The University of Jordan

Mechatronics Engineering Department

Electronics Lab.(0908223)
Experiment 1: Lab Equipment Familiarization

Objectives

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

Theory

1) Resistor Color Codes

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. Resistors act to reduce current flow, and, at the same time, act to lower voltage levels within circuits. In electronic circuits, resistors are used to limit current flow, to adjust signal levels, bias active elements, and terminate transmission lines among other uses. Resistors are coded with colors to identify their value. The following figure shows Resistor Color Codes Chart:

Note: The value of R=120 kΩ ± 10% = 120 kΩ ± [120 kΩ * (10/100)] =132 kΩ or 108 kΩ.

Color	Signficant figures			Multiply	Tolerance (%)	Temp. Coeff. (ppm/K)	Fail Rate (%)
black	0	0	0	x 1		250 (U)	
brown	1	1	1	x 10	1 (F)	100 (S)	1
red	2	2	2	x 100	2 (G)	50 (R)	0.1
orange	3	3	3	x 1K		15 (P)	0.01
yellow	4	4	4	x 10K		25 (Q)	0.001
green	5	5	5	x 100K	0.5 (D)	20 (Z)	
blue	6	6	6	x 1M	0.25 (C)	10 (Z)	
violet	7	7	7	x 10M	0.1 (B)	5 (M)	
grey	8	8	8	x 100M	0.05 (A)	1(K)	
white	9	9	9	x 1G			
gold			3th digit only for 5 and 6 bands	x 0.1	5 (J)		
silver				x 0.01	10 (K)		
none					20 (M)		

6 band — 3.21kΩ 1% 50ppm/K

5 band — 521Ω 1%

4 band — 82kΩ 5%

3 band — 330Ω 20%

gap between band 3 and 4 indicates reading direction
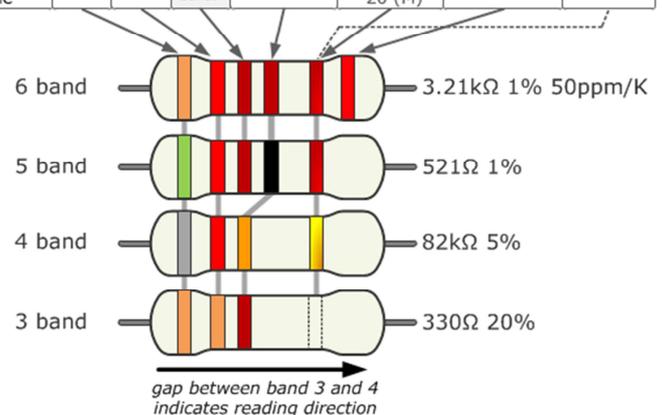
Figure1.1: Resistor Color Codes Chart

2) Project Bread Board

The power Breadboard shown in the figure includes DC Power supply with range from -15 to 15 Volts. The nodes in the white Breadboard shown in figure1.3 the line means all the halls represents one node.
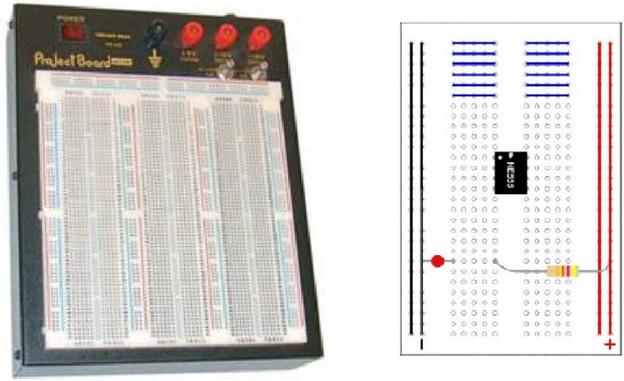

Figure1.2: Power Breadboard

3) Digital Multimeter (DMM)

is an electronic measuring instrument that is used to measure different quantities such as:
-Voltage (AC,DC)
-Current (AC,DC)
-Resistance
-Temperature
-Continuity (DMM emits an audible beep)
-Other quantities, such as frequency and diode test.

Connecting the DMM:

To measure voltage and resistance, the DMM is connected in **parallel.** The DMM's input impedance is high enough (several MΩ) so that it has negligible effect on the circuit being measured (i.e no loading effect). In case of measuring the resistance of a resistor, this resistor must be disconnected from the circuit. To measure current, the DMM is connected in **series**. The DMM's input impedance is small enough (in Ω's) so that it has negligible effect on the circuit being measured (i.e no loading effect). Refer to Figure 1.3 to see how this is done, which connectors are used and where the dial points.


(a) Voltage V   (b) Resistance Ω   (c) Current A

(a) Using a multimeter to measure voltage   (b) Using a multimeter to measure resistance.   (c) Using a multimeter to measure current.
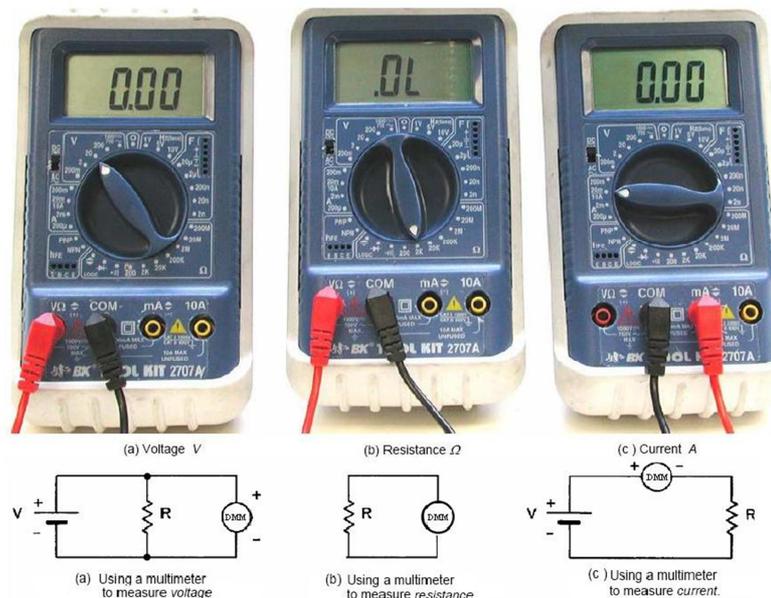
Figure 1.3 Using the DMM to measure voltage, current and resistance

4) DC-power supply

The DC power supply is an adjustable voltage source powered by 220VAC 50Hz. The bench type DC power supply is shown in Figure 1.4 with the following parts:

(1) Digital Display (No. 1 on the figure).
(2) Power control (No. 2 on the figure).
(3) Voltage Coarse: for the coarse adjustment of the output voltage (No. 3 on the figure).
(4) Voltage Fine: for the fine adjustment of the output voltage (No. 4 on the figure).
(5) "+" output terminal, red color (No. 7 on the figure).
(6) "GND terminal: earth and chassis ground, green color (No. 6 on the figure).
(7) "-" output terminal: negative polarity, black color (No. 5 on the figure).
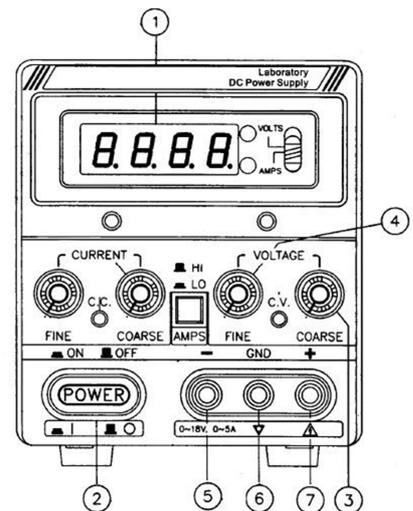
Figure1.4: DC power supply

5) Function Generator
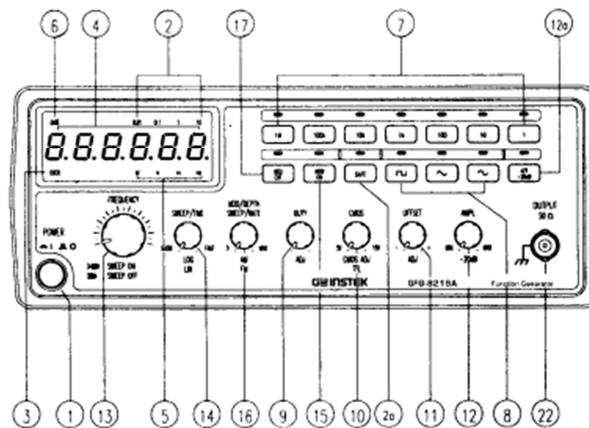
Figure 1.5: front panel of the function generator

1.   Power Switch   Connect the AC power, then press power switch.

4.   Counter Display   Shows the external frequency by 6×0.3" green display, and shows the internal frequency by 5×0.3 green display.

5.   Frequency Indicator   Indicate the current frequency value.

7.   Frequency Range   To select the required frequency range by pressing the relevant push button on the
     Selector   as shown in Table 1

Table 1(for GFG-8217A)

Push bottom	1	10	100	1k	10k	100k	1M
Frequency Range	0.3Hz | 3Hz	3Hz | 30Hz	30Hz | 300Hz	300Hz | 3kHz	3kHz | 30kHz	30kHz | 300kHz | 300kHz	300kHz | 3MHz

8.   Function Selector Press one of the three push buttons to select the desired output waveform.

9. Duty Function   Pull out and rotate the knob to adjust the duty cycle of the waveform.


    DC Offset   Pull out the knob to select any DC level of the waveform between ±10V, turn clockwise
11. Control   a negative
                     DC level waveform

    Output
12. Amplitude   Turn clockwise for MAX. output and invert for a –20dB
    Control with   output. Pull the knob out for an additional 20dB output
    Attenuation   attenuation.
    Operation
    Adjustment
    (Sweep On/Off)

13 MANU/SWEEP   Press and turn clockwise the knob for MAX frequency
                     and invert for MIN frequency. (Keep the pointer within
    Selector and   the scale range on the panel.). Pull out the knob to start the auto sweep
    Frequency   operation; the upper frequency limit is determined by the knob
    Adjustment   position.
    (Sweep On/Off)

6) Oscilloscope

It's an electronic instrument that allows observation of varying one or more signal voltages overtime in a two dimensional plot. The oscilloscope has certain basic features:

- **Screen**: Digital scopes screen operates like a computer monitor that displays the signals in a voltage versus time graph (V/t graph). The screen usually has **8 squares** or divisions on the vertical axis, and **10 squares** or divisions on the horizontal axis.

- **Signal inputs (channels)** where at least two channels typically called "CH1", "CH2, and one external "trigger" input called "EXT TRIG".

- **Vertical part control knobs**: consists of **Channels Coupling** part for the input signal ["DC" Direct Coupling (i.e. the scope will display both the AC and DC components), "AC" Coupling (i.e. the scope will display the AC component; block any DC component from being displayed since the signal pass through a capacitor before being displayed), or "GND" (i.e. Disconnects the input signal from the system so you can establish a zero line)]. The **Vertical Scaling** part applied to the signal is controlled by a knob called Volt/Div (e.g. 10mV/div setting means 10 millivolt for each division) and the last part the **Vertical Positioning** knob which used to move the signal on the screen up and down.

- **Horizontal part control knobs**: The **Horizontal Scaling** part for the time axis is controlled by a knob called Sec/Div (e.g. 1μs/div means that 1 microsecond for each division), while the **Horizontal Positioning** part is used to move the signal on the screen right and left.

- **Trigger control knobs:** It is used to synchronize the input signal to the horizontal display. Level triggering allows the user to vary the waveform in order to synchronize the start of the wave. Source triggering set to CH1 or CH2 whichever works better.

Note: The Oscilloscope has extremely high input impedance (1 MΩ, parallel with 25 pF), which means it will not significantly affect (load) the input signal. The probes are connected to an Oscilloscope using BNC's (Baby N- Connector) and it is called Coaxial Cable shown in Figure 1.6. The cable has 50Ω impedance with the inner (High) conductor carries the signal while the outer conductor is connected to ground (Low) at one or both ends of the cable. Figure 6 shows a cross section of a coaxial cable. Properly grounded coaxial cables reduce or

OSCILLOSCOPE INPUT
BNC socket

BNC plug

CH1

push and rotate

COAXIAL CABLE

outer insulation
braided copper sheath
inner insulation
core
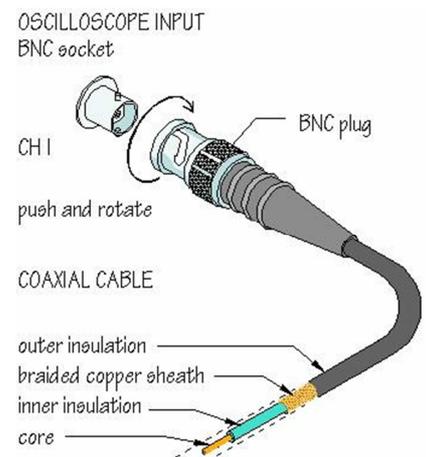
prevent the noise and interference signals.

Figure 1.6

Pre-lab:

1. Find the resistance for the following resistance codes:
   a. Brown, red, orange, gold
   b. Brown, black, brown, silver
2. Solve part c of the experiment using Multisim.

Procedure

Equipments & Part List

1- Oscilloscope.   2- Function Generator (FG) or Signal Generator.
3- Digital Multimeter (DMM).   4- Bread-board.
6- Connection Wires and coaxial cable Probes.

PART A - Measuring resistance

1) Choose two different resistors, find the expected value according to the color code and fill your reading in Table 1 in the answer sheet.
2) Switch on the DMM and select the dial point on Ohmmeter. Measure the value of each resistor you chose in the previous part. Calculate the percentage error according to the following equation:

$$(e\% = \frac{Measured - Expected}{Expected} x100\%)$$

3) Connect the two resistors in series on the bread board, measure the equivalent resistance and fill in Table 1 in the answer sheet.
4) Connect the two resistors in parallel on the bread board, measure the equivalent resistance and fill in Table 1 in the answer sheet.

PART B - Using The DC supply
Follow the steps below and fill the answer sheet:
1) Turn the voltage knobs to the minimum (maximum counter clock **Figure1. 7** wise CCW), then switch on the DC power supply.
2) Distinguish the difference between the coarse and fine voltage tuning knobs but slightly turning the knobs and read the display.

PART C - Building a simple circuit
1) Construct the circuit shown in Figure 7 on the bread board by connecting the two resistors **R1= 1kΩ and R2= 2.2kΩ** in series.
2) Adjust the DMM as an Ammeter, put the red lead to the "mA" output terminal and the black lead to the "com" output terminal and connect it in series with the resistors as shown in Figure 7.
3) Set the DC- power supply to **10 volt** by adjusting the coarse tuning knob. Connect the red lead to the "+" output terminal and the black lead to the "-" output terminal (Don't connect any leads to the "GND" output terminal). Then connect the supply in series as shown in Figure1. 7.
4) Measure the total current I and record it in Table 2 in the answer sheet.
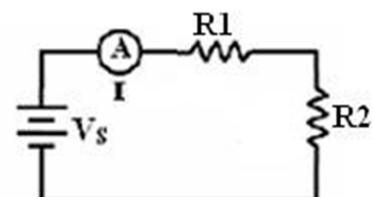
5) Now remove the DMM from the circuit and replace its location by short circuit, adjust it as Voltmeter, put the red lead to the "V" output terminal and the black lead to the "com" output terminal and connect it in parallel to R1 and measure V_{R1} and record it in Table 2 in the answer sheet.

6) Repeat step 5 to read the supply voltage (Vs) and the voltage on R2 (V_{R1}).

Note: you can use two DMMs; one is adjusted as an Ammeter (connected in series), while the other is adjusted as a voltmeter (connected in parallel).

PART D - Using the Oscilloscope and the Function Generator

1- Switch on the Oscilloscope, set the Oscilloscope's **Volt/Division** knob for "CH1" to 2V/DIV, and set the sweep **Second/Division** knob to 0.1 ms/DIV.

2- Set the coupling switch (AC/DC/GND) to **GND**, move the trace to the middle of the screen by using the vertical position knob, then when you finish set the coupling switch to **AC** again.

3- Switch 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 and the frequency knobs of the Function Generator to get $8V_{pp}$, 1kHz sine shape signal on the Oscilloscope screen.

5- Fill Table 3 in the answer sheet.

6- Turn the **"Volt/Division"** knob for CH1 CW and then CCW. How does that affect what you see on the Oscilloscope?

> **Note**
>
> Be sure that the VAR knob of the "Volt/Division" and "Second/Division" is locked in the CAL (Calibration) position, so don't change it.

7- Turn the **"Second/Division"** knob for CH1 in the CW and then CCW directions. How does that affect what you see on the Oscilloscope?

8- Turn the **"Vertical Position"** knob for CH1 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- Set the sine waveforms listed in Table 4 in the answer sheet, use the Oscilloscope to find out the number of the horizontal divisions for one period and the horizontal scale (sec/Div). Use the Digital Multi-Meter (DMM) to measure the **rms** and **average** voltages for the signals.

> **Note**
>
> DMM can be used as continuity tester to check the connection between the grounding pin (on the line plug) and the metal parts of the Oscilloscope, especially with BNC connectors and grounding jack. All metal parts of the Oscilloscope case connected to the building ground when is Oscilloscope plugged in, which is for safety purposes
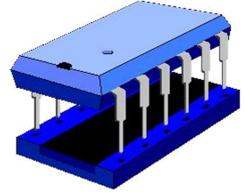
The University Of Jordan
Faculty of Engineering
Mechatronics Engineering Department

Electronics Lab Report

0908223

Experiment No.: _____   **Student Group: _____**

Experiment Name: _____

Students Name:

    1) _____

    2) _____

    3) _____

    4) _____

Lab Equipment Familiarization

PART A – Measuring resistance

Table 1

	Expected	Measured	e%	Color code
R1				
R2				
R (series)				
R (parallel)				

PART B - Using the DC supply

2) Distinguish the difference between the coarse and fine voltage tuning knobs.

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…………………………………………………………………………

PART C - Building a simple circuit

Table 2

I (mA)	V_{R1} (volt)	V_{R2} (volt)	Vs (volt)

Part D – Using the Oscilloscope and the Function Generator

5-

Table 3

# of Horizontal divisions for the period	# of vertical divisions for peak to peak	Sec/Div	Volt/Div

6- Turn the **"Volt/Division"** knob for channel 1 in the CW and then CCW directions. How does that affect what you see on the oscilloscope?

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7- Turn the **"Second/Division"** knob for channel 1 in the CW and then CCW directions. How does that affect what you see on the oscilloscope?

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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-

Table 4

Freq. and Amplitude	Sec/Div	# of Divisions for one period	Vrms (V)	Vavg (V)
f = 500 Hz @ 800 mV pp				
f = 10 kHz @ 10Vpp				

Exp. 2

Diode Characteristics and Applications (1)

Objectives

- To be familiar with the basic properties of the junction diodes.
- To study the characteristics of the diode and investigate the I-V curve.
- To investigate some of the diode applications such as the rectifier circuits, Peak Detector.

Theory

The diode in Figure 1 is a two-terminal semiconductor device with a nonlinear *i-v* characteristic. The **Anode (A)** corresponds to P-type side while the **Cathode (K)** corresponds to N-type side. The current flows in only one direction through the diode from the anode to the cathode. There are three operating regions for the diode according to the *i-v* characteristic of the diode as shown in Figure 2:
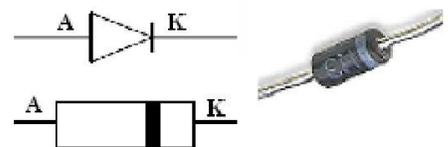
Figure 1

- Forward biased: The anode is more positive than cathode and the voltage drop on the diode is grater than the cut-in voltage (**$V\gamma$**), and the current will flow from anode to cathode in range of (mA). When analyzing the circuit, the diode is ideally replaced by short circuit, and practically by a voltage source has value of (**$V\gamma$**) in series with small resistor (**r_f**).

Figure 2

- Reverse biased: The cathode is more positive than anode, only reverse small current in range of (μA) called Saturation Current (I_S) passing in the circuit and it can be neglected. When analyzing the circuit, the diode is replaced by an open circuit.

- Reverse breakdown: it is typically happen at voltage 75V, at this moment very high value of current pass through the diode which cause huge power dissipation that may damage the diode, so we never test reverse breakdown.
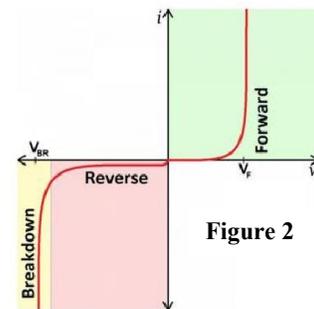
Different Diode applications can be found such as: Rectifier circuits (HWR and FWR), Clipper circuits, Clamper circuits, peak detector and Logic circuits. In this experiment we will study and test:

1) The Rectifier Circuit: It converts AC signal (Alternating signal) to DC signal (Direct signal) such that the current flows through a load in one direction only. There are two types of rectifications:

  a) Half Wave Rectifier (HWR): one of the input signal half cycle makes the diode forward biased and there exist a voltage at the output, while during the other half cycle the diode will be reverse biased and the output is zero as shown in Figure 3. The maximum output voltage of the **rectified unfiltered** signal (V_P (HWR)) can be found by:

$$V_P (HWR) = V_{\max} (input) - V_\gamma$$

Where $V_{\max}$ (*input*) is the input signal peak voltage. The amount of the average value (DC value) of the HWR rectified unfiltered signal over one period is given by:

$$V_{av}(HWR) = \frac{V_P(HWR)}{\pi} = (0.318) * V_P(HWR)$$

The frequency of the rectified output waveform can be expressed as:

$$f_o(HWR) = f_{source}$$
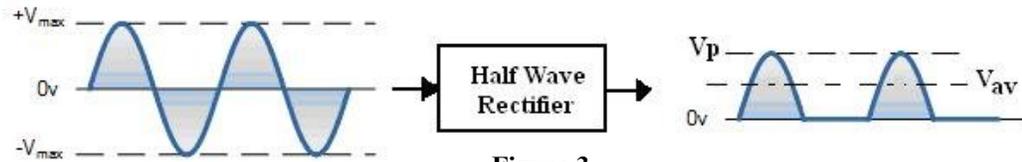
Figure 3

b) Full-Wave Rectifier (FWR) uses a diode bridge which consists of four diodes; two of them conduct in each half cycle of the input signal. As the input signal flips back and forth, the diodes allow the current to flow in the same direction as shown in Figure 4. The maximum output voltage of the **rectified unfiltered** signal (V_P (*FWR*)) can be found by:

$$V_P(FWR) = V_{\max}(input) - 2V_{\gamma}$$

The amount of the average value (DC value) of the FWR rectified unfiltered signal over one period is given by:

$$V_{av}(FWR) = \frac{2V_P(FWR)}{\pi} = (0.636) * V_P(FWR)$$

The frequency of the rectified output waveform can be expressed as:

$$f_o(FWR) = 2f_{source}$$
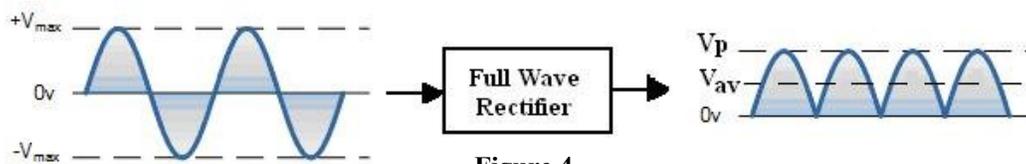
Figure 4

c) The Filter circuit: The rectified signal does not have constant value and it has plenty of ripples so it is not good for applications. It has to be smoothed out in order to obtain direct signals (it is dc only in the sense that it does not change polarity). This can be done by adding **Filter Capacitor** parallel to the load, with a value that is chosen to get minimum ripple voltage. The capacitor will charge to the peak voltage of the rectified signal (V_P (*HWR*) or V_P (*FWR*)) and when the rectified signal voltage falls below the capacitor maximum voltage, it start to discharge through the load resistance R_L as shown in Figure 5. The discharge time for the capacitor ($\tau = RC$) has to be greater than the period of the input signal (T).

The output filtered signal average voltage can be found as:

$$V_{av}\,(filtered) = V_P\,(rectified) - \frac{V_{r-pp}}{2}$$

Where $V_P\,(rectified)$ is the HWR or FWR signal peak voltage and V_{r-pp} is the ripple signal peak to peak voltage. V_{r-pp} represents the difference between the capacitor maximum voltage and the capacitor voltage after discharging, which can be found by the equation:

$$V_{r-pp} = V_1 - V_2 = \frac{V_P\,(rectified)}{2\,fRC}$$

Where (f) is the frequency of the input signal, (R) is the load resistance and (C) is the filtered capacitor. The ripple voltage can be controlled by changing R, C, f and V_P (rectified) (Note: V_P (rectified) is related to the input signal maximum voltage).
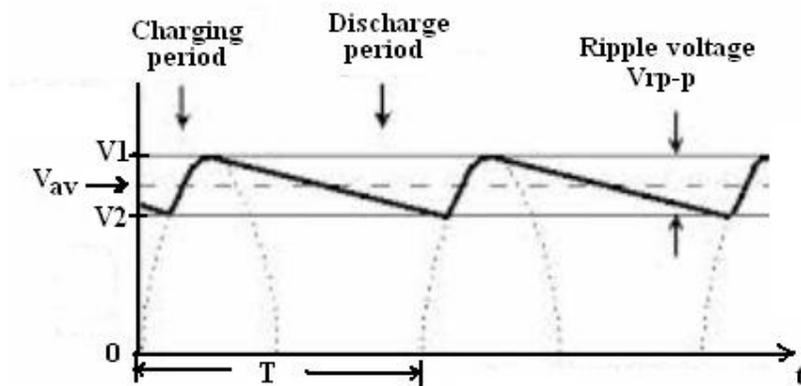
Figure 5

The percentage ripple is a measure of how much efficient is the filter. High values of percentage ripple means bad filter and low value of percentage ripple means good filter,
it can be expressed as:

$$Percentage\quad Ripple\,\% = \frac{V_{r-pp}}{V_{av}\,(filtered)}*100\%$$

2) The Peak Detector circuit: consists of a series connection of a diode and a capacitor, used to get a DC output voltage without ripple from an AC input signal. When the diode is forward biased the capacitor start charging until it reaches to a maximum value given by:

$$V_{max}\,(capacitor) = V_{max}\,(input) - V_\gamma$$

When the input signal falls below the maximum voltage stored in the capacitor, the diode will be reverse biased (open circuit). Since there is no path for the capacitor to discharge, it will retains on its maximum voltage value even as the waveform drops to zero as shown in Figure 6.
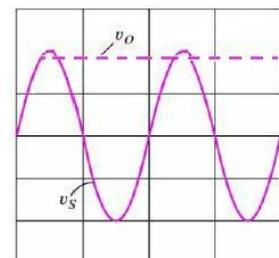

Figure 6

Note: The Other Diode applications will be explained and tested in the next experiment.

Procedure

Equipments & Part List

1- Oscilloscope.   2- Function Generator (FG) or Signal Generator.
3- Digital Multimeters (DMM).   4- DC power supply.
5- Project Breadboard.   6- Resistors of 100, 1K, 10K, 100K.
7- Capacitors of 1μF and 2.2μF.   8- Diode 1N4006 and Bridge rectifier.
9- Connection Wires and coaxial cables probes.

PART-A Diode Testing:

1- Insert the two leads of the Diode 1N4006 to the breadboard.
2- Turn on the DMM and select the dial point to diode test ▸⊢. Plug a black test lead into the Common (−) banana socket and a red test lead into the VΩ▸⊢ (+) banana socket of the DMM.
3- Connect the red lead of the DMM to the Anode terminal and the black lead of the DMM to the Cathode terminal then read the DMM and records it in the answer sheet.
4- Connect the black lead of the DMM to the Anode terminal and the red lead of the DMM to the Cathode terminal then read the DMM and records it in the answer sheet.
5- Determine if the diode is working well or not. Explain your test result.

PART-B Diode (i-v) characteristics

B-1 Forward Bias Mode

1- Construct the circuit shown in Figure 7. (Make sure your diode has the correct polarity).
2- Ask the instructor to check your circuit.
3- Set the DC power supply output to minimum value fully Counter Clock Wise (CCW). Then switch it ON.
4- Adjust the voltage source (Vs) corresponding to Table 1 on the answer sheet. Use the DMM to measure the remaining values and record it in Table 1.
5- When finish, set the (VS) to 0.0V. Then switch OFF the DC power supply.
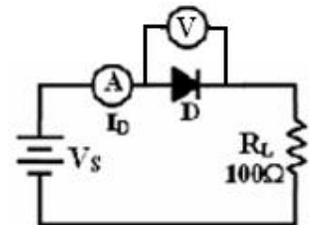
Figure 7

B-2 Reverse Bias Mode

1- Reverse the polarity of the DC power source (V_S) as shown in Figure 8.
2- Adjust the voltage source (V_S) corresponding to Table 2 in the answer sheet. Use the DMM to measure the diode current and voltage then record them 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 from part B-1 and part B-2 above, plot the diode (*i-v*) characteristic curve.

Figure 8.

5- Write the equation of the load line for the circuit and draw it on the same (*i-v*) characteristic curve.
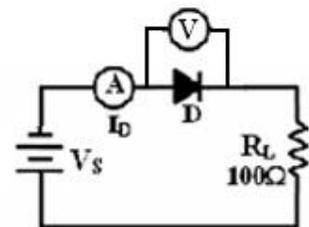
PART-C Rectification

C-1 Unfiltered Half-wave Rectifier

1- Construct the circuit shown in Figure 9.a by using $R_L=1k\Omega$.
2- Switch ON the Oscilloscope and put the channel coupling for CH2 to DC.
3- Switch ON the Function Generator and set the source voltage (V_S) to **10V$_{p-p}$**, **100Hz**, sinusoidal.
4- Use the Oscilloscope to measure and record V_{Load-P} from CH2. Sketch the Oscilloscope screen on the respective grids in Table 3 on the answer sheet.
5- Reverse the diode according to Figure 9.b and repeat step 4.
6- What is the Output Signal Frequency.
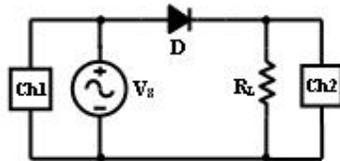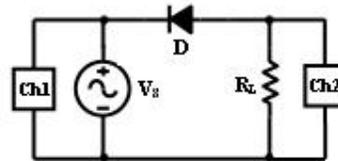
Figure 9.a   Figure 9.b

C-2 Filtered Half-wave Rectifier

1- Construct the circuit shown in Figure 10.
2- Use a Capacitor **C = 1µF** and Load resistor **R_L = 1kΩ.**
3- From the signal shown on the scope screen, find the following and record the results in Table 4 in the answer sheet:

Figure 10

   a) Sketch the oscilloscope screen on the respective grids.
   b) Measure the **Average Voltage (V$_{avg}$)** using DMM (put the DMM to DC).
   c) Measure the **Ripple Voltage V_{r-pp}** *(since V_{r-pp} = V_{out-pp})* from CH2.
   d) Calculate the **Ripple Percentage (Ripp.%)**.
4- Repeat step 3 for all the values of capacitors and resistors as shown in Table 4. 5- Switch OFF the Function Generator, Oscilloscope and DMM.
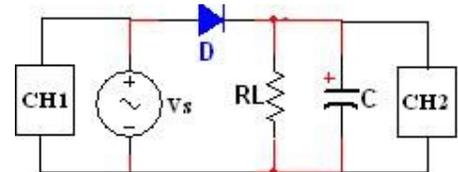
C-3 Full-wave Bridge Rectifier

1- Construct the circuit shown in Figure 11 by using the **Bridge rectifier** component.
2- Switch ON the Function Generator and set the source voltage (V_S) to **10V$_{p-p}$**, **100Hz**, sinusoidal signal.
3- Use the Oscilloscope CH2 to observe the output FWR signal, and to do that you had to disconnect CH1 **Why?**
4- What is the Output Signal Frequency?
5- From the signal shown on the scope screen, find the following and record the results in Table 5 in the answer sheet:

Figure 11

   a) Sketch the oscilloscope screen on the respective grids.
   b) Measure the **Average Voltage (V$_{avg}$)** using DMM (put the DMM to DC).
   c) Measure the **Ripple Voltage V_{r-pp}** *(since V_{r-pp} = V_{out-pp})* from CH2.
   d) Calculate the **Ripple Percentage (Ripp.%)**.
6- Repeat step 5 for all the values of capacitors and resistors as shown in Table 5.
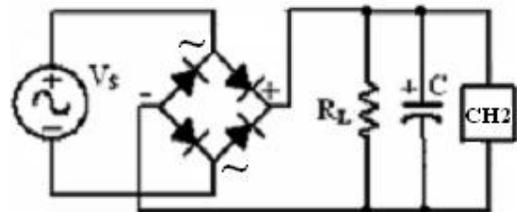
7- On the same circuit shown in Figure 11 use $R_L = 1\ k\Omega$, and $C = 1.0\ \mu F$, measure the ripple
voltage ($V_{r\text{-}PP}$) when the input signal frequency is 500Hz, 1kHz, 5kHz and 10kHz and
record them in Table 6 in the answer sheet. What is the effect of increasing input signal
frequency on the ripple voltage? Explain.

8- How many ways to control the ripple voltage? Mention.

PART-D The Peak Detector

1- Construct the circuit shown in Figure 12 using $C = 10\ \mu F$.
2- Switch ON the Function Generator and set the source voltage
(V_S) to $8V_{p\text{-}p}$, *1kHz*, sinusoidal.
3- Sketch the oscilloscope screen shown on CH2 on the
respective grids on the answer sheet.
4- Comment on the output signal shown on CH2.
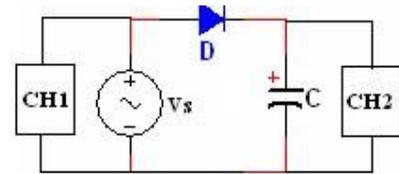
Figure 12

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Mechatronics Engineering Department
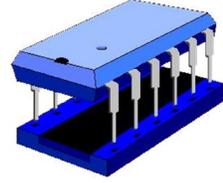
Electronics Lab Report

0908223

Experiment No.: _____   **Student Group: _____**

Experiment Name: _____

Students Name:

  1) **_____**

  2) **_____**

  3) **_____**

  4) **_____**

Diode Characteristics and Applications (1)

PART-A Diode Testing

3- Connect the red lead of the DMM to the Anode terminal and the black lead of the DMM to the Cathode terminal then read the DMM and records it in the answer sheet.

....

....

4- Connect the black lead of the DMM to the Anode terminal and the red lead of the DMM to the Cathode terminal then read the DMM and record it in the answer sheet.

....

....

5- Determine if the diode is working well or not. Explain your test result

....

....

PART-B Diode (i-v) characteristics

B-1 Forward Bias Mode

4-

Table 1

V_S (V)	0.0	0.2	0.4	0.6	0.8	1.0	1.2
I_D (mA)							
V_D (V)							

B-2 Reverse Bias Mode

2-

Table 2

V_S (V)	2.0	5.0
I_D (mA)		
V_D (V)		

4- Using the data from part B-1 and part B-2 above, plot the diode (i-v) characteristic curve.
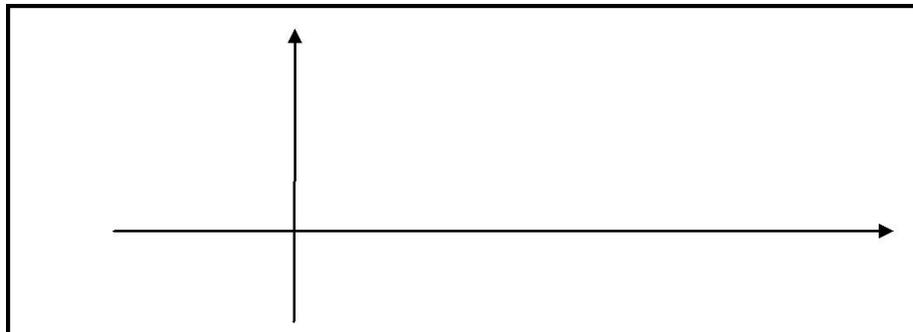
5- Write the equation of the load line for the circuit and draw it on the same (*i-v*) characteristic curve.

……………………………………………………………………………………

……………………………………………………………………………………

PART-C Rectification

C-1 Unfiltered Half-wave Rectifier
4-

Table 3

Waveform for Figure 4.a	Waveform for Figure 4.b
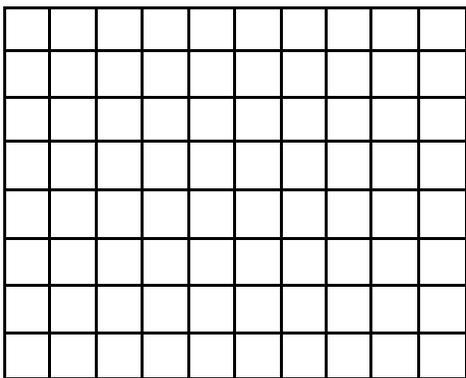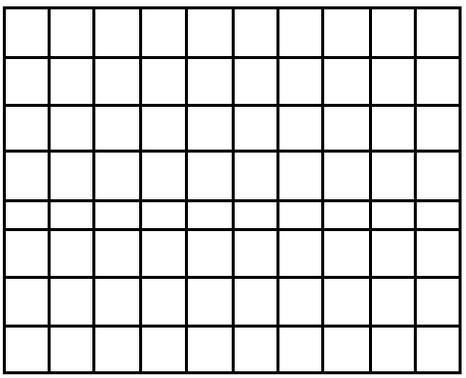
6- What is the Output Signal Frequency?

……………………………………………………………………………………

C-2 Filtered Half-wave Rectifier

Table 4

V_S & V_L waveforms	$V_{r\text{-}PP}$ (V)	V_{avg} (V)	*Ripp.%*	V_S & V_L waveforms
	$R_L = 1$ kΩ. $C = 1$ μF.			
	$R_L = 10$ kΩ. $C = 1$ μF.			
	$R_L = 10$ kΩ. $C = 2.2$ μF.			
	$R_L = 100$ kΩ. $C = 2.2$ μF.			
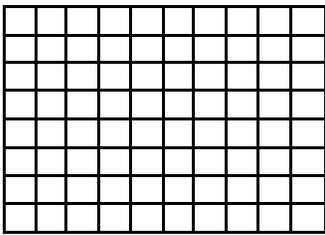
C-3 Full-wave Bridge Rectifier

Table 5

V$_L$ waveform	V$_{r\text{-}PP}$ (V)	V$_{avg}$ (V)	*Ripp.%*	V$_L$ waveform
	R$_L$ = 1 kΩ. **Without capacitor**	
	R$_L$ = 1 kΩ. C = 2.2 µF.	
	R$_L$ = 10 kΩ. C = 2.2 µF.	
	R$_L$ = 100 kΩ. C = 2.2 µF.	

3- Use the Oscilloscope CH2 to observe the output FWR signal, and to do that you had to disconnect CH1 **Why?**

. . . .

. . . .

4- What is the Output Signal Frequency?

. . . .

. . . .

7- On the same circuit shown in Figure 6 use **R$_L$ = 1 kΩ,** and **C = 1.0 µF**, measure the ripple voltage (**V$_{r\text{-}PP}$**) when the input signal frequency is 500Hz, 1kHz, 5kHz and 10kHz and record it in Table 6 in the answer sheet. What is the effect of increasing input signal frequency on the ripple voltage? Explain.

Table 6

Frequency (kHz)	0.5	1	5	10
V$_{r\text{-}PP}$ (V)				

Explain: . . . .

. . . .

8- How many ways to control the ripple voltage? Mention.

…………………………………………………………………………………

…………………………………………………………………………………

PART-D Peak Detector

3-

4- Comment on the output signal shown on CH2?

…………………………………………………………………………………

…………………………………………………………………………………

Objectives:
• To investigate some of the diode applications such as the rectifier circuits clippers and clampers

Pre-lab

Construct all the circuits in the sheet using Multisim.

1) Diode Clipper circuits: also called <u>limiters</u>, is used to clip (limit) off the positive or negative part of an input signal. They can be used for circuit protection or waveform shaping. Types of Diode clipper: Positive, Negative and dual clipper circuits. The **Positive Clipper** circuit clips (limits) the output signal during the positive half cycle of the input signal to (V_γ) (the diode is forward biased), and passes the entire input voltage during the negative half cycles of the input signal (the diode is reversed biased). The positive clipper circuit with a bias (adding DC voltage to the circuit) will clip the output signal to ($V_{DC} + V_\gamma$). The **Negative Clipper** circuit allows the positive half cycle of the input voltage to pass (the diode is reversed biased) and clips the negative half cycle to ($-V_\gamma$) (the diode is forward biased). The negative clipper circuit with a bias (adding DC voltage to the circuit) will clip the output signal to ($-V_{DC} + -V_\gamma$).

The **Dual diode clipper** is a combination of positive and negative clipper circuits, where both positive and negative half cycles of the input signal are clipped to and respectively. The dual clipper circuit with a bias (adding two DC supplies to the circuit) will clip the output signal to and respectively. The output signals from the types of clipping circuits are shown in Figure 2.
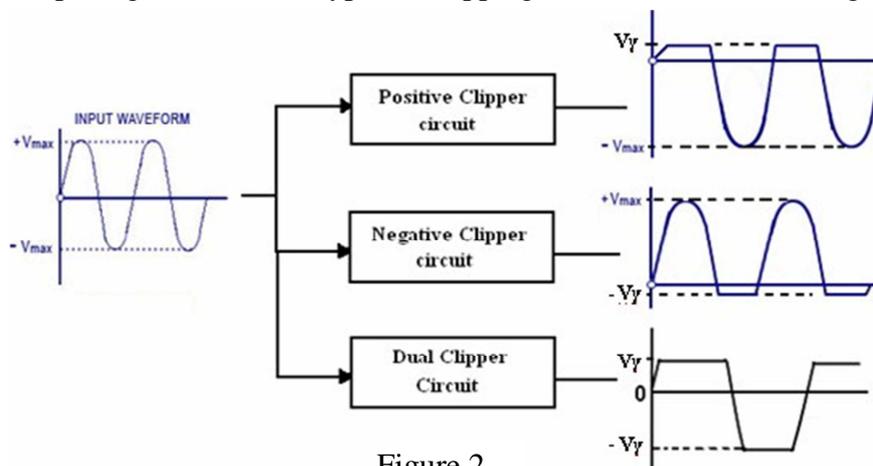
Figure.2

2) Diode Clamper circuits: also called <u>DC restorers</u> circuit, is used to add a dc level to an AC signal. When we want to get **-5V** to **0V** voltage from a signal swings between **0V** and **5V** we can provide the proper DC offset by using a passive Clamper circuit. For the clamping circuit to work properly, the period (T) of the input signal should be less than the time constant ($\tau=RC$) of the circuit by a factor of **5** approximately (τ >>T). This condition is needed to avoid changing significantly the voltage across the capacitor during the input signal period.

The output signal is simply the input signal shifted by the voltage across the capacitor which could be positive or negative. The **Positive Clamper** circuit shifts the input signal upward with an amount of the capacitor voltage while the **Negative Clamper** shifts the input signal downward with an amount of the capacitor voltage. The positive or negative clamper circuits with a bias (adding DC voltage to the circuit) will shift the output signal to upward or downward respectively with an amount of the capacitor voltage plus the value of
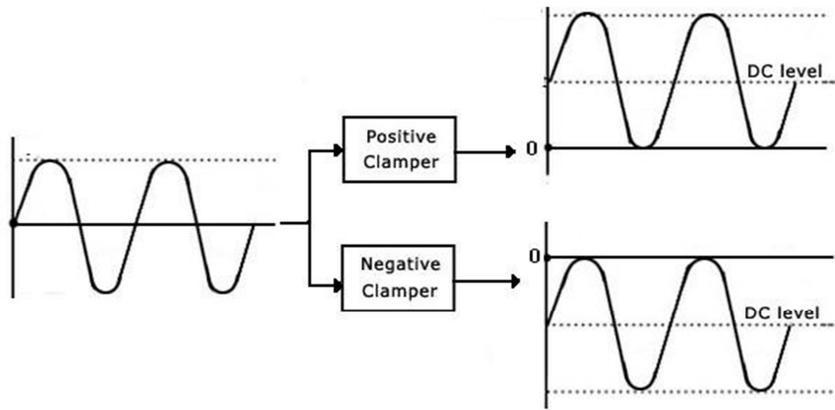
Figure.3

the DC voltage. The output signals from the positive and the negative clamper circuits are shown in Figure 3.

Procedure:

Equipment & Part List:

1- Oscilloscope
2- Function Generator (FG) .
3- Two Digital Multimeters (DMM).
4- DC power supply.
5- Project Breadboard.
6- Resistors of 100, 1K, 10K, 100K.
7- Capacitors of 1µF,2.2 µF.
8- Diode 1N4006.
9- Connection Wires and coaxial probes

1- Full-wave Bridge Rectifier

1- Construct the circuit shown in Figure.4 by using the **Bridge rectifier** component.

2- Switch ON the Function Generator and set the source voltage (V_S) to **$10V_{p-p}$, $100Hz$**, sinusoidal signal.

3- Use the Oscilloscope CH2 to observe the output FWR signal, and to do that you had to disconnect CH1 **Why?**

4- What is the Output Signal Frequency?

Figure.4

5- From the signal shown on the scope screen, find the following and record the results in Table 1 in the answer sheet:

  a) Sketch the oscilloscope screen on the respective grids.

  b) Measure the **Average Voltage (V_{avg})** using DMM (put the DMM to DC). c) Measure the **Ripple Voltage V_{r-pp}** (since $V_{r-pp} = V_{out-pp}$) from CH2.

  d) Calculate the **Ripple Percentage (Ripp.%)**.

6- Repeat step 5 for all the values of capacitors and resistors as shown in Table 1.

7- On the same circuit shown in Figure 3 use **$R_L = 1\ k\Omega$,** and **$C = 1.0\ \mu F$**, measure the ripple voltage (**V_{r-PP}**) when the input signal frequency is 500Hz, 1kHz, 5kHz and 10kHz and record them in Table 6 in the answer sheet. What is the effect of increasing input signal frequency on the ripple voltage? Explain.

8- How many ways to control the ripple voltage? Mention.
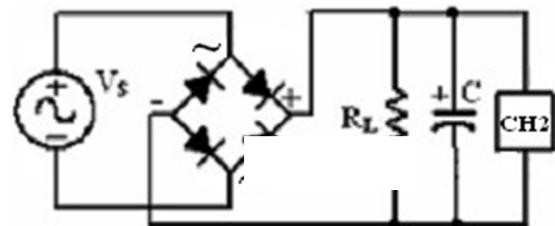
PART-A The Diode Clipper circuits
A-1 Positive Clipper circuit
1- Construct the circuit shown in Figure 5 by using *1N4006 Si* diode.
2- Switch ON the Function Generator and set the voltage (V_S) to $8V_{p-p}$, *100Hz*, sinusoidal.
3- Connect CH1 and CH2 of the Oscilloscope to V_S and V_O respectively and set the channel coupling of CH2 to DC coupling mode.
4- Sketch the Oscilloscope screen on the respective grids in Table 1 in the answer sheet and label the necessary voltages.
5- Comment on the output signal shown on the CH2.
6- Switch OFF the Function Generator, and insert 2V DC power supply as shown in Figure 6 (**Positive clipper with bias**), then switch ON the Function Generator and repeat step 4.
7- Comment on the output signal shown on the CH2.
8- When finished, switch OFF the DC power supply and the Function Generator.
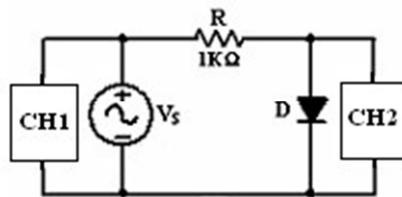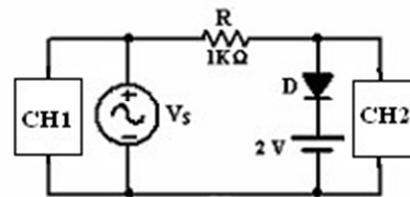
Figure 5   **Figure 6**

A-2 Negative Clipper circuit
1- Construct the circuit shown in Figure 7 by reversing the diode of the previous circuit.
2- Connect CH1 and CH2 of the Oscilloscope to V_S and V_O respectively and set the channel coupling for CH2 to DC coupling.
3- Sketch the Oscilloscope screen on the respective grids in Table 2 in the answer sheet and label the necessary voltages.
4- Comment on the output signal shown on the CH2.
5- Switch OFF the Function Generator, and insert 2V DC power supply as shown in Figure 8 (**Negative clipper with bias**), then switch ON the Function Generator and repeat step 3.
6- Comment on the output signal shown on the CH2.
7- When finished, switch OFF the DC power supply and the Function Generator.
8- Explain the effects of using a diode that is not ideal.
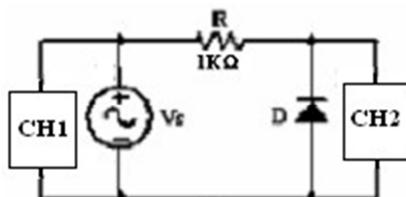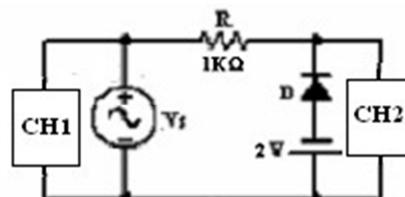
Figure.7   Figure.8

A-3 Dual Clipper circuit

1- Construct the circuit shown in Figure 9, where the supply Vs is sinusoidal signal with **8Vpp, 100Hz** and **R=1kΩ**.
2- Connect CH1 and CH2 of the Oscilloscope to V_S and V_O respectively and set the channel coupling for CH2 to DC coupling.
3- Sketch the Oscilloscope screen on the respective grids in Table 3 in the answer sheet and label the necessary voltages.
4- Comment on the output signal shown on the CH2.

5- Switch OFF the Function Generator, and insert two DC power supplies **V1 = V2 = 2V** as shown in Figure 10 (To avoid any problems and short circuits, connect the branch of D1 in series with V1 somewhere on the breadboard, connect the other branch of D2 in series with V2 in another place, then connect both branches in parallel). Switch On the DC supplies and the Function Generator then repeat step 3.
6- Comment on the output signal shown on the CH2.
7- When finished, switch OFF the DC power supply and the Function Generator.
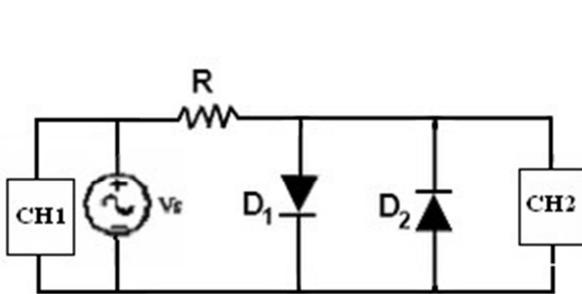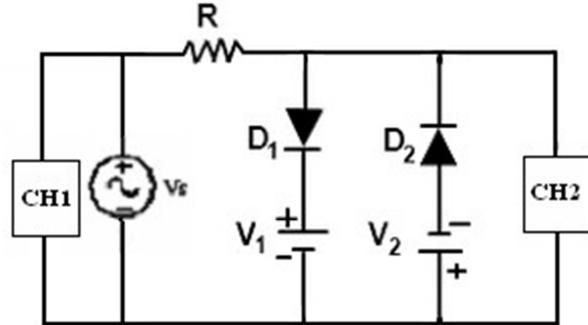
Figure.9   Figure.10

## PART-B The Diode Clamper circuits
B1- Positive Clamper circuit

1- Construct the circuit shown in Figure 11, where the supply Vs is sinusoidal signal with **8Vpp,100Hz**
2- Connect CH1 and CH2 of the Oscilloscope to V_S and V_O respectively and set the channel coupling for CH2 to DC coupling.
3- Sketch the Oscilloscope screen on the respective grids in Table 4 in the answer sheet and label the necessary voltages.
4- What is the difference between the input and the output?
5- To plot the voltage of the capacitor, connect CH2 parallel to the capacitor and disconnect CH1 (**Why?**). Sketch the capacitor waveform respective grids in Table 4 in the sheet answer and label the necessary voltages.
6- Switch OFF the Function Generator and insert 2V DC power supply as shown in Figure 12 (**Positive Clamper with bias**), then switch ON the Function Generator and repeat step 3.
7- What is the effect of adding DC bias voltage to the positive clamper circuit?
8- When finished, switch OFF the Function Generator.
9- What happen when using clamping circuit to drive low load impedance? Does the circuit still work as clamper? Explain.
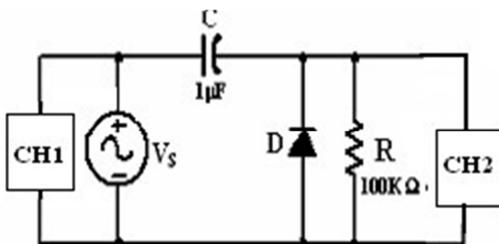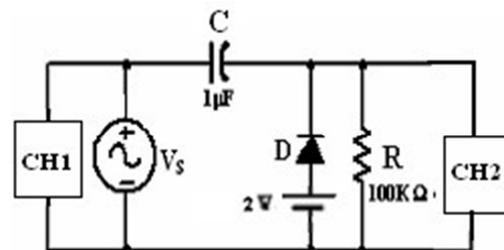
Figure 11   Figure 12

B-2 Negative Clamper circuit
1- Construct the circuit shown in Figure 13, where the supply Vs is sinusoidal signal with **8Vpp, 100Hz**
2- Connect CH1 and CH2 of the Oscilloscope to V_S and V_O respectively and set the channel coupling for CH2 to DC coupling.

3- Sketch the Oscilloscope screen on the respective grids in Table 5 in the answer sheet and label the necessary voltages.

4- What is the difference between the input and the output?

5- To plot the voltage of the capacitor, connect CH2 parallel to the capacitor and disconnect CH1 (**Why?**), sketch the capacitor waveform respective grids in Table 5 in the sheet answer and label the necessary voltages on the figure.

6- Switch OFF the Function Generator, and insert 2V DC power supply as shown in Figure 14 (**Negative Clamper with bias**), then switch ON the Function Generator and repeat step 3.

7- What is the effect of adding DC bias voltage to the Negative clamper circuit?

8- When finished, switch OFF the all the instruments.
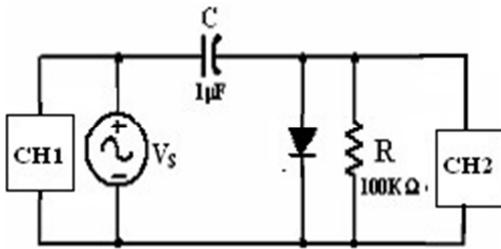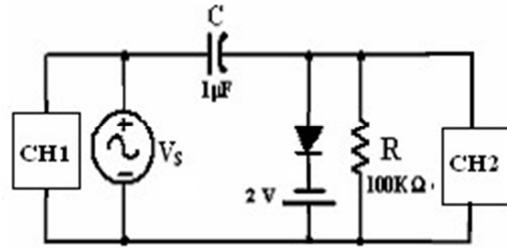
Figure 13   **Figure 14**

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Mechatronics Engineering Department
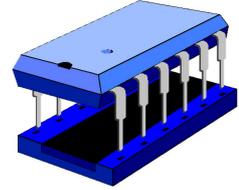
Electronics Lab Report

0908223

Experiment No.: _____   **Student Group:** _____

Experiment Name: _____

Students Names:

1) _____

2) _____

3) _____

4) _____

PART-A The Diode Clipper circuits
A-1 Positive Clipper circuit

Positive clipper data of Figure 3.a	Positive clipper data of Figure 3.b
$V_{O-min} =$ …………… $V_{O-max} =$ ……………	V_{O-n}
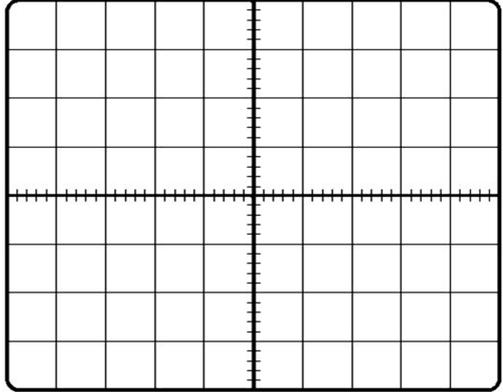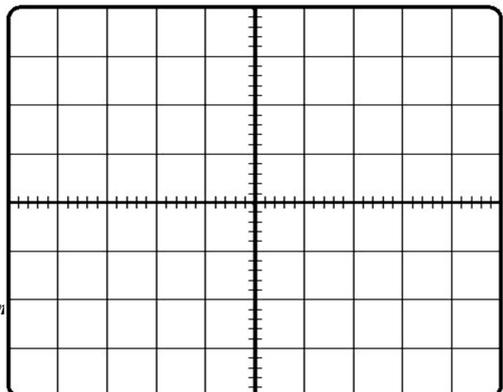
5- Comment on the output signal shown on the CH2.

………………………………………………………………………………

………………………………………………………………………………

7- Comment on the output signal shown on the CH2.

………………………………………………………………………………

………………………………………………………………………………

A-2 Negative Clipper circuit

Negative clipper data of Figure 4.a	Negative clipper data of Figure 4.b
$V_{O-min} =$ …………… $V_{O-max} =$ ……………	V_{O-n} $V_{O-min} =$ …………… $V_{O-max} =$ ……………
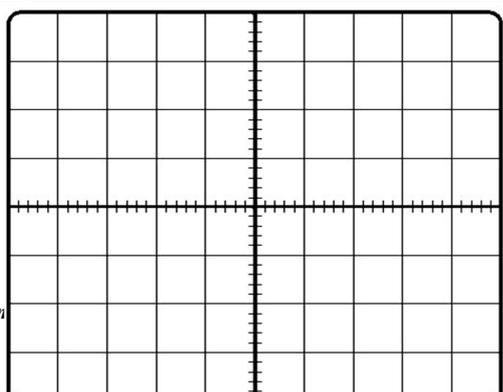
4- Comment on the output signal shown on the CH2.

………………………………………………………………………………

………………………………………………………………………………

6- Comment on the output signal shown on the CH2.

…………………………………………………………………………………

…………………………………………………………………………………
8- Explain the effects of using a diode that is not ideal.

…………………………………………………………………………………

…………………………………………………………………………………

A-3 Dual Clipper circuit

Negative clipper data of Figure 5.a	Negative clipper data of Figure 5.b
V_{O-min} = ………… V_{O-max} = …………..	V_{O-n} V_{O-min} = ………… V_{O-max} = …………..
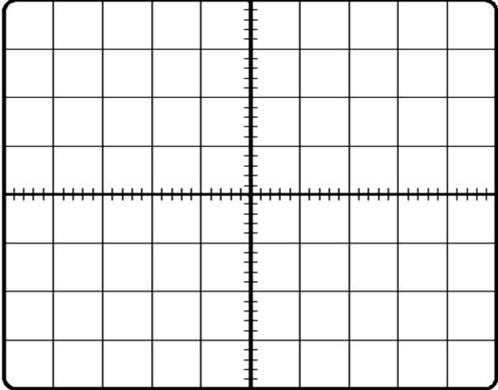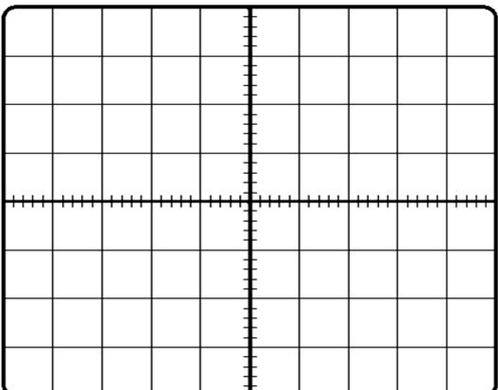
4- Comment on the output signal shown on the CH2.

…………………………………………………………………………………

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6- Comment on the output signal shown on the CH2.

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PART-B The Diode Clamper circuits
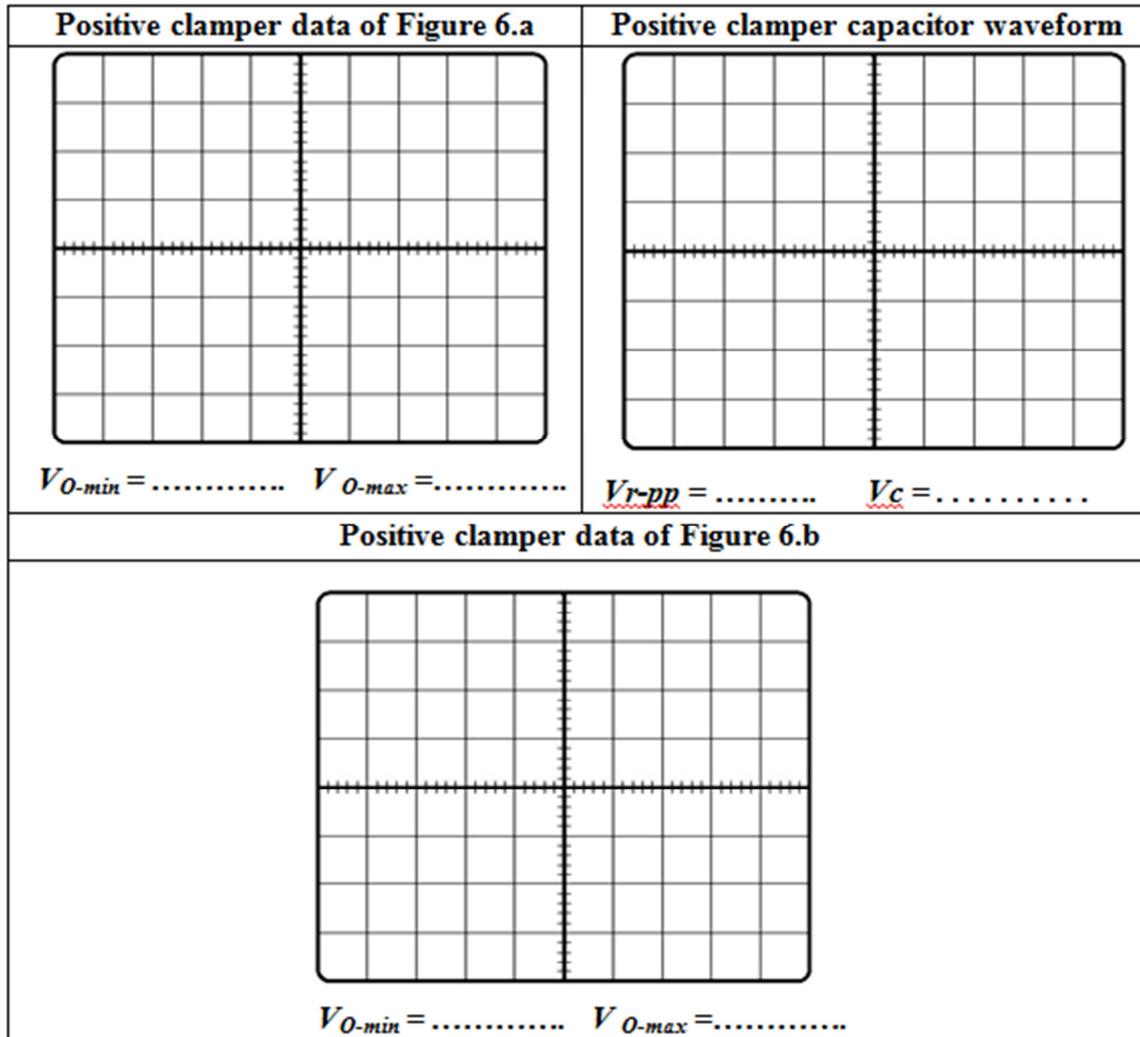
B1- Positive Clamper circuit

Positive clamper data of Figure 6.a	Positive clamper capacitor waveform
$V_{O-min} =$ .... $V_{O-max} =$	$V_{r-pp} =$ .... $V_C =$ ....

Positive clamper data of Figure 6.b
$V_{O-min} =$ .... $V_{O-max} =$ ....

4- What is the difference between the input and the output?

....

....

7- What is the effect of adding DC bias voltage to the positive clamper circuit?

....

....

9- What happen when using clamping circuit to drive low load impedance? Does the circuit still work as clamper? Explain.

....

12

B-2 Negative Clamper circuit

Negative clamper data of Figure 7.a	Negative clamper capacitor waveform
$V_{O\text{-}min} = \ldots\ldots\ldots\ldots$ $V_{O\text{-}max} = \ldots\ldots\ldots\ldots$	$V_{r\text{-}pp} = \ldots\ldots\ldots$ $V_C = \ldots\ldots\ldots$
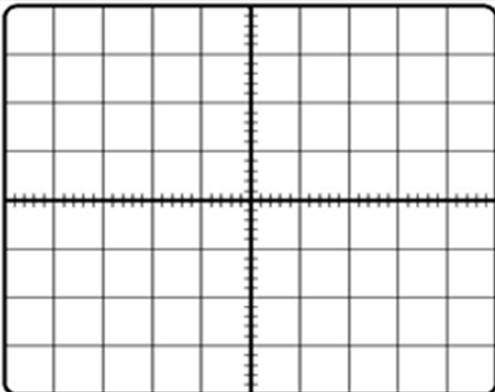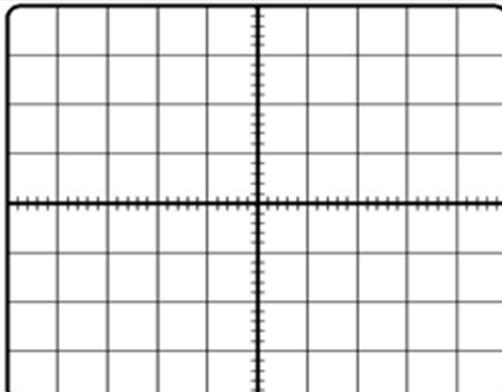
Negative clamper data of Figure 7.b
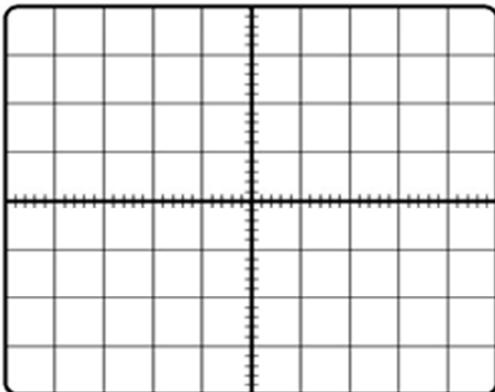
$V_{O\text{-}min} = \ldots\ldots\ldots\ldots$ $V_{O\text{-}max} = \ldots\ldots\ldots\ldots$

4- What is the difference between the input and the output?

....

....

7- What is the effect of adding DC bias voltage to the negative clamper circuit?

....

....

Exp. 4

Zener Diode Characteristics & Applications

Objectives

To be familiar with the reverse Zener Diode Characteristic and the application of the Zener diode as Voltage regulation and Clipper.

Theory

The Zener diode is a diode which allows current to flow in both directions. The Zener diode *i-v* characteristic shown in Figure 1 shows three operating regions: Forward Bias region, Reverse off region and Breakdown region. The Zener in the **Forward Bias region** works the same manner as an ideal diode and permit current to flow when the voltage across the diode is greater than the cut-in voltage Vγ. In the **Reverse off region**, the Zener diode acts as an open circuit and no current flow in the circuit. In the **Breakdown region**, the Zener diode permits the current to flow in the reverse direction when the voltage is above a certain value known as the breakdown voltage (V_{zth}).

The Zener diode has almost a constant voltage across it as long as the Zener diode current is between the knee current $I_{Z(min)}$ and the maximum current rating $I_{Z(max)}$.

The Zener diode applications are:

1) The **voltage regulator circuit:** is required to maintain a constant dc output voltage across the load terminals in spite of the variation in the input main voltage (Vs) or Change in the load current (I_L). The Zener voltage regulator circuit shown in Figure 2 consists of a current limiting resistor **R_S** (to protect the Zener diode from high current at no load condition) connected in series with the input voltage **Vs** and Zener diode in reverse biased condition connected in parallel with the load R_L. Zener diode **MUST be operated under load**, if not, the Zener diode may burn.
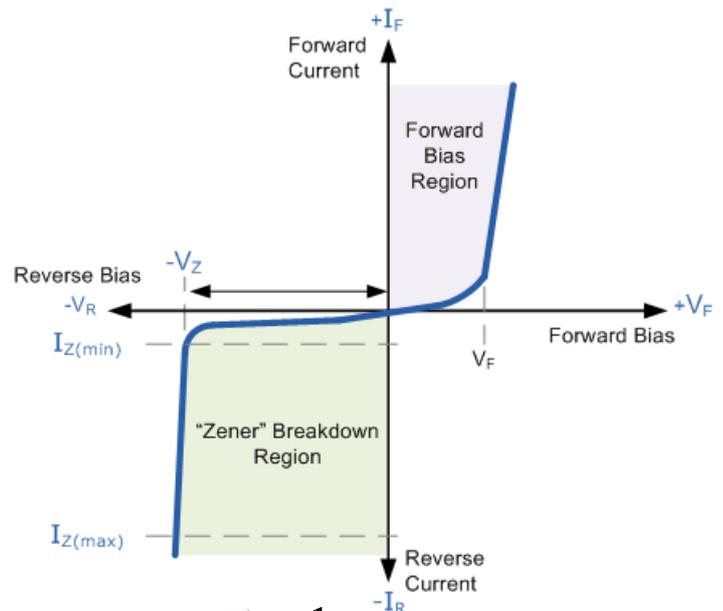
Figure 1

The input source current:
$$I_S = I_Z + I_L$$
………….. **(1)**

The drop across the series resistance R_S:
$$V_{Rs} = V_s + V_Z$$
………….. **(2)**

The current flowing through R_S:
$$I_S = \frac{V_S - V_Z}{R_S}$$
………….. **(3)**

The voltage across the Zener diode:
$$V_Z = V_{Zth} + (I_Z)(r_Z) = V_L$$
………….. **(4)**

Where (r_z) is the internal resistance of the Zener diode when it is reversed biased.

Two Types of voltage regulation can be defined:
a) **Source regulation** is defined as the change in the output voltage with respect to the change of the input voltage while keeping the load resistance **R_L** fixed (the load current **I_L** will be constant too).

$$Source \quad Re\,gulation\% = \frac{\Delta V_L}{\Delta V_s} x100\%$$

Since the load is fixed, we can assume it (**R_L** = ∞ so the Zener current **I_z** = **I_s**), as the input voltage (Vs) increases, **Is** increase according to equation (3). The increase in **I_z** will not affect huge variation on **V_L** so the output voltage will remain constant.

b) **Load regulation** is defined as the change in load voltage with respect to change in the load current (by vary the load resistance **R_L** value) while keeping the input voltage constant. To find the load regulation, we calculate the output voltage in two cases: removing the load **R_L** (find $V_{No\text{-}load}$) and applying load (find $V_{full\text{-}load}$). From reverse bias characteristics even **I_z** changes, **V_z** remains same so the output voltage remains fairly constant.

$$\textbf{Load Regulation} = \frac{V_{full-Load} - V_{No-load}}{V_{full-Load}} x100\%$$

2) **The Clipper circuit:** is the same as the normal diode clipping, but you had to remember that Zener diode work in both directions.

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Procedure

Equipments & Part List

1- Oscilloscope   2- Function Generator (FG) .
3- Two Digital Multimeters (DMM).   4- DC power supply.
5- Project Breadboard.   6- Resistors of 100, 220, 1K and 10K.
7- Zener diode 5V.   8- Connection Wires and coaxial cables.

PART A- Zener Diode Characteristics

1- Construct the circuit shown in Figure 2 by using *Zener* diode. (*Make sure the diode is connected with the correct polarity*).

2- Set the DC power supply output adjustment potentiometer fully counter clock wise (CCW), then switch it ON.

3- Adjust the voltage source (V_S) corresponding to Table 1 in the answer sheet. Use the DMM to **measure Iz** and **Vz** then record them in Table 1.

4- When finished, set the ($_{VS}$) to **0.0V**. Then switch OFF the DC power supply.

Figure 2

5- Plot the reverse diode current **Iz** *versus* the reverse diode voltage **Vz** and label each axis with suitable units.

6- From the *i-v* characteristics you draw, determine the Zener breakdown voltage V_{Zth}.

7- Calculate the Zener diode dynamic resistance r_Z, using the following equation:

$$r_Z = \Delta V_D / \Delta I_Z \qquad (\text{ for } |V_{ZK}| < |V_D| < |V_{ZM}|)$$

8- Using the data in Table 1, calculate the percentage Source regulation **(S.R.%)** when **Vs** varies between (7 – 9) volt.
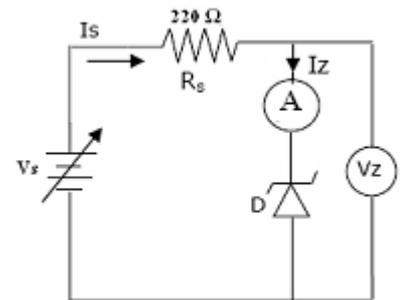
PART-B The Zener Diode as a Voltage Regulator
B-1 Effect of the DC Voltage source on the Zener regulator

1- Construct the circuit shown in Figure 3.

2- Set the DC power supply output fully counter clock wise. Then switch it ON.

3- Adjust the voltage source (V_S) corresponding to Table 2 in the answer sheet. Use the DMM to **measure** the load voltage V_L, I_S and record the results in Table 2. **Calculate** I_L , I_Z and P_Z using the following equations:

$$I_L = V_L / R_L , \quad I_Z = I_S - I_L \quad and \quad P_Z = (I_Z)(V_Z).$$

Figure 3

4- When finished, set the (V_S) to **0.0V**.

6- Explain what happens to the output voltage V_L and why.

7- Calculate the value of the minimum Source voltage (V_{Smin}) in Figure 3 for which below this value the Zener diode will no longer provide voltage regulation. (*Assume that the minimum Zener diode current I_{Zmin} = 1 mA*). Compare your calculated result with that from Table 2.

8- Calculate the value of maximum source voltage (V_{Smax}) in Figure 3, for which the greater than this value the Zener diode will reach the maximum power dissipation, (*Assume that the maximum Zener diode current I_{Zmax} = 25 mA*).

9- Calculate the percentage load regulation (**L.R %**) of your circuit by taking **$V_{No-load}$** from Table 1 and **$V_{full-load}$** from Table 2 at **Vs > 8** volt, then record it in Table 2.

10- Calculate the minimum value of the series resistor **R_{S-min}** in Figure 3 at V_S = *10V* and **R_L = 1 KΩ**. (*Assume that $I_{Z(max)}$ = 25 mA and $I_{Z(min)}$ = 1 mA*).

B-2 Effect of the Load Resistance on the Zener regulator

1- Set the DC power source (V_S) to **10.0V** as shown in Figure 4.

2- Use the DMM to **measure** the load voltage V_L and I_S and record it in Table 3. **Calculate** I_L, I_Z and P_Z.

3- Replace the load resistance R_L corresponding to Table 3. Then repeat step 2.

4- When finished, set the (V_S) to **0.0V**, then switch OFF the DC power supply and disconnect the circuit.


Figure 4

5- Calculate the minimum value of the load resistance (**R_{Lmin}**) in Figure 4, for which below this value the Zener diode will no longer provide voltage regulation. Verify your calculation experimentally. (*Assume I_{Zmin} = 1 mA*).

6- Explain why the Zener diode stops regulating for certain values of **R_L**.

7- Calculate the value of the minimum series resistor (**R_{S-min}**) in Figure 4, at no load condition (R_L = ∞). (*Assume $I_{Z(max)}$ = 25 mA*).
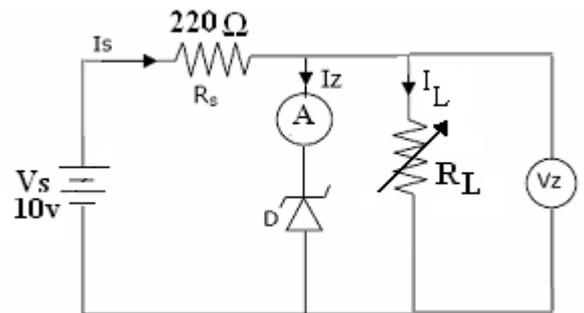
Part C: The Zener Diode as A diode clipper

1- Construct the circuit shown in Figure 5.a.

2- Set the Function Generator output to 15Vp-p, 2kHz sine wave.

3- Use the Oscilloscope to measure and record V_S from CH1 and V_L from CH2. Sketch the Oscilloscope screen on the grid shown in the answer sheet.

4- Connect the circuit shown in Figure 5.b and 5.c using two Zener diodes and repeat step 3.

5- When finished, set the (V_S) to **0.0V**.
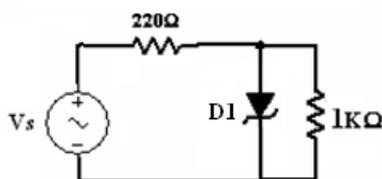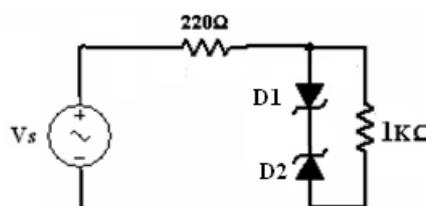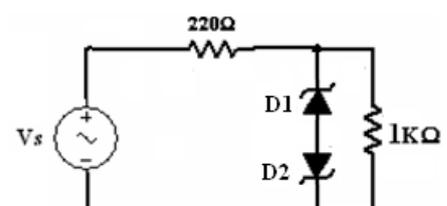
Figure 5.a   **Figure 5.b**   **Figure 5.c**

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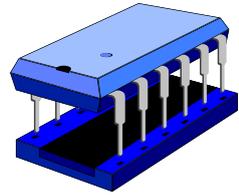
Electronics Lab Report

0908322

Experiment No.: _____   **Student Group: _____**

Experiment Name: _____

Students Name:

1) _____

2) _____

3) _____

4) _____

Zener Diode Characteristics & Applications

PART A- The Zener Diode Characteristics

Table 1

V_S (V)	1.0	2.0	4.0	5.0	5.2	5.5	6.0	6.5	7.0	8.0	9.0
I_z (mA)											
V_z (V)											

5- Plot the reverse diode current *versus* the reverse diode voltage on Figure 3 and label each axis with suitable units.
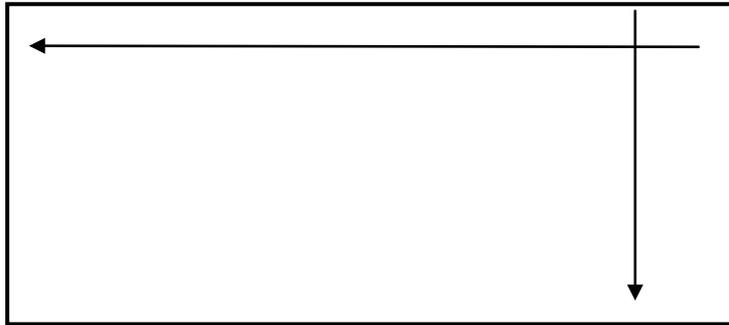

Figure 3

6- From the *i-v* characteristics you draw determine the Zener breakdown voltage V_{Zth}.

…………………………………………………………………………………

7- Calculate the Zener diode dynamic resistance r_Z.

…………………………………………………………………………………

…………………………………………………………………………………

8- Using the data in Table 1, calculate the percentage Source regulation **(S.R.%)** when **Vs** varies between 7 volt and 9 volt.

…………………………………………………………………………………

…………………………………………………………………………………

PART-B The Zener Diode Voltage Regulator
B-1 Effect of the DC Voltage source on the Zener regulator

Table 2

V_S (V)	1.0	2.0	4.0	5.0	6.0	7.0	8.0	9.0
V_L (V)								
I_S (mA)								
I_L (mA)								
I_Z (mA)								
P_Z (mW)								
L.R. %								

6- Explain what happens to the output voltage V_L and why.

. . . .

. . . .

7- Calculate the value of the minimum Source voltage (V_{Smin}) in Figure 3 for which below this value the Zener diode will no longer provide voltage regulation. (*Assume that the minimum Zener diode current $I_{Zmin} = 1\ mA$*). Compare your calculated result with that from Table 2.

. . . .

. . . .

8- Calculate the value of maximum source voltage (V_{Smax}) in Figure 3, for which the greater than this value the Zener diode will reach the maximum power dissipation, (*Assume that the maximum Zener diode current $I_{Zmax} = 25\ mA$*).

. . . .

. . . .

10- Calculate the value of the series resistor $R_{S\text{-}min}$ in Figure 3, at $V_S = 10V$ and
$R_L = 1\ k\Omega$. (*Assume $I_{Zmax} = 25\ mA$, $I_{Zmin} = 1\ mA$*)

. . . .

. . . .

B-2 Effect of the Load Resistance on the Zener regulator

Table 3

R_L (V)	10KΩ	1KΩ	220Ω	100Ω
V_L (V)				
I_S (mA)				
I_L (mA)				
I_Z (mA)				
P_Z (mW)				

5- Calculate the minimum value of the load resistance (R_{Lmin}) in Figure 4, for which below this value the Zener diode will no longer provide voltage regulation. Verify your calculation experimentally. (*Assume $I_{Zmin} = 1\ mA$*).

. . . .

. . . .

6- Explain why the Zener diode stops regulating for certain values of R_L.

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7- Calculate the value of the minimum series resistor $(R_{S\text{-}min})$ in Figure 4, at no load condition $(R_L = \infty)$. (Assume $I_{Z(max)} = 25\ mA$).

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Part C: The Zener Diode as A diode clipper

Figure 5.a
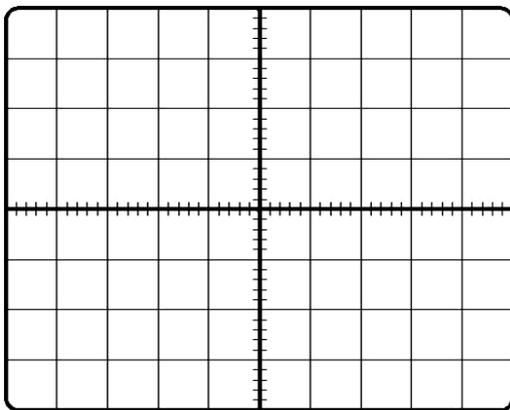
Figure 5.b
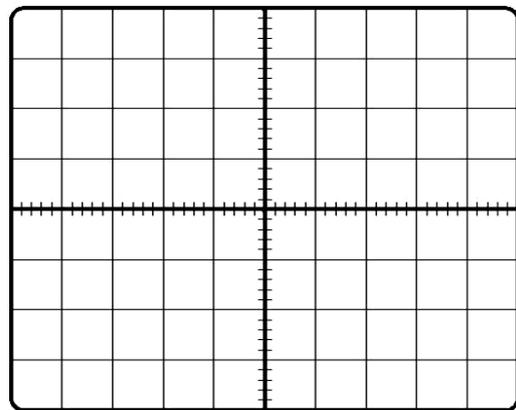
Figure 5.c
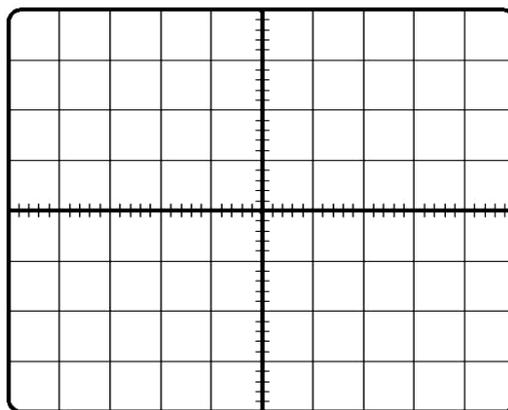
Exp. 5

Bipolar Junction Transistor Characteristics

Objectives

- To identify the leads of the Bipolar Junction Transistors (BJT) by using the DMM.
- To investigate the DC behavior, analyze and design a DC bias circuit, its operating point, and the characteristics of a BJT in several regions of operation.

Theory

A Bipolar Transistor consists of three doped regions contains a pair of PN-Junction diodes. Each PN- junction has two modes of operation (forward biased and reversed biased) which means that the transistor has four possible modes of operation depending on the bias condition for each diode. They are found everywhere and used in many electronic circuit applications such as in sensors, amplifiers, OP-AMPs, oscillators and digital logic gates.

There are different sorts, shapes, and sizes of transistor. In this experiment we will consider one basic general purpose type of transistor which is the **Bipolar Junction Transistor (BJT)** that comes in two constructions called PNP and NPN as shown in Figure 1, which show the block diagram and circuit symbol for each type. For this experiment we will use the **BC107** NPN transistor which is built into a standard **TO-18** package with three leads, each lead connected to one doped region. Figure 2 show what the package looks like and identifies the three leads or terminals as **Emitter (E)**, **Collector (C)** and **Base (B)**. The basic transistor principle is that:" the voltage drop between two terminals control the currents in the third terminal".
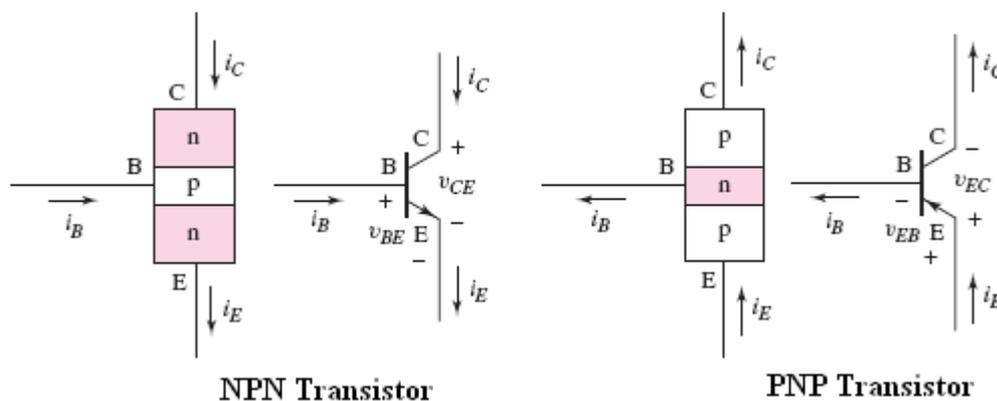
Figure 1

Using the diode function of a DMM to perform the diode test, the DMM outputs a constant current of about **1 mA** and it measures the voltage between the two leads (terminals) without computing a resistance. The measured voltage is the threshold voltage (*Vγ, i.e. (0.5 - 0.65))* volt if the PN-junction is forward biased. If the PN-junction is reverse biased, then the DMM cannot force 1 mA of current to pass into the PN-junction and the voltage across the PN-junction rises up to the upper range limit of the DMM, usually about (1.5 to 3.0) Volts. Other types of DMM give an over-limit (**.OL, 1.,** or **2 to 3V**) indication.
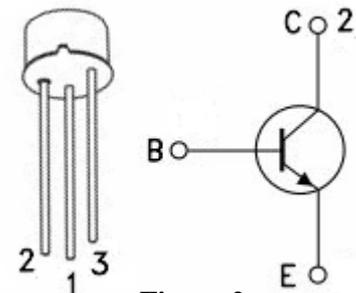
Figure 2

The Common Emitter NPN circuit output *i-v* characteristics are shown in Figure 3, where the collector current (**Ic**) is plotted versus the collector –emitter voltage (**V$_{CE}$**) at certain base current (**I$_B$**). The four regions of the transistor are: **Forward Active region** (BE junction is forward biased while BC junction is reversed biased)**, Saturation region** (Both BE and BC junctions are forward biased)**, Cut-off region** (Both BE and BC junctions are reversed biased) and **Reverse region** (BE junction is reversed biased while BC junction is forward biased). The DC-load line is a linear relationship between the collector current (Ic) and the collector –emitter voltage (V$_{CE}$). The intersection between the load line and the *i-v* characteristics of the transistor is the quiescent point (Q-point) where the transistor works.
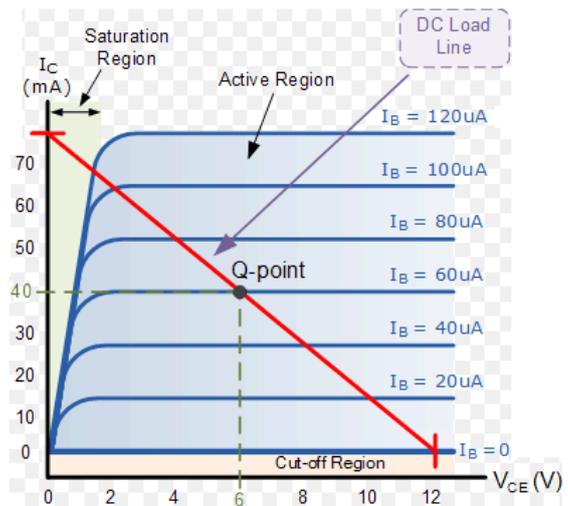
Figure 3

The operation of the BJT transistors is very strongly affected by heat, which is usually internally generated due to power dissipation. It is advisable, therefore, to limit transistor heating in this experiment by starting data runs with maximum current and voltage then decrease the voltages. (*Note: Transistor currents change due to heating effects even when supply voltages are kept constant*).

Important Current relationships:

$$I_E = I_C + I_B \quad \text{........ (1)}$$

$$\boldsymbol{I_C = \beta I_B} \quad \text{........ (2) (only in the forward active mode)}$$

$$\alpha = \frac{\beta}{1+\beta} \quad \text{........ (3)}$$

$$\beta = \frac{\alpha}{1-\alpha} \quad \text{....... (4)}$$

Procedure

Equipments & Part List

1- Two Digital Multimeters (DMM).   2- DC power supply.
3- Project Breadboard.   4- Resistors of 1K and 100K.
5- Connection Wires.   6- BC107 transistor or equivalent.

Part-A : BJT Lead Identifications using the DMM

1- Insert the three leads of the **BC107** BJT to three locations on the breadboard.
2- Turn on the DMM and configure it to measure ➤⊦. Plug a black test lead into the Common (−) 4mm banana socket, and a red test lead into the VΩ ➤⊦ (+) 4mm banana socket of the DMM.
3- Randomly, label the leads of the transistor as x, y, z.
4- Read the display of the DMM and record it in Table 1 in the sheet answer.
5- According to your data, determine which lead of the BJT is the base (**B**), collector (**C**) and emitter (**E**). Find out whether the BJT is an NPN or PNP device and record the results in Table 1.

NOTE: You had to know that $V_{BE} > V_{BC}$

Part-B : *i-v* Characteristics of a CE BJT

1- Construct the circuit shown in Figure 4 by using the **BC107 BJT**.
2- Set the DC power supplies output adjustment potentiometers fully CCW, then switch them ON.
3- Adjust the DC power supply that called **V$_{CC}$** to **15** volt.
4- Adjust the DC power supply that called **V$_{BB}$** to **6** volt.

Figure 4

5- Use the voltmeter to **measure V$_{BE}$, V$_{CE}$** and **I$_C$. Calculate I$_B$** using the equation ($I_B = \dfrac{V_{BB} - V_{BE}}{R_B}$) then record all the readings in Table 2 in the sheet answer.
6- Repeat steps 4 and 5 for all values of **V$_{BB}$** at the same value of **V$_{CC}$** (move horizontally in the table).
7- Repeat steps 3 to 6 for the other values of **V$_{CC}$** and **V$_{BB}$**.
8- When finished, switch OFF the DC power supplies.
9- Calculate the Q-point values (I_{BQ}, I_{CQ} and V_{CEQ}) at **V$_{CC}$=15v** and **V$_{BB}$=2v**.
10- Find out the Load line equation at **V$_{CC}$=15v**.
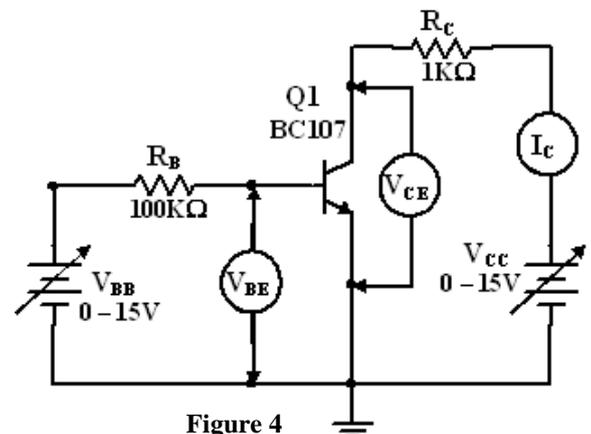
11- From your data in Table 2, plot the experimental output collector characteristics (I_C vs. V_{CE}) at V_{BB}= 4 volt. **On the same graph**:
   a) Draw the load line.
   b) Determine the Q-point (Operating Point).
   c) Determine the four regions of operations.

12- From your data in Table 2, plot the input characteristics (I_B vs. V_{BE}) at V_{CC}= 15V.

13- From the experimental results calculate the <u>average</u> β (h_{FE}).

14- Calculate the corresponding alpha α using the calculated β,.

15- On the basis of the measurements you made, what material is the transistor made of? How did you arrive to this conclusion?

16- Explain how the **Common Emitter (CE)** characteristics would be different if β were increased?

17- Explain how the **Common Emitter** (**CE**) output characteristics would be affected by a decrease in temperature.

18- According to the reading in Table 2, what is the value of the supply (V_{BB}) that make the transistor enter saturation directly using V_{CC}=15v.

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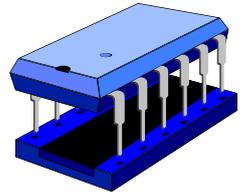
Electronics Lab Report

0903322

Experiment No.: _____   **Student Group: _____**

Experiment Name: _____

Students Name:

    1) _____

    2) _____

    3) _____

    4) _____

Bipolar Junction Transistor Characteristics

Part-A: BJT Lead Identifications by using the DMM

Table 1

DMM leads	+ x, - y	+ x, - z	- x, + y	- x, + z	+ y, - z	- y, + z
♪≶ ➤⊢ test (V)						
From the measurements above, summarize the type and terminals of the given BJT						
Transistor type	**Base (B)**		**Collector (C)**		**Emitter (E)**	

Part-B Current-Voltage Characteristics of a CE BJT

9- Calculate the Q-point values (I_{BQ}, I_{CQ} and V_{CEQ}) at V_{CC}=**15v** and V_{BB}=**2v**..

…………………………………………………………………

…………………………………………………………………

10- Find out the Load line equation at V_{CC}=**15v**.

…………………………………………………………………

…………………………………………………………………

11- From your data in Table 2, plot the experimental output collector characteristics (I_C vs. V_{CE}) at V_{BB}= 4 volt. On the same graph:
a) Draw the load line.
b) Determine the **Q**-point (Operating Point).
c) Determine the 4 regions of operations.

12- From your data in Table 2, plot the input characteristics (I_B vs. V_{BE}) at V_{CC}= 15V.
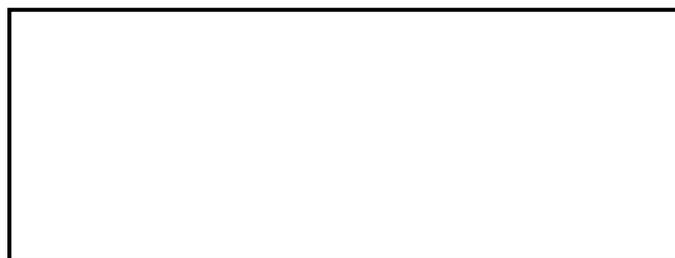
Table 2

V_{CC} ⇩	V_{BB}(V)	6.0	4.0	2.0	0.0
V_{CC} = 15V	V_{CE}(V)				
	I_C(mA)				
	V_{BE}(V)				
	I_B (μA)				
	β				
V_{CC} =12V	V_{CE}(V)				
	I_C(mA)				
	V_{BE}(V)				
	I_B (μA)				
	β				
V_{CC} = 9 V	V_{CE}(V)				
	I_C(mA)				
	V_{BE}(V)				
	I_B (μA)				
	β				
V_{CC} = 6 V	V_{CE}(V)				
	I_C(mA)				
	V_{BE}(V)				
	I_B (μA)				
	β				
V_{CC} = 4 V	V_{CE}(V)				
	I_C(mA)				
	V_{BE}(V)				
	I_B (μA)				
	β				
V_{CC} = 2 V	V_{CE}(V)				
	I_C(mA)				
	V_{BE}(V)				
	I_B (μA)				
	β				
V_{CC} = 0 V	V_{CE}(V)				
	I_C(mA)				
	V_{BE}(V)				
	I_B (μA)				
	β				

13- From the experimental results calculate the **average** β_{DC} (h_{FE}).

....

....

14- Calculate the corresponding alpha α from the calculated β,.

....

15- On the basis of the measurements you made, what material is the transistor made of? How did you arrive at this conclusion?

....

16- Explain how the **CE** characteristics would be different if β were increased?

....

....

17- Explain qualitatively how the **CE** input characteristics would be affected by a decrease and increase in temperature.

....

....

18- According to the reading in Table 2, what is the value of the supply V_{BB} that make the transistor enter saturation directly using $V_{CC}=\mathbf{15v}$.

....

....

Exp. 6

BJT Applications

Objectives

> To investigate the bipolar junction transistor (BJT) applications as simple common-emitter and common-collector AC amplifiers biased in the active mode and switching device

Theory

A typical integrated circuit (IC) and operational amplifier OP-AMP contains a large number of transistors that perform many functions. The simplest way to analyze such a circuit is to regard each individual transistor as a stage and to analyze the circuit as a collection of single transistor stages. In this part of the experiment, you will examine the behavior of some AC single-stage amplifiers with resistors supplying the bias voltages and currents. In this experiment, we will investigate the following BJT applications:

1) **Common-Emitter Amplifier (CE):** It is characterized by <u>high voltage and current gains</u>, A_v and A_i, respectively. The amplifier typically has a relatively <u>high input impedance Z_i</u> (*1 to 10 kΩ*) and <u>high output impedance Z_o</u> so it is generally used to drive medium to high loads. Since the amplifier cannot drive low resistance loads R_L, then usually it is cascaded with a Common-Collector (CC) (*some times called, emitter follower or buffer*) circuit that can act as an impedance matching.

2) **Common-Collector (CC):** It is characterized by <u>voltage gain lower than or equal to one</u> *($A_v \leq 1$)* and a high current gain A_i. When the circuit has a unity voltage gain *($A_v = 1$),* it became an **Emitter Follower** or **Buffer** that provide isolation between two circuits while providing driving capability for low loads resistance. The CC has <u>high input impedance Z_i</u> (*1 to 10 kΩ*) and <u>low output impedance</u>.

3) **BJT Switching Device:** The transistor switch is the basic element of logic circuits since mechanical switches are not used. A schematic of such a switch is shown in Figure 1, where the transistor circuit is switched between cutoff and saturation regions. <u>Open switch</u> condition when $V_{in} < V_{BE\text{-}on}$ the transistor will be in cut-off region, $I_B = I_C = 0.0$ mA providing a constant output voltage $V_O = V_{CC}$. <u>Closed switch</u> condition when $V_{in} = V_{CC}$, the transistor is in saturation region and $I_C = (V_{CC} - V_{CE\text{-sat}})/ R_C$, providing a small constant output voltage $V_{CE\text{-sat}} \cong 0.2V$.
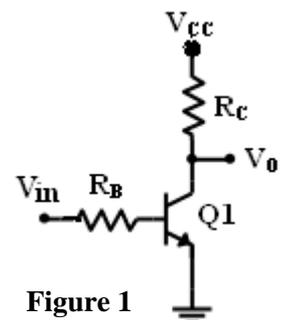
Figure 1

4) **Digital Logic circuits:**
   1) **Inverter or NOT logic circuit:** The Inverter circuit is the same as the switch circuit with $V_{CC} = 5$ V. If $V_{in} = 0V$ (Logic 0), The BJT will be in cut-off region, and $V_O = V_{CC} = 5$ V (Logic 1). If $V_{in} = 5V$ (Logic 1), The BJT will be in saturation region, and $V_O = V_{CE\text{-Sat}} \cong 0.2$ V (Logic 0).

2) NOR logic gate circuit: The circuit for the NOR logic gate is shown in Figure 2. When the two inputs $V_1 = V_2 = 0$ (Logic 0), both transistors (Q_1 and Q_2) are in cutoff, and $V_O = 5$ V (Logic 1). When $V_1 = 5$ V (Logic 1) and $V_2 = 0$ (Logic 0), transistor Q_1 can be driven into saturation, and Q_2 remains in cutoff, such that the output voltage is $V_O = V_{CE(sat)} = 0.2$ V (Logic 0). If the input voltages $V_1 = 0$ (Logic 0) and $V_2 = 5$ V (Logic 1), then Q_1 is in cutoff, Q_2 can be driven into saturation, and $V_O = VCE(sat) = 0.2$ V (Logic 0). If both inputs are $V_1 = V_2 = 5$ V (Logic 1), then both transistors can be driven into saturation, and $V_O = V_{CE(sat)} = 0.2$ V (Logic 0).
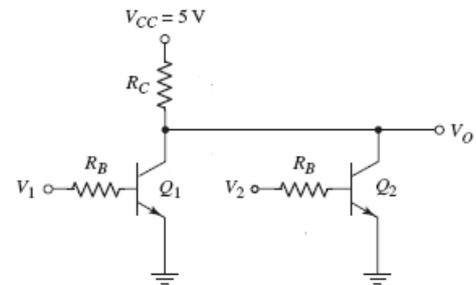
Figure 2

Procedure

Equipments & Part List

1- Oscilloscope.	2- Function Generator (FG)
3- Two Digital Multimeters (DMM).	4- DC power supply.
5- Project Breadboard.	6- Resistors of 100,220,2x1K,10K, 470K.
7- Capacitors of 2.2µF.	8- BC107 BJT .
9- Connection Wires and coaxial cables Probes.	

PART A: BJT Common-Emitter AC Amplifier

1- Construct the circuit shown in Figure 3, using **BC107 BJT** and use **V_{CC} = +15V**. (*Make sure the BJT is connected with the correct leads*). **Do not connect the Function Generator and the Oscilloscope channels.**

2- Set the correct setting of the DMM to **measure** the amplifier's **Q**-point values: **V_{CEQ}, V_{BEQ}, I_{CQ}, V_{RB2}** and **I_{BQ}**. **Calculate** the DC current gain β then fill all the data in Table 1 in the sheet answer.

3- Connect the Function Generator at the input of the circuit. Connect CH1 of the Oscilloscope to input voltage source and CH2 to the output such that the high terminal of CH2 is at the collector **(C)** as shown in Figure 3.

4- Set the Function Generator to a sinusoidal signal, **100mV$_{PP}$, 2kHz**. Set the input coupling switch of the Oscilloscope to the **AC** coupling mode for both channels. Measure the voltage gains $A_v = V_o/V_s$ using the Oscilloscope,.

5- Sketch the Oscilloscope screens on the respective grids in Table 2 in the sheet answer.

6- Gradually increase the source signal V_s amplitude and watch the signal on CH2 until it starts to clip. Read the input source voltage at the onset of clipping in the output signal and draw the signal on Table 2.

7- When you finished, set the source voltage back to **100mV$_{PP}$**, don't disconnect the circuit.

8- Why choosing $V_{CE} \cong 7.5$ **V** at the middle of the forward active region is a good choice? Explain.

9- What is the value of r_π?
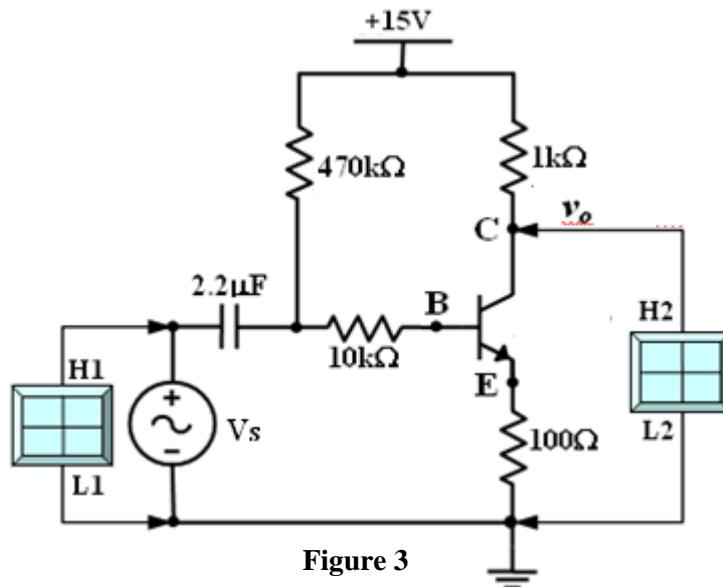
Figure 3

Part B: Common-Collector (Emitter Follower)

1- On the same circuit of Figure 3, connect the high terminal of the CH2 probe to the emitter (**E**).
2- Using the Oscilloscope, measure the voltage gains $A_v = V_o / V_s$. Sketch the Oscilloscope screens on the respective grids in Table 3 in the sheet answer.
3- Gradually increase the source signal V_s amplitude and watch the signal on CH2 until it starts to clip. Read the input source voltage at the onset of clipping in the output signal and draw the signal on Table 3.
4- When you finished, set the source voltages to **0.0**. Then switch off the supplies and disconnect the circuit.
5- Compare between the two types of circuits (**CE** and **CC**) in terms of **Av, Zi, Zo and φ** (phase shift between the input and the output signals).

PART C: BJT Switching Device

1- Construct the circuit shown in Figure 4. By using **BC107 BJT** and use $V_{CC} = +5V$, $R_C = 1k\Omega$ and $R_B = 4.7k\Omega$.
2- Set the DC supply output adjustment potentiometers fully counter clock wise, then switch it ON.
3- Vary the input voltage V_{in} according to Table 4. Use the DMM to **measure** the output voltage V_O and record it in Table 4 in the sheet answer.
4- Set the DC supply back to zero (V_{in} to **0.0V**), then increase it slowly using the fine tuning knob until $V_O = 0.2$ V, record the reading of the DC supply in the sheet answer.
5- Calculate the minimum value of V_{in} for which the BJT will start to enter the saturation region. Compare your result with that in question 4.
6- When finished, set V_{in} to **0.0V** then switch it OFF, don't disconnect the circuit.
7- Verify the two regions of the BJT in the switch circuit according to your reading.
8- Sketch the V_O vs. V_{in}.
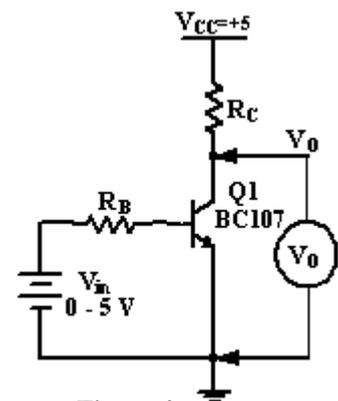
Figure 4

PART D: Digital Logic Circuits
1) Inverter circuit
1- For the same circuit shown in Figure 4, set $V_{in}= 0.0V$, read the value of V_O and fill it in Table 5 in the sheet answer.
2- Set $V_{in}= 5.0V$, read the value of V_O and fill it in Table 5.
3- Verify your results.

2) NOR Gate circuit
1- Connect the circuit shown in Figure 5 by using $V_{CC} = +5$ V, $R_C= 1$ kΩ and $R_B = 4.7$ kΩ.
2- Set V_1 and V_2 according to Table 6 in the sheet answer
3- Connet the DMM and read the value of V_O then fill it in Table 6 in the sheet answer.
4- Repeat steps 2 and 3 for all values of input voltages recorded in Table 6.
5- Verify your results.
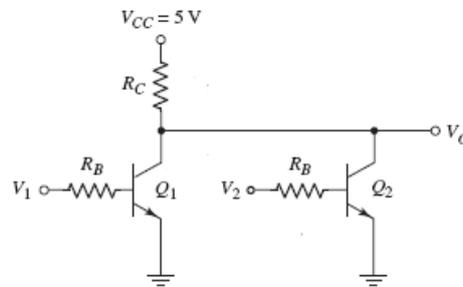
Figure 5

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Mechatronics Engineering Department

Electronics Lab Report

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Experiment No.: _____   **Student Group:** _____

Experiment Name: _____

Students Name:

1) _____

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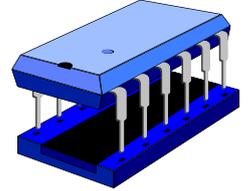
PARTA: BJT Common-Emitter AC Amplifier

Table 1

V_{CC} (V)	V_{CEQ} (V)	V_{RB2} (V)	I_{BQ} (µA)	I_{CQ} (mA)	V_{BE} (V)	β_{DC}
15						
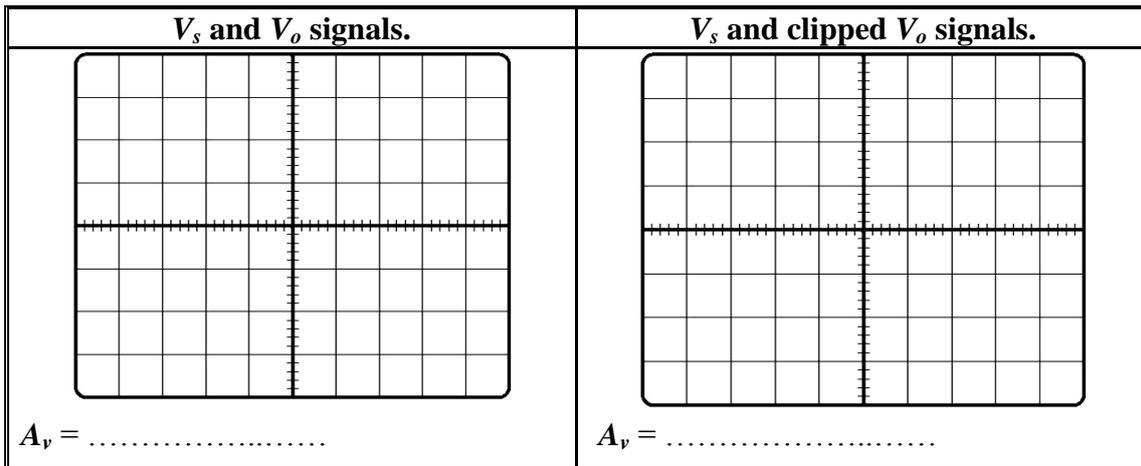
Table 2

V_s and V_o signals.	V_s and clipped V_o signals.
A_v = …………….………	A_v = …………….………

8- Why choosing $V_{CE} \cong 7.5\ V$ at the middle of the forward active region is a good choice? Explain.

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……………………………………………………………………………

9-What is the value of r_π?

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Part B: Common-Collector (Emitter follower)

Table.3
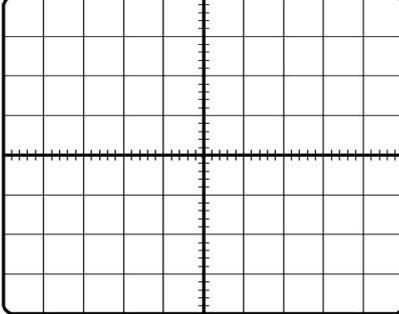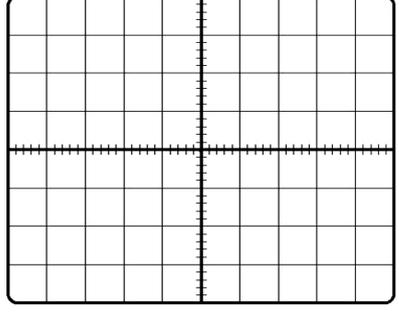
V_s and V_o signals.	V_s and clipped V_o signals.
A_v = …………………..……	A_v=…………………..……

5- Compare between the two types of circuits (**CE** and **CC**) in terms of **Av, Zi, Zo and φ** (phase shift between the input and the output signals).

	Av	**Zi**	**Zo**	**φ**
Common Emitter (CE)				
Common Collector (CC)				

PART-C : BJT Switching Device

Table 4

	V_{in} (V)	V_O (V)	I_C (mA)
R$_B$ = 4.7kΩ	0.0		
	0.7		
	1.0		
R$_C$ = 1kΩ	3.0		
	5.0		

4- Set the DC supply back to zero (V_{in} to **0.0V**), then increase it slowly using the fine tuning knob until V_O =0.2 V, record the reading of the DC supply in the sheet answer.

…………………………………………………………………………………………

5- Calculate the minimum value of V_{in} for which the BJT will start to enter the saturation region. Compare your result with that in question 4.

…………………………………………………………………………………………

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6- Verify the two regions of the BJT in the switch circuit according to your reading.

…………………………………………………………………………………………

…………………………………………………………………………………………

8- Sketch the V_O vs. V_{in}.

PART-D: Logic Circuit
1) Inverter circuit:

Table 5

V_{in} (volt)	V_O (volt)
0	
5	

3- Verify your results.

…………………………………………………………………………

…………………………………………………………………………

2) Nor Gate Circuit

Table 6

V_1 (volt)	V_2 (volt)	V_O (volt)
0	0	
0	5	
5	0	
5	5	

5- Verify your results.

…………………………………………………………………………

…………………………………………………………………………

Exp. 7

BJT Frequency Response Amplifier

Objectives

- To investigate the AC behavior of the frequency and phase response of a BJT.
- To measure upper and lower cutoff frequencies of a CE amplifier.

Theory

The Frequency response of an electronics circuit is a measure of output gain and the phase of the output signal as a function of frequency, in comparison to the input signal. In simplest terms, if a sine wave is injected into a system at a given frequency, the system will respond differently if we change the value of that frequency.

The frequency response of a circuit is shown in Figure 1, where we can plot the circuits' gain (**Vo/Vs**) or output voltage (**Vo**) against a frequency (**f**) scale over which the circuit is operated. The horizontal frequency axis is usually plotted on a logarithmic scale while the vertical axis representing the voltage output or gain, is usually drawn as a linear scale as shown in Figure 1.
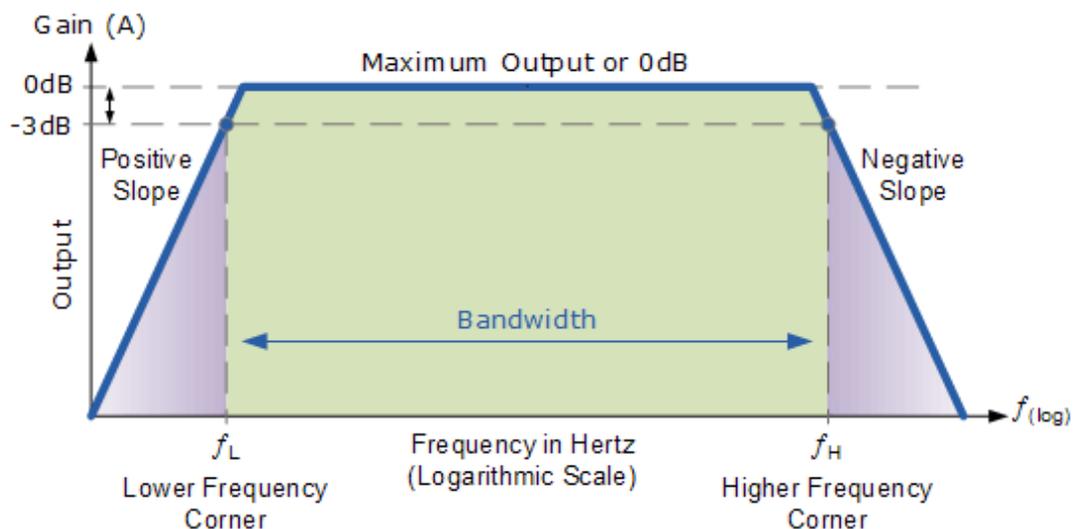
Figure 1

Three frequency ranges: Low, Midband and high. In the **Low frequency range ($f < f_L$)**, the gain increases as frequency increase because of the coupling and the bypass capacitorseffects. In the **High frequency range ($f > f_H$)**, the gain decreases as the frequency increases due to the effect of the stray capacitors and the transistors capacitors. In the **Midband frequency range ($f_L < f < f_H$)**, the coupling and the bypass capacitors act as short circuits while the stray and the transistors capacitances act as open circuits which will cause the gain to keep almost constant.

The bandwidth of the amplifier (f_{BW} = f_H - f_L) Hz, and the gain at f_L and f_H (the low and high frequency corners) is 3dB less than the maximum midband gain (**V(corners)=V(max)/$\sqrt{2}$**).

When adding a load to the amplifier circuit, the output voltage (Vo) will decrease, which mean the voltage gain (Vo/Vs) will also decrease. This can be explained by replacing the amplifier wih the equievelant thevenin circuit as shown in Figure 2. The bandwidth for the amplifier circuit with load will increase compared to the amplifier circuit without load as shown in Figure 3.

Figure 2

Figure 3

Procedure

Equipments & Part List

1- Oscilloscope
3- Two Digital Multimeters (DMM).
5- Project Breadboard.
7- Capacitor of 1µF, 2.2µF, 22µF.
9- Connection Wires and coaxial cables.

2- Function Generator (FG)
4- DC power supply.
6- 680,820, 2x(1, 2.2, 3.3,10) kΩ.
8- BC107 BJT

Part A: Frequency response of a BJT Common Emitter amplifier

1- Construct the circuit shown in Figure 4 by using **BC107** transistor.
2- Switch ON the Oscilloscope and the Function Generator. Set the input source voltage to **1.5Vpp** sinusoidal signal.
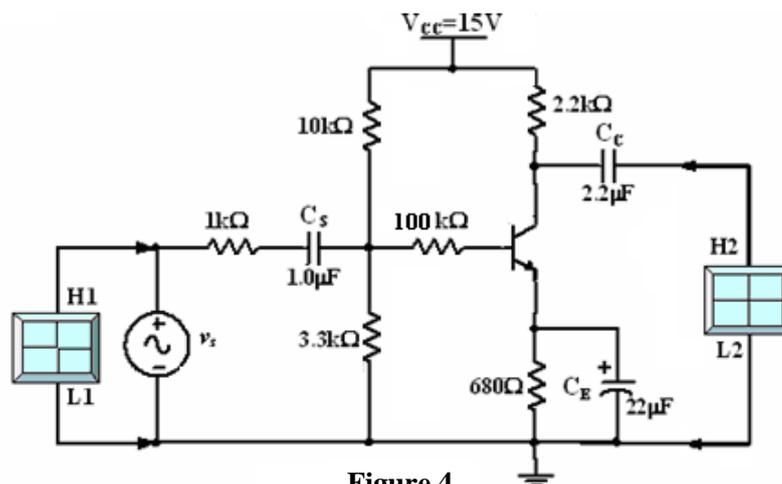
Figure 4

3- Use the Oscilloscope to measure and record the peak value for V_S from CH1 and V_O from CH2.

4- Vary the input signal frequency according to Table 1 in the sheet answer. **Measure** the value of V_o, **calculate** the value of voltage gain A_v and the phase shift ($\phi°$) between the input and the output signals.

5- When finished, switch OFF the DC power supply and the Function Generator.

6- According to the filled data in Table 1, determine the midrange, Lower corner and the Upper corner frequencies and fill them in Table 2 in the sheet answer.

7- What is the value of the phase shift at the midrange frequencies? What does that mean?

8- What is the relation between the voltage at the midrange and the voltage at the corner frequencies (lower and the upper corner frequencies)?

9- Draw the frequency response of a Common Emitter Amplifier.

Part B: Frequency response of a BJT CE Loaded amplifier

1- Connect the circuit shown in Figure 5 which is the same circuit shown in Figure 4 but we add **load resistor $R_L = 1.2k\Omega$**.

2- Change the value of the input signal frequency according to Table 1, and determine the midrange, the lower and the upper frequencies then fill the data in Table 3 in the sheet answer.

3- What happen when we add a load resistor to the common emitter amplifier? Explain.
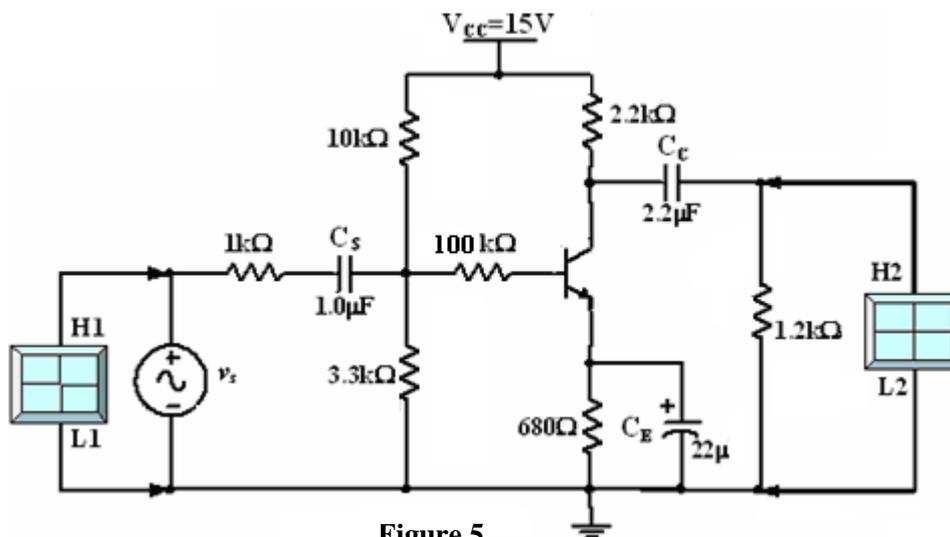
Figure 5

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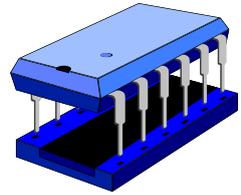
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Experiment Name: _____

Students Name:

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    2) _____

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BJT Frequency Response Amplifier

Part A: Frequency response of a BJT Common Emitter amplifier

Table 1

f (Hz)	V_s (V$_P$)	V_o (V$_P$)	A_v (V/V)	Phase Shift $\phi°$
100				
500				
1K				
5K				
10K				
20K				
50K				
100K				
200K				
500K				
1M				

Table 2

Critical Points	f (Hz)	V_s (V$_P$)	V_o (V$_P$)	A_v (V/V)	Phase Shift $\phi°$
Mid Range					
Lower Corner					
Upper Corner					

7- What is the value of the phase shift at the midrange frequencies? What does that mean?

....

....

8- What is the relation between the voltage at the midrange and the voltage at the corner frequencies (lower and the upper corner frequencies)?

…………… N. A. …………………………………………………………………………

………………………………………………………………………………………………

9- Draw the Frequency Response of a Common Emitter Amplifier.

Part B: Frequency response of a BJT CE Loaded amplifier

Table 3

Critical Points	f (Hz)	V_s (V$_P$)	V_o (V$_P$)	A_v (V/V)	Phase Shift $\phi°$
Mid Range					
Lower Corner					
Upper Corner					

4- What happen when we add a load resistor to the common emitter amplifier? Explain.

………………………………………………………………………………………………

………………………………………………………………………………………………

1

Exp. 8

Metal Oxide Semiconductor Field Effect Transistor (MOSFET)

Objectives

- To identify the leads of the Metal Oxide Semiconductor Field Effect Transistors (MOSFET) by using the DMM and data sheet.
- To investigate the DC behavior and the characteristics of a MOSFET in several regions of operation.
- To determine small signal parameter g_m .
- To investigate the MOSFET applications as simple common-source and common-drain AC amplifiers.

Theory

The Metal Oxide Semiconductor Field Effect Transistor (MOSFET) is anther type of transistors that used to amplify or switch electronic signals. The Name Field Effect is due to the fact that the current is controlled by the applied electric field. The MOSFET, compared to BJT, has small size and low power dissipation. Two modes of MOSFET are exist; the enhancement mode (where voltage must be applied to the gate to creat a channel) and Depletion mode (where channel are existed and by applying a voltage on the gate we remove it). Each mode has n-type and p-type channels which are called an NMOS or a PMOS respectively.

The MOSFET is a three terminal component: Drain (D), Source (S) and Gate (G). The circuit symbols of the two modes and the real shape of the component are shown in Figure 1. In this Experiment we will use NMOS (n-channel MOSFET) enhancement mode transistor.
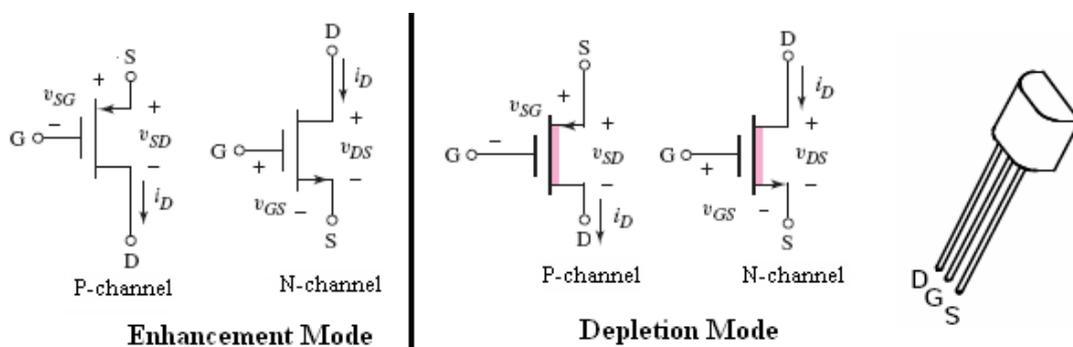
Figure 1

The **Threshold voltage (V_{TN})** of the NMOS is defined as the gate voltage needed to turn on the transistor and create the channel between the drain and the source and it is positive voltage for the NMOS transistor.

- **MOSFET operation regions**

The operation of the MOSFET can be separated into three different regions, depending on the voltages at the terminals. The *i-v* output characterstics for the **enhancement mode n-channel MOSFET** are shown in Figure 2, where I_D *vs.* V_{DS} is plotted with V_{GS} as a parameter. The three operational regions are:

1) Cutoff region: when $V_{GS} < V_{TN}$ the transistor is turned off, and there is no conduction between drain and source and **$I_D = 0$**.

2) Triode (or non saturation or linear) region: when $V_{GS} > V_{TN}$ and $V_{DS} < (V_{GS} - V_{TN})$, the transistor is turned on, and a channel is created which allows current to flow between the drain and the source. The MOSFET operates like a resistor, controlled by the gate voltage relative to both the source and drain voltages. The current **I_D** is described by the equation:

$$I_D = K_n[2(V_{GS} - V_{TN})V_{DS} - V_{DS}^2]$$

3) Saturation region: when $V_{GS} > V_{TN}$ and $V_{DS} > (V_{GS} - V_{TN})$, the drain current is now weakly dependent upon drain voltage, and controlled primarily by the gate source voltage and it is described by the equation:

$$I_D = K_n(V_{GS} - V_{TN})^2$$
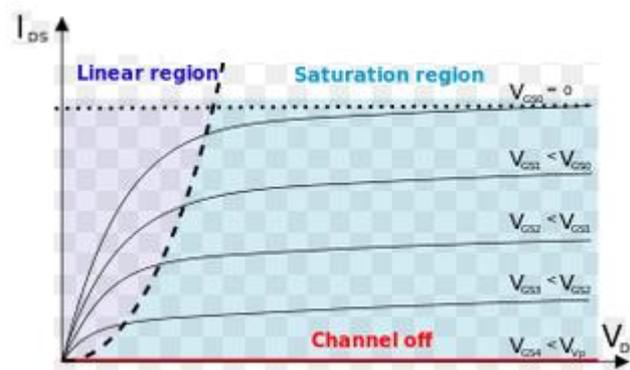
Figure 2

- **The MOSFET Applications**

Two of the most popular configurations of small-signal MOSFET are the **Common Source (CS)** configuration where it can be used as an amplifier circuit and **Common Drain (CD)** configuration which can be used as a buffer.

The Common Source (CS) and Common Drain (CD) configurations have the characteristic of <u>high input impedance</u> which is basically limited only by the biasing resistors R_{G1} and R_{G2}. High input impedance is desirable to keep the amplifier from loading the signal source. One popular biasing scheme for the CS and CD configurations consists of the voltage divider R_{G1} and R_{G2}. This voltage divider

supplies the MOSFET gate with a constant DC voltage. The main difference with the BJT biasing scheme is that ideally no current flows from the voltage divider into the MOSFET ($I_G = 0$).

The CS and CD MOSFET amplifiers can be compared to the CE and CC BJT amplifiers respectively. Like the CE amplifier, the CS amplifier has negative voltage gain and output impedance approximately equal to the drain resistor (collector resistor for the CE amplifier). The CD amplifier is comparable to the CC amplifier with the characteristics of high input impedance, low output impedance, and less than unity voltage gain.

Procedure

Equipments & Part List

1- Oscilloscope.   2- Function Generator (FG)
3- Two Digital Multimeters (DMM).   4- DC power supply.
5- Project Breadboard.   6- Resistors of 1K, 220K, 470, 100, 120K.
7- Capacitor of 1, 10µF.   8- ZVN2110A MOSFET or equivalent.
9- Connection Wires and Coaxial Cables.

Part-A MOSFET Lead Identifications using the DMM

Hold the MOSFET from the case or the tab and don't touch the metal parts of the MOSFET's terminals until needed. Do NOT allow a MOSFET to come in contact with your clothes, plastic or plastic products, etc. because it is affected by the high static voltages they can generate.

1- Refer to Figure 1 to determine the pin configuration for the MOSFET.
2- Turn on the DMM and set it to (⊶). Plug a black test lead into the Common (−) banana socket, and a red test lead into the VΩ ⊶ (+) 4mm banana socket of the DMM.
3- Connect the (-) lead to the Source (S) terminal.
4- Connect the (+) lead to the Gate (G) terminal, the MOSFET's internal capacitance on the gate has now been charged up by the meter and the device is turned-on.
5- Remove the (+) lead and connect it to the Drain (D) terminal, you should get a low reading. Record your reading.
6- Now touch a finger between source and gate. The gate will be discharged through your finger and the meter reading should go high, indicating a non-conductive device.
7- Connect the (-) lead to the Drain (D) terminal and connect the (+) lead pin to the Source (S) terminal, the meter now will read the conducting voltage. Record your DMM reading.

Part-B The *i-v* Characteristics of a CS MOSFET
## B-1 : Input Characteristic (I_D versus V_{GS})

1- Construct the circuit shown in Figure 3 by using the **ZVN2110A NMOS**. (*Make sure the transistor is connected with the correct leads as shown in Figure 1*).

2- Set the DC power supplies output adjustment potentiometers fully counter clock wise, then switch them ON.

3- Adjust the DC power supply of $V_{DD} = $ **+12 volt**.

4- Adjust the V_{GG} power supply to obtain the values according to Table 1 in the sheet answer and **measure** the values of I_D. You had to find that $V_{GS} = V_{GG}$ since $I_G = 0$.

5- When finished, set the V_{GG} and V_{DD} to **0.0***V*. Then switch OFF the DC power supplies.

6- From the results in Table 1, what is the value of threshold voltage V_{TN}?

7- From your results in Table 1, plot the experimental input characteristics (I_D *vs.* V_{GS}), and determine V_{TN} on the plot.
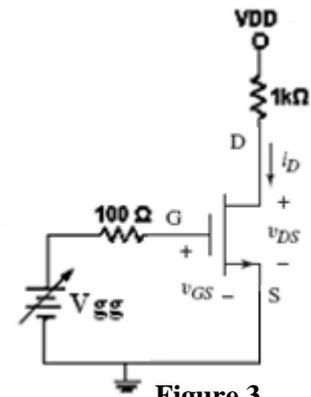
Figure 3

B-2: Output Characteristic (I_D versus V_{DS})

1- Construct the circuit shown in Figure 4.

2- Set the DC power supplies output adjustment potentiometers fully counter clock wise, then switch ON the supplies.

3- Adjust the DC power supply $V_{DD} = $ **12V**.

4- Adjust the DC power supply $V_{GG} = $ **4V**.

5- **Measure** the values of V_{DS} and I_D then record them in Table 2.

6- Adjust the DC power supply $V_{GG} = $ **3V**.

7- Repeat step 5.

8- Repeat steps 3 to7 for all values of V_{GG} and V_{DD}.

9- When finished, set the V_{GG} and V_{DD} to **0.0***V*. Then switch OFF the DC power supplies.

Figure 4

10- From your data in Table 2, plot the experimental output characteristics (I_D *vs.* V_{DS}) when $V_{GG} = 4$ volt, draw the load line, determine the regions of operations, and determine the **Q**-point (*operating point*).
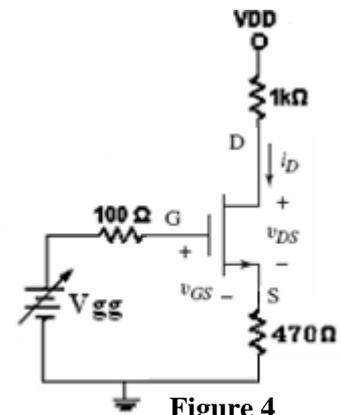
PART-C The MOSFET Applications
C-1 Common-Source Amplifier with Source Resistor (R_S)

1- Construct the circuit shown in Figure 5, Use $V_{DD} = $ **+12V**. **Do not connect** the Oscilloscope and the Function Generator at this stage.

2- Set the correct setting of the DMM to measure amplifier's **Q**-point. **Do not** apply any V_s from Function Generator. **Measure** V_{DSQ}, I_{DQ} and V_{GSQ} quiescent DC values. Record the measured values in Table 3 in the sheet answer.

3- Connect the Function Generator and the Oscilloscope to the circuit as shown in Figure 5.

Figure 5
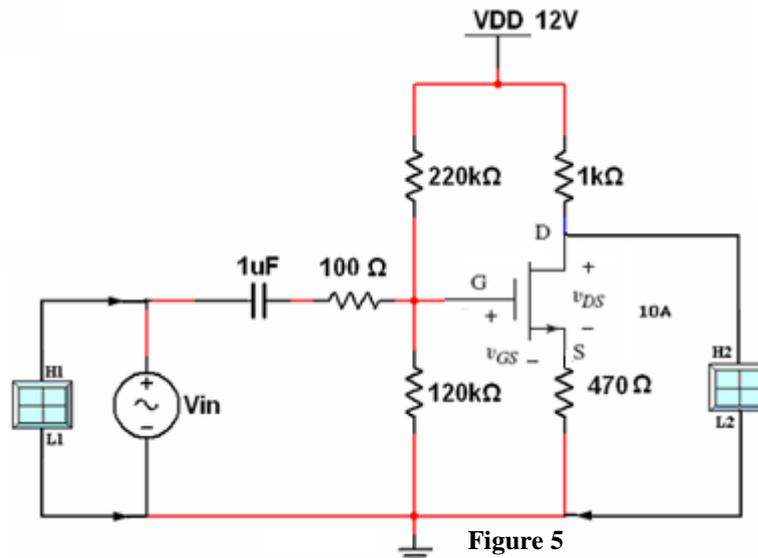
4-Switch ON the Oscilloscope and the Function Generator and set the source voltage V_s to sinusoidal signal, **100mV$_{PP}$**, **5kHz**. (*Note: set the input coupling switch of the Oscilloscope to the AC coupling mode*).

5- Using the Oscilloscope, connect CH2 to the Drain (D) and measure the small-signal voltage gain, $A_v = V_o / V_s$. Sketch the Oscilloscope screens on the respective grid.

6- Note the phase shift between output and input voltages, is the amplifier inverting or non-inverting?

C-2 Common-Source Amplifier without Source Resistor (R$_S$)

1- For the same circuit shown in Figure 4, add **10µF** in parallel with the Source resistance (**R$_S$**), change the input frequency to **40 KHz** while keeping the signal voltage to **100mV$_{PP}$**.

2- Connect CH2 of the Oscilloscope to the Drain (D).

3- Using the Oscilloscope, measure the small-signal voltage gain, $A_v = V_o / V_s$. Sketch the Oscilloscope screens on the respective grid in the sheet answer.

4- What happen to the Voltage Gain when adding the capacitor parallel to R$_S$? Explain.

C-3 Common-Drain (Sourse-Follower) Amplifier

1- For the same circuit shown in Figure 5, connect CH2 to the Source (S) and **remove** 10µF in parallel with the Source resistance (**R$_S$**).

2- Adjust the Function Generator to sinusoidal signal, **100mV$_{PP}$**, **5kHz**.

2- Using the Oscilloscope, measure the small-signal voltage gain, $A_v = V_o / V_s$. Sketch the Oscilloscope screens on the respective grids in Table 6 in the sheet answer.

3- When finished, set the voltage source to 0.0V, switch them and disconnect the circuit.

4- Note the phase shift between output and input voltages, is the amplifier inverting or non-inverting?

5- Compare between the **CS** and **CD** amplifiers in terms of **Av (voltage gain), φ (phase shift between the output and the input signals)**.

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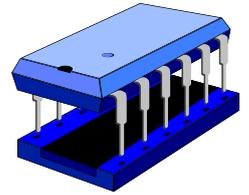
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Experiment Name: _____

Students Name:

  1) _____

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  3) _____

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Metal Oxide Semiconductor Field Effect Transistor

Part-A MOSFET Lead Identifications by using the DMM

4-Record your reading.

…………………………………………………………………

6- Record your reading.

…………………………………………………………………

Part-B Current-Voltage Characteristics of a CS MOSFET
B-1 : I_D versus V_{GS} Characteristic

Table 1

V_{GG} (V)	0.0	1	1.2	1.3	1.4	2	3
I_D (mA)							

6- From the results in Table 1, what is the value of threshold voltage V_{TN}?

…………………………………………………………………

…………………………………………………………………

7- From your data in Table 1, plot the experimental input characteristics (I_D *vs.* V_{GS}), and determine V_{TN} on the plot.

B-2 : I_D versus V_{DS} Characteristic

Table 2

V_{DD} ⇩	V_{GG}(V)	4	3
12V	I_D (mA)		
	V_{DS} (V)		
9 V	I_D (mA)		
	V_{DS} (V)		
6 V	I_D (mA)		
	V_{DS} (V)		
3 V	I_D (mA)		
	V_{DS} (V)		
0 V	I_D (mA)		
	V_{DS} (V)		

10- From your data in Table 2, plot the experimental output characteristics (*I_D vs. V_{DS}*) when V_{GG} = 4 volt, draw the load line, determine the regions of operations, and determine the **Q**-point (*operating point*).

PART-C MOSFET AC Amplifier Device
C-1 Common-Source Amplifier with Source Resistor (R_S)

Table 3

V_{DD} (V)	V_{DSQ} (V)	V_{GSQ} (V)	I_{DQ} (mA)
12			

V_s and V_o signals.

A_v = …………………..……
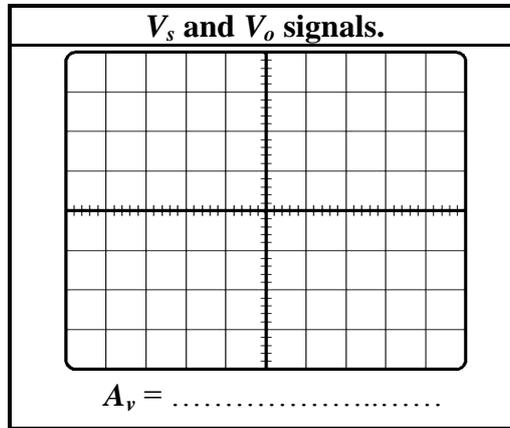
7- Note the phase shift between output and input voltages, is the amplifier inverting or non-inverting?

……………………………………………………………………………

C-2 Common-Source Amplifier without Source Resistor (R_S)

4- What happen to the Voltage Gain when adding the capacitor parallel to **R_S**? Explain the effect of **R_S**.

……………………………………………………………………………

……………………………………………………………………………

V_s and V_o signals.

A_v = …………………..……
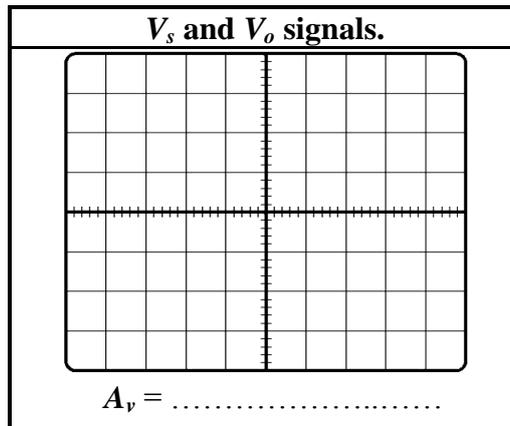
C-3 Common-Drain (Source-Follower) Amplifier

4- Note the phase shift between output and input voltages, is the amplifier inverting or non-inverting?

……………………………………………………………………………………

5- Compare between the **CS** and **CD** amplifiers in terms of **Av, φ**.

	Av (voltage gain)	**φ** (phase shift)
Common Source (CS)		
Common Drain (CD)		

V_s **and** V_o **signals.**
A_v = ……………….………
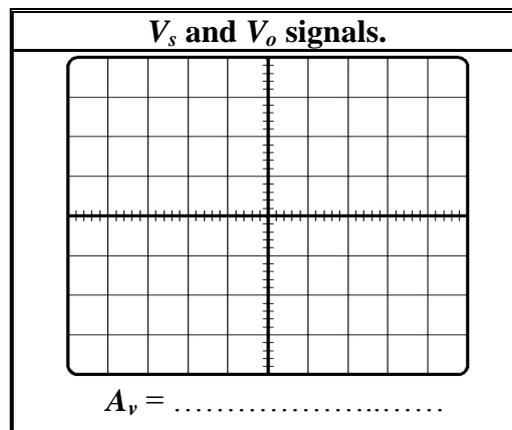
Exp. 9

Operational Amplifier Applications

Objectives

- To gain experience with Operational Amplifier.
- To study the use of Op.Amp. as an inverting amplifier, integrator, Adder, Non inverting (Op.Amp) and comparator.
- To study use of the OP amp as a Precision Rectifier and Square wave Oscillator.

Theory

The operational amplifier is an integrated circuit (IC) that operates as a voltage amplifier, where the circuit symbol and the pin configuration of the OP-Amp IC is shown in Figure 1 (according to the datasheet for the OP-Amp 741). The Op-amp has high-gain and it is used with feedback connections for controlling by using passive elements. The term operational amplifier (OP-Amp) is from the original applications in analog computation that used to perform different mathematical operations (i.e. summation and integration).
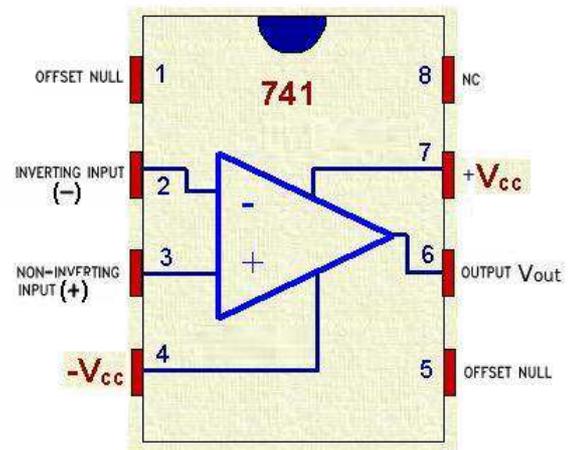
Figure 1

The Operational amplifiers can be used to in different applications such as inversion amplifier, non-inversion amplifier, Voltage follower, comparator, addition (summing amplifier), subtraction (differential amplifier), integration, differentiation, precision rectifier, square wave oscillator and sine wave oscillator (Wien bridge oscillator). The **Inversion amplifier circuit** is shown in Figure 2, the input signal (Vin) is connected to the inverting input (-), such that the output gain of this amplifier is negative, which mean that the output signal is out of phase by
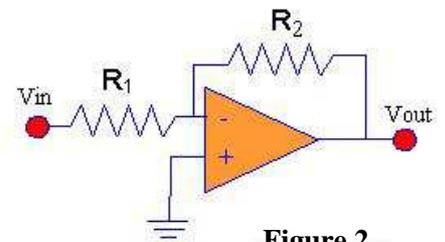
Figure 2

180˚ with the input signal. The voltage gain of the Inverting amplifier is given by:

$$A_v = \frac{V_o}{V_{in}} = - \frac{R_2}{R_1}$$

For the **Non-inversion amplifier circuit**, shown in Figure 3, the input voltage signal (Vin) is applied to the non-inverting input, such that the output gain of the amplifier is positive which mean that the output signal is in-phase with the input signal. The voltage gain of the Non-Inverting amplifier is given by:

$$A_v = \frac{V_o}{V_{in}} = 1 + \frac{R_F}{R_2}$$
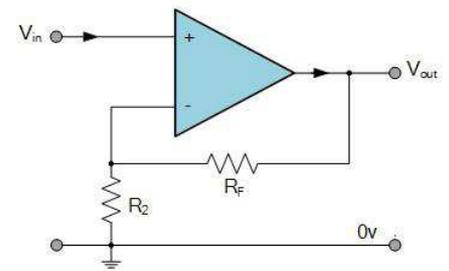
Figure 3

In the Non-inverting amplifier circuit if the feedback resistor (R_F) is replaced by short circuit ($R_F = 0\Omega$), then the output signal is the same as the input signal such that the gain is unity ($A_v = 1$). This circuit has the name of **Voltage Follower circuit** as shown in Figure 4.
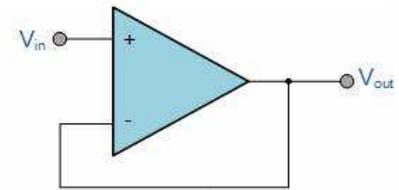
Figure 4

In the **Comparator circuit**, shown in Figure 5, when the non-inverting input (V1) is higher than the inverting input (V2), the high gain of the op-amp causes the output to saturate at the highest positive voltage it can output. When the non-inverting input (V1) is lower than the inverting input (V2), the output saturates at the most negative voltage it can output. The op-amp's output voltage is limited by the supply voltage.
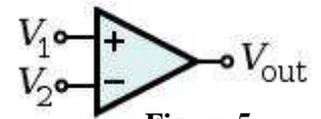
Figure 5

If more than one supply is applied to the inverting Op-Amp, we had to combine all the multiple inputs into one single signal voltage by connecting the **Summing amplifier (Adder) circuit** shown in Figure 6. The output voltage from the op-amp is given by:

$$V_o = -\frac{R_F}{R_{in}}(V_1 + V_2)$$
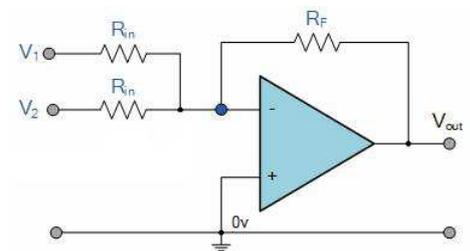

Figure 6

The **Differential Amplifier (Subtractor) circuit**, shown in Figure 7, is an amplifier circuit that amplifies the difference between the two input voltages. One voltage signal (V1) is connected to one input terminal and another voltage signal (V2) is connected to the other input terminal, the resultant output voltage will be proportional to the difference between the two input voltage signals of V1 and V2. If R1 = R2 and R3 = R4, then the output voltage is given by:

$$V_o = \frac{R_3}{R_1}(V_2 - V_1)$$
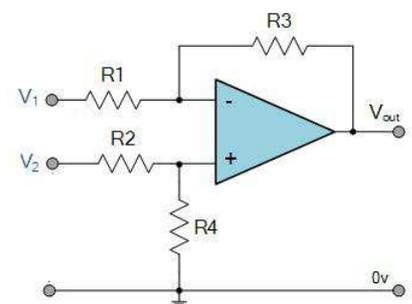
Figure 7

The **Inverting Integrator circuit**, shown in Figure 2, is used to perform
the mathematical operation of inverting and integrating the input signal
over time. The output voltage is given by:

$$V_o(t) = -\frac{1}{RC}\int_{t_0}^{t_1} V_{in}(t)\,dt$$

The **Inverting Differentiator circuit**, shown in Figure 3, is used to perform the mathematical
operation of differentiation for the input signal. The output voltage is given by:

$$V_o(t) = -RC\frac{dV_{in}(t)}{dt}$$

For the Half wave rectifier studied in Experiment 2, we saw that the output voltage has an offset
about 0.7 volt due to the cut-in voltage (Vγ). This offset voltage (Vγ) is unacceptable in many
practical applications, so the **Precision half wave rectifier circuit**, shown in Figure 4, is used to form
an ideal diode where the offset voltage can be eliminated from the output signal. The other advantage
from this circuit is the possibility to rectify very small input signal without caring that the input
voltage must exceed the cut-in voltage of the diode.

The **Square wave generator circuit**, shown in Figure 5, is used to generate a square wave. It's the
reference voltage for the comparator depends on the output voltage. The period of the output signal
(T) is given by the following equation:

$$T = 2RC\ln(\frac{2R_2}{R_1} + 1)$$

The **Sine wave oscillator circuit** (Wien Bridge Oscillator), shown in Figure 6, is used to produce a
sinusoidal output waveform. It uses a feedback circuit consisting of a series RC circuit connected
with a parallel RC of the same component values (R1 = R2 and C1 = C2) producing a phase delay or

 phase advance circuit depending upon the frequency. The frequency of the output signal is given by:

$$f = \frac{1}{2\pi R_1 C_1}$$

Procedure

Equipments & Part List

1- Oscilloscope (Scope).   2- Function Generator.
3- Digital Multimeter (DMM).   4- DC power supply.
5- Bread-board.   6- 3 X 10K, 1K, 2X 15K , 1μF and 0.1μF.
7- Connection Wires and Coaxial Cables.   8- Op-Amp 741

<u>Part A: The Inverting amplifier circuit</u>

1- Construct the Op-Amp circuit as shown in Figure 8 using
    R1 = 1KΩ and R2 = 2.2KΩ.
2- Connect CH1 to the function generator and set V_S to **2V$_{p-p}$**
    and **1 kHz** sine wave.
3- Connect CH2 to the output of the op-amp and sketch the
    output voltage V_o on the respective screen grids in the
    sheet answer.
4- Calculate the voltage gain **Av**. **Figure 8** 5- What is the phase shift between the input and
the output
    signals?
6- Increase the function generator amplitude until the output signal start to clip,
    read the value of the input voltage that saturate the op-amp and find the
    maximum value of the output voltage.
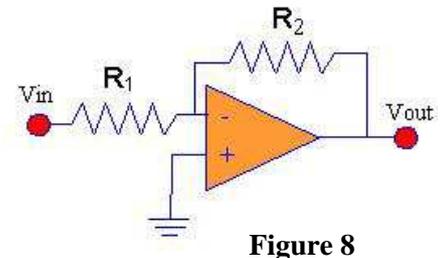
**Figure 8**

<u>Part B: The Non - Inverting amplifier circuit</u>

1- Construct the Op-Amp circuit as shown in the Figure 9
    using **R1 = 1KΩ and R2 = 2.2KΩ**.
2- Connect CH1 to the function generator and set V_S to **1.5V$_{p-p}$**
    and **1 kHz** sine wave.
3- Connect CH2 to the output of the op-amp and sketch the
    output voltage V_o on the respective screen grids in the
    sheet answer.
4- Calculate the voltage gain **Av**.
5- What is the phase shift between the input and the output signals?
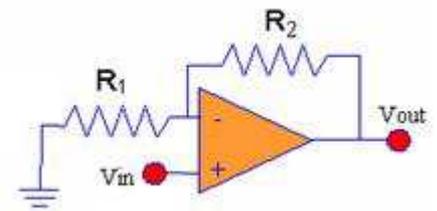
Figure 9

<u>Part C: The Voltage Follower circuit</u>

1- Construct the Op-Amp circuit as shown in the Figure
    10
2- 2- Set the source voltage (Vs) to **2 V$_{p-p}$, 1kHz** sine
    wave.
3- Measure the output peak voltage and sketch V_o on the
    respective screen grids in the sheet answer.
4- Increase the input voltage amplitude to **3 V$_{p-p}$**, **4 V$_{p-p}$** and
    measure the output voltage. Comment on your readings.
5- Calculate the voltage gain **Av**.
6- What is the phase shift between the input and the output signals?
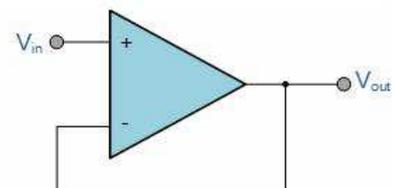
Figure 10

Part D: The Comparator circuit

1- Refer to Figure 11, set $V_{ref} = 0$ V (DC), Vin =10V_{p-p}, 1 kHz. 2- Observe Vin and Vo on the Oscilloscope Channels.

3- Sketch the signals appear on the Channels on the respective screen grids in the sheet answer.

4- Set $V_{ref} = 2$ V (DC) and repeat steps 2 and 3.

5- Does the output signal differ when $V_{ref} = 0$ V from that when $V_{ref} = 2$ V? Explain.
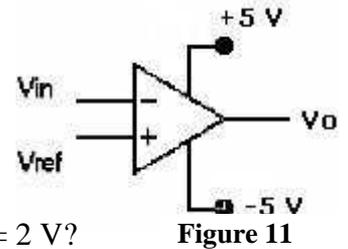
Figure 11

Part E: The Summing Amplifier (Adder) circuit

1- Construct the circuit shown in Figure 12.

2- Connect V_1 to **1V** (D.C supply)

3- Connect V_2 to a Function Generator (Sine wave **2V_{p-p}, 1kHz**)

4- Connect the Oscilloscope CH1 to the input sine wave (V_2) and CH2 to the output voltage (V_o), be sure to put CH2 coupling to **DC coupling**. Sketch the output signal on the respective Oscilloscope screen in the sheet answer.

5- Repeat steps (2 - 4) by changing the amplitude of V_2 to **6V_{p-p},1kHz**. Explain what happen.
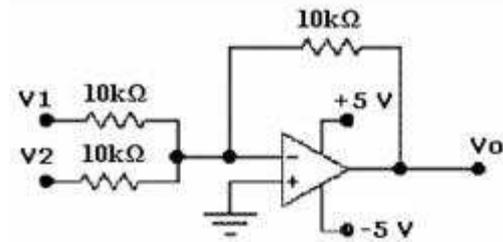
Figure 12

Part F: The Differential Amplifier (Subtractor) circuit

1- Construct the circuit shown in Figure 13 using **R1 = R2 = R3 = R4 = 10KΩ**.

2- Connect V_1 to **1V** (D.C supply)

3- Connect V_2 to a Function Generator (Sine wave **2V_{p-p}, 1kHz**)

4- Connect the Oscilloscope CH1 to the input sine wave (V_2) and CH2 to the output voltage (V_o), be sure to put CH2 coupling to **DC coupling**. Sketch the output signal on the respective Oscilloscope screen in the sheet answer.

5- Repeat steps (2 - 4) by changing the amplitude of V_2 to **6V_{p-p},1kHz**. Explain what happen.
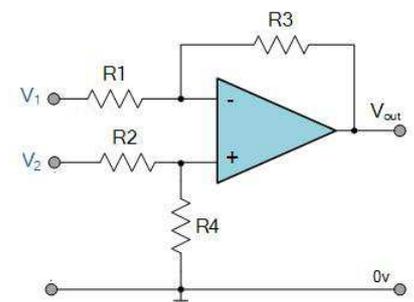
Figure 13

Part G: The Inverting Integrator circuit

1- Construct the circuit shown in Figure 14 by using **R=1KΩ and C=1μF**.

2- Apply a square-wave signal at V_{in} with **1kHz** frequency and **5 V_{p-p}**.

3- Connect CH1 to the input signal and CH2 to the output signal and set the coupling of channel 2 to **AC coupling**.

4- Sketch Vo(t) Signal on the respective Oscilloscope screen in the sheet answer.

5- Comment on the output signal and its relation to the input signal.
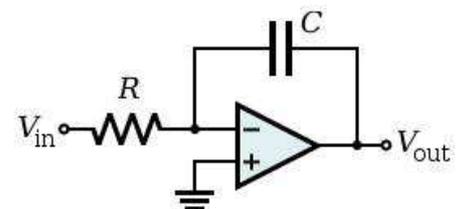
Figure 14

Part H: The Inverting Differentiator circuit

1- Construct the circuit shown in Figure 15 by using **R=10KΩ and C=10μF**.

2- Apply a triangle-wave signal at V_{in} with **1kHz** frequency and **5 V_{p-p}**.

3- Connect CH1 to the input signal and CH2 to the output signal.
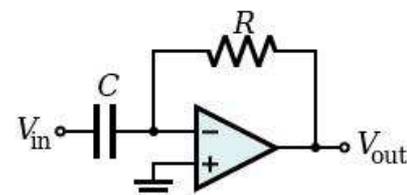
Figure 15

5

4- Sketch Vo(t) Signal on the respective Oscilloscope screen in the sheet answer
5- Comment on the output signal and its relation to the input signal.

Part I: The Half wave Precision Rectifier circuit

1- Construct the circuit shown in Figure 16 using $R_L = 1k\Omega$.

2- Apply a sine wave signal at the input with **400mV$_{p-p}$, 2kHz**.
3- Connect CH1 to the input signal and CH2 to the Output signal.

4- Draw the output signal on the respective Oscilloscope screen in the sheet answer,
and measure the output peak voltage.

5- What is the main difference between the rectified signals if we use Op-amp
instead of using diode only as in Experiment 2?
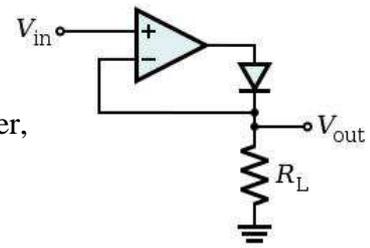
Figure 16

Part J: The Square Wave generator circuit

1- Construct the circuit shown in Figure 17 by using **R = 10KΩ,**
2- **R1 = R2 = 15 KΩ and C = 0.1µF**.

Connect CH2 of the Oscilloscope to the Output of the Op-amp and draw
the output signal on the respective Oscilloscope screen in the sheet answer.

3- Measure the frequency of the output signal from the scope screen and
compare it with the calculated frequency.
4- Explain how can we change the frequency of the output signal?
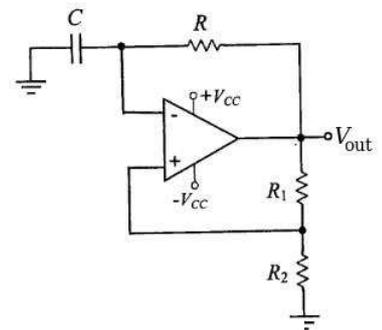
Figure 17

Part K: The Sine Wave Oscillator circuit

1- Construct the circuit shown in Figure 18 by using **C1 = C2 = 0.1µF, R1 = R2 = 1kΩ, R3 = 22 kΩ**
and **R4 = 10 kΩ.**

2- Connect CH2 of the Oscilloscope to the Output of the Op-amp and draw the output signal on the
respective Oscilloscope screen below.

3- Measure the frequency of the output signal from the scope screen and compare it with the
calculated frequency.

4- Explain how can we change the frequency of the output signal?
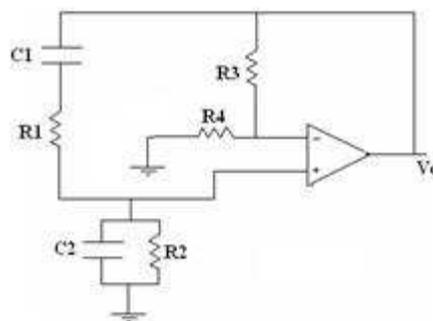
Figure 18
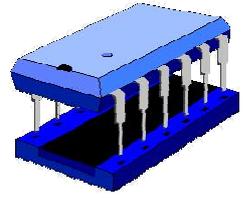
University Of Jordan
Faculty of Engineering
Mechatronics Engineering Department

Electronics Lab Report

0908322

Experiment No.: _____   **Student Group: _____**

Experiment Name: _____

Students Name:

   1) _____

   2) _____

   3) _____

   4) _____

Operational Amplifier Application

Part A: The Inverting amplifier circuit
3-
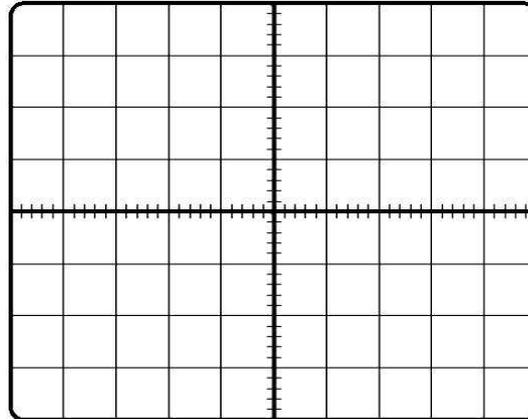
4- Calculate the voltage gain **Av**.

....

....

5- What is the phase shift between the input and the output signals?

....

....

6- Increase the function generator amplitude until the output signal start to clip, read **the value of the input voltage** that saturate the op-amp and find **the maximum value of the output voltage**.

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Part B: The Non - Inverting amplifier circuit
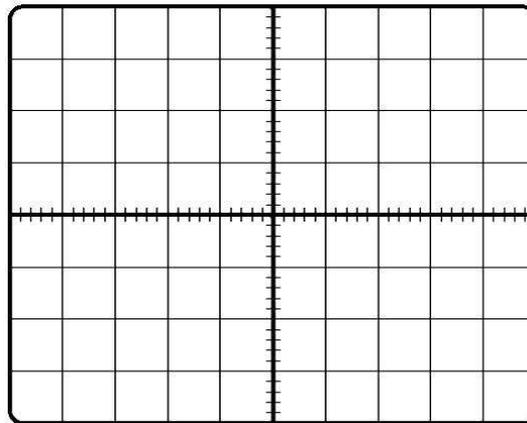
3-

4- Calculate the voltage gain **A*v***.

....

....

5- What is the phase shift between the input and the output signals?

....

....

Part C: The Voltage Follower circuit

3-
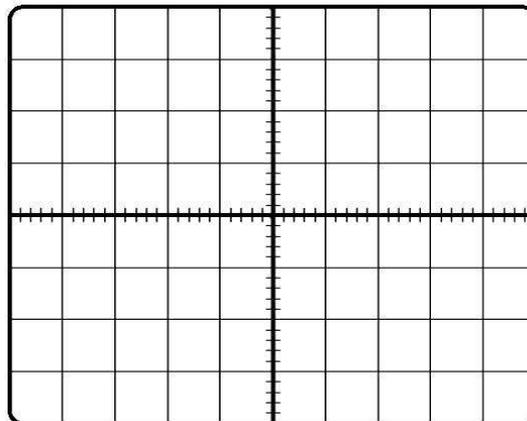
4- Increase the input voltage amplitude to **3 V$_{p-p}$**, **4 V$_{p-p}$** and measure the output voltage. Comment on your readings.

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5- Calculate the voltage gain **A***v*.

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. . . .

6- What is the phase shift between the input and the output signals?

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Part D: The Comparator circuit
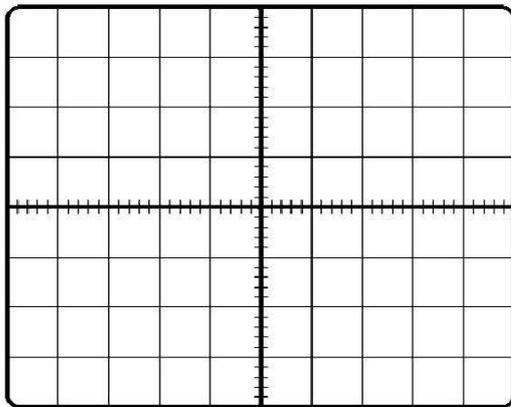
Vref=0 V   **Vref=2 V**
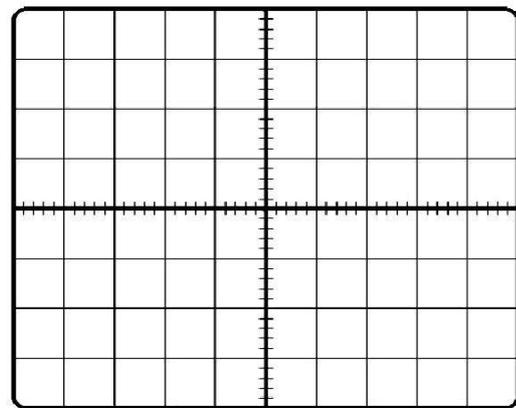
5- Does the output signal differ when $V_{ref} = 0$ V from that when $V_{ref} = 2$ V? Explain.

. . . .

. . . .

Part E: The Summing Amplifier (Adder) circuit
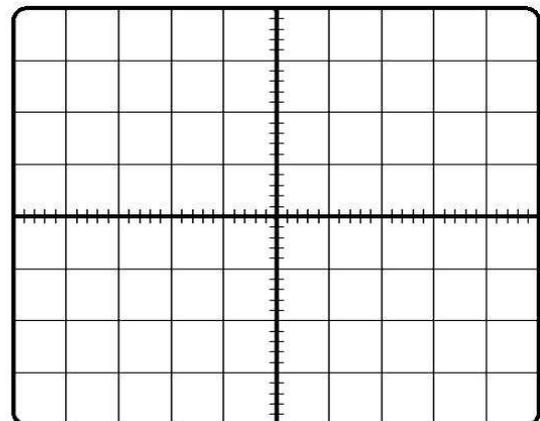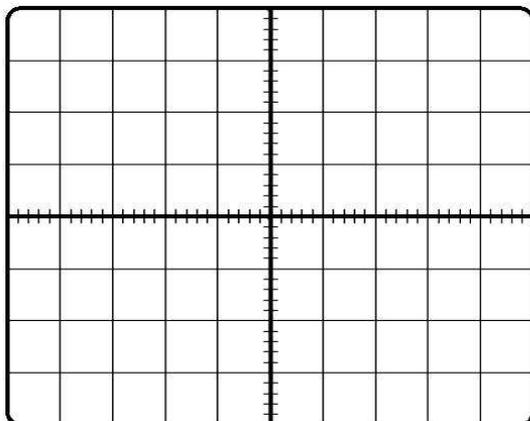
5- Explain what happen.

. . . .

Part F: The Differential Amplifier (Subtractor) circuit
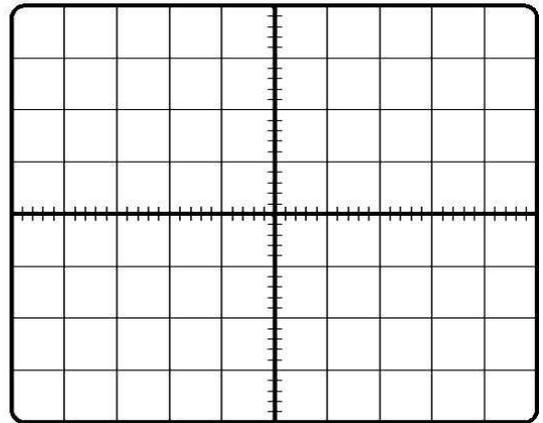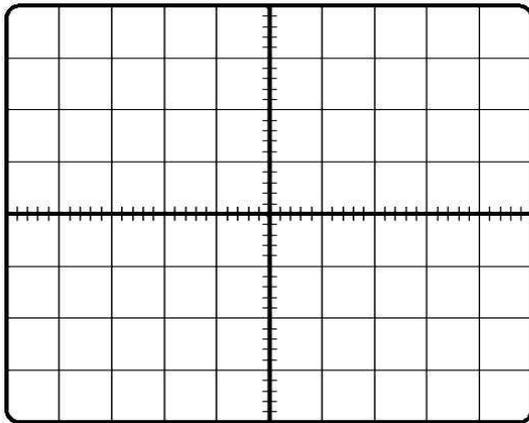
5- Explain what happen.

. . . .

. . . .

Part G: The Inverting Integrator circuit
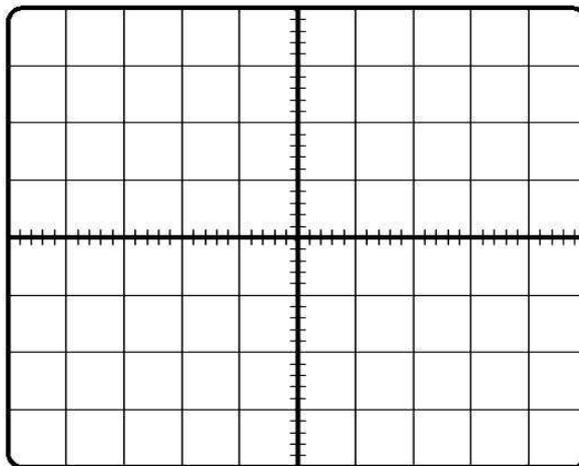
5- Comment on the output signal and its relation to the input signal.

. . . .

. . . .

## Part H: The Inverting Differentiator circuit
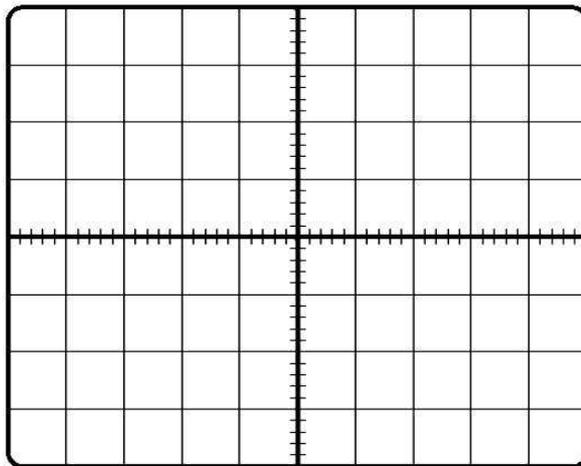
5- Comment on the output signal and its relation to the input signal.

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Part I: The Half wave Precision Rectifier circuit
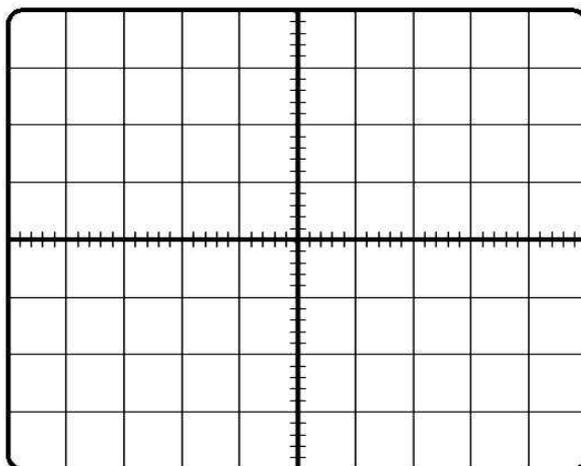
5- What is the main difference between the rectified signals if we use Op-amp instead of using diode only as in Exp2?

……………………………………………………………………

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Part J : The Square Wave generator circuit

3- Measure the frequency of the output signal from the scope screen and compare it with the calculated frequency.

. . . .

. . . .
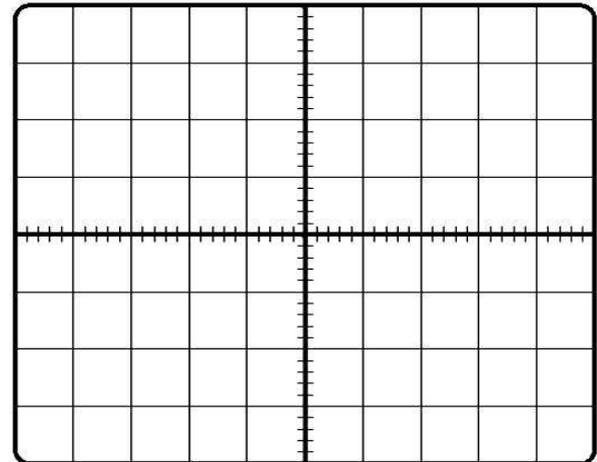
4- Explain how can we change the frequency of the output signal?

. . . .

. . . .

Part K: The Sine Wave Oscillator circuit

3- Measure the frequency of the output signal from the scope screen and compare it with the calculated frequency.

. . . .

. . . .

4- Explain how can we change the frequency of the output signal?

. . . .

. . . .