EE 255
ELECTRONICS I LABORATORY
EXPERIMENT 2
POWER SUPPLY DESIGN CONSIDERATIONS

OBJECTIVES

In this experiment you will

- Learn how to select the best rectifier circuit for your application
- Gain experience in designing to meet specifications
- Obtain experience in using manufacturers' data sheets.

INTRODUCTION

In class, you were introduced to 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, while Fig. 3 shows the full-wave bridge rectifier. The question logically arises as to which configuration is the best choice for a given application.

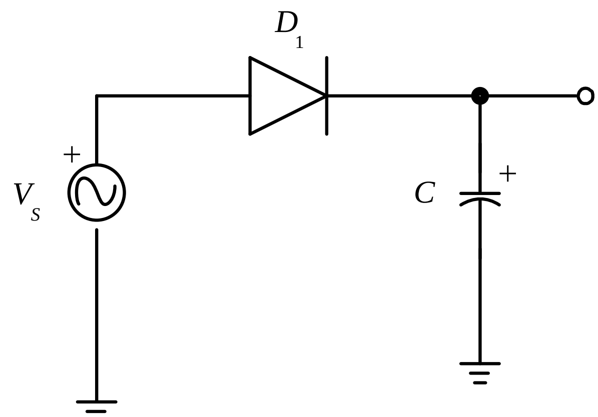


Fig. 1. The Half-Wave Rectifier with Capacitive Filtering.

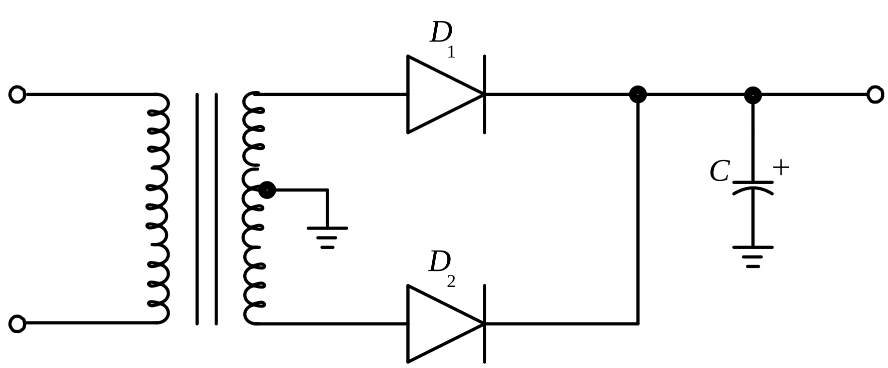


Fig. 2. The Classical Full-Wave Rectifier with Capacitive Filtering.

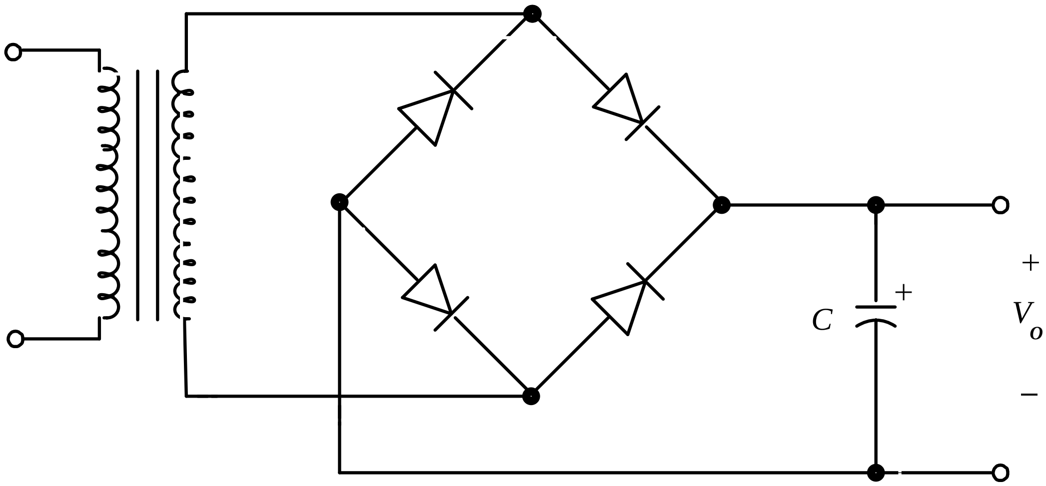


Fig. 3. The Full-Wave Bridge rectifier with Capacitive Filtering.

If you will look closely at each configuration, you see the following advantages and disadvantages of each:

HALF-WAVE RECTIFIER

Advantages

* Less complex - requires only one diode.
* A transformer is not required.

Disadvantages

* Only half of the input sine wave is utilized – input power factor is poor.
* For a given C, ripple voltage and peak current will be large.
* The PIV rating must be > $2V_p$.

CLASSICAL FULL-WAVE RECTIFIER

Advantages

* Both half cycles are utilized; input power factor is improved.
* For a given C, ripple voltage and peak diode current will be less than in the case of the half-wave rectifier.

Disadvantages

* Two diodes are needed.
* A center-tapped transformer is necessary.
* The PIV rating must be > $2V_p$.

FULL-WAVE BRIDGE RECTIFIER

Advantages	Disadvantages
* A PIV rating only > V_p is needed. * For a given C, ripple voltage and peak diode current will be less than in the case of the half-wave rectifier.	* Four diodes are required. * 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 C can be very small). The classical full-wave 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 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 Fig. 4. The circuit in Fig. 4(a) is called the full-wave doubler. The circuit in Fig. 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 Fig. 5.

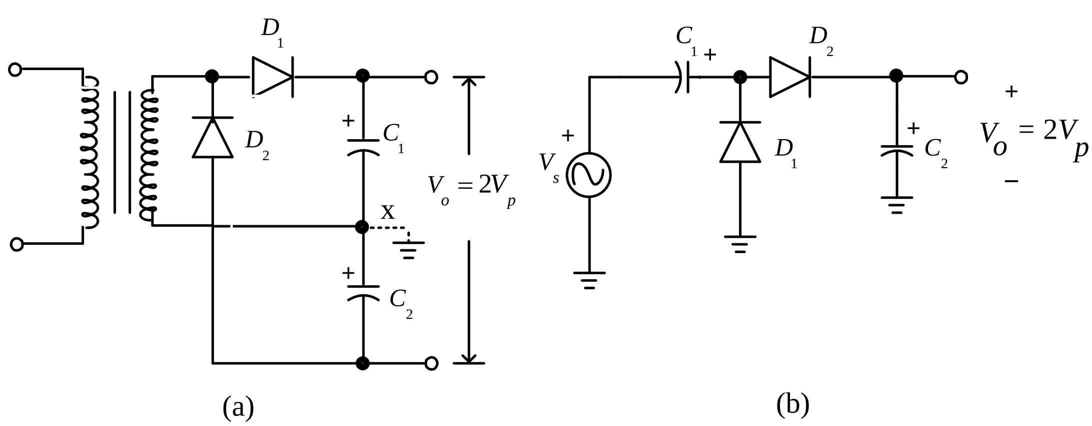


Fig. 4. Two Forms of the Voltage Doubler

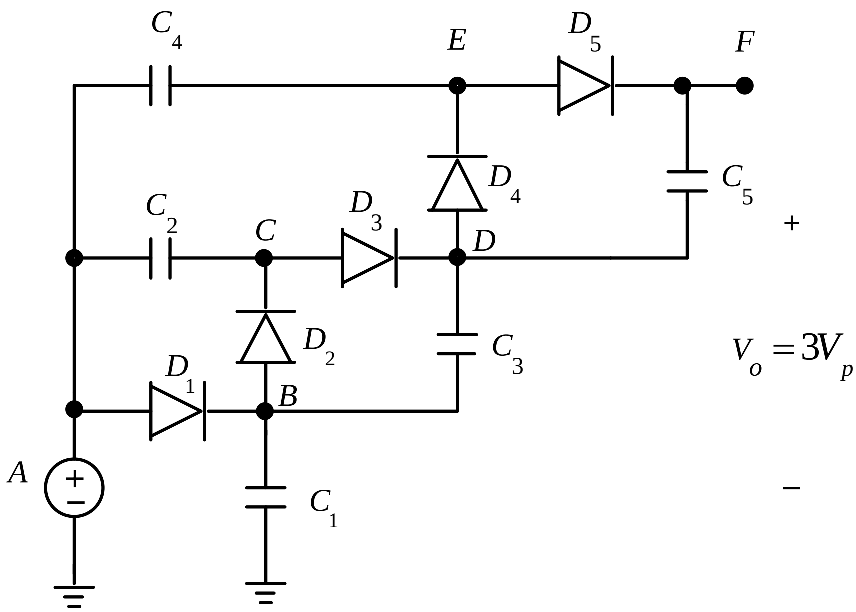


Fig. 5. A Voltage Tripler

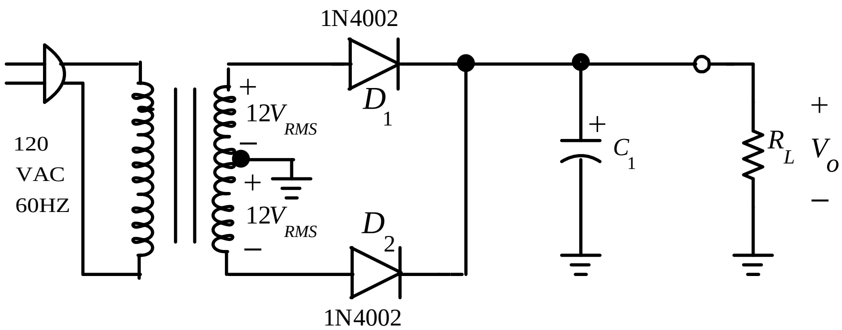
Normally, we begin a power supply design by starting with the output specifications and working back towards the input side. One of the last components you will specify is the transformer. However, if you intend on building only one or just a few of the supplies, it may be more-economical to just buy an off-the-shelf transformer that will work, but just not result in an optimum design. That is the approach we will take in this experiment for practical reasons.

EXPERIMENT

1. *Before class*, go to the internet and print out the data sheet for the 1N4001-1N4007 series of rectifier diodes. You can use www.digikey.com, www.onsemi.com, or other web sites. It will also be advantageous to look up the required equations in your textbook. *Perform as many of the following steps as you can before class.*

2. We wish to design a rectifier/filter circuit that will deliver approximately 16 VDC @ 130mA, with a peak-to-peak ripple $\leq$ 0.5 V. We will use the circuit shown in Fig. 6. Calculate the required value for C1, as well as the required working voltage of the capacitor. Select a capacitor from the lab stock that has at least these values.

3. Calculate the peak diode current $i_{D(peak)}$ and $i_{D(ave)}$ over the conduction interval. Using the information in the data sheet, how much do you expect the diode drop to be under full load? Explain your reasoning. Calculate the PIV rating required. 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.



Transformer: Pri: 120VAC, Sec: 24VCT

Fig. 6. Schematic of the power supply to be designed.

4. Calculate the peak voltage required of the secondary winding of the transformer. From this, you can calculate the rms voltage of the secondary. Will the supplied transformer be suitable? Explain. (Note: The transformer will be specified at a specific load current and at a specified input voltage. Typically, the power line voltage in Rolla runs over 120 VAC. If the load current is less than the specified test current, what secondary voltage would you expect to see? Measure the output voltage without a load to confirm your thinking.)

5. Construct the circuit of Fig. 6. Use a resistor of suitable power rating to simulate the the required load current of 130mA. Have your lab partner(s) check over the circuit to make sure the connections are right.

6. Energize the circuit. Using the oscilloscope, observe the output voltage and measure both the peak-to-peak ripple voltage and the dc average voltage. How do these compare with your design values? Explain any discrepancies.

7. 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.

8. Next, consider the half-wave voltage doubler of Fig. 7. Determine the voltage ratings required for the capacitors and select suitable capacitors from the lab stock. Construct the circuit and carefully check your connections. Be careful since the voltages you are dealing with are potentially hazardous.

9. Connect the oscilloscope to the output and energize the circuit. Sketch the output waveform, indicating all details. Carefully remove the load. What effect does the load have on the output voltage? What would the advantage be if you could increase the frequency of the input AC?

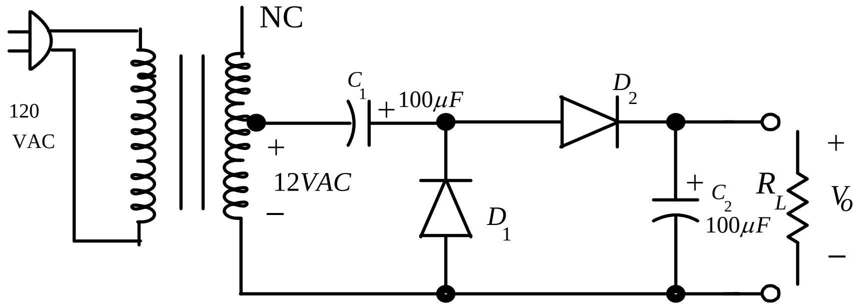


Fig. 7. A half-wave voltage doubler test circuit.