Diode Applications

by Kenneth A. Kuhn
Sept. 1, 2008

This note illustrates some common applications of diodes.

Power supply applications

A common application for diodes is converting AC to DC. Although half-wave rectification can be done, full-wave is preferred. Figure 1 shows a full-wave rectifier using a center-tapped secondary. The diodes, D1 and D2 alternately conduct on each half cycle creating a net full-wave. The capacitor stores energy and smoothes the output voltage. In theory, the capacitor can charge up to about 1.4 times Vp although with a significant load a more typical value is less.

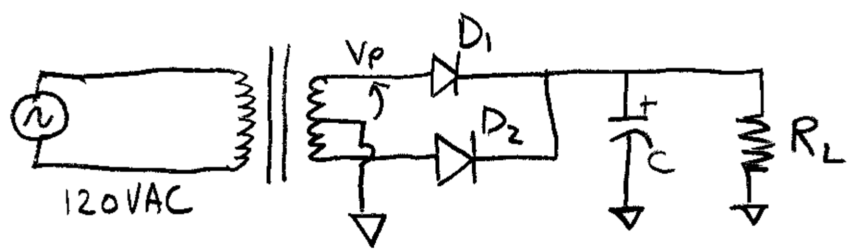

Figure 1: Full-wave rectifier with center-tapped transformer

Figure 2 shows a full-wave bridge rectifier that does not require a center-tap transformer. On one half-cycle current from the transformer conducts through D1 and through the load and back through D3 to the other end of the secondary winding. On the other half-cycle current from the transformer conducts through D2 and through the load and back through D4 to the other end of the secondary winding. The capacitor stores energy and smoothes the output voltage.

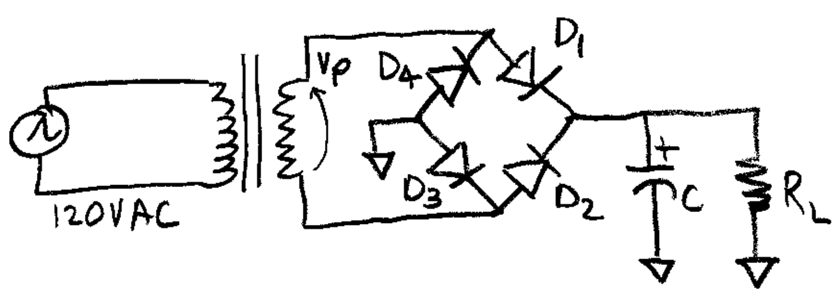

Figure 2: Full-wave bridge rectifier

Small power transformers like used in power supplies for small equipment generally are not very efficient and have significant source impedance. The output voltage will typically drop about 15 percent from no load to full load. Transformers are generally rated at full load so the unloaded open-circuit output voltage is often surprisingly higher than might be expected. The approximate maximum DC power that can be developed is about 63% of the transformer volt-ampere rating. The output DC voltage at full load is approximately 1.2 times the rated secondary rms voltage. The time constant formed by the filter capacitor and the load resistance should be at least 3/F seconds so that the ripple voltage is not excessive (F is the line frequency in Hz). There is not much to gain by making the time constant greater than about 12/F.

Figure 3 shows a simulation of full-wave rectification using a 14 volt, 20 VA transformer. The filter capacitance is 6,800 uF and the load resistance is 25 ohms for a time constant of 0.17 seconds which produces about 1% ripple for the 60 Hz line frequency. The average output voltage is 17.8 volts and the load current is 0.71 amperes and the load power is 12.6 watts which is about the limit that this transformer can provide. Note that the diodes only conduct for a small portion of the cycle and so the peak current from the diodes is about 2.6 amperes although the average current from each diode is 0.355 amperes. The theoretical open circuit voltage from the transformer is shown as a dotted line. The capacitor does not charge to the peak of this waveform because there is a finite source resistance in the transformer and there is voltage drop across the diodes.

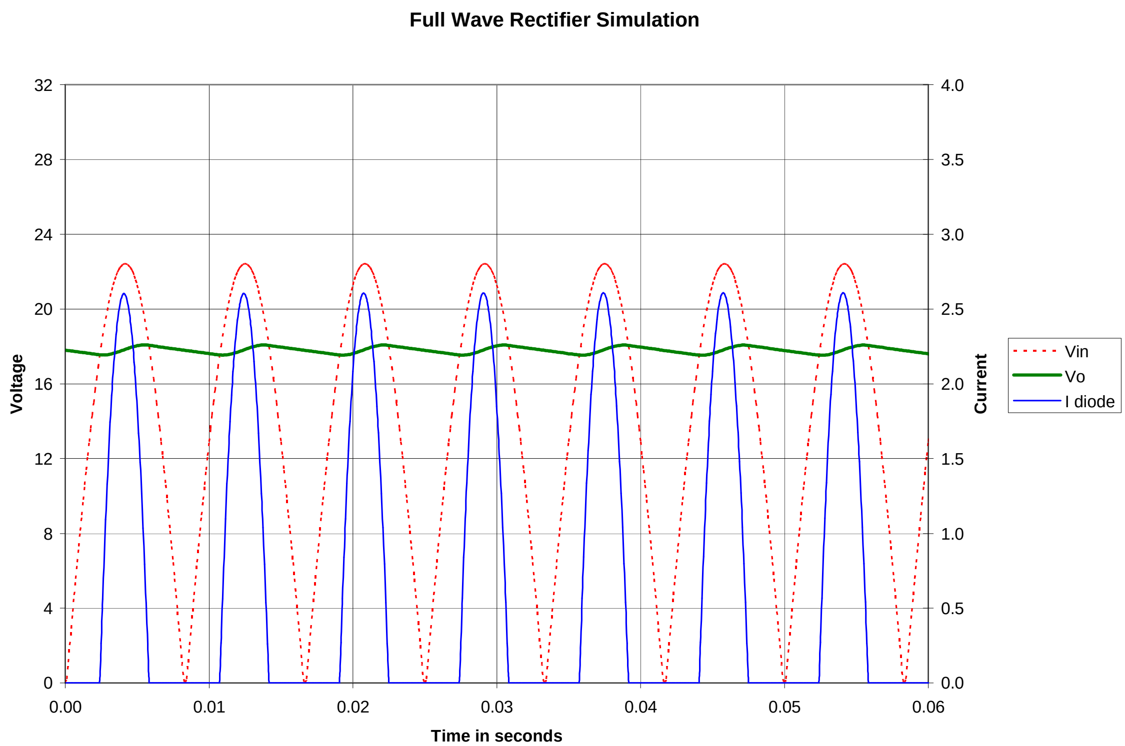

Figure 3: Full-wave rectifier simulation

Diodes can also be used to make charge pumps to make a high DC voltage from a low-voltage AC source. An alternate name for this is voltage multiplier. The diodes operate much the same way as valves in a pneumatic pump which allow flow only in one direction. Figure 4 shows the circuit for a voltage doubler. The process can be extended to make voltage triplers, quadruplers, and even higher factors. The output voltage is always less than the integer multiplier because of losses. During the negative portion of the input voltage, C1 charges to Vp via the D1 path. During the positive portion of the in input voltage, C2 charges to twice Vp since the voltage across C1 is added to the waveform.

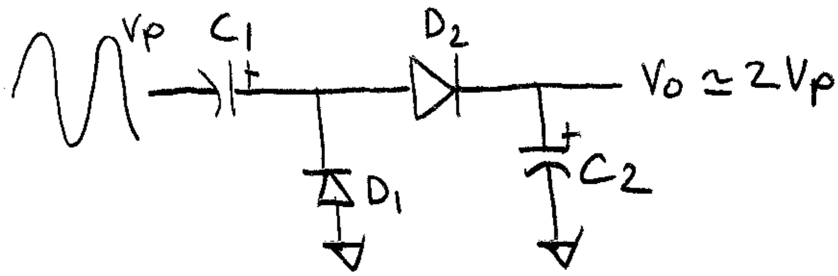

Figure 4: Voltage doubler

AM detectors

A rectifier is ideal for recovering the modulation on an amplitude modulated radio frequency signal such as in the AM broadcast band. Figure 5 shows two types of AM detectors, the series type on the left and the shunt type on the right. AM detectors are most often half-wave for simplicity and convenience. Contrary to some myths, there is little advantage to full-wave except in unusual applications. In each case the time constant of the RC load must be short enough to pass the highest modulation frequency of interest. This time constant is normally very long compared to the applied RF.

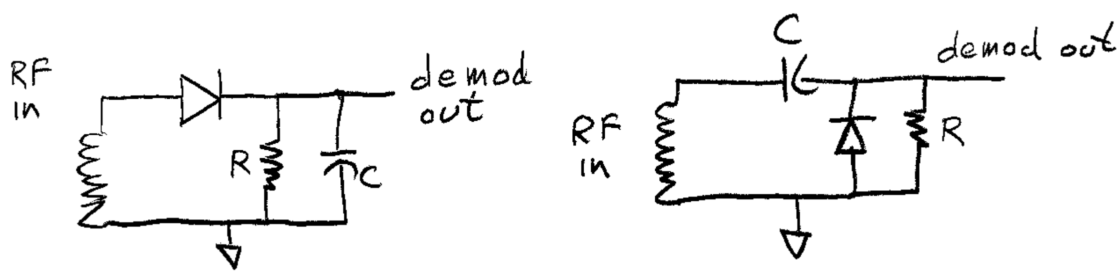

Figure 5: Amplitude modulation detectors

Back-EMF path

Anytime a DC current through an inductive device such as a solenoid or relay is switched off a back EMF is generated by the collapsing magnetic field around the inductance. The back EMF can easily attain a surprisingly high voltage that can damage or destroy electronics. The solution is to place a diode across the coil such that it is in reverse bias when the coil is energized. When the coil is de-energized the back EMF then has a closed path and high voltages are not generated. See Figure 6. The initial current through the diode when the coil is de-energized is identical to the current through the energized coil. The diode current will decay exponentially from that point. Because the diode impedance is low in the forward direction the L/R time constant may be long enough to delay the action driven by the coil. The solution is to add some series resistance in the diode path to shorten the time constant to an acceptable level. This raises the peak voltage at the collector of the transistor but to a controlled level.

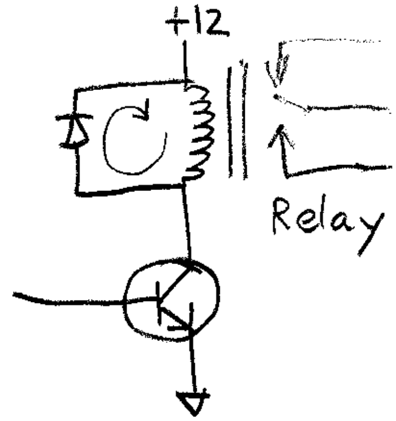

Figure 6: Back EMF diode application

Clamping or DC restoration

Clamping is the act of forcing a level on a waveform to be a specific voltage all the time. This is also known as DC restoration because the process can restore an original DC voltage lost via numerous AC couplings in a transmission process. A common example is the complex waveform of analog television. This waveform is illustrated in Figure 7 and the absolute black or white level is measured from a specific point. After passing through AC coupling the original DC level is lost but can be recovered by clamping the synchronization tip to a known voltage using a clamping circuit shown in Figure 8. In this example the sync tips are clamped to about -0.6 volts (1 diode drop) and the black and white video levels are a fixed voltage from this point. Without the clamp the video black level would vary depending on the scene content. With the clamp the black level is fixed as desired.

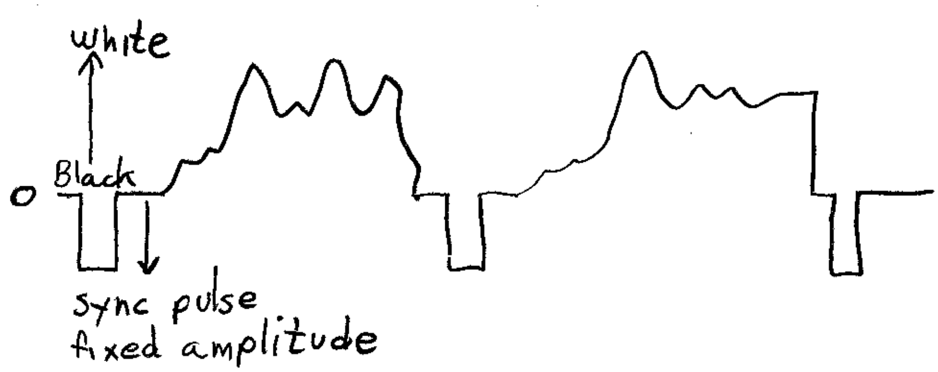

Figure 7: Video waveform

Diode Applications

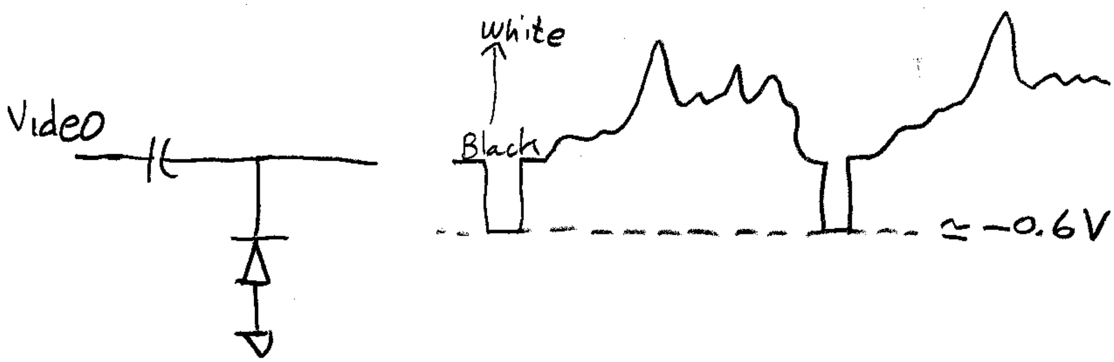

Figure 8: Clamp circuit (a.k.a. DC restorer)

Clipper or limiter

Clipping is the act of limiting the amplitude of a signal. A common application is reducing the effect of high amplitude random interference pulses on a signal. Other applications could be to prevent a signal from becoming too large. Either polarity of a signal could be clipped or both polarities could be clipped. Figure 9 shows an example where the clipping level is high enough to pass the desired signal but limits the amplitude of an undesired spike.

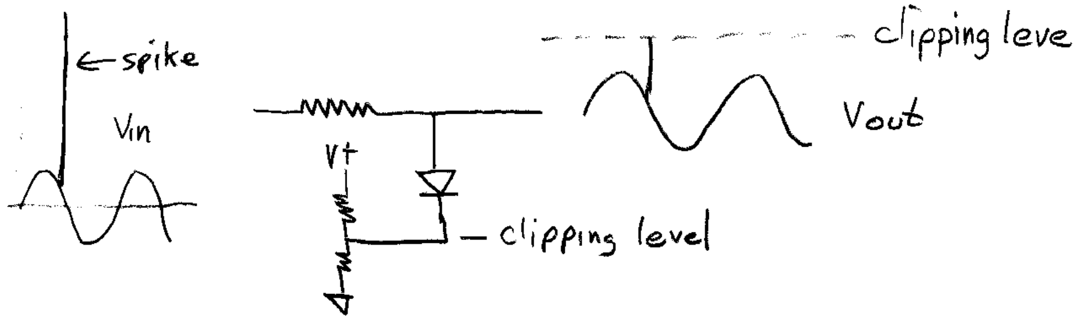

Figure 9: Clipping example

Diode Applications

Non-linear circuits

Diodes are ideal for building non-linear functions based on linear piecewise approximations. Figure 10 shows an example.

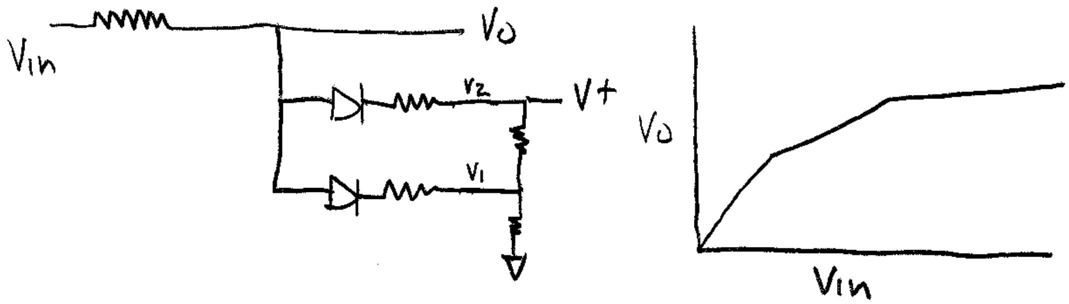

Figure 10: Non-linear transfer function using piecewise linear segments

Logic

Diodes are often used for implementing simple logic functions such as various AND – OR combinations. Figure 11 shows an AND gate and an OR gate constructed with diodes. For the AND gate all inputs must be a logic ‘1’ or high voltage for the output to be a logic ‘1’ or high voltage. For the OR gate the output is high if any input(s) are high.

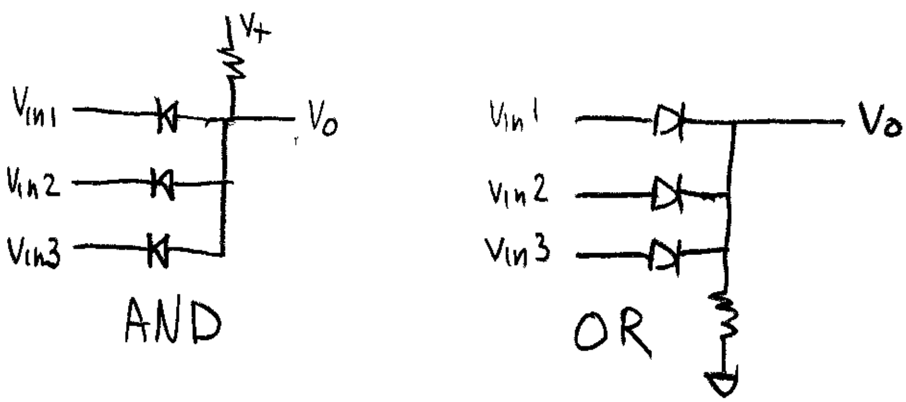

Figure 11: Logic circuits