



## Rectifier Circuits

**By:** Al Christman  
Grove City College  
100 Campus Drive  
Grove City, PA

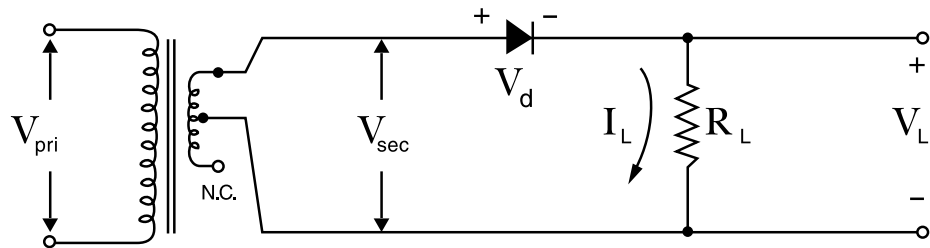
Rectifiers are used to convert AC to pulsating DC, and can be combined with various types of filters to form power supplies.

**Equipment:**

- Agilent 54600B Oscilloscope
- Center-tapped transformer 115: 6.3 volts
- 82 ohm, 1/2 watt resistor
- 1 N 4001 diode

### A. Half-wave (HW) Rectifier

The circuit below shows a simple half-wave rectifier, utilizing a low-voltage transformer, silicon diode, and a load resistor.



XFMR: 115: 6.3 VCT

The transformer has a center tap (CT), which means that 1/2 of the total secondary voltage is available between the CT and each end of the winding. For this example we will only use 1/2 of the secondary winding in order to keep the circuit voltages low. Construct this circuit using a 1N4001 diode and an 82Ω(ohm), 1/2 watt resistor.

1. Observe the secondary voltage,  $V_{sec}$ , with a 'scope, and carefully draw one complete cycle of the waveform, showing the amplitude and the time of each zero-crossing. What is the period of the wave? What is the frequency? Note the peak value and then calculate the rms value of  $V_{sec}$ . Recall that  $V_{sec(peak)} = 1.414 V_{sec(rms)}$ .
2. Next, use the scope to observe  $V_L$ , the voltage across the load resistor. Carefully draw one complete cycle of  $V_L$ , again noting the amplitude and time values. What is the peak load voltage? This value should be equal to the peak secondary voltage minus the "cut-in" or "offset" voltage of the diode:

$$V_L (peak) = V_{sec} (peak) - V_g$$



What is the peak load current? It is given by:

$$I_{L(\text{peak})} = \frac{V_L (\text{peak})}{R_L}$$

For a half-wave rectifier, the average load voltage is found by dividing the peak value by pi:

$$V_L (\text{ave.}) = \frac{V_L (\text{peak})}{\pi}$$

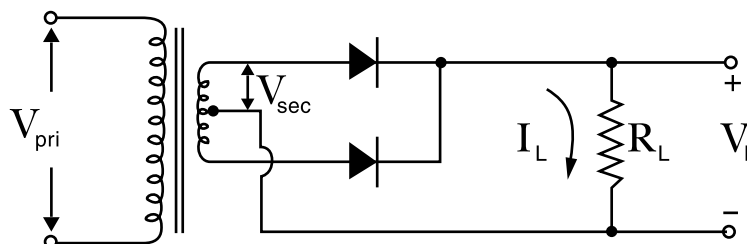
The average load current is related to the peak value by the same formula. What is the average load voltage, and what is the average load current? The 1N4001 diode is rated for 1 Ampere of average forward current, often listed as  $I_0$  on the specification sheets. (This is an average value.) For the HW rectifier, the average forward current through the diode is the same as the average load current. What is the average power dissipated by the load resistor?

- Now use the oscilloscope to view  $V_D$ , the voltage across the diode. You should be able to easily observe the “offset” or “cut-in” voltage amplitude in this case. Again, make a careful drawing of the waveform, showing all important magnitude and time values. Notice that, when the diode is reverse-biased (OFF), a voltage appears across the diode which is equal to the secondary voltage. The diode must be able to withstand this “Reverse” or “Inverse” voltage without breaking down. The 1N4001 diode has a PIV or PRV (Peak Inverse Voltage or Peak Reverse Voltage) rating of 50 V. (Note that this is a peak value.)

Show  $V_D$  and its value on the drawing.

### B. Full-wave (FW) Rectifier

The drawing below illustrates a full-wave rectifier. When the top of the secondary winding is positive, the upper diode conducts current, but the lower diode is OFF. When the bottom of the secondary winding is positive, the lower diode is ON, but the upper diode is reverse-biased. Thus, one diode conducts on each half-cycle, and current always flows into the load resistor in the same direction, as shown by the arrow. In order to use a full-wave rectifier with two diodes (as in the illustration below) the transformer secondary MUST have a center tap, or else two identical transformers must be used to derive a center tap. Build this circuit:





1. Use the oscilloscope to observe the load voltage. Make a careful drawing of this waveform, noting all pertinent values. If  $V_{sec}$  is defined as the voltage between the CT and one end of the winding, then the peak value of the load voltage is given by

$$V_{L \text{ (peak)}} = V_{sec \text{ (peak)}} - V_g$$

As before,  $V_{sec \text{ (peak)}} = 1.414 V_{sec \text{ (rms)}}$ . Since there are two diodes in the circuit, both halves of the input cycle are used, and current flows through the load resistor in pulses which occur twice as often as in the half-wave rectifier. Thus,

$$V_{L \text{ (ave.)}} = \frac{2V_{L \text{ (peak)}}}{\pi} = 0.636 V_{L \text{ (peak)}}$$

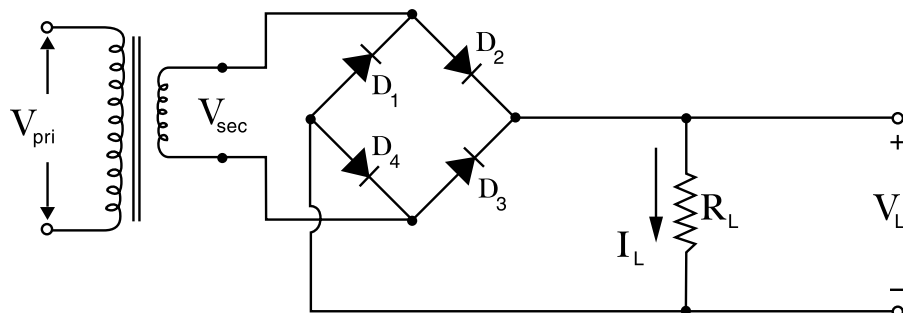
and

$$I_{L \text{ (ave.)}} = \frac{V_{L \text{ (ave.)}}}{R_L}$$

For the output circuit, what is the peak load voltage? The average load voltage? The average load current? The period? What power is dissipated by the load resistor? Note that each diode only carries half of the total load current. The PIV rating for each diode must be greater than the peak voltage between the ENDS of the transformer secondary winding.

### C. Full-wave Bridge (FWB) Rectifier

A drawing of a full-wave bridge rectifier is given below. NO center-tap is required on the transformer secondary in this circuit. The bridge is composed of four diodes in a diamond shape. The transformer secondary is connected to two corners of the diamond, and the load is connected to the remaining corners. When the top of the secondary winding is positive, diodes D2 and D4 are forward-biased; current flows through diode D2, then through the load, and through diode D4. The remaining two diodes are OFF. When the bottom of the winding is positive, diodes D3 and D1 are now forward-biased and turn ON; similarly, diodes D2 and D4 are now OFF. Thus, the full voltage between both ends of the transformer secondary winding is utilized, and current flows during both halves of the input cycle. The full-wave bridge rectifier makes the most efficient use of the transformer, when compared to the HW and the FW rectifiers.





1. Build this circuit and monitor the load voltage with the scope. As usual, make a detailed drawing of this waveform, noting all important data. Here in this case,  $V_{sec}$  is the voltage between the ends of the secondary winding. Since there are always two diodes operating in series, the formula for peak load voltage is modified slightly:

$$V_{L \text{ (peak)}} = V_{sec \text{ (peak)}} - 2V_g$$

The average load voltage is found from:

$$V_{L \text{ (ave.)}} = \frac{2V_{L \text{ (peak)}}}{\pi} = 0.636V_{L \text{ (peak)}}$$

and the average load current is:

$$I_{L \text{ (ave)}} = \frac{V_{L \text{ (ave)}}}{R_L}$$

Find the average values for the load current and load voltage, and find the power dissipated in the load. The PIV rating of each diode must be greater than the peak voltage across the ends of the secondary winding, but the average current through each diode is only 1/2 of the average current through the load.

- D. Design a FWB rectifier which will supply an average current of 50 mA to the load. What is your calculated value of  $R_L$ ? What value of  $R_L$  did you actually use in the circuit? What power rating did you pick for  $R_L$ ? Next, construct this circuit. Use the same transformer and diodes as before. What is the actual load current? How much power is dissipated in the load? In your Lab Report, be sure to explain your design procedure. Also compare the actual and calculated (design) values of load current. Why are they different?