

Power Supply

1. Objective

This lab will show some of the basic principles of power supplies using a full-wave rectifier with a filter capacitor, a Zener diode, and a fixed-voltage regulator integrated circuit.

2. Components

Qty	Device
1	Bridge Rectifier IC (50 PIV, 1A)
1	Zener Diode (10V at 500 mW)
1	340LZA-5.0 Regulator

3. Introduction

Most of the direct current (dc) power used in electronic devices is derived by converting 60 Hz, 120 V_{rms} alternating current (ac) power to direct current power. This ac to dc conversion usually involves a step- down transformer, a rectifier, a filter, and a regulator. The step-down transformer is used to decrease the ac line voltage from 120 V_{rms} to 12 V_{rms} , which is much closer to the dc voltage needed. The output of the step-down transformer is then fed into a diode rectifier circuit that flips the negative swings of the input voltage up. A filter is then used to smooth the rectifier output to achieve a reasonably constant dc voltage level. A regulator can be added after the filter to ensure a constant output voltage regardless of changes in load current and input voltages.

Two different types of voltage regulators will be used in this project. The first regulator uses a Zener diode, and the second uses a voltage regulator integrated circuit. A Zener diode can be used as a voltage regulator when the diode is reverse biased and operated in the breakdown region. To maintain voltage regulation, the Zener diode must be in the breakdown region at a current greater than the knee current (I_{ZK}). For currents greater than I_{ZK} , the Zener diode characteristic curve is nearly vertical and the voltage across the diode changes very little. Of course, there is a maximum current the diode can tolerate, so good regulation is provided when the diode is reversed biased with currents between I_{ZK} and I_{Zmax} . Zener diodes are available with a wide variety of breakdown voltages.

Another type of voltage regulator is available with the 340 series of regulator integrated circuits. This series of fixed-voltage regulators is numbered 340L-xx, where xx corresponds to the value of the output voltage. Output voltages from 5 to 15 volts are available. These regulators are easy to use and work very well.

4. Prelab Design Project

Please show all work, include your schematics, and sketch or print waveforms. Label all schematics and waveforms with name, date, axis scale, conditions, and any important information (peak voltage, cutoff frequency, etc.).

4.1. (35 point) Find an approximation for the dc output voltage level, V_{dc} with $V_s=12V_{RMS}$ you will need to convert to peak. For the circuit in Figure 1, find the ac **peak-to-peak** ripple voltage, $V_R = \frac{I_L T}{2C}$ for $C=220\mu F$, $R_{Load} = 1k\Omega$ and $R_{Load} = 560\Omega$. Note that $T = \frac{1}{60 \text{ Hz}}$ the United States, and assume the forward diode drop for the two diodes in the bridge is 1.2 V total. **Hint:** Assume $V_R = 0$ to find V_{dc} . Then use V_{dc} to find I_L .

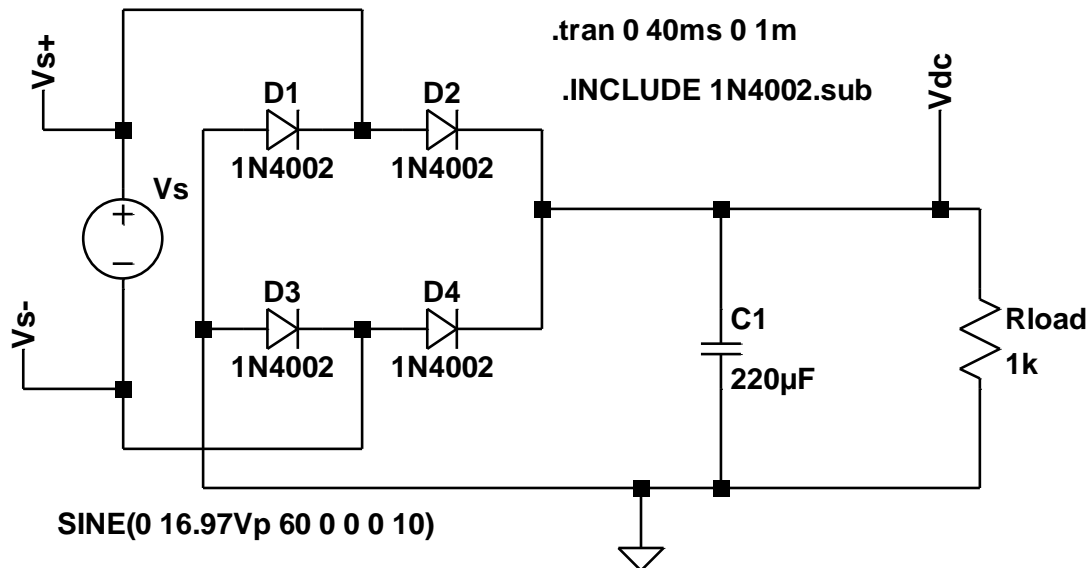


Figure 1

4.2. (30 point) For the Zener diode regulator circuit in Figure 2, assume that the Zener diode will regulate at 10 V over a diode current range of 5 mA to 25 mA. Find the minimum value of R and the minimum value for R_L . Assume that the maximum value of load R_{Load} is ∞ . You may assume the forward diode drop for the two diodes in the bridge is approximately 1.2 V total.

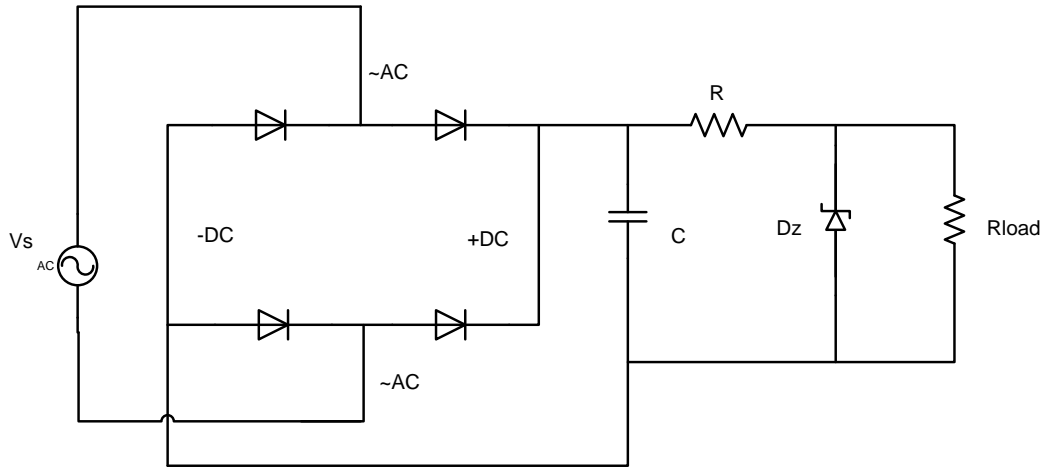


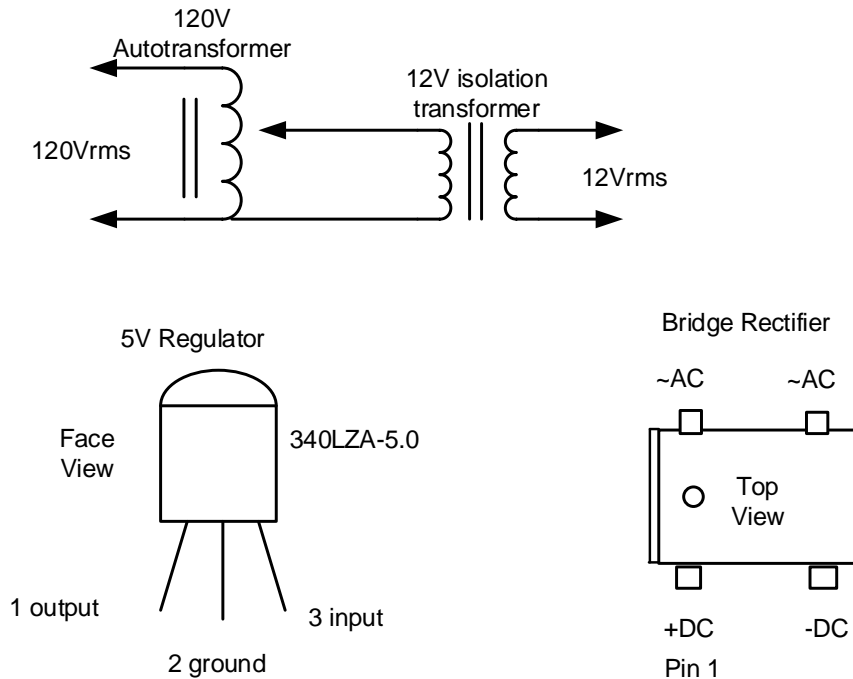
Figure 2

4.3. (25 point Total) Simulate the circuit in Figure 1 in LTspice use V source at 60 Hz to replace the secondary of the transformer in Figure 1 (neglect the transformer entirely for the purpose of simulation). In the time domain, show the input to the bridge rectifier use **1N4002** diodes for the bridge (add the file **1N4002.SUB** sub circuit to your **LTspice**) the output of bridge with filter capacitor C removed and $R_L = 1\text{k}\Omega$, the output waveform (zoom in to show ripple voltage) with capacitor C installed and $R_L = 1\text{k}\Omega$, and the output waveform with capacitor C installed and $R_L = 560\ \Omega$. (10 point) Include your schematic with your (15 point) four plots with white background input to bridge ($V_{s+} - V_{s-}$), Vdc w/o C, Vdc with C $R_{load}=1\text{k}\Omega$, and Vdc with C $R_{load}=560\ \Omega$

4.4. (10 point) Why can't the input source (secondary of transformer) for the bridge rectifier and load have a common ground between the input and load in the bridge rectifier circuit? Redraw the schematic to explain your answer.

5. Lab Procedure

5.1. Construct the circuit shown in Figure 1, using the bridge rectifier without the capacitor and with $R_L = 1k$. Use the VARIAC with the step-down transformer to control the input voltage to the bridge rectifier. With the transformer plugged into the VARIAC, adjust the VARIAC until the secondary voltage from the transformer equals $12 V_{rms}$. Use only one *scope probe* (**do not use BNC to alligator clip cables!**). *Be very careful* not to short the secondary terminals of the transformer! Record the DC voltage, peak V_{dc} , and the peak-to-peak ripple voltage, V_R . With the scope on DC coupling, set trigger to AC Line, capture the waveform before and after the bridge rectifier (you will need to move the ground connection) and print it out. (Scope time/record 20mS, Range 50V) **Two printouts.**



5.2. Remove power from the circuit. Insert the capacitor ($C=220\mu F$) as shown in Figure 1, being sure to observe the correct polarity. Energize the circuit. With the oscilloscope on (DC coupling), observe the load and (AC Coupling) ripple voltages and record them. Now, measure the load (DC Volts) and ripple voltage (AC volts) using the digital multimeter and record them. With the oscilloscope on (AC coupling, Range 5V, time/record 40mS), capture and print the voltage across the load. Compare your measured values with the values you calculated in your prelab. **One printout. Note** if the scope times out in Signal express set the trigger to AC line.

5.3. Observe the effect of loading on the circuit by changing the load resistor from $1 k\Omega$ to 560Ω , and repeat step 2. **One printout.**

5.4. Record the **forward** ($V_{max}=1v$, $I_{max}=50\mu A$, $R=1k$ $P=.5w$) and **reverse** ($V_{max}=20$, $I_{max}=50\mu A$, $R=10k$, $P=0.5$) Zener diode characteristic curve from the digital curve tracer, and turn this in with your report. Note the value of the breakdown voltage in the breakdown region. Also note the value of the knee current I_{ZK} . **Two printouts.**

5.5. After verifying your designed values for R and R_L with your instructor, construct the Zener diode regulator circuit shown in Figure 2. Measure the dc voltage level with the digital voltmeter

for the minimum value of R_L along with several values above and below the minimum value ($R_L = 220, 330, 680, 820, \text{ and } R_{L\min}$) Be careful not to overload the Zener diode. Comment on the circuits operation for these different load resistances and calculate the load current for each case. **No printouts.**

5.6. Construct the 340LZA-5.0 regulator circuit shown in Figure 3, being careful to observe the correct pin configuration of the regulator. Use two DC voltmeters one on (V_{in} Pin3) the other on (V_L Pin1). Set (V_{in} Pin3) to 10Vdc measure the load voltage for R_L equal to 330Ω , 220Ω , and 100Ω . Calculate the current for each of these cases. Does the value of the load resistor affect the output voltage? **No printouts.**

5.7. Using $R_L = 220 \Omega$, record the 340LZA-5.0 regulator input voltage (pin 3) and output voltage (pin 1). Decrease the regulator input voltage by decreasing the setting of the VARIAC. For each decrease in input voltage, record the regulator input and output voltages. Continue decreasing the amplitude until the output of the regulator drops a measurable amount below 5 V. Start the regulator input voltage at 10 V and drop it to 4 V in 0.5 V decrements. What is the minimum input voltage needed for the 340LZA-5.0 regulator to produce a 5 V output and not drop out of regulation? **No printouts.**

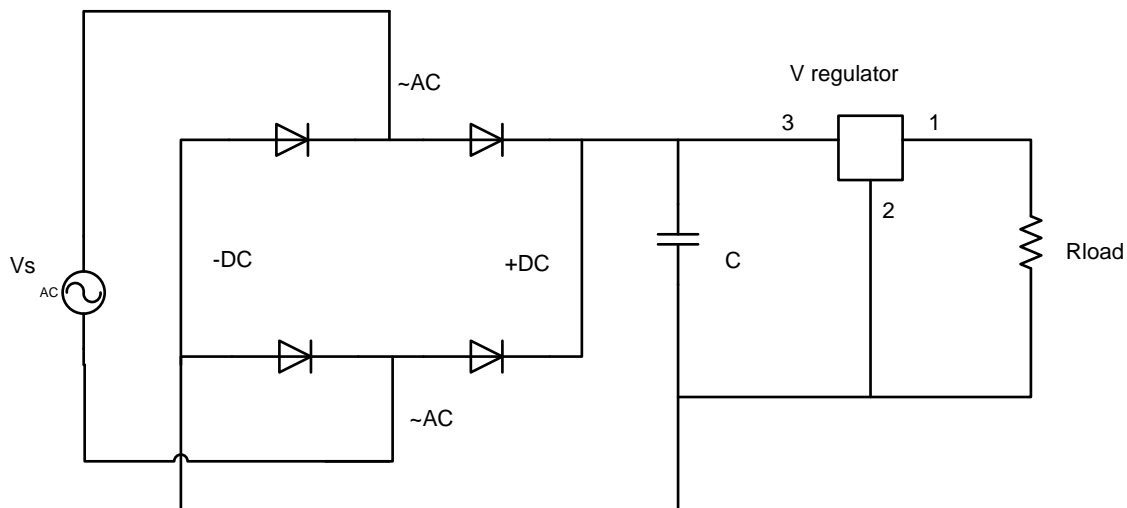


Figure 3

6. Postlab Questions

6.1. Can the Zener diode be used as a conventional diode? Explain your answer and verify with a curve from the curve tracer. Are there any limiting constraints?

6.2. Would the value of the output filter capacitor have to increase, decrease, or remain the same to maintain the same ripple voltage if the bridge rectifier were changed to a half-wave rectifier? Show calculations or a sketch to backup your answer.

6.3. How would increasing the frequency of the input source affect the ripple voltage, assuming all components remained the same? Show calculations or a sketch to back up your answer.

Experiment Data Sheet

Bench #: _____ **Lab Date:** _____ **Grade:** _____
Student names _____

Remember to include units for all answers and to label all printouts. There are a total of six (6) printouts in this lab. *Only one set of printouts is required per group.*

5.1. Full-wave rectifier with $R_L = 1\text{ k}\Omega$ without the capacitor. **Two printouts** (scope DC Coupled)

Maximum $V_L (V_{dc})$: _____ **$V_{Ripple} (V_{peak\ to\ peak})$:** _____

5.2. Full-wave rectifier with $R_L = 1\text{ k}\Omega$ with the capacitor. **One printout** (scope AC coupled)

Oscilloscope: $V_L (V_{dc})$: _____ $V_R (V_{p-p})$: _____
Digital Multimeter: $V_L (V_{dc})$: _____ $V_R (V_{rms})$: _____
Prelab Calculations: $V_L (V_{dc})$: _____ $V_R (V_{rms})$: _____
Comments:

5.3. Full-wave rectifier with $R_L = 560\ \Omega$ with the capacitor. **One printout** (scope AC coupled)

Oscilloscope: $V_L (V_{dc})$: _____ $V_R (V_{p-p})$: _____
Digital Multimeter: $V_L (V_{dc})$: _____ $V_R (V_{rms})$: _____
Prelab Calculations: $V_L (V_{dc})$: _____ $V_R (V_{rms})$: _____
Comments:

5.4. Zener Diode characteristic curves. **Two printouts (from curve tracer Forward and Reverse).**

$V_{breakdown}$: _____ I_{zk} : _____

5.5. Zener diode used as a voltage regulator. **No printouts.**

Design Values: R : _____ R_L : _____
Experimental Values: R : _____ R_L : _____

R_L	V_L	I_L
220 Ω		
330 Ω		
prelab $R_L =$		
680 Ω		
820 Ω		

5.6. 340-LZA-5.0 Voltage Regulator. No printouts. Vin Pin3 = 10Vdc

R_L	V_L	I_L
100 Ω		
220 Ω		
330 Ω		

5.7. 340-LZA-5.0 Voltage Regulator, with $R_L = 220 \Omega$ use two DC voltmeters. No printouts.

Pin 3 (V_{in})dc	Pin 1 (V_{out})dc	Pin 3 (V_{in})dc	Pin 1 (V_{out})dc
10.0 V		7.0 V	
9.5 V		6.5 V	
9.0 V		6.0 V	
8.5 V		5.5 V	
8.0 V		5.0 V	
7.5 V		4.5 V	

V_{in} Minimum: _____

Postlab Questions

- Can the Zener diode be used as a conventional diode? Explain your answer and verify with a curve from the curve tracer. Are there any limiting constraints?
- Would the value of the output filter capacitor have to increase, decrease, or remain the same to maintain the same ripple voltage if the bridge rectifier were changed to a half-wave rectifier? Show calculations or a sketch to backup your answer.
- How would increasing the frequency of the input source affect the ripple voltage, assuming all components remained the same? Show calculations or a sketch to back up your answer.