EE 462: Laboratory # 4
DC Power Supply Circuits Using Diodes

by
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(Lab 3 report due at beginning of the period) (Pre-lab4 and Lab-4 Datasheet due at the end of the period)

I. Instructional Objectives

- Design and construct circuits that transform sinusoidal (AC) voltages into constant (DC) voltages.
- Design and construct a voltage regulator based on the characteristics of the Zener diode.
- Evaluate the performance of simple rectifier and regulator circuits.

See Horenstein 4.3 and 4.4

II. Background

Electric power transmits best over long distances at high voltages. Since $P = I V$, a larger voltage implies a smaller current for the same transmitted power. And smaller currents allow for the use of smaller wires with less loss. The high voltages used for power transmission must be reduced to be compatible with the needs of most consumer and industrial equipment. This is done with transformers that only operate with AC (DC does not pass through a transformer). However, most electronic devices powered by a home outlet require DC (constant) voltages. Therefore, the device must have a power supply that converts AC voltages into a DC (constant) voltage.

The terminology "DC" is somewhat ambiguous. DC can mean the voltage or current always has the same polarity but changes with time (pulsating DC), or it can mean a constant value. In this lab assignment DC will refer to a constant voltage or current. Voltages or currents that maintain the same polarity, but change with time, have both a DC and AC component. The process of changing an AC signal to a signal with only positive values is called *rectification*, and circuits that perform this operation are called rectifier circuits. The rectifier circuit operates similar to the clipping circuits used in a previous lab. Figure 1 a) shows a half wave rectifier and Fig. 1 b) shows a full wave rectifier.

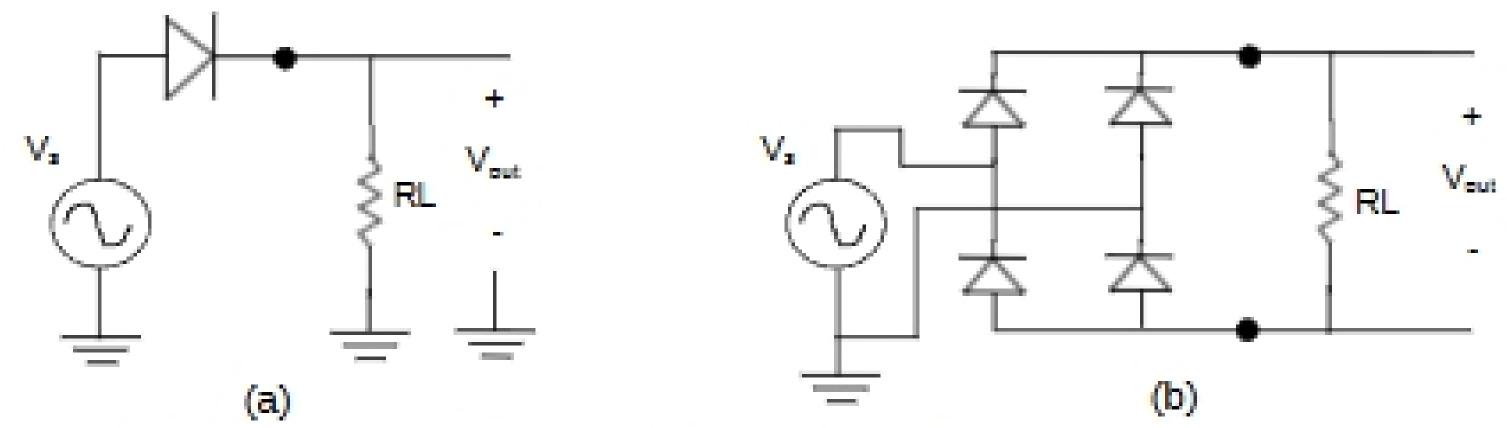

Fig. 1 a) Half wave rectifier. b) Full wave rectifier.

Although the output of a rectifier is always positive, it is generally not constant, often going from zero to a peak value. Thus, the output of the rectifier must be filtered to remove the AC component so as to pass only the DC (constant) component to the output. Since DC has a frequency of 0 Hz, a low-pass filter can be applied to attenuate or block the higher frequency signal components. The simplest low-pass filter is a capacitor. Figure 2 shows examples of passing rectified signals through a low-pass filter. Low-pass filtering a waveform is sometimes called smoothing because it *smoothes-out* fast or sharp voltage jumps. Real-time filter can not have a cut-off sharp enough to totally eliminate unwanted frequencies, so the actual output of the filter will always have some AC content, often called ripple (ripple voltage or ripple current). A rectifier combined with a filter forms a simple DC power supply.

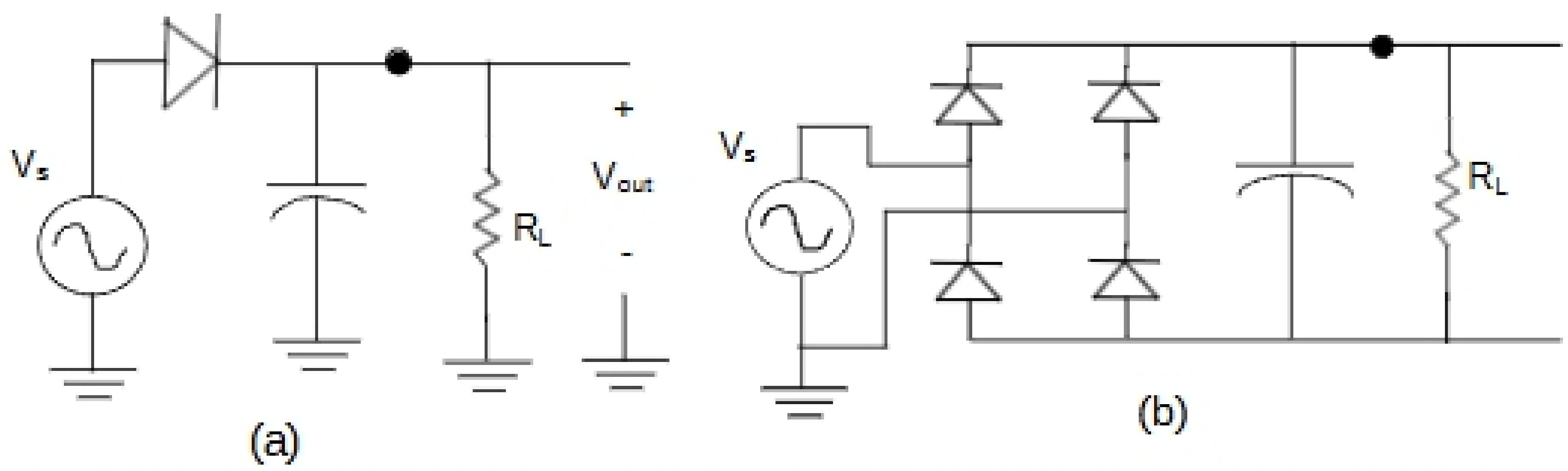

Fig. 2 a) Half wave rectifier with capacitor filter. B) Full wave rectifier with capacitor filter.

One performance measure of a DC power supply is the *percent output ripple* computed from the ratio of the (peak-to-peak) output voltage to the average (DC) output voltage. Output ripple can be expressed as *r* in the equation below:

$$r = \frac{V_{op-p}}{\langle V_o \rangle} \qquad (1)$$

where V_{op-p} is the peak-to-peak output voltage and $\langle V_o \rangle$ is the mean of the output voltage, which is equivalent to the DC component. Multiply *r* by 100 for *percent output ripple*. A typical output signal is illustrated in Fig. 3. The best performance occurs when the percent ripple is zero (a battery produces ideal DC). This lab examines and compares the two rectifier schemes in Fig. 2, and demonstrates the contributions of the different stages to the final output.

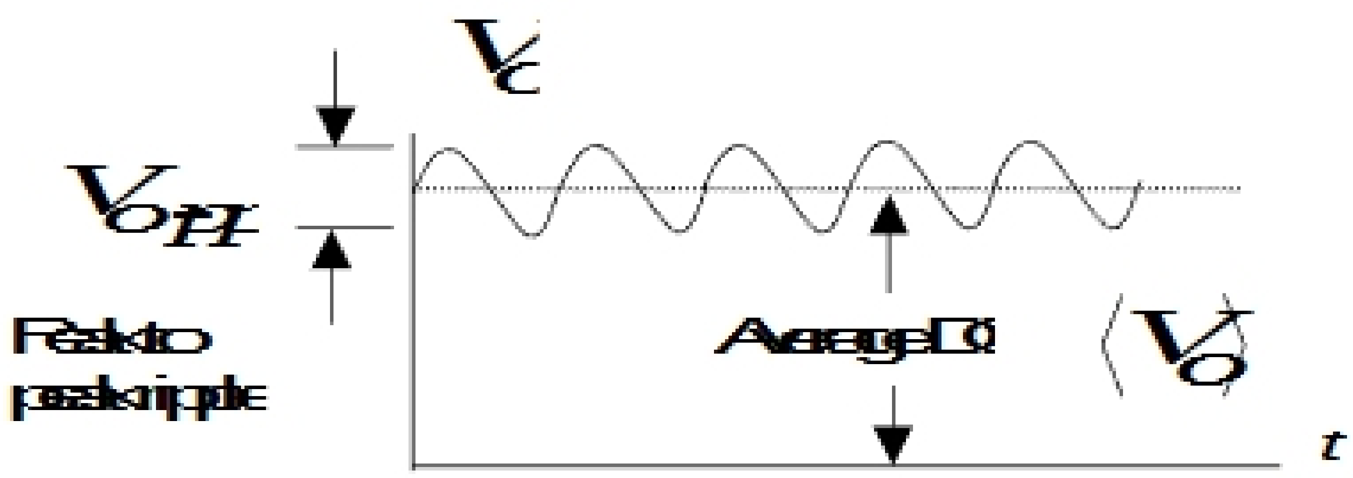

Fig. 3. Definition of percent ripple

A DC power supply provides constant DC voltage to a load, which can be modeled as a resistor. Ideally the constant DC output should be independent of the load and input voltage fluctuations. In an actual power supply, however, when a load is applied to the output (as in Figs. 1 and 2), the output voltage decreases due to increased current drawn and the increased internal voltage drops. A voltage regulator circuit is used to prevent/limit these output voltage changes. A Zener diode can be used to make a voltage regulator circuit (as shown in Fig. 4) by taking advantage of the Zener diode's reverse breakdown characteristic. Recall that once a Zener diode breaks down, its voltage remains essentially constant independent of its reverse current. The regulator's resistor, Rreg, limits the current through the Zener to reduce the power dissipated in the Zener. This is done, however, at the price of limiting the maximum load current that can be supplied with a regulated output voltage.

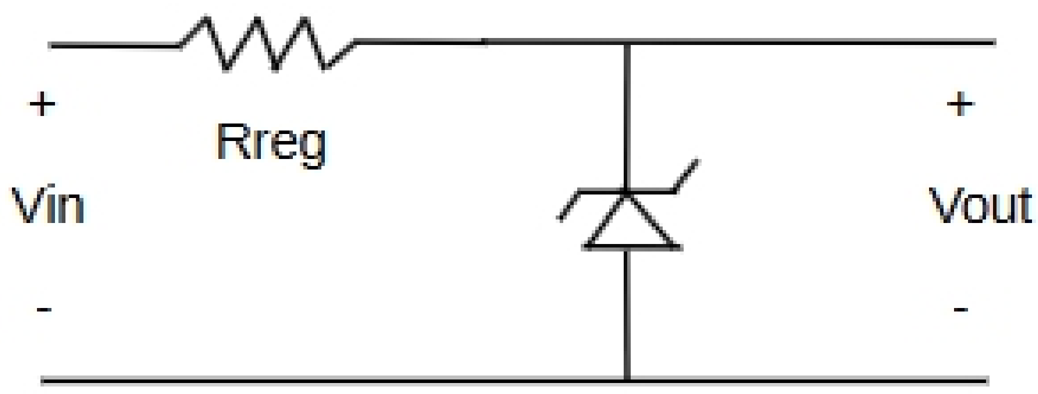

Fig. 4. Zener voltage regulator

An important characteristic of a voltage regulator is its percent regulation defined as the difference between the average no-load voltage (implies zero load current and thus infinite load resistance) and the average full-load voltage (the load draws its maximum (or rated) current and thus has its minimum (or rated) resistance) divided by the average full-load voltage. Regulation can be expressed in the equation below:

$$\text{Regulation} = \frac{\langle V_{oNL} \rangle - \langle V_{oFL} \rangle}{\langle V_{oFL} \rangle} \qquad (2)$$

where $\langle V_{oNL} \rangle$ is the average output no-load voltage and $\langle V_{oFL} \rangle$ is the average output full-load voltage. *Percent regulation* is obtained by multiplying Regulation in Eq. 2 by 100. The best regulation performance is achieved with a 0 % regulation.