ECE 2274
Diode Basics and a Rectifier
Completed Prior to Coming to Lab

Perlab: Part I – I-V Characteristic Curve for the 1N4002

1. Construct the circuit shown in figure 1. Using a DC Sweep, simulate in LTspice the current-to-voltage characteristic of a diode.

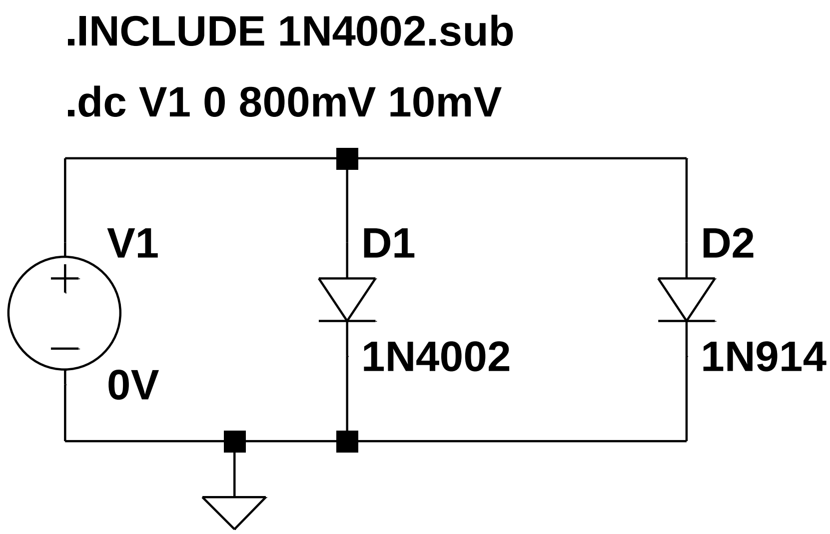


Figure 1

a. Select VDC source for your input voltage supply.

b. For 1N4002 select generic diode from Edit menu choose Diode place on schematic – change "D" to "1N4002". For 1N914 right click on diode and pick new diode menu. Down load 1N4002.sub from class website.

c. Plot a current of each diode, so that you can measure the diode current as a function of diode voltage.

d. Set the start value to 0V and the end value to 800mV step size 10mV for the DC Sweep analysis. The plot obtained is called the I-V characteristic curve. Change the Y- axis scale to 5mA maximum. Find Vd (diode forward drop) for each diode at 1mA.

e. Print and label your graph to turn in as part of your pre-lab.

f. In the LTspice Model. Determine N, and Rs, which are the non-ideality factor(N), and forward-bias series resistance (Rs).
Use a Text editor to view in **lib\sub** (sub circuit) directory the **1N4002.sub** file. The 1N914 model is in the **lib\cmp** (standard component) directory view **standard.dio** file and find the 1N914 in the list

Find the diode forward voltage drop Vd at a 1mA current from the plot. You may need to change the Y axis scale. Record these values of both diodes.

Part II – Half-Wave Rectifier

3. Figure 2 shows a half-wave rectifier. Build a half-wave rectifier in LTspice using the 1N4002 diode.

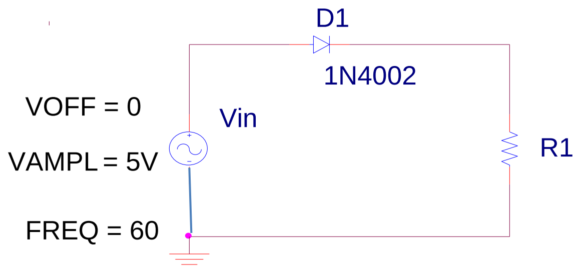


Figure 2: A half-wave rectifier

a. Set the attributes to the source, part Vin, as follows:

i. VOFF = 0V (DC offset)

ii. VAMPL = 5Vp (peak voltage of sinewave)

iii. FREQ = 60 Hz (frequency of sinewave)

b. Choose a resistor value that is relatively large (500Ω < R1 < 10kΩ) from the list of 5% tolerance resistors. The lab has only the 10% values. **Do not use the default value of 1kΩ for the resistance.**

4. Run a transient simulation to measure the voltage across the source and the resistor using a time span equal to at least two full cycle of the input voltage.

a. Does the output voltage across the resistor match the input voltage in the positive domain? Why or why not?

c. Print and label your graph to turn in.

5. Using DC Sweep, simulate the Vout the output voltage (voltage across R1) of a half-wave rectifier. Run the sweep of Vin (Vin X axis) from -5V to +5V with a step size 0.01V. The **plot obtained** is called the voltage **transfer function**. Set the Y axis (Vout) scale to -5V to +5V. Print and label your graph to turn in.

Transfer Function is defined as $V_{TF} = V_{OUT} / V_{IN}$

6. Using the half wave rectifier Fig 3, V_{AMPL} = Vin_{PEAK} design a circuit in which a capacitor is in parallel with R1 (use R1 from part 3b above) such that the ripple voltage, Vr, is 0.5Vpp. Assume that V_{drop} = 700mV for the D1N4002. Be sure to show all your work. T is the period of the waveform and it will be different for have-wave and full-wave circuits. Solve for C. Set Vin = 5Vpeak

$$V_r = (V_{AMPL} - V_{drop})(1- e^{-T/RC})$$ Vr is a peak to peak value

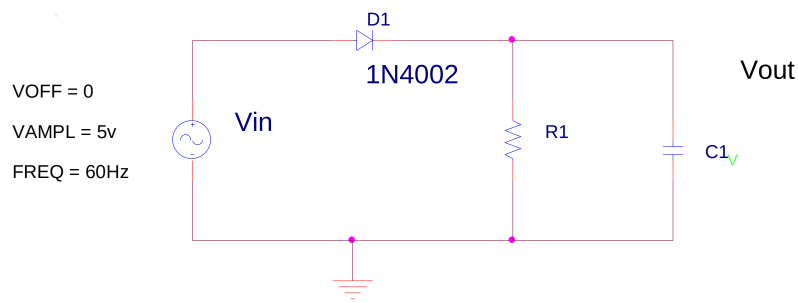


Figure 3: Half-wave rectifier

a. Verify your design using LTspice transient simulation turn in the plot.

b. Find and record the maximum value of the voltage over the resistor.

c. Print out the simulation results to turn in.

Part III – Full-Wave Rectifier

7. Build a full wave rectifier bridge in LTspice with 1N4002 diodes as shown in figure 4 (use R1,and C1 from above) set V1 =5Vp.
   a. How does the ripple voltage compare to that of the half-wave rectifier? Why has the ripple voltage changed?
      *HINT: Try taking the capacitor out and seeing how the rectified signal has changed. Compare the period of the two waveforms and take a look at the ripple formula.
   b. How does the maximum voltage output compare to that of part 6? Why has the maximum output voltage changed? This is related to the previous part.

Do not use scope on input source (output of transformer)

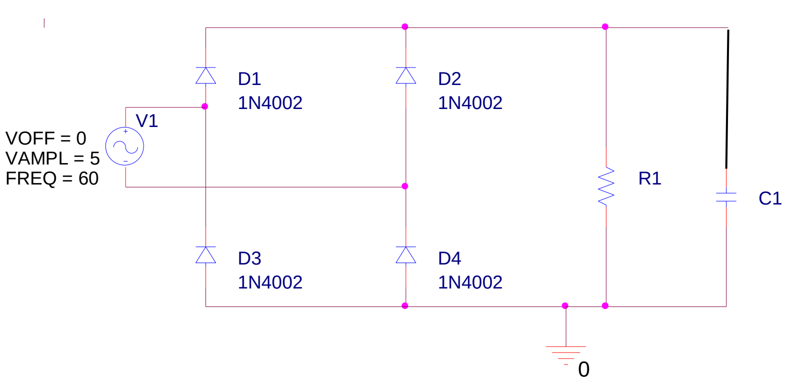


Figure 4: Full-Wave Rectifier

Name: ___________________ CRN: __________________

Pre-lab Answer Sheet:

1. I-V curve

From LTspice model and from the I-V characteristics curve what are the voltage drop across each diode at 1mA?

1N4002 N _________ R_S _________ Vd @ 1mA __________

1N914 N _________ R_S _________ Vd @ 1mA __________

Half wave rectifier.

3.b R1 = __________________

Ripple voltage from LTspice plot _____________Vpp

4.a. Does input match output voltage? Why not?

4.b. Maximum voltage across resistor without capacitor. _________

6. R1 = ________ Capacitor which gives 0.5Vpp ripple C1= _________

Full-wave rectifier

Do not use scope on input source (output of transformer)

7. a. R1= ___________________ C1= _______________

Ripple voltage from LTspice _____________Vpp

How do the half-wave and full wave rectifier ripple voltages compare? Why, justify with the equations?

7. b. Maximum voltage across resistor without capacitor. _________

How do the half-wave and full wave rectifier maximum voltages compare? Why?

Required Graphs:

1. DC sweep of 1N4002 and 1N914 (I-V Characteristics curve) Change Y scale 5mA max.
2. Voltage transfer function of half-wave rectifier
3. Transient of half-wave rectifier with capacitor
4. Transient of half-wave rectifier without capacitor
5. Transient of full-wave rectifier with capacitor
6. Transient of full-wave rectifier without capacitor

Lab Exercise
Diode Basics and a Rectifier

***Part I – I-V Characteristic Curve* (use 1N4001 diode)**

1. Using a curve tracer, determine the forward I-V characteristic of the diode that you actually use in the lab. Print out the characteristic curve to turn in with your Data Sheet. Set Rload = 10Ω, Pmax = 0.5W, max current to 10mA maximum and voltage to 1V maximum.

***Part II – Half-Wave Rectifier (*use 1N4001 diode)**

Build the half-wave rectifier you designed in the pre-lab. Use the Varic (Autotransformer) and the 10:1 isolation transformer to create a ±5V sinusoidal source (10Vpp). Use the closest standard resistor value that is available in the lab. Record the resistor value in your Data Sheet.

2. Determine the maximum voltage across the resistor using the scope and compare it with the value you found in the pre-lab. Capture both the input and output waveform, remember to use DC coupling. Subtract the output from input to calculate the maximum diode Vdrop. From the waveform of the output across the resister calculate the peak current.

3. Install the capacitor in the circuit.

a) Measure the ripple voltage (Vr). AC coupling

b) Determine your percent error between your measured ripple voltage and the one expected from your design in pre-lab.

%Error = ((Measured – Calculated) / Calculated) X 100%

c) Capture the ripple voltage waveform with about 2-3 periods use AC coupling, Trigger AC Line.

Why is the maximum output voltage different than the LTspice value?

4. Using a digital multimeter, capacitance meter, and curve tracer determine the actual values for R1, C, and Vdrop* from the curve diode I-V characteristic.

    a. Using these values, recalculate the ripple voltage. Be sure to show all your work.

    b. Determine your percent error between your measured ripple voltage and the one that you just calculated.

*Note: One method to calculate Vdrop is to calculate the peak current by knowing the peak voltage across the load resistor (I = V/R) from the scope. Mark on the the diode I-V characteristic the peak current on the forward I-V characteristic to find the voltage drop on the I-V on the x-axis. The voltage at this intersection is Vdrop at your peak current.

Part III – Full-Wave Rectifier **(use the bridge IC) use only one scope probe**

Using the same valued capacitor and load, construct the full wave rectifier designed in the Pre-Lab. Again, use the Autotransformer and the 10:1 isolation transformer to create a ±5V source.

Do not use scope on input source (output of transformer)

a. Measure the ripple voltage (Vr) (AC coupling, Trigger AC Line)

b. Capture the ripple voltage waveform with capacitor using AC coupling selected. **Use only one scope probe**

c. How does it compare with the Pre-+Lab?

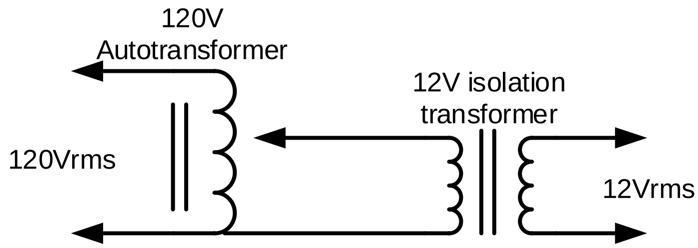
d. Again recalculate the ripple voltage using the actual measured values of C, R1, and Vdrop.

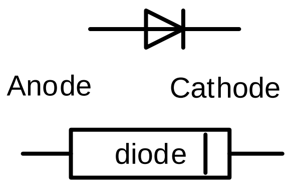
e. Determine your percent error between your measured ripple voltage and the one that you just calculated

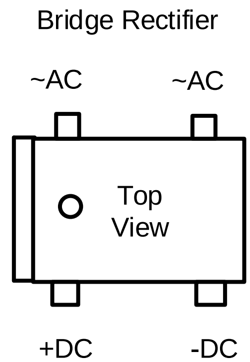
f. Measure the maximum peak to peak voltage without the capacitor.

g. Capture the waveform without the capacitor with DC coupling selected. **Use only one scope probe**

a) What would be a benefit of using a half wave rectifier instead of a full wave? What would be a benefit of using a full-wave rectifier instead of a half wave? List a few of the pros and cons to each design.


120V
Autotransformer
12V isolation
transformer
120Vrms
12Vrms


Anode
Cathode
diode


Bridge Rectifier
~AC
~AC
Top
View
+DC
-DC

Data Sheet
Diode Basics and a Half-wave Rectifier

Name: ______________________ **Name:** _____________________
Insructor: ___________________ **Class Time and Day:** __________________
Date: _________________ **Bench number:** __________ **CRN:**______________

Part I – I-V Characteristic Curve **(use 1N4001 diode)**

1. Print out the characteristic curve of 1N4001 to turn in with your Data Sheet.

Part II – Half-Wave Rectifier **(use 1N4001 diode)**

a) Standard value used R1 = ______________

Voltage without capacitor in circuit across R1: V_{max} = ____________Vpp DC coupling, Trigger AC line

% error = ____________ to reference LTspice

2. Calculate the Peak current in the diode I_{diode} = ___________
   Calculate the Peak voltage across the diode V_{Drop} = ____________

3. Standard capacitance nominal value: C = ___________

   a. V_{ripple} across R (measured) = ___________Vpp AC coupling, Trigger AC line

   b. % error = ___________

Why is the maximum output voltage different than the LTspice value?

4. Measured values:

R1 = ____________

C = ____________

Vdrop = ____________

a. V_{ripple} (calculated) from component values = ___________

b. % error = ___________

***Part III – Full-Wave Rectifier (*use the bridge IC) use only one scope probe**
Do not use scope on input scource (output of transformer)

5. a. Ripple voltage ____________ Vpp with capacitor AC coupling, Trigger AC line

b. % error from Prelab : ____________

c. Calculated ripple voltage from measured components: ____________

d. % error from calculated to lab values: ____________

e. Maximum output voltage _____________ Vpp without capacitor DC coupling

Why is the maximum output voltage different than the half wave value?

6. Discuss Pro's and Con's to each the Full-Wave and Half-Wave rectifier

Required graphs:
1. I-V Characteristics curve of 1N4001 from curve tracer
2. Scope capture of half-wave w/capacitor AC coupling
3. Scope capture of half-wave w/out capacitor DC coupling
4. Scope capture of full-wave w/capacitor AC coupling
5. Scope capture of full-wave w/out capacitor DC coupling