



**College of Applied  
Sciences / Hit  
University of Anbar**



# **Laboratory Experiments**

## **Bioelectronics**

### **Experiment No. 2**

**Second Stage**

**Department of Medical Physics**

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## Week 2:

### Experiment 1: Lab Equipment Familiarization

#### OBJECTIVES:

- To be familiar with the main blocks of the oscilloscope and the functions of each block.
- Understand how the oscilloscope work, and how to use the various controls.
- Generate and explore different waveforms that are commonly used.
- Compute and measure  $V_{p-p}$ ,  $V_p$ ,  $V_{avg}$  and  $V_{rms}$ .
- Measure the period and frequency of periodic ac signals.

#### Test Standard : [IEEE 503-1978](#)

#### THEORY:

##### • Oscilloscope

Using an *Oscilloscope* can be easy! The less you ask from it, the easier it is to use. Work in any circuits & electronics lab relies heavily on the use of the digital multi-meter (DMM), the Oscilloscope, and the Function Generator. You have already gained some experience with the DMM; in this experiment we want you to become familiar with the Oscilloscope.

The Oscilloscope is simply the most useful instrument available for testing circuits because it allows you to *see (observe)* the signals at different points in the circuit. The best way of investigating an electronic system is to monitor signals at the input and output of each system block, checking that each block is operating as expected and is correctly linked to the next. With a little practice, you will be able to find and correct faults quickly and accurately. Also it can be employed to measure voltage, frequency and phase shift. Many other quantities such as pulse width, rise time, fall time and delay time can be investigated.

The function of an Oscilloscope is very simple. It draws a  $V/t$  graph, a graph of voltage against time, voltage on the vertical or Y-axis, and time on the horizontal or X-axis. As you can see in Figure 1, the screen of an Oscilloscope almost has **8** squares/divisions on the vertical axis, and **10** squares/divisions on the horizontal axis. Usually, these squares are 1 cm in each direction.

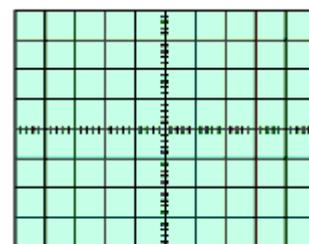


Figure 1

The Oscilloscope has extremely high input impedance (1 MΩ, parallel with 25 pF), which means it will not significantly affect the input signal. This is nice because you can use it to test a circuit without worrying about causing the circuit to behave differently. The probes are connected to an Oscilloscope using BNC's( Baby N-Connector).

An Oscilloscope can be separated into four major sections: **Display, Vertical, Horizontal and Triggering sections**. Table 1 summarized these sections.

Table 1: The four major sections of the oscilloscope.

<b>Display Section</b>	<b><i>Controls the graph on the CRT.</i></b>	
	<b>POWER</b>	Turns ac mains on and off.
	<b>INTENSITY</b>	Adjusts the brightness of the trace.
<b>Vertical Section</b>	<b><i>Supplies the information for the Y-axis (or vertical axis). Usually the scope has two channels. This means two signals can be viewed at once.</i></b>	
	<b>VOLTS/DIV</b>	Vertical sensitivity controls the number of volts between each horizontal line on the screen.
	<b>POSITION</b>	Allows you to move the trace up or down as you see it fit. This way you can zero the trace when no voltage is applied, or if you are viewing two waves at once you can separate them.
	<b>VERT MODE</b>	Channel 1/A: shows only channel 1's signal. Channel 2/B: shows only channel 2's signal.
	<b>AC/GND/DC</b>	Called coupling switch. AC coupling: the scope will display the AC component; block any DC component from being displayed. DC coupling: the scope will display the complete signal including the DC component. GND: Disconnects the input signal from the system so you can establish a zero line.
<b>Horizontal Section</b>	<b><i>The horizontal axis on a scope changes with respect to time.</i></b>	
	<b>POSITION</b>	Allows you to adjust the wave to the left or right.
	<b>TIME/DIV</b>	Controls the rate at which the trace travels between divisions. Set it to one second and the trace will take a second to travel between one division and the next.

<b>Triggering Section</b>	<b><i>This tells the scope when to trigger or start the beginning of a trace. Helps it to "lock-on" to the trace.</i></b>	
	<b>LEVEL</b>	Allows the user to vary the waveform in order to synchronize the start of the wave.
	<b>AUTO</b>	Automatically operates trigger on its own action.
	<b>SOURCE</b>	Set to Channel 1/A or Channel 2/B. Whichever works better.
	<b>SLOPE + -</b>	Flips the waveform on both channels by determining whether the slope triggers on the positive or the negative slope.

**• Coaxial Cables**

The cables you are using to connect the FG and the Scope, are called coaxial cables, and they contain two coaxial conductors with characteristic impedance of 50 Ω. The center or inner (High) conductor carries the signal and the outer conductor is typically connected to ground (Low) at one or both ends of the cable. Figure 2 shows a cross section of a coaxial cable. Properly grounded coaxial cables are reducing or prevent the noise and interference signals.

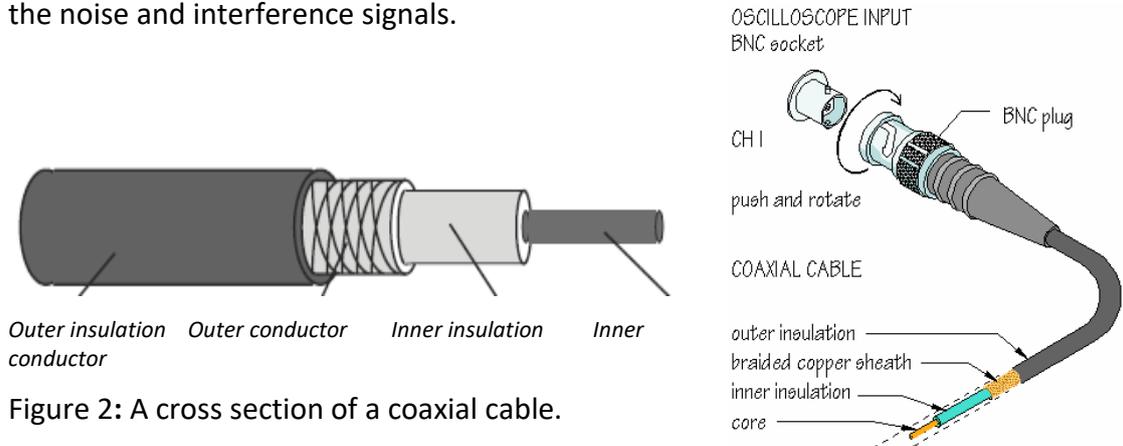


Figure 2: A cross section of a coaxial cable.

**• Function Generator**

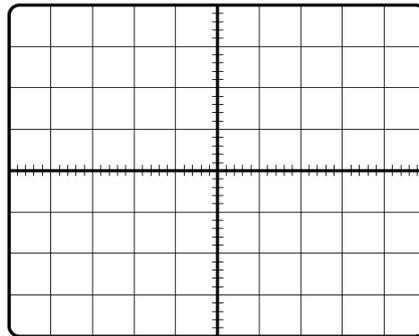
The Function Generator can produce periodic signals of varying frequency, amplitude, and several different shapes including: **Sine**, **Square** and **Triangular** signals, **TTL/CMOS** digital pulses, ...etc. Both frequency and amplitude can be varied.

**PROCEDURE:**

**PART A – Using Oscilloscope and Function Generator**

1- Turn on the Oscilloscope, press on CH1 to display only channel 1 signal. Set the Oscilloscope's Volts/Division knob for channel 1 to 2 V/DIV, and set the sweep Seconds/Division knob to 0.25 ms/DIV.

2- On the menu appear on the oscilloscope screen as shown in Figure 3. Choose the coupling to be GND and move the trace to the middle of the screen by using the vertical position knob. When you finish set the coupling switch to AC again.



Volts/Div: \_\_\_\_\_ Time/Div: \_\_\_\_\_

Figure 3: oscilloscope screen.

3- Turn on the Function Generator and connect the output of it to the input of CH1 on the Oscilloscope.

4- While observing the signal on the Oscilloscope, turn the amplitude potentiometer knob and the frequency knob of the Function Generator to get 8 V<sub>pp</sub>, 1 kHz on the Oscilloscope screen.

5- Draw the signal displayed on the Oscilloscope screen.

6- Turn the “**Volts/Division**” knob for channel 1 in the CW and then CCW directions. How does that affect what you see on the Oscilloscope?

7- Turn the “**Seconds/Division**” knob for channel 1 in the CW and then CCW directions. How does that affect what you see on the Oscilloscope?

8- Turn the “**Vertical Position**” knob for channel 1 in the CW and then CCW directions. And turn the “**Horizontal Position**” knob in the CW and then CCW directions. What are the affects of these knobs on the signal?

9- Turn the “**Level**” knob in the CW and then CCW directions until the signal become unstable. What is the affect of this knob on the signal?

10- Go to the Trigger Block. Choose **Source**. Different choices will appear: CH1, CH2, External and Line. Choose the **Triggering Source** to External. What happen to the signal? Explain. (When you finish set it back to CH1).

11- How many screen divisions of the Oscilloscope:

1) Horizontally: . . . . .

2) Vertically: . . . . .

3) Subdivisions: . . . . .

12- For a sine wave of 250 kHz, what is the **“Second/Division”** needed to display 2.5 cycles on the Oscilloscope screen?

**PART B - Measuring Time , Frequency and Amplitude**

1. Connect the output of a Function Generator to the CH1 input of the Oscilloscope.
2. Set the sine waveforms listed in Table 2. Use the Oscilloscope and (Digital Multi-Meter) **DMM** to complete the rest of the table.
3. Sketch the waveforms. Record the HORZ. and VERT. settings.

Table 2: Results

Freq. and Amplitude	Vrms (V)	Vavg (V)
f = 500 Hz @ 800 mVp-p		
f = 10 kHz @ 2Vp-p		
f = 10 kHz @ 5Vp-p		

## Week 3:

### Experiment 2: Diode Characteristics

#### OBJECTIVES:

- To be familiar with the basics properties of the junction Diodes.
- To study the characteristics of the Diode and investigate the I-V curve.
- **Test Standard :** [IEEE 503-1978](#)

#### THEORY:

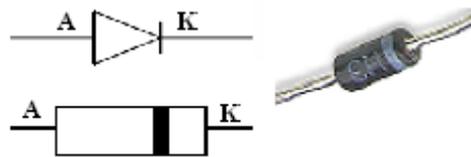


Figure 1: Diode.

The diode is a two-terminal semiconductor device with a nonlinear  $i-v$  characteristic. The current flows in only one direction through the diode from the anode to the cathode. There are three operating regions for the diode:

- Forward biased.
- Reverse biased.
- Reverse breakdown.

From examining Figure 1, you should note that the **Anode (A)** corresponds to the P-type side while the **Cathode (K)** corresponds to the N-type side of the diode.

#### Ideal Diode Equation:

The relationship between the diode current and voltage is given by the diode equation

$$I_D = I_s \left( e^{V_D/nV_T} - 1 \right) \quad 1$$

The terms in Equation (1) are defined as follows:

$I_D$  = the diode current (amperes).

$V_D$  = the voltage across the diode (volts).

$I_s$  = the reverse saturation current or the reverse leakage current (amperes).

$I_s$  is a function of the diode material, the doping densities on the p-side and n-side of the diode, the geometry of the diode, the applied voltage, and temperature.  $I_s$  is usually of the order of  $1\mu\text{A}$  to  $1\text{mA}$  for a germanium diode at room temperature and of the order of  $1\text{pA}$  for a silicon diode at room temperature.  $I_s$  increases as the temperature rises.  $V_T = kT/q =$  the thermal equivalent voltage  $= 0.0258\text{ V}$  at room temperature where

$q = 1.6 \times 10^{-19}$  Coulombs = the electric charge,

$k = 1.38 \times 10^{-23}$  J/K = Boltzmann's constant,

and

$T =$  absolute temperature (Kelvin) [room temperature = 300K].

$n =$  the ideality factor or the emission coefficient.

**Cut-in Voltage  $V_\gamma$ :**

A sketch of a diode characteristic, as it would be measured, is shown in Figure 2. The figure shows the forward I-V characteristics. The characteristics shown in Figure 3 are the combination of the forward and reverse characteristics. Appreciable conduction occurs from around 0.4V to 0.7V for silicon and from around 0.2V to 0.4V for germanium at room temperature. The value of  $V_\gamma$  is a function of the current at which  $V_\gamma$  is measured. This point is discussed below and is one of the concepts you should master from this experiment. If the applied voltage exceeds  $V_\gamma$ , the diode current increases rapidly.

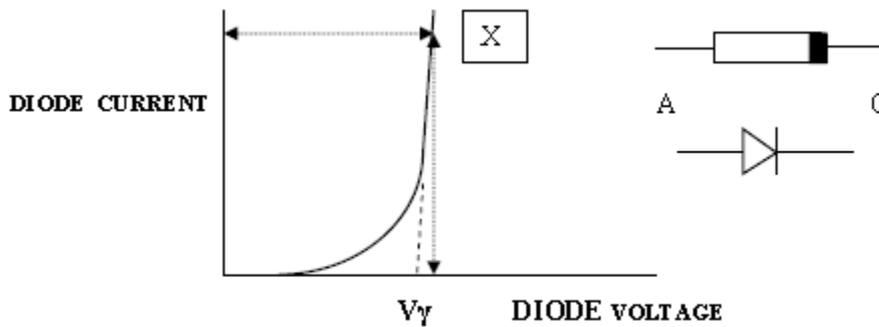


Figure 2: Diode forward I-V characteristic showing the definition of  $V_\gamma$ .

The complete diode characteristic is shown in Figure 3, piecing together the forward-biased data and the reverse-biased data. Note that the scales of  $+V$  and  $-V$  may differ by a factor of 100, and while  $+I$  may be mA or A,  $-I$  is likely to be  $\mu\text{A}$  or nA.

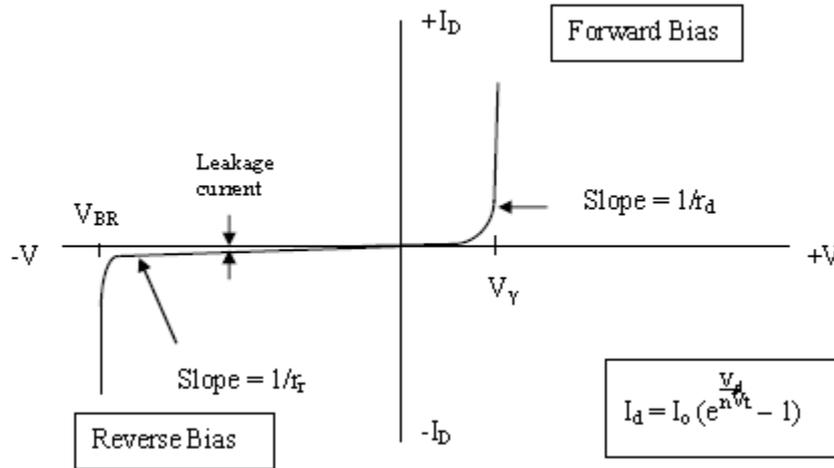


Figure 3: Diode forward I-V characteristic showing the definition of  $V_f$ .

### Diode Current and Diode Saturation Current:

If the diode is operated in the forward-bias region at room temperature ( $27^\circ\text{C} = 300\text{ K}$ ), the exponential first term in the brackets in Equation (1) dominates and the diode current equation is given approximately by

$$I_D = I_s e^{V_D/nV_T} \quad 2$$

The current for forward bias is an exponential function of the applied voltage,  $V_D$ . If the diode is reverse-biased, only the small reverse current (the reverse saturation current or the reverse leakage current),  $-I_s$ , flows. This current flows as long as the applied reverse voltage does not exceed the diode breakdown voltage,  $V_{BR}$ . If the reverse voltage exceeds  $V_{BR}$ , a large amount of current flows and the diode may be destroyed if there is not enough series resistance to limit the diode current. In silicon diodes,  $I_s$  may be very small and  $V_{BR}$  may be very large.

### Diode Resistance

Three diode resistances are commonly calculated:

- DC or Static forward resistance,  $R_F$  or  $R_D$ .
- AC or Dynamic forward resistance,  $r_f$  or  $r_d$ .
- Reverse resistance,  $r_r$ .

**DC or Static forward resistance,  $R_F$  or  $R_D$ ,** is the total voltage drop across the diode divided by the current flowing through the diode, just as one would calculate using Ohm's Law. It includes contact resistance, lead resistance, material resistance, and the resistance of the p and n regions of the diode.

$$R_F = \frac{V_D}{I_D} \quad 3$$

**AC or Dynamic forward resistance,  $r_f$  or  $r_d$ :** In practice we don't often use the static forward resistance; more important is the dynamic or AC resistance, which is the opposition offered by the diode to *changing* current. It is calculated by the ratio [change in voltage across the diode] / [the resulting change in current through diode] at the operating voltage,  $V_D$ . That is,  $r_d$  is the *reciprocal of the slope* of diode current versus voltage at the operating point.

$$r_f \equiv r_d = \frac{1}{\Delta I_D / \Delta V_D} = \frac{\Delta V_D}{\Delta I_D} = \frac{\text{change in voltage}}{\text{resulting change in current}} \quad 4$$

Applying the diode equation and differentiating, we find the dynamic forward resistance is given by

$$r_f \equiv r_d = \frac{dV_D}{dI_D} = \frac{1}{dI_D/dV_D} = n \frac{V_T}{I_D} \quad 5$$

Owing to the nonlinear shape of the forward characteristic, the value of AC resistance of a diode is in the range of 1 to 25 ohms. Usually it is smaller than DC resistance of the diode.

**Reverse Resistance,  $r_r$ :** When a diode is reverse biased, besides forward resistance, it also possesses another resistance known as reverse resistance. It can be either DC or AC depending upon whether the reverse bias is direct or alternating voltage. Ideally, the reverse resistance of the diode is infinite. However, in actual practice, the reverse resistance is never infinite, due to the existence of leakage current in a reverse-biased diode.

The **reverse resistance,  $r_r$** , is given by the reciprocal of the slope of the reverse characteristic, prior to breakdown (see Figure 3).

## PROCEDURE:

### PART-A Diode (I-V) characteristics

#### A-1 Forward Bias Mode

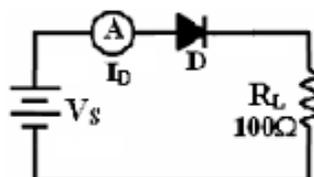


Figure 4

- 1- Construct the circuit shown in Figure 4. By using **1N4007 Si** diode. (*Make sure your diode has the correct polarity*).
- 2- Ask the instructor to check your circuit.
- 3- Set the DC power supply output adjustment potentiometer fully counter clock wise. Then switch it ON.
- 4- Adjust the voltage source ( $V_S$ ) corresponding to Table 1. Use the DMM to measure the remaining values and record it in Table 1.
- 5- When finish, set the ( $V_S$ ) to **0.0V**. Then switch OFF the DC power supply.

**Table 1:**

<b><math>V_S</math> (V)</b>	<b>0.0</b>	<b>0.2</b>	<b>0.4</b>	<b>0.6</b>	<b>0.8</b>	<b>1.0</b>	<b>1.2</b>	<b>1.6</b>
<b><math>I_D</math> (mA)</b>								
<b><math>V_D</math> (V)</b>								

**A-2 Reverse Bias Mode**

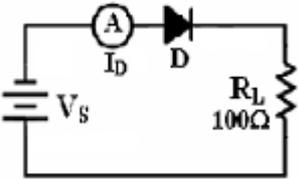


Figure 5

- 1- Reverse the polarity of the DC power source ( $V_S$ ) as shown in Figure 4.
- 2- Adjust the voltage source ( $V_S$ ) corresponding to Table 2. Use the DMM to measure the remaining values and record it in Table 2.
3. When you finished, set the ( $V_S$ ) to **0.0V**. Then switch OFF the DC power supply.
- 4- Using the data obtained in part A-1 and part A-2 above, plot the diode ( **$I-V$** ) characteristic curve.

**Table 2:**

<b><math>V_S</math> (V)</b>	<b>2.0</b>	<b>5.0</b>	<b>10.0</b>	<b>15.0</b>
<b><math>I_D</math> (mA)</b>				
<b><math>V_D</math> (V)</b>				

- To understand the difference between linear and non-linear I-V Characteristic curve, plot the I-V characteristics curve of the resistor.

**Problems and Discussion:**

Q1 : Define semiconductor diode.

Q2: Define depletion layer.

Q3: What do you mean by forward biased?

Q4: What do you mean by reverse biased?

Q5. Define Knee voltage.

Q6. Define breakdown voltage.

Q7. Define max. Forward current.

Q8. Define max. Power rating.

Q9. What is hole current?

Q10: What is cut-in voltage?

## Week 4:

### Experiment 3: Study of Zener diode in Break down Region

#### OBJECTIVES:

- To be familiar with the basics properties of the Zener Diodes.
- Study of Zener diode in Breakdown region.

#### Test Standard : [IEEE 503-1978](#)

#### Introduction:

A Zener Diode is a special kind of diode which permits current to flow in the forward direction as normal, but will also allow it to flow in the reverse direction when the voltage is above a certain value – the breakdown voltage known as the Zener voltage.



Figure 1: Zener Diode

The Zener voltage of a standard diode is high, but if a reverse current above that value is allowed to pass through it, the diode is permanently damaged. Zener diodes are designed so that their zener voltage is much lower – for example just 2.4 Volts. When a reverse current above the Zener voltage passes through a Zener diode, there is a controlled breakdown which does not damage the diode. The voltage drop across the Zener diode is equal to the Zener voltage of that diode no matter how high the reverse bias voltage is above the Zener voltage.

