For multiple choice, circle the correct answer. All are 2pts, unless otherwise indicated.

a. The dc current through each reverse-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 blue 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

(9-3.5)/470=11.7mA so the closest answer is 12mA

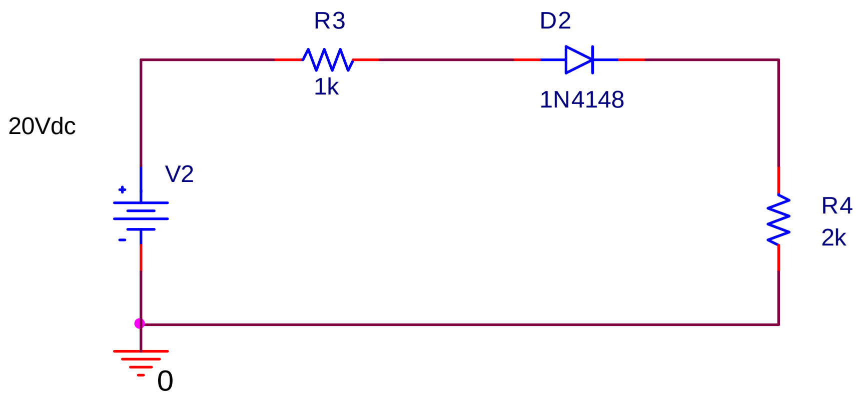
Question III Multiple Choice & Short Answer Questions (continued)

c. A filtered full-wave rectifier voltage has a smaller ripple than does a half-wave rectifier voltage for the same load resistance and capacitor values because:
   a. There is a shorter time between peaks
   b. There is a longer time between peaks
   c. The larger the ripple, the better the filtering action
   d. None of the above

d. Testing a good diode with an ohmmeter should indicate
   a. High resistance when forward or reverse biased
   b. Low resistance when forward or reverse biased
   c. High resistance when reverse biased and low resistance when forward biased
   d. High resistance when forward biased and low resistance when reverse biased

e. The peak forward voltage across a conducting diode in a full-wave bridge rectifier equals approximately:
   a. Twice the on voltage for the diode
   b. Twice the peak value of the secondary (output) voltage
   c. The peak value of the secondary (output) voltage
   d. The on voltage for the diode

f. What is the current through the diode?

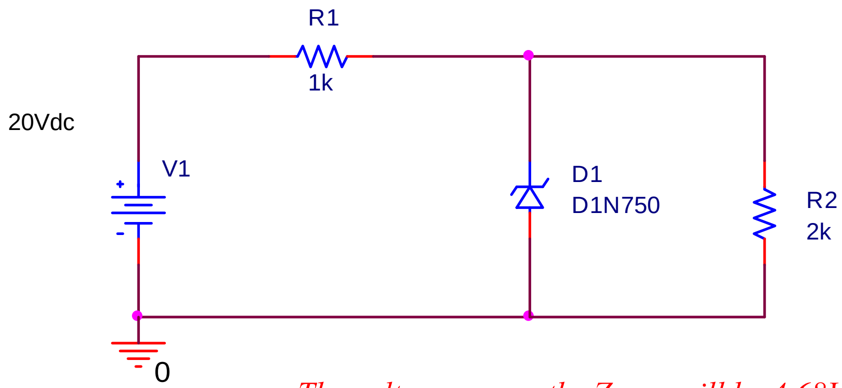


   a. 11 mA
   b. 6.5 mA
   c. 1.4 mA
   d. 0.0 mA

(20-.7)/(3k)=6.4mA and the closest answer is 6.5mA. Would be 6.5mA for a diode voltage of 0.6V

Question III Multiple Choice & Short Answer Questions (continued)

g. What is the current through the zener diode? $V_Z = 4.68V$



a. 0.0 mA
b. 7 mA
c. 8.3 mA
d. 13 mA

The voltage across the Zener will be 4.68V so the voltage across R1 is (20-4.68). The current from through R1 is (20-4.68)/1000=15.3mA. The current through R2 is 4.68/2000=2.3mA. The remaining current passes thru the Zener or 13mA

h. When a diode is reverse biased, the voltage across it
a. Is directly proportional to the current
b. Is inversely proportional to the current
c. Is directly proportional to the source voltage
d. Remains approximately the same no matter what the current is

i. When checking a diode, high resistance readings both ways indicate the diode is:
a. Open
b. Satisfactory
c. Faulty
d. Not the problem

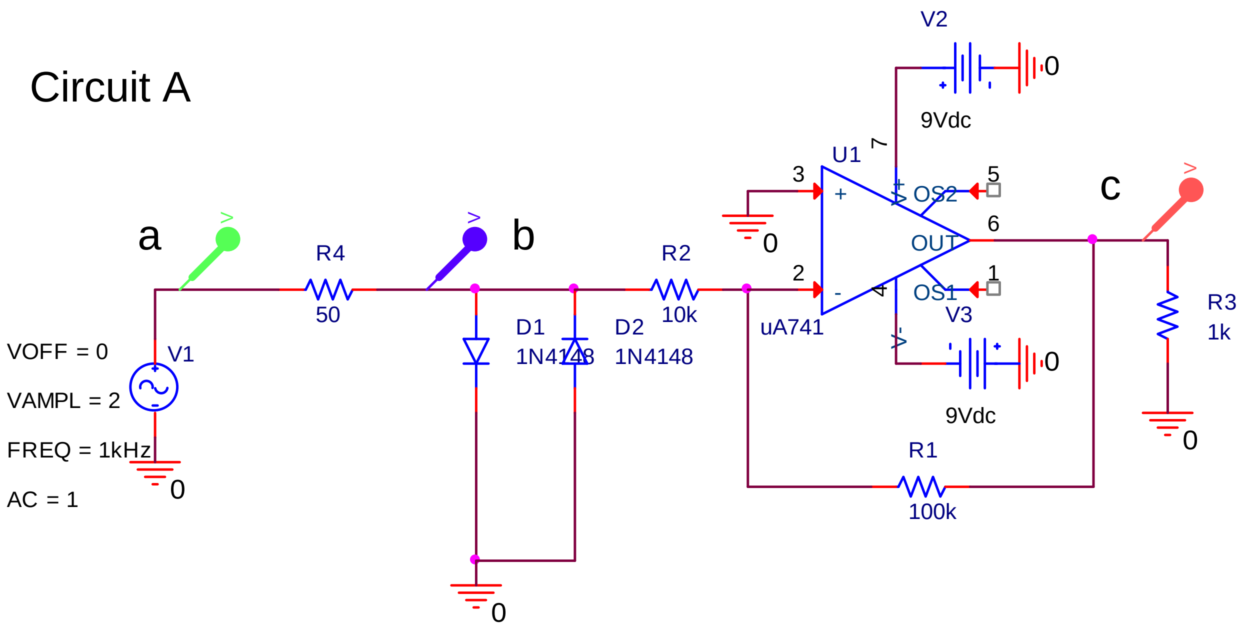
Two possible answers for this question.

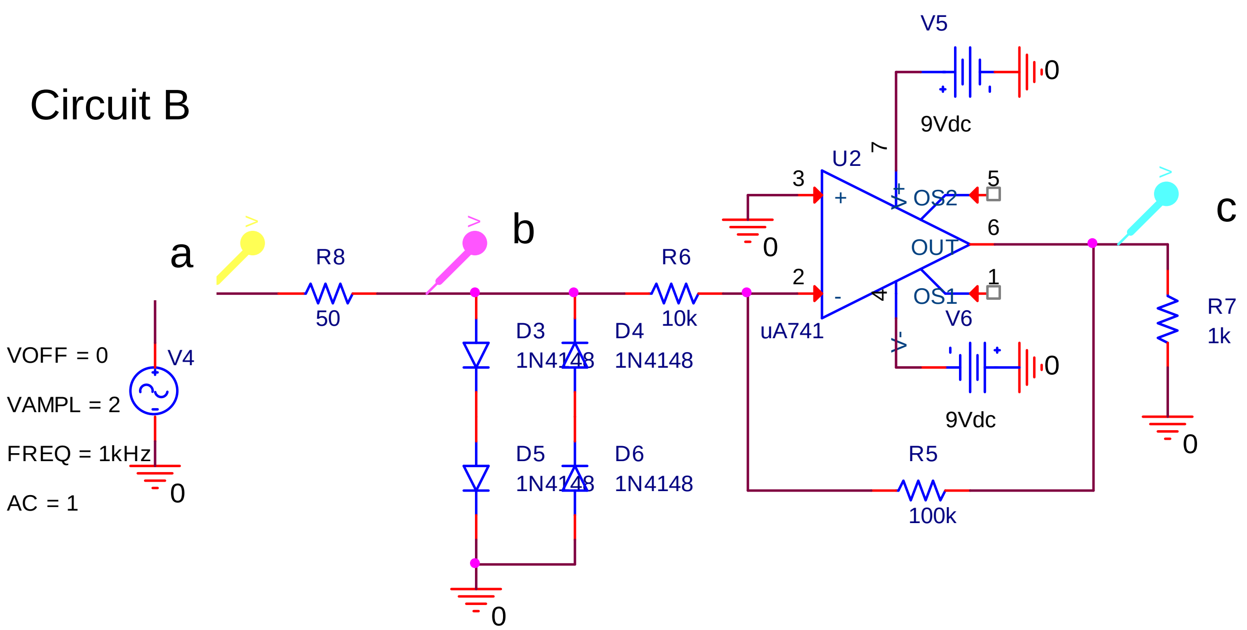
j. On this quiz, you must solve problems II, III & V. For **<u>one</u>** of the other two problems, you can choose to write ‘do not grade’ on it and you will receive the full 20 points, regardless of your actual answer. Note that you have this option for only **<u>one</u>** of the other two problems. You must solve the remaining three problems.

Question IV - Diode Limiter vs. Op-Amp Saturation (20 points)

Hint: To answer the questions most efficiently in this problem, you should treat the diodes as ideal with a finite turn-on voltage.

Two different circuit configurations are considered, each of which involves the use of diodes to limit the input to a simple non-inverting op-amp amplifier. All components used are the same as the ones used in class. The only difference between the circuits is the number of diodes used.

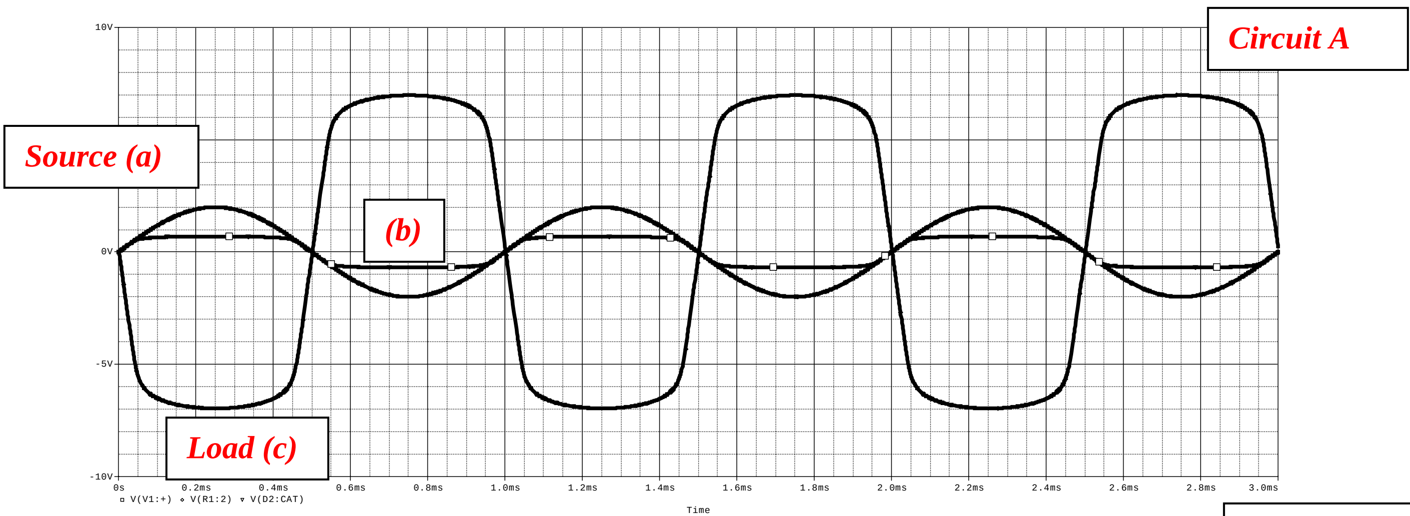


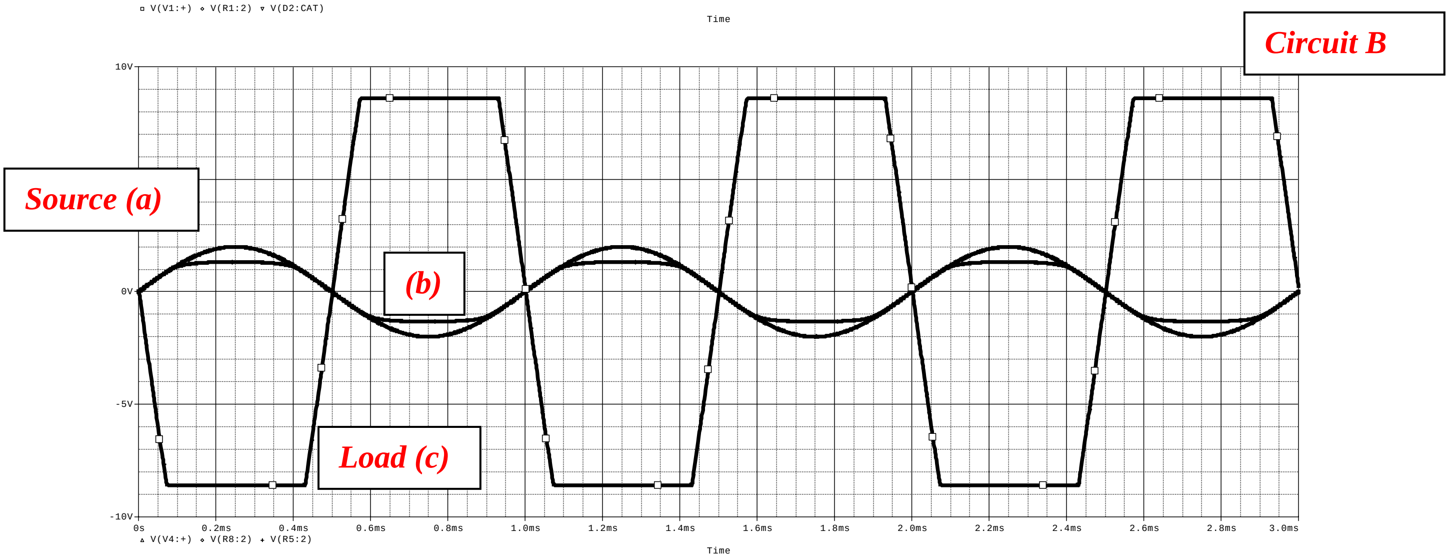


Question IV - Diode Limiter vs. Op-Amp Saturation (continued)

For each circuit, a variety of input voltage levels have been analyzed and the following plots produced. The horizontal scale for all plots goes from 0 to 3ms. The vertical scale for the first two plots is from -10V to +10V.

a. (6 pts) Which of the plots is for circuit A and which is for circuit B with an input voltage amplitude of 2V? For each plot label the three individual traces with the corresponding point in the circuit (a, b, c). Explain your answer in the space below the figures.

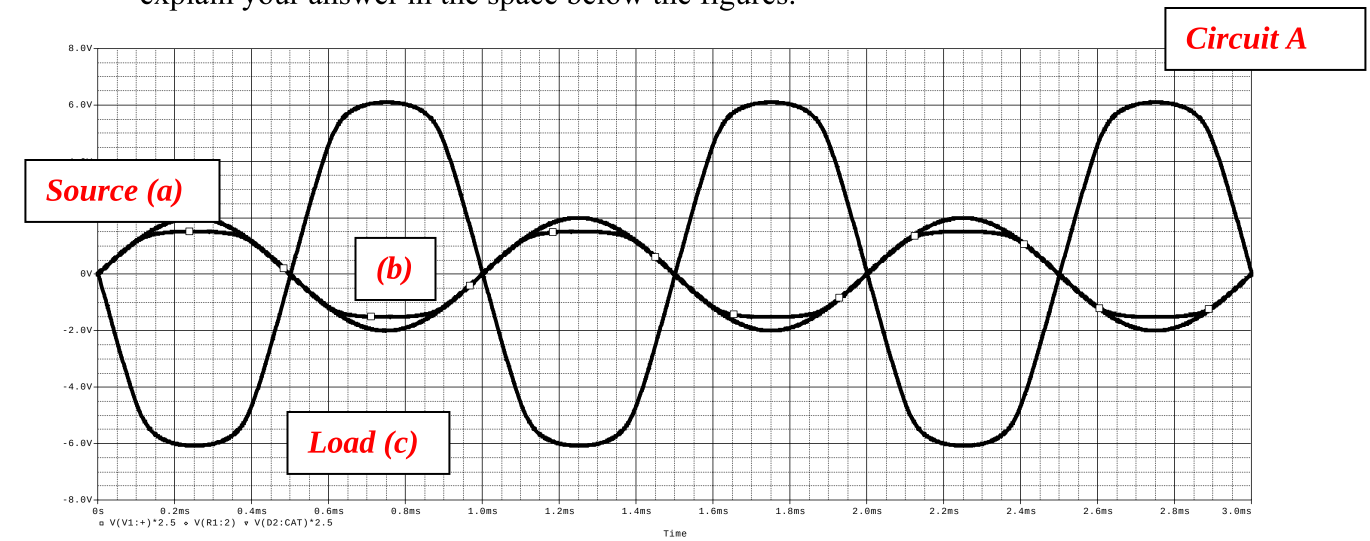


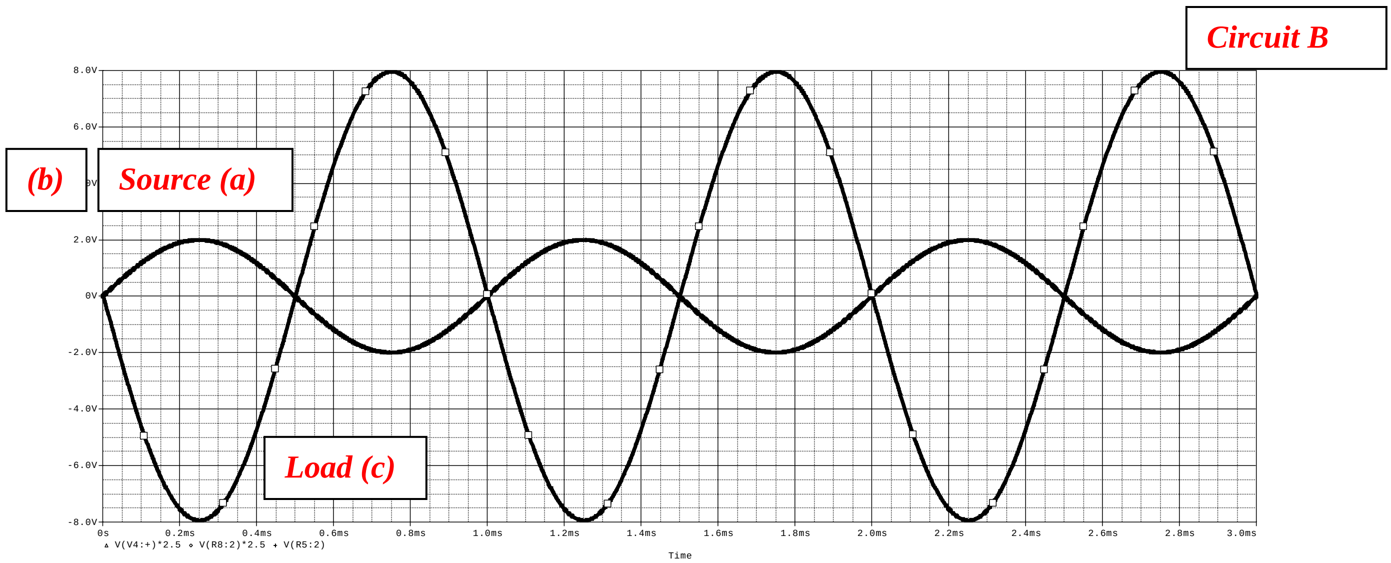


The source voltage is easy to ID in each case because it is a 2V sine wave. The load is the largest voltage because it is the output of a gain of 10 inverting op amp. The third trace in the top plot is limited at a voltage a little less than 1V so it is due to a single limiting diode while the one on the bottom exceeds 1V so it is due to two limiting diodes. Thus, the top is circuit A and the bottom is circuit B. Also, with B, the input voltage to the op-amp is greater than 1V so the output voltage tries to be greater than 9V so the output saturates due to the voltage limitations of the op-amp.

Question IV - Diode Limiter vs. Op-Amp Saturation (continued)

b. (6 pts) The input voltage amplitude is changed to 0.8V. Again, identify the plots and traces. Note that the two smaller voltage traces in each case have been multiplied by 2.5 to make them easier to see on the plot. Also, in one of the cases, the two smaller voltages lie on top of one another. The vertical scale for these two plots is -8V to +8V. Again, explain your answer in the space below the figures.



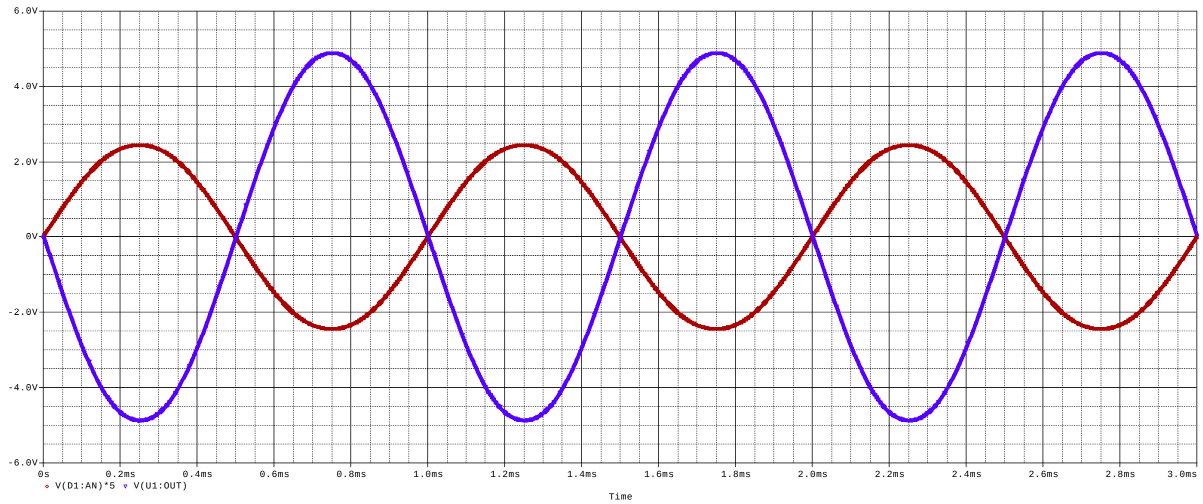


The lower plot shows no limiting at the input to the op-amp because the voltages at a and b are *the same. Thus, this is circuit B where two limiting diodes are used. The output and input to the op-amp (b and c) in the top plot are both limited due to the single limiting diode on the input. They also show the 10:1 ratio in amplitude as expected. There is no saturation of the op-amp this time because no voltage tries to exceed 9V.*

Question IV - Diode Limiter vs. Op-Amp Saturation (continued)

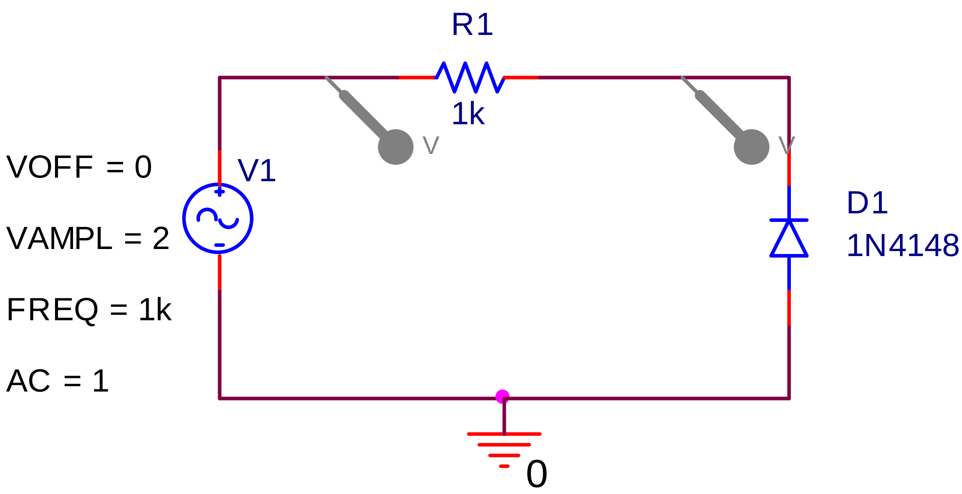
c. (4 pts) The input voltage has been lowered to 0.5V. For the two plots below, the input voltage (at point a) is shown (multiplied by 10 to make it easier to see). You are to sketch the voltages at the other two points for both circuits. In this case, the plots have already been labeled by circuit.

Circuit B **Circuit A**

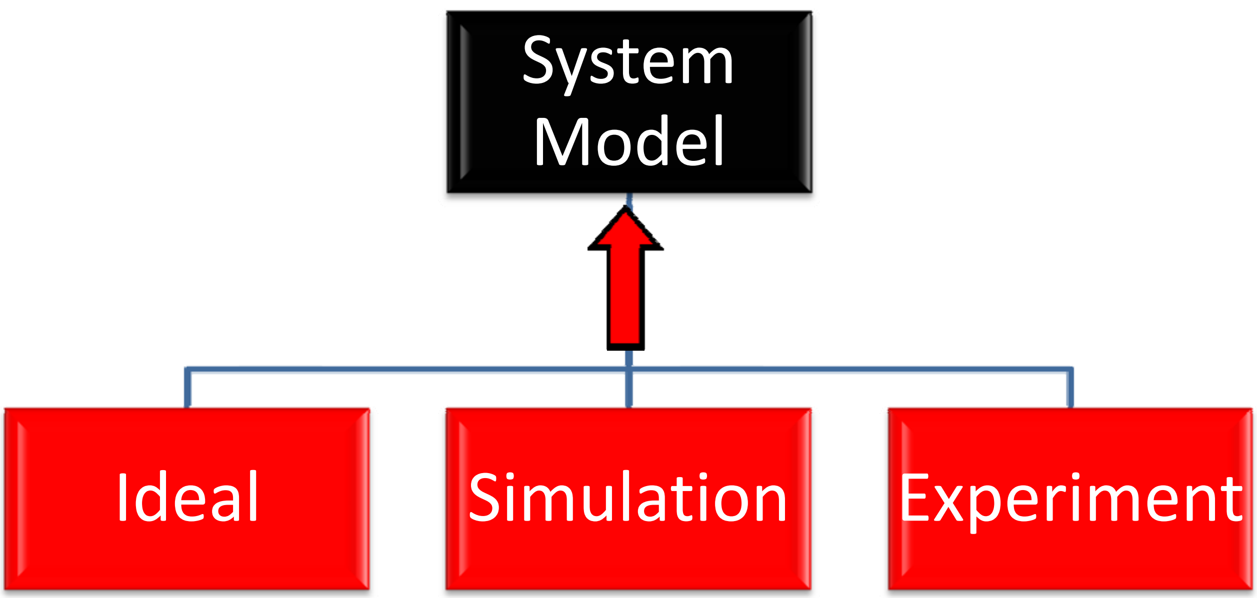


Both circuit A and circuit B look the same because at this input voltage the diodes do not limit anything so the op-amp makes the output 10x the input and inverted.

Question V – Rectifier: System Model (20 points)



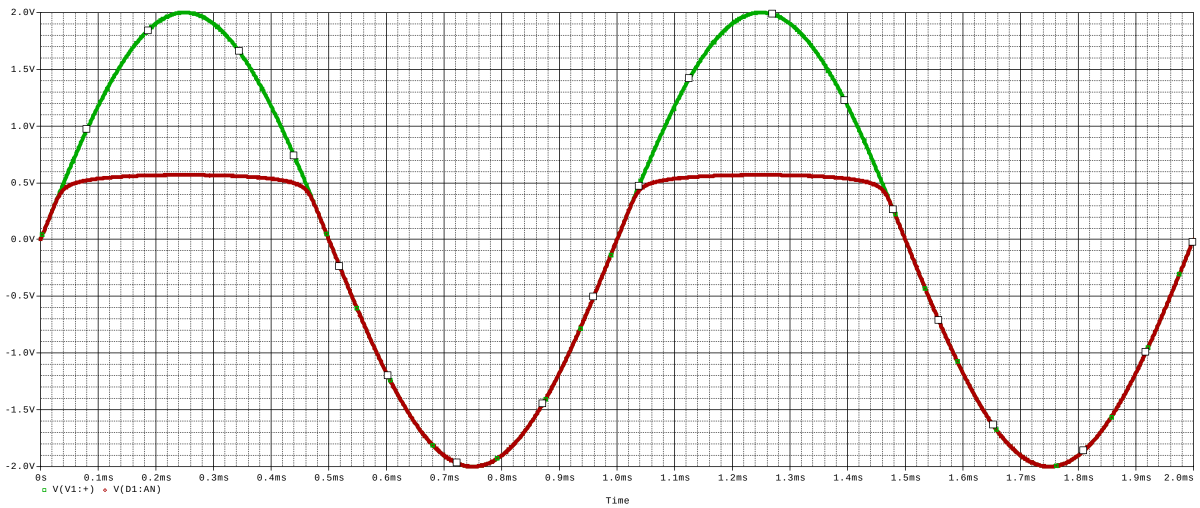
A single 1N4148 diode is connected to a function generator through a 1kΩ resistor. The function generator produces a sinusoidal voltage with an amplitude of 2V and frequency of 1kHz. In this problem, you are to consider this simple circuit using the three basic approaches: from ideal models based on fundamental knowledge of how the components behave, simulation and experimentation.

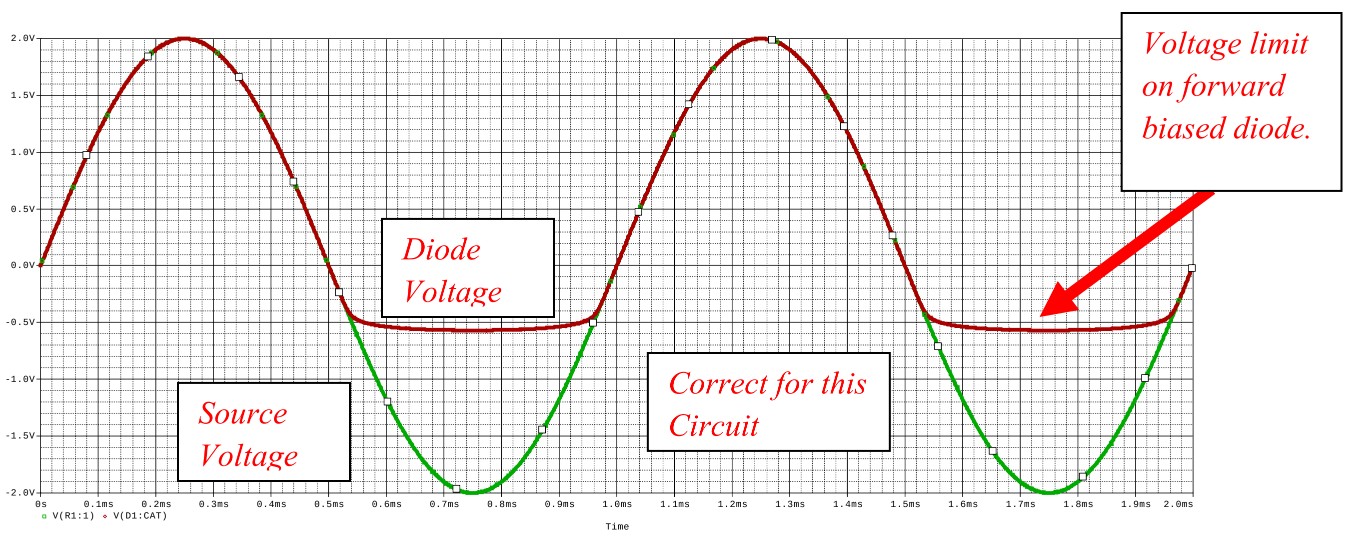


Question V – Rectifier: System Model (continued)

Since we can begin this process at any point, we will start with results from simulation. Note that for all plots in this question, the vertical scale is 0.5V/major division and the horizontal scale goes from 0 to 2ms.

a) (4pts) Shown below are two possible plots of the source voltage and the voltage across the diode generated using PSpice. Select the correct plot and label the source and diode voltage signals. In the space at the bottom of this page, explain your choice and also label any key features in the correct plot that support your choice.



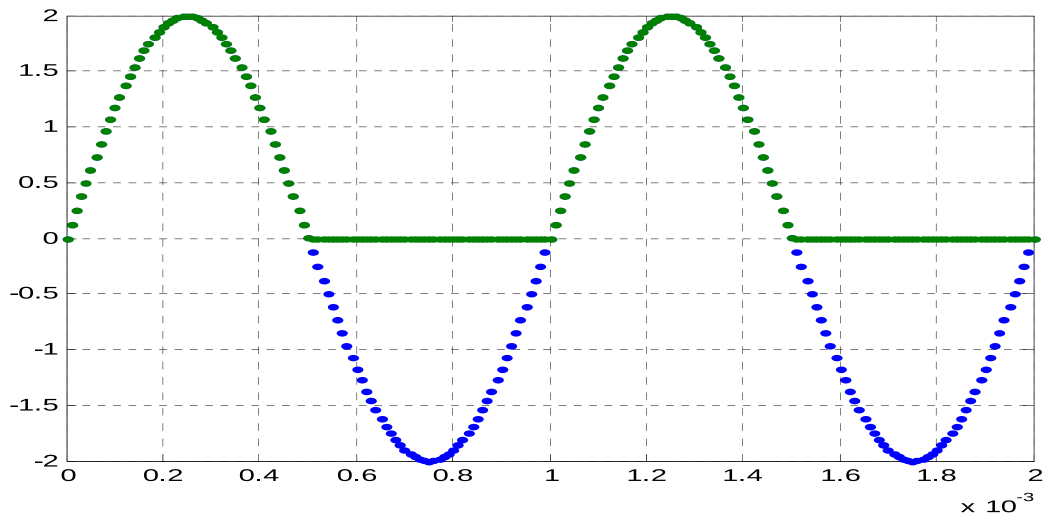


The bottom circuit plot is correct because the diode is oriented so that it turns on when the voltage is negative. The sine wave is the source and the diode voltage shows the limiting by the forward biased diode.

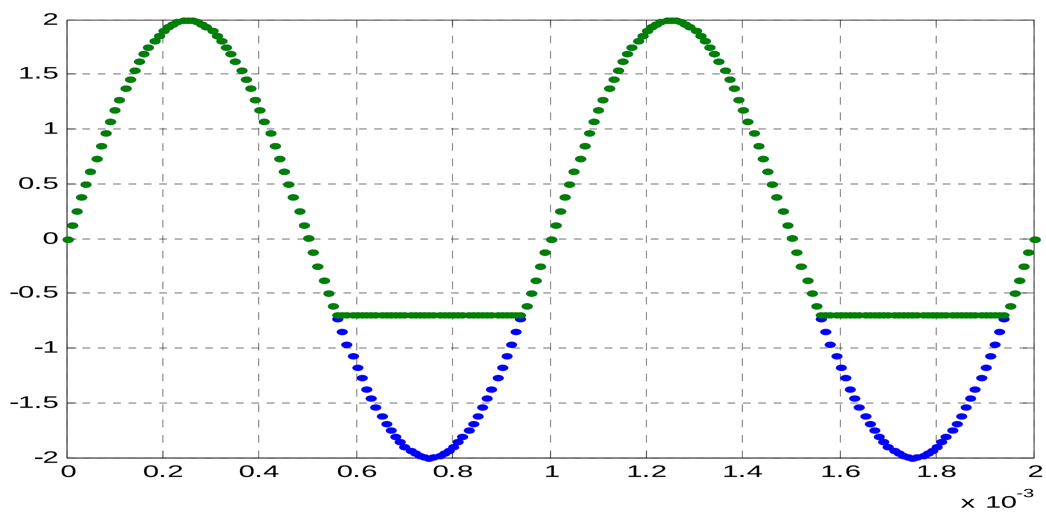
Question V – Rectifier: System Model (continued)

b) (4pts) Included in the formula sheet for this quiz is information on two diode models – the ideal model and the ideal model with the turn on voltage. Sketch the source voltage (V_S) and the voltage across the diode (V_D) for these two ideal models on the two blank plots below. Explain your answers in the space below.

Ideal Diode



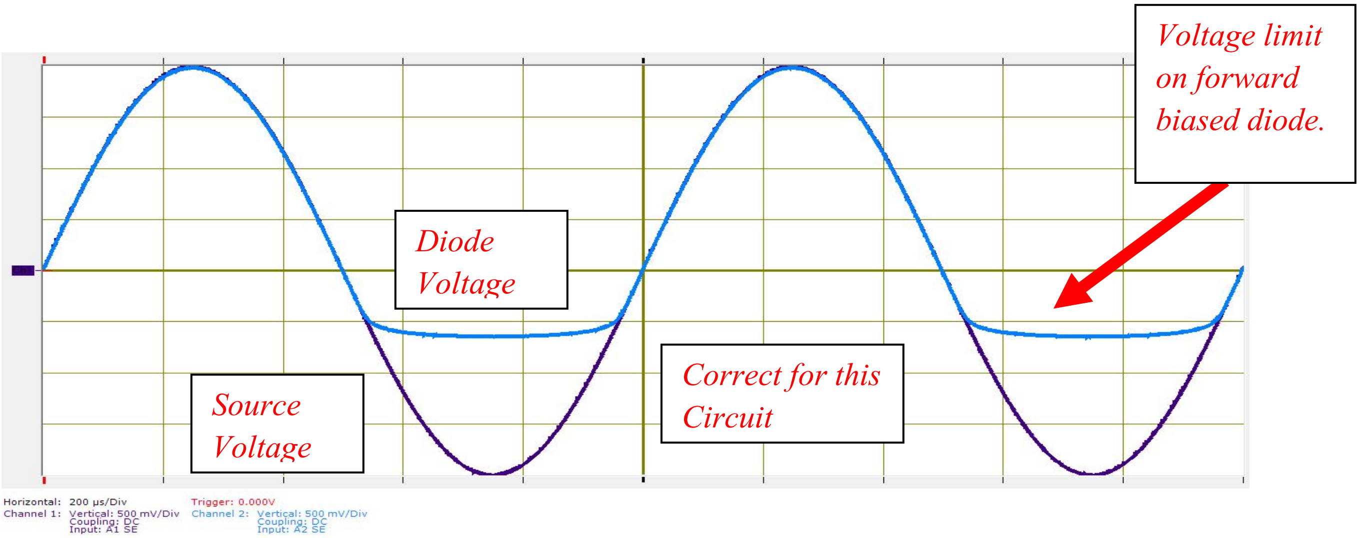
Ideal Diode with V_{ON}

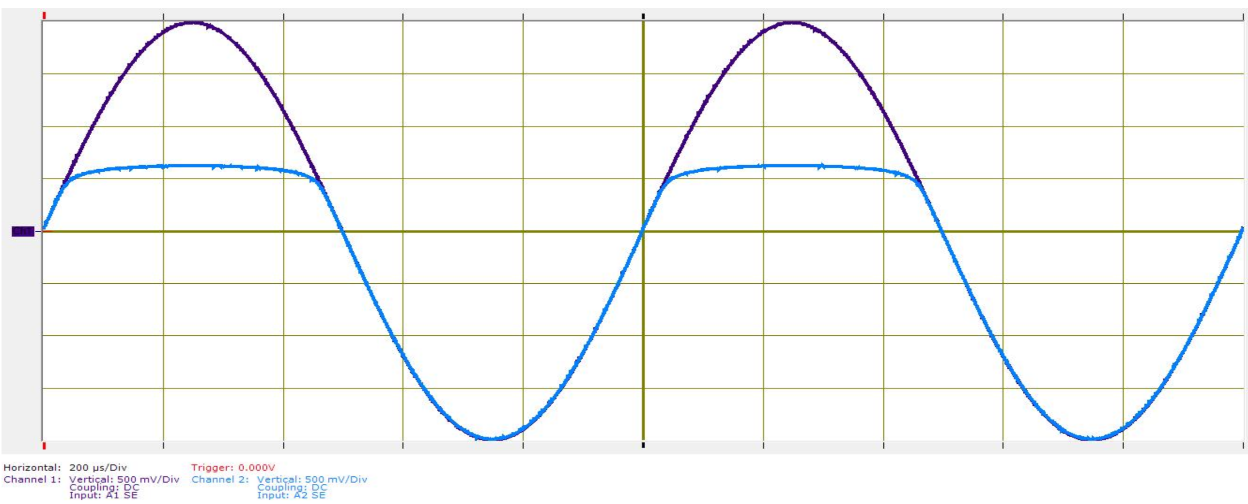


When the ideal diode is forward biased, the voltage is zero (top plot). When we include the on voltage in the model, there is a constant voltage of about 0.7V (bottom plot)

Question V – Rectifier: System Model (20 continued)

c) (4pts) The circuit was also analyzed experimentally using the Mobile Studio. Again, choose the correct figure and label the function generator voltage and the diode voltage. Explain your answer.





Same explanation as in part a.

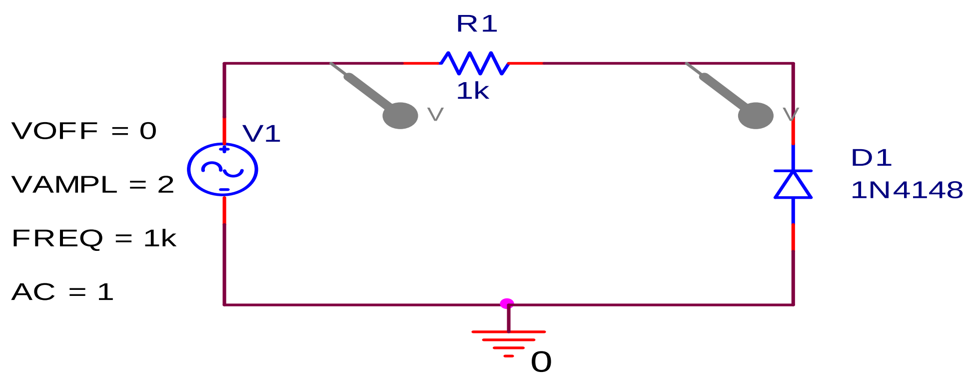
Question V – Rectifier: System Model (20 points)

d) (4pts) Identify two differences between the results from experiment, simulation and the ideal model with the turn on voltage.

The most obvious difference between the ideal model (with the turn on voltage) and the other two is that the diode voltage is constant across the ideal diode, but changes some for the simulation and experiment.

The differences between the simulated and experimental results are much smaller because the PSpice model is pretty good. The turn on voltage is a little larger for the real experiment and there is a little noise on the signal, but the latter is not significant in this case. The main difference is the small increase in turn on voltage for the real device. It is expected that individual devices can differ some from the typical case because manufacturing tolerances are never perfect.

e) (4pts) Determine the peak diode current from the experimental data. The circuit diagram is repeated here for your convenience.



The peak current occurs at the peak voltage of 2V. The turn on voltage is 0.7V or so. Thus, the current is I=(2-.7)/1000=1.3mA or 1.4mA for 0.6V turn on voltage. Any answer near this value is acceptable. PSpice output below.