

Physics 310

Lab 4 – Transformers, Diodes, & Power Supplies

Equipment: SPICELIB.zip, DI spicemodels_all.zip, O'scope, W02G Bridge Rectifier, 110 – 6.3V transformer, four 1N4004 diodes, 1k, 10 μ F, 100 μ F, 1N5231 Zeener diode, ½ - Watt 100 Ω , 270 Ω , LED, LM7805 Regulator, LM317 Adjustable Regulator, Heathkit Power Supply, function Generator

General Lab Notebook instructions (from syllabus)

You should be sure to write down enough so that you can recall what you did several weeks later (it may come in handy when you're working on your final project.) The following information should be included:

1. Titles for labs and sections of labs.
2. Description of procedures followed (e.g. what was measured).
3. Well-labeled diagrams of circuits.
4. Record of observations and data (in tabular form when appropriate).
5. Analysis of data: computations and tables or graphs of results.
6. Comparison with theory: calculations and graphical or tabular comparison.
7. Answers to all questions.

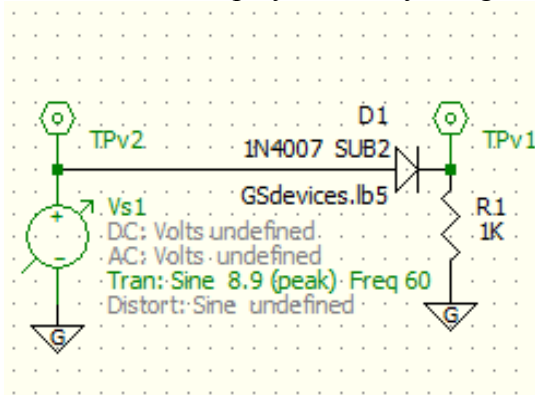
General Procedures:

- When wiring up any circuit involving a transformer, first unplug the transformer. The frequency of the signal from a transformer plugged into an outlet will be 60 Hz.
- Be careful to use 1/2-Watt resistors where specified. Also, make sure to connect any polarized capacitor so that its positive end will always be at a higher voltage.
- Switch the oscilloscope temporarily to AC mode to measure the size of any small ripple.

4-1. Rectifiers

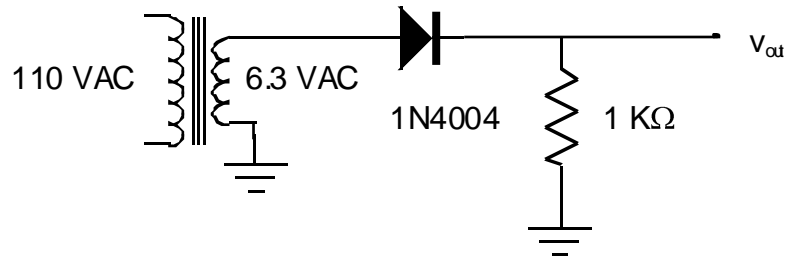
A. The Half-Wave Rectifier

1. **Pre-Lab.** Construct the following circuit in 5Spice. The Diode type, 1N4007 can be selected from a list that is displayed when you right-click and select "edit value."



2. In the Analysis tab of the Analysis Dialog box, select the power supply to be the Vs1 (lower left of the Dialog box), and set the time to run from 0.03125 to 0.0625s (mid left of the Dialog box). Then through the Graph/Table tab, set up a plot of both TPv1 and TPv2 so you can compare the input voltage to the output voltage. Click the "Apply & Run" button and print off the resulting plot.

- Construct the following circuit with a 6.3-V transformer. Note that the stripe on the diode corresponds to the stripe in the diagram.

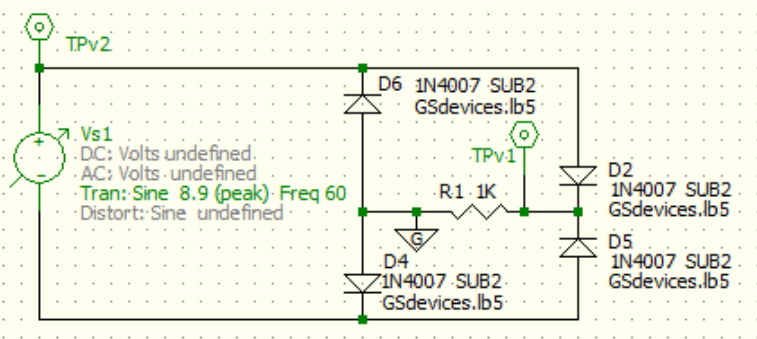


- Plug in the transformer. With the oscilloscope in DC mode, carefully sketch the input from the transformer and the output on the same axes; indicate their peak values.

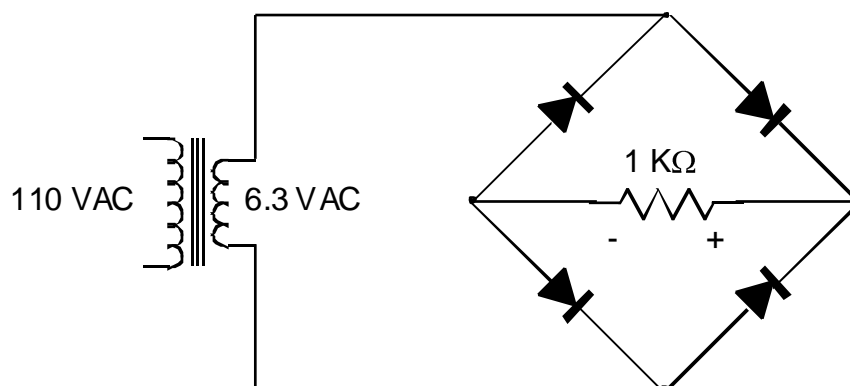
Questions: What feature of the output is due to the diode having a voltage drop across it when it is conducting? Do your measurements confirm the rule of thumb that this voltage drop is about 0.6 V? Explain.

B. Bridge Rectifiers

- Pre-lab.** Modify your circuit to be that shown below (if you squint really hard, you'll see that it's the same as the one you'll construct in lab.)



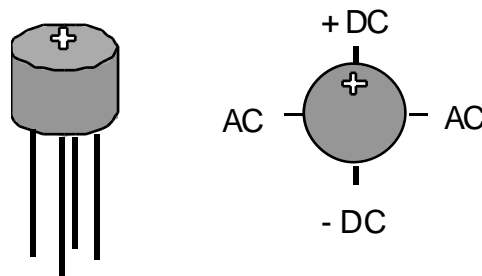
- Print out the plot showing how the output (TPv1) and input (TPv2) behavior differ.
- Construct the following circuit using a 6.3-V transformer and 1N4004 diodes. Note that neither end of the transformer's secondary is connected to ground. Keep it that way, i.e., you can't use the o'scope to simultaneously look across the source and the resistor or you'll inadvertently short out some of the diodes and, for half the phase, the supply itself.



- Attach the oscilloscope leads across the 1-k Ω resistor so that the side marked with a minus in the circuit diagram is grounded. Plug in the transformer and carefully sketch the voltage across the 1-k Ω resistor. Trying to view the output of the transformer will cause grounding problems and disrupt the operation of the bridge rectifier.

Question: How does the output differ from that of an ideal full-wave rectifier? (In other words, is the output exactly the absolute value of the input sine wave?) Explain.

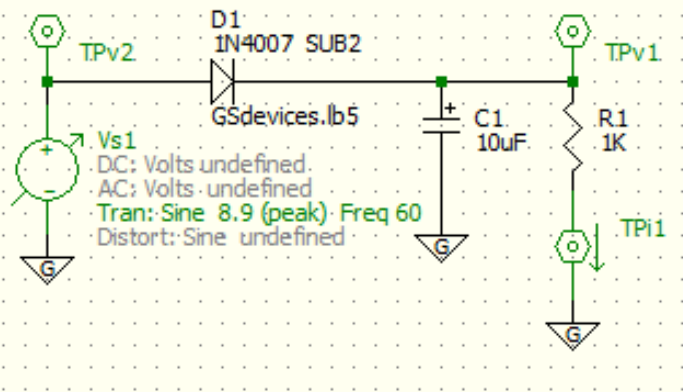
- Bridge rectifiers can be purchased as single components. The diagram below shows the connections for the W02G. Connect a 1-k Ω resistor between the negative (- DC) and positive (+ DC) output terminals. Connect the output of a 6.3-V transformer to the input terminals (AC). Attach the oscilloscope leads across the 1-k Ω resistor so that appropriate end is grounded. Plug in the transformer and carefully sketch the voltage across the 1-k Ω resistor.



Question: How does the performance of the W02G compare to the bridge rectifier that you built?

4-2. Filtering

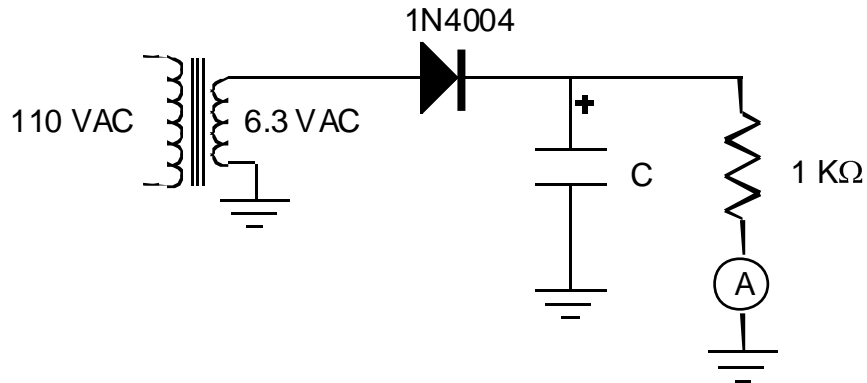
- Pre-Lab.** In 5Spice, create the circuit shown below.



Question: On your print-out for Pre-lab of section 4-1, sketch the TPv1 signal observed here.

(I suggest you also plot current being observed by TPi1 so you'll understand the behavior you'll observe in lab.)

- Construct the following circuit with a 10- μF capacitor and using a DMM as an ammeter. Be careful about the polarity of the capacitor.



- Plug in the transformer and carefully sketch the voltage across the 1-k Ω resistor. Determine the ripple voltage (ΔV). Measure the average current through the resistor (the reading may fluctuate slightly because the voltage is not constant).
- Change the capacitor to one with a value of 100 μF . Repeat the measurements of the ripple voltage and the current.

Question: How do the measured ripple voltages compare with the theoretical prediction of $\Delta V \approx i/Cf$? Note: this is based on the approximation that $\frac{dV}{dt} \approx \frac{\Delta V}{\Delta t}$ while the capacitor is discharging through the resistor; that's only good if $f \gg \frac{1}{T_{RC}} = \frac{1}{RC}$.

- Attach a 10- μF capacitor (be careful about the polarity) and a 1-k Ω resistor in parallel across the output terminals of the W02G bridge rectifier and a 6.3-V transformer to its inputs terminals.
- Plug in the transformer and measure the ripple voltage and the current.

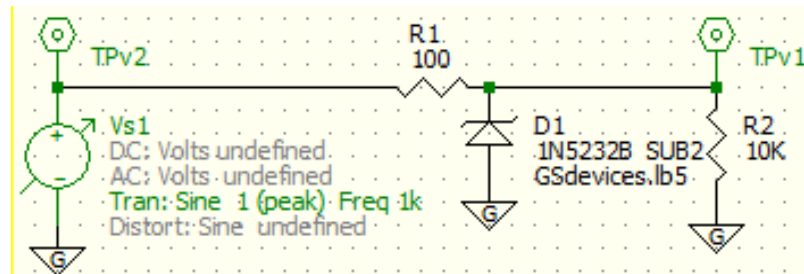
Questions: How does the ripple voltage for the fully rectified wave compare to that of the half rectified wave with the same capacitor? How does the measured ripple voltage compare with the theoretical value? (Hint: What is the frequency?)

4-3. Voltage Regulation

A. Zener Diode

1. **Pre-lab.** Build the following 5Spice model.

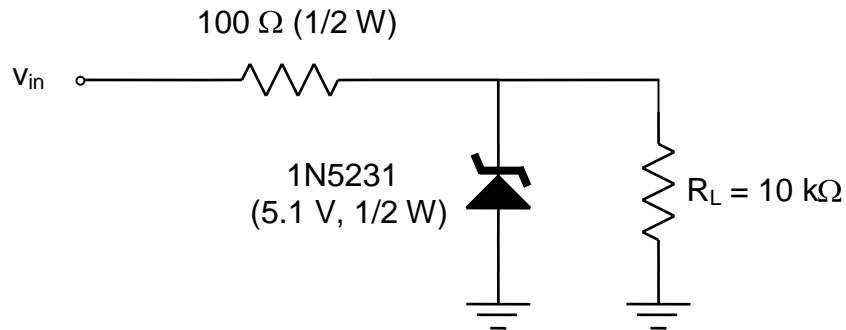
- (1) Though not apparent in the figure, the power supply should be set to have a 10V DC offset. To do that, right click on the supply, select “Edit Value”, and then on the “TRAN/FFT analysis” tab, once you’ve chosen the signal to be sinusoidal, you can set the frequency, amplitude, and DC offset.
- (2) To select the particular type of Zener diode shown, the 1N5232B, first select Zener diode icon (note: there are two similar icons, choose the one that looks just like the one in the figure.) Once you’ve placed the diode on the page, right-click it and “Edit Value.” This will present you with a long list of diode models; either scan down that list or enter “1N5232B” into the search box. Select that model and hit “OK”.



2. You’ll first look at a graph of both the supply’s voltage (TPv2) and the output voltage (TPv1), since they’re on slightly different scales, you’ll then just look at the output (TPv1). Through the Analyze menu, and Select/Edit, bring up the Analysis Dialog box.
 - (1) On the Analysis tab: You’ll need to adjust a few settings, working your way down the left side of the dialog window, for Select Analysis, chose “Transient”, for Time, run from 1 to 1.002 (seconds), and if it isn’t already selected, select Vs1 as the Source.
 - (2) On the Graph/Table tab: set TPv1 and TPv2 to both use the left axis, and hit “Apply & Run” to generate the graph. Observe that the output is being held relatively constant, but it ‘ripples’ a little.
 - (3) Now plot just the output voltage. Back on the Graph/Table tab, turn off the display of TPv2 (for its Axis, select “off”) and then “Apply & Run” again.

Question: One measure of how well a voltage regulator is working is the ripple rejection which is defined as the ripple voltage of the output over the ripple voltage of the input ($\Delta V_{out} / \Delta V_{in}$), which should be small. In this case, that’s simply the amplitude of the output’s oscillations divided by the amplitude of the input’s oscillations (which you’d set to be 1 Volt.) What is the ripple rejection for this Zener diode?

3. The 1N5231 Zener diode can be used as a simple 5.1-V DC voltage regulator. Construct the following circuit to regulate the voltage across the load resistor (R_L). Note the orientation of the Zener diode!



4. Input a 1-kHz sine wave with 2 V peak-to-peak that is centered around +10 V using the function generator's offset. Measure the ripple voltage across the 10-k Ω resistor.

Question: One measure of how well a voltage regulator is working is the ripple rejection which is defined as the ripple voltage of the output over the ripple voltage of the input ($\Delta V_{out}/\Delta V_{in}$), which should be small. What is the ripple rejection for this Zener diode?

5. Shift the sine wave downward so that it is centered around +5 V.

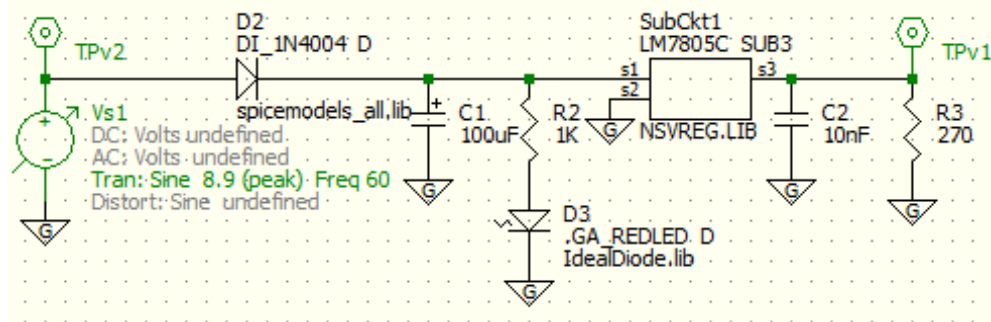
Question: What happens to the voltage across the load resistor when the input drops below 5.1 V? Sketch it.

B. Fixed Regulators

1. **Pre-Lab.** You're going to create the circuit shown at the bottom of the page and determine the size of the ripple voltage for the output. First though, 5Spice doesn't come with a model of either the LM7805 or the 1N4004, so if you're using your own computer (instead of one in the Physics Department), you'll need to add them to 5Spice's library; in the process, you'll be adding models of a handful of other circuit components. By the time you're working on your project at the end of this semester, you'll probably want to acquire and add even more models to your library, so this is an opportunity to get a little practice.

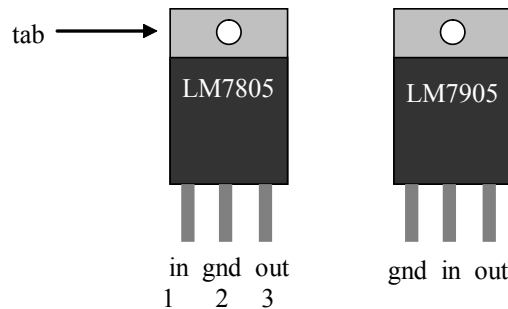
- (1) Acquire the zipped "for Library" folder from your instructor or from the course website (there's a link in the schedule right by the one for this lab handout.)
- (2) To locate the 5Spice library on your computer, launch 5Spice, go to the Tools menu, and select the "Rebuild / Update library..." In the pop-up window, the address of your Library folder will be highlighted in yellow; heed the parenthetical note that appears just above it about un-hiding system folders. *Don't* yet hit the "Rebuild Library Index" button – that's step (6).
- (3) Navigate yourself to that folder, ...5Spice Analysis/Library.
- (4) Within the zipped "for Library" folder that your instructor gave you, you'll see a "for Subcircuits" folder – place its contents into ...5Spice Analysis/Library/Subcircuits.
- (5) Also within the zipped "for Library" folder you'll find a "for Diode_BJT_FET" folder, place its contents in ...5Spice Analysis/Library/Diode_BJT_FET; you'll probably be asked about replacing or merging the "DiodesInc" and the "IRF" folders – either is fine (the ones already on your machine are empty anyway.)

- (6) Finally, go back to the 5Spice program, and from the Tools menu select “Rebuild/Update spice library”; that will bring up a dialog box, and you’ll hit the “Rebuild Library Index” button.

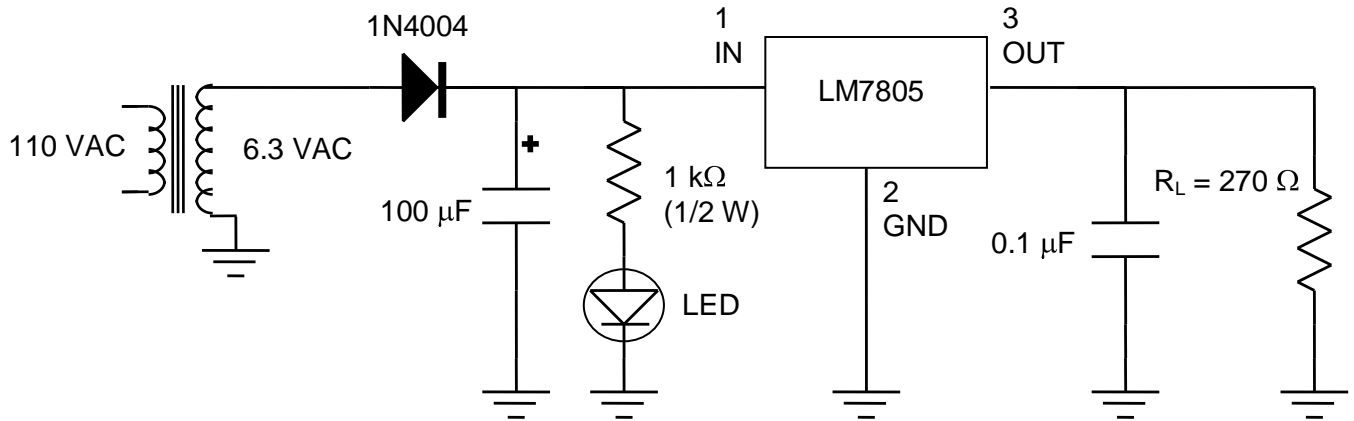


2. Note that D3 is an LED (the little squiggle by its side represents light.)
3. To add the LM7805C to the circuit, go to the column of icons to the left of the page in 5Spice, just below the icon for diodes is one for analog integrated circuits, move the cursor over that and in the window that opens the top right icon, under the Sub Circuit heading is for generic integrated circuit ‘chip’ – select it and place the ‘chip’ on your page. Next, go to Edit its Parameters, and you’ll get a long list of chips to choose from – select the LM7805C.
4. Once you’ve build the circuit, have 5Spice plot the TPv2 and TPv1 voltages for 1 to 1.02 (seconds)
5. **Question:** What is the ripple voltage of the output (TPv1), i.e., the difference between its highest and lowest values?

6. For the most common family of fixed voltage regulators, the connections are slightly different for positive (LM78XX) and negative (LM79XX) regulators as shown below (the last two digits indicate the regulated voltage). Also, the metal tab on a positive regulator is ground, but not the tab on a negative regulator. If the tab on a negative regulator is attached to ground it will not function properly.



7. Use the 6.3-V transformer to construct the voltage regulator circuit shown below with the LM7805. The flat side of the LED corresponds to the stripe in the diagram.

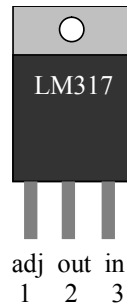


8. The 1-k Ω resistor and light-emitting diode (LED) serve two purposes: indicating when the supply is turned on and discharging the large filter capacitor when it is turned off to prevent shock. The 0.1- μ F capacitor on the output smoothes out very high frequencies.
9. When the input voltage of the LM7805 is kept between 8 and 18 V, the ripple of its output should be at least 62 dB less than that of the input (that is $10\log(\Delta V_{\text{out}}/\Delta V_{\text{in}}) < -62$).

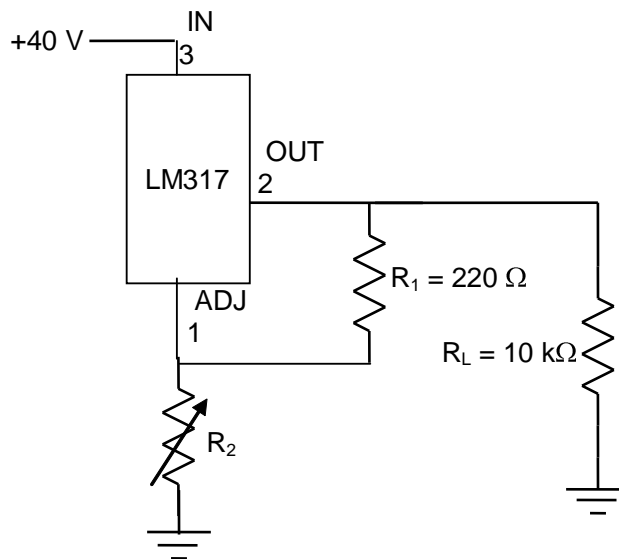
Question: What is the ripple voltage of the output of the LM7805 in this circuit?

C. Adjustable Regulator

1. The connections for the LM317 adjustable regulator are shown below. The tab is connected to “out”.



2. A +40-V input will be supplied by a Heathkit power supply. Switch the supply to “independent” mode and connect the “+” terminal of output A to the “-” terminal of output B. Use the “-” terminal of output A as ground and the “+” terminal of output B for the positive voltage. The output voltage is controlled with both “supply A” and “supply B” knobs. Test the power supply output with a voltmeter before proceeding.
3. Build the following adjustable voltage regulator using a decade resistance box for R_2 .



4. Measure the voltage across the load resistor for several values of R_2 from 0 to 10 kΩ. Make a table comparing the measurements with theoretical values calculated using:

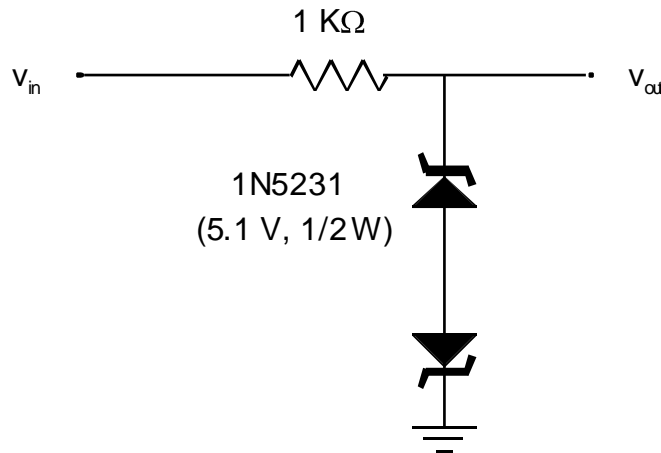
$$V_{\text{out}} = \left(1 + \frac{R_2}{R_1} \right) 1.25 \text{ Volts.}$$

Questions: How do the measured output voltages compare to the theoretical predictions? What are the minimum and maximum output voltages possible?

4-4. Additional Diode Circuits

A. Diode Clipper

1. Construct the following circuit.

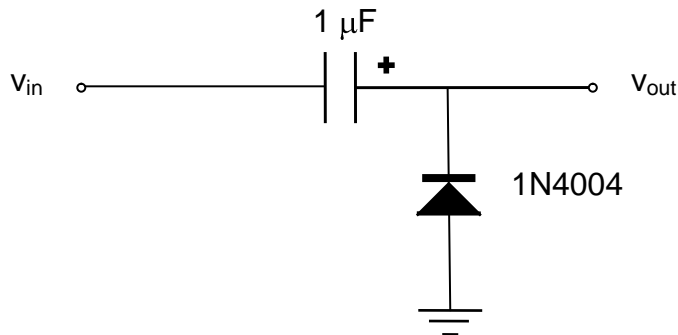


2. Use a function generator to input a 1-kHz sine wave with a peak voltage of about 10 Volts. Sketch the input and output voltages.

Question: Where is the signal clipped?

B. Diode Clamp

1. Construct the following circuit.



2. Use a function generator to input a 1-kHz sine wave with a peak voltage of about 5 Volts. Sketch the input and output voltages.

Question: Ideally this circuit would just shift the sine wave input so that it varies between zero and two times the peak voltage from the transformer. How does the output vary from this ideal behavior?