EE 3101 ELECTRONICS I LABORATORY
EXPERIMENT 2 LAB MANUAL

POWER SUPPLY DESIGN CONSIDERATIONS

OBJECTIVES

In this experiment you will

- Learn how resonant circuits can be used to make band-pass and band-reject filters.
- Gain experience in measuring the frequency response of a simple network.
- Become familiar with the laboratory layout and equipment.

LAB NOTEBOOKS

The format of lab notebooks should be such that the information can be used to reproduce the lab, including what values were used in a circuit, why the values were used, how the values were determined, and any results and observations made. This lab manual will be used as a guide for what calculations need to be made, what values need to be recorded, and various other questions. The lab notebook does not need to repeat everything from the manual verbatim, but it does need to include enough information for a 3rd party to be able to use the notebook to obtain the same observations and answers. In the following numbered sections there are **bolded words and/or lines**. These bolded words and/or lines are statements and/or questions that the lab TA will be looking for an answer either in the lab preliminary, or lab notebook.

INTRODUCTION

The lecture part of this class covers the most-commonly-used rectifier configurations. Figure 1 shows the half-wave rectifier with a capacitive filter section. Figure 2 shows the classical full-wave filter, and Figure 3 shows the full-wave bridge rectifier. The question logically arises as to which configuration is the best choice for a given application.

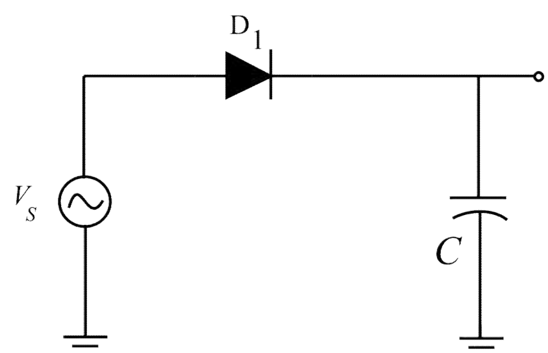


Figure 1: The Half-Wave Rectifier with Capacitive Filtering.

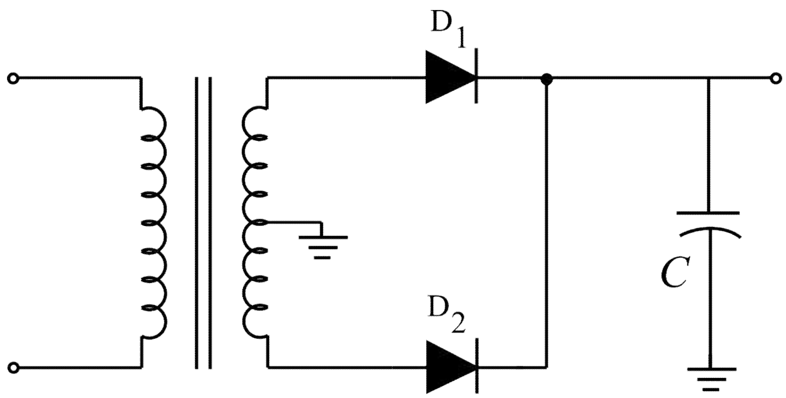


Figure 2: The Classical Full-Wave Rectifier with Capacitive Filtering.

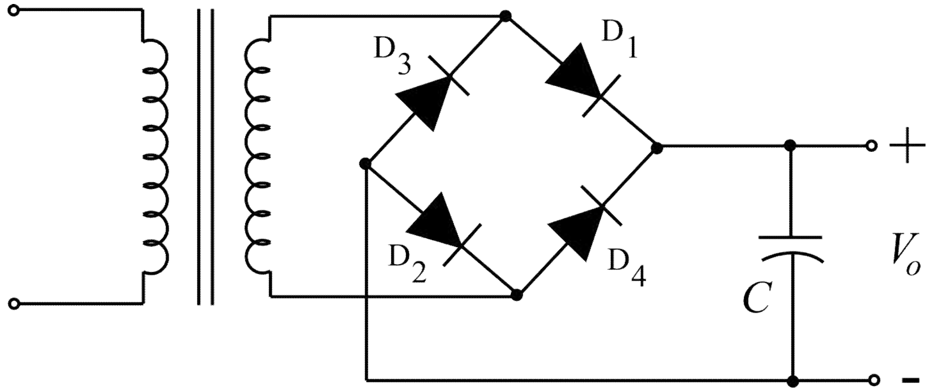


Figure 3: The Full-Wave Bridge rectifier with Capacitive Filtering.

Each configuration has the following advantages and disadvantages:

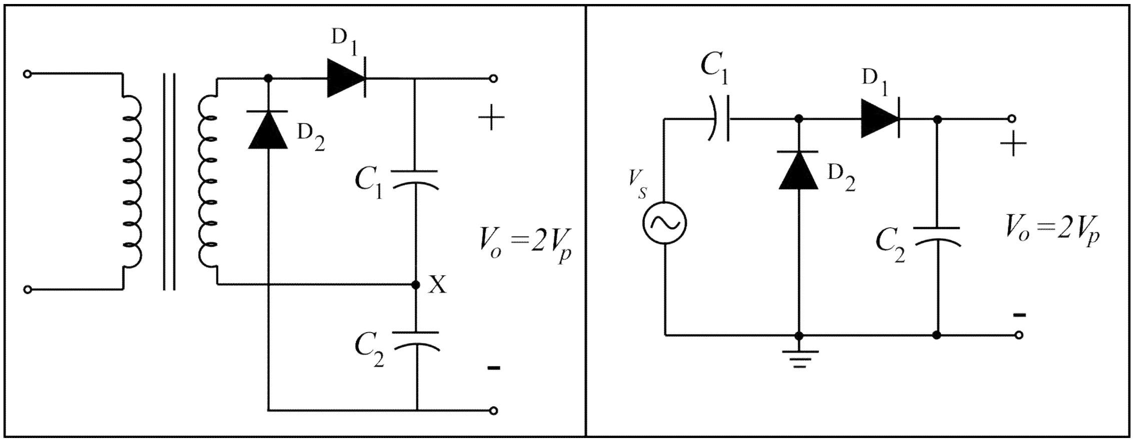
HALF-WAVE RECTIFIER	
Advantages	Disadvantages
Less complex – requires only one diode	Only half of the input sine wave is utilized – input power factor is poor
A transformer is not required	For a given C, ripple voltage and peak current will be large
	The Peak Inverse Voltage rating must be

CLASSICAL FULL-WAVE RECTIFIER	
Advantages	Disadvantages
Both half cycles are utilized - input power factor is improved	Two diodes are needed
For a given C, ripple voltage and peak diode current will be less than in the case of the half-wave rectifier	A center-tapped transformer is needed
	The Peak Inverse Voltage rating must be > 2Vp

FULL-WAVE BRIDGE RECTIFIER	
Advantages	Disadvantages
A Peak Inverse Voltage rating of only > Vp is needed	Four diodes are needed
For a given C, ripple voltage and peak diode current will be less than in the case of the half-wave rectifier	There are now two diode drops during each half cycle

Generally, you will use a half-wave rectifier only when the load current is very small, and the filter capacitance can be very small. The classical full-wave rectifier would be selected when power conversion efficiency is the highest priority and the voltage drop across each diode is significant with respect to the output voltage. The bridge rectifier has an advantage at high voltages since the Peak Inverse Voltage (PIV) rating only has to be half the rating of the other configurations, and diode drops are also relatively insignificant.

Another type of rectifier/filter is the voltage doubler, shown in Figure 4. The circuit in Figure 4(a) is called the full-wave doubler. The circuit in Figure 4(b) is called the half-wave doubler. The full-wave doubler can be used to produce an output voltage of roughly $2V_p$, or $\pm V_p$ (if point X is grounded). The half-wave doubler is used when one lead of output and input must share a common ground. These circuits are used extensively in high-voltage applications such as cathode-ray tube (CRT) power supplies, TV sets, Geiger counters, stun guns, and so forth. One can extend this principle to design voltage multiplier circuits. For example, a voltage tripler is shown in Figure 5.



(a) *(b)*

Figure 4: Two Forms of the Voltage Doubler.

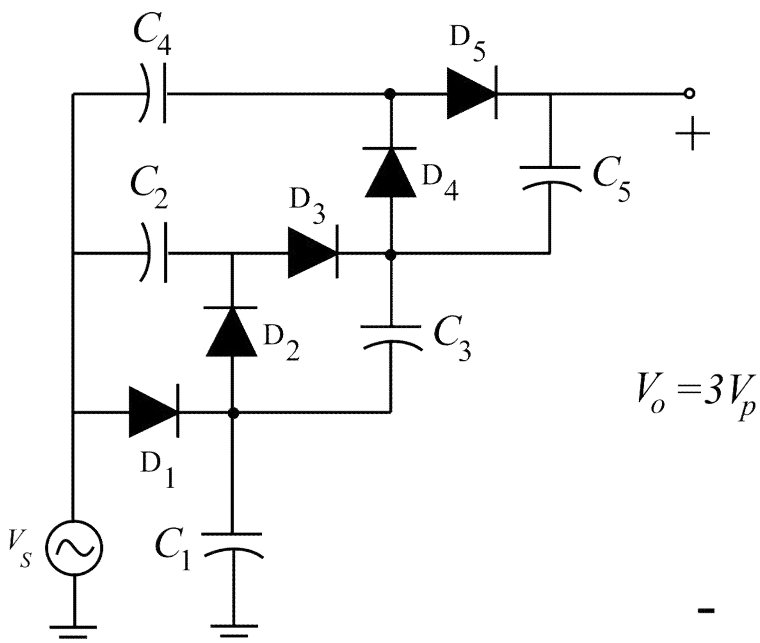


Figure 5: A Voltage Tripler.

Normally, power supply design begins with the output specifications and working back towards the input side. One of the last components specified is the transformer. However, if only one or just a few power supplies are to be built, it may be more-economical to just buy an off-the-shelf transformer that will work, but just not result in an optimum design. That is the approach taken with this experiment for practical reasons.

PRELIMINARY

1. Find a data sheet for the general purpose rectifier model 1N4002. **From the datasheet find the following parameters to populate Table 1.** Good places to find data sheets are; www.digikey.com, www.mouser.com, www.newark.com, and www.onsemi.com.

Table 1: 1N4002 Diode parameters.

Parameter	**Value**
V_{RRM}, Maximum Repetitive Peak Reverse Voltage	
$I_{F(AV)}$, Maximum average forward rectified current	
V_F, Maximum instantaneous forward voltage	

2. The circuit shown in Figure 6 demonstrates the full-wave rectifier design for this part of the lab. The rectifier/filter circuit design will require approximately 16 V_{DC} @ 130 mA output capability, with a peak-to-peak voltage ripple less than 0.5 V. It is shown in the textbook that for a full-wave rectifier the ripple voltage is [1]

$$V_r = \frac{V_M}{2fRC}$$

where V_r, V_M, f, R, and C, are the ripple voltage, peak voltage, frequency, load resistance, and filter capacitance, respectively.

   a. **Calculate the required value for C_1, as well as the required working voltage of the capacitor**.

   b. **Calculate the value of the load resistance**, where it can be assumed that the load resistance will satisfy the output voltage and current specifications given.

   c. **Note the resistance value and its power rating.** *When performing the lab, select a capacitor from the lab stock that has at least the value calculated, and a load resistance that is close to the value calculated. You will also need to consider that the power rating is at least the value calculated.*

3. It is also shown in the textbook that for a full-wave rectifier the peak and average diode currents during a conduction interval are approximately

$$i_{D,peak} \cong \frac{V_M}{R}\left(1 + \pi\sqrt{\frac{2V_M}{V_r}}\right)$$

$$i_{D,avg} \cong \frac{V_M}{R}\left(1 + \frac{\pi}{2}\sqrt{\frac{2V_M}{V_r}}\right)$$

a. **Calculate the peak diode current $i_{D,peak}$ and $i_{D,avg}$ over the conduction interval**.

b. **Calculate the PIV rating required** for a diode to function safely in the rectifier design.

Q1. **Using the information in the data sheet, how much do you expect the diode drop to be under full load?** Explain your reasoning.

Q2. **According to the data sheet, will a 1N4002 be sufficient in terms of current and voltage?** Think carefully about this and explain your reasoning. If you have doubts, discuss your reasoning with your instructor.

4. If you know that there will be a voltage of V_F, drop across one of the diodes between the secondary output and the output voltage of the rectifier.

   a. **Calculate the peak voltage required of the secondary winding of the transformer for the output voltage specification of 16 V_{DC} to be satisfied**.

   b. **Calculate the Root Mean Square (RMS) voltage of the secondary.**

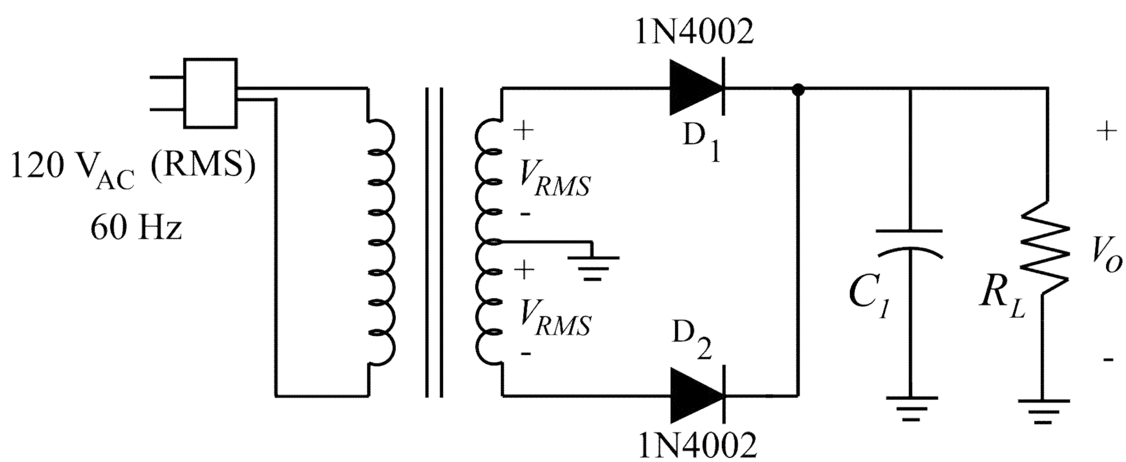


Figure 6: Schematic of the power supply to be designed.

EXPERIMENT

PART A. POWER SUPPLY CIRCUIT USING A FULL WAVE RECTIFIER

When performing the lab, select a capacitor from the lab stock that has at least the value calculated, and a load resistance that is close to the value calculated. You will also need to consider that the power rating is at least the value calculated.

1. Obtain one of the transformers from the parts cabinet and use the DMM to measure the output of one of the secondary terminals relative to the center tap connection. **Note the value.**

Q3. **Will the supplied transformer be suitable? Explain.**

2. Construct the circuit of Figure 6. Have your lab partner(s) check over the circuit to make sure the connections are right. Energize the circuit. Using the oscilloscope, observe the output voltage. **Sketch the output waveform, and measure both the peak-to-peak ripple voltage and the dc average voltage**.

Q4. **How do the measured ripple and average values compare with your design values? Explain any discrepancies.**

3. Make sure you have written down all of the details of your circuit. You will be using a similar circuit in next week's experiment.

PART B. HALF-WAVE VOLTAGE DOUBLER

Consider the half-wave voltage doubler of Figure 7. **Determine the voltage ratings required for the capacitors and select suitable capacitors from the lab stock**.

1. Construct the circuit without the load resistance R_L and carefully check your connections. Be careful since the voltages you are dealing with are potentially hazardous.
2. Connect the oscilloscope to the output and energize the circuit. **Sketch the output waveform, and measure both the peak-to-peak ripple voltage and the dc average voltage**.
3. Carefully remove the transformer cord from the wall socket and connect the load resistance R_L and energize the circuit again. **Sketch the output waveform, and measure both the peak-to-peak ripple voltage and the dc average voltage**.

Q5. What effect does the load have on the output voltage?

Q6. What would the advantage be if you could increase the frequency of the input AC?

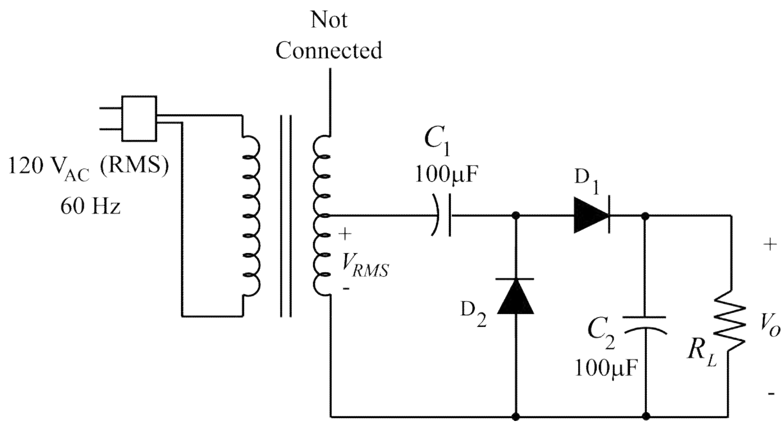


Figure 7. A half-wave voltage doubler test circuit.

[1] Neamen, D. 2010. Microelectronics: Circuit Analysis and Design, Fourth Edition. New York, NY. McGraw-Hill.