Experiment #1

Category: Diode/Application

Half-Wave and Full-Wave Rectification

Purpose: Use diodes in different circuit configurations to rectify AC signal to DC.

Equipment: Multimeter, oscilloscope, function generator, power supply, resistors: 1 kΩ (2), 2.2 kΩ (1) and 4.7 kΩ (1), capacitor: 1 µF (1), 10 µF (1), diodes: 1N457 (4).

Theory: In a half-wave rectifier only half of the AC signal is converted to DC. In the circuit shown below, the diode is forward biased during the positive half of the applied AC signal and the output Vo follows the input excitation. During the negative half of the input AC excitation, the diode is reverse biased and behaves like an open circuit (ideal diode) with zero current flowing through the resistor R and consequently zero output voltage as shown in the output wave form. Note, during reverse bias the applied input voltage in its entirety drops across the diode and one has to make sure it does not exceed the diode breakdown voltage.

During positive half of the sinusoidal input signal, vo(t) = vin(t) for an ideal diode. Please note, an ideal diode is characterized by a short circuit while conducting or forwards biased and behaves like an open circuit when reverse biased. However, as we have seen form the measured I-V characteristic of a diode, a finite voltage drop occurs across the diode while conducting. This will results in the following:

* vo(t) = vi(t) – VD, where VD is the voltage drop across the diode while conducting (or forward biased)
* The angle of conduction will be reduced from π (= 180 degrees) to π – 2\*arc sin (VD/VM).

The DC component of the output voltage is calculated as follows [or the mean of the output signal can be calculated by integrating:

Where, t1 = and t2 = . However, for VD<<VM, ϴ is negligible and t2 = & t1 = 0.



Figure 1-Half wave rectifier circuit

The DC magnitude is rather low in a half-wave rectifier and that is due to the utilization of only half-of the input sinusoid. In a full-wave rectifier the circuit topography is revised allowing the negative cycle of the ac output wave to flip. This results in doubling of the DC output voltage.



Figure 2-Input and output waveform of a bridge rectifier.

eta)/omega

Note, the output voltage is not a steady DC value but is fluctuating is nature. To smoothen the output voltage the circuit needs to be slightly modified. One way to reduce the effect of ripples is to connect a capacitor that by-passes all the high frequency components, as shown in the circuit below. The diode only conducts for a brief period of time, ∆t, to charge the capacitor C. When diode turns off, the capacitor C is discharged through R. At the end of the discharge period, vO = vP – vr. If RC >> T, then if Vr is small enough and IL ~ VP/RL.

Figure 3- Voltage waveforms in the peak rectifier assuming CR >> T and an ideal diode.

, for RC >> T → →

→ or

Reference:

* Microelectronic Circuits (7th edition) by Sedra & Smith, pags. (207 − 218)

**Experiment:**

1- Half-Wave Rectifier

A. Build the circuit illustrated in Figure 4. Using the signal generator to apply a sinusoidal excitation with an amplitude of 10V peak-to-peak and a frequency of 1kHz. Use the multimeter and the oscilloscope to measure the AC voltage across the output resistance. Take a screenshot of the input and output signals.  
  
VR (multimeter)\_\_\_\_\_\_\_\_1.597\_\_\_\_  
VR (oscilloscope)\_\_\_\_\_\_1.627\_\_\_\_\_\_\_\_\_\_

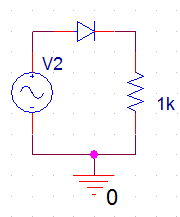


Figure 4-Half wave rectifier using a silicon diode.

What is the difference between the voltages? Explain your answer.  
~0.03V Difference. The oscilloscope calculates *true RMS* directly from the waveform, while the multimeter may make assumptions about the waveform shape. The half-wave rectified signal is not purely sinusoidal, so the oscilloscope is more accurate.

B. Measure the DC voltage across the 1kΩ resistor.

VR (DC-measured) \_\_\_\_\_\_\_\_\_\_\_\_\_1.254\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Calculate the DC component of the output signal and compare it to the measured value.  
VR (DC-calculated) \_\_\_\_~1.37V\_\_\_\_\_\_\_\_\_\_\_

Does the 1N4148 diode meet the requirement of the PIV (including the 50% of safety margin)?

C. Decrease the amplitude to 2V peak-to-peak, measure and calculate the DC component of the signal.  
VR (@2V-measured)\_\_\_86.0mV\_\_\_\_\_\_\_\_\_\_\_  
VR (@2V-calculated)\_\_\_\_\_\_~95mV\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Why is the DC calculation closer to the experimental value for Vsignal = 10V?  
At 10 Vpp, the diode drop (0.7 V) is small relative to the peak (5 V). Errors due to diode modeling are proportionally small.  
At 2 Vpp, the diode drop is a large fraction of the signal (0.7/1 ≈ 70%). Small variations in diode behavior, multimeter resolution, and waveform distortion dominate.

2- Full-Wave Rectifier/Bridge Rectifier:

A. Build the circuit shown in the Figure 5. Before connecting the transformer to your circuit, ask someone else to verify that your circuit match the schematic. Once you are certain about your circuit, your instructor will verify your circuit one more time and provide you with the transformer.



Figure 5-Bridge rectifier

B. Measure the transformer secondary voltage, VIN and across the 2.2kΩ resistor, VOUT using the oscilloscope and take a screenshot of the input and output signals.

VIN\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
VOUT (maximum) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
VOUT (DC) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

3- Full-Wave center-tapped:

A. Build the circuit in figure 6. Before connecting the transformer to your circuit, ask someone else to verify that your circuit match the schematic. Once you are certain about your circuit, your instructor will verify your circuit one more time and provide you with the transformer.



Figure 6-Full wave center tap configuration

B. Measure and take a screenshot of the input and output signals:  
Vin(+)\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Vin(-)\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

VR\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

How does Vout compares to Vout in part 3 (bridge rectifier), in terms of VD?

What is the difference between the PIV of the circuit in section 3 vs section 4?

4- Rectifier with a filter capacitor:

A. Design Problem: For the following rectifier with a filter capacitor: Calculate the value of C and R that will result in a Vr of 0.8V. Your sinusoidal input signal is a 5V (peak-to-peak?) with a frequency of 60Hz. Remember that the equations are only valid for CR >> T. Also, pick values that are available in your component kit.

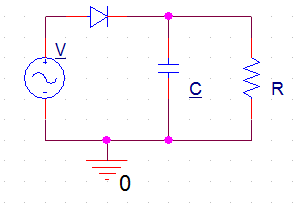


Figure 7-Rectifier with a filter capacitor

R (calculated)\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
R (measured)\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
C (calculated)\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
Vr (calculated)\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

B. Using the oscilloscope, take a screenshot of the output voltage and extract Vr. How does the calculated value of Vr compares to the measured value? Explain your answer. Explain the requirement of CR>>T.