ECE 310L: Microelectronic Circuits Lab

Lab 4: Rectifying Circuits

Name:

Lab partner:

Objectives

1. Experimentally verify the operation of half-wave and full-wave rectifier circuits with varying loads.
2. Active regulator stage to the rectifier outputs and observe the effects on load regulation.

Background:

Almost all modern electrical and electronic equipment operates on DC for the internal circuits, amplifiers, microprocessors, etc. The utility system operates on AC to be able to transmit power efficiently over long distances. Therefore, a method is necessary to convert the AC to DC for electronic systems to operate.

The conversion from AC to DC is performed by a rectifier circuit which directs the positive and negative half-cycle current to a common node to produce a pulsing DC voltage. This pulsating DC voltage is not suitable for operating DC circuits (since it goes to 0V 120 times per second!), so a filter is added to provide a nearly constant DC voltage. Figure 1 shows a typical power supply system that incorporates a step-down transformer, rectifier, filter, and regulator to supply a load.

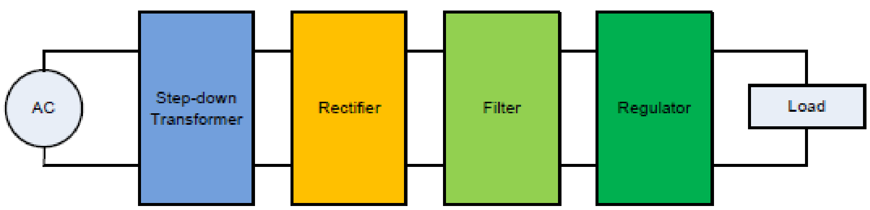


Figure 1

The step-down transformer converts the 120VAC from the utility to the desired lower voltage such as 12.6VAC or 6.3VAC. The rectifier converts the stepped down voltage to either a half- or full-wave rectified voltage which is then filtered by a capacitor to provide a DC voltage with much less ripple. The regulator circuit then provides a lower but much more stable DC voltage with much improved load regulation.

$$\text{Load Regulation\%} = \frac{v_{out}^{no\ load} - v_{out}^{full\ load}}{v_{out}^{full\ load}} \times 100\%$$

You will construct several rectifier circuits in the lab. The circuit in Figure 2 is a half-wave rectifier circuit that is connected across the full secondary winding of the transformer box. The 1 Ω resistor will be used to measure the diode current.

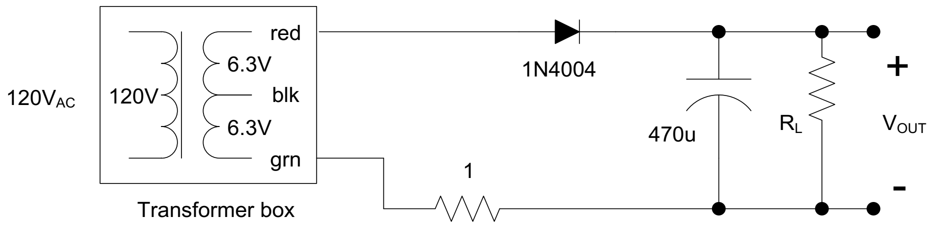


Figure 2 Half-wave rectifying circuit.

The circuit in Figure 3 is a full-wave rectifier circuit that is connected across half of the secondary winding of the transformer box while using the center tap.

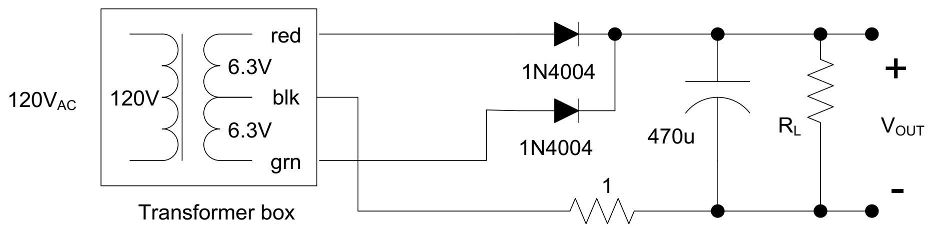


Figure 3 Full-wave rectifying circuit.

Materials

- DMM, Agilent E3631A
- Oscilloscope, Agilent DSO5014A
- Solderless breadboad
- Hookup wires
- Resistors: 1Ω, 150Ω, (3) 2.0kΩ
- Diodes: 1N4004
- Capacitor: 470 µF aluminum electrolytic

Pre-lab Assignments

Question 1. Calculate the theoretical ripple voltage, V_R, and peak current, I_P, for the half-wave rectifier in Fig. 2 and the full-wave rectifier in Fig. 3. The total load for these calculations will be three parallel 2 KΩ resistors. Use 0.7 V for the diode drop, V_F. The United States electric utility system operates at 60 Hz.

Please pay attention to the difference of peak-to-peak voltage and RMS voltage.

Half-Wave

$$V_R = \frac{V_p - V_{D,on}}{R_L C_1 f_{in}} = 0.9106\ V$$

$$I_p = \frac{V_p}{R_L}\left(R_L C_1 \omega_{in}\sqrt{\frac{2V_R}{V_p}} + 1\right) = 1.0361\ A$$

Full-Wave

$$V_R = \frac{V_p - 2 * V_{D,on}}{2R_L C_1 f_{in}} = 0.1997\ V$$

$$I_p = \frac{V_p}{R_L}\left(R_L C_1 \omega_{in}\sqrt{\frac{2V_R}{V_p}} + 1\right) = 0.3476\ A$$

Question 2. For the half-wave rectifier circuits shown in Fig. 2, simulate the voltage across the load R_L and the current through the diode with LT Spice. The full transformer secondary voltage is 12.6 V_{RMS}. Model four cases where load is open $R_L = \infty$, 2 KΩ, 2 KΩ **// 2** KΩ**,** 2 KΩ **// 2** KΩ **// 2** KΩ. The United States electric utility system operates at 60 Hz.

The LT Spice model for the case of R_L = 2 KΩ has been done for you and is shown below.

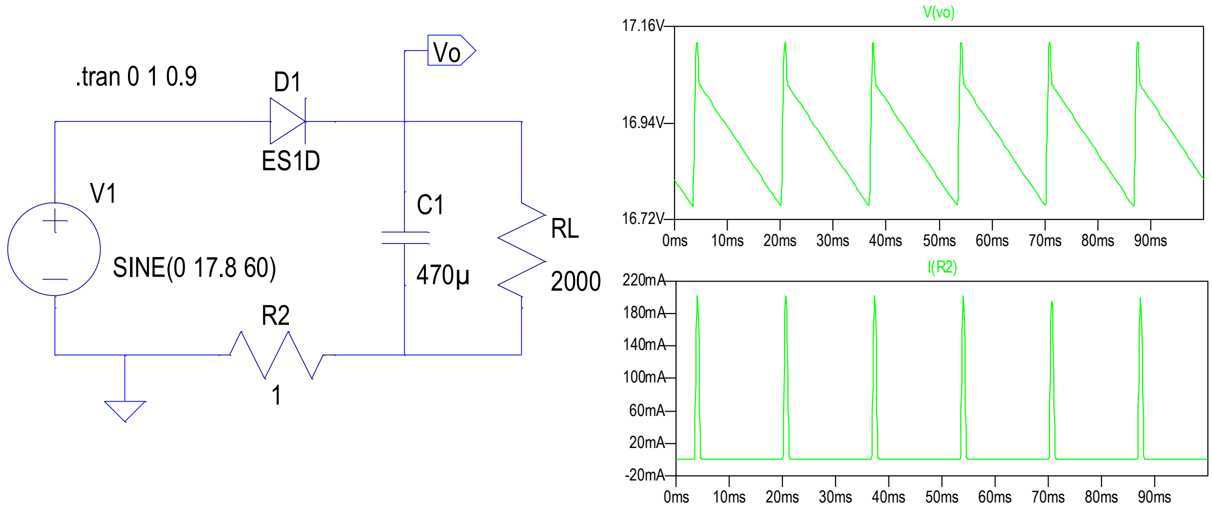
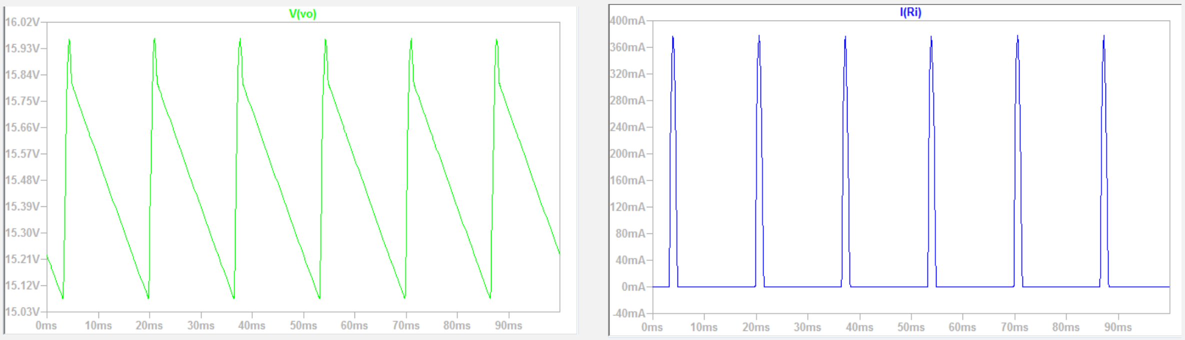
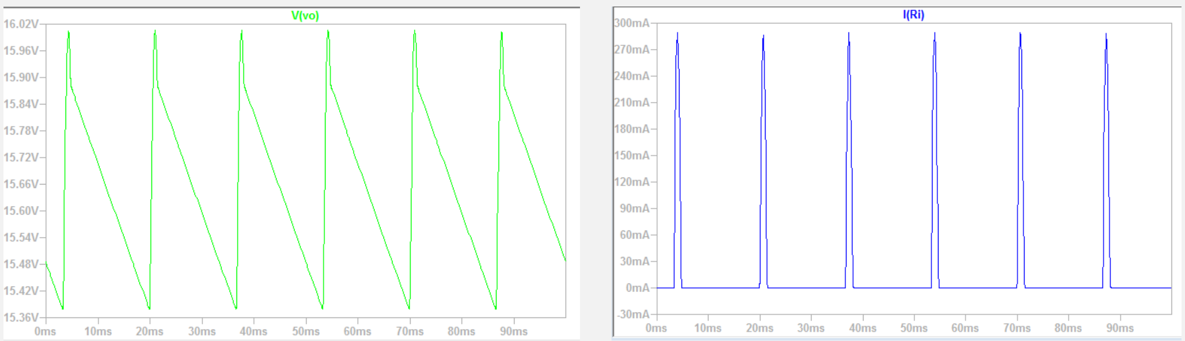


Figure 5. LT Spice model of a half-wave rectifier under 2 KΩ load (left). The voltage V_o across the load and the current $I(R_L)$ through the load (right).

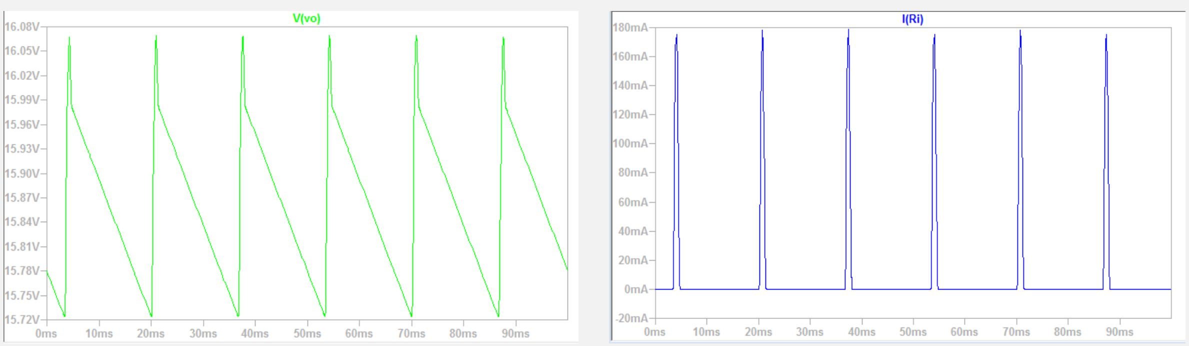
$R_L = 2||2||2\ K\Omega$



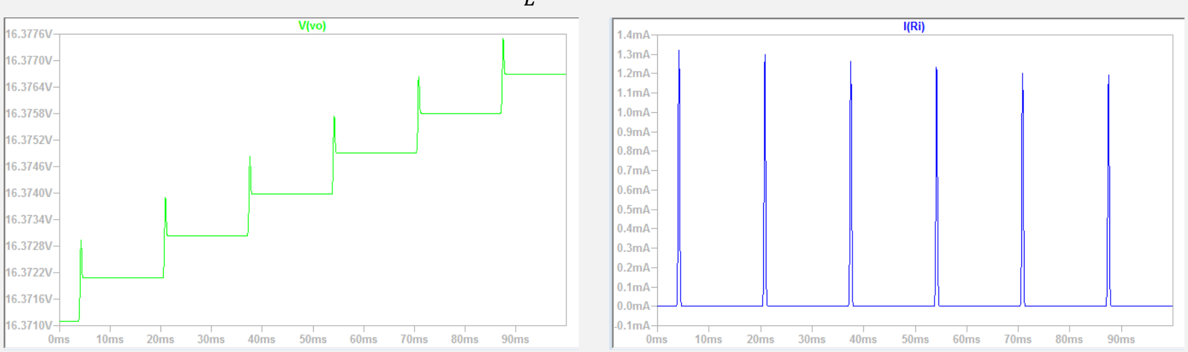
$R_L = 2||2\ K\Omega$



$R_L = 2\ K\Omega$



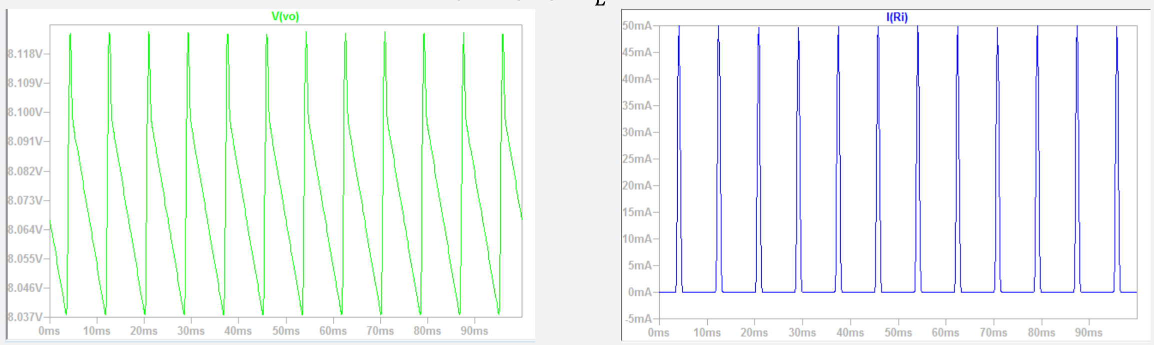
$R_L = No\ Load$



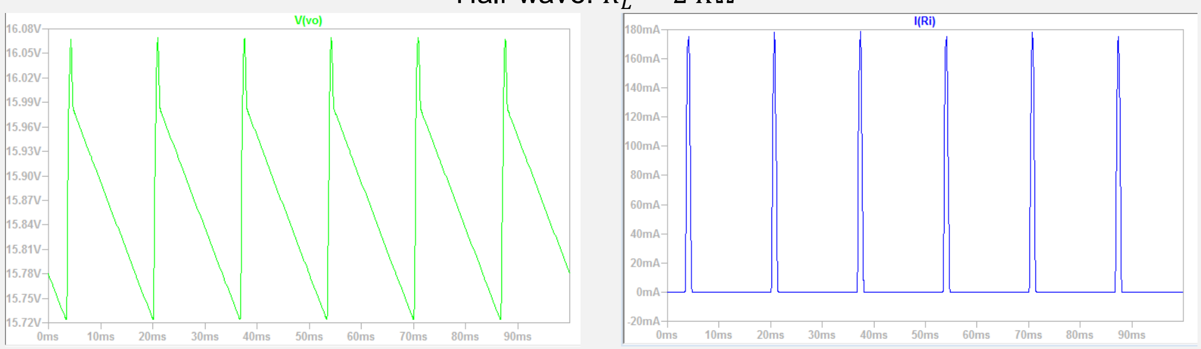
Question 3. For the full-wave rectifier circuits shown in Fig. 3, simulate the voltage across and current through the load R_L if R_L = 2 K**Ω**. The full transformer secondary voltage is 12.6 V_{RMS}. Show the LT Spice model for the half-wave rectifier in the textbox below. Also plot the voltage V_o and current $I(R_L)$ after the circuit reaches a steady state.

Remember that the full-wave rectifier uses the center-tap.

Full-wave: $R_L = 2\ K\Omega$



Half-wave: $R_L = 2\ K\Omega$



Question 4. From the results in Questions 1 and 2, find the ripple voltage, V_R, and peak current, I_P, for the half-wave rectifier and the full-wave rectifier in Figure 3. Calculate the load regulation for both rectifiers. Fill the results in the table 1 below.

Recall load regulation definition from Lab 1. Show your work on load regulation in the text box below.

Table 1: Ripples of half-wave and full-wave rectifying circuits

Load resistance	Half-wave rectifier			Full-wave rectifier		
	Voltage ripple	Peak current	Load regulation	Voltage ripple	Peak current	Load regulation
	V_R (V)	I_P (A)		V_R (V)	I_P (A)	
No load	0.326	0.001		0.002	0.004	
2 KΩ	0.357	0.188		0.085	0.049	
2‖2 KΩ	0.656	0.302		0.159	0.082	
2‖2‖2 KΩ	0.922	0.398		0.223	0.114	

$$\text{Load Regulation\%} = \frac{v_{out}^{no\ load} - v_{out}^{full\ load}}{v_{out}^{full\ load}} \times 100\%$$

$$LR_{HW}\% = \frac{V_{o,nl} - V_{o,fl}}{V_{o,fl}} \times 100\% = \frac{17.2 - 16.8}{16.8} \times 100\% = 2.38\%$$

$$LR_{FW}\% = \frac{V_{o,nl} - V_{o,fl}}{V_{o,fl}} \times 100\% = \frac{8.36 - 8.06}{8.06} \times 100\% = 3.72\%$$

Question 5 (extra credit for good justification and trying other formula). In a rectifier circuit with a filter capacitor, there will be a large surge current when it is first turned on with the filter capacitor completely discharged. Consider the half-wave rectifier circuit shown in Figure 2. Assume the 120:12.6 transformer is connected to an ideal 120 V_{RMS} source, and that the transformer has R_{pri} = 50 Ω and R_{sec} = 0.5 Ω. Assume that the diode and capacitor are ideal. Disregard the 1 Ω current sense resistor. Estimate the worst-case peak surge current that you would expect to flow through the diode. Explain the rationale for your answer.