Department of Electrical and Computer Engineering
University of California, Santa Barbara
ECE 2B, Lab 1a

DIODE AND LED CHARACTERISTICS AND APPLICATIONS

OBJECTIVE

To explore the uses of diodes and LEDs in various applications and to learn about their current and voltage characteristics.

INTRODUCTION

Diodes are semiconductors that allow current to pass through in only one direction. Diodes play a very vital role in electrical systems since they have similar characteristics to a simple switch. All diodes have a positive and a negative leg. The negative leg is the one with the line closest to it and is called the cathode. The positive side is called the anode. Figure 1, below, is an illustration of the diode.

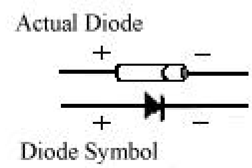


Figure 1: Illustration of the Actual Diode and Diode Symbol

Light emitting diodes (LEDs) are diodes that are made out of a special material that will emit light when the current passes through. The cathode of the LED is the shorter leg while the anode is the longer one. Figure 2, below, illustrates the positive and negative sides of an LED.

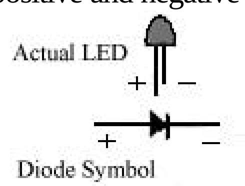


Figure 2: Illustration of Actual LED and Diode Symbol

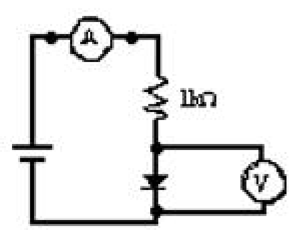
PROCEDURE

1. Measuring I-V Characteristics

In this section of the lab you will measure data points to show the I-V characteristic of a diode. You do this by connecting a diode in series with a resistor to limit the amount of current that will pass through the diode. The reason for using the resistor is that the diode does not have a resistance of it’s own that will limit the amount of current that goes through. Excessive current going through a diode may lead to the diode’s burn out.

Materials required: one 1kΩ resistor, one diode, <u>two</u> Multi-Meters (share with another group)

(a) Setup the following circuit. You will need to use two DMMs:one to measure current (A in the figure below) below and one to measure voltage (V in the figure below).

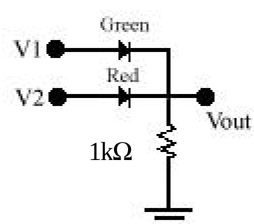


(b) Adjust the power supply using the voltage knob until the Ammeter, which is part of the DMM, reads a current of 10mA through the diode.
(c) Measure and record the voltage drop across the diode with your other DMM.
(d) Repeat steps (b) and (c) for currents varying from 10mA to 0mA. Take 1mA steps from 10mA to 7mA and 0.5mA steps from 7mA to 0mA.
(e) Graph your results. Voltage should be on the x-axis.
(f) Use the curve tracer in the front of the classroom to graph the I-V characteristics of the diode. The following is a description of how to do this. If you need more help, ask your TA.
1. Turn the curve tracer on.
2. At type choose "DIODE"
3. Set V_{CE} max to 2V and I_A max to 10mA.
4. Set R_{Load} to 0.25Ω, and P_{Max} to 0.1W.
5. Press START to see the graph and then Copy to print out the graph.
(g) Using both graphs, find the voltage required to turn on the diode. Are they the same? This is also known as 'biasing' the diode.

2. *Using Diodes for Logic Gates:*

Logic gates are used in computer architecture to manipulate binary information that is represented in computers by physical quantities called signals. In this section of the lab you will build some logic gates using diodes. You will be asked to determine the voltage output of the circuit.

Materials: one green LED, one red LED, one 1kΩ resistor
(a) Using the curve tracer, find the voltage that is required to turn on the LEDs.
(b) Setup the following circuit.



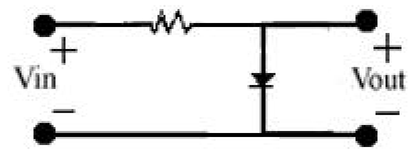
(c) Set both V_{IN1} and V_{IN2} to be 4V.
(d) Which of the two LEDs turned on? Why?
(e) Using the DMM measure the output voltage.
(f) If you change V_{IN2} to 2V, what will happen? Change V_{IN2} to 2V.
(g) Which of the LEDs are on? Why?
(h) Using Kirchoff's laws calculate the expected output voltage.
(i) Using the DMM measure the output voltage. How does your calculated value compare?

3. *Using Diodes as Clippers*

A clipper is a network of diodes that has the ability to "clip" off a portion of the input signal without distorting the remaining part of the waveform. This is useful to protect sensitive circuits from high voltages.

In this part of the lab you will begin using an AC signal. Read through the Description of the Oscilloscope and Function Generator before beginning this section.

Materials: one 47kΩ resistor, one diode.
(a) Setup the resistor and diode as shown in the following circuit:

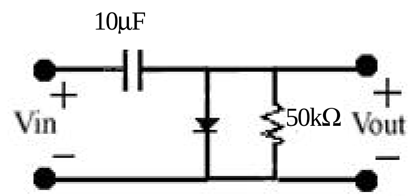


(a) By connecting the leads of the function generator directly to the leads of the oscilloscope's CH1, set the function generator to produce a $10V_{PP}$ square wave at a frequency of 400Hz.
(b) After setting up the input signal connect the red lead of the function generator to the positive Vin and the black lead to the negative Vin. Connect the oscilloscope's CH1 to the input of the circuit in a similar manner in order to view the signal on the oscilloscope.
(c) Connect the red lead of CH2 to the positive output (Vout) of the circuit and the black lead to the negative output of the circuit.
(d) Sketch the input and output voltages shown on the oscilloscope. (Make sure you align the axis of CH1 with the axis of Ch2.) Label your graph and note the maximum and minimum values of the input and output signal.
(e) What happens if a DC voltage source is put in series with the diode?

4. *Using Diodes as Clampers*

A clamper is a network of diodes that is used to "clamp" or shift a signal to a different DC level.
Materials: one 10μF capacitor, one 50kΩ resistor, one diode

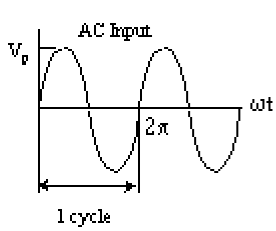
(a) Setup the following circuit:

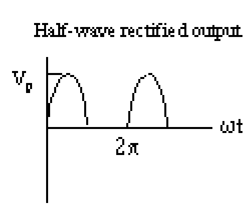


(b) Set V_{IN} to be the same $10V_{PP}$, 400Hz square wave.
(c) Connect the function generator and the oscilloscope's CH1 to the circuit's input.
(d) Connect the oscilloscope's CH2 to the circuit's output.
(e) Sketch the input and output voltages shown on the oscilloscope.

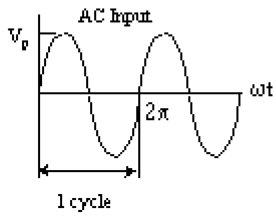
5. *Using Diodes as Rectifiers*

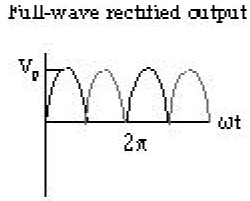
Rectification is the procedure of converting AC signals into DC. There are two kinds of rectifiers that are built with diodes and LEDs: half wave rectifiers and the full wave rectifiers. The difference between the two rectifiers is the output signal. The half wave rectifier allows the positive half of the AC signal to pass through while blocking the negative half. This will result in a positive output when the input is positive and to a zero output when the input is negative. The following diagram shows the input and the output of a half wave rectifier.





The full wave rectifier gives you a positive output at all times. When the input is positive you get a positive output. When the input is negative, you still get a positive output. Why? The following graph shows the input and the output of a full wave rectifier.

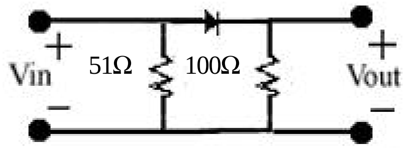




5a. Half Wave Rectifier

Materials: one 51Ω resistor, one 100Ω resistor, one red LED, one 1µF capacitor, one 10µF capacitor, one 100µF capacitor

(a) Setup the following circuit.

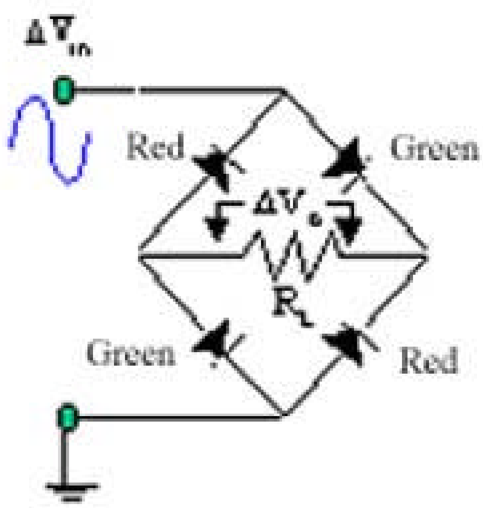


(b) Set the function generator to produce an $18V_{PP}$ sine wave at a frequency of 400Hz.
(c) After setting up the input signal, connect the function generator and the oscilloscope's CH1 to the circuit's input.
(d) Connect the oscilloscope's CH2 to the circuit's output.
(e) Sketch the input and output voltages shown on the oscilloscope.
(f) Connect a 10µF capacitor to the circuit's output. What happens and why?
(g) Repeat step (f) with a 1µF capacitor and a 100µF capacitor. What happens?
(h) Decrease the frequency. What happens?

5b. Full Wave Rectifier

Materials: two red LEDs, two green LEDs, one 1kΩ resistor

(a) Setup the following circuit:



(b) Set V_{IN} to be a 400Hz sine wave with an amplitude of $18V_{PP}$.
(c) Decrease the frequency. What is going on? Why is this happening?

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DESCRIPTION OF THE FUNCTION GENERATOR

The function generator is a device used to produce AC signals in the form of low distortion sine waves, square waves, triangle waves, TTL sync signals, positive and negative pulses, and ramp waveforms. The amplitude and frequency of the signal are user controlled. The amplitude can be varied from 0-20 V_{PP} and the frequency from 0.1 Hz to 11 MHz. Figure 1, below, is an illustration of the function generator's front panel. Below that are brief descriptions of some of the buttons that you will be using for your lab experiments.

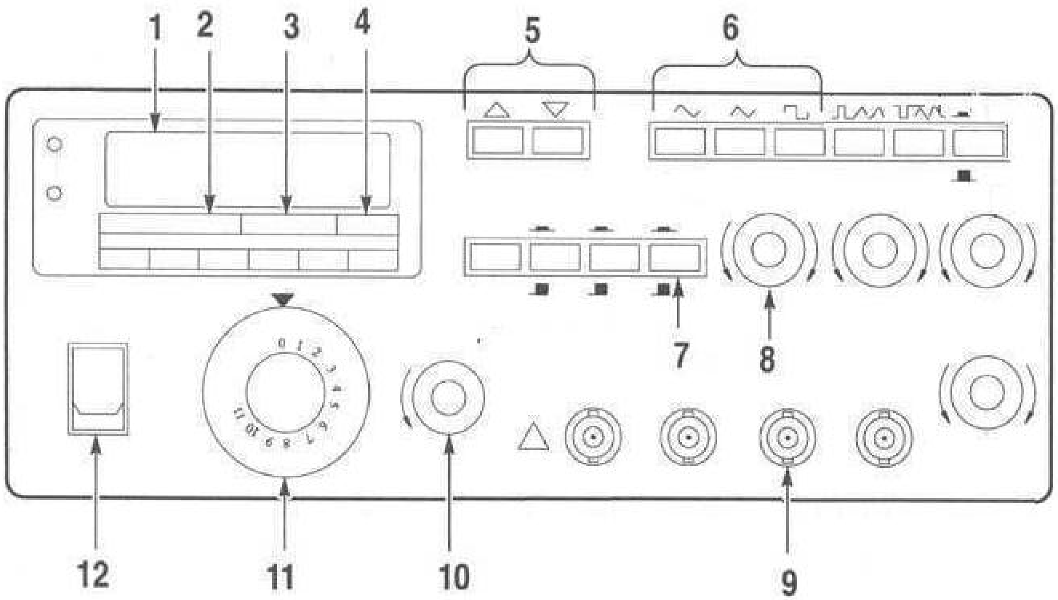

Figure 1: Front Panel of the Function Generator

1. FREQUENCY DISPLAY. This is a five-digit display that shows the frequency counter values. The decimal point is automatically placed in the appropriate position, depending on the settings and resolution.
2. MULTIPLIER LEDs. These lights indicate the frequency multiplication factor of the function generator outputs. The 10-1M LED indicates a multiplication factor of 10 to 10^5.
3. FREQUENCY RANGE LEDs. These lights indicate the range (either MHz or kHz) of the reading shown on the Frequency Display. For example, if the Frequency Dial is set on 9, the 10- 1 M LED is lighted, the kHz LED is lighted, and the counter readout shows .090, then the function generator output frequency is 0.090 kHz = 90 Hz.
4. SEC LED. This light indicates when the Frequency Display is in period mode. This means that the Frequency Display does not show frequency in hertz, but shows the period in seconds. For example, if the Frequency Dial is set at 4, the Multiplier LED is lighted, the Sec LED is lighted, and the frequency display shows a value of 0.250, the generator's output has a period of 0.25s (or a frequency of 4Hz).
5. MULTIPLIER Buttons. These buttons set the frequency range. The left button raises the range by a power of ten and the right button lowers the range by a power of ten. For example, if the Frequency Dial is set to 4.7 and the output is set to kHz, when you press the left multiplier button the output frequency will jump from 4.7 x 10^3 Hz (4.7 kHz) to 4.7 x 10^4 (47 kHz).

6. FUNCTION Buttons. These buttons select the type of waveform generated: sine, triangle, or square.
7. MAIN Button. This button toggles between two voltage ranges: 0-2V_{PP} and 0-20V_{PP}. For small signals, the button should be set in the position for the range of 0 to 2 V_{PP} so you can get the most accuracy.
8. AMPLITUDE Knob. This knob adjusts the amplitude of the signal within the range specified by the Main Button.
9. MAIN OUT BNC. This connector is where you connect the lead for your signal output.
10. FREQ FINE ADJ Knob. This knob allows for small adjustments in the set frequency.
11. FREQUENCY Knob. This knob sets the numerical value of the frequency. Used with the Multiplier Button and Fine Frequency Knob, this knob allows you to set the exact desired frequency.
12. POWER Switch. This switch turns the instrument on and off.

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DESCRIPTION OF THE OSCILLOSCOPE

The oscilloscope is a device used to display and therefore measure ground-referenced AC signals. Figure 2, below, is an illustration of the oscilloscope's front panel. We will discuss four of the most widely used features: Vertical Controls, Horizontal Controls, Menu Buttons and the Autoset Button.

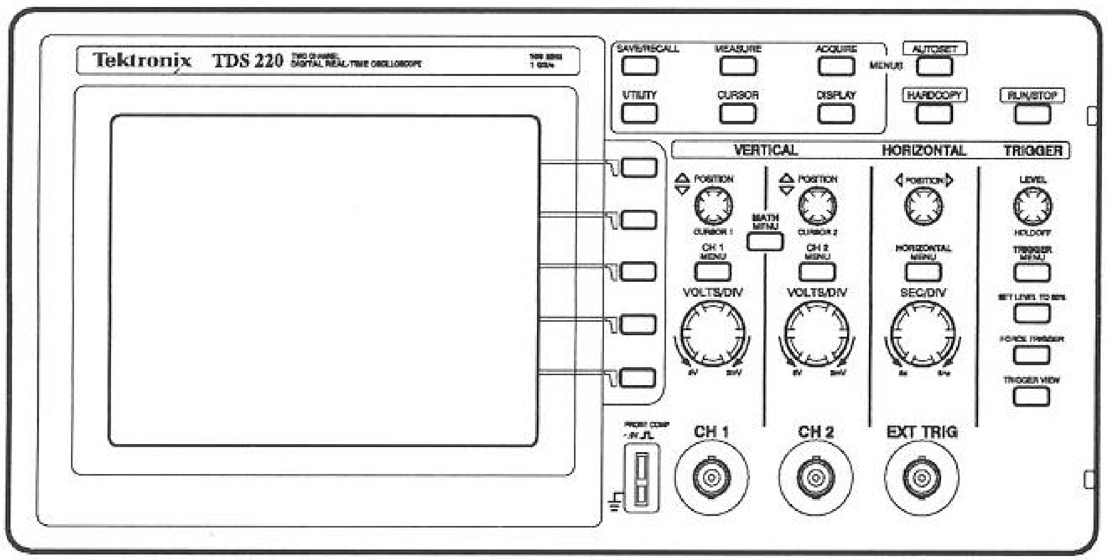

Figure 1:Front Panel of the Oscilloscope

The Vertical Controls allow you to manually move the signal up and down on the display as well as change the scaling factor. An explanation of each of the knobs and buttons is provided after the illustration of the Vertical Controls (Figure 3).

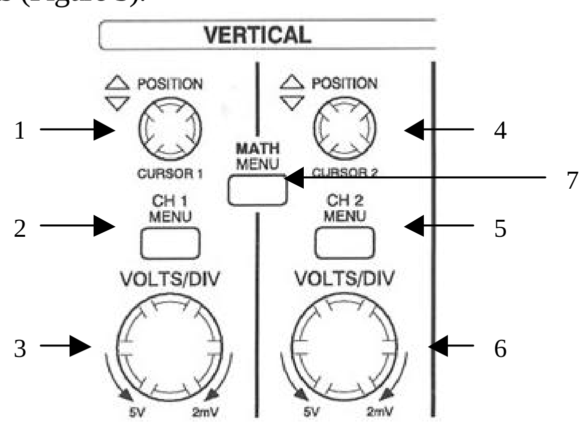

Figure 2: Vertical Controls of the Oscilloscope

1. POSITION/CURSOR 1 Knob. This knob moves the signal from CH1 up and down on the display.
2. CH1 MENU Button. This button shows the menu for CH1. It also serves as a display switch so the signal on CH1 can be turned on or off on the screen. The two features you will use from this menu are the PROBE and INVERT options. The Probe option acts as a multiplier of the incoming signal. For example, if the VOLT/DIV knob for CH1 is set to 2V/DIV and the probe is set to 1X, the voltage shown on the display is 2V/DIV. However, if the Probe option is set to 10X, the display will

show 20V/DIV, even if your signal really is 2V/DIV. The Invert option inverts the signal when it is selected.

3. VOLTS/DIV Knob. This knob adjust the volts per division on the display for CH1.
4. POSITION/CURSOR 2 Knob. This knob moves the signal from CH2 up and down on the display.
5. CH2 MENU Button. This button shows the menu for CH2. It also serves as a display switch so the signal on CH2 can be turned on or off on the screen. The features of the menu are the same as for CH1.
6. VOLTS/DIV Knob. This knob adjusts the volts per division on the display for CH2.
7. MATH MENU Button. This button displays the math menu of the oscilloscope. The only feature you will use is the (CH1 + CH2) function which adds the signals of CH1 and CH2 and displays the result on the screen. (If CH2 is inverted, the two signals will be subtracted.)

The horizontal controls allow you to manually move the signal on the display from side to side as well as change the seconds per division. An explanation of the knobs you will use is provided after the illustration of the Horizontal Controls (Figure 4).

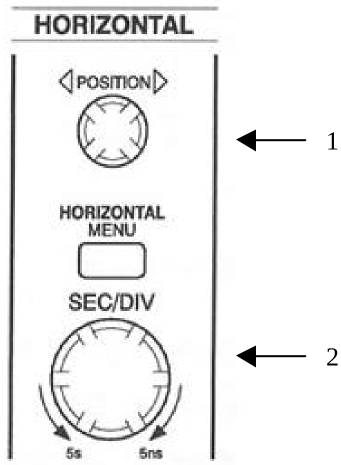

Figure 3: Horizontal Controls of the Oscilloscope

1. POSITION 1 Knob. This knob moves the signal to the right and left on the display.
2. SEC/DIV Knob. This knob allows you to change the scaling of the seconds per division on the x-axis.

The menu panel is where you can access many of the oscilloscope's functions. The only feature that we will be using is the Measure menu. Below is an illustration of the menu panel.

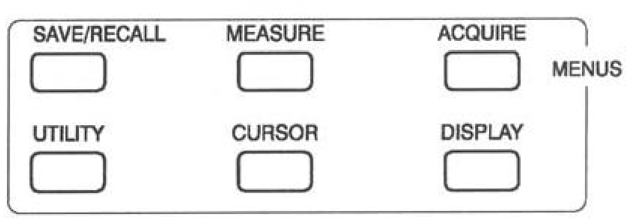

Figure 4: Menu Panel of the Oscilloscope

The measure function of the oscilloscope is very useful. When the measure button has been pressed, a measuring display is shown on the side of the screen. Figure 6, below, illustrates the screen after the measure button has been pushed.

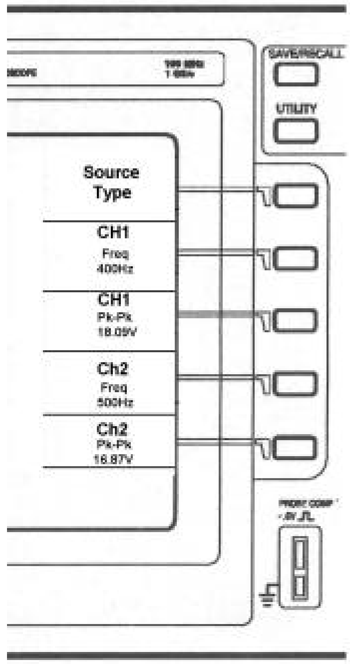

Figure 5: The Measure Menu

The top button next to the Source/Type is a toggle that allows you to either specify which probe you would like to measure, or what you would like to measure. If SOURCE is highlighted, you will be prompted to select either CH1 or CH2 for the four buttons below. If TYPE is highlighted, you will be prompted to select one of five measuring options for the four buttons below: Cyc RMS, Mean, Period, Pk-Pk or Freq.

The Cyc RMS option provides the value of the true Root Mean Square measurement of one complete cycle of the waveform. The Mean option provides the value of the arithmetic mean voltage over the entire record. The Period option provides the value of the time of one cycle. The Pk-Pk option provides the value of the absolute difference between the maximum and minimum peaks of the entire waveform. The Freq option provides the frequency of the waveform.

The Autoset button, located to the right of the Menu Panel, is perhaps the most useful and misleading of buttons on the oscilloscope. The autoset feature automatically adjusts the controls to produce a ‘pretty’ and usable display of the signals the oscilloscope is receiving. This is a very useful feature in most cases, however there will be times when it is necessary to adjust settings manually. It is always good to double check that you are viewing the ‘whole picture’ when using the autoset function, however it is very helpful in initially viewing the signal.

FREQUENTLY ASKED QUESTIONS:

Q: How do we set the function generator to produce a signal of 18 volts, peak to peak, with a frequency of 400Hz?

A: You will have to do the following:

1. Connect the function generator's red lead to the red CH1 lead on the oscilloscope. Connect the black leads together as well.
2. Set the measure function on the oscilloscope so you are viewing both the frequency and peak-to-peak voltage of CH1. If you do not remember how to do this, read the Description of the Oscilloscope.
3. Use the frequency knobs and the multiplier buttons on the function generator to set the frequency to 400Hz
4. Use the amplitude knob on the function generator to set the voltage to 18 V peak to peak as viewed on the oscilloscope. Make sure the main toggle button is in the right position so you can get a signal of 18V.

Q: How do we measure both the input and the output signal using the oscilloscope?

A: You will do this by using both CH1 and CH2 on the oscilloscope as follows. After you set the input signal to the required value, connect both the red lead of CH1 and the red lead of the function generator to the positive input of the circuit and the black leads to the negative input. Connect the red lead of CH2 to the positive output of the circuit and the black lead to the negative out put of the circuit. Look at the oscilloscope display and you will notice that you have two different signals shown on the screen.