OBJECTIVE

To calculate, draw, and measure the DC output voltages of half-wave and full-wave rectifier circuits.

EQUIPMENT REQUIRED

Instruments
- Oscilloscope
- DMM

Components
- Resistors
  (2) 2.2-kΩ
  (1) 3.3-kΩ
- Diodes
  (4) Silicon

Supplies
- Function generator

Miscellaneous
- 12.6-V Center-tapped transformer with fused line cord
EQUIPMENT ISSUED

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<th>Item</th>
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<td>Oscilloscope</td>
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RÉSUMÉ OF THEORY

The primary function of half-wave and full-wave rectification systems is to establish a DC level from a sinusoidal input signal that has zero average (DC) level.

The half-wave voltage signal of Fig. 4.1 normally established by a network with a single diode has an average or equivalent DC voltage level equal to 31.8% of the peak voltage $V_m$.

That is,

$$V_{dc} = 0.318V_{peak} \text{ volts} \quad (4.1)$$

The full-wave rectified signal of Fig. 4.2 has twice the average or DC level of the half-wave signal, or 63.6% of the peak value $V_m$.

That is,

$$V_{dc} = 0.636V_{peak} \text{ volts} \quad (4.2)$$

For large sinusoidal inputs ($V_m \gg V_T$) the forward-biased transition voltage of a diode can be ignored. However, for situations when the peak value of the sinusoidal signal is not that much greater than $V_T$, $V_T$ can have a noticeable effect on $V_{DC}$.

![Figure 4-1](image1)

![Figure 4-2](image2)

In rectification systems the peak inverse voltage (PIV) or Zener breakdown voltage parameter must be considered carefully. The PIV voltage is the maximum reverse-bias voltage that a diode can handle before entering the Zener breakdown region. For typical single-diode half-wave rectification systems, the required PIV level is equal to the peak value of the applied sinusoidal signal. For the four-diode full-wave bridge rectification system, the required PIV level is again the peak value, but for a two-diode center-tapped configuration, it is twice the peak value of the applied signal.
Part 1. Threshold Voltage

Choose one of the four silicon diodes you received and determine the threshold voltage, \( V_T \), using the diode-checking capability of the DMM or a curve tracer.

\[ V_T = \quad \]

Part 2. Half-Wave Rectification

a. Construct the circuit of Fig. 4.3 using the chosen diode of Part 1. Record the measured value of the resistance. Set the function generator to a 1000-Hz 8-V p-p sinusoidal voltage using the oscilloscope.

![Figure 4-3 Half-wave rectifier.](image)

b. The sinusoidal input \( e \) of Fig. 4.3 has been plotted on the screen of Fig. 4.4. Determine the chosen vertical and horizontal sensitivities. Note that the horizontal axis is the 0 V line.

![Figure 4-4](image)

Vertical sensitivity = \( \quad \)

Horizontal sensitivity = \( \quad \)

c. Using the threshold voltage of Part 1 determine the theoretical output voltage \( v_o \) for the circuit of Fig. 4.3 and sketch the
waveform on Fig. 4.4 for one full cycle using the same sensitivities employed in Part 2(b). Indicate the maximum and minimum values on the output waveform.

d. Using the oscilloscope with the AC-GND-DC coupling switch in the DC position, obtain the voltage $v_o$ and sketch the waveform on Fig. 4.5. Before viewing $v_o$ be sure to set the $v_o = 0$ V line using the GND position of the coupling switch. Use the same sensitivities as in Part 2(b).

![Figure 4-5](image)

How do the results of Parts 2(c) and 2(d) compare?

e. Calculate the DC level of the half-wave rectified signal of step 2(d). Assume the positive pulse of the waveform is equal to one-half the period of the input waveform when using Eq. 4.1.

\[ V_{DC} \text{ (calculated)} = \]

f. Measure the DC level of $v_o$ using the DC scale of the DMM and find the percent difference between the measured value and the calculated value of Part 2(e) using the following equation:

\[ \% \text{ Difference} = \left| \frac{V_{DC} \text{ (calo)} - V_{DC} \text{ (meas)}}{V_{DC} \text{ (calo)}} \right| \times 100\% \]

\[ V_{DC} \text{ (measured)} = \]

\[ (% \text{ Difference}) = \]
g. Switch the AC-GND-DC coupling switch to the AC position. What is the effect on the output signal \( v_o \)? Does it appear that the area under the curve above the zero axis equals the area under the curve below the zero axis? Discuss the effect of the AC position on waveforms that have an average value over one full cycle.

h. Reverse the diode of Fig. 4.3 and sketch the output waveform obtained using the oscilloscope on Fig. 4.6. Be sure the coupling switch is in the DC position and the \( v_o = 0 \) V line is preset using the GND position. Include the maximum and minimum voltage levels on the plot as determined using the chosen vertical sensitivity.

![Figure 4-6](image)

i. Calculate and measure the DC level of the resulting waveform of Fig. 4.6. Insert the proper sign for the polarity of \( V_{DC} \) as defined by Fig. 4.3. Assume the positive pulse of the waveform is equal to one-half the period of the input waveform when using Eq. 4.1.

\[
V_{DC} \text{ (calculated)} = \\
V_{DC} \text{ (measured)} = 
\]

Part 3. Half-Wave Rectification (continued)

a. Construct the network of Fig. 4.7. Record the measured value of the resistor \( R \).
b. Using the threshold voltage of Part 1 determine the theoretical output voltage \( v_o \) for Fig. 4.7 and sketch the waveform on Fig. 4.8 for one full cycle using the same sensitivities employed in Part 2(b). Indicate the maximum and minimum values on the output waveform.

![Figure 4-7](image)

![Figure 4-8](image)

c. Using the oscilloscope with the coupling switch in the DC position obtain the voltage \( v_o \) and sketch the waveform on Fig. 4.9. Before viewing \( v_o \) be sure to set the \( v_o = 0 \) V line using the GND position of the coupling switch. Use the same sensitivities as in Part 3(b).

![Figure 4-9](image)
How do the results of Parts 3(b) and 3(c) compare?

d. What is the most noticeable difference between the waveform of Fig. 4.9 and that obtained in Part 2(h)? Why did the difference occur?

e. Calculate the DC level of the waveform of Fig. 4.9 using the following equation:

\[ V_{DC} = \frac{\text{Total Area}}{2\pi} = \frac{2V_m - (V_T)^2\pi}{2\pi} = 0.318V_m - V_T^2/2 \text{ volts} \]

\[ V_{DC} \text{ (calculated)} = \]

f. Measure the output DC voltage with the DC scale of the DMM and calculate the percent difference using the same equation appearing in Part 2(f).

\[ V_{DC} \text{ (measured)} = \]

\[ \% \text{ Difference} = \]

Part 4. Half-Wave Rectification (continued)

a. Construct the network of Fig. 4.10. Record the measured value of each resistor.

![Figure 4-10](image)
b. Using the measured resistor values and \( V_T \) from Part 1, forecast the appearance of the output waveform \( v_o \) and sketch the result on Fig. 4.11. Use the same sensitivities employed in Part 2(b) and insert the maximum and minimum values of the waveform.

![Figure 4-11]


Figure 4-11

\[ 0 \text{ V} \]


c. Using the oscilloscope with the coupling switch in the DC position obtain the waveform for \( v_o \) and record on Fig. 4.12. Again, be sure to preset the \( v_o = 0 \text{ V} \) line using the GND position of the coupling switch before viewing the waveform. Using the chosen sensitivities determine the maximum and minimum values and place on the sketch of Fig. 4.12.

![Figure 4-12]

\[ 0 \text{ V} \]


Figure 4-12

Are the waveforms of Figs. 4.11 and 4.12 relatively close in appearance and magnitude?

d. Reverse the direction of the diode and record the resulting waveform on Fig. 4.13 as obtained using the oscilloscope.
Part 5. Full-Wave Rectification (Bridge Configuration)

a. Construct the full-wave bridge rectifier of Fig. 4.14. Be sure that the diodes are inserted correctly and that the grounding is as shown. If unsure, ask your instructor to check your setup. Record the measured value of the resistor $R$. 

Compare the results of Figs. 4.12 and 4.13. What are the major differences and why?
In addition, measure the rms voltage at the transformer secondary using the DMM set to AC. Record that rms value below. Does it differ from the rated 12.6 V?

\[ V_{\text{rms, measured}} = \ \ \ \ \ \ \ \ \ ]

b. Calculate the peak value of the secondary voltage using the measured value \( V_{\text{peak}} = 1.414 \times V_{\text{rms}} \).

\[ V_{\text{peak, calculated}} = \ \ \ \ \ \ \ \ \ ]
c. Using the \( V_T \) of Part 1 for each diode sketch the expected output waveform \( v_o \) on Fig. 4.15. Choose a vertical and horizontal sensitivity based on the amplitude of the secondary voltage. Consult your oscilloscope to obtain a list of possibilities. Record your choice for each below.

![Figure 4-15](image)

Vertical sensitivity = 
Horizontal sensitivity = 

d. Using the oscilloscope with the coupling switch in the DC position obtain the waveform for \( v_o \) and record on Fig. 4.16. Use the same sensitivities employed in Part 5(c) and be sure to preset the \( v_o = 0 \) V line using the GND position of the coupling switch. Label the maximum and
minimum values of the waveform using the chosen vertical sensitivity.

How do the waveforms of Parts 5(c) and 5(d) compare?

e. Determine the DC level of the full-wave rectified waveform of Fig. 4.16.

\[ V_{DC} \text{(calculated)} = \]

f. Measure the DC level of the output waveform using the DMM and calculate the percent difference between the measured and calculated values.

\[ V_{DC} \text{(measured)} = \]

\[ \% \text{ Difference} = \]

g. Replace diodes \( D_3 \) and \( D_4 \) by 2.2 k\( \Omega \) resistors and forecast the appearance of the output voltage \( v_o \) including the effects of \( V_T \) for each diode. Sketch the waveform on Fig. 4.17 and label the magnitude of the maximum and minimum values. Record your choice of sensitivities below.

\[ V_{DC} = 0.318 V_m \]

\[ V_{DC} = 0.318 (V_m - V_T) \]

\[ \text{Vertical sensitivity} = \]

\[ \text{Horizontal sensitivity} = \]
h. Using the oscilloscope, obtain the waveform for \( v_o \) and reproduce on Fig. 4.18 indicating the maximum and minimum values. Use the same sensitivities as determined in Part 5(g).

Figure 4-18

How do the waveforms of Figs. 4.17 and 4.18 compare?

i. Calculate the DC level of the waveform of Fig. 4.18.

\[ V_{DC} \text{ (calculated)} = \]

j. Measure the DC level of the output voltage using the DMM and calculate the percent difference.

\[ V_{DC} \text{ (measured)} = \]
\[ \% \text{ Difference} = \]

k. What was the major effect of replacing the two diodes with resistors?
Part 6. Full-Wave Center-Tapped Configuration

a. Construct the network of Fig. 4.19. Record the measured value of the resistor $R$.

![Diagram](image)

Figure 4-19

Measure the two secondary voltages of the transformer with the DMM set on AC. Record below. Do they differ from the 6.3 V rating?

\[ V_{\text{rms (measured)}} = \] 
\[ V_{\text{rms (measured)}} = \] 

Using an average of the two rms readings, calculate the peak value of the overall secondary voltage.

\[ V_{\text{peak (calculated)}} = \] 

b. Using the $V_T$ of Part 1 for each diode, sketch the expected output waveform $v_o$ on Fig. 4.20. Choose a vertical and horizontal sensitivity based on the amplitude of the secondary voltage. Consult your oscilloscope to obtain a list of possible settings. Record your choice for each below.

![Diagram](image)

Figure 4-20

Vertical sensitivity = 
Horizontal sensitivity =
c. Using the oscilloscope with the coupling switch in the DC position obtain the waveform for \(v_o\) and record on Fig. 4.21. Use the same sensitivities employed in Part 6(b) and be sure to preset the \(v_o = 0\) V line using the GND position of the coupling switch. Label the maximum and minimum values of the waveform using the chosen vertical sensitivity.

![Figure 4-21](image)

How do the waveforms of Figs. 4.20 and 4.21 compare?

d. Determine and compare the calculated and measured values of the DC level associated with \(v_o\).

\[
\text{(calculated) } = \underline{} \\
\text{(measured) } = \underline{}
\]

Part 7. Computer Exercise

Analyze the network of Fig. 4.3 using PSpice Windows. Compare the results with those obtained in Part 2.