Lab #2

Diodes: Rectifiers and Switches

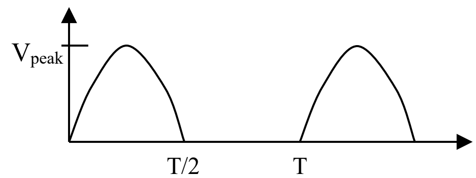
Purpose
In this lab you will explore some common diode circuits and gain experience applying simple diode models for rapid analysis of circuit behavior.

Skills to develop
After completing this lab you should be able to:

- build a diode half-wave or full wave *rectifier* (AC-to-DC converter), and analyze it
- build and analyze a voltage controlled diode switch

Preliminary work:
COMPLETED IN YOUR NOTEBOOK PRIOR TO ARRIVING AT THE LAB

1) Diode half-wave rectifier



a) Consider the half-wave rectified sinewave voltage waveform at the right. What is the DC voltage and RMS voltage in terms of V_{peak}? Remember:

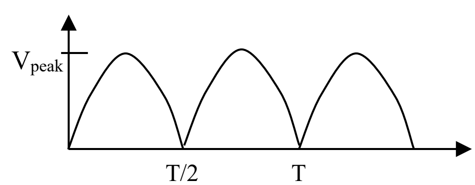
$$V_{avg} = DC = \frac{1}{T}\int_0^T v(t)dt \quad \text{and} \quad V_{rms} = \sqrt{\frac{1}{T}\int_0^T v^2(t)dt}$$

Clearly SHOW YOUR WORK.

b) For the circuit from Part 1, sketch the output waveform expected. What is the peak voltage expected for V_o? What is the ripple frequency?

c) Your lab kit includes the following capacitor values (microfarads): 0.001, 0.015, 0.047, 0.1, 1.0, 10.0, 47.0, and 100.0 μF. Choose the smallest capacitor value from your kit that, when placed in parallel with the 10 kΩ load resistor, will result in a peak-to-peak ripple voltage that is less than 5% of the DC output voltage (SEE pp. 214-216, and eqn. 4.29a). What ripple percentage do you expect with this capacitor? Sketch the expected output waveform.

2) Diode full-wave rectifier



a) Consider the full-wave rectified sinewave voltage waveform at the right. What is the DC voltage and RMS voltage in terms of V_{peak}? Clearly SHOW YOUR WORK.

b) For the circuit from Part 2, sketch the output waveform expected. What is the peak voltage expected for V_o? What is the ripple frequency?

c) Choose a capacitor from your kit that, when placed in parallel with the 10 kΩ load resistor, will result in a peak-to-peak ripple voltage that is less than 5% of the DC output voltage (SEE eqn. 4.33). What ripple percentage do you expect with this capacitor? Sketch the output waveform.

Equipment Introduced in the Lab

No new equipment introduced this week

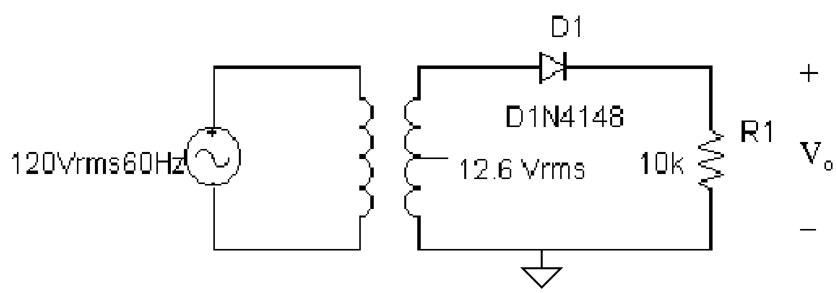
Experiments

1) Diode half-wave rectifier

Use the 12.6 Vrms step-down transformers available in the laboratory for the half wave and full wave rectifiers. **Note that the transformer primary is attached to line voltage: use proper care to avoid electrical shock hazards!**

a) Before connecting any components, measure the open circuit output waveform from the transformer secondary using your oscilloscope and the DMM. What is the peak-to-peak output voltage? What is the RMS output voltage? Does your measured RMS voltage agree with the specified 12.6 Vrms? Explain.

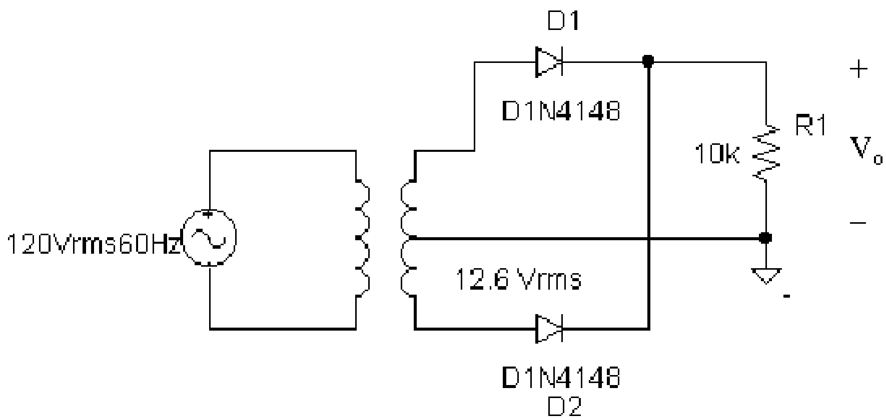
b) Connect the half-wave rectifier circuit shown below and measure the output voltage across the 10kΩ resistor. Sketch the waveform in your lab notebook, or capture a screen shot to paste in later. From the oscilloscope, what is the peak voltage of the output waveform? Using the DMM, what is the DC (average) voltage? What is the RMS voltage? How do the DMM numbers compare to calculations made from the oscilloscope waveform data? How do the measurements compare to the pre-lab calculations?



c) For the pre-lab work, you calculated the value of capacitor that, when placed in parallel with the 10kΩ resistor, would reduce the peak-to-peak voltage ripple to less than 5% of the DC value. Connect this capacitor in parallel with the resistor. If using an electrolytic capacitor, be sure to connect it with the correct polarity. Measure the DC voltage and peak-to-peak voltage ripple out of the circuit. Sketch the waveform in your lab notebook, or capture a screen shot to paste in later. Is the ripple less than 5% of the DC level? Explain.

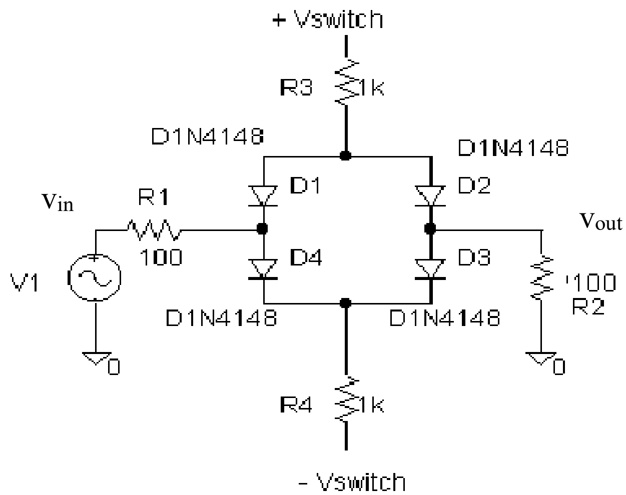
2) Diode full-wave rectifier

a) Connect the full-wave (center-tapped transformer) rectifier circuit shown below, and measure the output voltage across the 10kΩ resistor. Sketch the waveform in your lab notebook, or capture a screen shot to paste in later. What is the peak voltage? Using the DMM, what is the DC voltage? What is the RMS voltage? How do the DMM numbers compare to your calculations from the oscilloscope waveform data, and from the pre-lab calculations?



b) In the pre-lab you calculated the value of capacitor that, when placed in parallel with the resistor, would reduce the peak-to-peak voltage ripple to less than 5% of the DC value. Connect this capacitor in parallel with the resistor. If using an electrolytic capacitor, be sure to connect it with the correct polarity. Measure the DC voltage and peak-to-peak voltage ripple out of the circuit. Sketch the waveform in your lab notebook, or capture a screen shot to paste in later. Is the ripple less than 5% of the DC level?

3) Diode Switch



a) Connect the circuit shown above. Apply a sinusoidal voltage so that v_{in} = 0.2 volt amplitude at a frequency of 1 kHz. With $+V_{switch}$ = 6 volts DC and $-V_{switch}$ = -6 volts DC, use the oscilloscope to observe v_{in} and v_{out}. Are the diodes forward biased (conducting), or reverse biased (off)?

b) Increase the input voltage amplitude until you observe noticeable clipping. Sketch the output voltage waveform, or capture the oscilloscope trace to a file for later pasting into your lab notebook. Describe what is happening to the output, and explain the reason that clipping is occurring.

c) Now *reverse* the switch control voltage polarity so that $+V_{switch}$ = -6 volts DC and $-V_{switch}$ = +6 volts DC (this turns your switch 'off'). Observe v_{in} and v_{out}. Explain any change to both v_{in} and v_{out}.

d) Increase the input signal amplitude to its maximum value. Does v_{out} change? When in the switch 'off' condition, can the diode switch isolate the input and output, even if v_{in} is greater than V_{switch}? Explain.

e) Reverse the V_{switch} polarity again (turn it back 'on'), and reduce v_{in} to 0.2 volt amplitude. Repeat steps (a) and (b), with R3 and R4 1 kΩ resistors replaced with 5 kΩ resistors. Explain any differences from parts (a) and (b).

Final considerations (answer in your lab notebook):

1) What dc current is flowing in each diode in part (a)?

2) At what peak voltage does the output waveform clip? What current does this correspond to in the 100Ω load resistor? How does this current compare to the bias current flowing in the switch resistors?

3) When the output is clipped, which diodes are on, and which ones are off?

4) With V_{switch} reversed (so your diode switch is 'off') and v_{in} = 10 volts, which, if any, diodes are conducting? Does this switch protect the output from high voltage transients on the input side?