

3 Circuit Analysis

Objective

In this lab exercise, we will investigate various circuit analysis techniques and instruments. We will build two different circuits on a breadboard and use test instruments to analyze the performance of the circuits. First, we will learn how to operate equipment such as: function generators and oscilloscopes. Next we will build breadboard circuits for driving light emitting diodes (LEDs). Lastly, we will also explore using diodes for AC-to-DC power conversion.

Theory

When designing circuits, it is important to consider the tools available to drive the circuitry and test the circuit under load. When designing circuits for AC, the function generator and oscilloscope are commonly used.

Function generators are used to generate an arbitrary waveform at a specified frequency and amplitude. Function generators will often have pre-configured settings to generate: sine waves, saw-tooth waves, triangular waves and square waves. The function generator may be useful when designing circuits that require a periodic clock signal or to drive alternating current circuits.

An oscilloscope is a test instrument that is used to analyze the voltage at a node as it varies in time. Repeated signals such as waveforms utilize the oscilloscopes trigger system. The trigger allows a repeating signals to always start from the same position on the horizontal (time) axis. To learn more details about how oscilloscopes work and their various modes of operation, review the following resource: <https://www.tek.com/en/documents/primer/oscilloscope-systems-and-controls>

Equipment

- Breadboard
- Resistors
- Diodes
- LEDs
- Oscilloscope
- Function Generator
- DC Power Supply
- Digital Multimeter

Procedure

The procedure for this exercise will consist of three parts. (1) Function Generator and Oscilloscope, (2) Diodes and LEDs, and (3) Power Conversion.

3.1 Function Generator and Oscilloscope

In this procedure, we will cover how to use a function generator to generate waveforms. The oscilloscope will be used to assess the generated waveform.

1. Obtain a function generator and oscilloscope. **Record the make and model of each for the lab report.**
2. Turn on the function generator and familiarize yourself with the interface.
3. Turn on the Oscilloscope.
4. Configure the function generator to generate a sine wave with an amplitude of 5 volts peak-to-peak and a frequency of 100 Hz. If there is an option for DC-offset, ensure that this value is 0 volts.
5. Connect the oscilloscope leads to the the leads of the function generator.
6. Use the "Auto" button to automatically set the scale/resolution of the oscilloscope.
7. Use the cursor feature to measure the period of the wave. Place one cursor at the peak of the observed waveform, and the next cursor at the peak of the next cycle. Confirm that the period equals 1/100 seconds.
8. Use the cursor feature to measure the peak-to-peak amplitude of the waveform. Confirm that this value equals the programmed peak-to-peak voltage of 5 volts.
9. Toggle through each waveform type on the function generator and observe the waveform structure on the oscilloscope.
10. Change the frequency of the waveform on the function generator, and manually adjust the oscilloscope time scale to view the waveform.
11. Power down the equipment.

3.2 Diodes and LEDs

Diodes are electrical components that only allow the flow of current through one direction, similar to one-way check valves in water systems. Diodes can be modeled as having zero resistance in the forward direction, and infinite resistance in the reverse direction. Diodes are semiconductor devices that use a P-N junction. One side of the diode is positive doped silicon (p-type), which has electron "holes" effectively giving the p-type silicon a positive charge. The other side consists of negative doped silicon (N-type) which has an excess of electrons. This junction creates a "depletion" region where electrons diffuse to fill the holes of the p-type silicon. When a positive voltage is applied to the p-type silicon, and ground on the n-type, the depletion region shrinks and allows more current to flow, this is called forward bias. Likewise, if the positive voltage is applied to the n-type silicon, and ground

on the p-type, the depletion region expands and allows less current to flow, this is called reverse bias. The P-N junction, as illustrated in Figure 9, is used in diodes, LEDs, and solar cells.

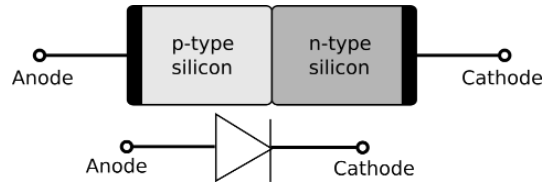


Figure 9: P-N Junction Diode https://en.wikipedia.org/wiki/P%E2%80%93n_junction

In this lab procedure, we will build a simple circuit to drive a diode in its forward direction and the reverse.

1. Obtain a DC power supply, digital multimeter, breadboard, a diode, and 1 k Ω resistor.
2. Construct the circuit in Figure 10 on the breadboard.
3. Set the DC power supply to 5 Volts.
4. Connect the power supply to the circuit.
5. Measure the voltage drop over the diode. **Record for lab report.**
6. Turn off the DC power supply and reverse the leads so that negative 5 volts is going over the circuit. Then turn the power supply back on.
7. Measure the voltage drop over the diode for the reverse direction. **Record for lab report.**

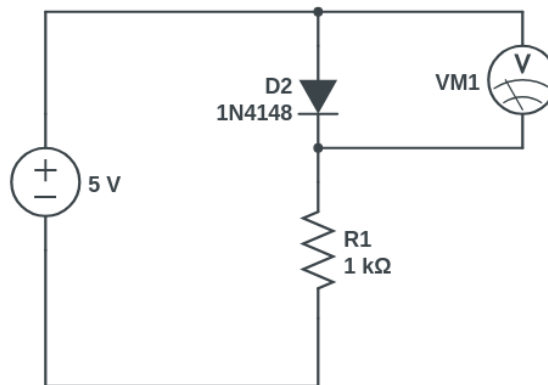


Figure 10: Diode in forward direction

Repeat the procedure with an LED. Replace the diode with an LED and replace the 1k resistor with a 220 Ω resistor. Use Figure 11 for reference.

- Measure the voltage drop over the diode for the forward direction. **Record for lab report.**
- Measure the voltage drop over the diode for the reverse direction. **Record for lab report.**

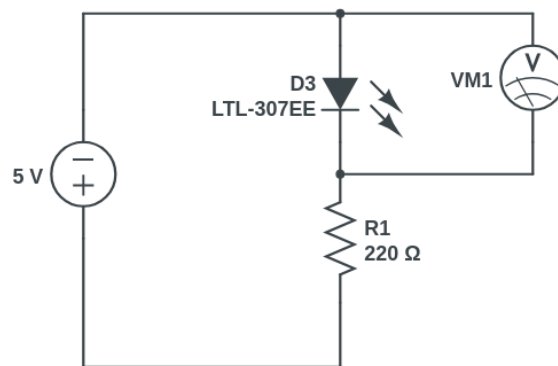


Figure 11: LED circuit

3.3 Power Conversion

Diodes are useful devices for converting power supplies from AC sources into DC sources. To illustrate this application, we will construct a half-wave rectifier and a full-wave bridge rectifier and analyze its performance using the function generator and oscilloscope.

A half-wave rectifier was actually already constructed in the previous exercise, Figure 10. When an AC source is used instead of a DC source the diode will only allow current to flow when the voltage is positive, and no current will flow when the voltage is negative. The output signal appears as a sine wave with only the positive cycles.

1. Obtain a function generator and oscilloscope. Also obtain a breadboard, a diode and 1 k Ω resistor.
2. Build the circuit from Figure 10. Replace the DC source with the function generator.
3. Connect the oscilloscope probes over the resistor load.
4. Configure the function generator to produce a sine wave with a peak-to-peak voltage of 5 volts, and a frequency of 100 Hz.
5. Observe the resultant signal on the oscilloscope. **Take a picture and note the appearance for the lab report.**

6. Use the cursor feature of the oscilloscope to measure the peak-to-peak voltage of the resultant signal. **Record for the lab report.**

A full-wave bridge rectifier goes one step further and flips the negative cycles of the AC source and make them positive. The bridge rectifier uses 4 diodes arranged such that current will flow through the resistor load during the positive and negative cycle of the AC source. Consider the circuit in Figure 12, during the positive cycle current will only flow through diodes D1 and D2. During the negative cycle only the other two diodes, D3 and D4, will conduct. The resultant current through the resistor, R1, will always flow in one direction.

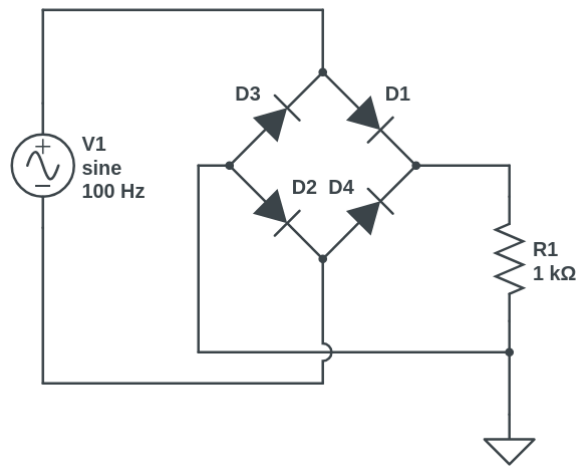


Figure 12: Full-wave bridge rectifier

1. Obtain a function generator and oscilloscope. Also obtain a breadboard, 4 diodes, and 1 k Ω resistor.
2. Build the circuit from Figure 12.
3. Connect the oscilloscope probes over the resistor load.
4. Configure the function generator to produce a sine wave with a peak-to-peak voltage of 5 volts, and a frequency of 100 Hz.
5. Observe the resultant signal on the oscilloscope. **Take a picture and note the appearance for the lab report.**
6. Use the cursor feature of the oscilloscope to measure the peak-to-peak voltage of the resultant signal. **Record for the lab report.**
7. Return all equipment.

Questions

1. What is the make and model of the function generator you used?
2. What is the make and model of the oscilloscope you used?
3. What was the measured voltage drop across the diode circuit when operating in forward direction? And the measured voltage drop across the diode when operating in the reverse direction?
4. What was the measured forward voltage drop across the LED circuit? And the measured reverse voltage drop across the LED?
5. Describe the appearance of the "DC" signal generated by the half-wave rectifier. And compare to the appearance of the "DC" signal generated by the full-wave rectifier. Include pictures of the waveform on the oscilloscope in the Appendix of the lab report.
6. Considering the AC-to-DC circuits, compare the peak-to-peak voltage of the input signal to the peak-to-peak voltage of the output signal for the half-wave rectifier and the full-wave rectifier circuits. Explain any similarities and differences of the output signal for the half-wave rectifier and the full-wave rectifier.