



**The University of Jordan  
School of Engineering  
Mechatronics Engineering department**

# **Electronics Laboratory Manual (0908322)**

Experiment 1: Electronics lab familiarization

Experiment 2: Diode characteristics

Experiment 3: Diode applications

Experiment 4: Zener Diode characteristics and applications

Experiment 5: BJT characteristics

Experiment 6: BJT applications

Experiment 7: BJT frequency Response

Experiment 8: MOSFET characteristics

Experiment 9: OP-AMP applications

Experiment 10: Design Problems

## Laboratory Safety Symbols and Rules:

### Emergency Response



1. It is your responsibility to read safety and fire alarm posters and follow the instructions during an emergency.
2. Know the location of the fire extinguisher in your lab and know how to use them.
3. Know the location and function of all laboratory safety equipment.
4. Notify your instructor immediately after any injury, fire or explosion, or spill.
5. Know the building evacuation procedures.



<b>EMERGENCY PHONE NUMBERS</b>	
Fire	52
Ambulance	52
Uni. Security	54
Clinic	51

### General Safety Rules

1. Read all directions for an experiment and follow the directions exactly as they are written.  
If in doubt, ask the teacher.
2. Always obtain permission before experimenting on your own.
3. Never handle any equipment unless you have specific permission.
4. Report any accident or injury, no matter how small, to your teacher immediately.
5. Dispose of all material according to the teacher's instructions.
6. Never eat, drink, or smoke while working in the laboratory.
7. You have long hair or loose clothes, make sure it is tied back or confined.

### Electrical Safety

1. Obtain permission before operating any high voltage equipment.
2. Make sure electronic equipment is OFF when plugging or unplugging from an outlet.
3. Make sure the work area for electrical equipment is clean and dry.
4. Do not "daisy-chain" electrical power cords.
5. Maintain an unobstructed access to all electrical panels.
6. Avoid using extension cords whenever possible. If you must use one, obtain a heavy-duty one that is electrically grounded, with its own fuse, and install it safely. Extension cords should not go under doors,



across aisles, be hung from the ceiling, or plugged into other extension cords.

7. Never, ever modify, attach or otherwise change any high voltage equipment.
8. Always make sure all capacitors are discharged (using a grounded cable with an insulating handle) before touching high voltage leads or the "inside" of any equipment even after it has been turned off. Capacitors can hold charge for many hours after the equipment has been turned off.

### **End of Laboratory activity rules**

1. Clean all laboratory equipment and return to their locations
2. Unplug and store properly any electrical device.
3. Wash your hands after every experiment.
4. Clean up your work area before leaving. .



### **Report guidelines:**

The lab report Reflects your understanding of what you have done from theory to the experimental results which you can discuss and verify its correctness. In Lab report you introduce briefly the objectives of the experiment, how it was done (The methodology) and finally you show the results and discuss it.

Your report should be clear, interconnected and understood

Using past tense. As a rule of thumb, past tense is used to describe work you did over the course of the report timeline.

Using present tense. As a rule of thumb, present tense is used to describe Knowledge and facts that were known before you started.

Lab Report should include:

- Table of contents.
- List of figures
- List of tables
- Abstract
- Introduction
- Methodology
- Results

- Discussion
- References

1. Abstract: should briefly describe the work you have done and the result you got.

2. Introduction: in this part you describe the sensor its technology (resistive, capacitive....etc) what is it used for, some applications. and the theory behind.

3. Methodology: here you write the details about:

- a) The signal conditioning circuit design.
- b) Procedure you follow in measurement.
- c) The accuracy of devices you used.

4. Results include data collected, tables ....

5. Discussion includes:

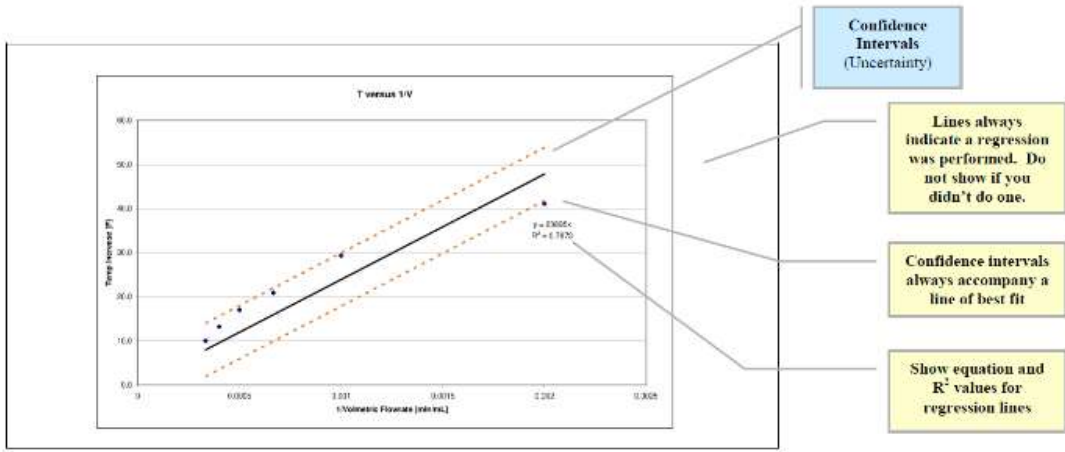
- a) Explaining the results and finding the characteristics of the transducers
- b) Explanation of Errors
- c) You may add conclusion or summary
- d) Future Work what can be done to improve results

- **Font** should be Times new roman size 12 except headings size 14.
- **Title of the figures** should be at the bottom of the figure and figures should be at the middle
- **Title of tables** should be above the table and on the right

### **Data analysis and regression:**

To find the characteristics and calibration curve use cftool in matlab for regression and note the following:

Don't connect the experimental data with solid line





**The University of Jordan**  
**Mechatronics Engineering Department**  
**Electronics lab for Mechatronics**  
**0908322**

**Experiment 1: Electronics lab Equipment Familiarization**

**Objectives:**

To be familiar with electronics lab equipment

Learn how to build an electronic circuit and show the results.

**Background:**

In this lab each group of students will perform the experiments on a lab bench that is equipped with a dc power source, function generator, bench digital multi-meter, portable Digital multi-meter, oscilloscope and a self powered breadboard. The dc power supply and the function generator are power sources while the oscilloscope and the multi-meters are measuring devices that are used to measure current(AC and DC), voltage (AC and DC), resistance and other quantities.

**1.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 1.1 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).

The output voltage range is 0-30V

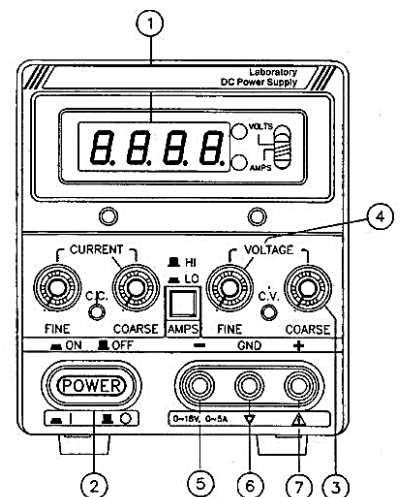


Figure 1.1: DC power supply front panel

## 2. Function Generator

The Function Generator generates signals in the frequency range up to 3MHz some of the most common waveforms produced by the function generator are the sine, square, triangular shapes Figure 1.2 shows the front panel for the GFG 8217A Function generator with each function.

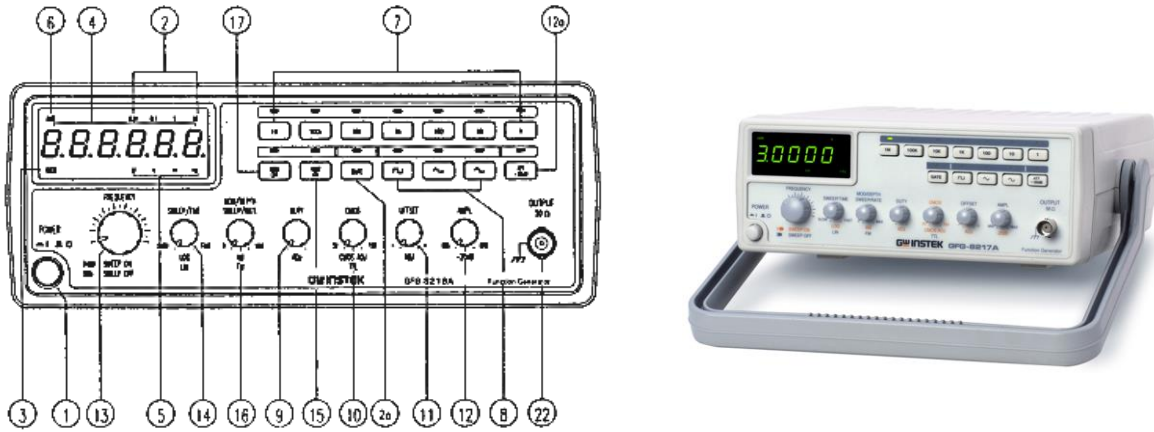


Figure 1.2: front panel of the function generator

### FUNCTION DESCRIPTION

1. Power Switch            Connect the AC power, then press power switch.
4. Counter Display        Shows the external frequency by  $6 \times 0.3''$  green display, and shows the internal frequency by  $5 \times 0.3''$  green display.
5. Frequency Indicator    Indicate the current frequency value.  
To select the required frequency range by pressing the relevant push button on the panel as shown in
7. Frequency Range Selector    Table 1

Table 1(for GFG-8217A)

Push bottom	1	10	100	1k	10k	100k	1M
Frequency Range	0.3Hz	3Hz	30Hz	300Hz	3kHz	30kHz	300kHz
	3Hz	30Hz	300Hz	3kHz	30kHz	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.
11. DC Offset Control        Pull out the knob to select any DC level of the waveform between  $\pm 10V$ , turn clockwise to set a positive DC level waveform and invert for a negative DC level waveform.
12. Output Amplitude Control with Attenuation Operation    Turn clockwise for MAX. output and invert for a  $-20dB$  output. Pull the knob out for an additional 20dB output attenuation.
- 3 MANU/SWEEP            Press and turn clockwise the knob for MAX frequency and invert for MIN frequency. (Keep the pointer within the scale range on the panel.). Pull out the knob to start the auto sweep operation; the



Adjustment upper frequency limit is determined by the knob position.  
(Sweep On/Off)

17 INT/EXT MOD Selector When press the button once, the indicator will lighten, then the EXT MOD has been selected. Press the key again, the indicator will be off, then INT MOD has been selected.

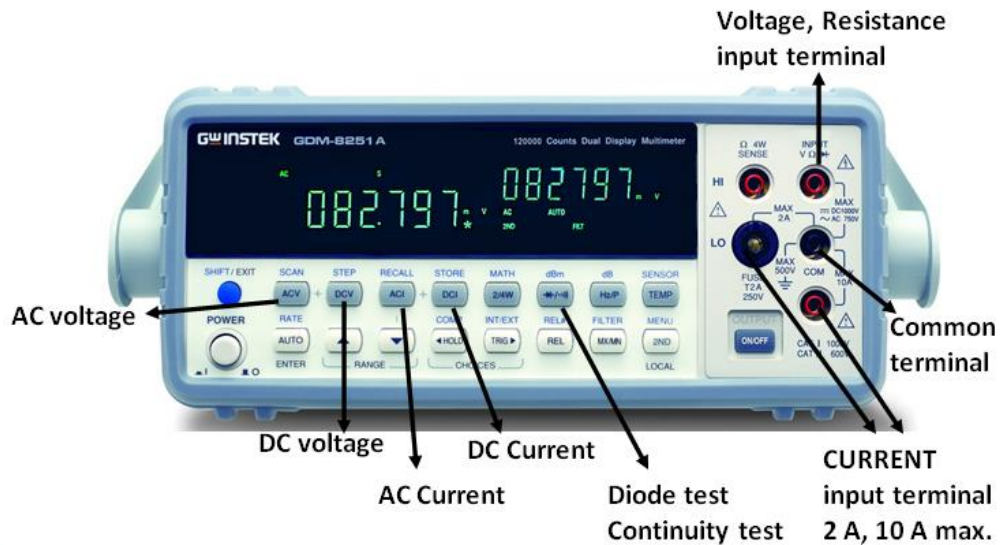
### 3. Digital Multi-meter (DMM):

Two different Digital multi-meters in the lab are used to measure different quantities; voltage (AC,DC), current (AC,DC), resistance, temperature, capacitance, frequency in addition to diode test and continuity test.

When measuring AC current or voltage the DMM reading is the RMS value (Root-Mean-Square). The commonly-encountered sinusoidal wave has an RMS value of where is the peak voltage of the sine wave.

$$V_{rms} = \frac{V_p}{\sqrt{2}}$$

It should be note that the DMM's internal resistance affects the measured values (loading effect). The ideal voltmeter has an infinite resistance while the ideal ammeter has zero resistance. See the datasheet to find the internal resistance for each one and write the values in the report



ected in parallel. The DMM's input

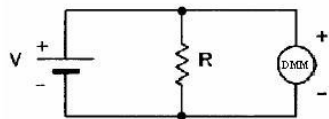
impedance is high enough (several  $M\Omega$ ) so that it has negligible effect on the circuit being measured (i.e no loading effect). In case of measuring the resistance of a resistor, this resistor must be disconnected from the circuit. To measure current, the DMM is connected in series. The DMM's input impedance is small enough (in  $\Omega$ 's) so that it has negligible effect on the circuit being measured (i.e no loading effect). Refer to Figure



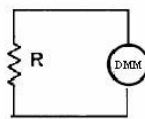
(a) Voltage V

(b) Resistance  $\Omega$

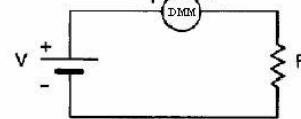
(c) Current A



(a) Using a multimeter to measure voltage



(b) Using a multimeter to measure resistance.



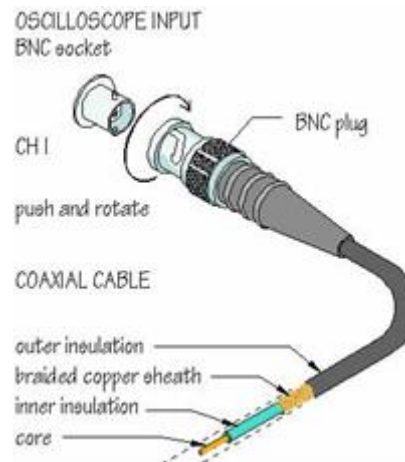
(c) Using a multimeter to measure current.

#### 4. 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. 1 $\mu$ s/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 ( $1\text{ M}\Omega$ , parallel with  $25\text{ pF}$ ), 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 6. The cable has  $50\Omega$  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 prevent the noise and interference signals.



### **5.Power Breadboard:**

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 figure 1.3 each five horizontal halls represents a node as they are connected with a build in conductor as in figure 1.3 means all the halls represents one node.

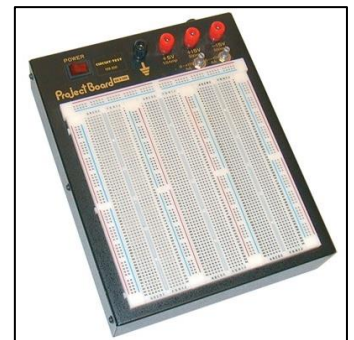


Figure1.2: Power Breadboard

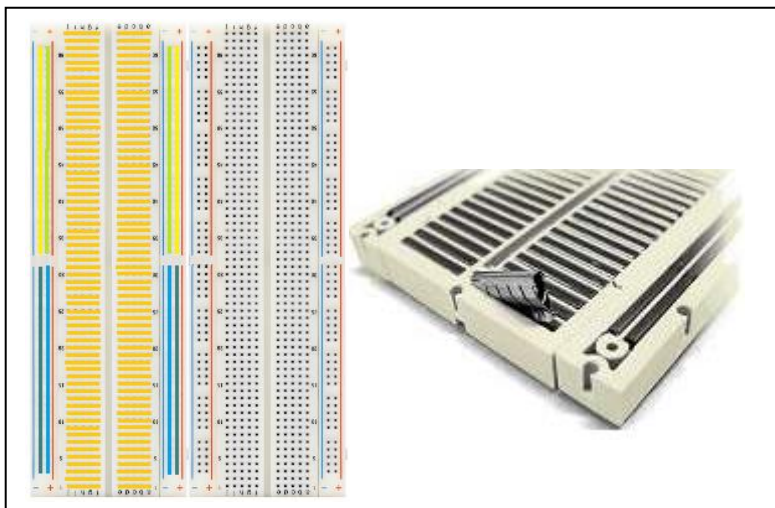


Figure1.3: Breadboard nodes (internal wiring).

## Resistors

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:

Color	Significant 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

Figure 1.1: Resistor Color Codes Chart

## Procedure

### Equipments and electronics component needed

- 1- Oscilloscope.
- 2- Function Generator (FG) or Signal Generator.
- 3- Digital Multi-meter (DMM).
- 4- Bread-board.
5. DC power supply
- 6- Two resistors 220,1K

### 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:

$$( e\% = \frac{Measured - Expected}{Expected} \times 100\% )$$

- 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.

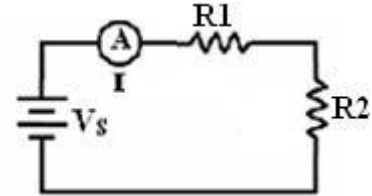
## PART B - Using The DC supply

Follow the steps below and fill the answer sheet:

- 1) Turn the voltage knobs to the minimum (maximum counter clock 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  $R_1 = 1\text{k}\Omega$  and  $R_2 = 2.2\text{k}\Omega$  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 Figure 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  $R_1$  and measure  $V_{R1}$  and record it in Table 2 in the answer sheet.
- 6) Repeat step 5 to read the supply voltage ( $V_s$ ) and the voltage on  $R_2$  ( $V_{R2}$ ).

**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 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- Change the amplitude of the signal to get 100 mV by pulling the amplitude knob on the function generator out and turn it until you get the required amplitude
- 7- 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



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**Electronics lab for Mechatronics**

**0908322**

**Experiment 1: Electronics lab equipment familiarization**

Group Number:.....

Student Name	ID

# Report of Exp. 1

## Electronics Lab Equipment Familiarization

### PART A – Measuring resistance

Table 1

	Expected	Measured	e%	Color code
<b>R1</b>				
<b>R2</b>				
<b>R (series)</b>				
<b>R (parallel)</b>				

### PART B - Using the DC supply

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

.....

.....

### PART C - Building a simple circuit

From The bench multi-meter datasheet find the following:

1. Bench multi-meter ammeter internal resistance:.....
2. Bench multi-meter Voltmeter internal resistance:.....

Table 2

I (mA)	V <sub>R1</sub> (volt)	V <sub>R2</sub> (volt)	V <sub>s</sub> (volt)

### Part D – Using the Oscilloscope and the Function Generator

5- Table 3

Signal	#of vertical divisions	Volt/Div	# of horizontal divisions for one cycle	Sec/Div
8 V <sub>pp</sub> , 1 kHz				
100 mV <sub>pp</sub> , 1 kHz				

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?

.....  
.....

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?

.....  
.....

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				



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## Experiment 2: Diode characteristics

### Objectives:

To study and verify the functionality of junction Diode and investigate its characteristics (i-v) curve.

### Background:

The diode is a device formed from a junction of n-type and p-type semiconductor material. The lead connected to the p-type material is called the anode and the lead connected to the n-type material is the cathode. In general, the cathode of a diode is marked by a solid line on the diode.

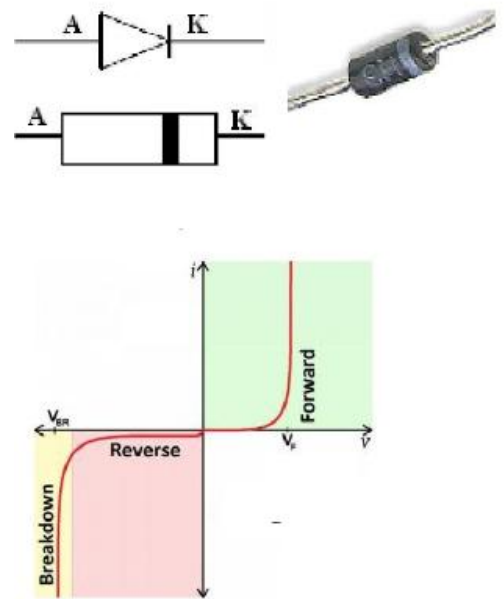
**Forward biased:** In forward bias the anode is more positive than cathode and the voltage drop on the diode is greater than the cut-in voltage ( $V_\gamma$ ), and the current will flow from anode to cathode in range of (mA). When analyzing the circuit, the diode is ideally replaced by short circuit,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

**Reversed biased:** Reverse biased: The cathode is more positive than anode, only reverse small current in range of ( $\mu\text{A}$ ) 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.

A general (i-v) curve is seen in figure 2.1.

In the forward-bias region the V-I relationship is described as follows:

$$I = I_s \left( e^{\frac{V}{nV_T}} - 1 \right)$$



In the above equation,  $I$  is the forward current,  $V$  is the forward voltage,  $I_0$  is the saturation current, and  $V_T = kT/q$  is the thermal voltage. Initially, the  $V$  vs  $I$  graph is linear but then after reaching breakdown, it becomes exponential.

Where  $I$  = current flowing in the diode,

$I_0$  = reverse saturation current  $V$  = voltage applied to the diode,  $V_T$  = volt- equivalent of temperature =  $kT/q = T/11,600 = 26\text{mV}$  (@ room temp) = 1 (for Ge) and 2 (for Si)

Circuit Diagram:

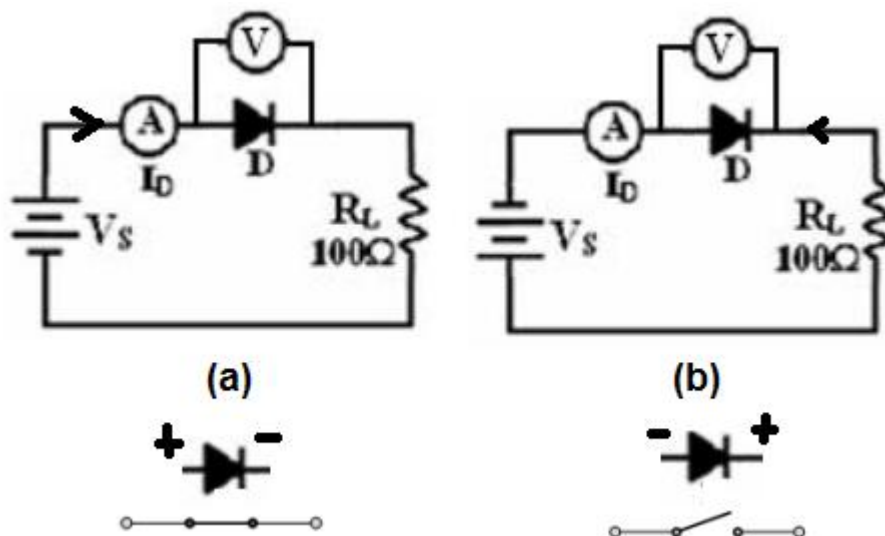


Figure 2.2 : (a) Forward biased condition and (b) reverse biased conditions

### Rectifiers:

Rectifiers are the main applications for diodes. They are used to convert AC signal to DC signal. In this lab you are going to build two types of rectifiers; half wave and full wave rectifiers.

#### **Unfiltered half wave rectifiers:**

If you use AC power source instead of the DC power supply source in figure 2.1 a or b then you build a half wave rectifier. In half wave rectifiers one half of the AC signal makes the diode forward biased and allow the current to pass and the other half makes the diode reverse biased and no current pass.

The output of the unfiltered half wave rectifier is shown in figure 2.3 below.



Figure 2.3: half wave rectifier output signal

The maximum output voltage of the rectified unfiltered signal ( $V_p$  (HWR) ) is found by the following equation:

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

Where V value (DC value) of the HWR rectified unfiltered signal over one period is given by: (input ) is the input signal peak voltage. The amount of the average

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

The frequency of the rectified output waveform can be expressed as:  $f (HWR) = f_{source}$

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

### Filtered half wave rectifiers:

If you add a capacitor in parallel with the resistor to the circuit in figure 2.2 a then you build a filtered half wave rectifier. By adding the capacitor to the circuit the signal will be smoothed out in order to obtain direct signals (it is dc only in the sense that it does not change polarity, no ripples in the signal). The capacitor will charge to the peak voltage of the rectified signal and when the rectified signal voltage falls below the capacitor maximum voltage, it start to discharge through the load resistance R shown in Figure 2.4. The discharge time for the capacitor ( $\tau = RC$ ) has to be greater than the period of the input signal (T).

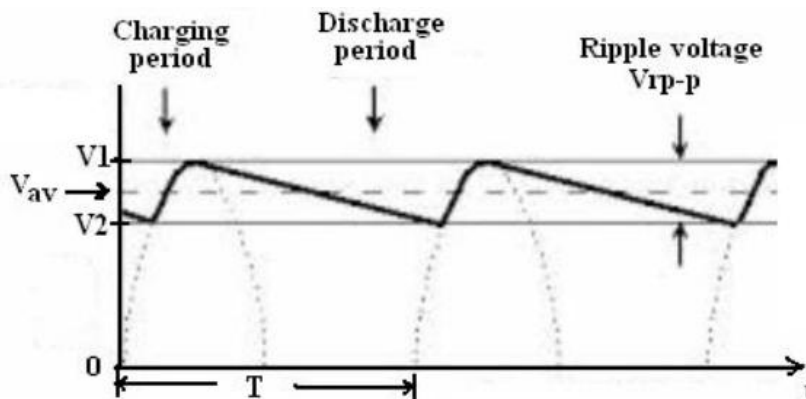


Figure 2.4: Filtered signal

The output filtered signal average voltage

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

Where V (rectified ) is the HWR or FWR signal peak voltage and Vr p-p is the ripple signal peak to peak voltage. Vrp-p represents the difference between the capacitor maximum voltage and the capacitor voltage after discharging, which can be found by the equation:

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

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 (rectified ) (Note: V (rectified ) is related to the input signal maximum voltage).

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:

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

### **Procedure:**

#### **Equipments and electronics component needed**

- |                              |   |
|------------------------------|---|
| 1- Oscilloscope.             | 2- Function Generator (FG) or Signal Generator. |
| 3- Digital Multimeter (DMM). | 4- Bread-board.                                 |
| 5- DC power supply           | 6- Resistors 100,1K,10 K,100 K.                 |
| 7- Capacitors: 1μF, 2.2μF    |   |

#### **(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 (+) 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 record the result 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 the results it in the answer sheet.

#### **(B-1) Forward biased:**

- 1-Construct the circuit in figure 2.2 a.
- 2- Turn the voltage supply knob fully CCW at 0V before switching the power on.
- 3- Switch on the Dc power supply and increase the voltage slowly and record the corresponding current and voltage values as in table 1 in the answer sheet.
- 4- After finishing set the output of the DC power supply to zero then switch it off.

### (B-2) Reverse biased:

- 1-Reverse the polarity of the voltage supply as in figure 2.2 b and repeat the previous steps with filling table in the answer sheet.
- 2-Draw the i-v characteristics curve of the diode on the given graph paper.
- 3- Find the approximate forward-bias turn-on voltage.
- 4- Write the equation of the load line for the circuit and draw it on the same (i-v) characteristic curve.

### (C) Unfiltered half wave rectifier:

- 1- Construct the circuit shown in Figure 2.5 where:  $R = 1k\Omega$ ,  $V_{p-p} = 10V$ , 100 Hz.

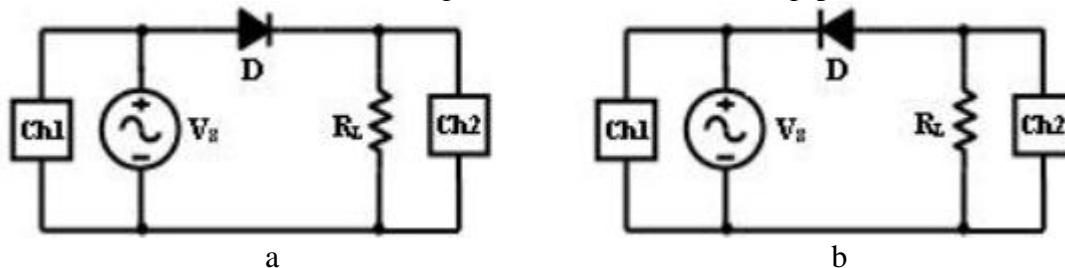


Figure 2.5: Unfiltered half wave rectifie

- 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 ) to 10V sinusoidal.
- 4- Use the Oscilloscope to measure voltage and sketch the results on the answer sheet showing all the peak voltage and the frequency of the resulted signal.
- 5- Reverse the diode according to Figure 9 and repeat the previous steps.
- 6- Again sketch the output on the answer sheet showing the peak voltage and frequency of the signal
- 7- Change the resistance and the capacitance values according to table 1 and sketch the output in the answer sheet.

### (C) Filtered half wave rectifier:

- 1- Construct the circuit shown in Figure 2.6 where:  $R = 1k\Omega$ ,  $V_{p-p} = 10V$ , 100 Hz.

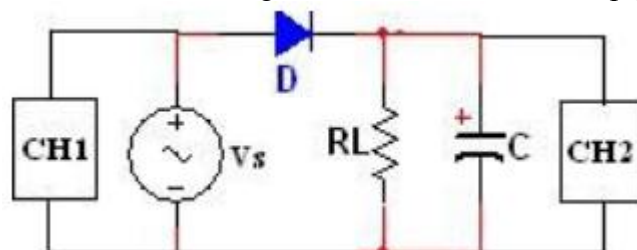


Figure 2.6: Filtered half wave rectifier.

- 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 ) to 10V sinusoidal.
- 4 Use the Oscilloscope to measure voltage and sketch the results on the answer sheet showing all the peak voltage and the frequency of the resulted signal.
- 5-Change the resistance and the capacitance values according to table 2 and sketch the output in the answer sheet.



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**Experiment 2: Diode characteristics**

Group Number:.....

Student Name	ID

## PART A

1-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.

2-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.

### B-1 Forward biased:

Table 1: I-V forward biased data

$V_s$ (V)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1
$V_d$ (V)												
$I_d$ (mA)												

### B-2 reverse biased:

Table 2: I-V reverse biased data.

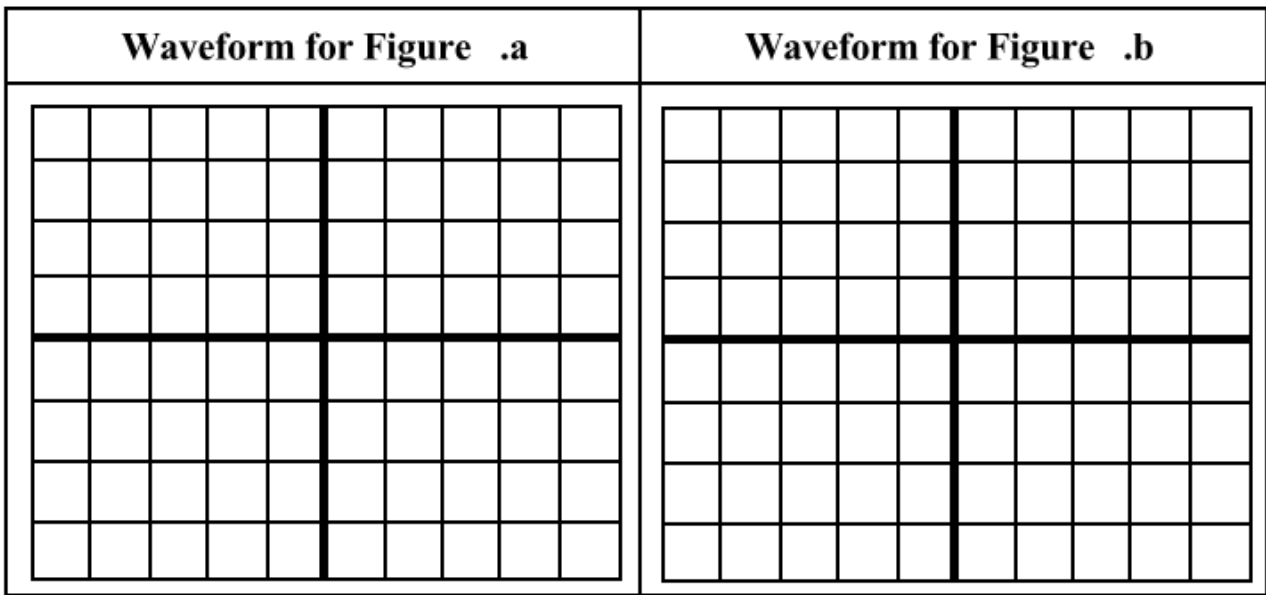
$V_s$ (V)	0	1	2	5
$V_d$ (V)				
$I_d$ (mA)				

Plot the Diode I-V curve on the graph paper and draw the load line on the curve.

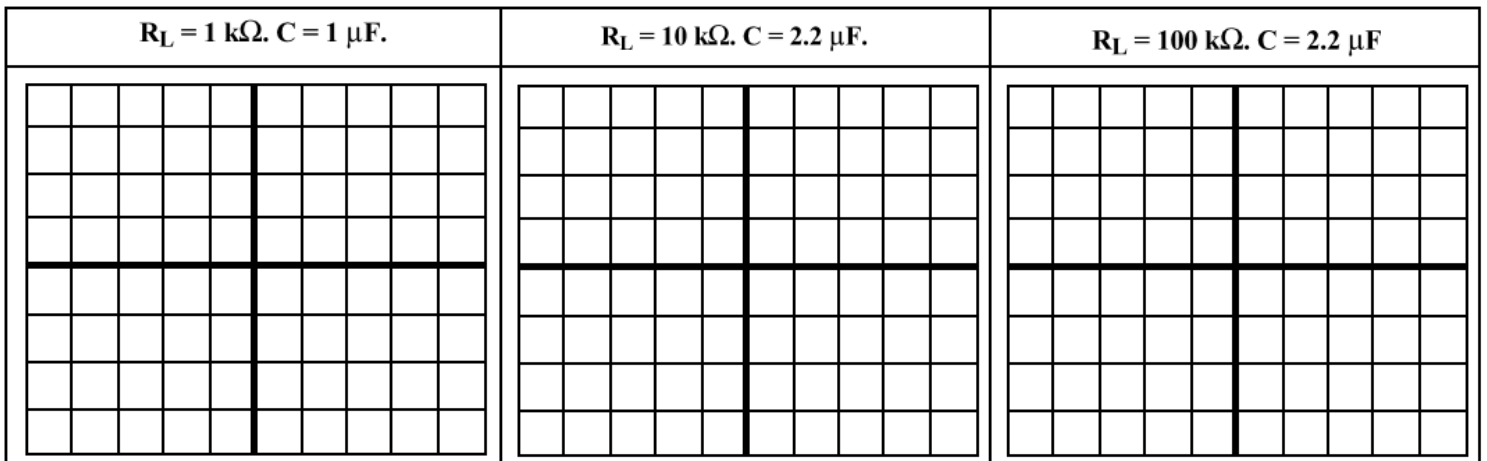


**C- Rectifiers:**

**Unfiltered half wave rectifier:**



**Filtered half wave rectifier:**



$V_{r-pp}$  \_\_\_\_\_

$V_{avg}$  (V) \_\_\_\_\_

**Ripp.%** \_\_\_\_\_

$V_{r-pp}$  \_\_\_\_\_

$V_{avg}$  (V) \_\_\_\_\_

**Ripp.%** \_\_\_\_\_

$V_{r-pp}$  \_\_\_\_\_

$V_{avg}$  (V) \_\_\_\_\_

**Ripp.%** \_\_\_\_\_





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**Experiment 1: Electronics lab Equipment Familiarization**

**Objectives:**

To learn about diode applications

To understand the theory of operation of the clipping and clamping diode circuits.

**Pre-lab**

Construct one of the circuits in the sheet using Multisim.

**Theory:**

In this experiment you are going to learn about some diode applications of using diodes in electronics. These applications are full wave bridge rectifiers, clippers, clampers and peak detectors.

**1-Full wave Bridge rectifier:**

In bridge rectifiers four diodes are used as the arrangement in figure 3.1. The four diodes are arranged in “series pairs” with only two diodes conducting current during each half cycle. During the positive half cycle of the supply, diodes D1 and D2 conduct in series while diodes D3 and D4 are reverse biased.

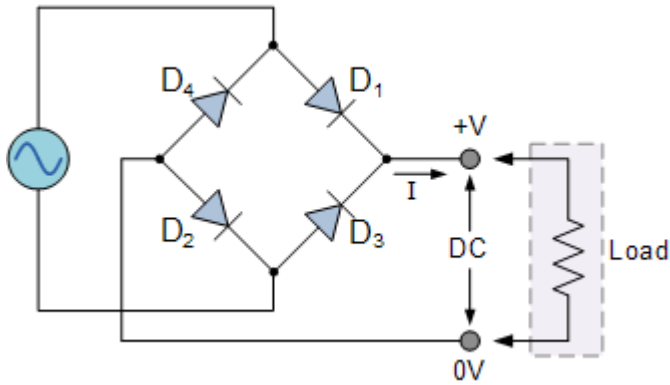


Figure 3.1: Diodes arrangement in full wave bridge rectifier

The amplitude of the output voltage is two voltage drops ( $2 \times 0.7 = 1.4\text{V}$ ) less than the input  $V_{\text{MAX}}$  amplitude. The ripple frequency is now twice the supply frequency (e.g. 100Hz for a 50Hz supply) see Figure 3.2.

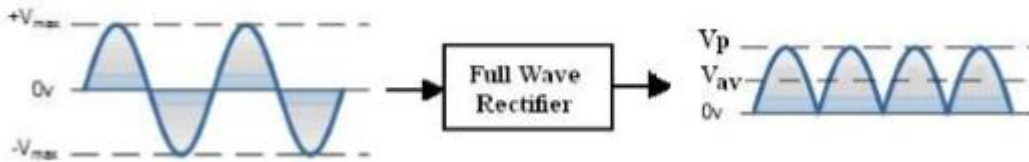


Figure 3.2: The output of full wave bridge rectifier

Where  $V_p$  of the rectifier can be found by:

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

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

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

### The Smoothing Capacitor

The full-wave bridge rectifier gives a greater mean DC value ( $0.637 V_{\text{max}}$ ) with ripple and the output waveform is twice that of the frequency of the input supply frequency. The average DC output of the rectifier can be improved and at the same time the AC variation of the rectified output can be reduced by using smoothing capacitors to filter the output waveform. Smoothing or reservoir capacitors connected in parallel with the load across the output of the full wave bridge rectifier circuit increases the average DC output level even higher as the capacitor acts like a storage device as shown in figure 3.3 below.

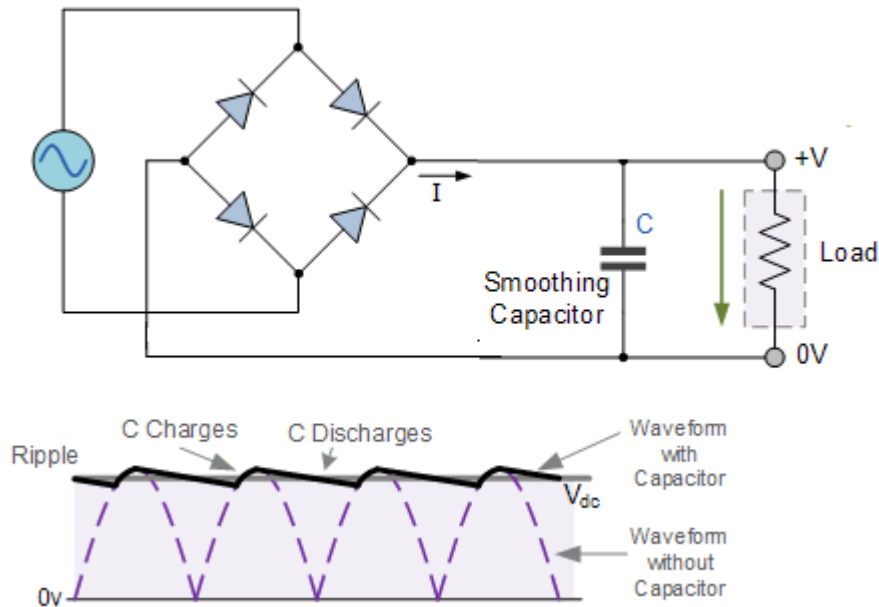


Figure 3.4: the output of full wave bridge rectifier with smoothing capacitor, filtered rectifier.

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 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:

$$V_r - pp = V - V' = \frac{V_P (rectified)}{2fRC}$$

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).

The **Diode Clipper**, also known as a *Diode Limiter*, is a wave shaping circuit that takes an input waveform and clips or cuts off its top half, bottom half or both halves together.

### Diode clippers:

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 ( $V_D$ ) (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 3.5 below.

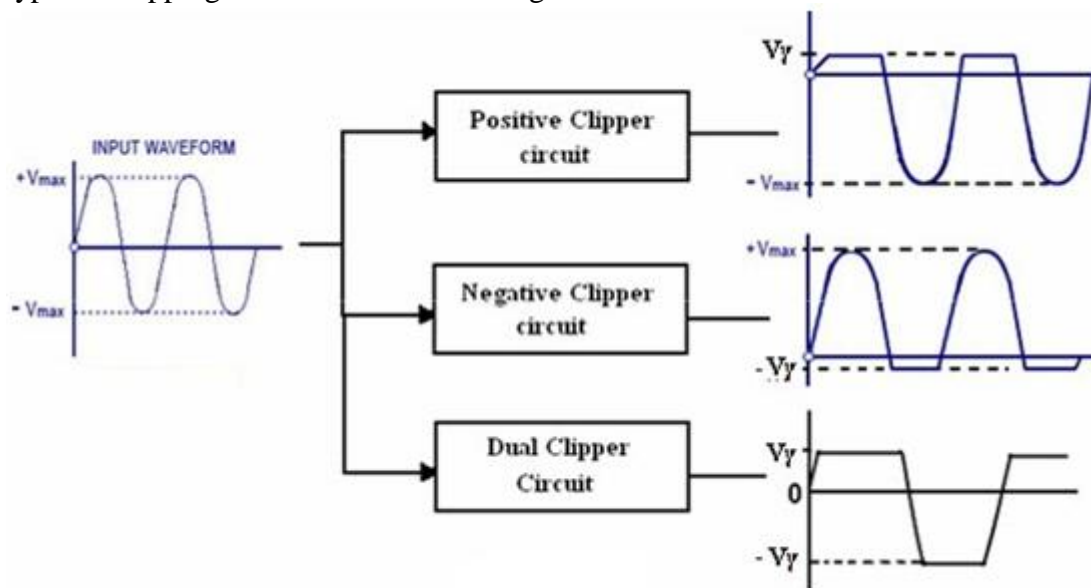


Figure 3.5: Different clipping circuits

### **Diode Clamper circuits:**

also called DC restorers 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 ( $\tau \gg T$ ).

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 the DC voltage. The output signals from the positive and the negative clamper circuits are shown in Figure 3.6.

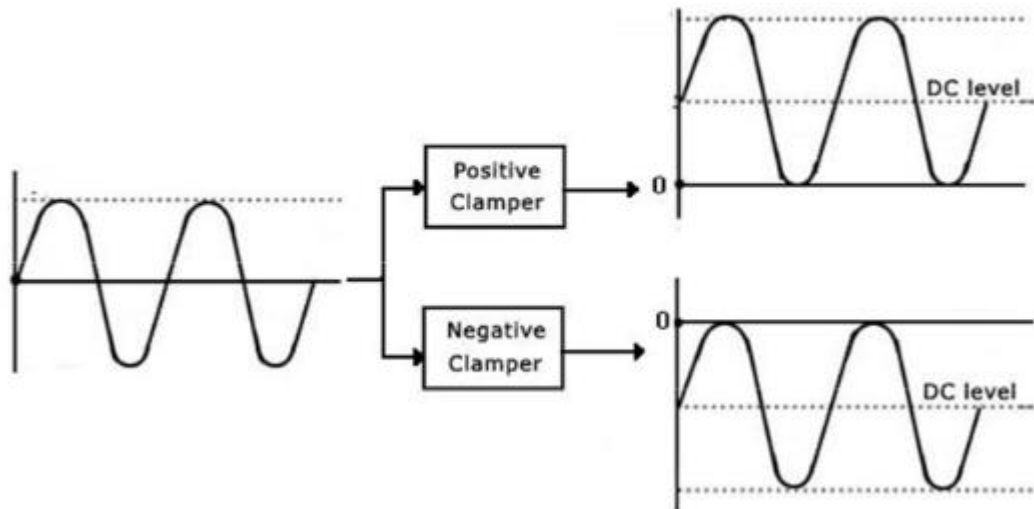


Figure3.6: Diode clamper circuits.

## Procedure

### Equipment and electronics component needed

- |  |   |
|--|---|
| 1- Oscilloscope.                         | 2- Function Generator (FG) or Signal Generator. |
| 3- Two Digital Multi-meter (DMM).        | 4- Bread-board.                                 |
| 5. DC power supply                       | 6- Resistors of 100, 1K,10K AND 100K            |
| 7. Capacitors of $1\mu F$ , $2.2\mu F$ . | 7. Diodes 1N4006                                |

### 1- Full wave bridge rectifier:

- 1- Construct the circuit shown in Figure 3.1,  $R_{load}=1\text{ k}$ ,  $V_s=0\text{ Vp-p}$  100Hz.
- 2- Use the Oscilloscope CH2 to observe the output signal, and to do that you had to disconnect CH1Why?
- 3- What is the Output Signal Frequency?
- 4- From the signal shown on the scope screen sketch oscilloscope screen on the respective grids on the answer sheet.
- 5- Measure the Average Voltage ( $V_{avg}$ ) using DMM (put the DMM to DC).
- 6- Measure the Ripple Voltage  $V_{r-pp}$  (since  $V_{-pp} = V_{out-pp}$ ) from CH2.
- 7- Calculate the Ripple Percentage (Ripp.%)
- 8- Repeat for all the values of capacitors and resistors as shown in the answer sheet.
- 9- On the same circuit shown in Figure 3.3 use  $R_L = 1\text{ k}\Omega$ , 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.
- 10- How many ways to control the ripple voltage? Mention.

## **2- Positive clippers:**

- 1- Construct the circuit shown in Figure 3.7 using 1N4006 Si diode.
- 2- Switch ON the Function Generator and set the voltage ( $V_S$ ) to 8Vp-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 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 3.8 (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.

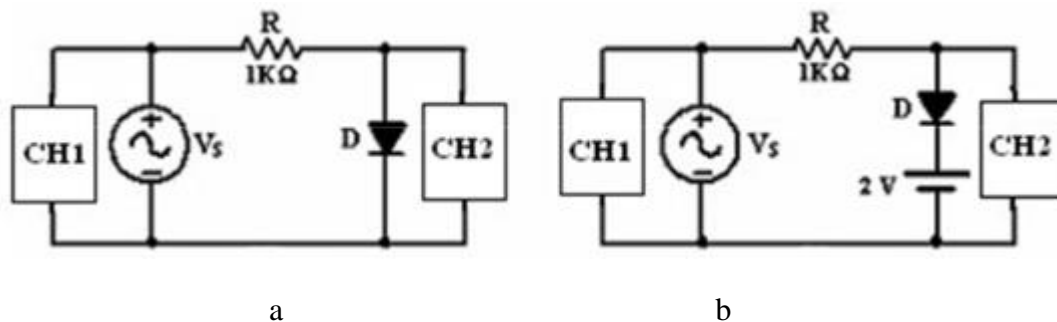


Figure 3.7: Positive clipper circuits

## **3-Negative Clipper circuit**

- 1- Construct the circuit shown in Figure 3.8 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 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 3.8 b (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.



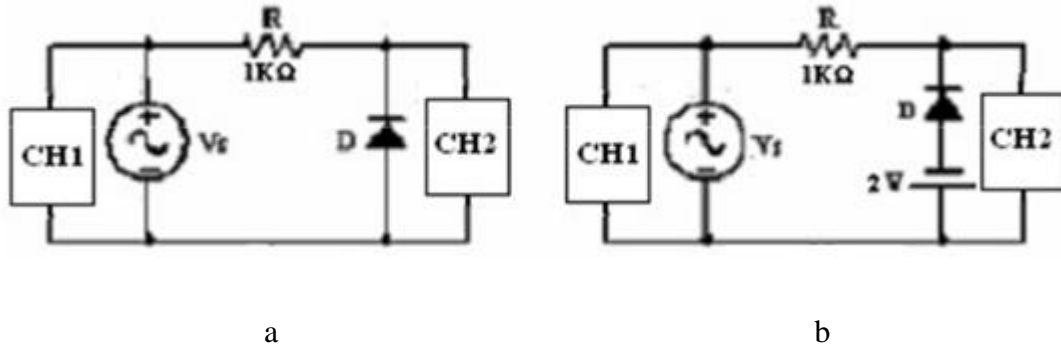


Figure 3.8: Negative clipper circuits

**4-Dual Clipper circuit**

- 1- Construct the circuit shown in Figure3.9, where the supply  $V_s$  is sinusoidal signal with  $8V_{pp}$ ,  $100Hz$  and  $R=1k\Omega$ .
- 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 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  $V_1 = V_2 = 2V$  as shown in Figure 3.9 b (To avoid any problems and short circuits, connect the branch of  $D_1$  in series with  $V_1$  somewhere on the breadboard, connect the other branch of  $D_2$  in series with  $V_2$  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.

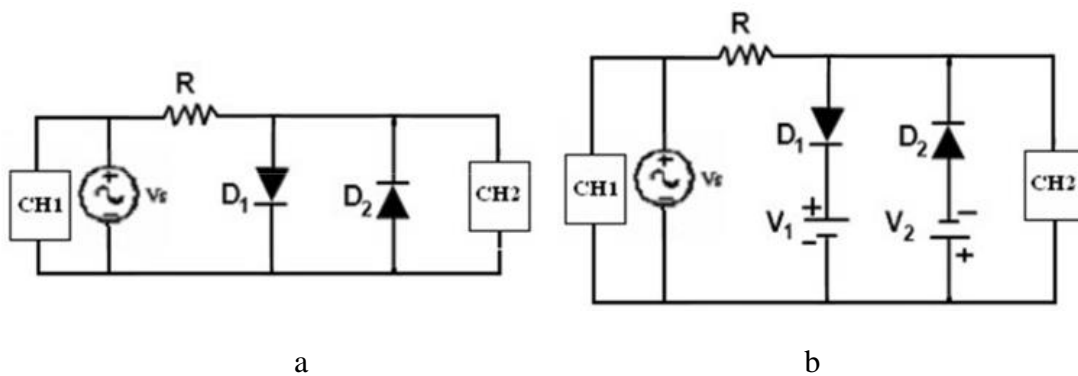


Figure 3.9: Dual clipper circuits

**5-The Diode Clamper circuits**

- Positive Clamper circuit

- 1- Construct the circuit shown in Figure 3.10, where the supply  $V_s$  is sinusoidal signal with  $8V_{pp}$ ,  $100Hz$
- 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 the answer sheet and label the necessary voltages.
- 4- What is the difference between the input and the output?

- 5- 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.
- 6- What is the effect of adding DC bias voltage to the positive clamper circuit?
- 7- When finished, switch OFF the Function Generator
- 8- What happen when using clamping circuit to drive low load impedance? Does the circuit still work as clamper? Explain.

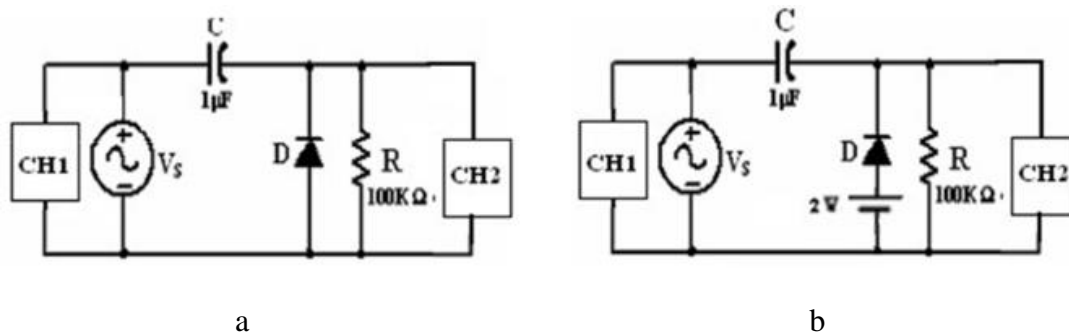


Figure 3.10 : Positive clamper circuits

### **6-Negative Clamper circuit**

- 1- Construct the circuit shown in Figure 3.11, where the supply  $V_s$  is sinusoidal signal with  $8\text{V}_{\text{pp}}, 100\text{Hz}$ .
- 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 the answer sheet and label the necessary voltages.
- 4- What is the difference between the input and the output?
- 5- Switch OFF the Function Generator, and insert 2VDC power supply as shown in Figure 3.11 (Negative Clamper with bias), then switch ON the Function Generator and repeat step 3.
- 6- What is the effect of adding DC bias voltage to the Negative clamper circuit?
- 7- When finished, switch OFF the all the instrument

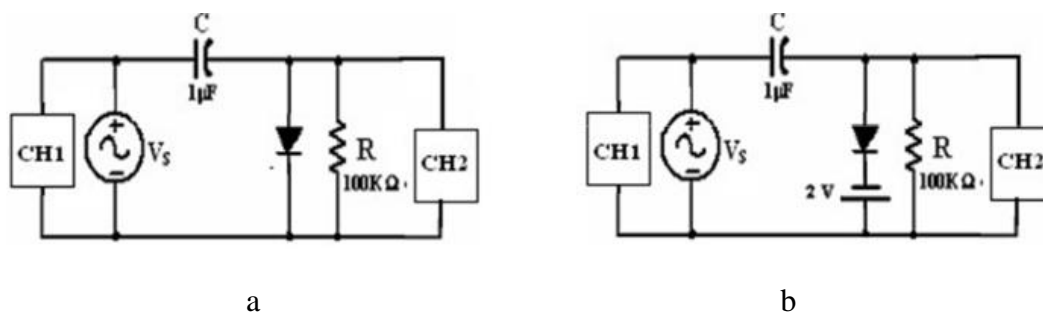


Figure 3.11: Negative Clamper circuits.



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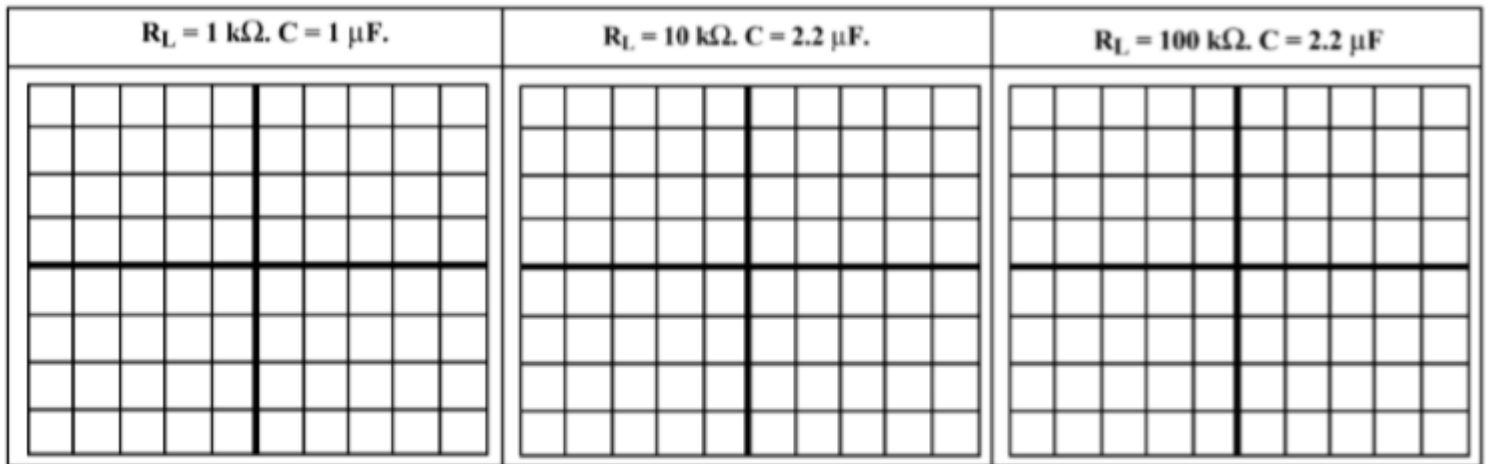
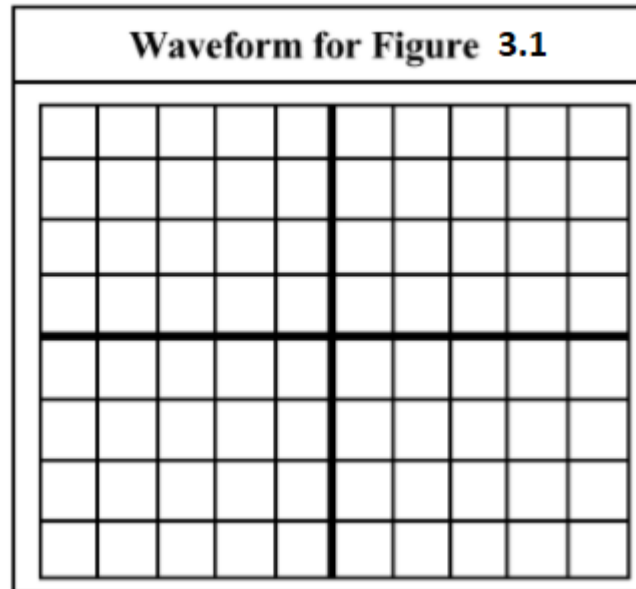
**0908322**

**Experiment 3: Diode Applications**

Group Number:.....

Student Name	ID

**PART 1 – Full wave bridge rectifier**



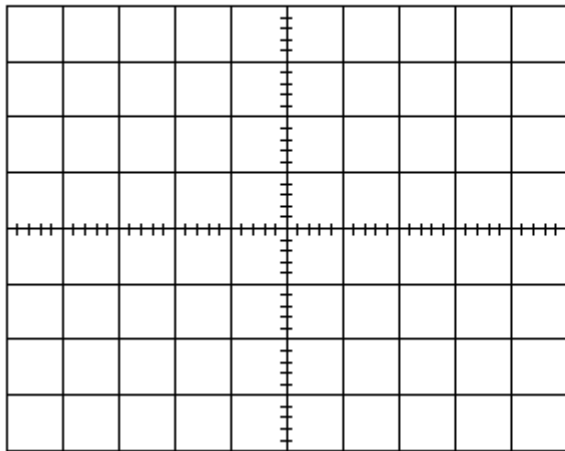
$V_{r-pp}$       \_\_\_\_\_  
 $V_{avg}$  (V)    \_\_\_\_\_  
 $Ripp. \%$      \_\_\_\_\_

$V_{r-pp}$       \_\_\_\_\_  
 $V_{avg}$  (V)    \_\_\_\_\_  
 $Ripp. \%$      \_\_\_\_\_

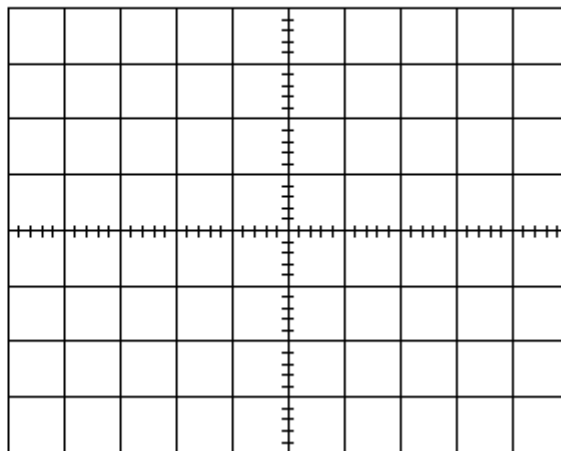
$V_{r-pp}$       \_\_\_\_\_  
 $V_{avg}$  (V)    \_\_\_\_\_  
 $Ripp. \%$      \_\_\_\_\_

**2-Positive clipper circuit:**

**Positive clipper of figure 3.7 a**



**Positive clipper of figure 3.7 b**

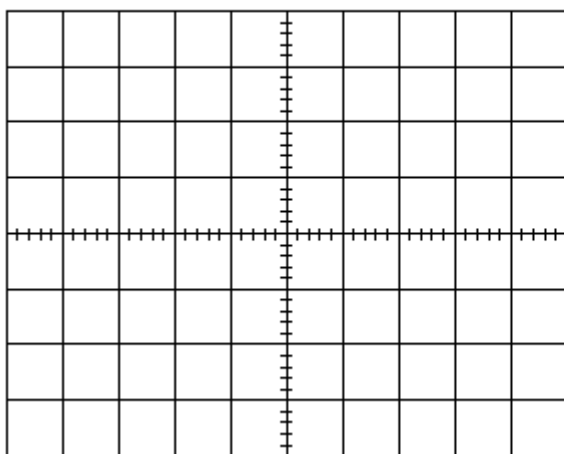


1- Show the output voltage peak values (min and max).

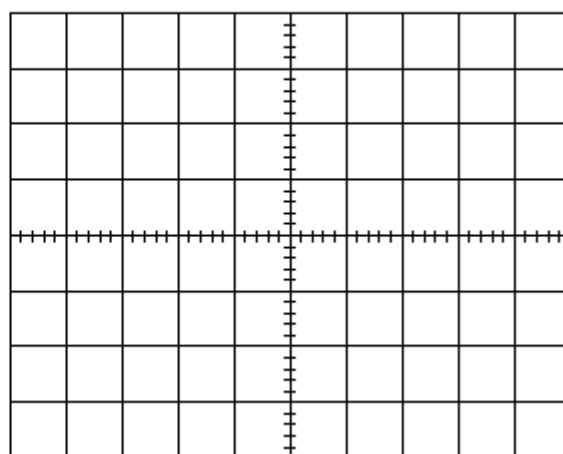
1-Comment on the output signal shown on CH2

**3-Negative clipper circuit:**

**Negative clipper of figure 3.8 a**



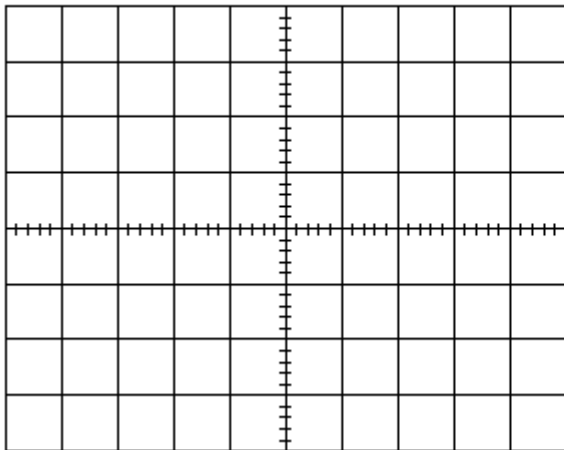
**Negative clipper of figure 3.8 b**



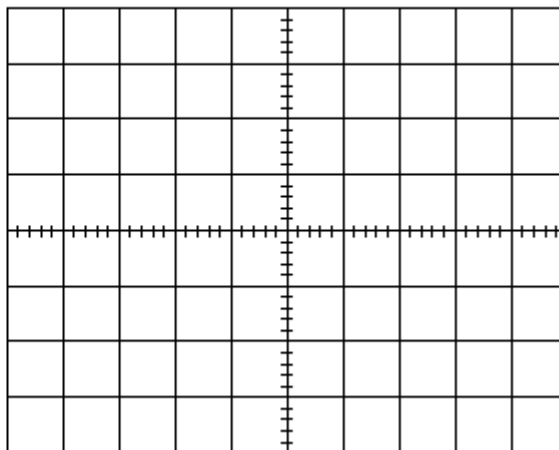
1- Show the output voltage peak values (min and max).  
Comment on the output signal shown on the CH2

**4-Dual Clipper circuit:**

**Dual Clipper of figure 3.9 a**



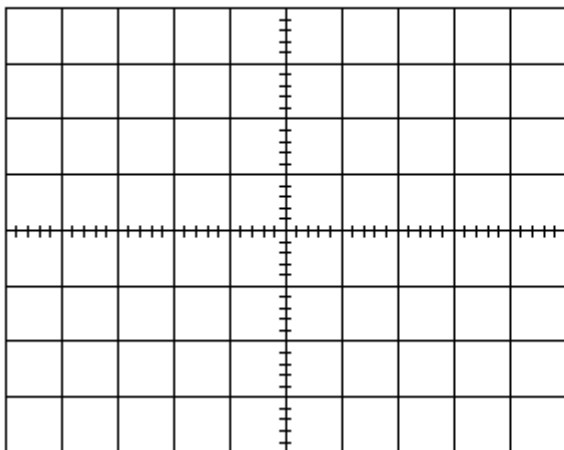
**Dual Clipper of figure 3.9 b**



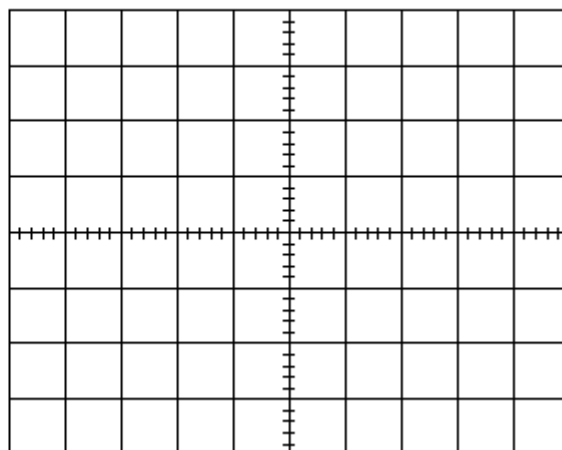
1- Show the output voltage peak values (min and max).  
2-Comment on the output signal shown on the CH2

**5-The Diode Clamper circuits**

**Positive clamper of figure 3.10 a**



**Positive clamper of figure 3.10 b**

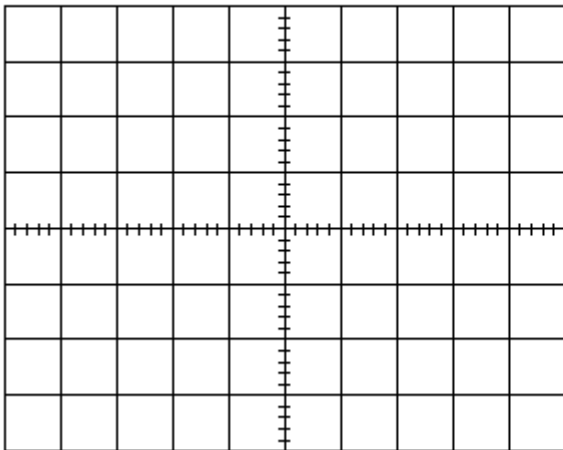


- 1- Show the output voltage peak values (min and max).
- 2-Comment on the output signal shown on the CH2

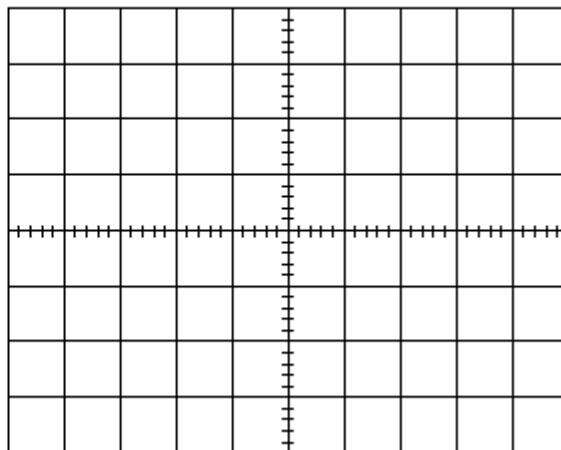
3-What happen when using clamping circuit to drive low load impedance? Does the circuit still work as clamper? Explain.

**6-Negative Clamper circuit**

**Negative clamper of figure 3.11 a**



**Negative clamper of figure 3.11 b**



- 1- Show the output voltage peak values (min and max).

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

3- 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  $V_\gamma$ . 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 ( $V_s$ ) 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  $V_s$  and Zener diode

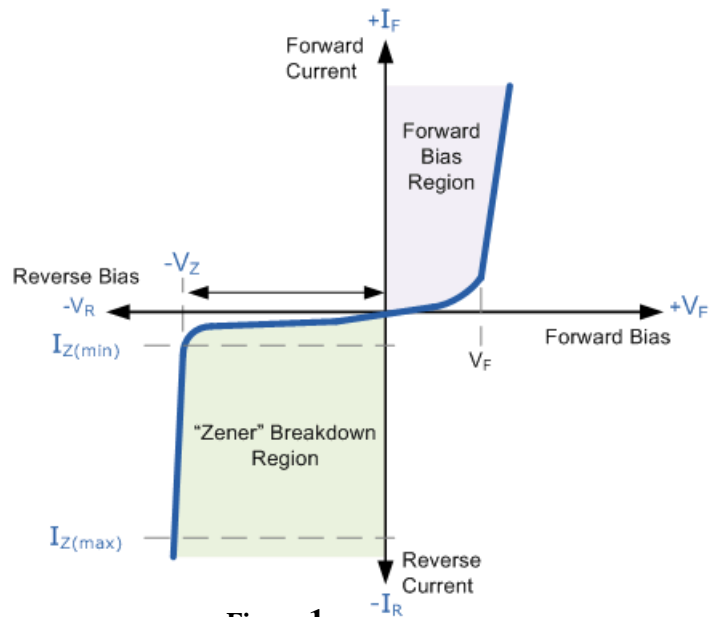


Figure 1

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.

The input source current:

$$I_S = I_Z + I_L \quad \dots\dots\dots (1)$$

The drop across the series resistance  $R_S$ :

$$V_{R_S} = V_s + V_Z \quad \dots\dots\dots (2)$$

The current flowing through  $R_S$ :

$$I_S = \frac{V_s - V_Z}{R_S} \quad \dots\dots\dots (3)$$

The voltage across the Zener diode:

$$V_Z = V_{zth} + (I_Z)(r_Z) = V_L \quad \dots\dots\dots (4)$$



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).

$$\text{Source Regulation \%} = \frac{\Delta V_L}{\Delta V_s} \times 100\%$$

Since the load is fixed, we can assume it ( $R_L = \infty$  so the Zener current  $I_Z = I_S$ ), as the input voltage ( $V_s$ ) increases,  $I_S$  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  $V_{No-load}$ ) and applying load (find  $V_{full-load}$ ). From reverse bias characteristics even  $I_Z$  changes,  $V_Z$  remains same so the output voltage remains fairly constant.

$$\text{Load Regulation} = \frac{V_{full-load} - V_{No-load}}{V_{full-load}} \times 100\%$$

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

## 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

- Construct the circuit shown in Figure 2 by using **Zener** diode. (*Make sure the diode is connected with the correct polarity*).
- Set the DC power supply output adjustment potentiometer fully counter clock wise (CCW), then switch it ON.
- Adjust the voltage source ( $V_S$ ) corresponding to Table 1 in the answer sheet. Use the DMM to **measure**  $I_Z$  and  $V_Z$  then record them in Table 1.
- When finished, set the ( $V_S$ ) to **0.0V**. Then switch OFF the DC power supply.
- Plot the reverse diode current  $I_Z$  versus the reverse diode voltage  $V_Z$  and label each axis with suitable units.
- From the  $i-v$  characteristics you draw, determine the Zener breakdown voltage  $V_{Zth}$ .
- Calculate the Zener diode dynamic resistance  $r_Z$ , using the following equation:

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

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

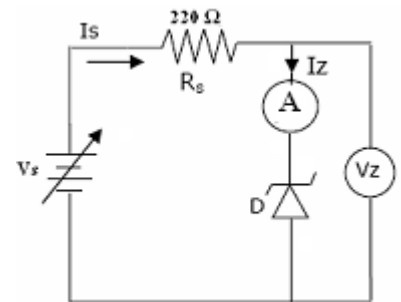


Figure 2

### PART-B The Zener Diode as a Voltage Regulator

#### B-1 Effect of the DC Voltage source on the Zener regulator

- Construct the circuit shown in Figure 3.
- Set the DC power supply output fully counter clock wise. Then switch it ON.
- 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:

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

- When finished, set the ( $V_S$ ) to **0.0V**.
- Explain what happens to the output voltage  $V_L$  and why.

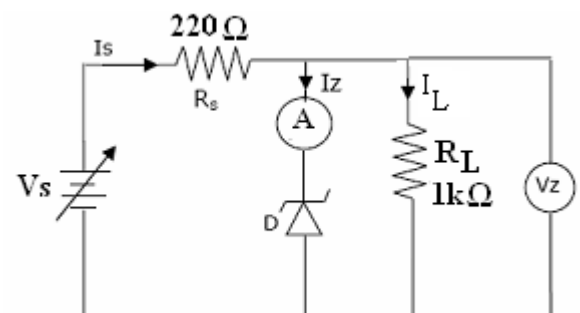


Figure 3

- 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  $I_{Zmin} = 1 \text{ mA}$ ). 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  $I_{Zmax} = 25 \text{ mA}$ ).
- 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  $V_S > 8$  volt, then record it in Table 2.
- 10- Calculate the minimum value of the series resistor  $R_{S-min}$  in Figure 3 at  $V_S = 10\text{V}$  and  $R_L = 1 \text{ K}\Omega$ . (Assume that  $I_{Z(max)} = 25 \text{ mA}$  and  $I_{Z(min)} = 1 \text{ mA}$ ).

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

- 1- Set the DC power source ( $V_S$ ) to  $10.0\text{V}$  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  $0.0\text{V}$ , then switch OFF the DC power supply and disconnect the circuit.
- 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  $I_{Zmin} = 1 \text{ mA}$ ).
- 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 ( $R_L = \infty$ ). (Assume  $I_{Z(max)} = 25 \text{ mA}$ ).

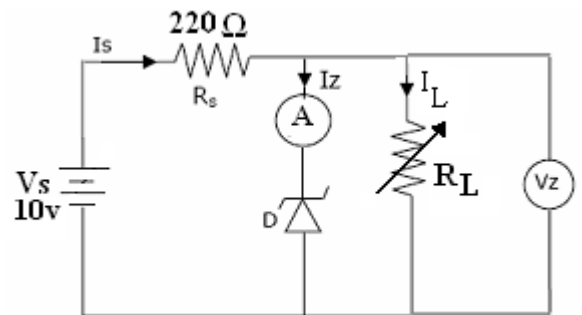


Figure 4

### **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  $15\text{Vp-p}$ ,  $2\text{kHz}$  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  $0.0\text{V}$ .

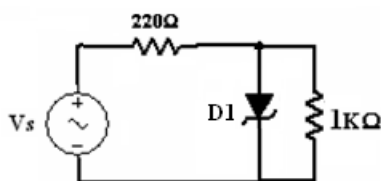


Figure 5.a

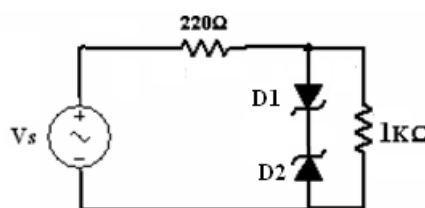


Figure 5.b

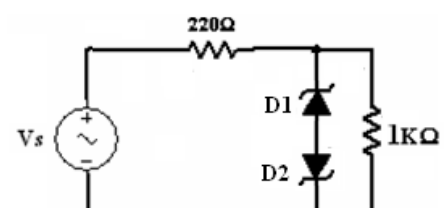
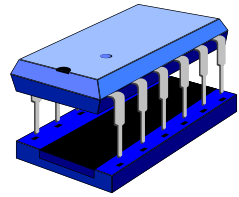


Figure 5.c



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) \_\_\_\_\_

## Report of Exp. 4

# Zener Diode Characteristics & Applications

### PART A- The Zener Diode Characteristics

Table 1

<b>V<sub>S</sub> (V)</b>	<b>1.0</b>	<b>2.0</b>	<b>4.0</b>	<b>5.0</b>	<b>5.2</b>	<b>5.5</b>	<b>6.0</b>	<b>6.5</b>	<b>7.0</b>	<b>8.0</b>	<b>9.0</b>
<b>I<sub>Z</sub> (mA)</b>											
<b>V<sub>Z</sub> (V)</b>											

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

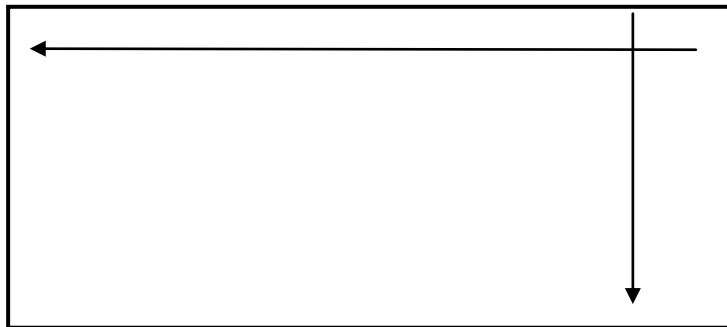


Figure 3

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  $V_s$  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

<b>V<sub>S</sub> (V)</b>	<b>1.0</b>	<b>2.0</b>	<b>4.0</b>	<b>5.0</b>	<b>6.0</b>	<b>7.0</b>	<b>8.0</b>	<b>9.0</b>
<b>V<sub>L</sub> (V)</b>								
<b>I<sub>S</sub> (mA)</b>								
<b>I<sub>L</sub> (mA)</b>								
<b>I<sub>Z</sub> (mA)</b>								
<b>P<sub>Z</sub> (mW)</b>								
<b>L.R. %</b>								

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  $I_{Zmin} = 1 \text{ mA}$ ). 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  $I_{Zmax} = 25 \text{ mA}$ ).

.....  
 .....

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

.....  
 .....

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

Table 3

$R_L$ (V)	10K $\Omega$	1K $\Omega$	220 $\Omega$	100 $\Omega$
$V_L$ (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  $I_{Zmin} = 1 \text{ mA}$ ).

.....  
 .....

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 ( $R_L = \infty$ ). (Assume  $I_{Z(max)} = 25\text{ mA}$ ).

.....  
.....

**Part C: The Zener Diode as A diode clipper**

Figure 5.a

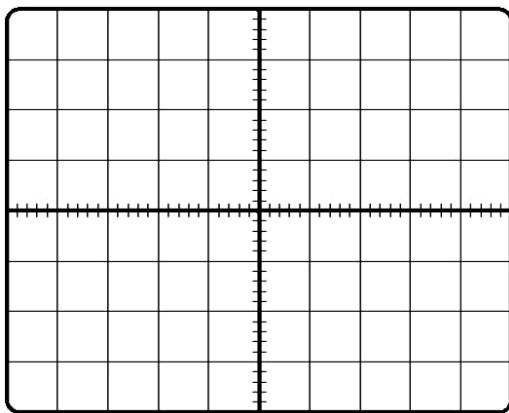


Figure 5.b

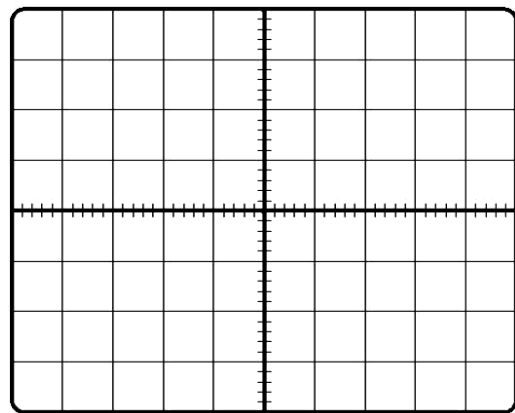
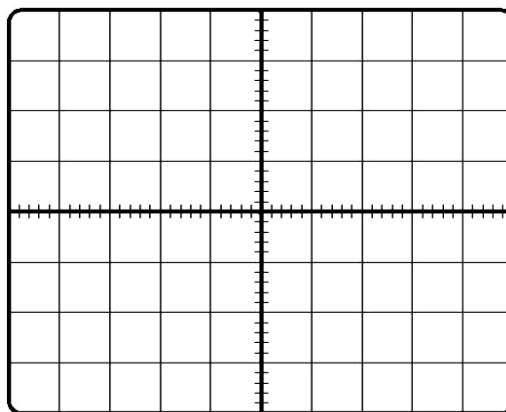


Figure 5.c



## 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".

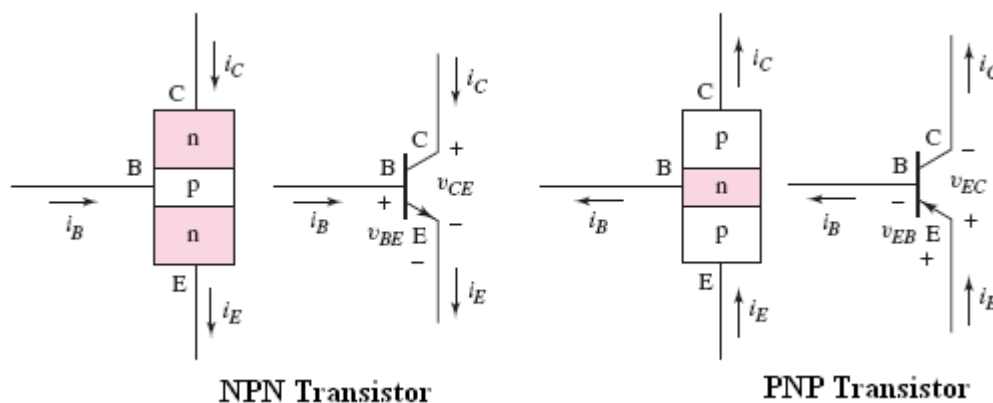


Figure 1



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 ( $V_{\gamma}$ , 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.

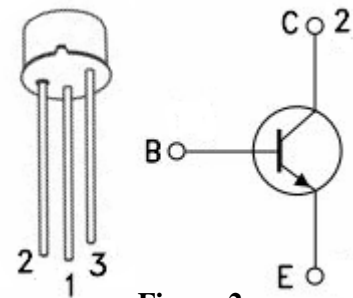


Figure 2

The Common Emitter NPN circuit output  $i-v$  characteristics are shown in Figure 3, where the collector current ( $I_C$ ) 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 ( $I_C$ ) 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.

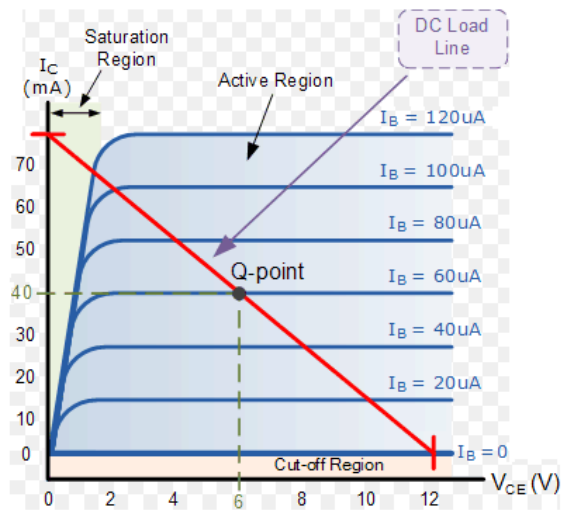


Figure 3

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:

$$I_E = I_C + I_B \quad \dots\dots (1)$$

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

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

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

## 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  $\rightarrow$ . Plug a black test lead into the Common (-) 4mm banana socket, and a red test lead into the  $V\Omega$   $\rightarrow$  (+) 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.
- 5- Use the voltmeter to measure  $V_{BE}$ ,  $V_{CE}$  and  $I_C$ . Calculate  $I_B$  using the equation ( $I_B = \frac{V_{BB} - V_{BE}}{R_B}$ ) 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  $V_{CC}=15v$ .

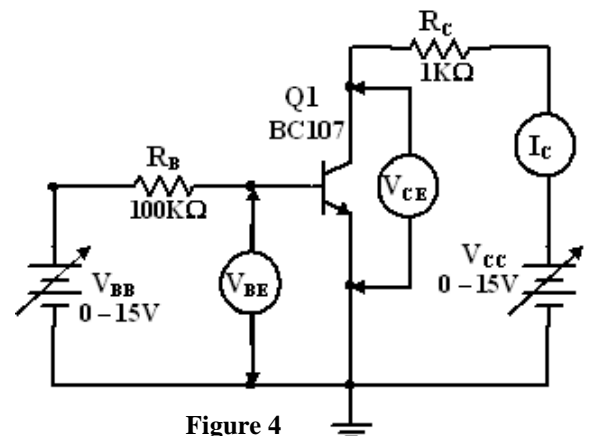
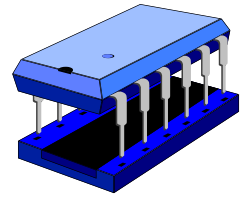


Figure 4

- 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 average  $\beta$  ( $h_{FE}$ ).
- 14- Calculate the corresponding alpha  $\alpha$  using the calculated  $\beta$ .
- 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  $\beta$  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  $V_{CC}=15v$ .



University Of Jordan  
School of Engineering  
Mechatronics Engineering Department



# 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
$\mu\Omega$ $\rightarrow$ 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  $V_{BB}=2v..$

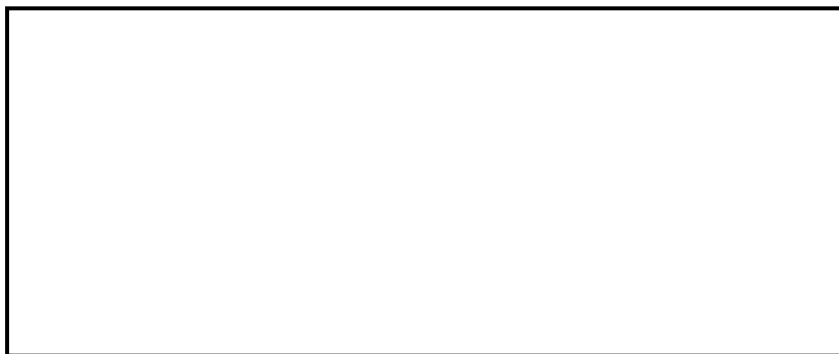
.....  
 .....

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

$V_{CC} \downarrow$	$V_{BB}(V)$	6.0	4.0	2.0	0.0
$V_{CC} = 15V$	$V_{CE}(V)$				
	$I_C(mA)$				
	$V_{BE}(V)$				
	$I_B (\mu A)$				
	$\beta$				
$V_{CC} = 12V$	$V_{CE}(V)$				
	$I_C(mA)$				
	$V_{BE}(V)$				
	$I_B (\mu A)$				
	$\beta$				
$V_{CC} = 9V$	$V_{CE}(V)$				
	$I_C(mA)$				
	$V_{BE}(V)$				
	$I_B (\mu A)$				
	$\beta$				
$V_{CC} = 6V$	$V_{CE}(V)$				
	$I_C(mA)$				
	$V_{BE}(V)$				
	$I_B (\mu A)$				
	$\beta$				
$V_{CC} = 4V$	$V_{CE}(V)$				
	$I_C(mA)$				
	$V_{BE}(V)$				
	$I_B (\mu A)$				
	$\beta$				
$V_{CC} = 2V$	$V_{CE}(V)$				
	$I_C(mA)$				
	$V_{BE}(V)$				
	$I_B (\mu A)$				
	$\beta$				
$V_{CC} = 0V$	$V_{CE}(V)$				
	$I_C(mA)$				
	$V_{BE}(V)$				
	$I_B (\mu A)$				
	$\beta$				

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

.....  
.....

14- Calculate the corresponding alpha  $\alpha$  from the calculated  $\beta$ ,

.....

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  $\beta$  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  $V_{CC}=15v$ .

.....  
.....

## 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 high voltage and current gains,  $A_v$  and  $A_i$ , respectively. The amplifier typically has a relatively high input impedance  $Z_i$  (1 to 10 k $\Omega$ ) and high output impedance  $Z_o$  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 voltage gain lower than or equal to one ( $A_v \leq 1$ ) 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 high input impedance  $Z_i$  (1 to 10 k $\Omega$ ) and low output impedance.
- 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. Open switch condition when  $V_{in} < V_{BE-on}$  the transistor will be in cut-off region,  $I_B = I_C = 0.0$  mA providing a constant output voltage  $V_O = V_{CC}$ . Closed switch condition when  $V_{in} = V_{CC}$ , the transistor is in saturation region and  $I_C = (V_{CC} - V_{CE-sat}) / R_C$ , providing a small constant output voltage  $V_{CE-sat} \cong 0.2V$ .

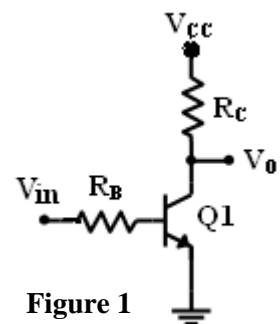


Figure 1

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  $V_O = V_{CE-Sat} \cong 0.2$  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  $V_O = V_{CE(sat)} = 0.2$  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).

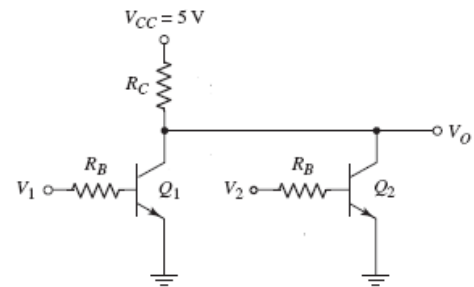


Figure 2

## 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 2.2 $\mu$ F.                  | 8- BC107 BJT .                          |
| 9- Connection Wires and coaxial cables Probes. |   |

### PART A: BJT Common-Emitter AC Amplifier

- Construct the circuit shown in Figure 3, using **BC107 BJT** and use  $V_{CC} = +15$ V. (Make sure the BJT is connected with the correct leads). **Do not connect the Function Generator and the Oscilloscope channels.**
- 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  $\beta$  then fill all the data in Table 1 in the sheet answer.
- 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.
- Set the Function Generator to a sinusoidal signal, **100mV<sub>PP</sub>, 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,.
- Sketch the Oscilloscope screens on the respective grids in Table 2 in the sheet answer.
- 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.
- When you finished, set the source voltage back to **100mV<sub>PP</sub>**, don't disconnect the circuit.
- Why choosing  $V_{CE} \cong 7.5$  V at the middle of the forward active region is a good choice? Explain.
- What is the value of  $r_{\pi}$ ?

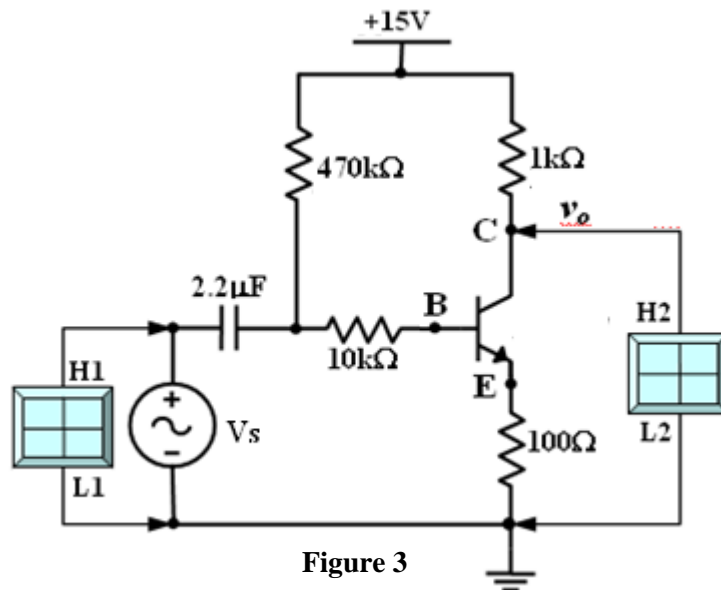


Figure 3

### 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  $A_v$ ,  $Z_i$ ,  $Z_o$  and  $\phi$  (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  $V_o = 0.2V$ , 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.  $V_{in}$ .

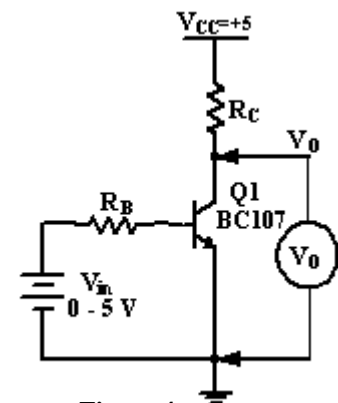


Figure 4

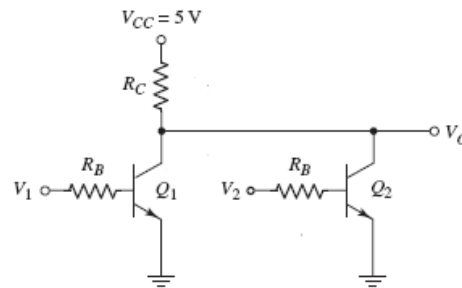
## **PART D: Digital Logic Circuits**

### **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**

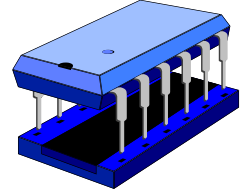
- 1- Connect the circuit shown in Figure 5 by using  $V_{CC} = +5V$ ,  $R_C = 1k\Omega$  and  $R_B = 4.7k\Omega$ .
- 2- Set  $V_1$  and  $V_2$  according to Table 6 in the sheet answer
- 3- Connet the DMM and read the value of  $V_O$  then fill it in Table 6 in the sheet answer.
- 4- Repeat steps 2 and 3 for all values of input voltages recorded in Table 6.
- 5- Verify your results.



**Figure 5**



University Of Jordan  
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Mechatronics Engineering Department



# Electronics Lab Report

0908322

Experiment No.: \_\_\_\_\_

Student Group: \_\_\_\_\_

Experiment Name: \_\_\_\_\_

Students Name:

1) \_\_\_\_\_

2) \_\_\_\_\_

3) \_\_\_\_\_

4) \_\_\_\_\_

# Report of Exp. 6

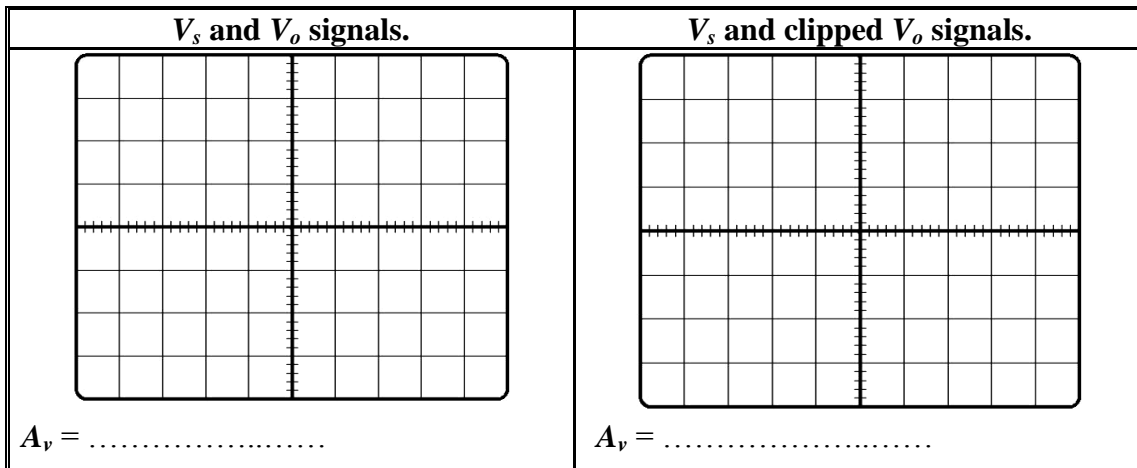
## BJT Applications

### PARTA: BJT Common-Emitter AC Amplifier

Table 1

$V_{CC}$ (V)	$V_{CEQ}$ (V)	$V_{RB2}$ (V)	$I_{BQ}$ ( $\mu A$ )	$I_{CQ}$ (mA)	$V_{BE}$ (V)	$\beta_{DC}$
<b>15</b>						

Table 2



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

.....

.....

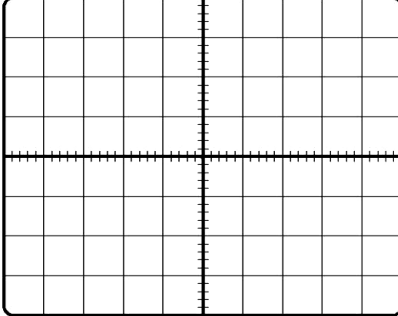
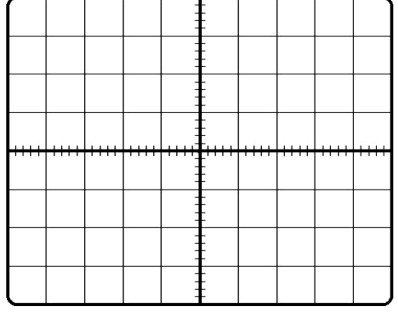
9-What is the value of  $r_n$ ?

.....

.....

**Part B: Common-Collector (Emitter follower)**

Table.3

$V_s$ and $V_o$ signals.	$V_s$ and clipped $V_o$ signals.
	
$A_v = \dots\dots\dots$	$A_v = \dots\dots\dots$

5- Compare between the two types of circuits (CE and CC) in terms of  $A_v$ ,  $Z_i$ ,  $Z_o$  and  $\phi$  (phase shift between the input and the output signals).

	Av	Zi	Zo	φ
<b>Common Emitter (CE)</b>				
<b>Common Collector (CC)</b>				

**PART-C : BJT Switching Device**

Table 4

	V <sub>in</sub> (V)	V <sub>O</sub> (V)	I <sub>C</sub> (mA)
<b>R<sub>B</sub> = 4.7kΩ</b>	<b>0.0</b>		
	<b>0.7</b>		
<b>R<sub>C</sub> = 1kΩ</b>	<b>1.0</b>		
	<b>3.0</b>		
	<b>5.0</b>		

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- 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 ( $V_o/V_s$ ) or output voltage ( $V_o$ ) 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.

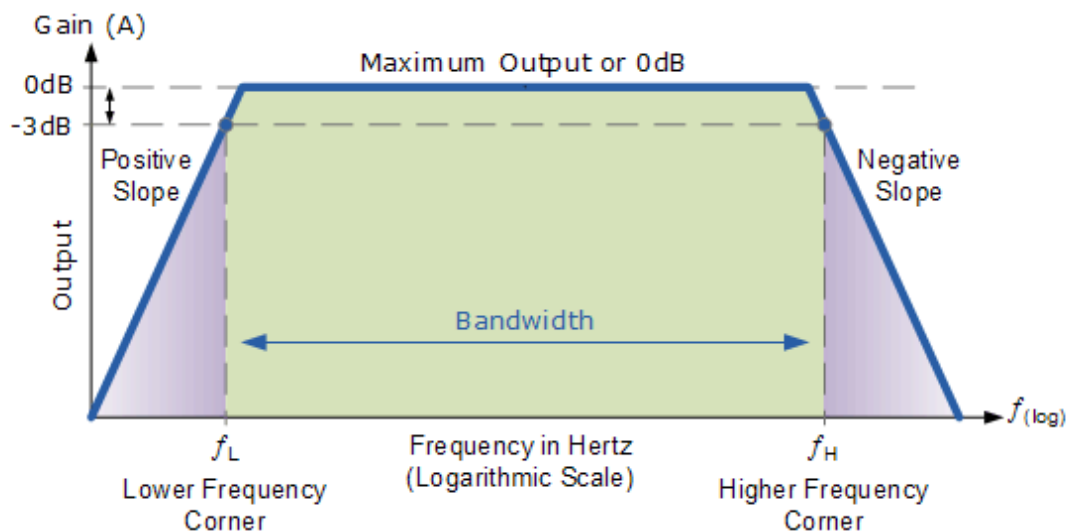


Figure 1

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 capacitor effects. 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 ( $V(\text{corners}) = V(\text{max})/\sqrt{2}$ ).

When adding a load to the amplifier circuit, the output voltage ( $V_o$ ) will decrease, which mean the voltage gain ( $V_o/V_s$ ) will also decrease. This can be explained by replacing the amplifier with the equivalent 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.

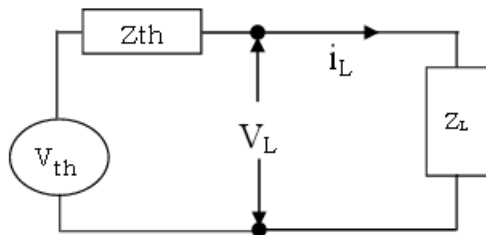


Figure 2

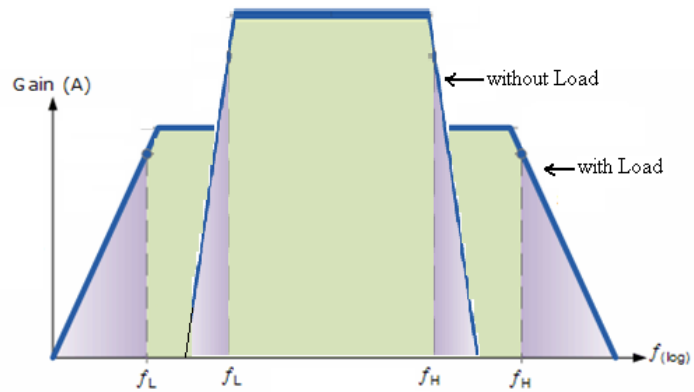


Figure 3

## Procedure

### Equipments & Part List

- |   |                                    |
|---|------------------------------------|
| 1- Oscilloscope                         | 2- Function Generator (FG)         |
| 3- Two Digital Multimeters (DMM).       | 4- DC power supply.                |
| 5- Project Breadboard.                  | 6- 680,820, 2x(1, 2.2, 3.3,10) kΩ. |
| 7- Capacitor of 1μF, 2.2μF, 22μF.       | 8- BC107 BJT                       |
| 9- Connection Wires and coaxial cables. |                                    |

### 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 **1.5V<sub>pp</sub>** sinusoidal signal.

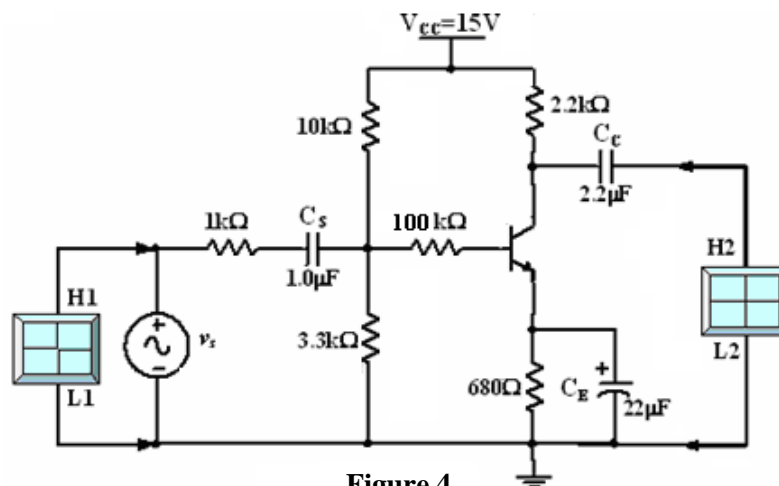


Figure 4

- 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 ( $\phi^\circ$ ) 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.

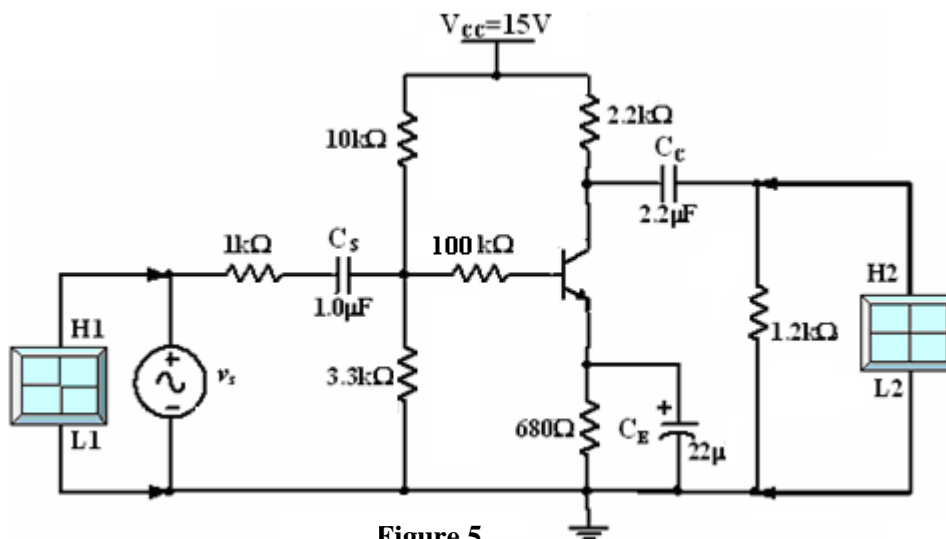
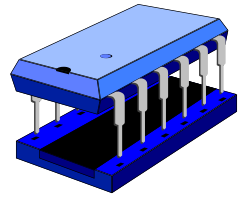


Figure 5



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# Electronics Lab Report

0908222

Experiment No.: \_\_\_\_\_

Student Group: \_\_\_\_\_

Experiment Name: \_\_\_\_\_

Students Name:

1) \_\_\_\_\_

2) \_\_\_\_\_

3) \_\_\_\_\_

4) \_\_\_\_\_

**BJT Frequency Response Amplifier**

**Part A: Frequency response of a BJT Common Emitter amplifier**

**Table 1**

$f$ (Hz)	$V_s$ (V <sub>P</sub> )	$V_o$ (V <sub>P</sub> )	$A_v$ (V/V)	Phase Shift $\phi^\circ$
100				
500				
1K				
5K				
10K				
20K				
50K				
100K				
200K				
500K				
1M				

**Table 2**

Critical Points	$f$ (Hz)	$V_s$ (V <sub>P</sub> )	$V_o$ (V <sub>P</sub> )	$A_v$ (V/V)	Phase Shift $\phi^\circ$
Mid Range					
Lower Corner					
Upper Corner					

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

.....

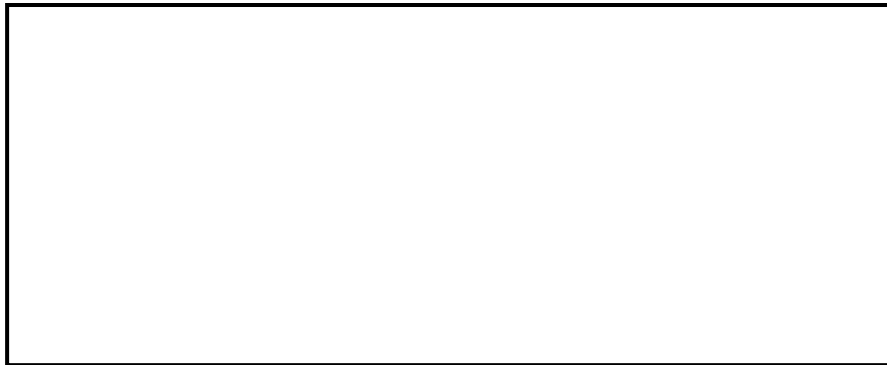
.....

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

.....

.....

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 <sub>P</sub> )	$V_o$ (V <sub>P</sub> )	$A_v$ (V/V)	Phase Shift $\phi^\circ$
Mid Range					
Lower Corner					
Upper Corner					

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

.....

.....

## 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 another 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 create 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.

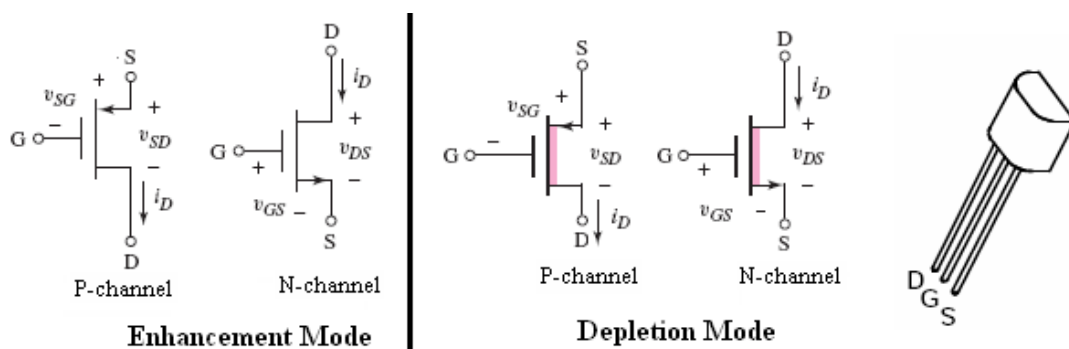


Figure 1

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 characteristics 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:

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

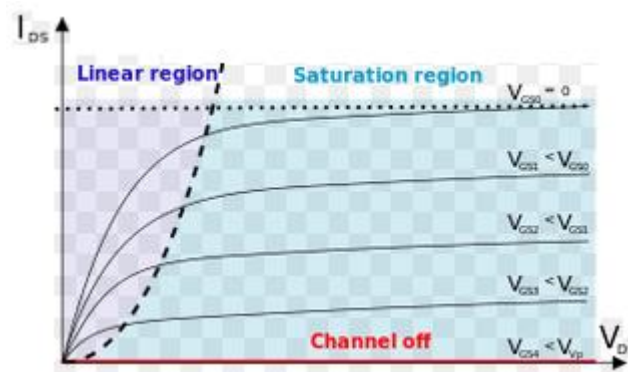


Figure 2

- **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 high input impedance 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, 10 $\mu$ F.          | 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  $\blacktriangleright+$ . Plug a black test lead into the Common (-) banana socket, and a red test lead into the  $V\Omega\blacktriangleright+$  (+) 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 **0.0V**. 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.

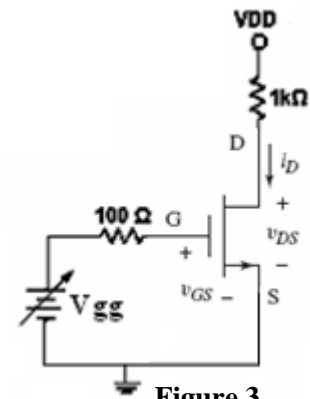


Figure 3

### **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 to 7 for all values of  $V_{GG}$  and  $V_{DD}$ .
- 9- When finished, set the  $V_{GG}$  and  $V_{DD}$  to **0.0V**. Then switch OFF the DC power supplies.
- 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).

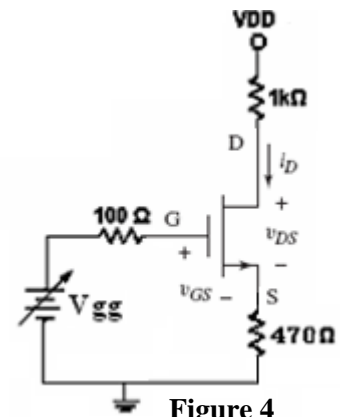
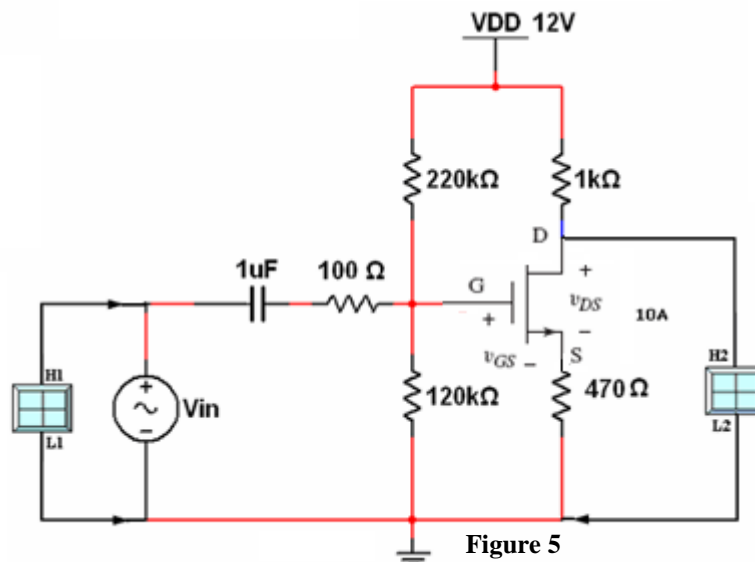


Figure 4

## **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.



- 4-Switch ON the Oscilloscope and the Function Generator and set the source voltage  $V_s$  to sinusoidal signal, **100mV<sub>PP</sub>**, **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 ( $R_S$ )

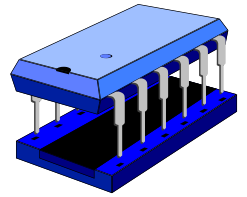
- 1- For the same circuit shown in Figure 4, add **10μF** in parallel with the Source resistance ( $R_S$ ), change the input frequency to **40 KHz** while keeping the signal voltage to **100mV<sub>PP</sub>**.
- 2- Connect CH2 of the Oscilloscope to the Drain (D).
- 3- Using the Oscilloscope, measure 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 (Source-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<sub>PP</sub>**, **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  $A_v$  (voltage gain),  $\phi$  (phase shift between the output and the input signals).



University Of Jordan  
Faculty of Engineering  
Mechatronics Engineering Department



# Electronics Lab Report

0908222

Experiment No.: \_\_\_\_\_

Student Group: \_\_\_\_\_

Experiment Name: \_\_\_\_\_

Students Name:

1) \_\_\_\_\_

2) \_\_\_\_\_

3) \_\_\_\_\_

4) \_\_\_\_\_

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

$V_{DD} \downarrow$	$V_{GG}(V)$	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*).

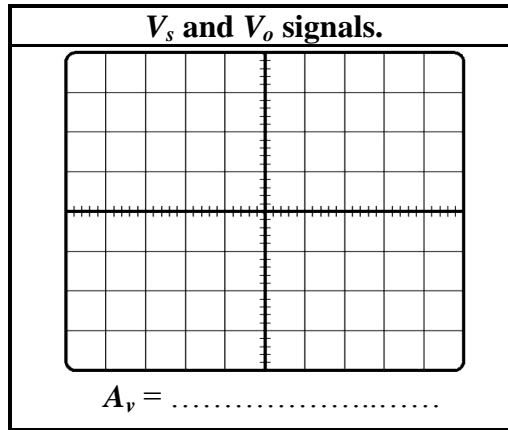


**PART-C MOSFET AC Amplifier Device**

**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			



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

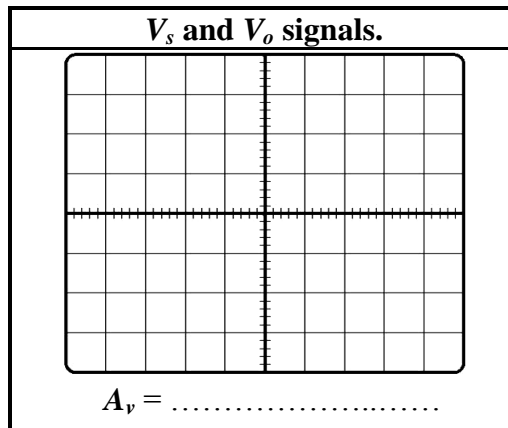
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**C-2 Common-Source Amplifier without Source Resistor ( $R_S$ )**

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

.....

.....



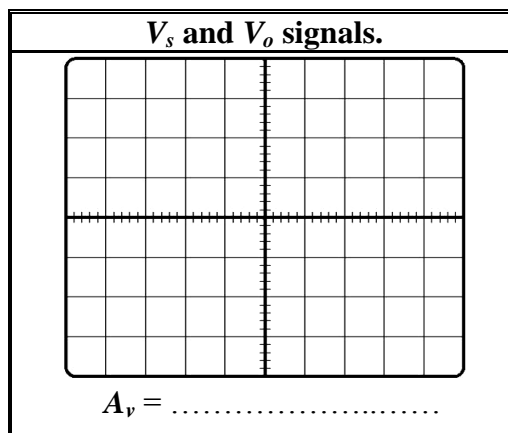
### C-3 Common-Drain (Source-Follower) Amplifier

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  $A_v$ ,  $\phi$ .

	$A_v$ (voltage gain)	$\phi$ (phase shift)
<b>Common Source (CS)</b>		
<b>Common Drain (CD)</b>		



## 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).

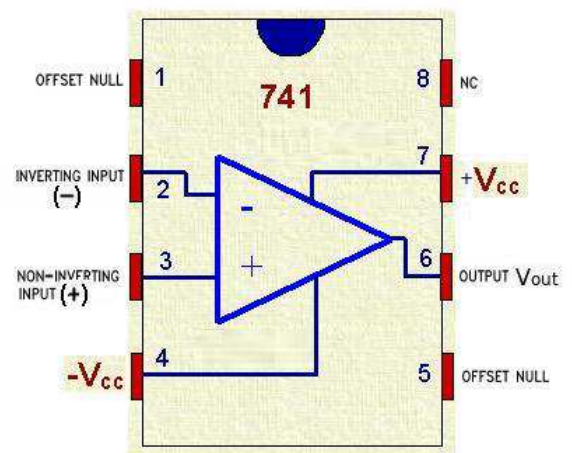


Figure 1

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 ( $V_{in}$ ) 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

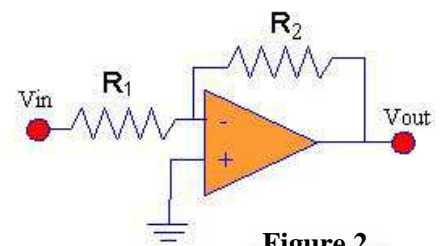


Figure 2

$180^\circ$  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 ( $V_{in}$ ) 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:

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

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.

In the **Comparator circuit**, shown in Figure 5, when the non-inverting input ( $V_1$ ) is higher than the inverting input ( $V_2$ ), 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 ( $V_1$ ) is lower than the inverting input ( $V_2$ ), the output saturates at the most negative voltage it can output. The op-amp's output voltage is limited by the supply voltage.

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:

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

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 ( $V_1$ ) is connected to one input terminal and another voltage signal ( $V_2$ ) is connected to the other input terminal, the resultant output voltage will be proportional to the difference between the two input voltage signals of  $V_1$  and  $V_2$ . If  $R_1 = R_2$  and  $R_3 = R_4$ , then the output voltage is given by:

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

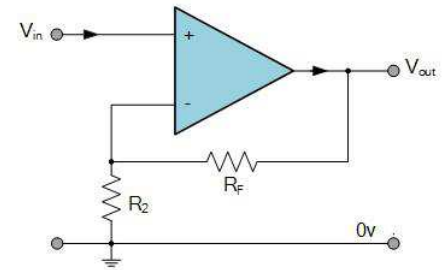


Figure 3

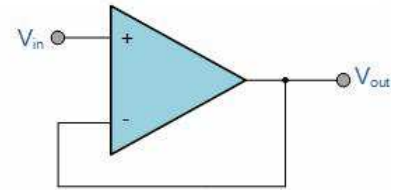


Figure 4

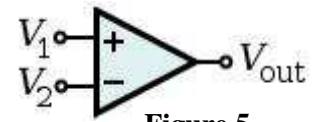


Figure 5

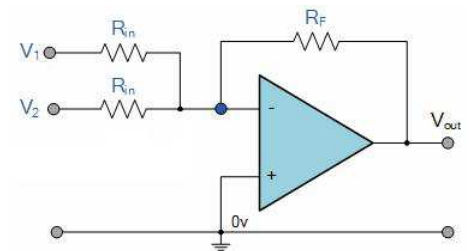


Figure 6

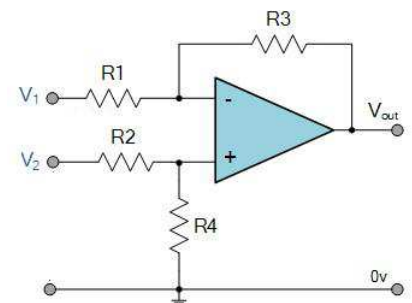


Figure 7

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 ( $V_\gamma$ ). This offset voltage ( $V_\gamma$ ) 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:

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

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 ( $R_1 = R_2$  and  $C_1 = C_2$ ) 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 , 1 $\mu$ F and 0.1 $\mu$ F. |
| 7- Connection Wires and Coaxial Cables. | 8- Op-Amp 741                                       |

### Part A: The Inverting amplifier circuit

- 1- Construct the Op-Amp circuit as shown in Figure 8 using  **$R_1 = 1K\Omega$  and  $R_2 = 2.2K\Omega$** .
- 2- Connect CH1 to the function generator and set  $V_S$  to  **$2V_{p-p}$  and  $1\text{ kHz}$**  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  $A_v$ . **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.

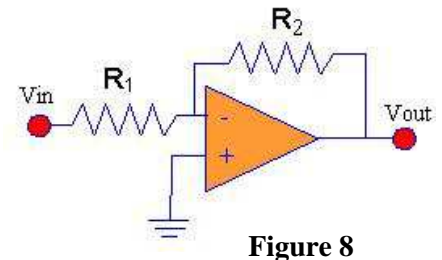


Figure 8

### Part B: The Non - Inverting amplifier circuit

- 1- Construct the Op-Amp circuit as shown in the Figure 9 using  **$R_1 = 1K\Omega$  and  $R_2 = 2.2K\Omega$** .
- 2- Connect CH1 to the function generator and set  $V_S$  to  **$1.5V_{p-p}$  and  $1\text{ kHz}$**  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  $A_v$ .
- 5- What is the phase shift between the input and the output signals?

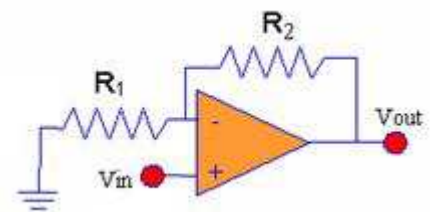


Figure 9

### Part C: The Voltage Follower circuit

- 1- Construct the Op-Amp circuit as shown in the Figure 10
- 2- Set the source voltage ( $V_s$ ) to  **$2 V_{p-p}$ ,  $1\text{ kHz}$**  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  $A_v$ .
- 6- What is the phase shift between the input and the output signals?

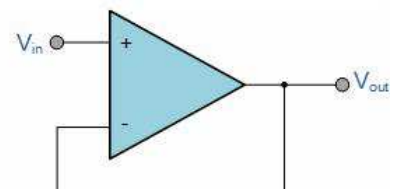


Figure 10

### Part D: The Comparator circuit

- 1- Refer to Figure 11, set  $V_{ref} = 0 \text{ V (DC)}$ ,  $V_{in} = 10\text{V}_{p-p}$ ,  $1 \text{ kHz}$ .
- 2- Observe  $V_{in}$  and  $V_o$  on the Oscilloscope Channels.
- 3- Sketch the signals appear on the Channels on the respective screen grids in the sheet answer.
- 4- Set  $V_{ref} = 2 \text{ V (DC)}$  and repeat steps 2 and 3.
- 5- Does the output signal differ when  $V_{ref} = 0 \text{ V}$  from that when  $V_{ref} = 2 \text{ V}$ ? Explain.

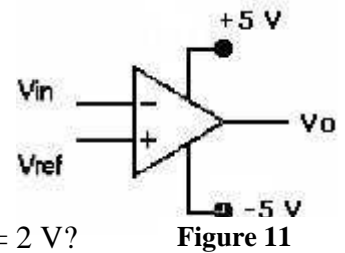


Figure 11

### Part E: The Summing Amplifier (Adder) circuit

- 1- Construct the circuit shown in Figure 12.
- 2- Connect  $V_1$  to  $1\text{V}$  (D.C supply)
- 3- Connect  $V_2$  to a Function Generator ( Sine wave  $2\text{V}_{p-p}$ ,  $1\text{kHz}$ )
- 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  $6\text{V}_{p-p}$ ,  $1\text{kHz}$ . Explain what happen.

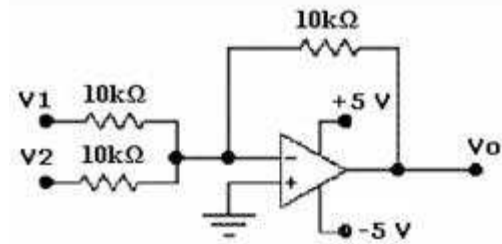


Figure 12

### Part F: The Differential Amplifier (Subtractor) circuit

- 1- Construct the circuit shown in Figure 13 using  $R_1 = R_2 = R_3 = R_4 = 10\text{K}\Omega$ .
- 2- Connect  $V_1$  to  $1\text{V}$  (D.C supply)
- 3- Connect  $V_2$  to a Function Generator ( Sine wave  $2\text{V}_{p-p}$ ,  $1\text{kHz}$ )
- 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  $6\text{V}_{p-p}$ ,  $1\text{kHz}$ . Explain what happen.

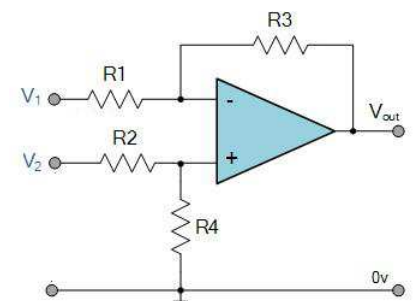


Figure 13

### Part G: The Inverting Integrator circuit

- 1- Construct the circuit shown in Figure 14 by using  $R=1\text{K}\Omega$  and  $C=1\mu\text{F}$ .
- 2- Apply a square-wave signal at  $V_{in}$  with  $1\text{kHz}$  frequency and  $5 \text{ V}_{p-p}$ .
- 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  $V_o(t)$  Signal on the respective Oscilloscope screen in the sheet answer.
- 5- Comment on the output signal and its relation to the input signal.

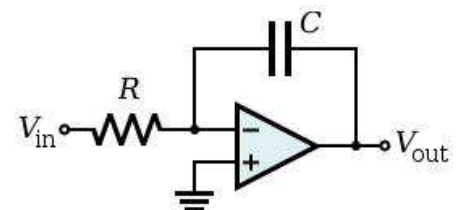


Figure 14

### Part H: The Inverting Differentiator circuit

- 1- Construct the circuit shown in Figure 15 by using  $R=10\text{K}\Omega$  and  $C=10\mu\text{F}$ .
- 2- Apply a triangle-wave signal at  $V_{in}$  with  $1\text{kHz}$  frequency and  $5 \text{ V}_{p-p}$ .
- 3- Connect CH1 to the input signal and CH2 to the output signal.

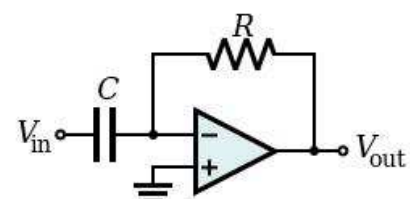


Figure 15

- 4- Sketch  $V_o(t)$  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?

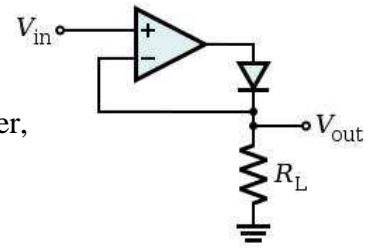


Figure 16

**Part J: The Square Wave generator circuit**

- 1- Construct the circuit shown in Figure 17 by using  $R = 10K\Omega$ ,
  - 2-  $R_1 = R_2 = 15 K\Omega$  and  $C = 0.1\mu F$ .
- 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?

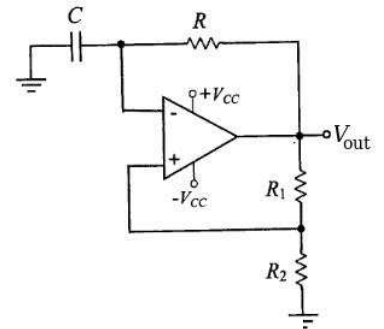


Figure 17

**Part K: The Sine Wave Oscillator circuit**

- 1- Construct the circuit shown in Figure 18 by using  $C_1 = C_2 = 0.1\mu F$ ,  $R_1 = R_2 = 1k\Omega$ ,  $R_3 = 22 k\Omega$  and  $R_4 = 10 k\Omega$ .
- 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?

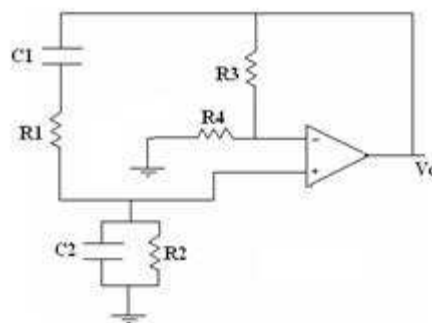
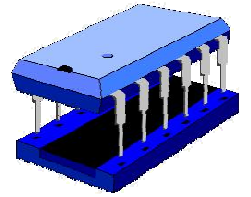


Figure 18



**University Of Jordan**  
Faculty of Engineering  
Mechatronics Engineering Department

# Electronics Lab Report

**0908322**

**Experiment No.:** \_\_\_\_\_

**Student Group:** \_\_\_\_\_

**Experiment Name:** \_\_\_\_\_

**Students Name:**

1) \_\_\_\_\_

2) \_\_\_\_\_

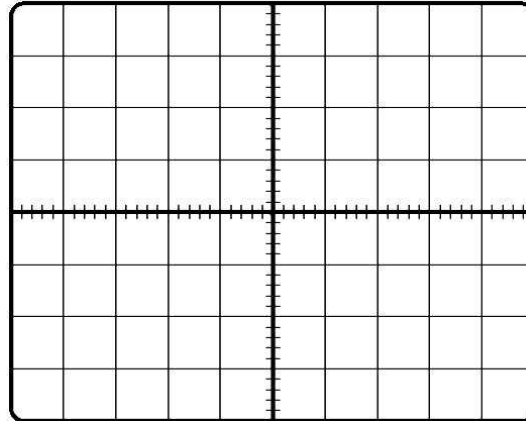
3) \_\_\_\_\_

4) \_\_\_\_\_

# Operational Amplifier Application

## Part A: The Inverting amplifier circuit

3-



4- Calculate the voltage gain  $A_v$ .

.....  
.....

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

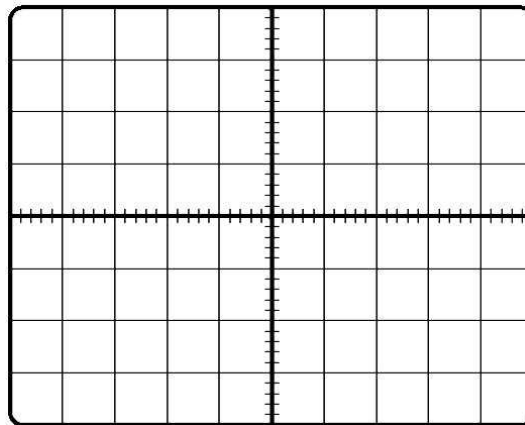
.....  
.....

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**.

.....  
.....

**Part B: The Non - Inverting amplifier circuit**

3-



4- Calculate the voltage gain  $A_v$ .

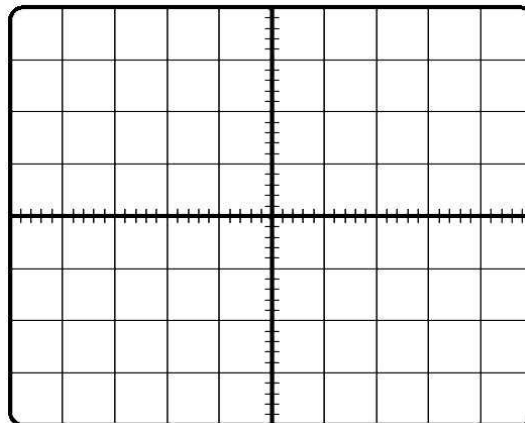
.....  
.....

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.

.....  
.....



5- Calculate the voltage gain  $A_v$ .

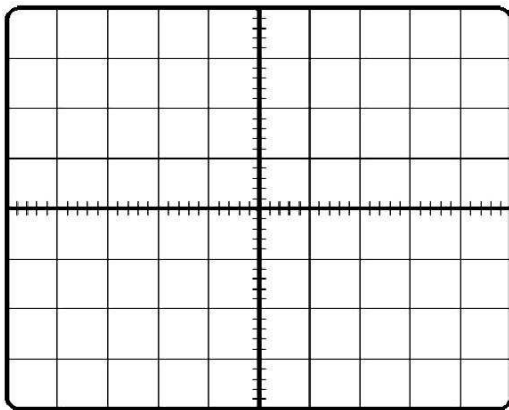
.....  
.....

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

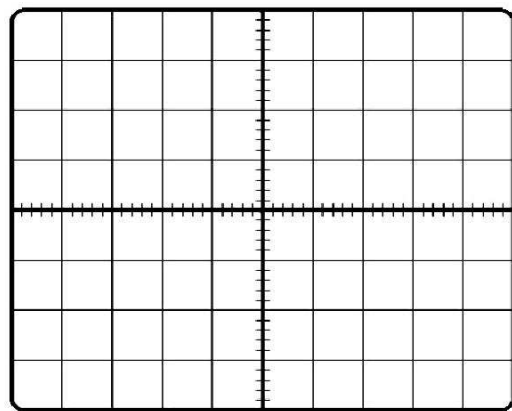
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**Part D: The Comparator circuit**

**Vref=0 V**



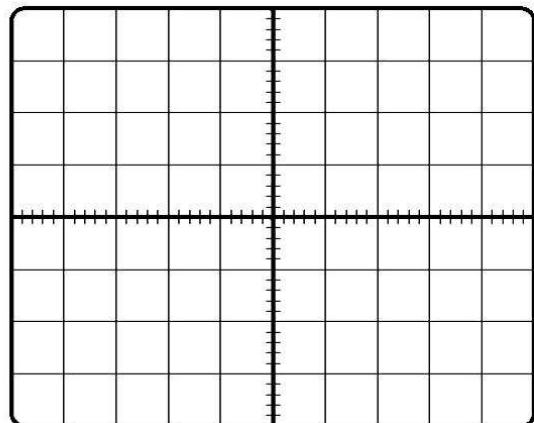
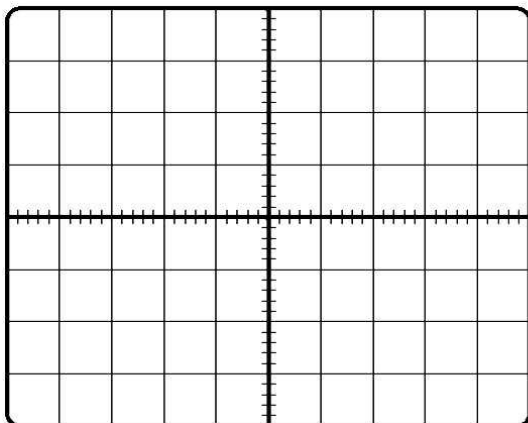
**Vref=2 V**



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

.....  
.....

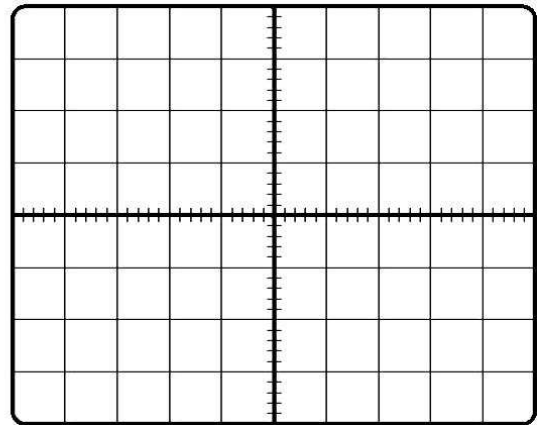
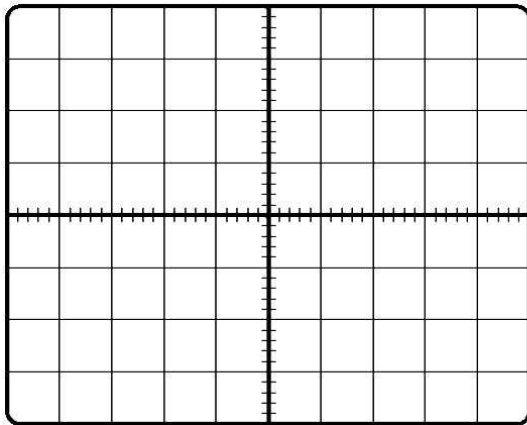
**Part E: The Summing Amplifier (Adder) circuit**



5- Explain what happen.

.....

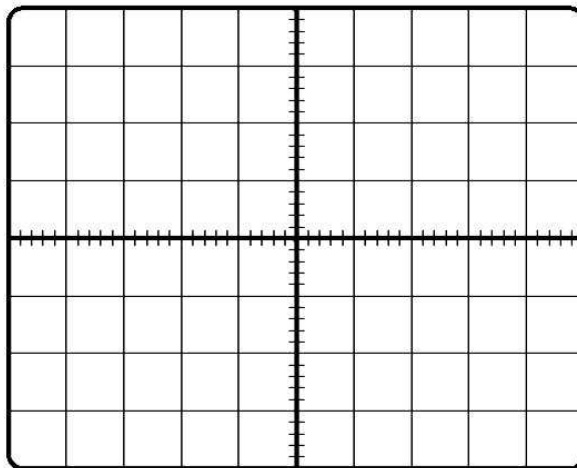
**Part F: The Differential Amplifier (Subtractor) circuit**



5- Explain what happen.

.....  
.....

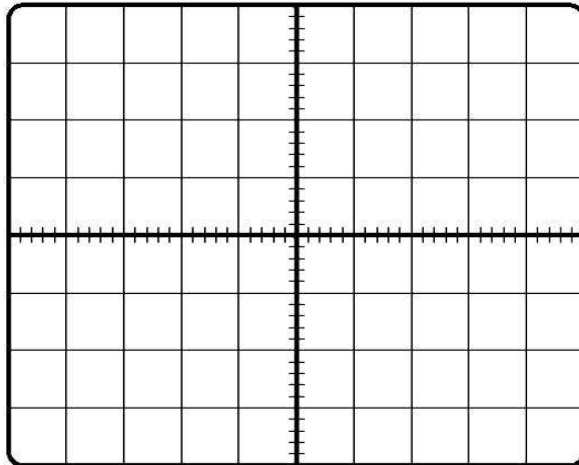
**Part G: The Inverting Integrator circuit**



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

.....  
.....

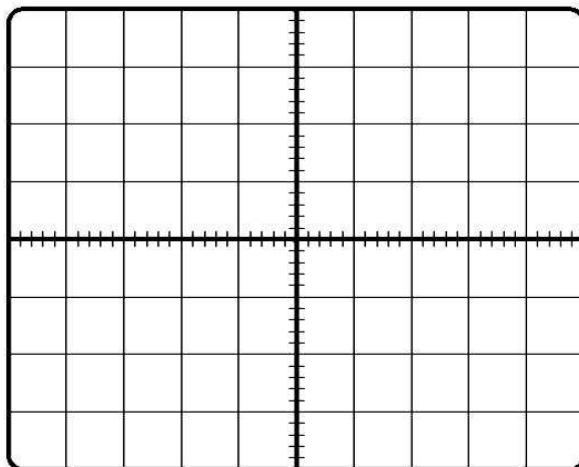
**Part H: The Inverting Differentiator circuit**



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

.....  
.....

**Part I: The Half wave Precision Rectifier circuit**



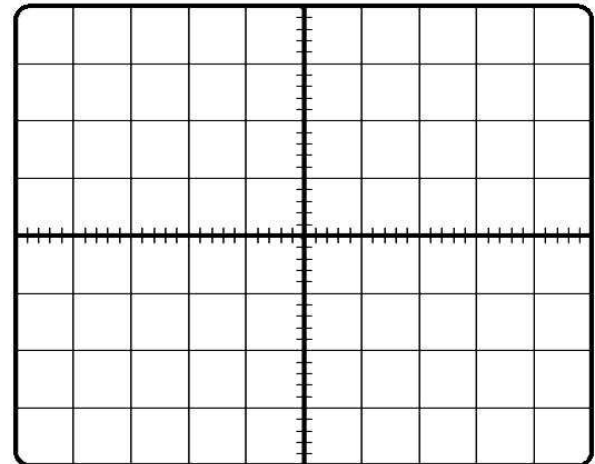
5- What is the main difference between the rectified signals if we use Op-amp instead of using diode only as in Exp2?

.....  
.....

**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.

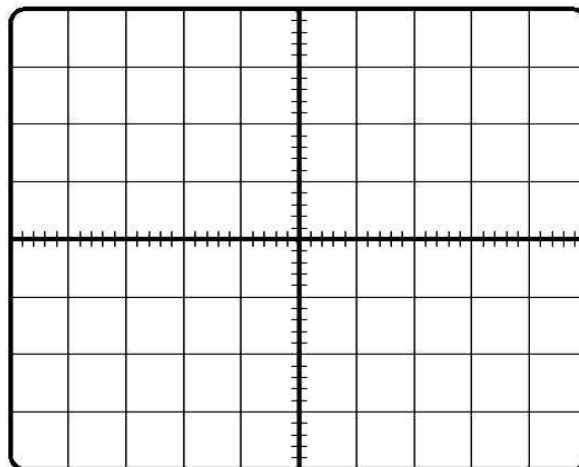
.....  
.....



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?

.....  
.....



