INDT 112 Information Sheet
Diodes & Rectifiers

In electronics, a diode is a component that restricts the direction of current flow. It allows an electric current to flow in one direction but essentially blocks it in the opposite direction. The diode can be thought of an electronic version of a check valve.

The first diodes were vacuum tube devices similar in appearance to incandescent light bulbs. Most modern diodes today are semiconductor p-n junctions made of silicon.

Metals tend to be good conductors of electricity because they usually have "free electrons" that can move easily between atoms. While silicon crystals look metallic, they are not, in fact, metals. All of the outer electrons in a silicon crystal are involved in perfect covalent bonds, so they can't move around. A pure silicon crystal is nearly an insulator. Very little electricity will flow through it.

The behavior of silicon can be changed by mixing a small amount of an impurity into the silicon crystal. This process is known as doping.

There are two types of impurities:

N-Type
In N-type doping, phosphorus or arsenic is added to the silicon in small quantities. N-type silicon is a good conductor. It takes only a very small quantity of the impurity to create enough free electrons to allow an electric current to flow through the silicon. N-type electrons have a negative charge, hence the name N-type. The N-type side of a diode is often referred to as the **Cathode**.

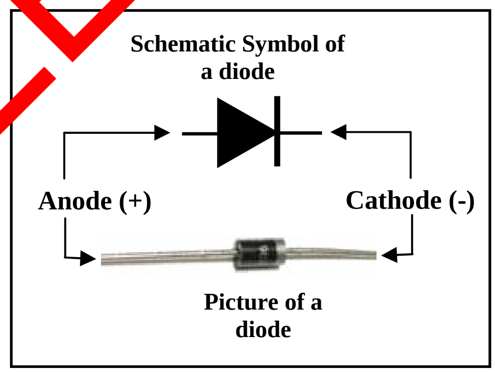

Figure 1

P-Type
In P-type doping, boron or gallium is added to the silicon. Boron and gallium each have only three outer electrons. When mixed into the silicon lattice, they form "holes" in the lattice where a silicon electron has nothing to bond to. The absence of an electron creates the effect of a positive charge. P-type gets its name from the positive charge that it carries. The P-type side of a diode is referred to as the **Anode**.

A very small amount of either N-type or P-type doping turns a silicon crystal from a good insulator into a viable (but not great) conductor. This is why diodes are called "semiconductors."

N-type and P-type silicon are not that amazing by themselves, but when they are put together as shown in Figure 2, some very interesting behavior occurs that gives diodes their unique properties.

Even though N-type and the P-type silicon by themselves are conductors, the combination shown in Figure 2 does not conduct any electricity. The negative electrons in the N-type silicon get attracted to the positive terminal of the battery. The positive holes in the P-type silicon get attracted to the negative terminal of the battery. No current flows across the junction because the holes and the electrons are each moving in the wrong direction. This is referred to as reversed-biased.

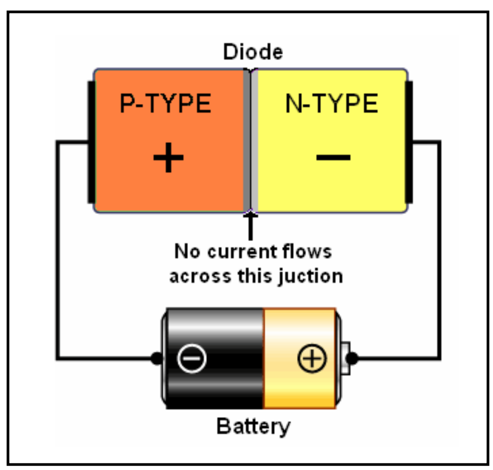

Figure 2

If the battery is flipped around the diode conducts electricity just fine. The free electrons in the N-type silicon are repelled by the negative terminal of the battery. The holes in the P-type silicon are repelled by the positive terminal. At the junction between the N-type and P-type silicon, holes and free electrons meet. The electrons fill the holes. The diode is forward-biased and the effect is that current flows through the junction.

An important application for diodes is to convert AC to DC. This process is known as rectification. Most of the time rectification will be filtered and then regulated. Many power supplies use rectification to produce a constant voltage that is used to power electronic equipment such as computers, DVD players, and so on.

Half-Wave Rectification

Refer to Figure 3. During the positive half-cycle the diode is forward-biased and conducts, but during the negative half-cycle it is reversed biased and does not. The result is a pulsating DC waveform. (b) The peak value of the waveform will be equal to the peak of the applied voltage minus the voltage drop across the diode. This voltage drop is usually about 0.7 or 0.3 volts depending on the type of diode. The average value of the rectified waveform is calculated as follows. (c) Average = peak x 0.637, or average = RMS x 0.9. The answer must then be divided by two since only half of the waveform has been converted to DC.

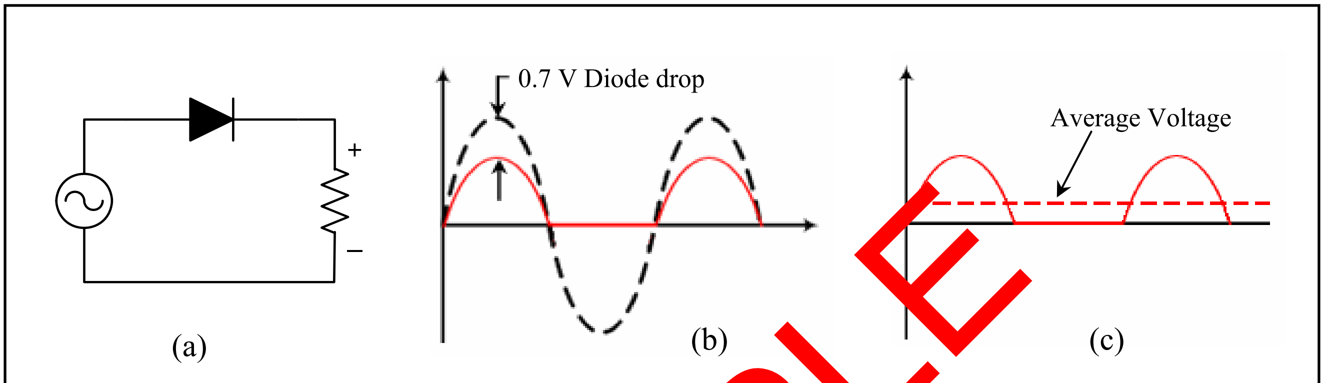

Figure 3

Full-Wave Rectification

Full-wave rectification is usually used instead of half-wave rectification because it provides a smoother dc output with double the average voltage and current. There are two basic types of full-wave rectifiers, the center-tapped transformer type and the bridge type.

With the center-tapped transformer type of rectifier, two diodes are needed as shown in Figure 4. During the positive half-cycle (a) diode D_1 conducts while D_2 (which is reverse biased) does not. During the negative half-cycle (b) the situation is reversed and diode D2 conducts. This enables the load current to be in the same direction for both half cycles. Since there is only one diode in the conduction path for each case, the peak of the rectified voltage is still only one diode voltage drop below the peak of the applied waveform.

The average voltage (c) of a full-wave rectifier can be calculated the same way as a half-wave rectifier. Average = peak x 0.637, or average = RMS x 0.9. Since the full-wave rectifier converts the full sine wave to DC rather than only half as in the case with a half-wave rectifier, the product does not need to be divided by two.

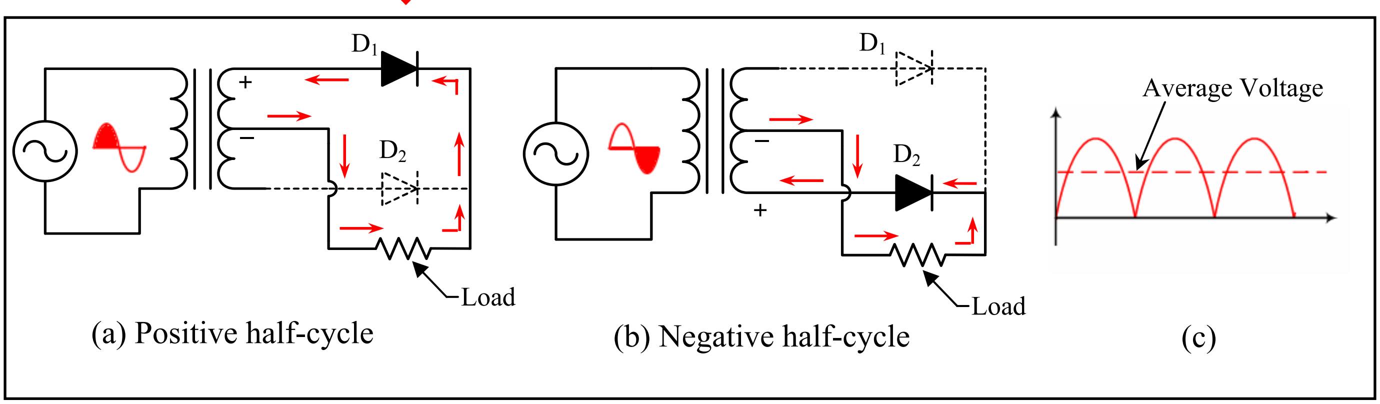

Figure 4

A bridge rectifier as shown in Figure 5 produces the same full-wave DC output. A bridge rectifier requires four diodes and eliminates the need for a center-tapped transformer. With this circuit, when the AC supply voltage is positive at point A and negative at point B, current flows from point B, through D_2, the load, D_1, and to point A (a).

When the AC supply voltage is positive at point B and negative at point A, current flows from point A, through D_4, the load, D_3, and to point B (b). The resulting output will be a full-wave pulsating DC waveform. Since there are two diodes in each conduction path, the peak output DC voltage will be two diode voltage drops below the applied AC voltage (c).

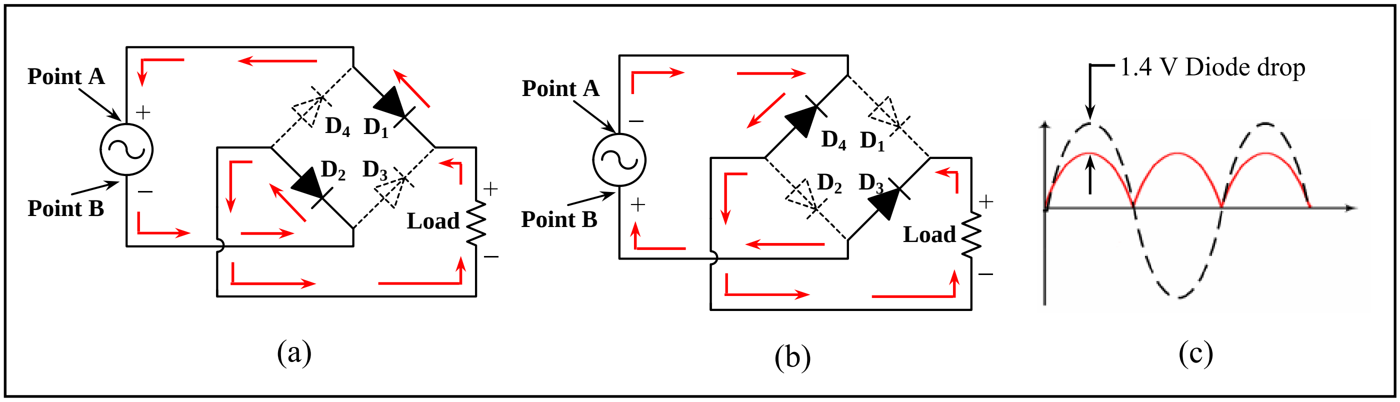

Figure 5

Many times DC waveforms produced by rectification are not suited to be used for electronic equipment. These waveforms need to be filtered or "smoothed out" to eliminate interference with sensitive electronic components. Filtered DC reduces or eliminates pulsations and provides DC at a more constant level along with increasing the average output voltage of the circuit. The simplest filter consists of a large value capacitor connected in parallel to the load.

Refer to Figure 6. Assume the capacitor is initially uncharged. During the first quarter cycle (a) the diode is forward-bias and the capacitor charges to peak voltage. When the applied voltage passes its peak and drops below that of the charged capacitor, the diode becomes reverse-biased and appears as an open in the circuit (b). The capacitor is now essentially isolated from the supply voltage and discharges through the load until the input voltage is once again high enough to forward-bias the diode.
The effect is a steady state waveform with very little ripple. The amount of ripple can be determined by the size of the capacitor for the given load.

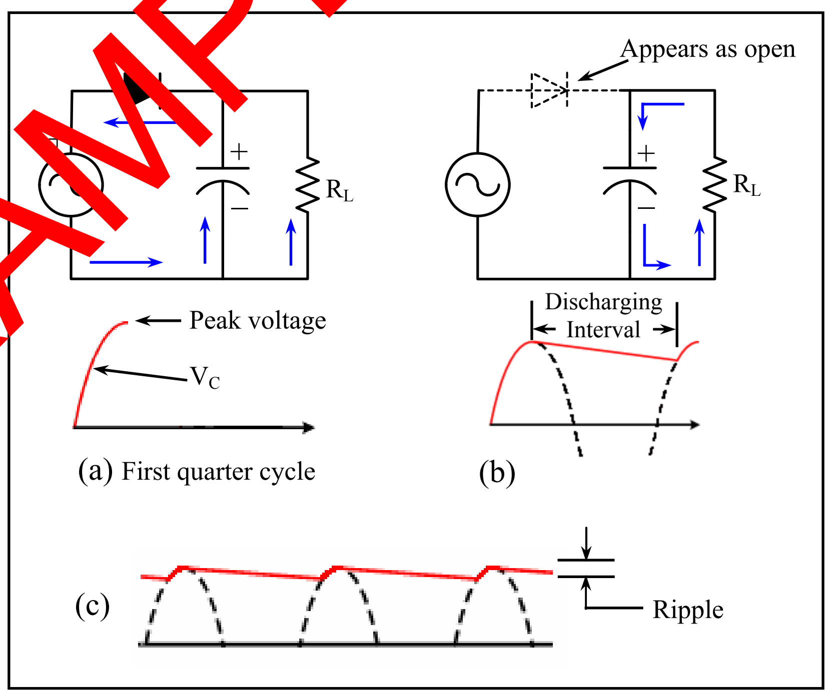

Figure 6

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