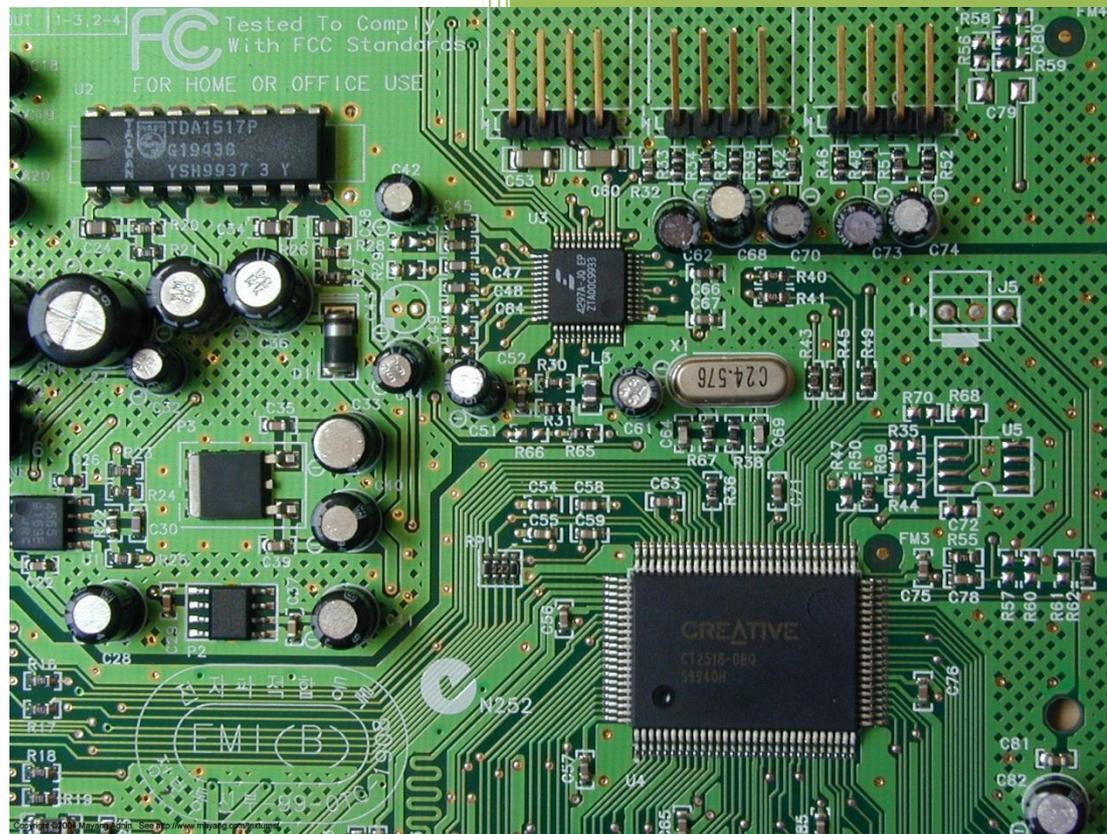




2020/2021

Biomedical Electronics Laboratory

BME 313



Biomedical Engineering Department
Lab Manual Prepared by:
Engr. Mashhour AL Tarayrah,
Dr. Hesham Enshasy
Electrical Engineering Department

Major Topics covered and schedule in weeks:

Topic	Week #	Courses Covered
Introduction and Lab safety.	1	Introduction
Lab equipment familiarization	2	BME 310
Diode characteristics	3	BME 310
Zener Diode characteristics	4	BME 310
Half- wave and Full-wave rectifier	5	BME 310
Half- wave and Full-wave rectifier (Con.)	6	BME 310
Clipper and Clamper circuits	7	BME 310
Bipolar junction transistor characteristics	8	BME 310
Bipolar junction transistor characteristics (Con.)	9	BME 310
Common –Emitter amplifiers	10	BME 310
Common –Emitter amplifiers (Con.)	11	BME 310
Introduction to MOSFET	12	BME 310
MOSFET Common-Source Amplifier	13	BME 310
MOSFET Common-Source Amplifier (Con.)	14	BME 310
Final Exam	15	

Specific Outcomes of Instruction (Lab Learning Outcomes):

1. An ability to run the Electronic lab measurement equipment. (5)
2. An ability to validate the theory of diodes. (1, 3, 5, 6)
3. An ability to Use Multisim software to simulate electronic circuits. (3, 5, 6)
4. An ability to Implement half and full wave rectifiers. (1, 3, 5, 6)
5. An ability to implement clipper and clamper circuits. (1, 3, 5, 6)
6. An ability to validate the BJT transistor bias circuit using load line. (1, 3, 5, 6)
7. An ability to Conduct and validate Common-Emitter bias BJT amplifier circuit. (1, 3, 5, 6)
8. An ability to perform basic operation of MOSFET. (1, 3, 5, 6)

Student Outcomes (SO) Addressed by the Lab:

z	Outcome Description	Contribution
	General Engineering Student Outcomes	
1.	an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics	M
2.	an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors	
3.	an ability to communicate effectively with a range of audiences	L
4.	an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts	

5.	an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	L
6.	an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	H
7.	an ability to acquire and apply new knowledge as needed, using appropriate learning strategies	

Table of Content

Goal	IV
General Guidelines	V
Safety	VI
General Report Guidelines	VII
Week 2:	1
Experiment 1: Lab Equipment Familiarization	1
Week 3:	6
Experiment 2: Diode Characteristics	6
Week 4:	12
Experiment 3: Study of Zener diode in Break down Region	12
Week 5 and Week 6:	17
Experiment 4: Half-Wave And Full-Wave Rectifier	17
Week 7:	25
Experiment 5 : Clipper And Clamper Circuits	25
Week 8 and Week 9:	29
Experiment 6: Bipolar Junction Transistor Characteristics	29
Week 10 and Week 11:	33
Experiment 7 : Transistor AC Amplifiers	33
Week 12:	37
Experiment 8: Introduction to MOSFET	37
Week 13 and Week 14:	42
Experiment 9: MOSFET Common-Source Amplifier	42

Goal

The goal of this laboratory is to study electronics through experimentation. Upon completion of this course, students should be able to use standard laboratory equipment to analyze the behavior of basic electronic devices and to design and construct simple circuits containing these devices.

The purpose of the experiments described here is to acquaint the student with:

- Analog devices.
- Design of circuits.
- Instruments & procedures for electronic test & measurement.

The aim is to teach a practical skill that the student can use in the course of his or her own experimental research projects in physics, electrical engineering, or another science.

At the end of this course, the student should be able to:

- Design and build simple circuits of his or her own design.
- Use electronic test & measurement instruments such as oscilloscopes, function generators, etc. in experimental research.

General Guidelines

Attendance Policy:

Students are required to attend all lab sessions. A student who misses a lab will receive a grade of zero for the lab and any associated reports. No make-up labs will be given.

Homework Policy:

Every lab requires preparation prior to performing the experiments. Most of the labs require Multisim simulations, and some of the labs require calculations of design parameters before beginning the experiment. Students are required to perform this preparatory work prior to coming to the lab. In order to fulfill the written communication component of the course, students are required to turn in pre-lab reports written in a proposal format prior to performing the laboratory work.

Pre-lab reports:

Each pre-lab report is due at the beginning of the lab period. The required report format is found in the lab manual. Each student is required to keep a copy of all pre-labs submitted. The pre-lab report should be used as the basis of the lab report, which will be written sometime after completion of the lab. In certain cases, an instructor may require the student to make corrections to simulations in the pre-lab reports, which will be due the following lab meeting. A 10-point deduction will be taken on every resubmission.

Lab reports:

Lab report must be completed independently. You can share only the collected data sets with your lab partner. Copying any part of the report from others is strictly prohibited and is against the college integrity policy. Lab reports are always due the next session after the lab is completed. Late report will be subjected to a penalty of 10% per day. Late reports will be accepted up to 3 days after the due date. No late reports are accepted after that. A student who misses a lab report will receive a grade of zero.

Safety

Safety is always an important topic whenever laboratory work is being considered, and it is certainly true in the case of BME 313 lab. Safety is important.

The experiments in the laboratory use low voltages and low currents. However, the lab equipment is powered by the 220V, 60Hz, line voltage. Be careful with the line voltages. Do not touch exposed prongs on the equipment plugs when connecting the equipment to the lines.

Take care when using power supplies, which may be low voltage but can supply currents in the ampere range. Shorting such a supply can lead to a serious burn as high currents arc and can ignite flammable material. This is precisely why a car battery needs to be treated with respect. The hundreds of amps a battery can supply are sufficient to cause serious burns.

The equipment is heavy enough to be generally stable on the bench. Be sure to keep the equipment away from the edges of the benches to avoid having a piece of equipment fall off the bench. Besides endangering people who might be struck, falling equipment endangers everyone in vicinity by stressing the power cords, possibly causing a line short or live fault on the equipment, not to mention damage to the expensive lab equipment. In general electronic equipment does not survive harsh treatment.

The capacitors furnished in your lab are electrolytic capacitors with positive and negative terminals. Be sure to always connect the positively marked terminal to the most positive terminal in your circuit. An excess negative voltage applied to these capacitors can cause the device to overheat and explode.

General Report Guidelines

A technical report is expected to contain the following items or subsections:

- Title page,
- Introduction,
- Theoretical discussion or background,
- Experimental procedure and methodology and experimental results,
- Discussion of results,
- Conclusion or summary,
- Acknowledgements,
- Appendices,
- References.

You may find some reports have one or more of these sections removed.

Title page: This page is the first page of the report and should act as the cover page. The title will often be the same as the title given in the lab manual. The title is centered on the top half of the page and is written in bold type, all capitals. Centered on the bottom half of the page is your name, the name of your lab partner(s), the course name, the course title, the instructor or the name of the institution for whom the report is being prepared.

Introduction: The introduction should explain the background of the work. It should put the experimental work into perspective and should lead the reader into the subject matter. It should have at least one sentence explaining why the work was undertaken. It should end with one or two sentences describing the general experimental approach and results.

Theoretical discussion or background: This section is used to develop the theoretical aspects of the experiment. Any relevant theory from class or from the lab manual can be used.

Experimental Procedure and Methodology and Experimental Results: This section is for explanation of apparatus, circuit configuration, and procedures used in this experiment. The title will probably change from experiment-to-experiment. You can put drawings and circuit diagrams into this section.

Discussion of experimental results: This section is probably the most important part of the report. The data should be presented in a reduced form. Usually figures are the easiest form to present data, but tables or lists can be used, where appropriate. Do not assume that the reader knows what you are talking about. Be descriptive. Include sample calculations along with your calculated data. Do not present data or graphs without explanation. Be sure to compare your measured results with those that you expected. Here is where theory meets reality. If the results agree with the theory show how. If the results do not agree with the predicted values, try to explain why you think they are different or where any errors in data-taking could have occurred. Explain any anomalous data.

Conclusion-Summary: This section should provide closure to your report. Conclusions should be based on the information described in the report. The conclusions may not exactly match the lab's objectives, but make sure your conclusions are supported by your data. Any advantages and/or limitations of the

information presented here should be included. You may want to include any personal observation that may not be reflected in the data, e.g., the problems encountered while using a particular instrument or when performing a particular step in the experiment.

Acknowledgements: This section is used to acknowledge any technical or financial aid that was received in support of this work. You should state who your lab partner was in this section.

Appendices: This section should contain any miscellaneous calculations, any mathematical derivations or proofs, and any computer programs or SPICE simulations.

References: This section contains all bibliographical work cited in the report. Usually you will reference your textbook and lab manual here. The format of these is

1. Author, *Title of reference*, page numbers, who published, where published, when published.
1. B. Grob, *Basic Electronics*, pg. 43 to 435, McGraw Hill, New York, NY, 1943.



King Faisal University – KFU
College Of Engineering
Biomedical Engineering Department

Course: Biomedical Electronic Lab – BME 313

Experiment # 1:

ABCD

Students:
AAAAAA
BBBBBB
CCCCCC
DDDDDD

**University
ID:**
000000
111111
222222
333333

Day: Monday.

12/1/2021

INTRODUCTION

A fidget can be combined with resistors and capacitors to change the wave shape of an ac signal. The position of the fidget in the circuit, with respect to the resistors and capacitors, causes the output wave shape to change. The resistor and capacitor act as a smoothing filter. Four basic fidget/resistor/capacitor circuits were studied. The resistor and capacitor values were changed over two orders of magnitude to make the RC time constant much smaller and much larger than the period of the input signal. The output wave shapes were studied as a function of resistor and capacitor values. It was found that the piecewise linear model of the fidget could adequately explain the output wave shapes.

BACKGROUND

When an RC network is placed across the output of a sinusoidal signal, the wave shape is filtered. The output wave shape is the input wave shape multiplied by a constant related to the RC time constant of the network and is given by

$$V_0 = V_{in} e^{-(t/RC)} \quad (1)$$

where V_{in} = the input voltage, etc. (Define all terms) (Continue with enough discussion to explain the general theoretical ideas, but don't put in so much material as to make this section overly long).

EXPERIMENTAL PROCEDURE AND RESULTS

The circuit shown in Figure 1 was constructed. The quiescent emitter-to-ground voltage and the collector-to-ground voltage were measured as R_3 was systematically varied from 10 k Ω to 100 k Ω in 1 Ω steps. The output voltage was simultaneously measured using an oscilloscope. At no time during this measurement did the output voltage wave shape become distorted. The measured values of V_{EO} and V_{CO} have been shown in Figure 2, along with the derived value of V_{CE} . The collector voltage, V_{CE} , was independent of variations in R_3 except when R_3 was varied from 43,445 Ω to 43,447 Ω . For these variations in R_3 the collector voltage dropped by almost two orders of magnitude.

Continue to describe each of your other measurements.

Include all data here and any preliminary discussion of the results.

DISCUSSION OF EXPERIMENTAL RESULTS

The theory predicted that the output current could be written as

$$I_0 = I_{in} e^{(V_{in}/V_T)}$$

where, define terms here. By plotting the measured values of I_0 vs V_{in} , on a semi-log graph, as shown in Figure 6, it is seen that the output current is proportional to the exponential of the input voltage. Noting that the output current increases by a factor of 10 every time the term (V_{in}/V_T) increases by 2.3, it was possible

to determine the value of V_T . V_T was found to be constant and equal to 4.4 V. This value of V_T is approximately 2x larger than expected. The difference was probably due to the fact that V_T is a function of voltage and we only measured V_T over a small range of voltages.

The value of V_2 was determined to be

$$V_2 = V_1^m$$

By plotting V_2 vs. V_1 on a log-log graph, the slope, m , was determined to be 2. This value of m agrees well with the expected value of 2.0. Continue to compare all of your results with your expected results, including any comparisons with SPICE simulations. For every SPICE simulation, include a net list or circuit diagram and include the plots of the SPICE outputs, not the tables of node values.

CONCLUSIONS

The current-voltage relationships governing operation of a super-duper-widget were measured over the range of input voltages from 0 V to 0.001 V. The output current was found to be proportional to the input voltage while the input current was exponentially proportional to the output voltage. These input-output relationships were those predicted by the text. If the input voltage had been varied over a somewhat larger range, these relationships may not have been found.

ACKNOWLEDGEMENTS

This section is used to acknowledge any technical or financial aid that was received in support of this work. You should state who your lab partner was in this section.

APPENDICES

This section should contain any miscellaneous calculations, any mathematical derivations or proofs, and any computer programs or SPICE simulations.

REFERENCES

This section contains all bibliographical work cited in the report. Usually you will reference your textbook and lab manual here. The format of these is

1. Author, *Title of reference*, page numbers, who published, where published, when published.
1. B. Grob, *Basic Electronics*, pg. 43 to 435, McGraw Hill, New York, NY, 1234.

Week 2:

Experiment 1: Lab Equipment Familiarization

OBJECTIVES:

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

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

THEORY:

• Oscilloscope

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

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

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

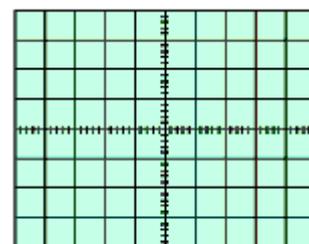


Figure 1

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

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

Table 1: The four major sections of the oscilloscope.

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

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

• Coaxial Cables

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

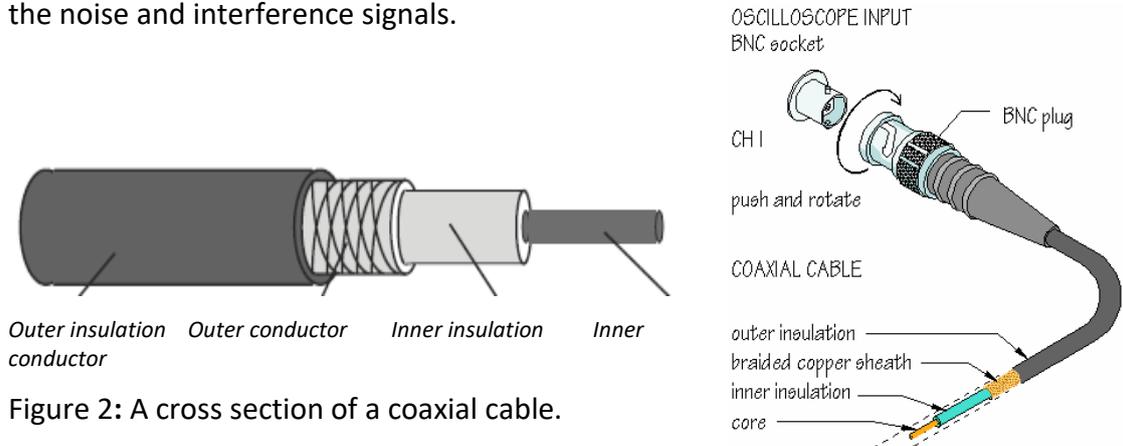


Figure 2: A cross section of a coaxial cable.

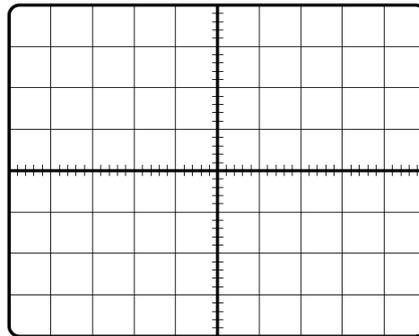
• Function Generator

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

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

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

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



Volts/Div: _____ Time/Div: _____

Figure 3: oscilloscope screen.

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

4- While observing the signal on the Oscilloscope, turn the amplitude potentiometer knob and the frequency knob of the Function Generator to get 8 V_{pp}, 1 kHz on the Oscilloscope screen.

5- Draw the signal displayed on the Oscilloscope screen.

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

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

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

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

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

11- How many screen divisions of the Oscilloscope:

1) Horizontally:

2) Vertically:

3) Subdivisions:

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

PART B - Measuring Time , Frequency and Amplitude

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

Table 2: Results

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

Week 3:

Experiment 2: Diode Characteristics

OBJECTIVES:

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

THEORY:

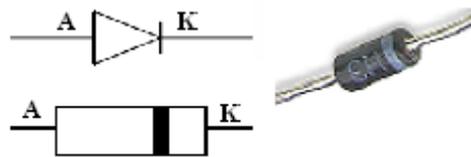


Figure 1: Diode.

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

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

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

Ideal Diode Equation:

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

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

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

I_D = the diode current (amperes).

V_D = the voltage across the diode (volts).

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

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

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

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

and

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

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

Cut-in Voltage V_γ :

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

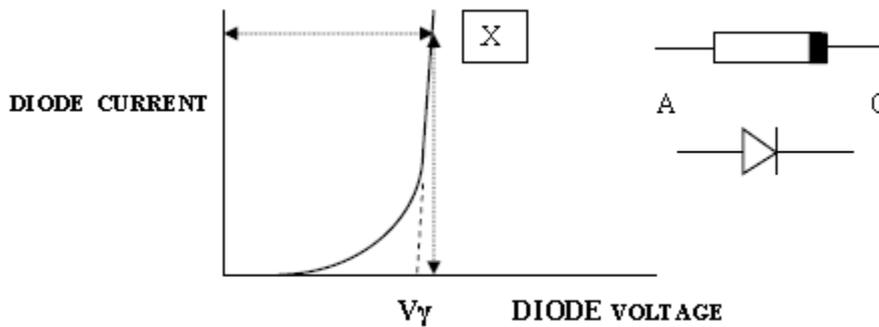


Figure 2: Diode forward I-V characteristic showing the definition of V_γ .

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

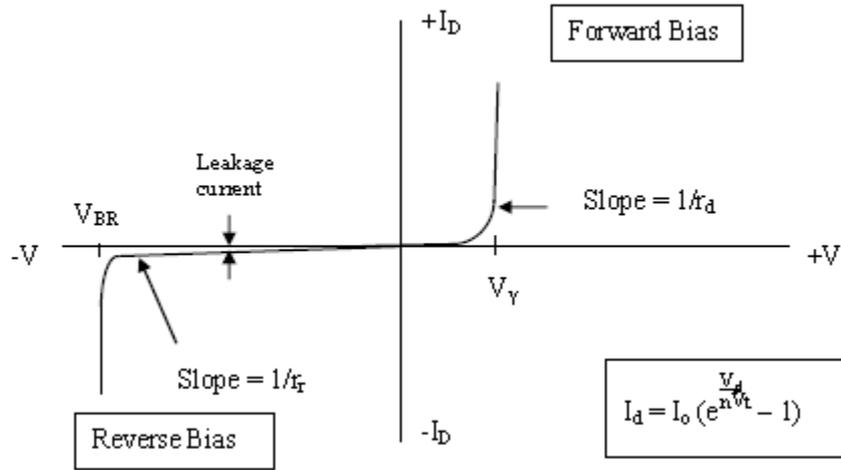


Figure 3: Diode forward I-V characteristic showing the definition of V_Y .

Diode Current and Diode Saturation Current:

If the diode is operated in the forward-bias region at room temperature (27oC = 300 K), the exponential first term in the brackets in Equation (1) dominates and the diode current equation is given approximately by

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

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

Diode Resistance

Three diode resistances are commonly calculated:

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

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

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

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

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

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

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

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

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

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

PROCEDURE:

PART-A Diode (I-V) characteristics

A-1 Forward Bias Mode

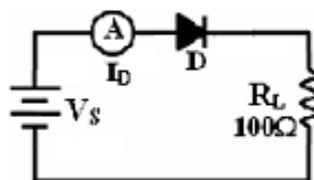


Figure 4

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

Table 1:

V_S (V)	0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.6
I_D (mA)								
V_D (V)								

A-2 Reverse Bias Mode

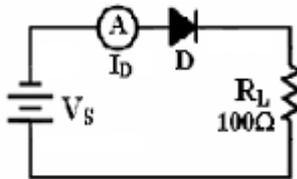


Figure 5

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

Table 2:

V_S (V)	2.0	5.0	10.0	15.0
I_D (mA)				
V_D (V)				

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

Problems and Discussion:

Q1 : Define semiconductor diode.

Q2: Define depletion layer.

Q3: What do you mean by forward biased?

Q4: What do you mean by reverse biased?

Q5. Define Knee voltage.

Q6. Define breakdown voltage.

Q7. Define max. Forward current.

Q8. Define max. Power rating.

Q9. What is hole current?

Q10: What is cut-in voltage?

Week 4:

Experiment 3: Study of Zener diode in Break down Region

OBJECTIVES:

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

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

Introduction:

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



Figure 1: Zener Diode

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

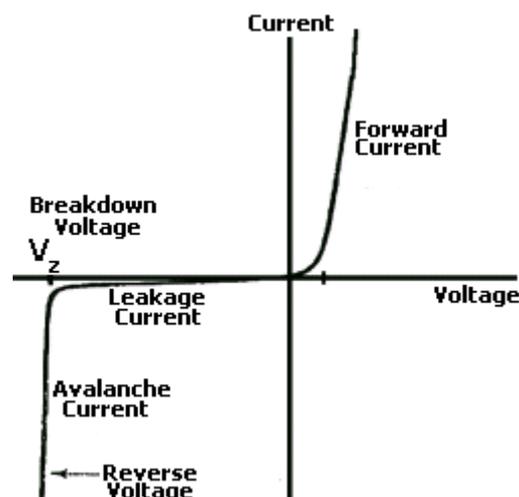


Figure 2: Zener Diode forward I-V characteristic showing the definition of V_z

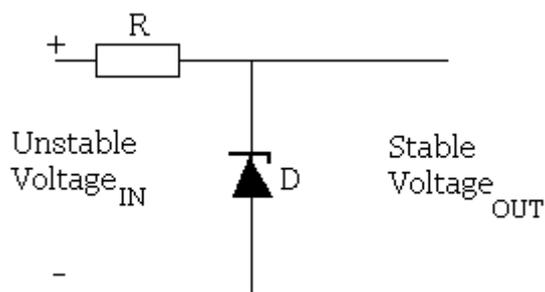
The illustration above shows this phenomenon in a Current vs. Voltage graph. With a zener diode connected in the forward direction, it behaves exactly the same as a standard diode – i.e. a small voltage drop of 0.3 to 0.7V with current flowing through pretty much unrestricted. In the reverse direction however there is a very small leakage current between 0V and the Zener voltage – i.e. just a tiny amount of current is able to flow. Then, when the voltage reaches the **breakdown voltage** (V_z), suddenly current can flow freely through it. For example if you pass a reverse 5V through a 3V zener diode and measure the voltage across the zener diode, that voltage will be 3V.

Uses of Zener Diodes

Since the voltage dropped across a Zener Diode is a known and fixed value, Zener diodes are typically used to regulate the voltage in electric circuits. Using a resistor to ensure that the current passing through the Zener diode is at least 5mA (0.005 Amps), the circuit designer knows that the voltage drop across the diode is exactly equal to the Zener voltage of the diode.

NEW Click here to visit Zener-Diode.co.uk for a site dedicated to zener diodes, their characteristics, usage, and other information.

Zener Diode Voltage Regulator Circuit

**Figure 3: Zener Diode Voltage Regulator Circuit**

A zener diode can be used to make a simple voltage regulation circuit as pictured above. The output voltage is fixed as the zener voltage of the zener diode used and so can be used to power devices requiring a fixed voltage of a certain value (equal to the rating of the zener diode). Click here to find out more about the Zener Diode Voltage Regulator and how you go about selecting the resistor which burns off the excess voltage as heat, and zener diode.

NEW The above mentioned article on zener diode voltage regulators has now been updated and a handy calculator has been added to help you select the

correct resistor (resistance value and power rating) and zener diode value and power rating.

THEORY:

An ideal P-N Junction diode does not conduct in reverse biased condition. A zener diode conducts excellently even in reverse biased condition. These diodes operate at a precise value of voltage called break down voltage. A zener diode when forward biased behaves like an ordinary P-N junction diode. A zener diode when reverse biased can either undergo avalanche break down or zener break down. Avalanche break down:-If both p-side and n-side of the diode are lightly doped, depletion region at the junction widens. Application of a very large electric field at the junction may rupture covalent bonding between electrons. Such rupture leads to the generation of a large number of charge carriers resulting in avalanche multiplication. Zener break down:-If both p-side and n-side of the diode are heavily doped, depletion region at the junction reduces. Application of even a small voltage at the junction ruptures covalent bonding and generates large number of charge carriers. Such sudden increase in the number of charge carriers results in zener mechanism.

Specifications:

Breakdown Voltage = 5.1V

Power dissipation = 0.75W

Max. Forward Current = 1A

Calculations from Graph:

Static forward Resistance $R_{dc} = V_f/I_f$

Dynamic forward Resistance $r_{ac} = \Delta V_f/\Delta I_f$

Static Reverse Resistance $R_{dc} = V_r/I_r$

Dynamic Reverse Resistance $r_{ac} = \Delta V_r/\Delta I_r$

CIRCUIT DIAGRAM:

Forward Bias Condition & Reverse Bias Condition:

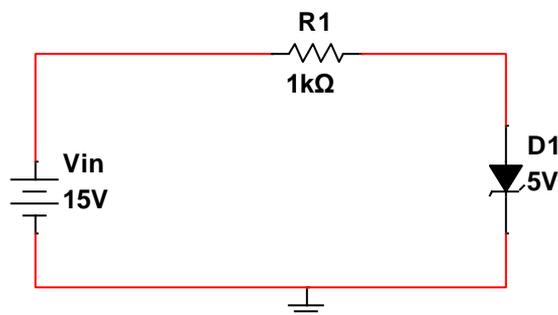


Figure 4: Forward Bias Condition

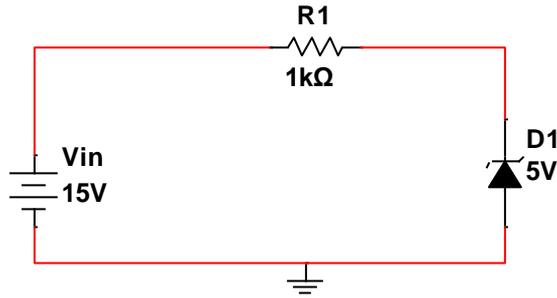


Figure 5: Reverse Bias Condition

PROCEDURE:

Forward biased condition:

- Connect the circuit as shown in fig (4).
- Vary V_{zf} gradually and note down the corresponding readings of I_{zf} .
- Step Size is not fixed because of non linear curve and vary the X-axis variable (i.e. if output variation is more, decrease input step size and vice versa).
- Tabulate different forward currents obtained for different forward voltages.

Reverse biased condition:

- Connect the circuit as shown in fig (5).
- Vary V_{zr} gradually and note down the corresponding readings of I_{zr} .
- Step Size is not fixed because of non linear curve and vary the X-axis variable (i.e. if output variation is more, decrease input step size and vice versa).
- Tabulate different reverse currents obtained for different reverse voltages.

Observations:

Zener diode in Forward Zener diode & reverse biased condition should be observed

Forward Voltage across the diode V_{zf} (volts)	Forward current through the diode I_{zf} (mA)	Reverse Voltage Across diode V_{zr} (volts)	Reverse current through the diode I_{zr} (mA)

PRECAUTIONS:

1. While doing the experiment do not exceed the ratings of the diode. This may lead to

damage the diode.

2. Connect voltmeter and Ammeter in correct polarities as shown in the circuit diagram.
3. Do not switch **ON** the power supply unless you have checked the circuit connections as per the circuit diagram.

RESULT:

1. The zener resistance at the breakdown voltage was found to be =

Problems and Discussion

- Q1: Give applications of Zener diode.
Q2: What is voltage regulation of Zener diode?
Q3: What is Zener current?
Q4: Give the equation from which series resistance of Zener diode regulator determined?
Q5: Give advantages of Zener diode regulator over other regulators.
Q6 : What is Zener diode?
Q7: Give several methods used to manufacture of Zener diodes?
Q8: In passivated structure of a Zener diode by which layer edges of the junction are covered?
Q9: Give the voltage range availability of Zener diodes?
Q10: What is Zener voltage?

Week 5 and Week 6:

Experiment 4: Half-Wave And Full-Wave Rectifier

OBJECTIVES:

- This laboratory session acquaints you with the operation of a diode power supply.
- You will study the operation of half-wave and full-wave rectifiers, and the effect of smoothing filters.
- You will also learn about DC voltage (V_{dc}), the ripple factor (RF), ripple voltage (V_r), and root mean square voltages (V_{rms} and $V_r(rms)$) of a power supply.

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

PRE-LAB:

You should simulate the circuits shown in this experiment with the different resistor and capacitor values that you will use in the experiment. You should be prepared to compare your simulations with your measurements after you have built your circuits.

THEORY:

The diode can be used to change the wave shape of an incoming signal. When used as a rectifier, the asymmetrical properties of the diode's current-voltage characteristics can be used to convert an ac signal into a dc signal. The rectification can either be a half-wave or full-wave.

Half-Wave Rectifier:

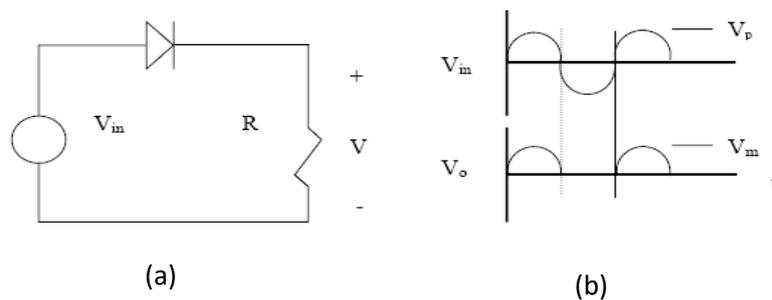


Figure 1: A half-wave rectifier.

Figure 1 (a) shows a basic half-wave diode rectifier circuit. During the positive half-cycle of the input voltage, the diode is forward-biased for all instantaneous voltages greater than the diode cut-in voltage, V_γ . Current flowing through the diode during the positive half-cycle produces approximately a half sine wave of voltages across the load resistor, as shown in the lower part of Figure 1 (b). To simplify our discussions, we will assume that the diode is ideal and that the peak input voltage is always much larger than the V_γ of the diode. Hence, we assume that the zero of the rectified

voltage coincides with the zero of the input voltage. On the negative half-cycle of the input voltage, the diode is reverse-biased. Ignoring the reverse leakage current of the diode, the load current drops to zero, resulting in zero load voltage (output voltage), as shown in Figure 1 (b). Thus, the diode circuit has rectified the input ac voltage, converting the ac voltage to a dc voltage.

The average or dc value of this simple half-wave rectified signal, V_{dc} , is given by

$$V_{dc} = \frac{1}{T} \int_0^{T/2} V_m \sin\left(\frac{2\pi t}{T}\right) dt = \frac{V_m}{\pi} = 0.318 V_m \quad 1$$

Here V_m is the peak value of the rectified signal.

The average voltage is called the dc voltage because this voltage is what a dc voltmeter connected across the load resistor would read. Hence, if $V_m = 10$ V and the diode is ideal, a dc voltmeter across the load resistor would read 3.18 V.

Full-Wave Rectifier:

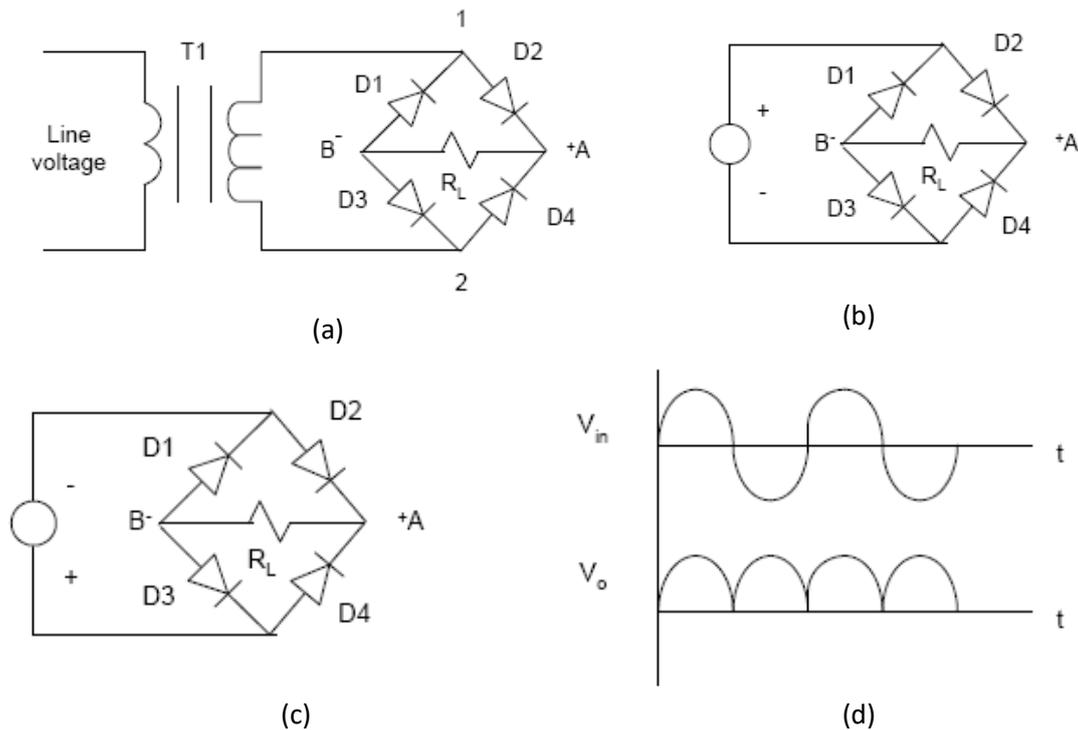


Figure 2: Full-wave rectifier.

Figure 2(a) shows a full-wave bridge rectifier with a load resistor R_L and an input sine wave derived from a transformer. During the positive half-cycle of the input voltage, diodes D2 and D3 are forward biased and diodes D1 and D4 are reverse biased. Therefore, terminal A is positive and terminal B is negative, as shown in Figure 13(b). During the negative half-cycle, illustrated in Figure 2(c), diodes D1 and D4 conduct, and again terminal A is positive and terminal B is negative. Thus, on either half-cycle,

the load voltage has the same polarity and the load current is in the same direction, no matter which pair of diodes is conducting. The full-wave rectified signal is shown in Figure 2(d), with the V_o being the output voltage.

Since the area under the curve of the full-wave rectified signal is twice that of the half-wave rectified signal, the average or dc value of the full-wave rectified signal, V_{dc} , is twice that of the half-wave rectifier.

$$V_{dc} = \frac{2V_m}{\pi} = 0.636V_m \quad 2$$

Filtering:

The rectifier circuits discussed above provide a pulsating dc voltage at the output. These pulsations are known as "ripple". The uses for this kind of output are limited to charging batteries, running dc motors, and a few other applications where a constant dc voltage is not necessary. For most electronic circuits, however, a constant dc voltage similar to that from a battery is required. To convert a half-wave or full-wave rectified voltage with ripple into a more constant dc voltage, a smoothing filter must be used at the rectifier's output. A popular smoothing filter is the capacitor-resistor filter, which consists of a single capacitor in parallel with the load resistor. Figure 3 shows such a filter connected to the output of a half-wave rectifier. The output wave shape of the filtered half-wave rectifier is similar to that shown in Figure 4, assuming that the time constant of the $R_L C$ filter is comparable to the period of the input voltage.

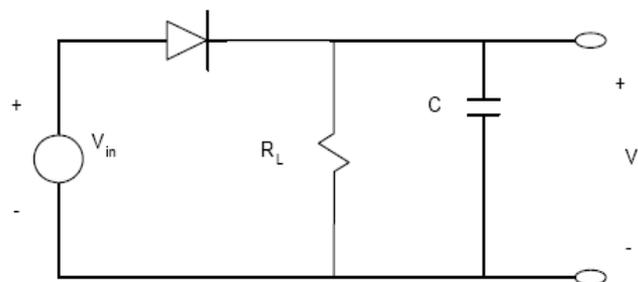


Figure 3: Rectifier circuit with an RC smoothing filter.

Notice that the output wave shape still has ripple, but the ripple is now saw-tooth or triangular shaped, and its variation is much less than that of the unfiltered pulses. The difference between the maximum and minimum of the filtered voltage is known as the **Ripple Voltage (V_r)**. In Figure 4, this voltage is labeled ΔV .

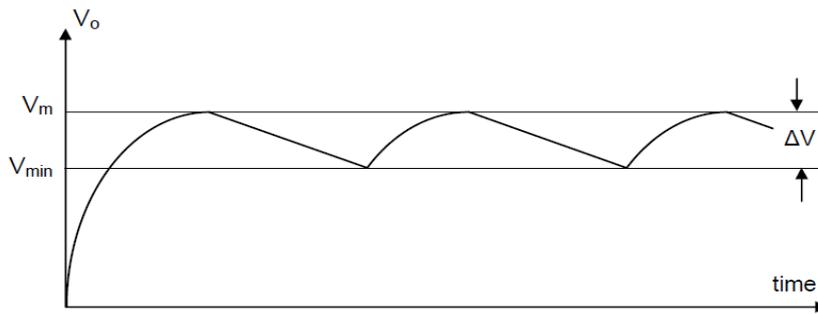


Figure 4: Output wave shape from a full-wave filtered rectifier.

Thus, we have

$$V_r \equiv V_{dc} = \Delta V = V_m - V_{min}$$

where

V_m = peak value of the rectified signal (smaller than the V_{in} , due to V_γ and R_s),
 V_{min} = the minimum of the filtered voltage. V_{min} increases as the ripple voltage decreases.

The design equation for selecting this capacitor is

$$\frac{V_r}{V_m} = \frac{T}{R_L C} = \frac{1}{f_p R_L C} \quad 3$$

where

R_L = load resistance

I_L = load current

C = filter capacitance

$T = 1/f_p$ = the period of the rectified wave.

For a half-wave rectifier, f_p is the frequency of the input voltage. For a full-wave rectifier, f_p is twice the frequency of the input voltage. The output of the filtered voltage for a full-wave rectifier is shown in Figure 4.

From Figure 4, we see that ΔV ($=V_r$) determines the amount of ripple in the output signal. From Equation (3), we see that for the ripple voltage V_r to be small, the $R_L C$ time constant must be large. In other words, the ripple can be reduced by increasing the discharging time constant $R_L C$. Hence, increasing either C or R_L will reduce the ripple voltage. It should be noted that the resistor R_L is usually inside a commercial power supply and any external load connected to the power supply is in parallel with R_L and acts both to lower the total load resistance and to increase the ripple. This is why an audible hum is often heard from power supplies when the external load resistance drops to a very low value.

Two figures of merit for power supplies are the ripple voltage, V_r , and the ripple factor, RF. V_r has already been defined. RF is defined as

$$RF = V_r(rms)/V_{dc} \quad 4$$

$V_r(rms)$ is the RMS value of the ripple voltage. The value of $V_r(rms)$ can be calculated for various input wave shapes. For a complicated wave shape, such as that shown in Figure 4, the value of $V_r(rms)$ is calculated as if the filtered, rectified wave were a triangular wave, for which

$$V_r(rms) = \frac{V_m - V_{min}}{2\sqrt{3}} = \frac{V_r}{2\sqrt{3}} \quad 5$$

It is important to note that V_r and $V_r(rms)$ are not the same.

Earlier we talked about the average or dc voltage, V_{dc} , for unfiltered, rectified supplies. Recall that for a sinusoidal input,

$$V_{dc} = \frac{V_m}{\pi} = 0.318V_m \quad \text{for an unfiltered half-wave rectifier.}$$

$$V_{dc} = \frac{2V_m}{\pi} = 0.636V_m \quad \text{for an unfiltered full-wave rectifier.}$$

The average (dc) voltage will lie between V_m and V_{min} . Therefore, for the filtered, triangular wave shape shown in Figure 4, a better value of V_{dc} would be given by

$$V_{dc} = V_m - \frac{V_r}{2} = \frac{V_m + V_{min}}{2} \quad 6$$

or equivalently,

$$V_{dc} = V_m - \frac{V_m}{2f_p R_L C} = V_m \left(1 - \frac{1}{2f_p R_L C} \right) = V_r \left(f_p R_L C - \frac{1}{2} \right) \quad 7$$

PROCEDURE:

PART-A: Unfiltered Half-wave Rectifier

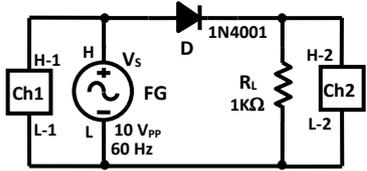


Figure 16: Unfiltered Half-wave Rectifier

- 1- Construct the circuit shown in Figure 16 by using **1N4007 Si** diode.
- 2- Switch ON the Oscilloscope.
- 3- Switch ON the Function Generator and set the source voltage (V_s) to **10V_{p-p}, 60Hz**, sinusoidal.
- 4- Use the Oscilloscope to measure and record V_L from Ch2. Sketch the Oscilloscope screen on the respective grid.
- 5- Reverse the diode according to Figure 6 and repeat step 4.
- 6- What is the output Frequency of the rectifier signal.

PART-B: Filtered Half-wave Rectifier

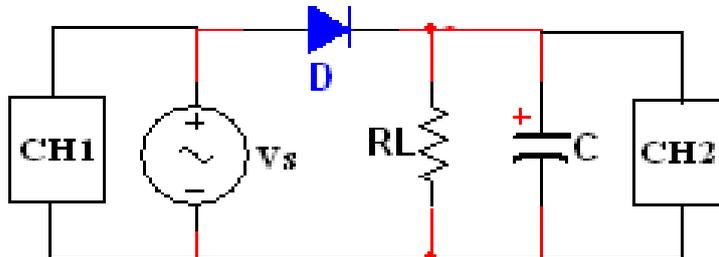


Figure 17: Filtered Half-wave Rectifier.

- 1- Construct the circuit shown in Figure 17.
- 2- Use the value of Capacitor **C** and Load resistor **R_L** according to Table 4. (*Be sure to observe the capacitor polarity*).
- 3- Use the Oscilloscope to measure the **Ripple Voltage V_r** from Ch2, use DMM to measure the **Average Voltage (V_{avg})**. Calculate **Ripple Factor (RF)** and sketch the Oscilloscope screen on the respective grids in Table 1.
- 4- Repeat the steps 2 to 3.
- 5- Switch OFF the Function Generator

Table 1:

V_s & V_L waveforms	V_{r-PP} (V)	V_{avg} (V)	$RF\%$	V_s & V_L waveforms
	$\leftarrow R_L = 1\text{ k}\Omega. C = 1\text{ }\mu\text{F.}$			
	$R_L = 10\text{ k}\Omega. C = 1\text{ }\mu\text{F.} \rightarrow$			
	$\leftarrow R_L = 10\text{ k}\Omega. C = 2.2\text{ }\mu\text{F.}$			
	$R_L = 100\text{ k}\Omega. C = 2.2\text{ }\mu\text{F.} \rightarrow$			

PART-C: Full-wave Bridge Rectifier

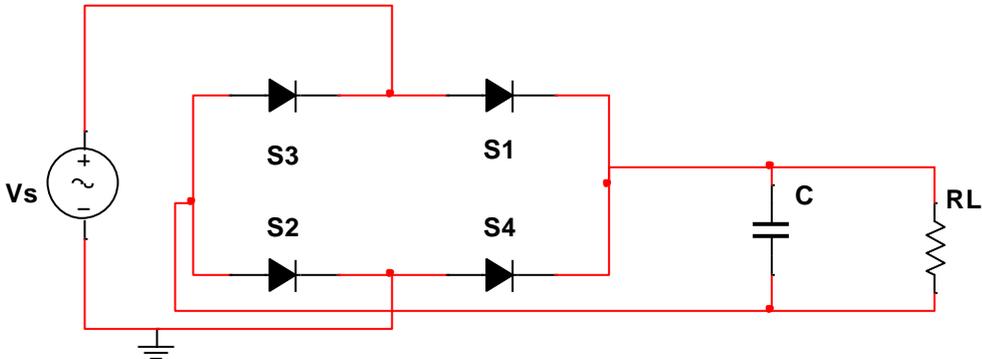


Figure 7: Full-wave Bridge Rectifier.

- 1- Construct the circuit shown in Figure 7 by using the **Bridge rectifier**. (Be sure to observe the capacitor polarity).
- 2- Switch ON the Function Generator and set the source voltage (V_S) to $10V_{p-p}$, $100Hz$, sinusoidal.
- 3- Use the Oscilloscope to measure and record the V_r from CH2 only while CH1 is disconnected (**Why?**). Sketch the Oscilloscope screen on the respective grids in Table 2.
- 4- Replace the components of R_L and C according to Table 2.
- 5- Repeat the steps 3 to 4.
- 6- What is the output Frequency of the rectifier signal.

Table 2:

V _L waveform	V _{r-PP} (V)	V _{avg} (V)	RF%	V _L waveform
	↩ R_L = 1 kΩ. without capacitor			
	R_L = 1 kΩ. C = 2.2 μF. ↪			
	↩ R_L = 10 kΩ. C = 2.2 μF.			
	R_L = 100 kΩ. C = 2.2 μF. ↪			

Week 7:

Experiment 5 : Clipper And Clamper Circuits

OBJECTIVES:

- The purpose of this experiment is to study the use of diodes in wave-shaping (clipper) circuits and in level-shifting (clamper) circuits.

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

PRE-LAB:

The circuits to be tested and simulated are several clipper circuits and a clamper circuit. The clippers use a diode, resistor, and voltage source in different orientations in a circuit. You should be familiar with the basic operation of clipper and clamper circuits as discussed in the lecture. You should be able to produce the output wave shapes for the circuits below. You have to simulate the circuits shown below in the Figures.

You will need to compare your measured circuits with the simulated circuits.

THEORY:

It is frequently necessary to modify the shape of various waveforms for use in instrumentation, controls, computation, and communications. Wave shaping is often achieved by relatively simple combinations of diodes, resistors, and voltage sources. Such circuits are called clippers, limiters, amplitude selectors, or slicers. Clipper circuits are primarily used to prevent a waveform from exceeding a particular limit, either positive or negative. For example, one may need to limit a power supply's output voltage so it does not exceed +5 V. The most widely used wave shaping circuit is the rectifier, which you have previously studied.

Diode Clamper add or shift a dc level to an ac signal, and are sometimes known as dc restorers. For example, if we have a clock signal that swings between 0V and 5V but our application requires a clock signal from -5V to 0V, we can provide the proper DC offset by using a passive Clamper circuit. For the clamping circuit to work properly the pulse width should be less than the RC time constant (τ) of the circuit, by a factor of 5 approximately. Because of the time constant requirement the voltage across the capacitor can not change significantly during the pulse width, and after a short transient period the voltage across the capacitor reaches a steady state offset value.

The output voltage is simply the input voltage shifted by this steady state offset. Also, observe that the peak-to-peak output voltage is equal to the peak-to-peak input voltage. Because the voltage across the capacitor can not change instantaneously and the full change of voltage on the input side of the capacitor will likewise be seen on the output side of the capacitor.

PROCEDURE:

PART-A Diode Clipper circuits

A-1 Positive Clipper

1. Construct the circuit shown in Figure 1.a by using **1N4007 Si** diode.
2. Switch ON the Oscilloscope.
3. Switch ON the Function Generator and set the voltage (V_s) to **$8V_{p-p}$, 100Hz** , sinusoidal.
4. Use the Oscilloscope to measure and record V_s from CH1 and V_o from CH2. Sketch the Oscilloscope screen. (*Note: set the input coupling switch of the Oscilloscope to the DC coupling mode*).
5. Switch OFF the Function Generator, and insert the DC power supply as shown in Figure 1.b.
6. Switch ON the DC power supply and the Function Generator, and set the DC voltage to 2V. Then repeat step 4.
7. When finished, switch OFF the DC power supply and the Function Generator.

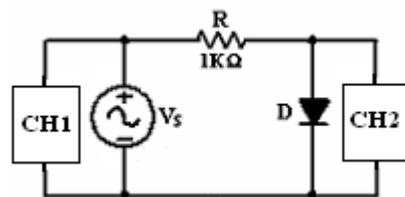


Figure 1.a

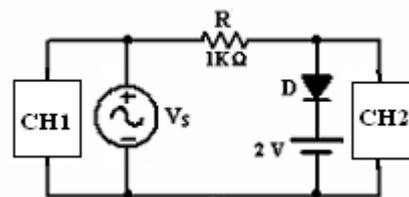


Figure 1.b

8. If you want to draw the resistor voltage waveform (Rectified Signal):
 - a. What are the changes you had to do in the circuit shown in Figure 1.a?
 - b. Draw the circuit again and show the locations of the Oscilloscope channels terminals. Explain.
 - c. Sketch the output waveform in this case.

A-2 Negative Clipper

- 1- Construct the circuit shown in Figure 2.a by reversing the diode of the previous circuit.
- 2- Use the Oscilloscope to measure and record V_S from CH1 and V_O from CH2. Sketch the Oscilloscope screen on the respective grids in Table 2. (Note: set the input coupling switch of the Oscilloscope to the DC coupling mode).
- 3- Switch OFF the Function Generator, and insert the DC power supply as shown in Figure 2.b.

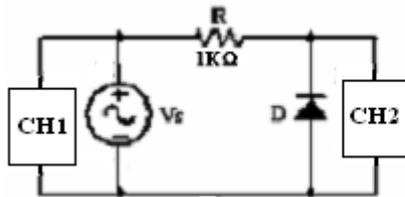


Figure 2.a

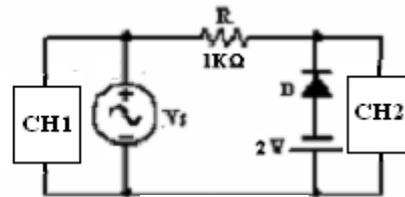


Figure 2.b

- 4- Switch ON the DC power supply and the Function Generator, and set the DC voltage to 2V. Then repeat step 2.
- 5- When finished, switch OFF the DC power supply and the Function Generator.
- 6- Explain the effects of using a diode that is not ideal.

PART-B Diode Clamper circuits

B1- Positive Clamper

- 1- Construct the circuit shown in Figure 3.
- 2- Use the Oscilloscope to measure and record V_S from CH1 and V_O from CH2. Sketch the Oscilloscope screen. (Note: set the input coupling switch of the Oscilloscope to the DC coupling mode).
- 3- When finished, switch OFF the Function Generator.

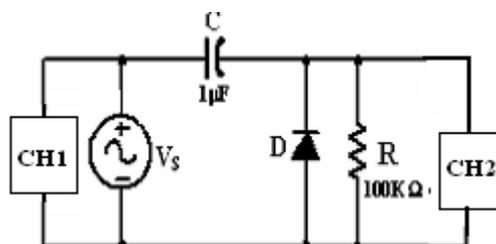


Figure 3

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

B-2 Negative Clamper

- 1- Construct the circuit shown in Figure 4.
- 2- Use the Oscilloscope to measure and record V_S from CH1 and V_O from CH2. Sketch the Oscilloscope screen.
- 3- When finished, switch OFF the instruments.

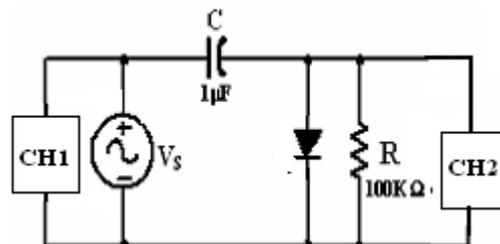


Figure 4

Week 8 and Week 9:

Experiment 6: Bipolar Junction Transistor Characteristics

OBJECTIVES:

- To investigate the DC behavior of BJT.
- To understand the transistor DC biasing circuit.
- To identify the characteristics of a BJT transistors in different regions of operations.

Test Standard : IEEE C62.42

PRE-LAB:

- By using the data sheet of the **BC140** transistor, look up to the following:
 - Pin out configuration package (Bottom View)
 - Minimum $h_{FE} (\beta)$ _____ .
 - Maximum $h_{FE} (\beta)$ _____ .
 - $V_{CE} (max)$ _____ V .
 - $I_C (max)$ _____ V .
 - Total maximum power dissipation _____ mW .
 - Semiconductor material and the type of transistor _____
 - The complementary transistor of the **BC140** is _____
- What is the difference between a BC140 BJT and its complementary transistor.
- Build the circuit in the experiment using the MULTISIM simulation package, to obtain the expected results and graphs.

THEORY:

The Bipolar Transistor essentially consists of a pair of PN-Junction diodes that are joined back-to-back. They can be found anywhere and used in many electronic circuit applications such as in sensors, amplifiers, OP-AMPS, oscillators and digital logic gates. The PC computer contains around a hundred million transistors; or more!

There are all sorts, shapes, and sizes of transistors. In this lab we will only consider one basic general purpose type, the bipolar junction transistor. This transistor comes in two constructions called PNP and NPN. For the following experiments you will use the **BD140 Si**, NPN transistors.

The DMMs in the lab have a separate function for PN-junction testing. In diode test, the DMM outputs a constant current of about **1 mA** and it measures the voltage between the two leads without computing the resistance. The measured voltage is the threshold voltage (V_γ ; i.e. **(0.5 - 0.65) V** for **Si**, typically less than the normal drop

of 0.7 V) of the PN-junction for a 1 mA current, 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 through 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. Some meters give an over-limit (.OL, 1., or 2 to 3V) indication. Using the DMMs diode function is one way to perform the transistor test, and it gives understandable information about the typical PN-junction voltages of the BJT.

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

PROCEDURE:

Part-A Current-Voltage Characteristics of a CE BJT

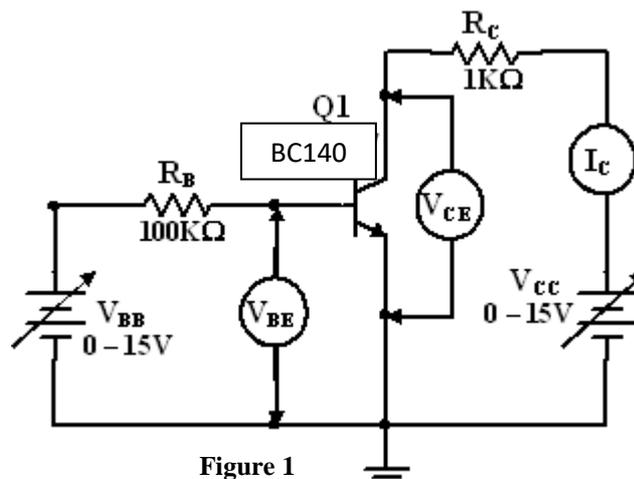


Figure 1

- 1- Construct the circuit shown in Figure 1. By using the **BC140 BJT**. (Make sure the transistor is connected with the correct polarity).
- 2- Set the DC power supplies output to zero volt, then switch the supply ON.
- 3- Adjust the DC power supply of V_{CC} according to Table 1.
- 4- Adjust the DC power supply V_{BB} to obtain the approximate values according to Table 1.
- 5- Use the voltmeter to measure V_{BE} , V_{CE} and I_C and calculate I_B and, and record the readings in Table 1.
- 6- Repeat steps 4 and 5 for all values of V_{BB} .
- 7- Repeat steps 3 to 6.

- 8- When finished, set the V_{BB} and V_{CC} to **0.0V**. Then switch OFF the DC power supplies.
- 9- From your data in Table 1, 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.
- 10- From your data in Table 1, plot the input characteristics (I_B vs. V_{BE}) at $V_{CC}= 15V$.
- 11- From the experimental results calculate the average β_{DC} (h_{FE}). For what significant reasons is the experimental β different from the manufacturer's specified value?
- 12- From the above β , calculate the corresponding alpha α .
- 13- On the basis of the measurements you made, what material is the transistor made of? How did you arrive at this conclusion?
- 14- Explain how the **Common Emitter (CE)** characteristics would be different if β were increased?
- 15- Explain how the **CE** output characteristics (V_{CE} , I_C) would be affected by a decrease in temperature.
- 16- Draw (I_C vs. I_B), and (V_{CE} vs. I_B) when $V_{CC}= 15$ volt.

NOTE:

$$I_B = (V_{BB} - V_{BE})/R_B$$

$$\beta_{DC} = I_C/I_B$$

Table 3:

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

Week 10 and Week 11:

Experiment 7 : Transistor AC Amplifiers

(This experiment would be for two weeks so that the lab can be synchronized with the lecture)

OBJECTIVES:

- To study AC transistor amplifiers
- Design and Conduct a Common-Emitter Amplifier circuit to illustrate how the voltage gain of a CE bipolar transistor circuit can be changed by using the Emitter Bypass capacitor.
- Understand the concept “Q-point determines the relationship between the input wave shape and the output wave shape”.
- The gain of the CE amplifier is a function of the transistor used in the circuit, the values of the resistors, and the presence of an emitter bypass capacitor. The CE amplifier with capacitor-bypassed emitter resistance shows good gain stability to variations in transistor β .
- **Test Standard : IEEE C62.42**

PRE-LAB:

- You should be familiar with the dc analysis techniques needed to find the Q-point of a common-emitter circuit.
- All the preparation parts must be computed before the experiments part. Consider the circuit of Fig. 1.

Let $V_{CC} = 12\text{ V}$, $R_C = 6.2\text{ k}\Omega$, $R_E = 1.8\text{ k}\Omega$, and $R_L = 2.2\text{ k}\Omega$.

- Calculate values of R_1 , R_2 so that $I_{CQ} \approx 1\text{ mA}$ and for good bias stability (or $R_{BB} = 0.1 \times (\beta + 1) \times R_E$).
- Compute the Q-point and the maximum unclipped output voltage with CE included ($C_E = 100\mu\text{F}$).
- Repeat 2 if capacitor C_E is removed.
- With R_C , R_E and R_L the same as what used in 1), re-calculate R_1 and R_2 so that the operating point is at the center of the AC load line. Re-calculate the maximum unclipped output with CE included ($C_E = 100\mu\text{F}$).
- Repeat 4 with the bypass capacitor C_E removed.
- Change the value of R_C to $3.2\text{ k}\Omega$ and re-calculate the DC operating point I_{CQ} . What do you notice?

You may find the following equations useful:

$$I_{CQ} \approx \frac{V_{BB} - V_{BE(on)}}{R_E + \frac{R_{BB}}{\beta}}, V_{BB} = \frac{V_{CC} \times R_2}{R_1 + R_2}, R_{BB} = \frac{R_1 \times R_2}{R_1 + R_2}, V_{BE(on)} \approx 0.7V$$

- Simulate all the circuits in the experiment sheet using the MULTISIM simulation package, to verify your results and graphs.

Background Information:

A typical common emitter amplifier stage is shown in the Figure 1. The placement of the Q-point on the AC load line determines the maximum symmetrical AC component in the collector voltage and current.

With an arbitrary location of the Q-point on the AC load line, the maximum unclipped voltage or current will occur first on either the positive or the negative cycles of the AC waveform, and as the input is increased, the output will eventually be clipped on both cycles. The maximum unclipped output can be optimized (maximized) placing the Q-point at the center of the AC load line.

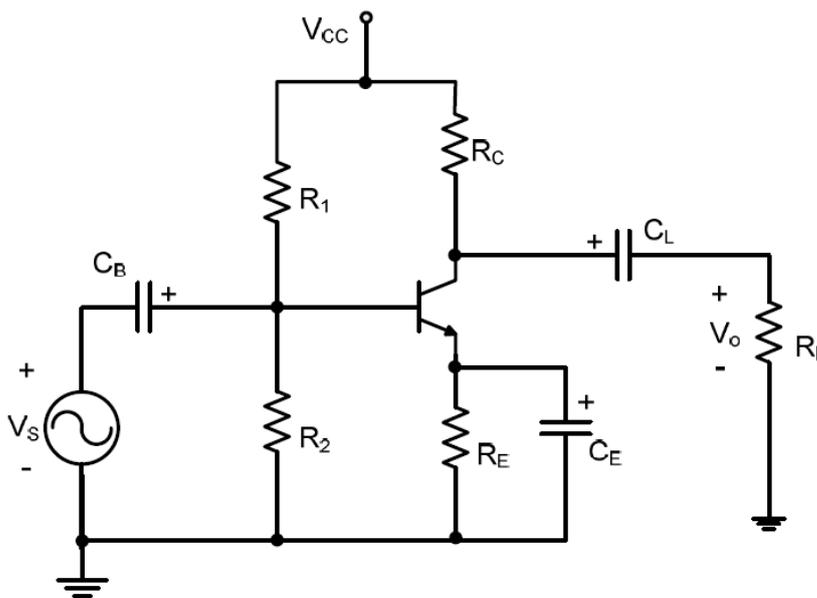


Figure 1: Common Emitter Amplifier

Common-Emitter Amplifier

The Common-Emitter (CE) amplifier is characterized by high voltage and current gains, A_v and A_i , respectively. The amplifier typically has a relatively high input resistance Z_i (1 to 10 k Ω) and is generally used to drive medium to high resistive loads. The circuit for the common-emitter used in applications where a small voltage signal needs to be amplified to a large voltage signal. Since the amplifier cannot drive low resistive loads

R_L , usually it is cascaded with a Common-Collector (CC) (some times called, emitter follower or buffer) circuit that can act as a driver.

Common-Collector (Emitter follower) Amplifier

The common-collector amplifier (emitter-follower), is a unity voltage gain A_v and a high current gain A_i amplifier. The input resistance Z_i for this type of amplifiers is usually (1 to 10 k Ω) which is relatively high. Because the amplifier has unity voltage gain ($A_v \cong 1$), it is useful as a buffer amplifier providing isolation between two circuits while providing driving capability for low resistive loads.

Experimental Procedure:

The purpose of the experiment is to verify the theoretical and simulation results. Use $C_B = 1 \mu\text{F}$, $C_L = 1 \mu\text{F}$, and $C_E = 100 \mu\text{F}$.

NOTE: Make sure capacitors are connected with the correct polarity.

- 1) Build the circuit in Fig.1 with the values you calculated in part (1) of the preparation. If necessary, re-adjust R_1 , R_2 so that $I_{CQ} \approx 1 \text{ mA}$.
- 2) Measure the maximum sinusoidal unclipped output. Set the input frequency to 5 kHz.
- 3) Repeat (2) with C_E removed.
- 4) Replace R_1 , R_2 with the ones found in the pre-lab preparation part (4) and measure the new unclipped output.
- 5) Repeat (4) with C_E removed.
- 6) Change R_C to 3.2 k Ω and measure I_{CQ} after the change.

Report:

In your lab report, present experimental data and compare them with your expected results. Discuss any discrepancies, make comments, and write conclusions.

Your report will include the following information:

1. Laboratory partner.
2. Date and time data were taken.
3. The pre-laboratory results.
4. The experimental procedures.
5. All calculations or simulation results for each step.
6. All plots or waveforms for each step.
7. Short summary discussing what was observed for each of the steps given in experiment.
8. What you learned.

Notes:

1- You have to connect the circuit.

2- You have to change V_s and record your results.

3- From your data you have to check V_{BE} and V_{BC} that verify the transistor is biased in the forward-active mode. Why is $V_{CE} = 7.5 \text{ V}$ a good choice?

4- You have to show all the steps and results. Also you have to write a report.

Week 12:

Experiment 8: Introduction to MOSFET

OBJECTIVES:

- To investigate 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 operations.
- To determine the small signal parameter g_m .
- **Test Standard : IEEE C62.42**

PRE-LAB:

- By using the data sheet of the **BS170** MOSFET, look up to the following:
 - Zero-Gate Voltage Drain Current I_{DSS} (min) _____ mA. I_{DSS} (max) ____ mA.
 - Maximum rated continuous drain current I_D (max) _____ mA .
 - Gate-source threshold voltage $V_{GS(th)}$ _____ V .
 - Static Drain-Source On-Resistance $R_{DS(ON)}$ _____ Ω .
 - Total maximum power dissipation P_D _____ mW .
- Simulate all the circuits in the experiment handout using the MultiSIM simulation packages, to verify your results and graphs.
- What is the primary difference between a MOSFET and a BJT ?

THEORY:

The Metal Oxide Semiconductor Field Effect Transistor (MOSFET) is a device used to amplify or switch electronic signals. The MOSFET includes a channel of n-type or p-type semiconductor material, and is accordingly called an NMOSFET or a PMOSFET (also commonly nMOS, pMOS). It is by far the most common transistor in both digital and analog circuits, though the bipolar junction transistor was at one time much more common.

A variety of symbols are used for the MOSFET as shown in Figure 1. Sometimes three line segments are used for enhancement mode and a solid line for depletion mode. Another line is drawn parallel to the channel for the gate.

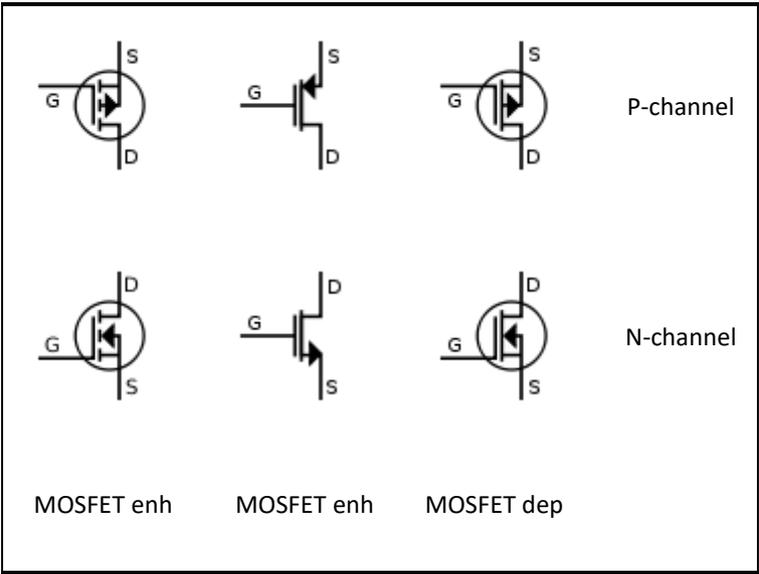


Figure 1: Symbols used for the MOSFET.

Mode of Operation

The operation of a MOSFET can be separated into three different modes, depending on the voltages at the terminals. For an enhancement mode, n-channel MOSFET, the three operational modes are:

1-Cutoff mode when $V_{GS} < V_{TN}$

Where V_{TN} is the threshold voltage of the device. According to the basic threshold model, the transistor is turned off, and there is no conduction between drain and source.

2- Triode mode or non saturation mode when $V_{GS} > V_{TN}$ and $V_{DS} < (V_{GS} - V_{TN})$

The transistor is turned on, and a channel has been 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.

3- Saturation or active mode 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

The DC behavior of a MOSFET is specified most completely by the output characteristics, I_D vs. V_{DS} , with V_{GS} as a parameter, and the input-output characteristic, I_D vs. V_{GS} .

MOSFET drain current vs. drain-to-source voltage for several values of ($V_{GS} - V_{TN}$); the boundary between linear (Ohmic) and saturation (active) modes is indicated by the upward curving parabola.

PROCEDURE:

Part-A MOSFET Lead Identifications by using the DMM

1. Use the data sheet to find the pin out of the MOSFET.
2. Check out that the used MOSFET is working properly using DMM, turn on the DMM and set it to (\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. Connect the black test lead into the $V\Omega \rightarrow$ (+) 4mm banana socket of the DMM.
3. Connect one lead of the DMM to the Drain (D) pin and the other lead of the DMM to the Gate (G) pin. Check the reading of the DMM. Explain your result.
4. Connect the one lead of the DMM to the Source (S) pin and the other lead of the DMM to the Gate (G) pin. Check the reading of the DMM. Explain your result.
5. Connect the one lead of the DMM to the Source (S) pin and the other lead of the DMM to the Drain (D) pin. Check the reading of the DMM. Explain your result.

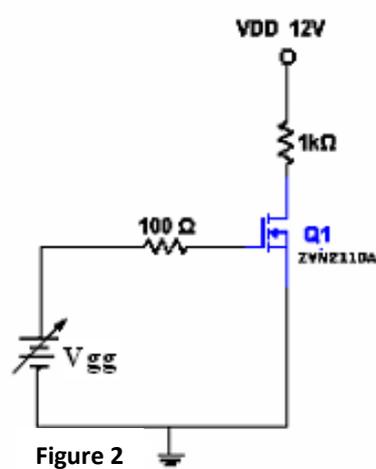
Current-Voltage Characteristics of a CS MOSFET

PART B: I_D versus V_{GS} Characteristic

1. Construct the circuit shown in Figure 2 by using the **BS170 MOSFET**. (*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 ON the supplies.
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.
5. Use the DMM to **measure** the values of I_D , and then record the readings in Table 1.

Table 1:

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



6. When finished, set the V_{GG} and V_{DD} to $0.0V$. Then switch OFF the DC power supplies.
7. From the results in Table 1, what is the value of threshold voltage V_{TN} ?
8. From your data in Table 1, plot the experimental output drain characteristics (I_D vs. V_{GS}), and determine V_{TN} on the plot.
9. From the experimental results calculate the average transconductance g_m . For what significant reasons is the experimental g_m different from the manufacturer's specified value?

PART C: I_D versus V_{DS} Characteristic

1. Construct the circuit shown in Figure 3.
2. Set the DC power supplies output adjustment potentiometers fully counter clock wise, then switch ON the supplies.
3. Adjust the DC power supply of V_{DD} according to Table 2.
4. Adjust the V_{GG} power supply to obtain the values according to Table 2.
5. Use the DMM to measure the values of V_{DS} and I_D , and then record the readings in Table 2.
6. Repeat steps 3 and 5 for all values of V_{GG} and V_{DD} .
7. When finished, set the V_{GG} and V_{DD} to $0.0V$. Then switch OFF the DC power supplies.

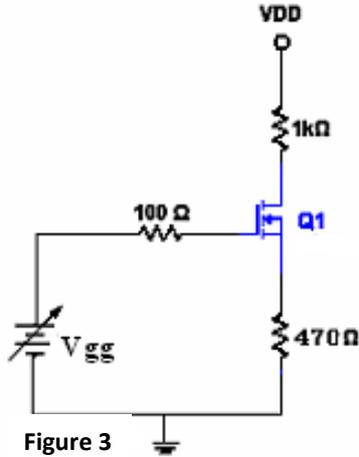


Table 2:

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

- From your data in Table 2, plot the experimental output drain 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).
- Explain qualitatively how the CS input characteristics would be affected by a decrease and increase in temperature.

Week 13 and Week 14:

Experiment 9: MOSFET Common-Source Amplifier

OBJECTIVES:

- To investigate the MOSFET applications as a simple common-source and common-drain AC amplifiers.
- **Test Standard : IEEE C62.42**

PRE-LAB:

- You should be familiar with the dc analysis techniques needed to find the Q-point of a common-source circuit.
- Simulate all the circuits in the experiment sheet using the MULTISIM simulation package, to verify your results and graphs.

THEORY:

MOSFET AC Amplifier Device:

Two of the most popular configurations of small-signal MOSFET amplifiers are the Common Source (CS) and Common Drain (CD) configurations.

The Common Source (CS) and Common Drain (CD) amplifiers, like all MOSFET amplifiers, have the characteristic of high input impedance. The value of the input impedance for both amplifiers is basically limited only by the biasing resistors R_{G1} and R_{G2} . Values of R_{G1} and R_{G2} are usually chosen as high as possible to keep the input impedance high. 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. This is very similar to the BJT biasing arrangement. The main difference with the BJT biasing scheme is that ideally no current flows from the voltage divider into the MOSFET.

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:

PART-A Common-Source Amplifier with Source Resistor (R_s)

1. Construct the circuit shown in Figure 1, 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, just apply V_{DD} then **measure** V_{DSQ} , I_{DQ} and V_{GSQ} quiescent DC values. Record the measured values in Table 1.
3. Connect the Function Generator and the Oscilloscope to the circuit as shown in Figure 1.

Table 1:

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

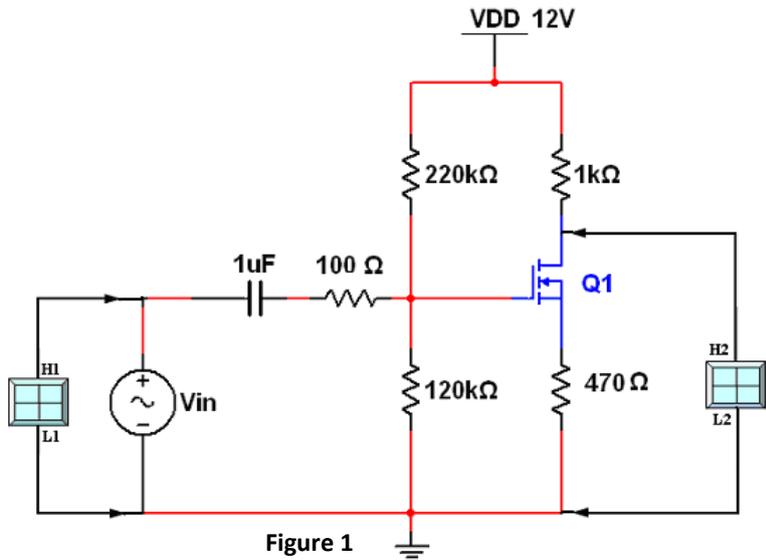


Figure 1

4. Switch ON the Oscilloscope and the Function Generator and set the source voltage V_s to sinusoidal signal, **100mV_{PP}**, **5kHz**. (Note: set the input coupling switch of the Oscilloscope to the AC coupling mode).
5. Using the Oscilloscope, measure the small-signal voltage gain, $A_v = V_o / V_s$. Sketch the Oscilloscope screens on the respective grid.
6. When finished, set the source voltage V_s to **100mV_{PP}**.
7. Note the phase shift between output and input voltages. Is the amplifier inverting or non-inverting?

PART-B Common-Source Amplifier without Source Resistor (R_S)

1. Starting again with the same circuit shown in Figure 1, add **10 μ F** in parallel with the Source resistance (R_S).
2. Connect channel 2 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.
4. What happen to the Voltage Gain when adding the capacitor parallel to R_S ? Explain the effect of R_S .