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Score: _____ / 100

Laboratory 02 – Diodes/DC Power Supplies/Function Generator

EE188L Electrical Engineering I
NAU + CQUPT (Fall 2020)

Objectives

1. Become familiar with diodes
2. Measure the turn-on voltage of a Light Emitting Diode with the DMM.
3. Use the switching characteristics of diodes to convert AC to DC to illustrate the basis behind DC power supplies.
4. Learn of ways to improve the quality of the DC voltage.
5. Learn how to use the function generator to produce AC voltage signals
6. Learn how to measure AC voltages and the True RMS of AC voltages mixed with DC voltages

Grading:

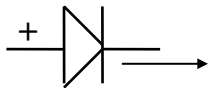
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Important Concepts

1. Below is a brief introduction to Diodes. You will study much more about diodes in your next circuits course (EE280).

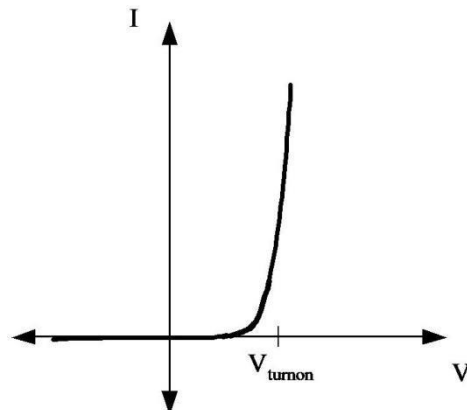
Diodes are semiconductor devices that allow current to flow in one direction but virtually none in the other. Diodes have two terminals, one positive and one negative. The diode symbol and I-V relationship is shown below:



If V is positive, current flows as shown by the arrow.

If V is negative, virtually no current flows.

When the voltage reaches the turn-on voltage, V_{turnon} , the slope is very steep and the diode acts like a constant voltage source with voltage



= V_{turnon} . For voltages below V_{turnon} , the diode acts like an open circuit. For diodes made from silicon, V_{turnon} is about 0.7 V., but for other types of diodes like LEDs (light-emitting diodes), V_{turnon} ranges from 1.5 to 2.2 V. The I-V relationship for the diode is also given by the following equation:

2. Diodes are used as on-off switches in rectifying circuits such as power supplies. Because they allow current to flow in only one direction, they can be arranged in a circuit that will convert AC waveforms to DC waveforms. This process is crucially important because all electronic circuits operate on DC power, even though the most readily available power source comes as AC power supplied over our electrical grid to homes, factories and businesses.
 - An ideal DC power supply has a voltage that is constant with time. It will not change in voltage, no matter how much current it must supply to a circuit.
 - A realistic DC power supply has a voltage that is not exactly constant and the current it supplies may not be able to satisfy the demands of the circuit. The variation in voltage is called *ripple*.
 - The power supplied by the power company is an AC voltage, which is a sinusoid of frequency 60 Hz and magnitude of 170 V peak = 120 V_{rms}.
 - The function of a DC power supply is to convert the sinusoidal voltage supplied by the power company to a constant DC voltage.
3. An AC voltage is more common than DC voltages in our homes and so to power electronic devices, we need to convert from AC to DC. AC voltages are sinusoidal in shape and vary in magnitude, going positive and negative 60 times per second. You will study a lot about AC power later in this course!

The DC equivalent measure of an AC voltage is called the **RMS (Root Mean Square) voltage** where RMS stands for the formula used to get the value. This means that an AC voltage of 120 VRMS and a DC voltage of 120 volts would deliver the same power to a resistive load. The RMS value of a sinusoidal waveform is the peak voltage divided by the square root of two.

$$V_{RMS} = V_{peak} / \sqrt{2} \quad (\text{for sine wave voltage})$$

True RMS is a way to get an equivalent DC voltage for a voltage waveform that is a mixture of AC and DC. **The formula is:**

$$TrueRMS = \sqrt{V_{DC}^2 + V_{RMS}^2}$$

Resources

1. 4 LEDs of different colors
2. 2.7 kohm resistor
3. 100 μ Farad capacitor

Activity #1 – Diode Testing

The diode is a nonlinear device that acts like an on-off switch that is controlled by the voltage applied across it. For a resistor, in contrast to a diode, the relationship between current and resistance is linear, as expressed by Ohm's Law, $v = i \cdot R$ or $i = v / R$. A resistor is bidirectional, so you can connect the terminals in either orientation and it will operate the same.

For a diode, the terminals are different and it matters how you connect the diode in the circuit. So you need to identify the anode (+) and the cathode (-) terminals. The diode is "on" when it allows current to flow into the anode (+), just like current flows into the higher voltage side of the resistor. The diode is "off" when it allows virtually no current through it. The diode package is often marked to identify the terminals, but in this activity you will use the DMM to identify the terminals.

The DMM has a diode test feature. Press the diode symbol button on the DMM and connect the diode, one terminal connected to the red V+ probe and the other terminal connected to the black COM probe. If the DMM reads a voltage > 0.6 volts, then the terminal connected to the red probe is the anode or "+" terminal. If no voltage is read (OL is displayed), then switch the DMM probes and repeat the test. **If no voltage reading results from either test, then the diode is probably damaged.** This table summarizes the tests and resulting implications:

Displayed voltage	Result of Test	Implication
< 50 mV	short-circuit, continuous beep	diode is damaged
0.6 V to 0.8 V	displays turn-on voltage,	+ side connected to V+ terminal, diode made from Silicon
0.8 V to 2.5 V	displays turn-on voltage,	+ side connected to V+ terminal, diode made from other material (not Silicon)
OL	open load	+ side connected to COM terminal or diode is damaged if OL in both directions

1. Choose 4 light emitting diodes (LEDs) of different colors (if available). Test and record the forward turn-on voltage for each diode. Keep track of the **anode and cathode** so you can build your circuit in the next activity. One way to do this would be to stick the positive end of each diode into the Protoboard until you are ready to use it.

Diode color	Turn-on voltage
Red	1.639V
Green	1.8795V
White(Orange)	2.587V
Yellow	1.859V

2. Connect a cable with a BNC connector (shown below) on one end and alligator clips on the other to the **function generator** output.



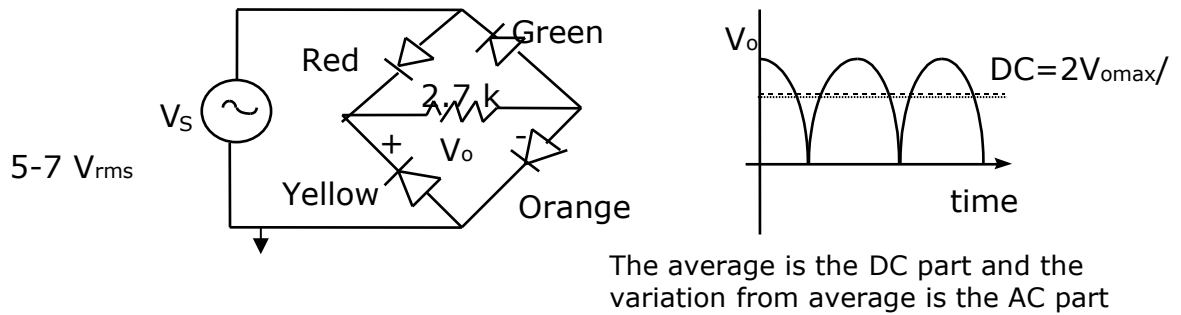
Turn on the function generator and make sure the DC offset knob and the Amplitude knobs are both pushed in and that the ATTN light is not lit. Press the sinusoidal button until the light is lit and press the MHz button until its light is lit. Then press the 1 on the number pad to set the frequency to 1 MHz. Connect the DMM probes to the output alligator clips and measure the AC RMS voltage (press the AC V button on the DMM). Turn the Amplitude knob until you get 5-7 V_{rms} and record the AC voltage being delivered by the function generator.

V_s RMS Voltage measured = 4.812

What are the units displayed on the DMM V

Activity #2: A simple 4-Diode Full Wave Rectifier

1. Construct a full wave bridge rectifier using the light emitting diodes, as shown in the schematic below.



All the LEDs should appear to be on since the frequency of 1 MHz is faster than your eyes can detect them turning on and off.

Notice that the output voltage of the full wave rectifier is the voltage across the resistor.

- Reduce the frequency to 1 Hz. You should be able to see the diodes turning on and off. Two diodes should be on at the same time for about 0.5 seconds, then the other pair will be on. Record which color diodes are on at the same time in the table below. Note that when V_s is positive, current comes out of the top terminal of the AC source, flows through the red diode, then through the 2700-ohm resistor from left to right and then through the orange diode before it returns to the bottom terminal of the AC source. When V_s is negative, current flows from the bottom terminal through the yellow and green diodes and through the 2700-ohm resistor in the same direction as when V_s was positive, so that the output voltage is always positive. To ensure that your circuit is working properly, make sure they match with what color diodes should be lit at the same time (given above in this paragraph).

When V_{Source} is:	Color of 1 st Diode Lit	Color of 2 nd Diode Lit
Positive	Red	White(Orange)
Negative	Yellow	Green

- Increase the frequency back to about 1 MHz. Using the DMM, **measure and record in the table below, the DC portion of the output voltage (press the DC V button), the ACRMS portion (press the AC V button)**. You can be sure you are measuring the right voltage by checking the units displayed on the DMM.
- Also calculate the True RMS with this formula.

$$TrueRMS = \sqrt{V_o DC^2 + V_o RMS^2}$$

	Value	Units
DC Output Voltage (VoDC)	115.88	mV
ACRMS Output Voltage (VoRMS)	2.745	V
Calculated True RMS Output Voltage	2.747	V

5. One way to increase the performance of your DC power supply is to add a **capacitor in parallel** with the 2.7K Ω resistor. Get a 100 μ F capacitor and add it to your circuit and repeat the above measurements.

	Value	Units
DC Output Voltage (VoDC)	126.43	mV
ACRMS Output Voltage (VoRMS)	14.580	mV
Calculated True RMS Output Voltage	127.268	mV

Notice that the DC level is much higher and the unwanted AC ripple is much lower. What happened to the True RMS value?

The True RMS value is almost equal to the expected value.

Important: Have your lab instructor sign below in order to receive credit for this lab!

Signature _____ **Date** _____

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