

**Department of Electronic Engineering**  
**N.E.D. University of Engineering & Technology,**

**PRACTICAL WORK BOOK**

**For the course**

**BASIC ELECTRONICS**

**(EL-103) For F.E(EL)**

**Instructors name:** \_\_\_\_\_

**Student Name:** \_\_\_\_\_

**Roll no.:** \_\_\_\_\_ **Batch:** \_\_\_\_\_

**Semester :** \_\_\_\_\_ **Year:** \_\_\_\_\_

**Department:** \_\_\_\_\_

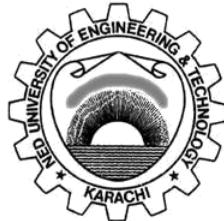
# **LABORATORY WORK BOOK FOR THE COURSE**

## **EL-103 BASIC ELECTRONICS**

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Approved By:

**The Board of Studies of Department of Electronic Engineering**

# Basic Electronic Laboratory

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## **LAB SESSION 01**

To learn about the Electrical & Electronic Symbols and Laboratory

**Student Name:** \_\_\_\_\_

**Roll no.:** \_\_\_\_\_ **Batch:** \_\_\_\_\_

**Semester :** \_\_\_\_\_ **Year:** \_\_\_\_\_

<b>Total Marks</b>	<b>Marks Obtained</b>

**Remarks (if any) :** \_\_\_\_\_

**Instructor Name:** \_\_\_\_\_

**Instructor Signature:** \_\_\_\_\_ **Date:** \_\_\_\_\_

\_\_\_\_\_

**NED University of Engineering and Technology, Karachi**  
**Department of Electronic Engineering**

Course Code: \_\_\_\_\_ Course Name: \_\_\_\_\_  
 Laboratory Session No. \_\_\_\_\_ Date: \_\_\_\_\_

		Psychomotor Domain Assessment Rubric-Level P3				
Skill Sets		Extent of Achievement				
		0	1	2	3	4
<b>Equipment Identification</b> Sensual ability to identify equipment and/or its component for a lab work	Unable to identify the equipment	Able to identify very few equipment and components to be used in lab work	Able to identify some of the equipment and components to be used in lab work	Able to identify most of the equipment and components to be used in lab work	Able to identify all of the equipment as well as its components	
<b>Procedural Skills</b> Displays skills to act upon sequence of steps in lab work	Unable to either learn or perform lab work procedure	Able to slightly understand lab work procedure and perform lab work	Able to somewhat understand lab work procedure and perform lab work	Able to moderately understand lab work procedure and perform lab work	Fully understands lab work procedure and perform lab work	
<b>Response</b> Capability to imitate the lab work on his/her own	Unable to imitate the lab work	Able to slightly imitate the lab work	Able to somewhat imitate the lab work	Able to moderately imitate the lab work	Fully initiates lab work	
<b>Observation's Use</b> Displays skills to perform related mathematical calculations using the observations from lab work	Unable to use lab work observations for mathematical calculations	Able to slightly use lab work observations for mathematical calculations	Able to somewhat use lab work Observations for mathematical calculations	Able to moderately use lab work Observations for mathematical calculations	Fully use lab work observations for mathematical calculations	
<b>Equipment Use</b> Sensory skills to describe the use of the equipment for the lab work	Unable to describe the use of equipment	Rarely able to describe the use of equipment	Occasionally describe the use of equipment	Often able to describe the use of equipment	Regularly able to describe the use of equipment	
<b>Equipment Handling</b> Equipment care during the use	Doesn't handle Equipment with required care	Rarely handles equipment with required care	Occasionally handles Equipment with required care	Often handles Equipment with required care	Handles equipment with required care	
Ability to troubleshoot errors and try to resolve with/without the supervision or guidance	Unable to troubleshoot experimentation errors and resolve them	Able to troubleshoot experimentation errors but cannot resolve them	Able to troubleshoot experimentation errors independently but need guidance in resolving them under supervision	Able to troubleshoot experimentation errors independently but need guidance in resolving them	Able to troubleshoot experimentation errors and resolve them without supervision or guidance	

Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

# LAB SESSION 01

## Objective

To learn about the electrical symbols and laboratory equipments like, Multimeter, Oscilloscope, Function Generator, Power Supplies. (<http://www.ladyada.net/learn/multimeter>)

## Theory

### Multimeters

The most important debugging tool in any Electronic Lab is a multimeter. A multimeter can measure continuity, resistance, voltage and sometimes even current, capacitance, temperature, etc.

You should go through all of these sections in order, as they build on each other.

1. Continuity measurements  
How to tell if two points are electrically connected
2. Resistance measurements  
How to measure resistance - resistors, potentiometers and sensors
3. Voltage measurements  
How to measure voltage - battery testing, wall adaptor testing, and mixed AC/DC measurements.

### What is continuity?

Continuity means, are two things electrically connected. So if two electronic parts are connected with a wire, they are continuous. If they are connected with cotton string, they are not: while they are connected, the cotton string is not conductive.

You can always use a resistance-tester (ohmmeter) to figure out if something is connected because the resistance of wires is very small, less than 100 ohms, usually. However, continuity testers usually have a piezo buzzer which beeps. This makes them very useful when you want to poke at a circuit and need to focus on where the probes are instead of staring at the meter display.

### Remember!

**You can only test continuity when the device you're testing is not powered.**

**Always** test to make sure your meter is working before starting the test by brushing the two tips together, and verifying you hear the beep. Maybe the battery is low or its not in the right mode.

**Continuity is non-directional**, you can switch probes and it will be the same.

If you are testing two points in a circuit and there is a (big) capacitor between those points **you may hear a quick beep and then quiet**. That's because the voltage the meter is applying to t

circuit is charging up the capacitor and during that time the meter 'thinks' its continuous (essentially)

**Small resistors (under 100 ohms or so) and also all inductors will seem like short circuits to a multimeter because they are very much like wires.**

**Likewise, continuity doesn't mean "short"** it just means very very low resistance. For example, if you have a circuit that draws an Amp from a 5V supply, it will appear to be a  $5\Omega$  resistor. If you measure that with your meter it will think its a short circuit, but really its just a high-drain circuit.

## Lab Procedure

First step is to get your multimeter into the correct mode. Look for the icon that looks sort of like a 'sound wave'.

Here are examples.

Turn the multimeter knob so that it points to this symbol

### Example 1

This meter is very simple. When the probes are not touching, the display shows "1".

When you touch the tips together, the display changes to a three digit mode (it's displaying resistance, which we will cover later) It also emits a beep.



### Example 2

This meter is dual-mode but still very easy to use. Turn the dial to the symbol. When the probes are not touching the display shows "OL" which stands for Open Loop. (Open loop is another way of saying there is no continuity)



When you touch the probes, the sound wave icon shows up in the display (upper right) and it also shows a number. The number is not the resistance, actually...it is the voltage (look for the V in the right hand side for Volts). This is because this mode is also a **Diode Test** (which will be discussed later)

## What is resistance?

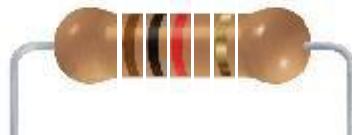
Resistance is just what it sounds like, it is the characteristic that makes a component fight current flow. The bigger the resistance value (in **ohms  $\Omega$** ) the more it fights. Most resistors you'll see range between 1 ohm and 1 mega ohm ( $1.0 \text{ M}\Omega$ ) they often have 5% tolerance but you can buy 1% or even 0.1% accuracy resistors.



In general, resistance testing is best for measuring resistors, but you may find yourself measuring the resistance of other things, such as sensors and speakers.

## Resistor coding

Resistors are color coded, at first it seems like a bad way to print the values but with a little time it becomes faster because you don't have to read any numbers and the stripes are visible no matter how it is rotated.



*This image shows a  $1.0 \text{ k}\Omega$  5% resistor (brown black red gold)*

## Remember!

**You can only test resistance when the device you're testing is not powered.** Resistance testing works by poking a little voltage into the circuit and seeing how much current flows, it is perfectly safe for any component but if it is powered there is already voltage in the circuit, and you will get incorrect readings

**You can only test a resistor before it has been soldered/inserted into a circuit.** If you measure it in the circuit you will also be measuring everything connected to it. In some instances this is OK but I would say that in the vast majority it is not. If you try, you will get incorrect readings and that's worse than no reading at all.

**Resistance is non-directional**, you can switch probes and the reading will be the same.

If you have a ranging meter (as most inexpensive ones are), you'll need to keep track of what range you are in. Otherwise, you will get strange readings, like **OL** or similar, or you may think you're in  $K\Omega$  when really you're in  $M\Omega$ . This is a big problem for beginners so be careful!

## Lab Procedure

Look for an ohm ( $\Omega$ ) symbol, if its a ranging meter there will be a bunch of subdivided modes. If its auto-ranging there will be only one.

This meter has the  $\Omega$  symbol and then 7 submodes, ranging from  $200\Omega$  to  $2000M\Omega$ .

### **Example1. Testing a resistor**

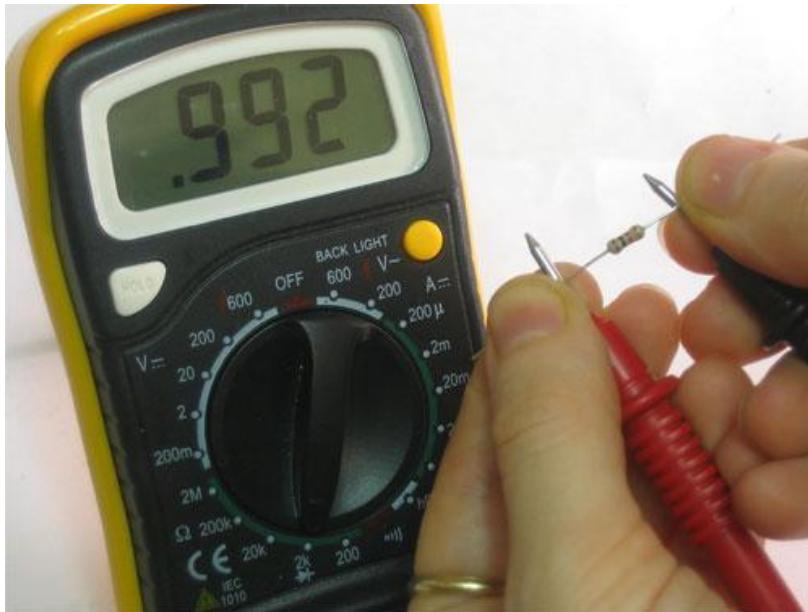
With an auto-ranging meter, just put the two probes across the resistor and read the number. For example, this  $1K\Omega$  5% resistor is actually  $0.988 K\text{ ohm}$ .

And this  $10K\Omega$  is really  $9.80K\Omega$ . Note that the numbers look similar but the decimal point has moved.





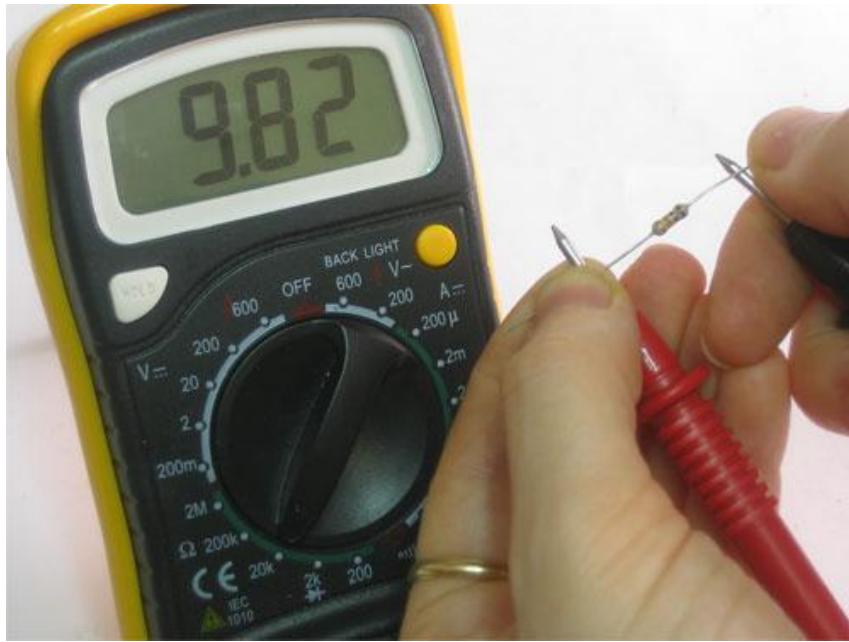
This ranged meter requires that you dial in the range. We'll guess that this resistor is under  $2\text{K}\Omega$  then measure it. We get 0.992 which means its  $0.992\text{ K}\Omega$  (or, a  $1\text{K}\Omega$  resistor)



Now testing a different resistor, we will again guess its under  $2\text{K}\Omega$ . However, this time we get a strange response, a **1.** which means out of range. Some meters will display an **OL** which you may remember from the continuity section as meaning "open loop" here it means "the measurement is higher than the range".



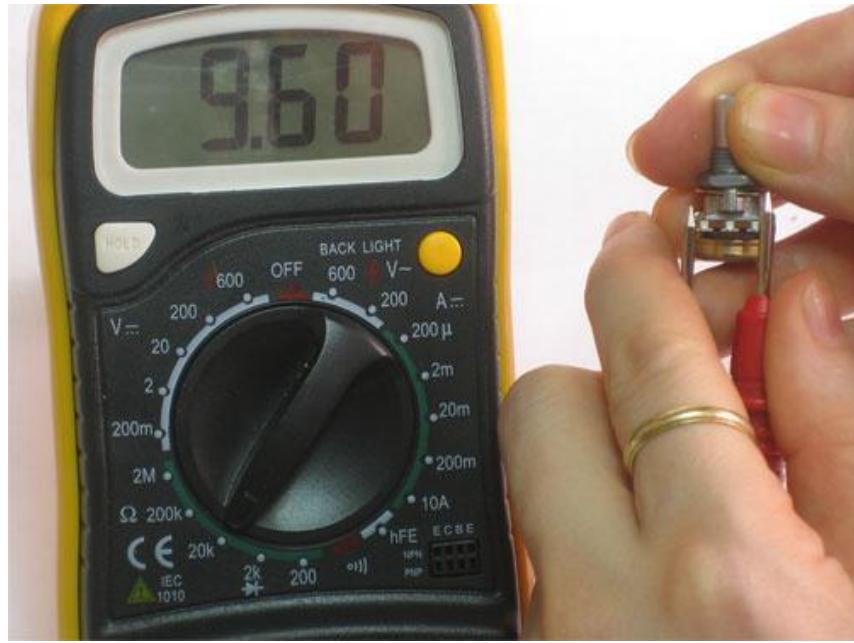
We try again, changing the range to  $20\text{K}\Omega$ .



It is a  $9.82\text{ K}\Omega$  resistor ( $10\text{K}\Omega$ )

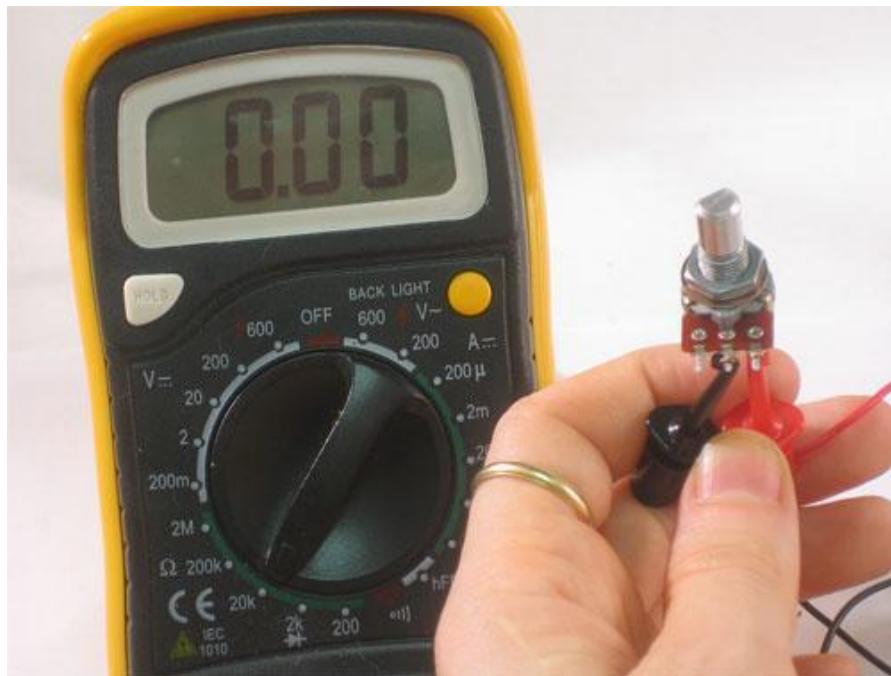
## Example 2. Testing a potentiometer

You can test the max-value of a potentiometer by measuring across the two 'ends' as shown here with a rotational  $10\text{K}\Omega$  pot. To find the 'range' look at the dial.



You can also use a multimeter to tell whether the potentiometer is a linear or logarithmic (audio) pot. When the pot is centered, if the resistance between the wiper and one end is half of the total value, its linear.

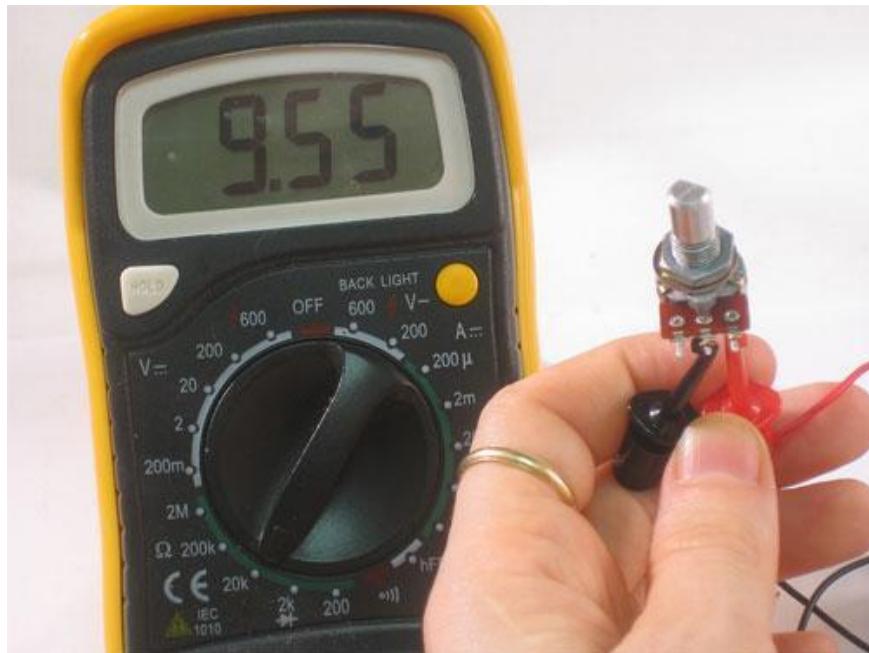
This is a  $10\text{K}\Omega$  linear potentiometer



The minimum resistance of the pot,  $0\Omega$  (a short) as expected



Potentiometer centered, about  $5\text{K}\Omega$

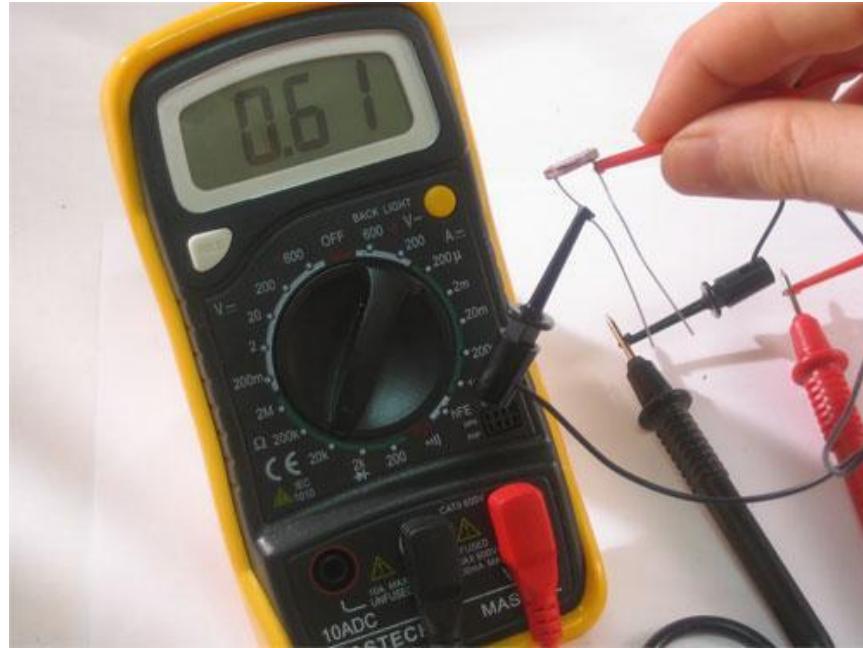


Maximum value is  $9.5\text{K}\Omega$  (it should be around  $10\text{K}\Omega$ )

### Example 3. Testing a sensor

Potentiometers are resistors that change value when they are moved. A Light Dependent Resistor (LDR) is a resistor that changes value with the amount of light it receives. This one has a range of about  $20\text{K}$  max.

First, set the range, in this case  $20\text{K}\Omega$  seems pretty good. In bright light, it measures about  $610 \Omega$



Slightly shaded it's  $5.84\text{K}\Omega$  (remember this is still a well-lit photo)



## What is voltage?

Voltage is used to provide power (via a battery or wall plug) and its also used as a way of transmitting data. For example, music is recorded from a microphone as an analog voltage

signal, if that voltage waveform is applied to a speaker the voltage performs the work of making air move and produces sound.

## AC/DC

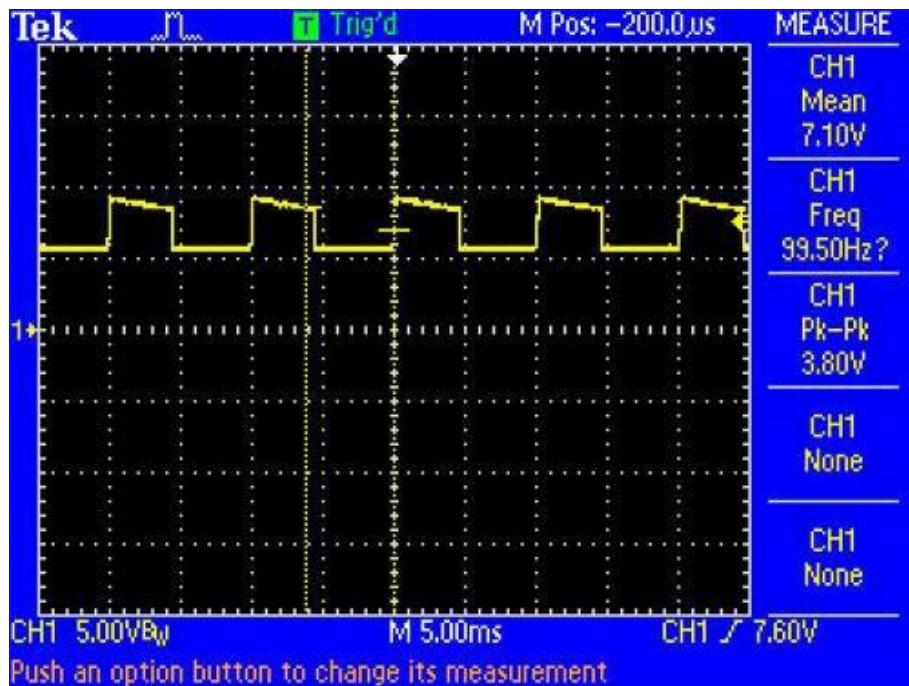
**Direct current voltage is what comes out of batteries.** The battery is at 9V, and it pretty much keeps that voltage constant, until it dies. The chemical reactions inside the battery create DC voltage. Most of the Electronic circuits work on DC voltage.

**Alternating current voltage is what comes out of the wall socket.** The generator at the US power plant creates a voltage that oscillates, going from -120V to 0 to +120V to 0 again, 60 times a second. At the European power plant its -240V to +240V at 50 times a second. (Note that those voltages are 'RMS' - Root Mean Square - which means that the peak voltage is actually about 1.4x higher, but since multimeters show RMS voltages, its easier to just use those)

AC voltage is great for power plants because its easy to transform AC voltages (using a transformer) up to 50KV for long distance travel and then down to 240V or 120V to safely power your home. Batteries only supply DC voltage and wall plugs only supply AC voltage. However, it is totally possible to have **both** AC and DC voltage at a certain point:

If an AC voltage is oscillating between -60V and +60V it has 120V AC and 0V DC because the **average** voltage of -60V and +60V is 0V.

If an AC voltage is oscillating between 0V and 120V then it has 120V AC and 60V DC because the average voltage of 0V and 120V is 60V.



In the above oscilloscope image, the dashed horizontal line in the center is ground (0V) and each dashed division is 5V. The scope is displaying a signal that has both AC and DC components.

There is an alternating voltage (a square wave) that is about 4V high at about 100Hz and a DC (mean average) voltage that is around 7V. Use the dashed divisions to verify for yourself that this is so.

## Remember!

**You can only test voltage when the circuit is powered** If there is no voltage coming in (power supply) then there will be no voltage in the circuit to test! It must be plugged in (even if it doesn't seem to be working)

**Voltage is always measured between two points** There is no way to measure voltage with only one probe, it is like trying to check continuity with only one probe. You must have two probes in the circuit. If you are told to **test at a point or read the voltage at this or that location** what it really means is that you should put the negative (reference, ground, black) probe at **ground** (which you must determine by a schematic or somewhere else in the instructions) and the positive (red) probe at the point you would like to measure.

**Voltage is directional** If you measure a battery with the red/positive probe on the black/negative contact and the black probe on the positive contact you will read a negative voltage. If you are reading a negative voltage in your circuit and you're nearly positive that this cannot be, then make sure you are putting the black probe on the reference voltage (usually ground)

**DC voltage and AC voltage are very different** Make sure you are testing the right kind of voltage. This may require pressing a mode button or changing the dial.

**Multimeters have different input impedances that affect readings of high impedance circuits** For example, measuring a sensor that has 1M ohm impedance with a 1 M ohm impedance meter will give you only half the correct reading

## Lab Procedure

There are often two separate modes for AC and DC voltage. Both will have a V but one will have two lines, one dashed and one solid (DC) and one with a wave next to it (AC).

This meter has the double line for DC voltage, and 5 ranges, from 200mV to 600V.



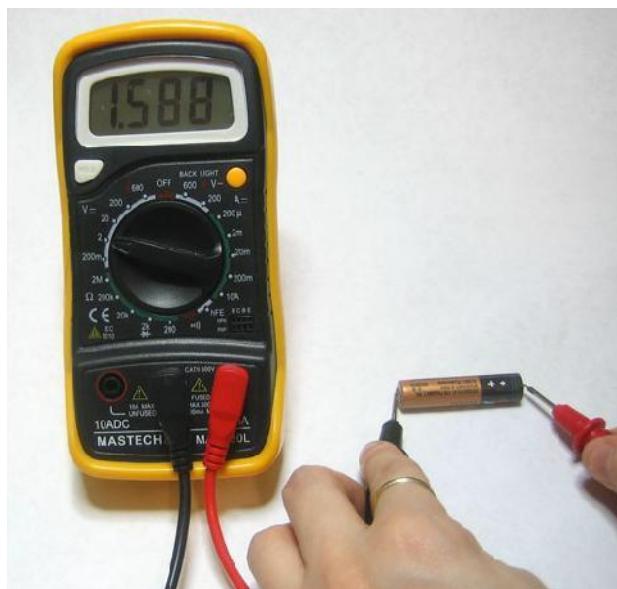
This ranged meter has 5 ranges, the top range is 750 VAC or 1000 VDC, to switch between DC and AC you need to press the DC/AC button on the upper right.

When the probes are not connected to anything, they should display 0V. They might flicker a bit if they pick up ambient voltage (your home is a big radiator of 60Hz voltage which can couple into your meter probes).

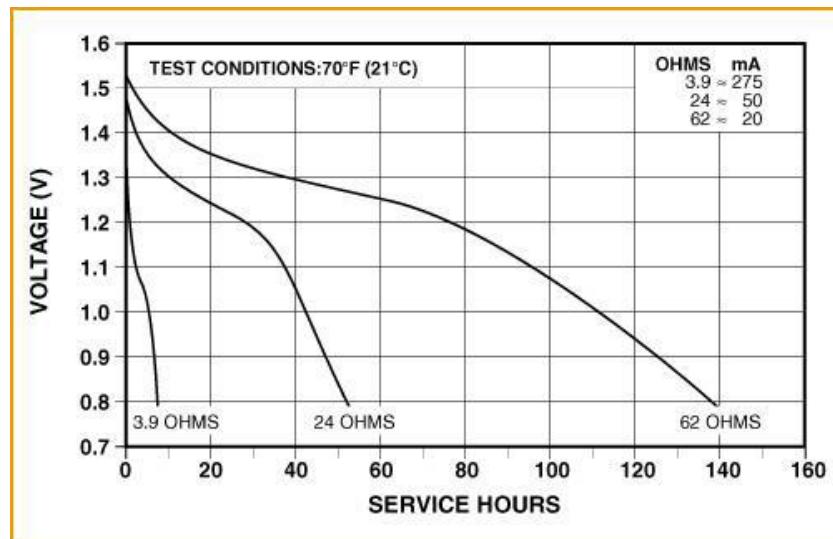


## Example 1: Testing batteries

Testing batteries is a super useful skill and is one of the best ways to practice with your multimeter. The first battery we'll test is a new 1.5V alkaline. This one is a AAA but a AA, C or D cell will be the same voltage. Set the range to **2V DC**.



We read 1.588V, which you may think is a mistake, after all its a 1.5V battery so shouldn't it be 1.5V? Not quite, the 1.5V written on the side is just a **nominal voltage**, or the "average" you may expect from the battery. In reality, an alkaline battery starts out higher, and then slowly drifts down to 1.3V and then finally to 1.0V and even lower.



Using this graph you can easily tell how fresh your battery is and how long you can expect it to last.

## Example 2: Testing wall wart (adapter) plugs

Testing wall adapters is also very handy, especially when you build your own circuits.

The first kind we will test is a **transformer-based** adapter.



Note that the label says **Transformer**, it is also blocky and heavy which indicates a transformer as well. It requires 120VAC input, US power only. The nominal output is 9VDC at 300mA. The polarity symbol shows that the middle is positive, the outside is negative, thus we place the ground (black) probe on the outside and the positive (red) probe on the inside.

14V? That's not anything like the 9V on the package, is this a broken wall wart? Turns out, its totally normal. Transformer-based wall adaptors are (almost always) **unregulated**, which means that the output is not guaranteed to be a particular value, only that it will be **at least** what is printed on the box. For example, with this adapter it means that when drawing 300mA, the voltage is guaranteed to be higher than 9V.



Since the output is unregulated, the voltage supplied will drop as more current is pulled from it, which means that open-circuit (connected to nothing) the measured output can be as high as 14V.

### **Example 3: Testing Wall output**

This is the 'easiest' test, just shove the two probes into a wall socket.

About 220V, as expected

### **Post Lab**

1. Plot a graph between your mobile battery voltage & Hours.
2. Calculate the voltage regulation of your cell phone charger.
3. From website check the data sheets of IC's present on any motherboard & find how much voltages are required by your PC processor, motherboard, hard disk, Ram memory & LAN card.
4. AC voltages are alternating voltages, but when measuring AC voltages why don't the reading keeps on varying with the variation in AC voltage?



### 3. Operation

#### 3-1. Controls, indicators and connectors

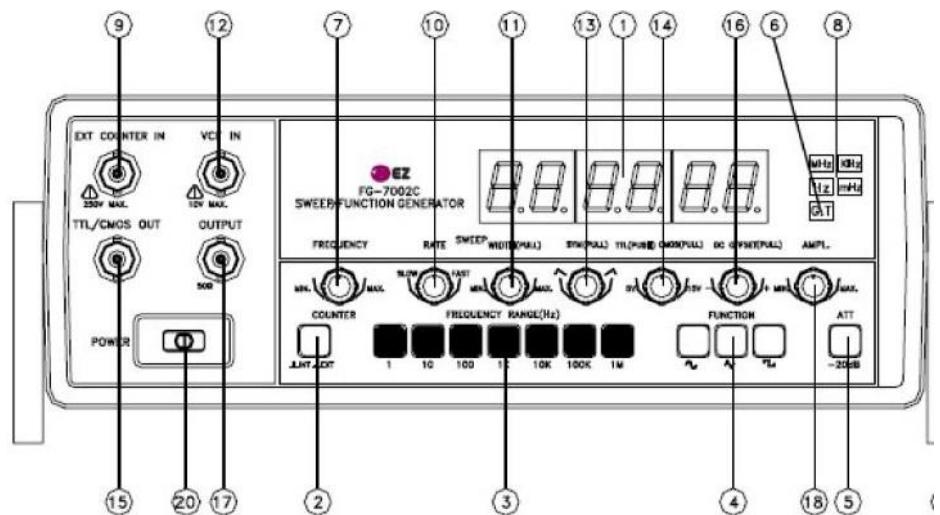


FIG 1. FRONT PANEL OPERATOR'S CONTROLS

CD LED DISPLAY.

Displays Internal Or External

Freauency

CV INTERNAL/EXTERNAL SWITCH.

PUSH IN : External Frequency

Counter.

PUSH OUT: Internal Frequency

Counter.

Frequency Range Selector.

Select Sine wave, Triangle Wave Or Square Wave Output.

Selects Output Level By -20 dB.

Gate Time Is Selected Automatically E Input Signal.

@ RANGE SWITCHES.

@ FUNCTION SWITCHES.

ATTENUATOR.

@ GATE TIME INDICATOR.

(J) FREQUENCY DIAL.

(R) MHz, kHz , Hz, mHz INDICATOR.

(R) EXTERNAL COUNTER INPUT BNC.

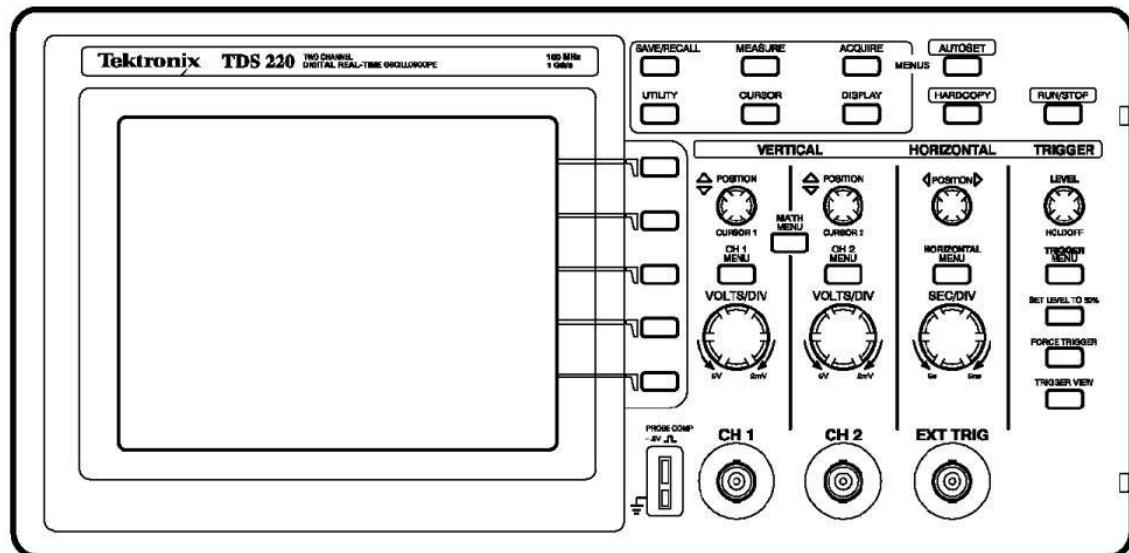
Indicates Unit Of Frequency.

Used As An External Frequency Counter.

- ⑪ SWEEP WIDTH CONTROL. Pullout And Adjusts Magnitude Of Sweep.
- ⑫ VCF INPUT BNC. Voltage Controlled Frequency Input Permits External Sweep.
- ⑬ SYMMETRY CONTROL. Frequency Control Sweep Rate Control Should Be Off When Applying External Voltage At This BNC.
- ⑭ TTL/CMOS CONTROL. Adjust Symmetry Of Output Waveform 1:1 to 10:1 With Push/Pull Switch On.
- ⑮ TTL/CMOS OUTPUT BNC. Selects TTL Or CMOS Mode Pull-out : CMOS Level Control, Push-In: TTL Level.
- ⑯ DC OFFSET CONTROLS. TTL/CMOS Level Output.
- ⑰ MAIN OUTPUT BNC. Adds Positive Or Negative DC Component To Output Signal.
- ⑱ AMPLITUDE CONTROL. Impedance 50 Ohm.
- ⑲ TILT STAND. Adjusts Output Level From 0 TO 20 dB.
- ⑳ POWER SWITCH. Pull Out To Adjust Tilt.
- Push type switch. turning on the power when pressed.

## Oscilloscopes

The next drawing shows the front of a TDS 220 oscilloscope.



## Lab procedure 1 - Getting Started

This lesson teaches you how to turn on the oscilloscope and display a simple signal. To perform the Getting Started lesson, follow these steps:

1. Plug in the oscilloscope and apply power by pressing the POWER button on the top of the case.

Notice that when you apply power, the oscilloscope immediately performs a self-test.

2. Wait until the display shows that all self tests passed and press the SAVE/RECALL front-panel button (top left).

The SAVE/REC menu displays on the right of the screen. The top right bezel button toggles between two menus: Setups and Waveforms.

3. Be sure that Setups is highlighted (in inverse video) and press the button beside "Recall Factory."

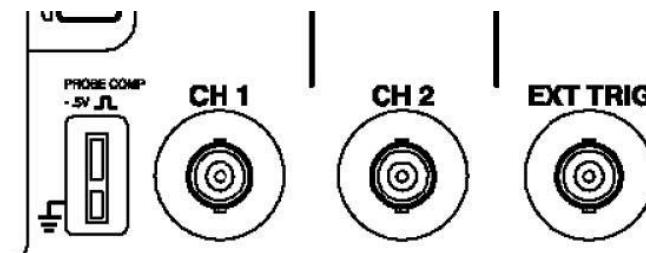
The oscilloscope recalls the default factory settings to initialize the instrument to a known state, which eliminates any nasty surprises. If at any time you do not understand what the oscilloscope is displaying, you can repeat this step.

*The box at the end of this lesson also gives some suggestions for getting out of odd screen modes without resetting everything.*

The display that dominates the left side of the scope is a digital LCD screen. This means that displayed signals have visible pixel "jaggies." If you have used an analog scope, you will notice that the signals, especially sine waves, do not look as smooth and continuous on this screen. The digital display does, however, have some significant advantages, as you will discover. Some of the information around the edges of the display will be explained as we go along; the rest can be looked up in the Tektronix manuals. The large area down the right side of the screen is the menu. A large number of menus are available and are called up by pressing various buttons on the control panel. The buttons immediately to the right of the screen correspond to the menu items; their functions change depending on the menu displayed.

Take a close look at the probes that are provided with the scope. These are important to the performance of the oscilloscope and should be handled with care. The sprung hook tip is removable, revealing a point that can be used in tight locations. The short wire that terminates in an alligator clip is the ground connection. If both probes are connected to the scope, disconnect one of them by turning the connector to the left and pulling it straight toward you.

Take a look at the connector and note that it is not quite like a regular BNC connector, on which the shell will rotate continuously. This connector only turns through a small arc and must be in the left, or unlocked, position, before being pushed onto the oscilloscope input. Do this now and turn the connector to the right to lock it. Now we will get a signal onto the display. Note that the first two BNC type connectors at the bottom edge of the front of



the scope are labelled CH 1 (for channel 1) and CH 2. Usually you will connect the probes here, but you can also use a coaxial cable with a BNC connector to connect the scope to a function generator or other signal source. Immediately to the left of the inputs is a pair of small metal tabs labelled PROBE COMP for probe compensation. This is an internal source of a square wave at about 5 volts magnitude and 1KHz, used to adjust the internal compensation of the probe.

4. Connect the probe on channel 1 of the scope to the top tab, and the ground clip of the probe to the bottom tab.

5. Press the AUTOSET button near the top right corner on the front-panel.

The oscilloscope sets the vertical, horizontal, and trigger controls automatically which usually results in a usable display. These settings are adequate in this and many other situations. Be aware that the oscilloscope also sets a number of background functions that might be not be desirable in some circumstances.

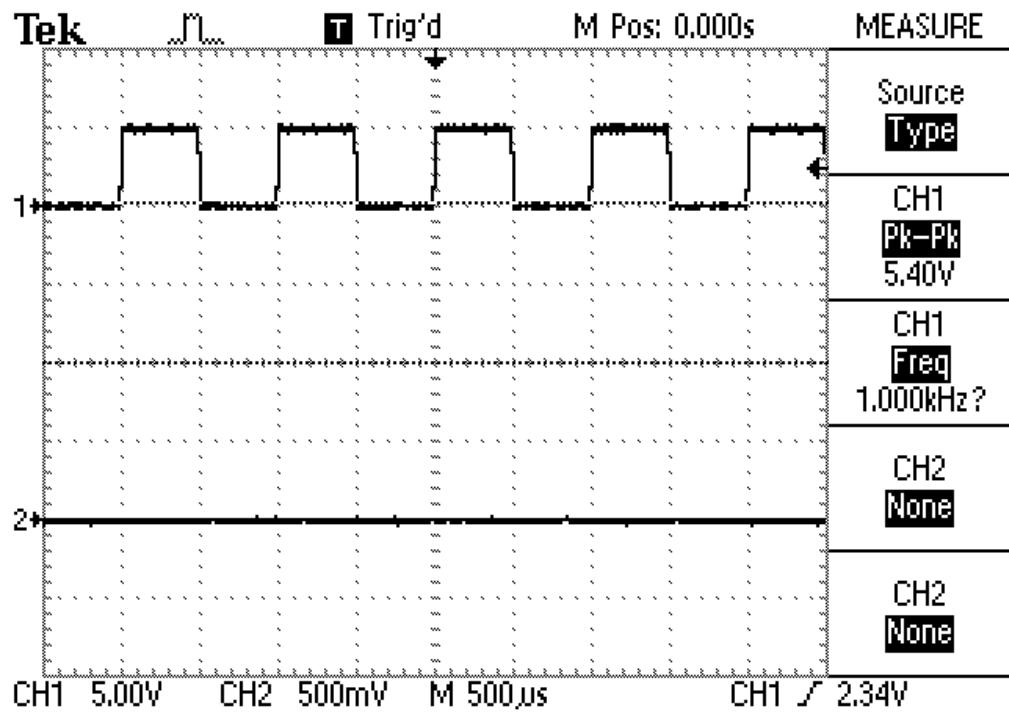
Depending on how the oscilloscope was being used when it was last turned off, you may see one or more channels displayed. The trace labels on the left edge of the screen correspond to the channel numbers on the front of the oscilloscope.

6. If only one channel appears, press the CH 2 MENU front-panel button to display channel 2, and then press AUTOSET again.

Now both channels display even though there is nothing but noise on channel two. The upper trace should show a steady square wave as depicted below. The wave is stationary on the screen because AUTOSET has set the oscilloscope's trigger to channel 1 and the trigger circuit causes successive similar waveforms to be superimposed on the screen. For a complete discussion of trigger see the Tektronix manual.

If the top and bottom of the square waves are not straight, your probe needs to be compensated, but you do not need to do it right now.

To demonstrate the downside of using Autoset, follow these steps:  
 a) Disconnect the channel 1 probe from PROBE COMP, and connect channel 2 instead.  
 Press AUTOSET. The wave is no longer stationary



because there is no signal on channel 1 to trigger the oscilloscope, which is now free-running. b) Press the TRIGGER MENU button (near the right edge of the scope). The third menu item is the trigger source, which is currently set to CH1.

c) Press the button beside this menu item once to switch the source to CH2. The display should become stable.

d) Now press AUTOSET again. Once again the scope is free running because Autoset sets the trigger source to the lowest displayed channel. This is just one of many settings that Autoset changes – see the Tektronix manual for the complete list, and use Autoset wisely.

e) Before proceeding, switch the probe compensation waveform back to channel 1. Now let us get rid of the useless channel 2 display and expand the channel 1 presentation.

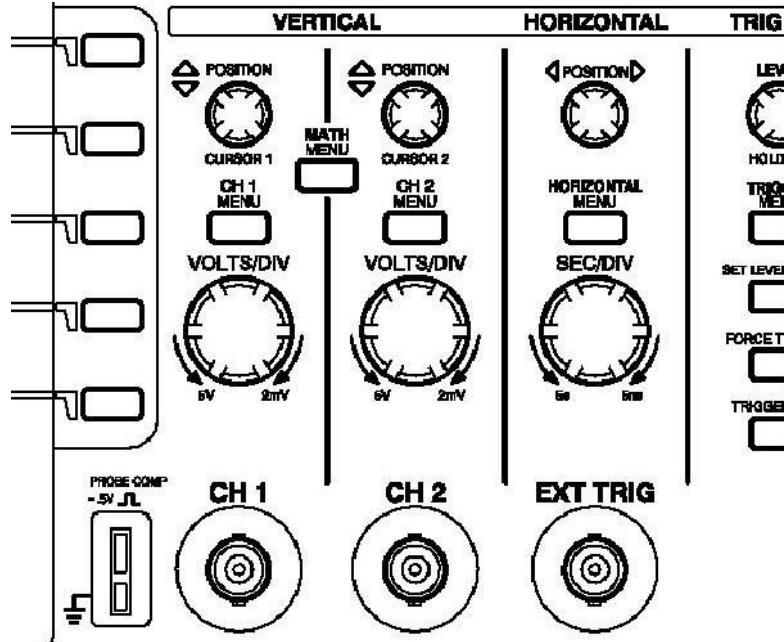
7. Press the CH 2 MENU front-panel button to remove the channel 2 waveform from the display. If that channel's menu is not already displayed, the first push of the button displays the menu (the top right corner of the screen will say CH1 or CH2). A second push turns off the channel. Do this and you should see that the channel 2 trace disappears. Now look at the channel 1 control area. In addition to the CH 1 MENU front-panel button, there are two knobs. The top one controls the vertical position.

8. Turn the POSITION knob to bring the displayed waveform

down to the middle of the screen.

Note that as soon as you start turning the knob, a line of text appears in the bottom left corner of the screen. This is telling you how far the zero level of this channel is from the vertical center of the screen. There are several reasons why you might want the display exactly centered, and this helps you to do that.

Once you have the trace centered you can expand it for a better view. The bottom knob of the channel, or vertical, controls is the volts per division range control. Turning the



VOLTS/DIV knob to the right increases the sensitivity (decreases the volts per division, and expands the display vertically). One division is the distance between the grid lines on the screen, a bit less than one centimeter apart. Just to the right, on the other side of the channel 2 controls, is a similar knob labelled SEC/DIV that controls the time base resolution. Turning it to the right reduces the time per division and expands the display horizontally.

**Quick fixes for display problems.** These relate to features that we will study later but may be just getting in your way right now. *My display is very dark or has very low contrast.* Press the DISPLAY button. The bottom two buttons at the right edge of the screen are

now labelled “Contrast Increase” and “Contrast Decrease.” These actually lower and raise, respectively, the brightness of the white part of the screen. As soon as you press one of them the “contrast” level appears at the bottom right corner. Set it to 50%. There are a pair of extra vertical or horizontal lines cluttering up my display. Press the CURSOR button. The top button at the right of the screen is now labelled “Type” and will have either “Voltage” or “Time” below it. Press it until it says “Off”. There is an “A” and/or a “B” (with or without an associated trace) at the left edge of the screen. Press the SAVE/RECALL button. Use the third screen button to select “Ref A” or “Ref B” if necessary, then press bottom button to turn it off.

## **Lab Procedure 2 – Measurements**

In general, you will use an oscilloscope to measure characteristics of a signal, such as magnitude or period of oscillation. You can look at the signal in relation to the screen grid or graticule to estimate the values of these characteristics, which was about one could do with early oscilloscopes. Modern oscilloscopes have much more powerful measurement capabilities. In this lesson, you will learn about the following topics:

- How to use the Measure menu to define the source and type of measurement to take
- How to set the Probe menu item to match the probe in use
- The difference between measuring a signal and a displayed waveform

Lesson 2 begins where lesson 1 ended. If the oscilloscope has been turned off or the settings changed since lesson 1, you need to quickly redo lesson 1 to get back the centered square waveform that fills most of the screen with two or three full cycles displayed.

To perform the Measurements lesson, follow these steps:

1) Press the MEASURE front-panel button.

The word “MEASURE” appears above the menu area, Type is the active menu, CH1 is the source for four measurements and no measurements are selected (NONE).

The Measure menu is a Page Selection type of menu. The top menu displays two menu names: Source and Type. The active menu is highlighted in inverse video - white letters in a black box. When Source is highlighted, you can press each of the other four bezel buttons to switch between CH1 and CH2 as the measurement source. When Type is highlighted, you can press each of the other four buttons to select the type of measurement to take from the selected source.

2) Press the second button until Freq appears. A question mark appears momentarily until the oscilloscope measures the frequency of the signal connected to CH1.

3) Press the third button until Period appears. The oscilloscope displays the period of the signal ( $1/f$ ).

4) Press the fourth button until Mean appears. The oscilloscope displays the mean voltage.

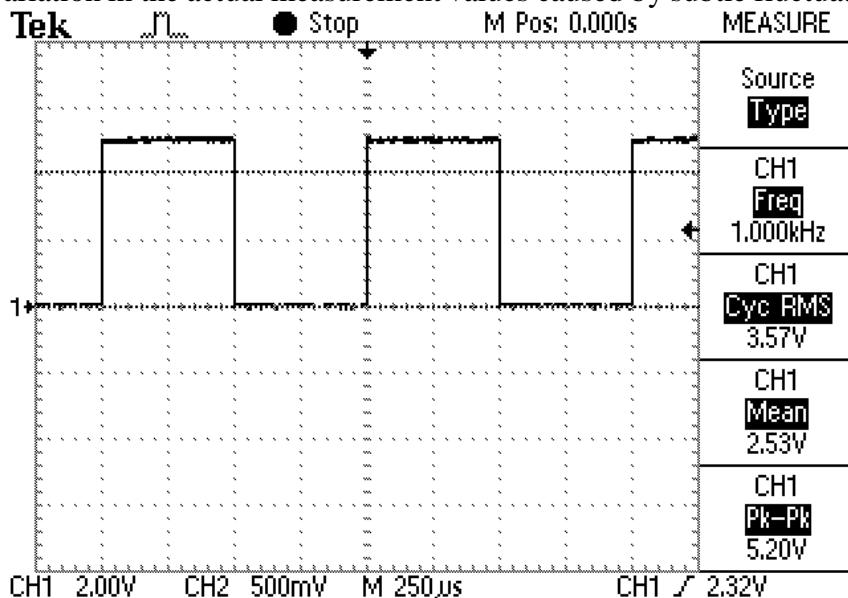
5) Press the fifth button until Pk-Pk appears. The oscilloscope displays the peak-to-peak voltage.

6) Press the third button until Cyc RMS appears. The oscilloscope displays the true RMS value of one cycle of the waveform.

The Freq, Period, Mean, Pk-Pk, and Cyc RMS measurements are always available. If you have a TDS2MM module in your oscilloscope, then there are some other measurements available that we will not cover here, such as rise time.

The next drawing shows how the oscilloscope display should now look. There may be

some variation in the actual measurement values caused by subtle fluctuations in the source



signal.

If the peak-to-peak voltage is not close to 5 volts, in particular if it is around 0.5 or 50 volts, the probe setting of the oscilloscope is incorrect. The oscilloscope displays voltage values based on the probes. The probes improve the performance of the oscilloscope by increasing the effective input impedance from 1 Megohm to 10 Megohms, thus reducing the loading effect that the oscilloscope has on the circuit. In doing so, the probe reduces the input signal by a factor of ten. For example, if a three volt signal is present at the probe tip, 0.3 volts appears at the oscilloscope input channel connector.

The oscilloscope compensates for this attenuation when it takes voltage measurements. Since the oscilloscope cannot detect which type of probe is connected to any input channel, you have to tell the oscilloscope through a channel menu selection.

The most common probe attenuates the signal 10 times and is called a 10X probe. The oscilloscope includes 10X probes although you can also use 100X and 1000X probes.

7) Press the appropriate channel menu front-panel button, such as CH 1 MENU.

The Probe menu item appears beside the fourth bezel button – successive presses of the button rotate through 1X, 10X, 100X and 1000X. As you press this button, watch the bottom left corner of the display – the number that is changing is the volts per division. If the readings seem wildly high or low when taking voltage measurements, check that the Probe menu setting matches the probe connected between the oscilloscope and the circuit. If you are using a straight coax cable connection, set the Probe menu to 1X.

8) Press the MEASURE front-panel button.

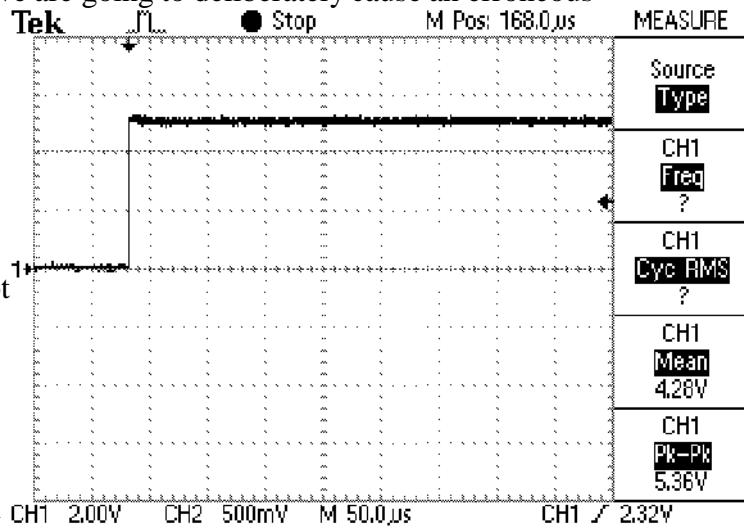
We will now discover one of the most important things to remember when using the oscilloscope to take measurements from signals displayed as waveforms. To do this, we need to understand how the oscilloscope displays signals.

Notice that there is a small arrow at the top of the display and another at the right side, both pointing inwards. The one at the top shows the time of the trigger event, and the one at the right shows the trigger voltage. Because this is a storage oscilloscope, it can display the waveform before the trigger event, and the default horizontal position for the trigger is the centre of the screen. If the arrow at the top of the display, the trigger time,

is not at the centre, use the Horizontal POSITION knob to move it to the centre. Read the mean voltage. The value should be approximately half the peak voltage; it may actually be a bit less because the peak voltage includes any overshoot – something to remember for the future when interpreting peak-to-peak values. Now we are going to deliberately cause an erroneous reading.

9) Turn the Horizontal SEC/DIV knob (time base control) until the time per division reads M 50.0  $\mu$ s. The oscilloscope no longer displays values for frequency or RMS voltage because there is not a full cycle to measure on the screen, but the mean voltage has not significantly changed.

10) Turn the Horizontal POSITION knob to move the waveform to the left, while reading the mean voltage. The mean value steadily increases, reaching close to the peak voltage when the trigger point is at the left side of the screen. The mean value of the signal has not actually changed – what has changed is the mean value of the part of the waveform that is displayed, which is the point of this exercise. The measurement functions of this oscilloscope (and digital scopes in general) operate on the displayed waveform, not on the input signal, and must be interpreted with care.



## Using the Display Menu

To understand various functions of the Display menu, follow these steps:

- 1) Press the DISPLAY front-panel button. The top menu item is Type, which switches between dots and vectors, and with this particular set of waveforms you will not see a noticeable difference. When displaying square waves or other waveforms that have rapid vertical excursions, the vectors setting draws in the vertical lines to make the waveform easier to recognize.
- 2) Press the Format bezel button and select XY. You should see an ellipse on the screen – we are now displaying channel 1 as the X axis versus channel 2 on the Y axis.
- 3) To make the ellipse more solid, go back to the Persist bezel button and set it to 2 Sec. Note that the ellipse fills in because the oscilloscope is now keeping two seconds of history on the screen. The bottom two buttons are labeled Contrast Increase and Contrast Decrease but they actually lower and raise, respectively, the screen brightness. If the screen is too dark you actually need to press the Contrast Decrease button to raise the contrast.

## **Post lab**

1. Using function generator & oscilloscope, generate & observe following waveforms. Also note down all parameters in following chart:
  - a) A pulse train with 50% duty cycle.
  - b) A waveform similar to the supply which comes in our wall socket.
  - c) A triangular wave with 50% duty cycle.

	Peak to Peak Value (V)	RMS Value (V)	Frequency (Hz)	Average Value (V)
a) Pulse Train				
b) Wall Supply				
c) Triangular				

## **Task:**

1. To find the pk-pk voltage and frequency of test waveform on Oscilloscope.

## **LAB SESSION 2**

To analyze and plot the characteristic curve of Silicon & Germanium diodes.

**Student Name:** \_\_\_\_\_

**Roll no.:** \_\_\_\_\_ **Batch:** \_\_\_\_\_

**Semester :** \_\_\_\_\_ **Year:** \_\_\_\_\_

<b>Total Marks</b>	<b>Marks Obtained</b>

**Remarks (if any) :** \_\_\_\_\_

**Instructor Name:** \_\_\_\_\_

**Instructor Signature:** \_\_\_\_\_ **Date:** \_\_\_\_\_

**NED University of Engineering and Technology, Karachi**  
**Department of Electronic Engineering**

Course Code: \_\_\_\_\_ Course Name: \_\_\_\_\_

Laboratory Session No. \_\_\_\_\_ Date: \_\_\_\_\_

Skill Sets		Psychomotor Domain Assessment Rubric-Level P3			
		Extent of Achievement			
		0	1	2	3
<b>Equipment Identification</b> Sensual ability to identify equipment and/or its component for a lab work	Unable to identify the equipment	Able to identify very few equipment and components to be used in lab work	Able to identify some of the equipment and components to be used in lab work	Able to identify most of the equipment and components to be used in lab work	Able to identify all of the equipment as well as its components
<b>Procedural Skills</b> Displays skills to act upon sequence of steps in lab work	Unable to either learn or perform lab work procedure	Able to slightly understand lab work procedure and perform lab work	Able to somewhat understand lab work procedure and perform lab work	Able to moderately understand lab work procedure and perform lab work	Fully understands lab work procedure and perform lab work
<b>Response</b> Capability to imitate the lab work on his/her own	Unable to imitate the lab work	Able to slightly imitate the lab work	Able to somewhat imitate the lab work	Able to moderately imitate the lab work	Fully imitates lab work
<b>Observation's Use</b> Displays skills to perform related mathematical calculations using the observations from lab work	Unable to use lab work observations for mathematical calculations	Able to slightly use lab work observations for mathematical calculations	Able to somewhat use lab work Observations for mathematical calculations	Able to moderately use lab work Observations for mathematical calculations	Fully use lab work observations for mathematical calculations
<b>Equipment Use</b> Sensory skills to describe the use of the equipment for the lab work	Unable to describe the use of equipment	Rarely able to describe the use of equipment	Occasionally describe the use of equipment	Often able to describe the use of equipment	Regularly able to describe the use of equipment
<b>Equipment Handling</b> Equipment care during the use	Doesn't handle Equipment with required care	Rarely handles equipment with required care	Occasionally handles Equipment with required care	Often handles Equipment with required care	Handles equipment with required care
Ability to troubleshoot errors and try to resolve with/without the supervision or guidance	Unable to troubleshoot experimentation errors and resolve them	Able to troubleshoot experimentation errors but cannot resolve them	Able to troubleshoot experimentation errors and resolve them under supervision	Able to troubleshoot experimentation errors independently but need guidance in resolving them	Able to troubleshoot experimentation errors and resolve them without supervision or guidance

Weighted CLO (Psychomotor Score)	Remarks
Instructor's Signature with Date:	

# LAB SESSION 2

## OBJECTIVE

To analyze and plot the characteristic curve of Silicon & Germanium diodes.

## Theory

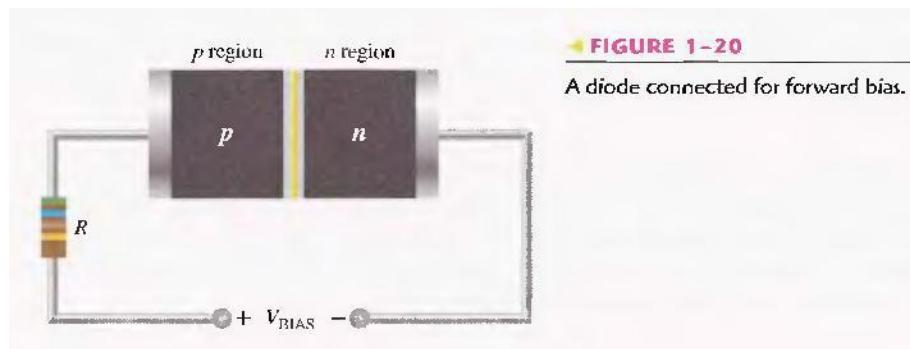
### Introduction

#### **Biassing a diode**

As you have learned, no electrons move through the pn junction at equilibrium. Generally the term bias refers to the use of a dc voltage to establish certain operating conditions for an electronic device. In relation to a diode, there are two bias conditions: forward and reverse. Either of these bias conditions is established by connecting a sufficient dc voltage of the proper polarity across the pn junction.

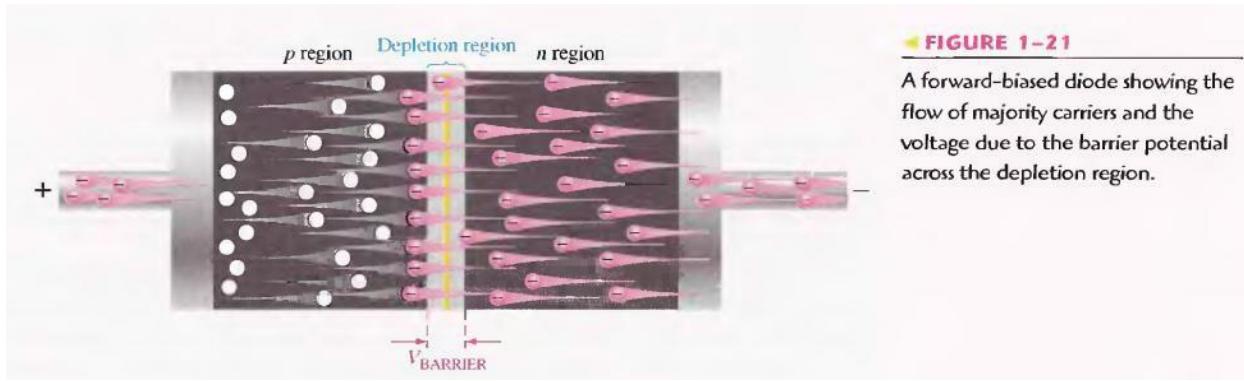
#### **Forward Bias**

To bias a diode, you apply a dc voltage across it. Forward bias is the condition that allows current through the pn junction. Figure 1-20 shows a dc voltage source connected by conductive material (contacts and wire) across a diode in the direction to produce forward bias. This external bias voltage is designated as  $V_{bias}$ . The resistor, R, limits the current to a value that will not damage the diode.



Notice that the negative side of  $V_{bias}$  is connected to the n region of the diode and positive side is connected to the p region. This is one requirement for forward bias. A second requirement is that the bias voltage,  $V_{bias}$ , must be greater than the barrier potential.

A fundamental picture of what happens when a diode is Forward-biased is shown in Figure 1-21. Because like charges repel, the negative side of the bias-voltage source "pushes" the free electrons which are the majority carriers in the n region toward the pn junction. This flow of free electrons is called electron current. The negative side of the source also provides a continuous flow of electrons through the external connection (conductor) and into the n region as shown.



**FIGURE 1-21**

A forward-biased diode showing the flow of majority carriers and the voltage due to the barrier potential across the depletion region.

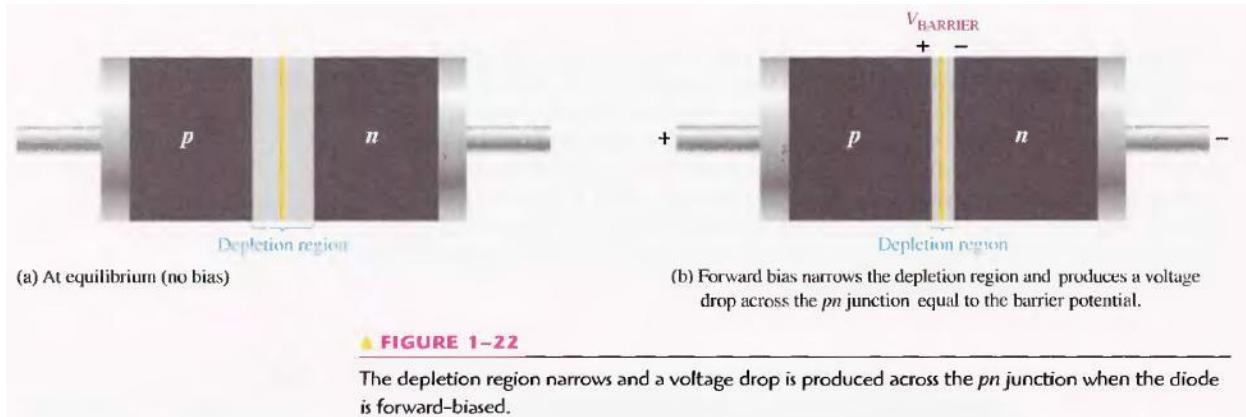
The bias-voltage source imparts sufficient energy to the free electrons for them to overcome the barrier potential of the depletion region and move on through into the p region. Once in the p region, these conduction electrons have lost enough energy to immediately combine with holes in the valence band.

Now, the electrons are in the valence band in the p region, simply because they have lost too much energy overcoming the barrier potential to remain in the conduction band. Since unlike charges attract, the positive side of the bias-voltage source attracts the valence electrons toward the left end of the p region. The holes in the p region provide the medium or "pathway" for these valence electrons to move through the p region. The electrons move from one hole to the next toward the left. The holes, which are the majority carriers in the p region, effectively (not actually) move to the right toward the junction, as you can see in Figure 1-21. This effective flow of holes is called the hole current. You can also view the hole current as being created by the flow of valence electrons through the p region, with the holes providing the only means for these electrons to flow.

A forward-biased diode showing the flow of majority carriers and the voltage due to the barrier potential across the depletion region.

As the electrons flow out of the p region through the external connection (conductor) and to the positive side of the bias-voltage source, they leave holes behind in the p region; at the same time, these electrons become conduction electrons in the metal conductor. Recall that the conduction band in a conductor overlaps the valence band so that it takes much less energy for an electron to be a free electron in a conductor than in a semiconductor. So there is a continuous availability of holes effectively moving toward the pn junction to combine with the continuous stream of electrons as they come across the junction into the p region.

**The Effect of Forward Bias on the Depletion Region** As more electrons flow into the depletion region the number of positive ions is reduced. As more holes effectively flow into the depletion region on the other side of the p/n junction, the number of negative ions is reduced. This reduction in positive and negative ions during forward bias causes the depletion region to narrow, as indicated in Figure 1-22.



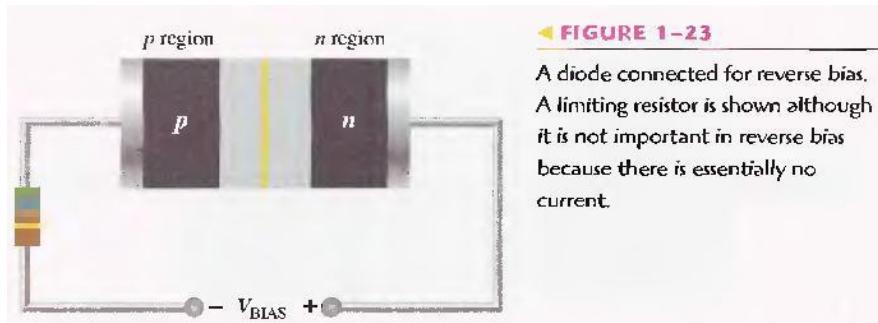
**FIGURE 1-22**

The depletion region narrows and a voltage drop is produced across the *pn* junction when the diode is forward-biased.

**The Effect of the Barrier Potential during Forward Bias** Recall that the electric field between the positive and negative ions in the depletion region on either side of the junction creates an "energy hill" that prevents free electrons from diffusing across the junction at equilibrium (see Figure 1-19(b)). This is known as the barrier potential. When forward bias is applied, the free electrons are provided with enough energy from the bias-voltage source to overcome the barrier potential and effectively "climb the energy hill" and cross the depletion region. The energy that the electrons require in order to pass through the depletion region is equal to the barrier potential. In other words the electrons give up an amount of energy equivalent to the barrier potential when they cross the depletion region. This energy loss results in a voltage drop across the *pn* junction equal to the barrier potential (0.7 V), as indicated in Figure 1-22(b). An additional small voltage drop occurs across the p and /1 regions due to the internal resistance of the material. For doped semi conductive material, this resistance, called the dynamic resistance, is very small and can usually be neglected.

### Reverse Bias

Reverse bias is the condition that essentially prevents current through the diode. Figure 1-23 shows a dc voltage source connected across a diode in the direction to produce reverse bias. This external bias voltage is designated as  $V_{\text{BIAS}}$  just as it was for forward bias. Notice that the positive side of  $V_{\text{BIAS}}$  is connected to the n region of the diode and the negative side is connected to the p region. Also note that the depletion region is shown much wider than in forward bias or equilibrium.

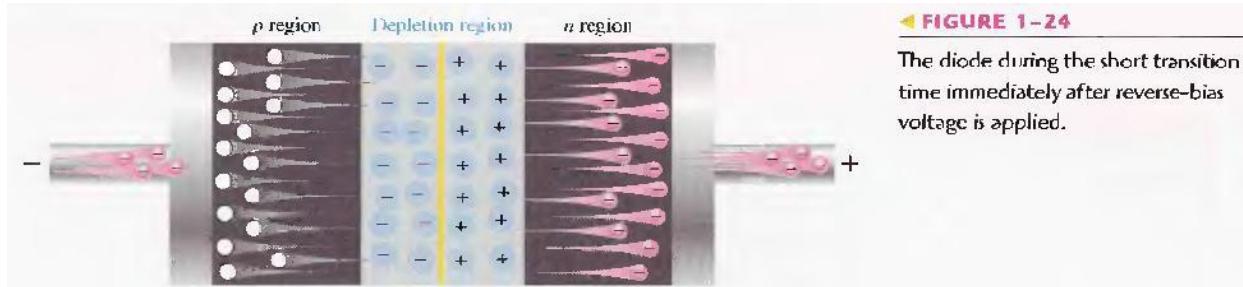


**FIGURE 1-23**

A diode connected for reverse bias. A limiting resistor is shown although it is not important in reverse bias because there is essentially no current.

An illustration of what happens when a diode is reverse-biased is shown in Figure 1-24. Because unlike charges attract, the positive side of the bias-voltage source "pulls" the free electrons, which are the majority carriers in the 17 region, away from the pn junction. As the electrons flow toward the positive

side of the voltage source, additional positive ions are created. This results in a widening of the depletion region and a depletion of majority carriers.



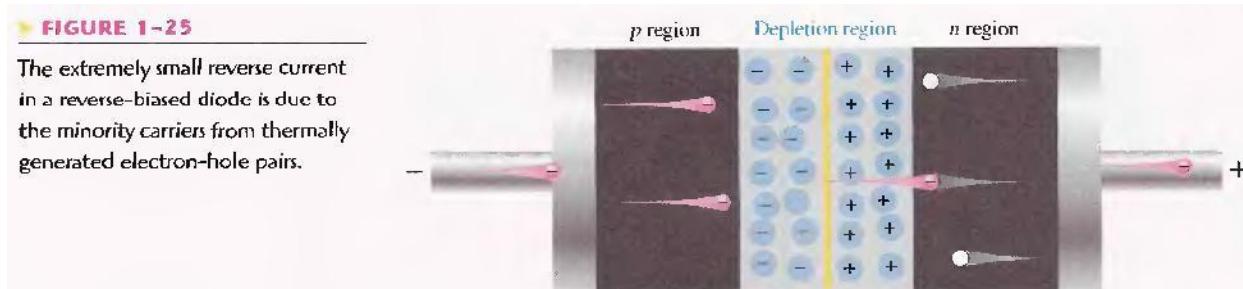
**FIGURE 1-24**

The diode during the short transition time immediately after reverse-bias voltage is applied.

In the p region, electrons from the negative side of the voltage source enter as valence electrons and move from hole to hole toward the depletion region where they create additional negative ions. This results in a widening of the depletion region and a depletion of majority carriers. The flow of valence electrons can be viewed as holes being "pulled" toward the positive side. The initial flow of charge carriers is transitional and lasts for only a very short time after the reverse-bias voltage is applied. As the depletion region widens, the availability of majority carriers decreases. As more of the n and p regions become depleted of majority carriers, the electric field between the positive and negative ions increases in strength until the potential across the depletion region equals the bias voltage,  $V_{bias}$ . At this point the transition current essentially ceases except for a very small reverse current that can usually be neglected.

**Reverse Current** The extremely small current that exists in reverse bias after the transition current dies out is caused by the minority carriers in the n and p regions that are produced by thermally generated electron-hole pairs. The small number of free minority electrons in the p region are "pushed" toward the pn junction by the negative bias voltage. When these electrons reach the wide depletion region, they "fall down the energy hill" and combine with the minority holes in the n region as valence electrons and flow toward the positive bias voltage, creating a small hole current. The conduction band in the p region is at a higher energy level than the conduction band in the n region. Therefore, the minority electrons easily pass through the depletion region because they require no additional energy. Reverse current is illustrated in Figure 1-25.

**Reverse Breakdown** Normally, the reverse current is so small that it can be neglected. However, if the external reverse-bias voltage is increased to a value called the breakdown voltage, the reverse current will drastically increase.



**FIGURE 1-25**

The extremely small reverse current in a reverse-biased diode is due to the minority carriers from thermally generated electron-hole pairs.

This is what happens. The high reverse-bias voltage imparts energy to the free minority electrons so that as they speed through the p region, they collide with atoms with enough energy to knock valence

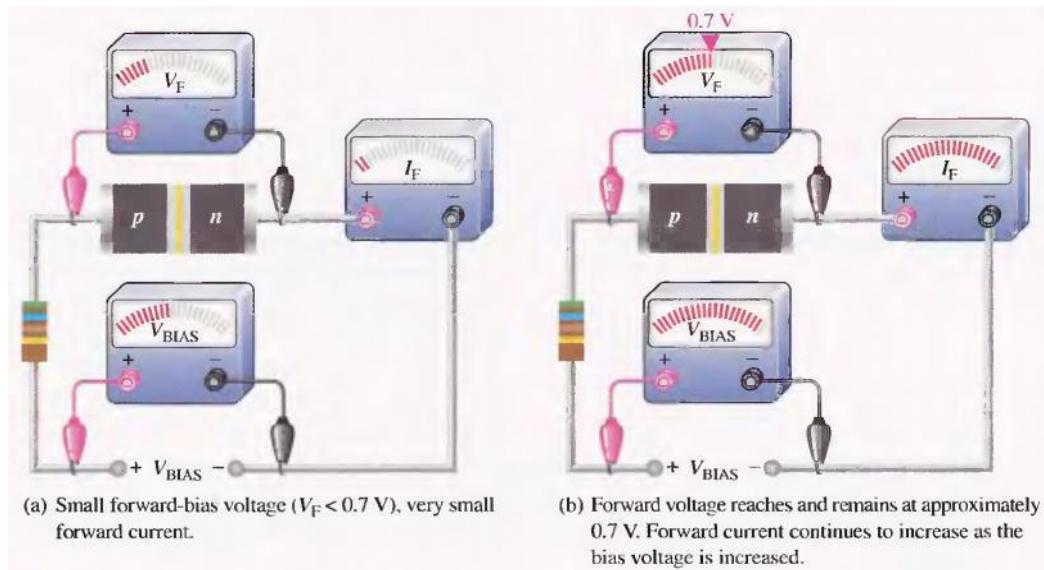
electrons out of orbit and into the conduction band. The newly created conduction electrons are also high in energy and repeat the process. If one electron knocks only two others out of their valence orbit during its travel through the p region. The numbers quickly multiply. As these high-energy electrons go through the depletion region, they have enough energy to go through the n region as conduction electrons, rather than combining with holes. The multiplication of conduction electrons just discussed is known as avalanche and results in a very high reverse current that can damage the diode because of excessive heat dissipation.

## **Voltage-current characteristic of a diode**

As you have learned, forward bias produces current through a diode and reverse bias essentially prevents current, except for a negligible reverse current. Reverse bias prevents current as long as the reverse-bias voltage does not equal or exceed the breakdown voltage of the junction.

### V-I Characteristic for Forward Bias

When a forward-bias voltage is applied across a diode, there is current. This current is called the forward current and is designated  $I_F$ . Figure 1-26 illustrates what happens as the forward-bias voltage is increased positively from 0 V. The resistor is used to limit the forward current to a value that will not overheat the diode and cause damage.



**FIGURE 1-26**

Forward-bias measurements show general changes in  $V_F$  and  $I_F$  as  $V_{BIAS}$  is increased.

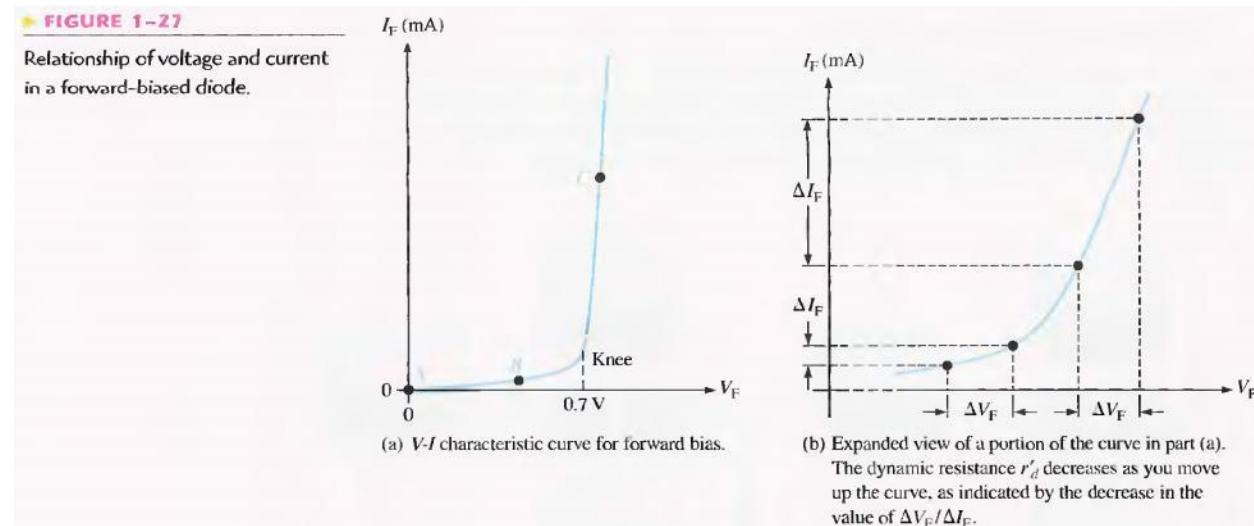
With 0 V across the diode, there is no forward current. As you gradually increase the forward-bias voltage, the forward current and the voltage across the diode gradually increase, as shown in Figure 1-26(a). A portion of the forward-bias voltage is dropped across the limiting resistor. When the forward-bias voltage is increased to a value where the voltage across the diode reaches approximately 0.7 V (barrier potential), the forward current begins to increase rapidly, as illustrated in Figure 1-26(b). As you continue to increase the forward-bias voltage, the current continues to increase very rapidly, but the voltage across the diode increases only gradually above 0.7 V. This small increase in the diode voltage

above the barrier potential is due to the voltage drop across the internal dynamic resistance of the semi-conductive material.

### Graphing the V-I Curve

If you plot the results of the type of measurements shown in Figure 1-26 on a graph, you get the V-I characteristic curve for a forward-biased diode, as shown in Figure 1-27(a). The diode forward voltage ( $V_F$ ) increases to the right along the horizontal axis, and the forward current ( $I_F$ ) increases upward along the vertical axis. As you can see in Figure 1-27(a), the forward current increases very little until the forward voltage across the pn junction reaches approximately 0.7 V at the knee of the curve. After this point, the forward voltage remains at approximately 0.7 V, but  $I_F$  increases rapidly. As previously mentioned, there is a slight increase in  $V_F$  above 0.7 V as the current increases due mainly to the voltage drop across the dynamic resistance. Normal operation for a forward-biased diode is above the knee of the curve. The  $I_F$  scale is typically in mA, as indicated.

Three points A, B, and C are shown on the curve in Figure 1-27(a). Point A corresponds to a zero-bias condition. Point B corresponds to Figure 1-26(a) where the forward voltage is less than the barrier potential of 0.7 V. Point C corresponds to Figure 1-26(a) where the



forward voltage approximately equals the barrier potential. As the external bias voltage and forward current continue to increase above the knee, the forward voltage will increase slightly above 0.7 V. In reality, the forward voltage can be as much as approximately 0.90 V, depending on the forward current.

**Dynamic Resistance** Figure 1-27(b) is an expanded view of the V-I characteristic curve in part (a) and illustrates dynamic resistance. Unlike a linear resistance, the resistance of the forward-biased diode is not constant over the entire curve. Because the resistance changes as you move along the V-I curve, it is called dynamic or ac resistance. Internal resistances of electronic devices are usually designated by lowercase italic  $i'$  with a prime, instead of the standard R. The dynamic resistance of a diode is designated  $r'_d$ .

Below the knee of the curve the resistance is greatest because the current increases very little for a given change in voltage ( $r'_d = \Delta V_F/\Delta I_F$ ). The resistance begins to decrease in the region of the knee of the curve

and becomes smallest above the knee where there is a large change in current for a given change in voltage.

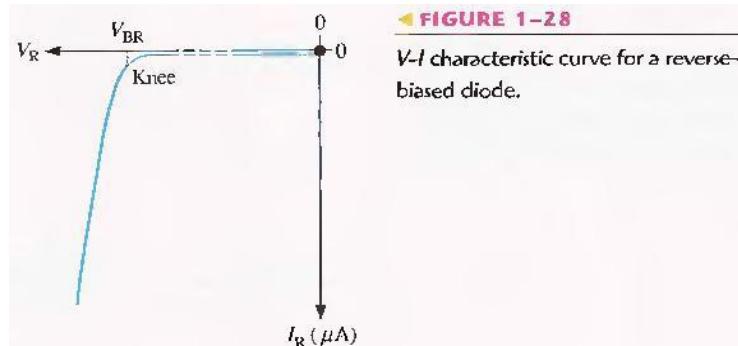
### V-I Characteristic for Reverse Bias

When a reverse-bias voltage is applied across a diode, there is only an extremely small reverse current ( $I_R$ ) through the pn junction. With 0 V across the diode, there is no reverse current. As you gradually increase the reverse-bias voltage, there is a very small reverse current and the voltage across the diode increases. When the applied bias voltage is increased to a value where the reverse voltage across the diode ( $V_R$ ) reaches the breakdown value ( $V_{BR}$ ), the reverse current begins to increase rapidly.

As you continue to increase the bias voltage, the current continues to increase very rapidly, but the voltage across the diode increases very little above  $V_{BR}$ . Breakdown, with exceptions, is not a normal mode of operation for most pn junction devices.

**Graphing the V-I Curve** If you plot the results of reverse-bias measurements on a graph, you get the V-I characteristic curve for a reverse-biased diode. A typical curve is shown in Figure 1-28. The diode reverse voltage ( $V_R$ ) increases to the left along the horizontal axis and the reverse current ( $I_R$ ) increases downward along the vertical axis.

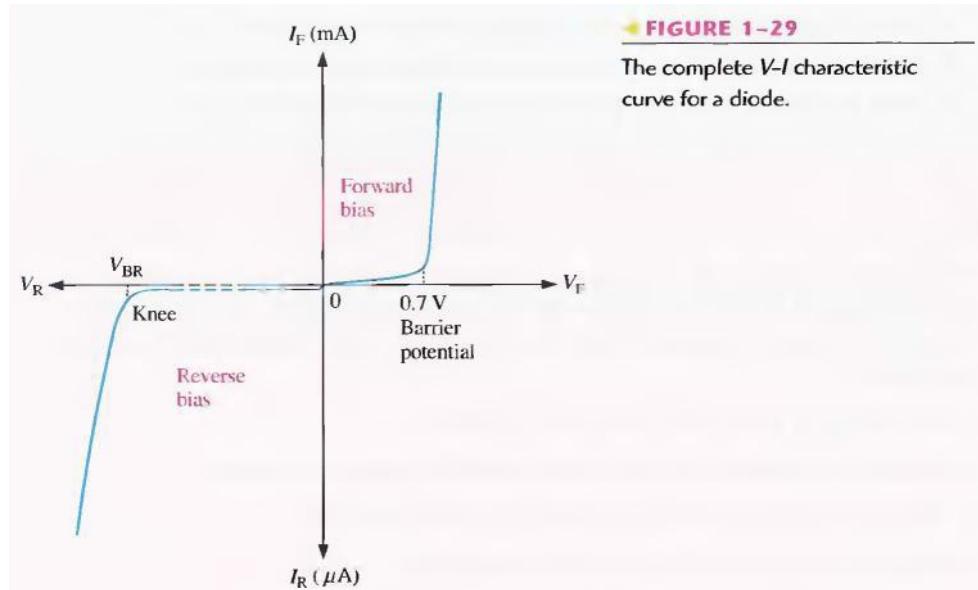
There is very little reverse current (usually  $\mu\text{A}$  or  $\text{nA}$ ) until the reverse voltage across the diode reaches approximately the breakdown value ( $V_{BR}$ ) at the knee of the curve. After this point, the reverse voltage remains at approximately  $V_{BR}$ , but  $I_R$  increases very rapidly, resulting in overheating and possible damage. The breakdown voltage for a typical silicon diode can vary, but a minimum value of 50 V is not unusual.



**FIGURE 1-28**  
V-I characteristic curve for a reverse-biased diode.

### The Complete V-I Characteristic Curve

Combine the curve, for both forward bias and reverse bias, and you have the complete V-I characteristic curve for a diode, as shown in Figure 1-29. Notice that the IF scale is in mA compared to the  $I_R$  scale in  $\mu\text{A}$ .



► FIGURE 1-29

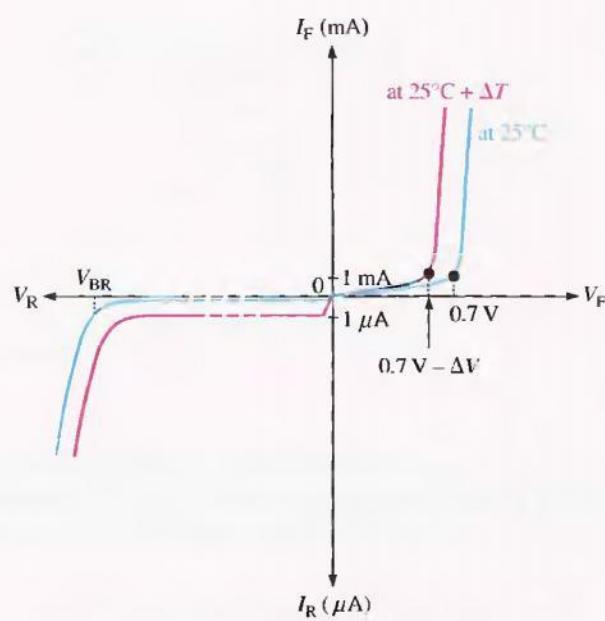
The complete  $V$ - $I$  characteristic curve for a diode.

**Temperature Effects** For a forward-biased diode, as temperature is increased, the forward current increases for a given value of forward voltage. Also, for a given value of forward current, the forward voltage decreases. This is shown with the  $V$ - $I$  characteristic curves in Figure 1-30. The blue curve is at room temperature ( $25^\circ\text{C}$ ) and the red curve is at an elevated temperature ( $25^\circ\text{C} + \Delta T$ ). Notice that the barrier potential decreases as temperature increases.

For a reverse-biased diode, as temperature is increased, the reverse current increases. The difference in the two curves is exaggerated on the graph in Figure 1-30 for illustration. Keep in mind that the reverse current below breakdown remains extremely small and can usually be neglected.

► FIGURE 1-30

Temperature effect on the diode  $V$ - $I$  characteristic. The  $1\text{ mA}$  and  $1\text{ }\mu\text{A}$  marks on the vertical axis are given as a basis for a relative comparison of the current scales.



## Pre lab

### Objective

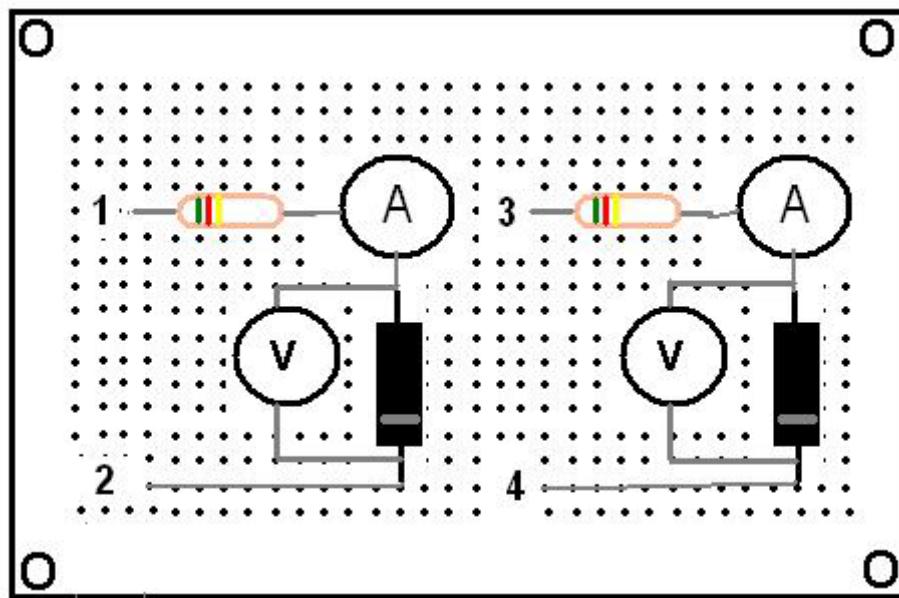
Construct the following circuit on bread board & Test for continuity.

### Required components

- 1) Bread-board
- 2) Silicon diode
- 3) Germanium diode
- 4) 2 Resistors ( $10K\Omega$  each)

### Procedure

Make the circuit as shown.



- 1- Apply positive supply across terminal 1 & 2. (Terminal 1 being positive)
- 2- Connect a voltmeter across 1<sup>st</sup> diode & start varying the variable supply voltages.
- 3- For each division of voltages, note the corresponding current & voltage across the diode.

- 4- Take at least nine readings & then reverse the supply voltages across terminal 1 & 2. (This time terminal 2 being positive)
- 5- Repeat the same procedure for negative voltages
- 6- Repeat the same procedure for germanium diode also.
- 7- After getting all the readings, plot the V-I curve for both diodes.

## **Observations**

### **Forward bias mode**

#### **SILICON**

Voltage	Current

#### **GERMANIUM**

Voltage	Current

### **REVERSE BIAS MODE**

#### **SILICON**

Voltage	Current

#### **GERMANIUM**

Voltage	Current

### **Graph:**

Attach both graphs here.

### **Post lab**

- 1- Make both circuits on multisim & attach the print out of simulated circuits.

**NED University of Engineering and Technology, Karachi**  
**Department of Electronic Engineering**

Course Code: \_\_\_\_\_ Course Name: \_\_\_\_\_  
 Laboratory Session No. \_\_\_\_\_ Date: \_\_\_\_\_

Psychomotor Domain Assessment Rubric-Level P3				
Skill Sets	Extent of Achievement			
	0	1	2	3
<b>Equipment Identification</b> Sensory ability to identify equipment and/or its component for a lab work	Unable to identify the equipment	Able to identify very few equipment and components to be used in lab work	Able to identify some of the equipment and components to be used in lab work	Able to identify most of the equipment and components to be used in lab work
<b>Procedural Skills</b> Displays skills to act upon sequence of steps in lab work	Unable to either learn or perform lab work procedure	Able to slightly understand lab work procedure and perform lab work	Able to somewhat understand lab work procedure and perform lab work	Able to moderately understand lab work procedure and perform lab work
<b>Response</b> Capability to initiate the lab work on his/her own	Unable to initiate the lab work	Able to slightly initiate the lab work	Able to somewhat initiate the lab work	Able to moderately initiate the lab work
<b>Observation's Use</b> Displays skills to perform related mathematical calculations using the observations from lab work	Unable to use lab work observations for mathematical calculations	Able to slightly use lab work observations for mathematical calculations	Able to somewhat use lab work Observations for mathematical calculations	Able to moderately use lab work Observations for mathematical calculations
<b>Equipment Use</b> Sensory skills to describe the use of the equipment for the lab work	Unable to describe the use of equipment	Rarely able to describe the use of equipment	Occasionally describes the use of equipment	Often able to describe the use of equipment
<b>Equipment Handling</b> Equipment care during the use	Doesn't handle Equipment with required care	Rarely handles equipment with required care	Occasionally handles Equipment with required care	Often handles Equipment with required care
Ability to troubleshoot errors and try to resolve with/without the supervision or guidance	Unable to troubleshoot experimentation errors and resolve them	Able to troubleshoot experimentation errors but cannot resolve them	Able to troubleshoot experimentation errors independently but need guidance in resolving them	Able to troubleshoot experimentation errors and resolve them without supervision or guidance

Weighted CLO (Psychomotor Score)	_____
Remarks	_____
Instructor's Signature with Date:	_____

## **LAB SESSION 3**

To design and analyze the half-wave rectifier

**Student Name:**

**Roll no.:                          Batch:**

**Semester :                          Year:**

<b>Total Marks</b>	<b>Marks Obtained</b>

**Remarks (if any) :**

**Instructor Name:**

**Instructor Signature:**

**Date:**

# **LAB SESSION 3**

## **Objective**

**To design and analyze the half-wave rectifier**

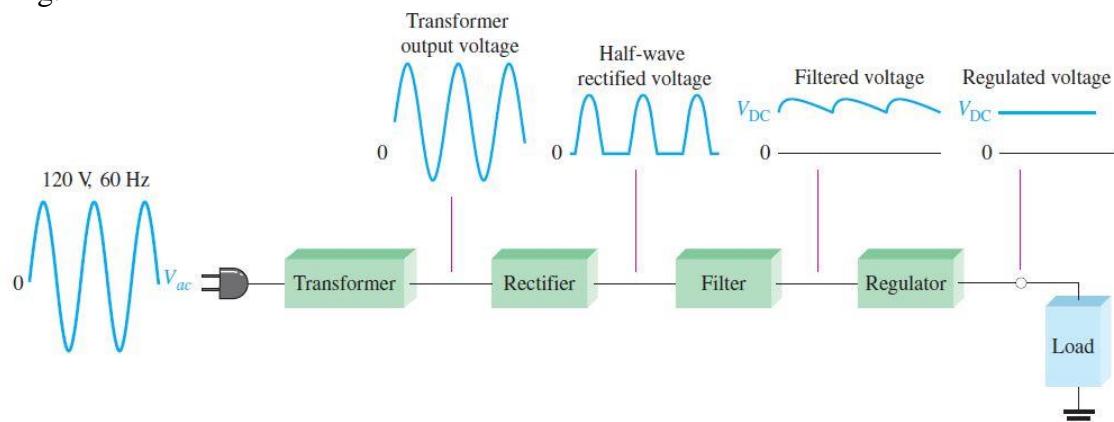
## **Theory Introduction**

Because of their ability to conduct current in one direction and block current in other direction, diodes are used in circuits called rectifiers that convert ac voltage into dc voltage. Rectifiers are found in all dc power supplies that operate from an ac voltage source. A power supply is an essential part of each electronic system from the simplest to the most complex. In this section, you will study the most basic type of rectifier, the half-wave rectifier.

## **The Basic DC Power Supply**

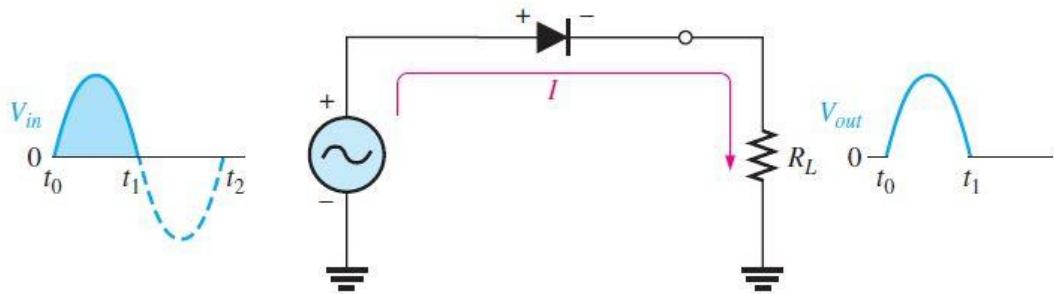
The DC power supply converts the standard 220 V, 50 Hz ac available at wall outlets into a constant dc voltage. It is one of the most common electronic circuits that you will find. The dc voltage produced by a power supply is used to power all types of electronic circuits, such as television receivers, stereo systems, VCRs, CD players and most laboratory equipment. A block diagram for a complete power supply is shown in Fig 2-1. The rectifier can be either a half-wave rectifier or a full-wave rectifier (covered in proceeding labs). The rectifier converts the ac input voltage to a pulsating dc voltage, which is half-wave rectified as shown in Figure 2-2. The filter eliminates the fluctuations in the rectified voltage and produces a relatively smooth dc voltage. The power supply filter is covered in proceeding labs. The regulator is a circuit that maintains a constant de voltage for variations in the input line voltage or in the load. Regulators vary from a single device to more complex integrated circuits. The load is a circuit or device for which the power supply is producing the dc voltage and load current.

Fig. 2-1

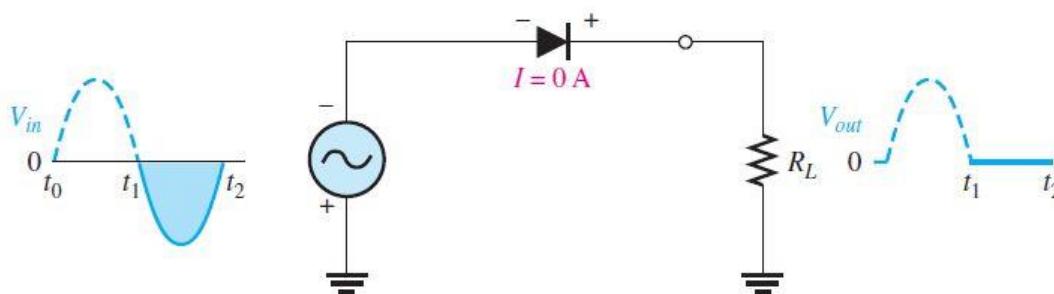


(a) Complete power supply with transformer, rectifier, filter, and regulator

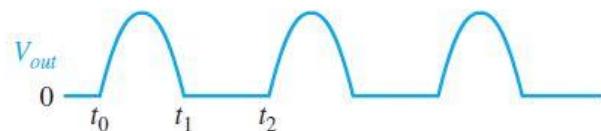
Fig 2-2



(a) During the positive alternation of the 60 Hz input voltage, the output voltage looks like the positive half of the input voltage. The current path is through ground back to the source.



(b) During the negative alternation of the input voltage, the current is 0, so the output voltage is also 0.



(c) 60 Hz half-wave output voltage for three input cycles

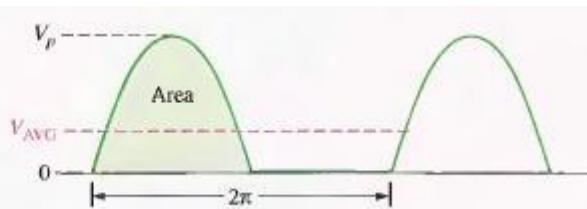
### Average Value of the Half-Wave Output Voltage

The average value of the half-wave rectified output voltage is the value you would measure on a dc voltmeter. Mathematically, it is determined by finding the area under the curve over a full cycle, as illustrated in Figure 2-3, and then dividing by  $2\pi$ , the number of radians in a full cycle. The result of this is expressed in Equation 2-1, where  $V_p$  is the peak value of the voltage. This equation shows that  $V_{AVG}$  is approximately 31.8% of  $V_p$  for a half-wave rectified voltage.

$$\text{Equation 2-1} \quad V_{AVG} = \frac{V_p}{\pi}$$

**FIGURE 2-3**

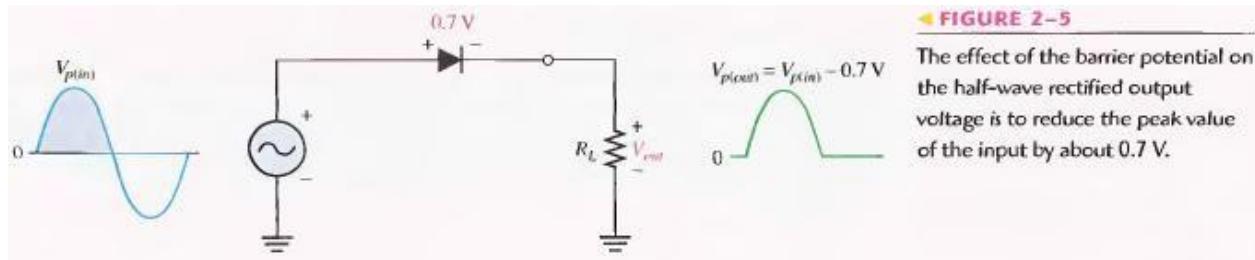
Average value of the half-wave rectified signal.



## Effect of the Barrier Potential on the Half-Wave Rectifier Output

In the previous discussion, the diode was considered ideal. When the practical diode model is used with the barrier potential of 0.7 V taken into account, this is what happens. During the positive half-cycle, the input voltage must overcome the barrier potential before the diode becomes forward-biased. This results in a half-wave output with a peak value that is 0.7 V less than the peak value of the input, as shown in Figure 2-5. The expression for the peak output voltage is:

$$\text{Equation 2-2} \quad V_{P(\text{out})} = V_{P(\text{in})} - 0.7$$

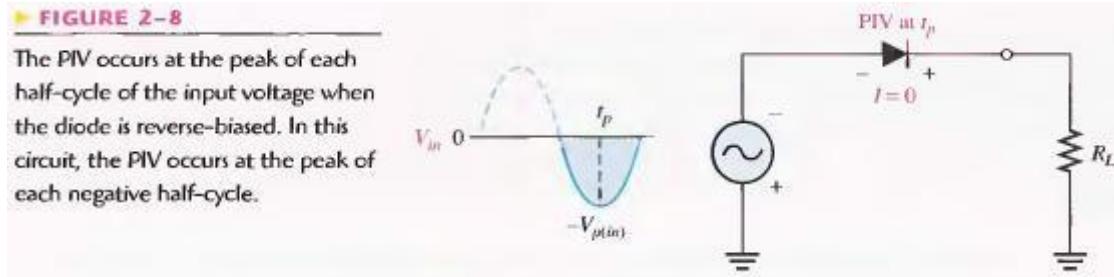


It is usually acceptable to use the ideal diode model, which neglects the effect of the barrier potential, when the peak value of the applied voltage is much greater than the barrier potential (at least 10 V, as a rule of thumb).

## Peak Inverse Voltage (PIV)

The peak inverse voltage (PIV) equals the peak value of the input voltage, and the diode must be capable of withstanding this amount of repetitive reverse voltage. For the diode in Figure 2-8, the maximum value of reverse voltage, designated as PIV occurs at the peak of each negative alternation of the input voltage when the diode is reverse-biased.

$$\text{Equation 2-3} \quad \text{PIV} = V_{P(\text{in})}$$

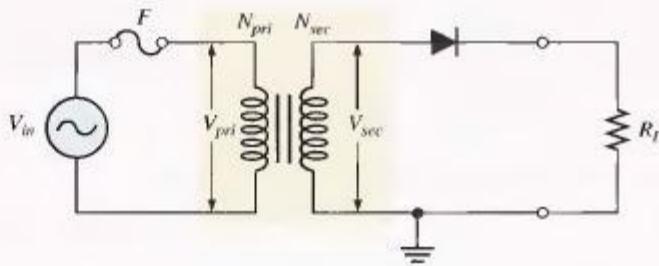


## Half-Wave Rectifier with Transformer-Coupled Input Voltage

A transformer is often used to couple the ac input voltage from the source to the rectifier, as shown in Figure 2-9. Transformer coupling provides two advantages. First, it allows the source voltage to be stepped up or stepped down as needed. Second, the ac source is electrically isolated from the rectifier, thus preventing a shock hazard in the secondary circuit.

**FIGURE 2-9**

Half-wave rectifier with transformer-coupled input voltage.



From your study of basic ac circuits, recall that the secondary voltage of a transformer equals the turns ratio,  $n$ , times the primary voltage, as expressed in Equation 2-4. We will define the turns ratio as the ratio of secondary turns,  $N_{\text{sec}}$  to the primary turns,  $N_{\text{pri}}$ :  $n = N_{\text{sec}} / N_{\text{pri}}$

$$\text{Equation 2-4} \quad V_{\text{sec}} = n V_{\text{pri}}$$

If  $n > 1$ , the secondary voltage is greater than the primary voltage. If  $n < 1$ , the secondary voltage is less than the primary voltage. If  $n = 1$ , then  $V_{\text{sec}} = V_{\text{pri}}$ .

The peak secondary voltage,  $V_{p(\text{sec})}$  in a transformer-coupled half-wave rectifier is the same as  $V_{p(\text{in})}$  in Equation 2-2. Therefore, Equation 2-2 written in terms of  $V_{p(\text{sec})}$  is:

$$\text{Equation 2-5} \quad V_{P(\text{out})} = V_{P(\text{sec})} - 0.7$$

and the Equation 2-3 in terms of  $V_{p(\text{sec})}$  is:

$$\text{Equation 2-6} \quad \text{PIV} = V_{P(\text{sec})}$$

## Pre-lab

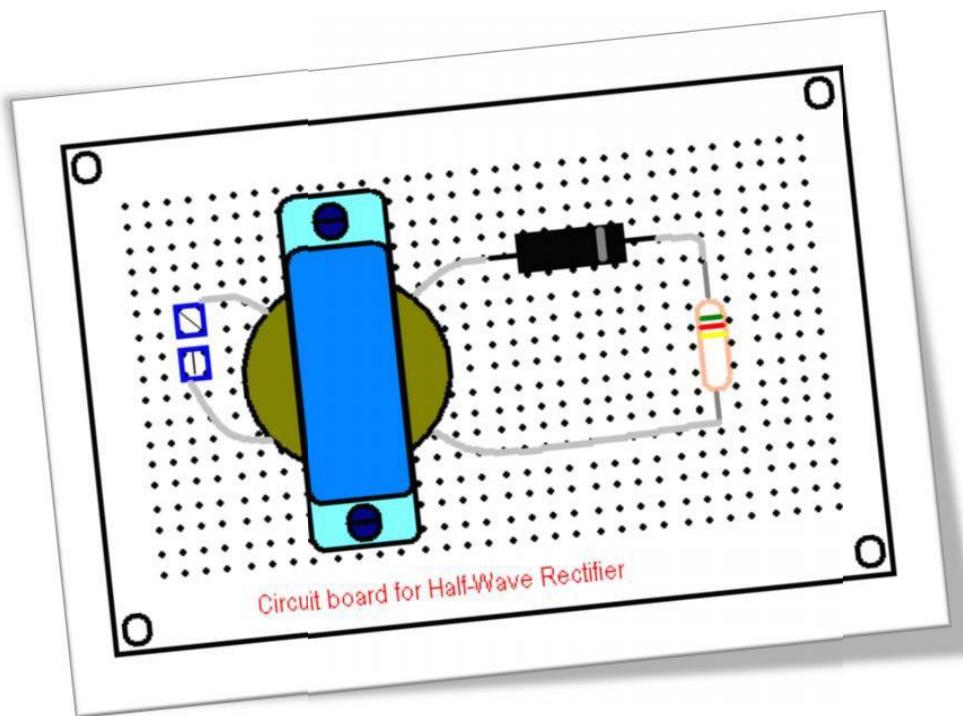
### Equipment required

- 1- Bread-board
- 2- One silicon diode (1N4001)
- 3- Transformer Center Tapped(220V – 12V)
- 4- Resistor (10kΩ)
- 5- Jumpers

### Procedure

- 1- Test the diode using diode tester in multimeter.
- 2- Set the multimeter to diode test & then put the multimeter probes on diode legs such that the black probe is at cathode & red on anode. The silver strip on diode indicates the cathode terminal.
- 3- If the multimeter shows a reading around 0.7 volts then your diode is OK.
- 4- Solder the circuit shown in fig 2-9, on bread-board.
- 5- After making the circuit should look like this.

- 6- Test the continuity of all connections



### Laboratory procedure

#### Objective

To apply a Sine wave input to the half wave rectifier circuit & observe the output waveform & parameters.

#### Equipment required

- 1- Oscilloscope
- 2- Circuit constructed in PRE-LAB

#### Procedure

- 1- Using wire, supply the voltages coming from wall socket at the circuit input (Transformer primary).
- 2- Observe the output using Oscilloscope & note down Vpeak-peak, Frequency, rms value & average value.
- 3- Observe the output of transformer & note down all values.
- 4- Now observe the output across resistor using oscilloscope & note down same values as mentioned in above step.

## Observations

Readings	Vpeak-peak	Frequency	Rms Value	Average Value
Input to transformer				
Transformer output				
Circuit output				

## Post lab

### Calculations

Using the formulas given in introduction of this lab & input values to the circuit, fill out:

Readings	Vpeak-peak	Frequency	Rms Value	Average Value
Input to transformer				
Transformer output				
Circuit output				

## Task to be submitted

- 1- Make the same circuit on Multisim & attach the print out of observed outputs.
- 2- Make the same circuit with output resistance  $1\text{K}\Omega$ ,  $100\Omega$  &  $1\text{M}\Omega$  & write the change in output values in the following table.

Readings	Vpeak-peak	Frequency	Rms Value	Average Value
$1\text{K}\Omega$				
$100\text{k}\Omega$				
$1\text{M}\Omega$				

- 3- Reverse the supply plug & check whether any change occurs in output voltage?  
Why?

- 4- In multisim, reverse the direction of diode & write the output value. Also provide the reason for each output.

**NED University of Engineering and Technology, Karachi**  
**Department of Electronic Engineering**

Course Code: \_\_\_\_\_ Course Name: \_\_\_\_\_

Laboratory Session No. \_\_\_\_\_ Date: \_\_\_\_\_

		Psychomotor Domain Assessment Rubric-Level P3				
		Extent of Achievement				
Skill Sets		0	1	2	3	4
Equipment Identification	Unable to identify the equipment	Able to identify very few equipment and components to be used in lab work	Able to identify some of the equipment and components to be used in lab work	Able to identify most of the equipment and components to be used in lab work	Able to identify all of the equipment as well as its components	
Procedural Skills	Unable to either learn or perform lab work procedure	Able to slightly understand lab work procedure and perform lab work	Able to somewhat understand lab work procedure and perform lab work	Able to moderately understand lab work procedure and perform lab work	Fully understands lab work procedure and perform lab work	
Response	Unable to initiate the lab work	Able to slightly initiate the lab work	Able to somewhat initiate the lab work	Able to moderately initiate the lab work	Fully initiates lab work	
Observation's Use	Unable to use lab work observations for mathematical calculations	Able to slightly use lab work observations for mathematical calculations	Able to somewhat use lab work Observations for mathematical calculations	Able to moderately use lab work Observations for mathematical calculations	Fully use lab work Observations for mathematical calculations	
Equipment Use	Unable to describe the use of equipment for the lab work	Rarely able to describe the use of equipment	Occasionally describe the use of equipment	Often able to describe the use of equipment	Regularly able to describe the use of equipment	
Equipment Handling	Doesn't handle Equipment with required care	Rarely handles equipment with required care	Occasionally handles Equipment with required care	Often handles Equipment with required care	Handles equipment with required care	
Ability to troubleshoot errors and resolve them	Unable to troubleshoot experimentation errors but cannot resolve them	Able to troubleshoot experimentation errors but cannot resolve them under supervision	Able to troubleshoot experimentation errors independently but need guidance in resolving them	Able to troubleshoot experimentation errors independently but need guidance in resolving them	Able to troubleshoot experimentation errors and resolve them without supervision or guidance	

Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

## **LAB SESSION 04**

To design and analyze the centre tapped full-wave rectifier

**Student Name:**

**Roll no.:                          Batch:**

**Semester :                          Year:**

<b>Total Marks</b>	<b>Marks Obtained</b>

**Remarks (if any) :**

**Instructor Name:**

**Instructor Signature:**                                    **Date:**

# **LAB SESSION 04**

## **Objective**

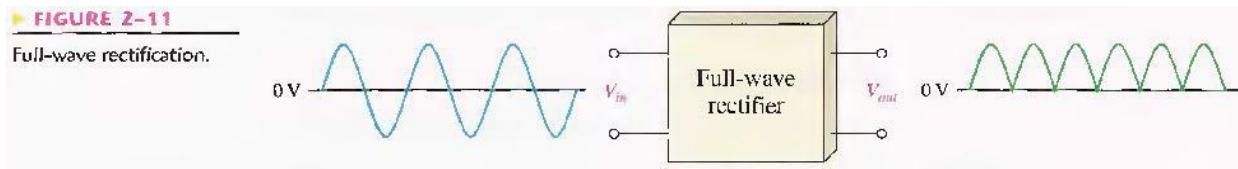
**To design and analyze the centre tapped full-wave rectifier**

## **Theory**

### **Introduction**

Although half-wave rectifiers have some applications, the full-wave rectifier is the most commonly used type in dc power supplies. In this section, you will use what you learned about half-wave rectification and expand it to full-wave rectifiers. You will learn about two types of full-wave rectifiers: center-tapped.

A full-wave rectifier allows unidirectional (one-way) current through the load during the entire 360 degree of the input cycle, whereas a half-wave rectifier allow current through the load only during one-half of the cycle. The result of full-wave rectification is an output voltage with a frequency twice the input frequency that pulsates every half-cycle of the input, as shown in Figure 2-11.



The number of positive alternations that make up the full-wave rectified voltage is twice that of the half-wave voltage for the same time interval. The average value, which is the value measured on a dc voltmeter, for a full-wave rectified sinusoidal voltage is twice that of the half-wave, as shown in the following formula:

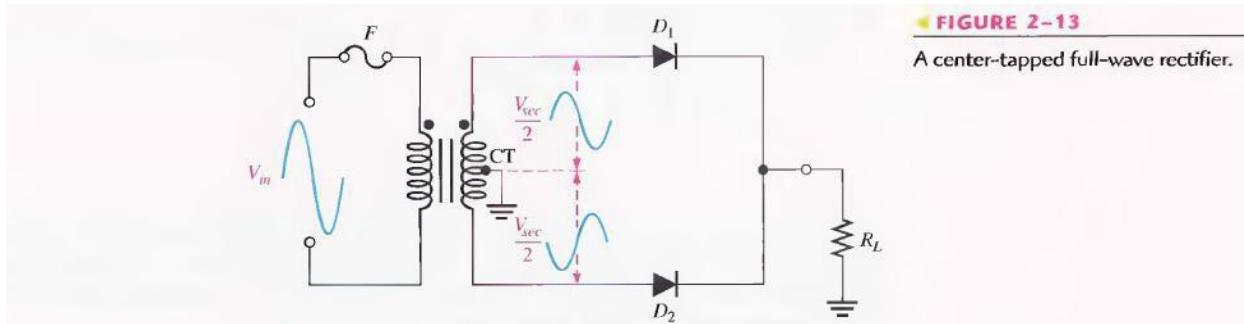
**Equation 2-5**

$$V_{AVG} = \frac{2V_p}{\pi}$$

$V_{AVG}$  is approximately 63.7% of  $V_p$  for a full-wave rectified voltage.

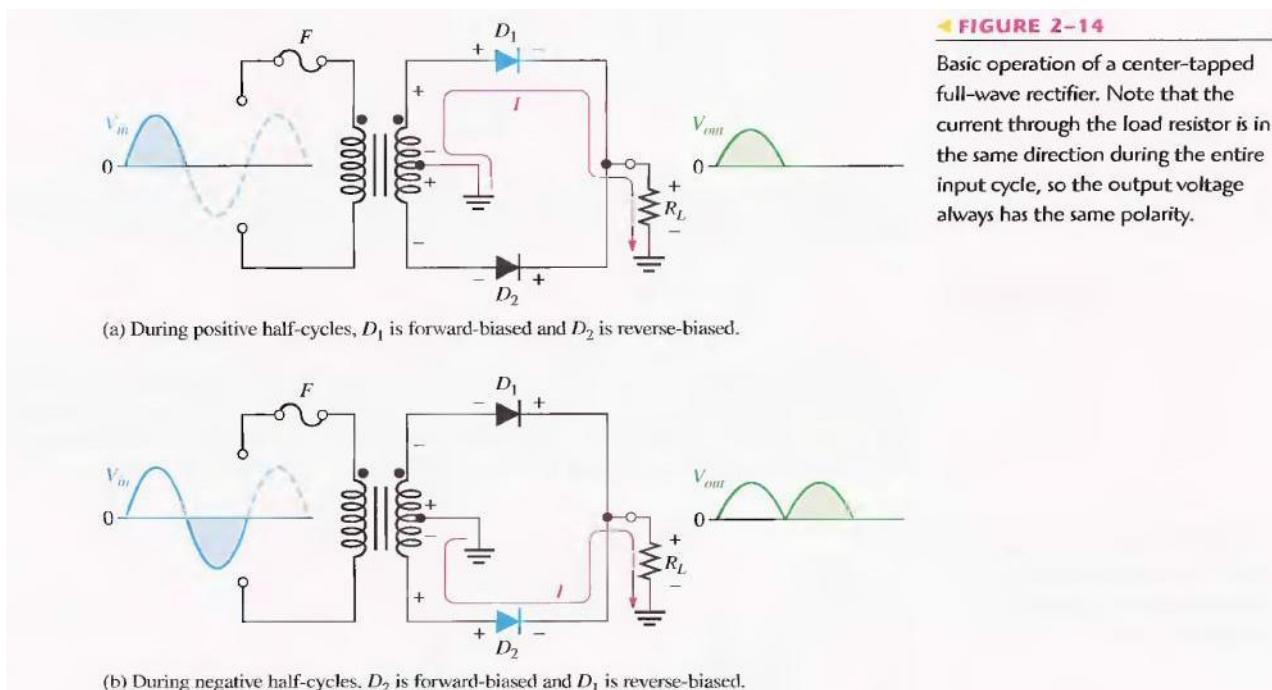
### **The Center-Tapped Full-Wave Rectifier**

A center-tapped rectifier is a type of full-wave rectifier that uses two diodes connected to the secondary of a center-tapped transformer, as shown in Figure 2-13. The input voltage is coupled through the transformer to the center-tapped secondary. Half of the total secondary voltage appears between the center tap and each end of the secondary winding as shown.



**FIGURE 2-13**  
A center-tapped full-wave rectifier.

For a positive half-cycle of the input voltage, the polarities of the secondary voltages are as shown in Figure 2-14(a). This condition forward-biases diode  $D_1$  and reverse-biases diode  $D_2$ . The current path is through  $D_1$  and the load resistor  $R_L$  as indicated. For a negative half-cycle of the input voltage, the voltage polarities on the secondary are as shown in Figure 2-14(b). This condition reverse-biases  $D_1$  and forward-biases  $D_2$ . The current path is through  $D_2$  and  $R_L$  as indicated. Because the output current during both the positive and negative portions of the input cycle is in the same direction through the load, the output voltage developed across the load resistor is a full-wave rectified dc voltage as shown.

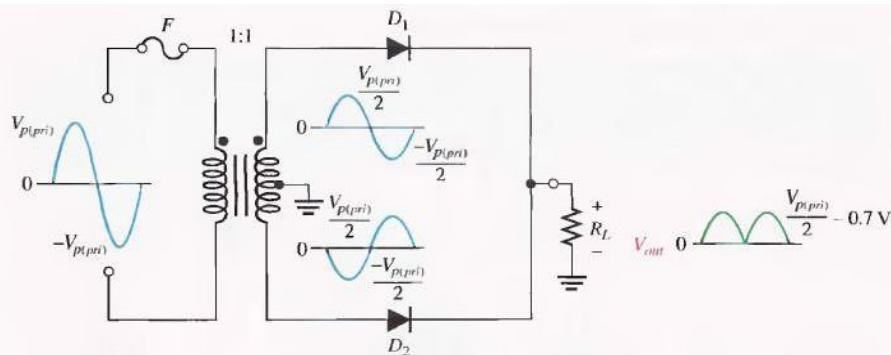


**FIGURE 2-14**  
Basic operation of a center-tapped full-wave rectifier. Note that the current through the load resistor is in the same direction during the entire input cycle, so the output voltage always has the same polarity.

**Effect of the Turns Ratio on the Output Voltage:** If the transformer's turns ratio is 1, the peak value of the rectified output voltage equals half the peak value of the primary input voltage less the barrier potential, as illustrated in Figure 2-15. Half of the primary voltage appears across each half of the secondary winding ( $V_{p(sec)} = V_{p(pri)}$ ). We will begin referring to the forward voltage due to the barrier potential as the diode drop.

► FIGURE 2-15

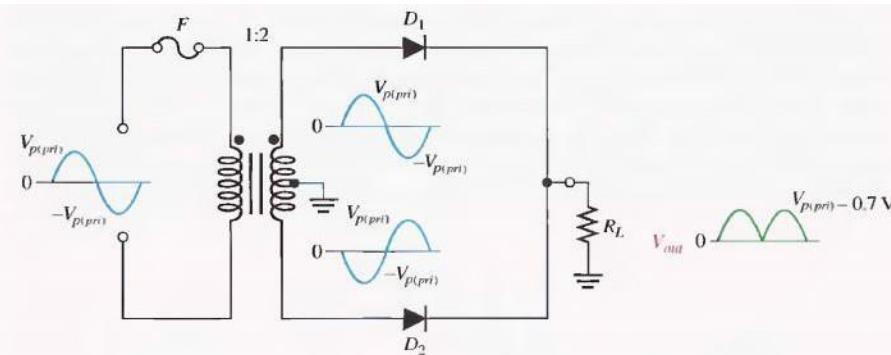
Center-tapped full-wave rectifier with a transformer turns ratio of 1.  $V_{p(pri)}$  is the peak value of the primary voltage.



In order to obtain an output voltage with a peak equal to the input peak (less the diode drop), a step-up transformer with a turns ratio of  $n = 2$  must be used, as shown in Figure 2-16. In this case, the total secondary voltage ( $V_{sec}$ ) is twice the primary voltage ( $2V_{pri}$ ), so the voltage across each half of the secondary is equal to  $V_{pri}$ .

► FIGURE 2-16

Center-tapped full-wave rectifier with a transformer turns ratio of 2.



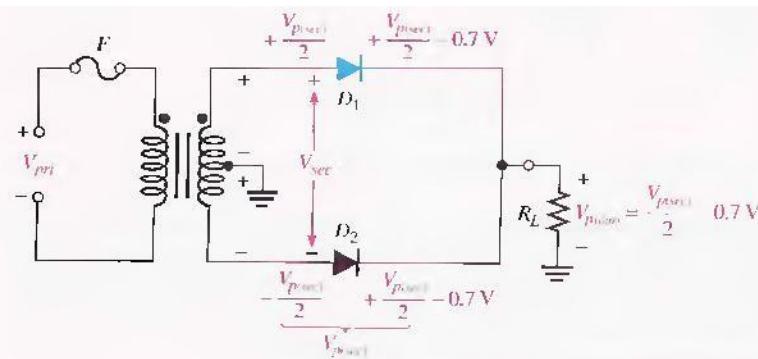
In any case, the output voltage of a center-tapped full-wave rectifier is always one-half of the total secondary voltage less the diode drop, no matter what the turns ratio.

$$\text{Equation 2-6} \quad V_{out} = \frac{V_{sec}}{2} - 0.7 \text{ V}$$

**Peak Inverse Voltage:** Each diode in the full-wave rectifier is alternately forward-biased and then reverse-biased. The maximum reverse voltage that each diode must withstand is the peak secondary voltage  $V_{p(sec)}$ . This is shown in Figure 2-17 where  $D_2$  is assumed to be reverse-biased and  $D_1$  is assumed to be forward-biased to illustrate the concept.

► FIGURE 2-17

Diode reverse voltage ( $D_2$  shown reverse-biased and  $D_1$  shown forward-biased).



When the total secondary voltage  $V_{sec}$  has the polarity shown, the maximum anode voltage of  $D_2$  is  $+V_{p(sec)}/2$  and the maximum anode voltage of  $D_2$  is  $-V_{p(sec)}/2$ . Since  $D_2$  is assumed to be forward-biased, its cathode is at the same voltage as its anode minus the diode drop; this is also the voltage on the cathode of  $D_2$ .

The peak inverse voltage across  $D_2$  is

$$\begin{aligned} \text{PIV} &= \left( \frac{V_{p(sec)}}{2} - 0.7 \text{ V} \right) - \left( -\frac{V_{p(sec)}}{2} \right) = \frac{V_{p(sec)}}{2} + \frac{V_{p(sec)}}{2} - 0.7 \text{ V} \\ &= V_{p(sec)} - 0.7 \text{ V} \end{aligned}$$

Since  $V_{p(out)} = V_{p(sec)}/2 - 0.7 \text{ V}$ , then by multiplying each term by 2 and transposing,

$$V_{p(sec)} = 2V_{p(out)} + 1.4 \text{ V}$$

Therefore, by substitution, the peak inverse voltage across either diode in a full-wave center-tapped rectifier is:

$$\text{PIV} = 2V_{p(out)} + 0.7 \text{ V}$$

**Equation 2-7**

## Pre-lab

### Objective

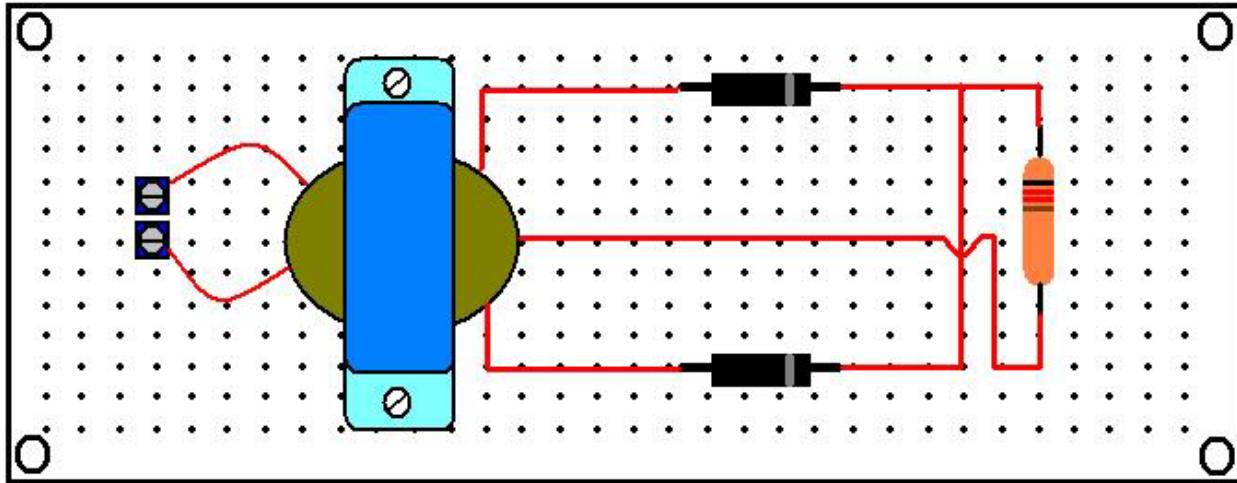
To construct a Full-Wave rectifier on a bread-board.

### Equipment required

- 1- Bread-board
- 2- Two silicon diodes (1N4001)
- 3- Transformer Center Tapped (220V – 12V)
- 4- Resistor (10kΩ)
- 5- Jumpers

### Procedure

- 1- Test the diode using diode tester in multimeter.
- 2- Make the circuit as shown, on bread-board.
- 3- Test the continuity of all connections.



## Laboratory procedure

### Objective

To apply a Sine wave input to the full wave rectifier circuit & observe the output waveform & parameters.

### Equipment required

- 3- Oscilloscope
- 4- Circuit constructed in PRE-LAB

### Procedure

- 5- Using wire, supply the voltages coming from wall socket at the circuit input.
- 6- Observe the output using Oscilloscope & note down Vpeak-peak, Frequency, rms value & average value.
- 7- Observe the output of transformer & note down all values.
- 8- Now observe the output across resistor using oscilloscope & note down same values as mentioned in above step.

### Observations

Readings	Vpeak-peak	Frequency	Rms Value	Average Value
Input to transformer				
Transformer output				
Circuit output				

## **Post lab**

### **Calculations**

Using the formulas given in introduction of this lab & input values to the circuit, fill out:

Readings	Vpeak-peak	Frequency	Rms Value	Average Value
Input to transformer				
Transformer output				
Circuit output				

### **Task to be submitted**

- 1- Make the same circuit on Multisim & attach the print out of observed outputs.
- 2- Make the same circuit with output resistance  $1\text{K}\Omega$ ,  $100\text{K}\Omega$  &  $1\text{M}\Omega$  & write the change in output values in the following table.

Readings	Vpeak-peak	Frequency	Rms Value	Average Value
$1\text{K}\Omega$				
$100\text{k}\Omega$				
$1\text{M}\Omega$				

- 3- In multisim, reverse the direction of each diode one by one & write the output values in each case. Also provide the reason for each output.
- 4- In multisim, make the same circuit with one changing, i.e apply supply at the transformer secondary connect the rest circuit with transformer's primary, what happens at output??? Provide the reason also.

**NED University of Engineering and Technology, Karachi**  
**Department of Electronic Engineering**

Course Code: \_\_\_\_\_ Course Name: \_\_\_\_\_

Laboratory Session No. \_\_\_\_\_ Date: \_\_\_\_\_

Skill Sets	Psychomotor Domain Assessment Rubric-Level P3			
	Extent of Achievement			
	0	1	2	3
<b>Equipment Identification</b> Sensual ability to identify equipment and/or its component for a lab work	Unable to identify the equipment	Able to identify very few equipment and components to be used in lab work	Able to identify some of the equipment and components to be used in lab work	Able to identify most of the equipment and components to be used in lab work
<b>Procedural Skills</b> Displays skills to act upon sequence of steps in lab work	Unable to either learn or perform lab work procedure	Able to slightly understand lab work procedure and perform lab work	Able to somewhat understand lab work procedure and perform lab work	Able to moderately understand lab work procedure and perform lab work
<b>Response</b> Capability to imitate the lab work on his/her own	Unable to imitate the lab work	Able to slightly imitate the lab work	Able to somewhat imitate the lab work	Able to moderately imitate the lab work
<b>Observation's Use</b> Displays skills to perform related mathematical calculations using the observations from lab work	Unable to use lab work observations for mathematical calculations	Able to slightly use lab work observations for mathematical calculations	Able to somewhat use lab work Observations for mathematical calculations	Able to moderately use lab work Observations for mathematical calculations
<b>Equipment Use</b> Sensory skills to describe the use of the equipment for the lab work	Unable to describe the use of equipment	Rarely able to describe the use of equipment	Occasionally describes the use of equipment	Often able to describe the use of equipment
<b>Equipment Handling</b> Equipment care during the use	Doesn't handle Equipment with required care	Rarely handles equipment with required care	Occasionally handles Equipment with required care	Often handles Equipment with required care
Ability to troubleshoot errors and try to resolve with/without the supervision or guidance	Unable to troubleshoot experimentation errors and resolve them	Able to troubleshoot experimentation errors but cannot resolve them	Able to troubleshoot experimentation errors and resolve them under supervision	Able to troubleshoot experimentation errors independently but need guidance in resolving them

Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

## **LAB SESSION 05**

To design and analyze the full-wave Bridge rectifier

**Student Name:**

**Roll no.:**

**Batch:**

**Semester :**

**Year:**

<b>Total Marks</b>	<b>Marks Obtained</b>

**Remarks (if any) :**

**Instructor Name:**

**Instructor Signature:**

**Date:**

# LAB SESSION 05

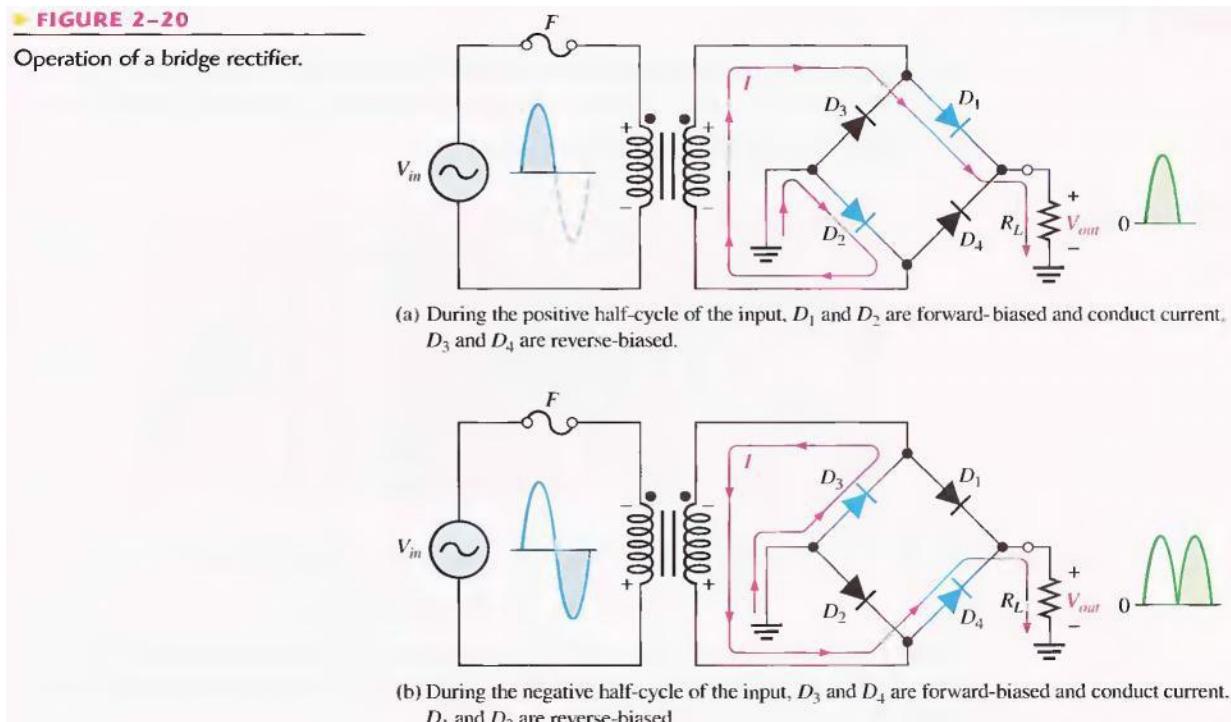
## Objective

To design and analyze the full-wave Bridge rectifier

## Theory

### Introduction

The bridge rectifier uses four diodes connected as shown in Figure 2-20. When the input cycle is positive as in part (a), diodes D<sub>1</sub> and D<sub>2</sub> are forward-biased and conduct current in the direction shown. A voltage is developed across R<sub>L</sub> that looks like the positive half of the input cycle. During this time, diodes D<sub>3</sub> and D<sub>4</sub> are reverse-biased.



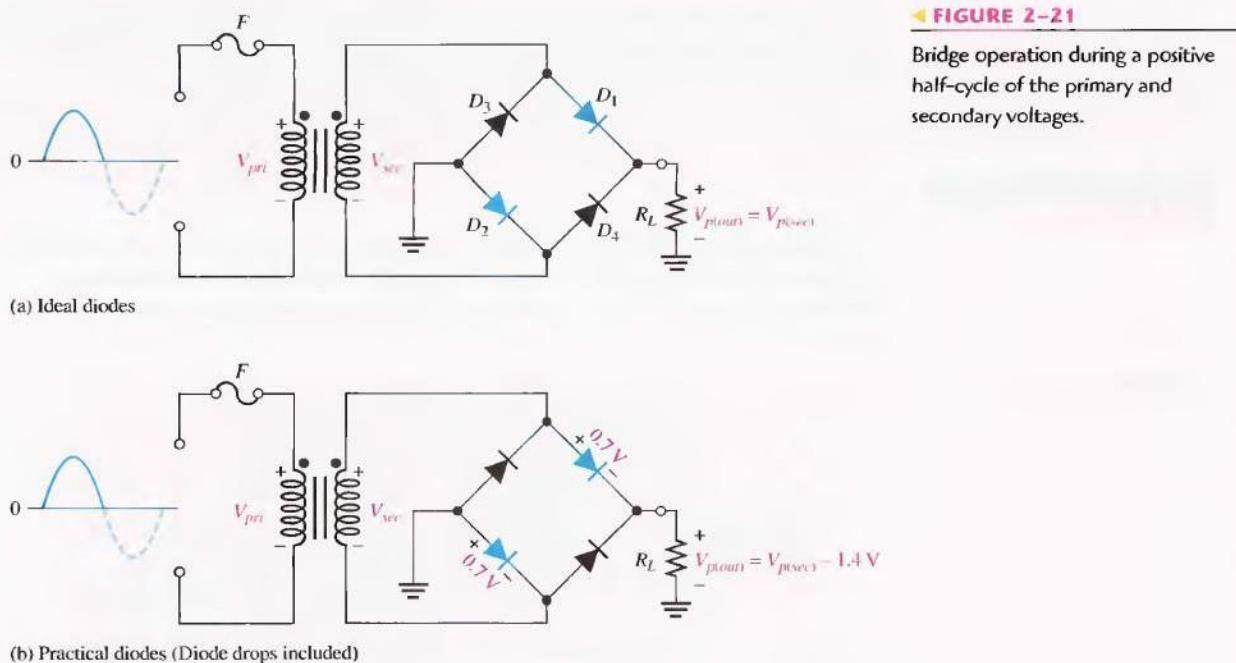
When the input cycle is negative as in Figure 2-20(b), diodes D<sub>3</sub> and D<sub>4</sub> are forward-biased and conduct current in the same direction through R<sub>L</sub> as during the positive half-cycle. During the negative half-cycle, D<sub>1</sub> and D<sub>2</sub> are reverse-biased. A full-wave rectified output voltage appears across R<sub>L</sub> as a result of this action.

**Bridge Output Voltage:** A bridge rectifier with a transformer-coupled input is shown in Figure 2-21 (a). During the positive half-cycle of the total secondary voltage, diodes D<sub>1</sub> and D<sub>2</sub> are forward-biased. Neglecting the diode drops, the secondary voltage appears across the load resistor. The same is true when D<sub>3</sub> and D<sub>4</sub> are forward-biased during the negative half-cycle.

$$V_{P(out)} = V_{P(sec)}$$

◀ FIGURE 2-21

Bridge operation during a positive half-cycle of the primary and secondary voltages.



As you can see in Figure 2-21 (b), two diodes are always in series with the load resistor during both the positive and negative half-cycles. If these diode drops are taken into account, the output voltage is

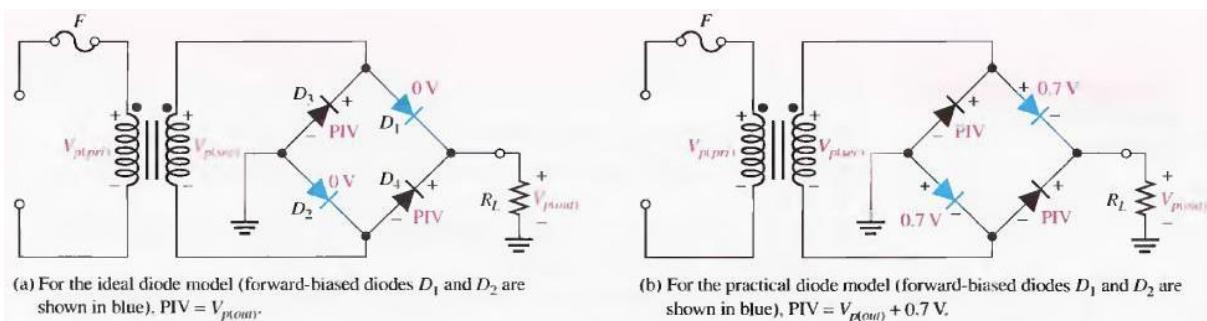
$$V_{P(out)} = V_{P(sec)} - 1.4 \text{ V}$$

**Peak Inverse Voltage:** Let's assume that  $D_1$  and  $D_2$  are forward-biased and examine the reverse voltage across  $D_3$  and  $D_4$ . Visualizing  $D_1$  and  $D_2$  as shorts (ideal model), as in Figure 2-22(a), you can see that  $D_3$  and  $D_4$ , have a peak inverse voltage equal to the peak secondary voltage. Since the output voltage is ideally equal to the secondary voltage,

$$\text{PIV} = V_{P(out)}$$

If the diode drops of the forward-biased diodes are included as shown in Figure 2-22(b), the peak inverse voltage across each reverse-biased diode in terms of  $V_{P(out)}$  is

$$\text{PIV} = V_{P(out)} + 0.7 \text{ V}$$



◀ FIGURE 2-22

Peak inverse voltages across diodes  $D_3$  and  $D_4$  in a bridge rectifier during the positive half-cycle of the secondary voltage.

The PIV rating of the bridge diodes is less than that required for the center-tapped configuration, if the diode drop is neglected. The bridge rectifier requires diodes with half the PIV rating of those in a center-tapped rectifier for the same output voltage.

## **Pre-lab**

### **Objective**

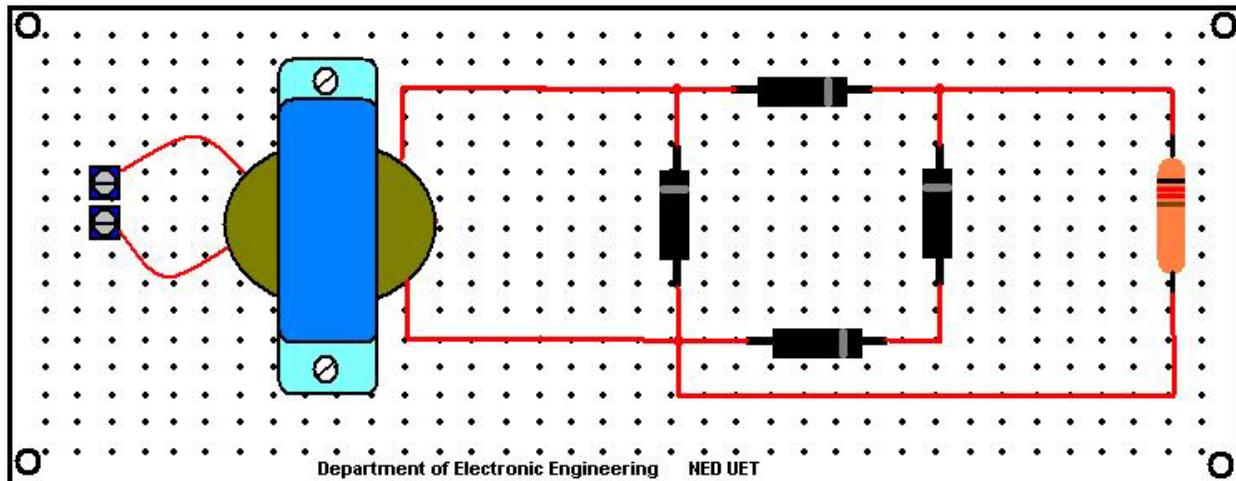
To construct a Full-Wave Bridge rectifier on a bread-board

### **Equipment required**

- 1- Bread-board
- 2- Four silicon diodes (1N4001)
- 3- Transformer (220V – 12V)
- 4- Resistor (10k $\Omega$ )
- 5- Jumpers

### **Procedure**

- 1- Test the diodes using diode tester in multimeter.
- 2- Make the circuit as shown, on Bread-board.
- 3- Test the continuity of all connections.



## **Laboratory procedure**

### **Objective**

To apply a Sine wave input to the full wave rectifier circuit & observe the output waveform & parameters.

### **Equipment required**

- 1- Oscilloscope
- 2- Circuit constructed in PRE-LAB

### **Procedure**

- 1- Using wire, supply the voltages coming from wall socket at the circuit input.
- 2- Observe the output using Oscilloscope & note down Vpeak-peak, Frequency, rms value & average value.
- 3- Observe the output of transformer & note down all values.
- 4- Now observe the output across resistor using oscilloscope & note down same values as mentioned in above step.

### **Observations**

Readings	Vpeak-peak	Frequency	Rms Value	Average Value
Input to transformer				
Transformer output				
Circuit output				

## **Post lab**

### **Calculations**

Using the formulas given in introduction of this lab & input values to the circuit, fill out:

Readings	Vpeak-peak	Frequency	Rms Value	Average Value
Input to transformer				
Transformer output				
Circuit output				

## **Task to be submitted**

- 5- Make the same circuit on Multisim & attach the print out of observed outputs.
- 6- Make the same circuit with output resistance  $1K\Omega$ ,  $100K\Omega$  &  $1M\Omega$  & write the change in output values in the following table.

Readings	Vpeak-peak	Frequency	rms Value	Average Value
$1K\Omega$				
$100K\Omega$				
$1M\Omega$				

- 7- In multisim, reverse the direction of each diode one by one & write the output values in each case. Also provide the reason for each output.
- 8- In multisim, make the same circuit with one changing, i.e apply supply at the transformer secondary connect the rest circuit with transformer's primary, what happens at output??? Provide the reason also.

9- The mean value of output voltage indicated on the voltmeter is it the same as it was for half-wave rectifier? If there is any difference explain why?

10- How does the mean value compare with that found for half-wave rectification?

**NED University of Engineering and Technology, Karachi**  
**Department of Electronic Engineering**

Course Code: \_\_\_\_\_ Course Name: \_\_\_\_\_

Laboratory Session No. \_\_\_\_\_ Date: \_\_\_\_\_

Skill Sets	Psychomotor Domain Assessment Rubric-Level P3			
	Extent of Achievement			
	0	1	2	3
<b>Equipment Identification</b> Sensual ability to identify equipment and/or its component for a lab work	Unable to identify the equipment	Able to identify very few equipment and components to be used in lab work	Able to identify some of the equipment and components to be used in lab work	Able to identify most of the equipment and components to be used in lab work
<b>Procedural Skills</b> Displays skills to act upon sequence of steps in lab work	Unable to either learn or perform lab work procedure	Able to slightly understand lab work procedure and perform lab work	Able to somewhat understand lab work procedure and perform lab work	Able to moderately understand lab work procedure and perform lab work
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Ability to troubleshoot errors and try to resolve with/without the supervision or guidance	Unable to troubleshoot experimentation errors and resolve them	Able to troubleshoot experimentation errors but cannot resolve them	Able to troubleshoot experimentation errors and resolve them under supervision	Able to troubleshoot experimentation errors independently but need guidance in resolving them

Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

## **LAB SESSION 06**

To design different filters and compare their performance for smooth output.

**Student Name:**

**Roll no.:                          Batch:**

**Semester :                          Year:**

<b>Total Marks</b>	<b>Marks Obtained</b>

**Remarks (if any) :**

**Instructor Name:**

**Instructor Signature:**                                    **Date:**

# LAB SESSION 06

## Objective

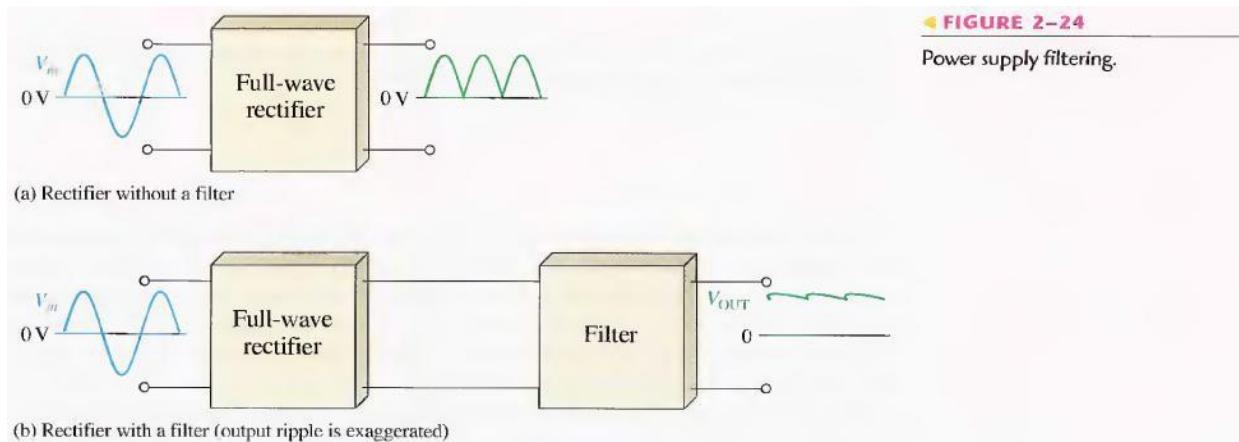
To design different filters and compare their performance for smooth output.

## Introduction

### **Power supply filters**

A power supply filter ideally eliminates the fluctuations in the output voltage of a half-wave or full-wave rectifier and produces a constant-level dc voltage. Filtering is necessary because electronic circuits require a constant source of dc voltage and current to provide power and biasing for proper operation. Filters are implemented with capacitors, as you will see in this section. Voltage regulation in power supplies is usually done with integrated circuit voltage regulators. A voltage regulator prevents changes in the filtered dc voltage due to variations in input voltage or load.

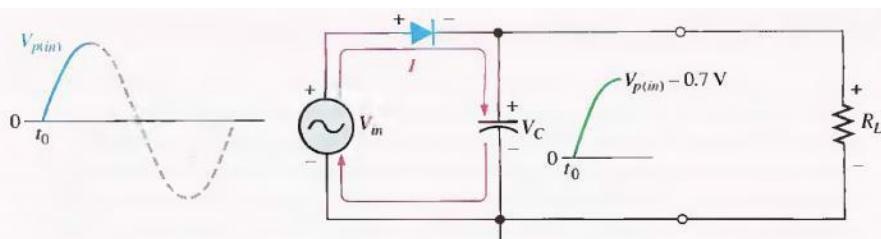
In most power supply applications, the standard 50 Hz ac power line voltage must be converted to an approximately constant dc voltage. The 50 Hz pulsating dc output of a half-wave rectifier or the 100 Hz pulsating output of a full-wave rectifier must be filtered to reduce the large voltage variations. Figure 2-24 illustrates the filtering concept showing a nearly smooth dc output voltage from the filter. The small amount of fluctuation in the filter output voltage is called ripple.



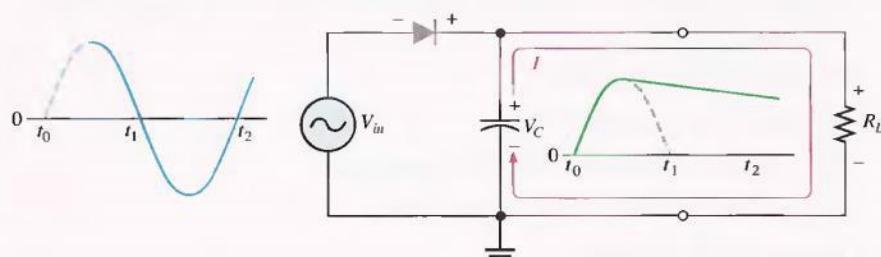
**Capacitor-Input filter:** A half-wave rectifier with a capacitor-input filter is shown in Figure 2-25. The filter is simply a capacitor connected from the rectifier output to ground.  $R_L$  represents the equivalent resistance of a load. We will use the half-wave rectifier to illustrate the basic principle and then expand the concept to full-wave rectification.

► FIGURE 2-25

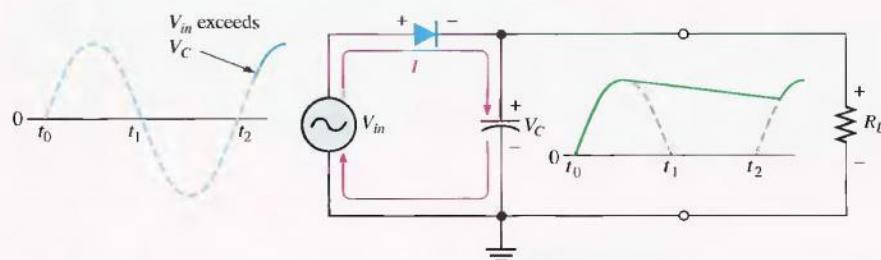
Operation of a half-wave rectifier with a capacitor-input filter. The current indicates charging or discharging of the capacitor.



(a) Initial charging of the capacitor (diode is forward-biased) happens only once when power is turned on.



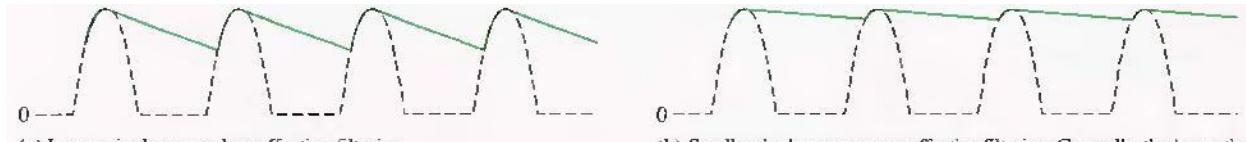
(b) The capacitor discharges through  $R_L$  after peak of positive alternation when the diode is reverse-biased. This discharging occurs during the portion of the input voltage indicated by the solid blue curve.



(c) The capacitor charges back to peak of input when the diode becomes forward-biased. This charging occurs during the portion of the input voltage indicated by the solid blue curve.

During the positive first quarter-cycle of the input, the diode is forward-biased, allowing the capacitor to charge to within 0.7 V of the input peak, as illustrated in Figure 2-25(a). When the input begins to decrease below its peak, as shown in part (b), the capacitor retains its charge and the diode becomes reverse-biased because the cathode is more positive than the anode. During the remaining part of the cycle, the capacitor can discharge only through the load resistance at a rate determined by the  $R L C$  time constant, which is normally long compared to the period of the input. The larger the time constant, the less the capacitor will discharge. During the first quarter of the next cycle, as illustrated in part (c), the diode will again become forward-biased when the input voltage exceeds the capacitor voltage by approximately 0.7 V.

**Ripple Voltage:** As you have seen, the capacitor quickly charges at the beginning of a cycle and slowly discharges through  $R_L$  after the positive peak of the input voltage (when the diode is reverse-biased). The variation in the capacitor voltage due to the charging and discharging is called the ripple voltage. Generally, ripple is undesirable; thus, the smaller the ripple, the better the filtering action, as illustrated in Figure 2-26.



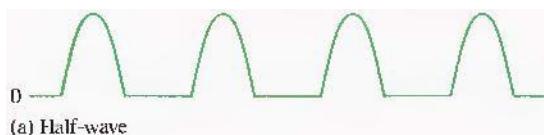
(a) Larger ripple means less effective filtering.

(b) Smaller ripple means more effective filtering. Generally, the larger the capacitor value, the smaller the ripple for the same input and load.

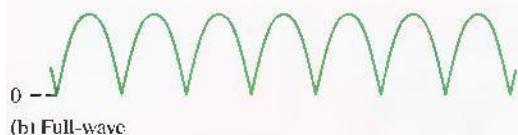
**FIGURE 2-26**

Half-wave ripple voltage (green line).

For a given input frequency, the output frequency of a full-wave rectifier is twice that of a half-wave rectifier, as illustrated in Figure 2-27. This makes a full-wave rectifier easier to filter because of the shorter time between peaks. When filtered, the full-wave rectified voltage has a smaller ripple than does a half-wave voltage for the same load resistance and capacitor values. The capacitor discharges less during the shorter interval between full-wave pulses, as shown in Figure 2-28.



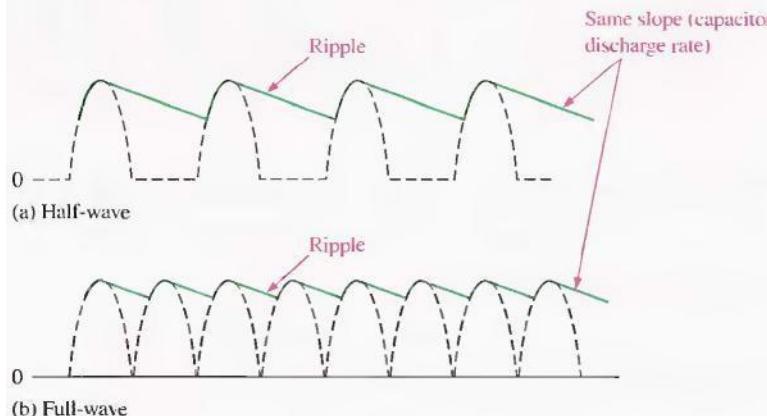
(a) Half-wave



(b) Full-wave

**FIGURE 2-27**

The frequency of a full-wave rectified voltage is twice that of a half-wave rectified voltage.



**FIGURE 2-28**

Comparison of ripple voltages for half-wave and full-wave rectified voltages with the same filter capacitor and load and derived from the same sinusoidal input voltage.

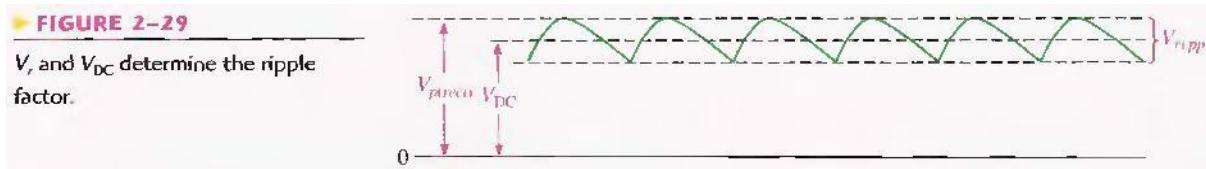
**Ripple Factor:** The ripple factor ( $r$ ) is an indication of the effectiveness of the filter and is defined as:

$$r = \frac{V_{r(pp)}}{V_{DC}}$$

Equation 2-10

where  $V_{r(pp)}$  is the peak-to-peak ripple voltage and  $V_{DC}$  is the dc (average) value of the filter's output voltage, as illustrated in Figure 2-29. The lower the ripple factor, the better the filter. The

ripple factor can be lowered by increasing the value of the filter capacitor or increasing the load resistance.

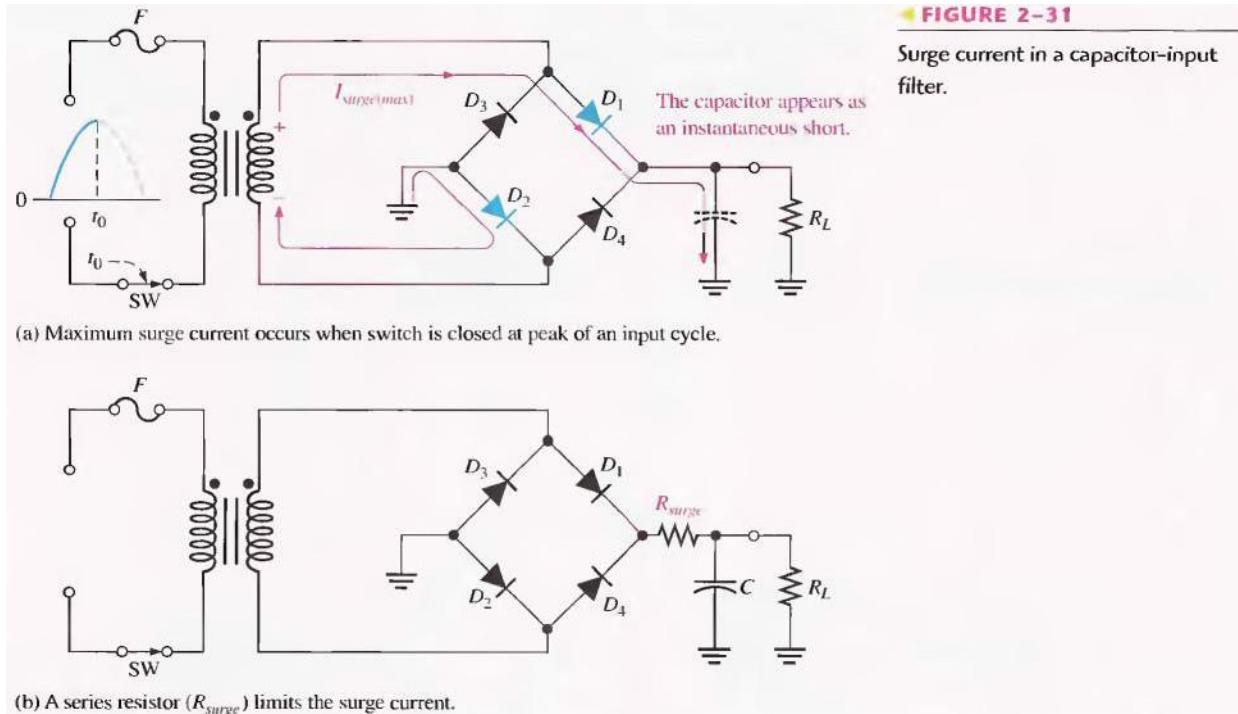


For a full-wave rectifier with a capacitor-input filter, approximations for the peak-to-peak ripple voltage,  $V_{r(pp)}$  and the dc value of the filter output voltage,  $V_{DC}$ , are given in the following expressions. The variable  $V_{p(rect)}$  is the unfiltered peak rectified voltage.

$$\text{Equation 2-11} \quad V_{r(pp)} \cong \left( \frac{1}{fR_L C} \right) V_{p(rect)}$$

$$\text{Equation 2-12} \quad V_{DC} \cong \left( 1 - \frac{1}{2fR_L C} \right) V_{p(rect)}$$

**Surge Current in the Capacitor-Input Filter:** Before the switch in Figure 2-31(a) is closed, the filter capacitor is uncharged. At the instant the switch is closed, voltage is connected to the bridge and the uncharged capacitor appears as a short, as shown. This produces an initial surge of current,  $I_{surge}$  through the two forward-biased diodes  $D_1$  and  $D_2$ . The worst-case situation occurs when the switch is closed at a peak of the secondary voltage and a maximum surge current,  $I_{surge(max)}$  is produced, as illustrated in the figure.



It is possible that the surge current could destroy the diodes, and for this reason a surge-limiting resistor is sometimes connected, as shown in Figure 2-31(b). The value of this resistor must be small compared to  $R_L$ . Also, the diodes must have a maximum forward surge current rating such that they can withstand the momentary surge of current. This rating is specified on diode data sheets as  $I_{FSM}$ . The minimum surge resistor value can be calculated as follows:

$$R_{\text{surge}} = \frac{V_{p(\text{surge})} - 1.4 \text{ V}}{I_{\text{FSM}}}$$
Equation 2-13

## Voltage Regulators

While filters can reduce the ripple from power supplies to a low value, the most effective approach is a combination of a capacitor-input filter used with a voltage regulator. A voltage regulator is connected to the output of a filtered rectifier and maintains a constant output voltage (or current) despite changes in the input, the load current, or the temperature. The capacitor-input filter reduces the input ripple to the regulator to an acceptable level. The combination of a large capacitor and a voltage regulator helps produce an excellent power supply.

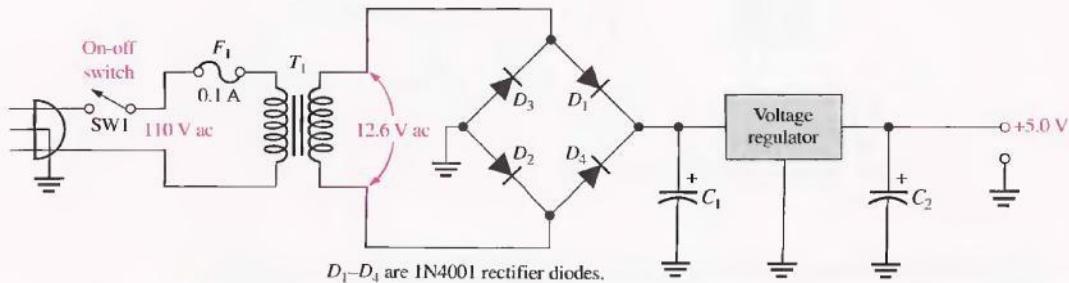
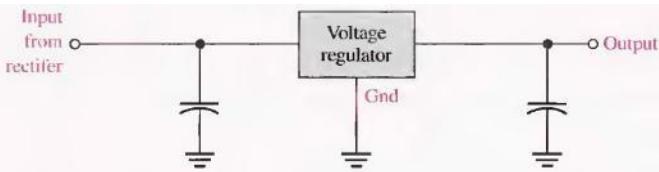
Most regulators are integrated circuits and have three terminals, an input terminal an output terminal and a reference (or adjust) terminal. The input to the regulator is first filtered with a capacitor to reduce the ripple to < 10%. The regulator reduces the ripple to a negligible amount. In addition, most regulators have an internal voltage reference, short circuit protection and thermal shutdown circuitry. They are available in a variety of voltages, including positive and negative outputs, and can be designed for variable outputs with a minimum of external components. Typically, voltage regulators can furnish a constant output of one or more amps of current with high ripple rejection.

Three-terminal regulators designed for fixed output voltages require only external capacitors to complete the regulation portion of the power supply, as shown in Figure 2-32. Filtering is accomplished by a large-value capacitor between the input voltage and ground. An output capacitor (typically 0.1  $\mu\text{F}$  to 1.0  $\mu\text{F}$ ) is connected from the output to ground to improve the transient response.

A basic fixed power supply with a +5 V voltage regulator is shown in Figure 2-33.

► FIGURE 2–32

A voltage regulator with input and output capacitors.



▲ FIGURE 2–33

A basic +5.0 V regulated power supply.

### Percent Regulation

The regulation expressed as a percentage is a figure of merit used to specify the performance of a voltage regulator. It can be in terms of input (line) regulation or load regulation. Line regulation specifies how much change occurs in the output voltage for a given change in the input voltage. It is typically defined as a ratio of a change in output voltage for a corresponding change in the input voltage expressed as a percentage.

$$\text{Line regulation} = \left( \frac{\Delta V_{\text{OUT}}}{\Delta V_{\text{IN}}} \right) 100\%$$

Equation 2–14

Load regulation specifies how much change occurs in the output voltage over a certain range of load current values, usually from minimum current (no load, NL) to maximum current (full load, FL). It is normally expressed as a percentage and can be calculated with the following formula:

$$\text{Load regulation} = \left( \frac{V_{\text{NL}} - V_{\text{FL}}}{V_{\text{FL}}} \right) 100\%$$

Equation 2–15

where V<sub>NL</sub> is the output voltage with no load and V<sub>FL</sub> is the output voltage with full (maximum) load.

### Pre-lab

### Objective

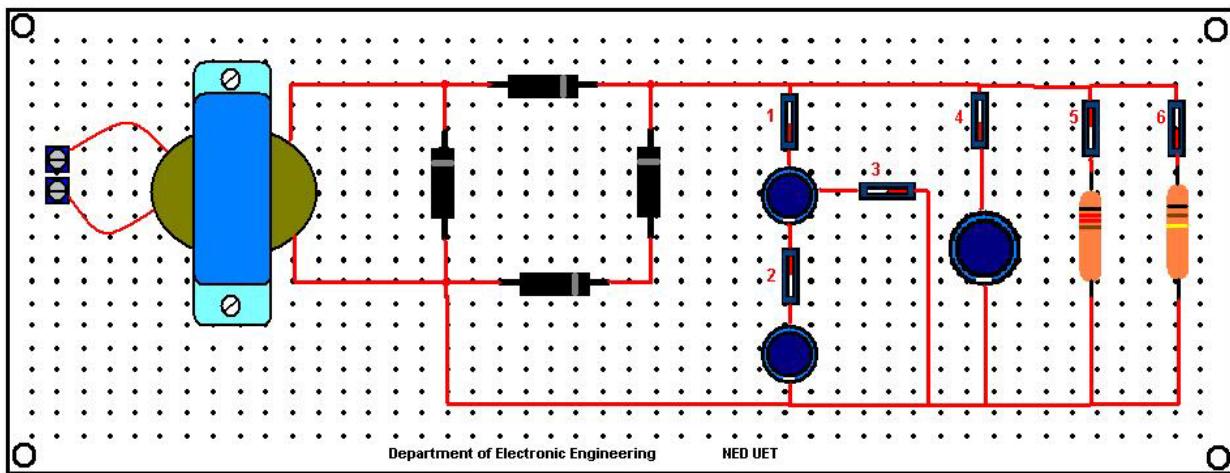
To insert capacitive filter in the circuit of half wave rectifier.

## **Equipment required**

- 1- Above three circuits on bread-board
- 2- Polar capacitors ( $4.7 \mu F$ ,  $47 \mu F$ ,  $470 \mu F$ )
- 3- Transformer (220V – 12V)
- 4- Resistor ( $10k\Omega$ )
- 5- Jumpers

## **Procedure**

- 1- Test the diodes using diode tester in multimeter.
- 2- Make the circuit as shown, on bread-board.
- 3- After making the circuit should look like this.



- 4- Test the continuity of all connections.

## **Laboratory procedure**

## **Objective**

To apply the output of each rectifier circuit to the filter circuit & observe the output waveform & parameters.

## **Equipment required**

- 1- Oscilloscope
- 2- Circuit constructed in PRE-LAB

## **Procedure**

- 1- Using wire, supply the voltages coming from wall socket at the circuit input.

- 2- Observe the output using Oscilloscope & note down Vpeak-peak, Frequency, rms value & average value.
- 3- Observe the output of transformer & note down all values.
- 4- Now observe the output across resistor using oscilloscope & note down same values as mentioned in above step.
- 5- Change the position of switches so as to make different RC combinations & observe the output & note down.

### **Observations without capacitor**

Readings	Vpeak-peak	Frequency	Rms Value	Average Value	Ripple Voltage
Input to transformer					
Transformer output					
Circuit output without capacitor					

### **Observations with capacitor**

Circuit Output with capacitor	Pk-Pk voltage	Ripple voltage
With $R = 200\Omega$ , $C = 10\mu F$		
With $R = 3k\Omega$ , $C = 10\mu F$		
With $R = 200\Omega$ , $C = 470\mu F$		

### **Post lab**

### **Calculations**

Using the formulas given in introduction of this lab & input values to the circuit, fill out:

Readings	Vpeak-peak	Frequency	Rms Value	Average Value	Ripple Voltage
Input to transformer					
Transformer output					
Circuit output without capacitor					

Circuit Output with capacitor	Pk-Pk voltage	Ripple voltage
With $R = 200\Omega$ , $C = 10\mu F$		
With $R = 3k\Omega$ , $C = 10\mu F$		
With $R = 200\Omega$ , $C = 470\mu F$		

### **Task to be submitted**

- 1- Make the same circuit on multisim & attach the print out of observed outputs.
- 2- State types of following filters & also the substance/parameter which they filter out & passes.

Name	Filter out?
Water filter	
Dc filters	
Communication receiver filter	

- 3- If capacitors are inserted in parallel then their total equivalent capacitance will become increase. Will you prefer small sized capacitor in parallel or a single big capacitor in your circuit for filtration? Why?
- 4- What is the difference b/w polar & non-polar capacitor? Can we insert polar capacitor in ac circuits? Why or why not? Can we insert non polar capacitor in dc circuits? Why or why not?
- 5- Find the voltage regulation of the circuit you have made.

**NED University of Engineering and Technology, Karachi**  
**Department of Electronic Engineering**

Course Code: \_\_\_\_\_ Course Name: \_\_\_\_\_

Laboratory Session No. \_\_\_\_\_ Date: \_\_\_\_\_

Skill Sets	Psychomotor Domain Assessment Rubric-Level P3				
	0	1	2	3	4
Equipment Identification Sensual ability to identify equipment and/or its component for a lab work	Unable to identify the equipment	Able to identify very few equipment and components to be used in lab work	Able to identify some of the equipment and components to be used in lab work	Able to identify most of the equipment and components to be used in lab work	Able to identify all of the equipment as well as its components
Procedural Skills Displays skills to act upon sequence of steps in lab work	Unable to either learn or perform lab work procedure	Able to slightly understand lab work procedure and perform lab work	Able to somewhat understand lab work procedure and perform lab work	Able to moderately understand lab work procedure and perform lab work	Fully understands lab work procedure and perform lab work
Response Capability to initiate the lab work on his/her own	Unable to initiate the lab work	Able to slightly initiate the lab work	Able to somewhat initiate the lab work	Able to moderately initiate the lab work	Fully initiates lab work
Observation's Use Displays skills to perform related mathematical calculations using the observations from lab work	Unable to use lab work observations for mathematical calculations	Able to slightly use lab work observations for mathematical calculations	Able to somewhat use lab work Observations for mathematical calculations	Able to moderately use lab work Observations for mathematical calculations	Fully use lab work Observations for mathematical calculations
Equipment Use Sensory skills to describe the use of the equipment for the lab work	Unable to describe the use of equipment	Rarely able to describe the use of equipment	Occasionally describe the use of equipment	Often able to describe the use of equipment	Regularly able to describe the use of equipment
Equipment Handling Equipment care during the use	Doesn't handle Equipment with required care	Rarely handles equipment with required care	Occasionally handles Equipment with required care	Often handles Equipment with required care	Handles equipment with required care
Ability to troubleshoot errors and try to resolve with/without the supervision or guidance	Unable to troubleshoot experimentation errors and resolve them	Able to troubleshoot experimentation errors but cannot resolve them	Able to troubleshoot experimentation errors and resolve them under supervision	Able to troubleshoot experimentation errors independently but need guidance in resolving them	Able to troubleshoot experimentation errors and resolve them without supervision or guidance

Weighted CLO (Psychomotor Score)	_____
Remarks	_____
Instructor's Signature with Date:	_____

## **LAB SESSION7**

**To design, analyze and measure the output of diode limiters**

**Student Name:**

**Roll no.:                          Batch:**

**Semester :**                          **Year:**

<b>Total Marks</b>	<b>Marks Obtained</b>

**Remarks (if any) :**

**Instructor Name:**

**Instructor Signature:**                          **Date:**

## **LAB SESSION7**

### **Objective**

**To design, analyze and measure the output of diode limiters**

### **Introduction**

Figure 2-34(a) shows a diode limiter (also called clipper) that limits or clips the positive part of the input voltage. As the input voltage goes positive, the diode becomes forward-biased and conducts current. Because, the cathode is at ground potential (0 V), the anode cannot exceed

0.7V (assuming silicon). So point A is limited to +0.7V when the input voltage exceeds this value. When the input voltage goes back below 0.7 V, the diode is reverse- biased and appears as an open. The output voltage looks like the negative part of the input voltage, but with a magnitude determined by the voltage divider formed by R<sub>1</sub> and the load resistor, R<sub>L</sub>, as follows:

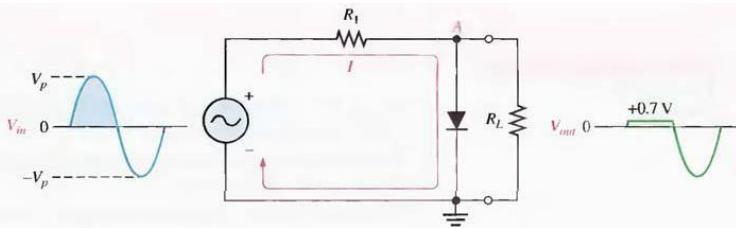
$$V_{out} = \left( \frac{R_L}{R_1 + R_L} \right) V_{in}$$

If R<sub>1</sub> is small compared to R<sub>L</sub>, then V<sub>out</sub> = V<sub>in</sub>.

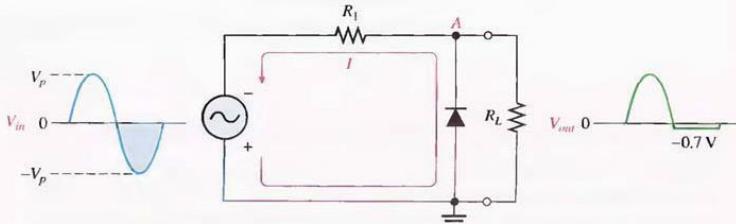
If the diode is turned around, as in Figure 2- 34(b), the negative part of the input voltage is clipped off. When the diode is forward-biased during the negative part of the input voltage, point A is held at -0.7 V by the diode drop. When the input voltage goes above -0.7 V, the diode is no longer forward-biased; and a voltage appears across R<sub>L</sub> proportional to the input voltage.

**FIGURE 2-34**

Examples of diode limiters (clippers).



(a) Limiting of the positive alternation. The diode is forward-biased during the positive alternation (above 0.7 V) and reverse-biased during the negative alternation.



(b) Limiting of the negative alternation. The diode is forward-biased during the negative alternation (below -0.7 V) and reverse-biased during the positive alternation.

## Pre-lab

### Objective

To construct the circuits of fig-2-34 on bread board & test the continuity.

### **Laboratory procedure**

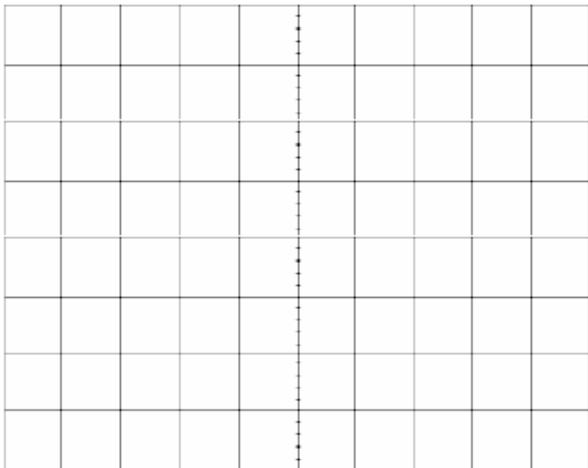
### Objective

To apply input to the above mentioned circuits & find out outputs.

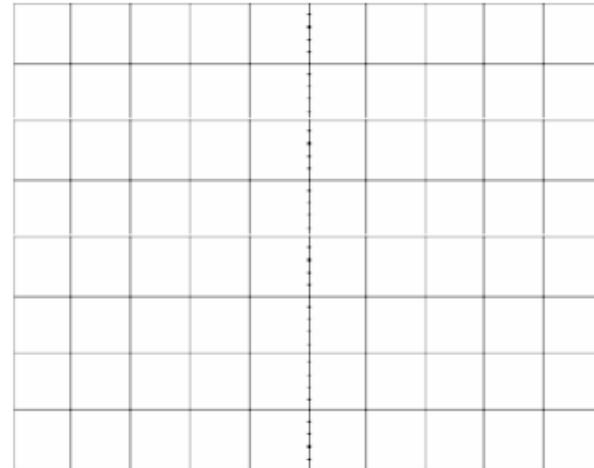
### Procedure

- 1- Set the function generator to 1KHz, 5Vpk-pk sine wave using oscilloscope.
- 2- Now apply the input to the circuits one by one & observe their output using oscilloscope.
- 3- Keep on filling the observation tables.

## **Observations**



Positive peak V= \_\_\_\_\_  
Negative peak V = \_\_\_\_\_



Positive peak V= \_\_\_\_\_  
Negative peak V = \_\_\_\_\_

## **Post lab**

### **Task to be submitted**

- 1- Write the application of Clipper in electronics circuits.
- 2- Make the circuit of Fig. fig-2-34 on Multisim & attach the print out of observed outputs.
- 3- Change the input supply to triangular and square waves and observe the output on  
Multisim.

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**Department of Electronic Engineering**

Course Code: \_\_\_\_\_ Course Name: \_\_\_\_\_

Laboratory Session No. \_\_\_\_\_ Date: \_\_\_\_\_

Skill Sets	Psychomotor Domain Assessment Rubric-Level P3				
	0	1	2	3	4
Equipment Identification Sensual ability to identify equipment and/or its component for a lab work	Unable to identify the equipment	Able to identify very few equipment and components to be used in lab work	Able to identify some of the equipment and components to be used in lab work	Able to identify most of the equipment and components to be used in lab work	Able to identify all of the equipment as well as its components
Procedural Skills Displays skills to act upon sequence of steps in lab work	Unable to either learn or perform lab work procedure	Able to slightly understand lab work procedure and perform lab work	Able to somewhat understand lab work procedure and perform lab work	Able to moderately understand lab work procedure and perform lab work	Fully understands lab work procedure and perform lab work
Response Capability to initiate the lab work on his/her own	Unable to initiate the lab work	Able to slightly initiate the lab work	Able to somewhat initiate the lab work	Able to moderately initiate the lab work	Fully initiates lab work
Observation's Use Displays skills to perform related mathematical calculations using the observations from lab work	Unable to use lab work observations for mathematical calculations	Able to slightly use lab work observations for mathematical calculations	Able to somewhat use lab work Observations for mathematical calculations	Able to moderately use lab work Observations for mathematical calculations	Fully use lab work Observations for mathematical calculations
Equipment Use Sensory skills to describe the use of the equipment for the lab work	Unable to describe the use of equipment	Rarely able to describe the use of equipment	Occasionally describe the use of equipment	Often able to describe the use of equipment	Regularly able to describe the use of equipment
Equipment Handling Equipment care during the use	Doesn't handle Equipment with required care	Rarely handles equipment with required care	Occasionally handles Equipment with required care	Often handles Equipment with required care	Handles equipment with required care
Ability to troubleshoot errors and try to resolve with/without the supervision or guidance	Unable to troubleshoot experimentation errors and resolve them	Able to troubleshoot experimentation errors but cannot resolve them	Able to troubleshoot experimentation errors and resolve them under supervision	Able to troubleshoot experimentation errors independently but need guidance in resolving them	Able to troubleshoot experimentation errors and resolve them without supervision or guidance

Weighted CLO (Psychomotor Score)	_____
Remarks	_____
Instructor's Signature with Date:	_____

## **LAB SESSION 08**

To design, analyze and measure the output of diode clamps.

**Student Name:**

**Roll no.:**

**Batch:**

**Semester :**

**Year:**

<b>Total Marks</b>	<b>Marks Obtained</b>

**Remarks (if any) :**

**Instructor Name:**

**Instructor Signature:**

**Date:**

# LAB SESSION 8

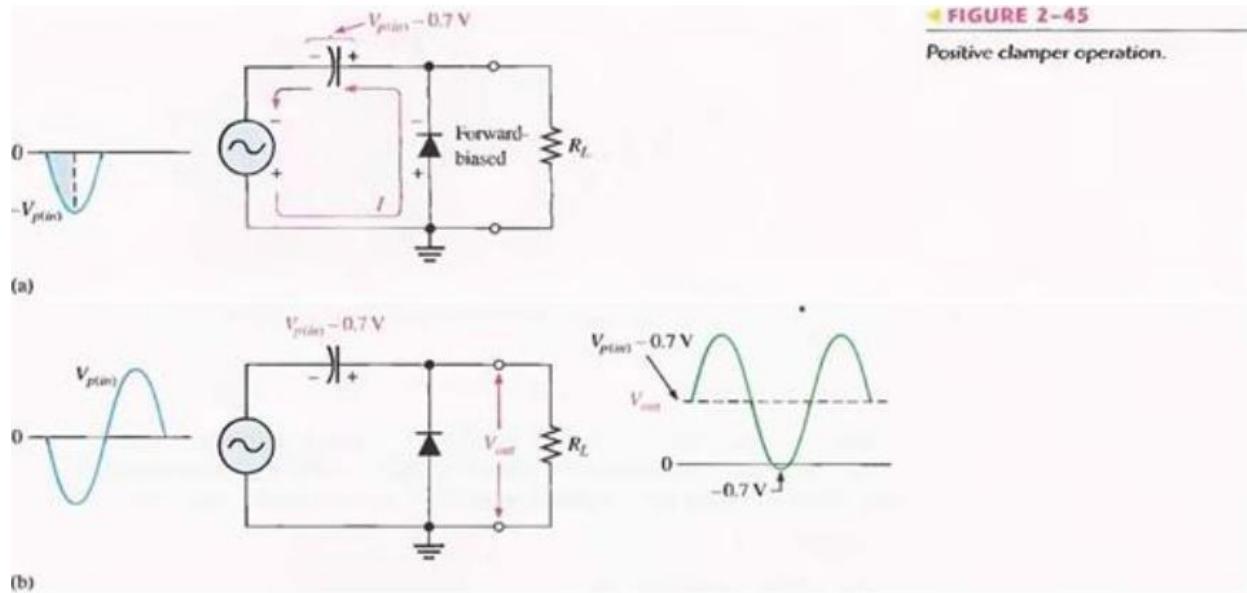
## Objective

To design, analyze and measure the output of diode clampers.

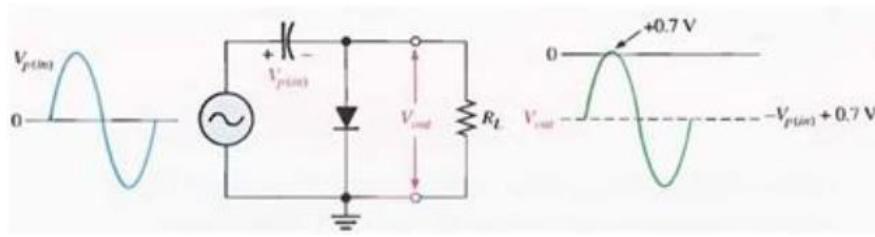
## Theory Introduction

### Diode Clampers

A clumper adds a dc level to an ac voltage. Clampers are sometimes known as dc restorers. Figure 2-45 shows a diode clumper that inserts a positive dc level in the output waveform. The operation of this circuit can be seen by considering the first negative half-cycle of the input voltage. When the input voltage initially goes negative, the diode is forward-biased, allowing the capacitor to charge to near the peak of the input ( $V_{p(in)}$  - 0.7 V), as shown in Figure 2-45(a). Just after the negative peak, the diode is reverse-biased. This is because the cathode is held near  $V_{p(in)} - 0.7$  V by the charge on the capacitor. The capacitor can only discharge through the high resistance of  $R_L$ . So, from the peak of one negative half-cycle to the next, the capacitor discharges very little. The amount that is discharged, of course, depends on the value of  $R_L$ . For good clamping action, the RC time constant should be at least ten times the period of the input frequency.



The net effect of the clamping action is that the capacitor retains a charge approximately equal to the peak value of the input less the diode drop. The capacitor voltage acts essentially as a battery in series with the input voltage. The dc voltage of the capacitor adds to the input voltage by superposition, as in Figure 2-45(b). If the diode is turned around, a negative dc voltage is added to the input voltage to produce the output voltage as shown in Figure 2-46.



**FIGURE 2-46**

## Pre-lab

## Objective

To construct the circuits of fig-2-45 & 46 on bread board & test the continuity.

## **Laboratory procedure**

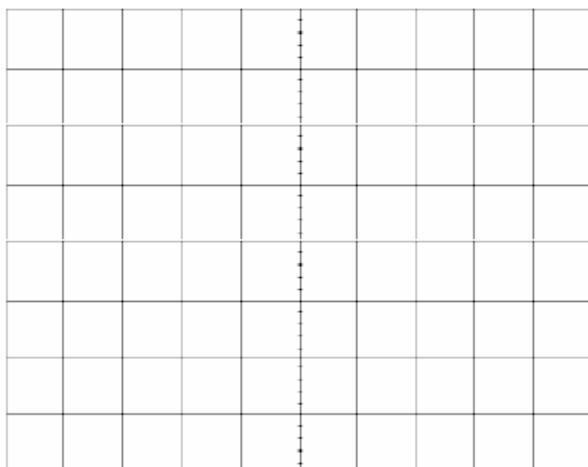
## Objective

To apply input to the above mentioned circuits & find out outputs

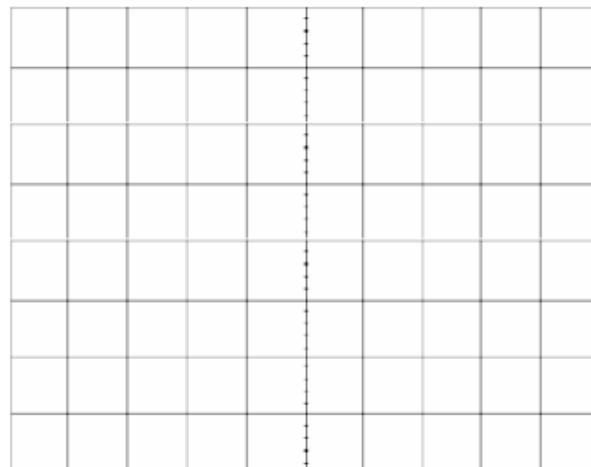
## **Procedure**

- 1- Set the function generator to 1KHz, 5Vpk-pk sine wave using oscilloscope.
  - 2- Now apply the input to the circuits one by one & observe there output using oscilloscope.
  - 3- Keep on filling the observation tables.

## Observations



Positive peak V=



Positive peak V=

Negative peak V =

Negative peak V =

### **Post lab**

#### **Task to be submitted**

- 1- Increase the frequency of the input waveform & find the frequency at which the output.

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**Department of Electronic Engineering**

Course Code: \_\_\_\_\_ Course Name: \_\_\_\_\_  
 Laboratory Session No. \_\_\_\_\_ Date: \_\_\_\_\_

Psychomotor Domain Assessment Rubric-Level P3						
Skill Sets	0	1	2	3	4	Extent of Achievement
<b>Equipment Identification</b> Sensual ability to identify equipment and/or its component for a lab work	Unable to identify the equipment	Able to identify very few equipment and components to be used in lab work	Able to identify some of the equipment and components to be used in lab work	Able to identify most of the equipment and components to be used in lab work	Able to identify all of the equipment as well as its components	
<b>Procedural Skills</b> Displays skills to act upon sequence of steps in lab work	Unable to either learn or perform lab work procedure	Able to slightly understand lab work procedure and perform lab work	Able to somewhat understand lab work procedure and perform lab work	Able to moderately understand lab work procedure and perform lab work	Fully understands lab work procedure and perform lab work	
<b>Response</b> Capability to initiate the lab work on his/her own	Unable to initiate the lab work	Able to slightly initiate the lab work	Able to somewhat initiate the lab work	Able to moderately initiate the lab work	Fully initiates lab work	
<b>Observation's Use</b> Displays skills to perform related mathematical calculations using the observations from lab work	Unable to use lab work observations for mathematical calculations	Able to slightly use lab work observations for mathematical calculations	Able to somewhat use lab work. Observations for mathematical calculations	Able to moderately use lab work. Observations for mathematical calculations	Fully use lab work observations for mathematical calculations	
<b>Equipment Use</b> Sensory skills to describe the use of the equipment for the lab work	Unable to describe the use of equipment	Rarely able to describe the use of equipment	Occasionally describe the use of equipment	Often able to describe the use of equipment	Regularly able to describe the use of equipment	
<b>Equipment Handling</b> equipment care during the use	Doesn't handle Equipment with required care	Rarely handles equipment with required care	Occasionally handles Equipment with required care	Often handles Equipment with required care	Handles equipment with required care	
Ability to troubleshoot errors and try to resolve with/without the supervision or guidance	Unable to troubleshoot experimentation errors but cannot resolve them	Able to troubleshoot experimentation errors but cannot resolve them under supervision	Able to troubleshoot experimentation errors independently but need guidance in resolving them	Able to troubleshoot experimentation errors and resolve them without supervision or guidance	Able to troubleshoot experimentation errors and resolve them without supervision or guidance	

Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

## **LAB SESSION 9**

To plot the characteristic curve of Zener Diode as a voltage regulator & find the Zener Voltage V<sub>Z</sub>.

**Student Name:**

**Roll no.:                          Batch:**

**Semester :                          Year:**

<b>Total Marks</b>	<b>Marks Obtained</b>

**Remarks (if any) :**

**Instructor Name:**

**Instructor Signature:**

**Date:**

# LAB SESSION 9

## Objective

To plot the characteristic curve of Zener Diode as a voltage regulator & find the Zener Voltage  $V_z$ .

## Theory

### Introduction

#### **ZENER DIODES**

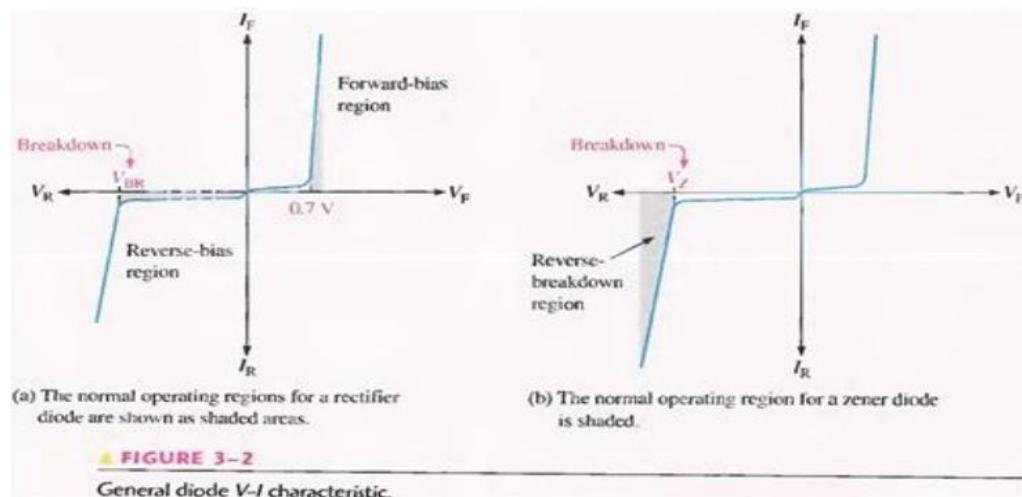


**FIGURE 3-1**

A major application for zener diode is as a type of voltage regulator for providing stable reference voltages for use in power supplies, voltmeters and other instruments. In this section, you will see how the zener diode maintains a nearly constant dc voltage under the proper operating conditions. You will learn the conditions and limitations for properly using the zener diode and the factors that affect its performance.

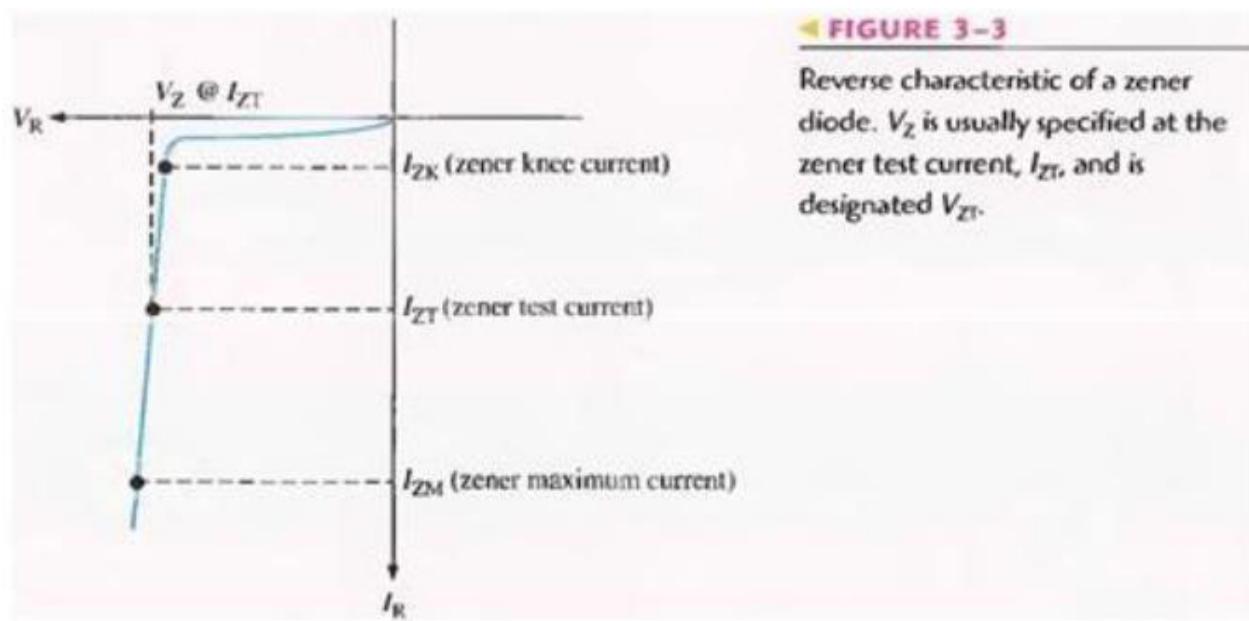
The symbol for a zener diode is shown in Figure 3-1. A zener diode is a silicon pn junction device that is designed for operation in the reversebreakdown region. The breakdown voltage of a zener diode is set by carefully controlling the doping level during manufacture.

Recall, from the discussion of the diode characteristic curve in Lab 3. That when a diode reaches reverse breakdown, its voltage remains almost constant even though the current changes drastically. This volt-ampere characteristic is shown again in Figure 3-2 with normal operating regions for rectifier diodes and for zener diodes shown as shaded areas. If a zener diode is forward-biased, it operates the same as a rectifier diode.



**Zener Breakdown** Zener diodes are designed to operate in reverse breakdown. Two types of reverse breakdown in a zener diode are avalanche and zener. The avalanche breakdown occurs in both rectifier and zener diodes at a sufficiently high reverse voltage. Zener breakdown occurs in a zener diode at low reverse voltages. A zener diode is heavily doped to reduce the breakdown voltage. This causes a very thin depletion region. As a result, an intense electric field exists within the depletion region. Near the zener breakdown voltage ( $V_z$ ), the field is intense enough to pull electrons from their valence bands and create current. Zener diodes with breakdown voltages of less than approximately 5 V operate predominately in zener breakdown. Those with breakdown voltages greater than approximately 5 V operate predominately in avalanche breakdown. Both types, however, are called zener diodes. Zeners are commercially available with breakdown voltages of 1.8 V to 200 V with specified tolerances from 1 % to 20%.

**Breakdown Characteristics** Figure 3-3 shows the reverse portion of a zener diode's characteristic curve. Notice that as the reverse voltage ( $V_R$ ) is increased, the reverse Current ( $I_R$ ) remains extremely small up to the "knee" of the curve. The reverse current is also called the zener current,  $I_z$ . At this point, the breakdown effect begins: the internal zener resistance, also called zener impedance ( $Z_z$ ), begins to decrease as the reverse current increases rapidly. From the bottom of the knee, the zener breakdown voltage ( $V_z$ ) remains essentially constant although it increases slightly as the zener current,  $I_z$ , increase.



◀ FIGURE 3-3

Reverse characteristic of a zener diode.  $V_z$  is usually specified at the zener test current,  $I_{ZT}$ , and is designated  $V_{ZT}$ .

**Zener Regulation** The ability to keep the reverse voltage across its terminals essentially constant is the key feature of the zener diode. A zener diode operating in breakdown acts as a voltage regulator because it maintains a nearly constant voltage across its terminals over a specified range of reverse-current values. A minimum value of reverse current,  $I_{ZK}$  must be maintained in order to keep the diode in breakdown for voltage regulation. You can see on the

curve in Figure 3-3 that when the reverse current is reduced below the knee of the curve, the voltage decreases drastically and regulation is lost. Also, there is a maximum current,  $I_{ZM}$  above which the diode may be damaged due to excessive power dissipation. So, basically, the zener diode maintains a nearly constant voltage across its terminals for values of reverse current ranging from  $I_{ZK}$ .

**Zener Equivalent Circuit** Figure 3-4(a) shows the ideal model of a zener diode in reverse breakdown. It has a constant voltage drop equal to the nominal zener voltage. This constant voltage drop is represented by a dc voltage source even though the zener diode does not actually produce an emf voltage. The dc source simply indicates that the effect of reverse breakdown is a constant voltage across the zener terminals.

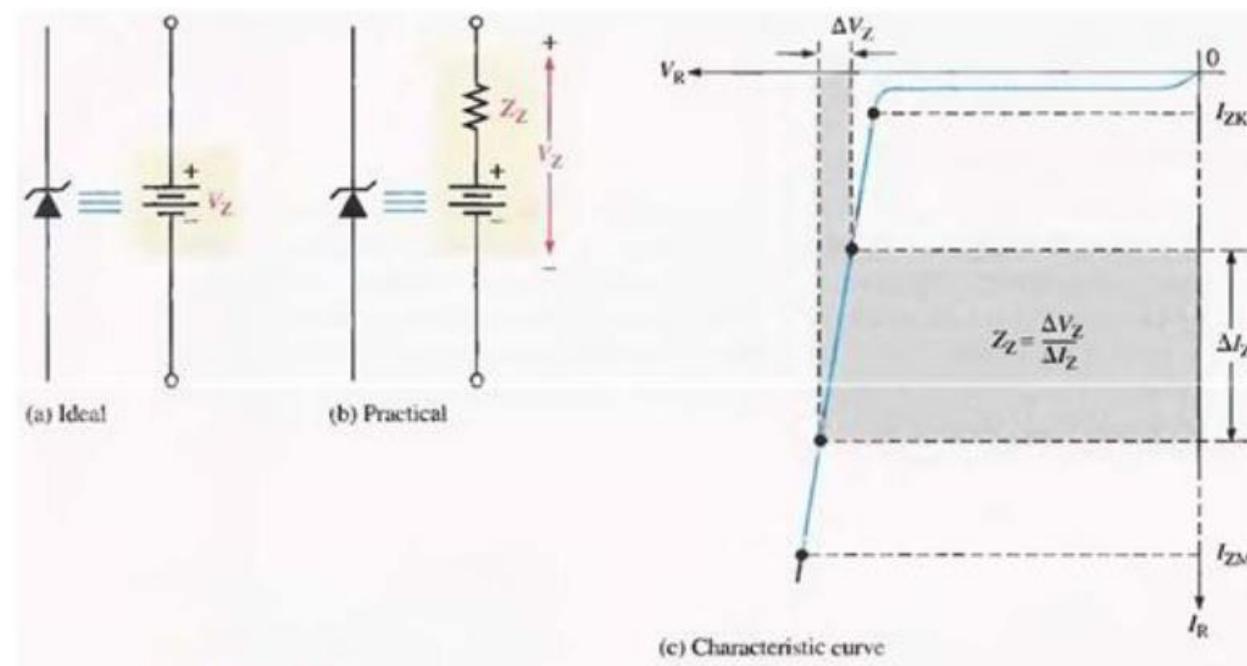


FIGURE 3-4

Zener diode equivalent circuit models and the characteristic curve illustrating  $Z_z$ .

Figure 3-4(b) represents the practical model of a zener diode, where the zener impedance ( $Z_z$ ) is included. Since the actual voltage curve is not ideally vertical, a change in zener current ( $\Delta I_z$ ) produces a small change in zener voltage ( $\Delta V_z$ ), as illustrated in Figure 3-4(c). By Ohm's law, the ratio of  $\Delta V_z$  to  $\Delta I_z$  is the impedance, as expressed in the following equation:

Equation 3-1

$$Z_z = \frac{\Delta V_z}{\Delta I_z}$$

Normally,  $Z_z$  is specified at  $I_{ZT}$ , the zener test current, and is designated  $Z_{ZT}$ . In most cases, you can assume that  $Z_z$  is constant over the full linear range of zener current values and is purely resistive.

### Temperature Coefficient

The temperature coefficient specifies the percent change in zener voltage for each degree centigrade change in temperature. For example, a 12 V zener diode with a positive temperature coefficient of 0.01 %/°C will exhibit a 1.2 mV increase in  $V_z$  when the junction temperature increases one degree centigrade. The formula for calculating the change in zener voltage for a given junction temperature change, for a specified temperature coefficient, is:

Equation 3-2

$$\Delta V_z = V_z \times TC \times \Delta T$$

where  $V_z$  is the nominal zener voltage at 25°C,  $TC$  is the temperature coefficient, and  $\Delta T$  is the change in temperature. A positive  $TC$  means that the zener voltage increases with an increase in temperature or decreases with a decrease in temperature. A negative  $TC$  means that the zener voltage decreases with an increase in temperature or increases with a decrease in temperature. In some cases, the temperature coefficient is expressed in mV/°C rather than as %/°C. For these cases,  $\Delta V_z$  is calculated as:

Equation 3-3

$$\Delta V_z = TC \times \Delta T$$

## Pre-lab

### Objective

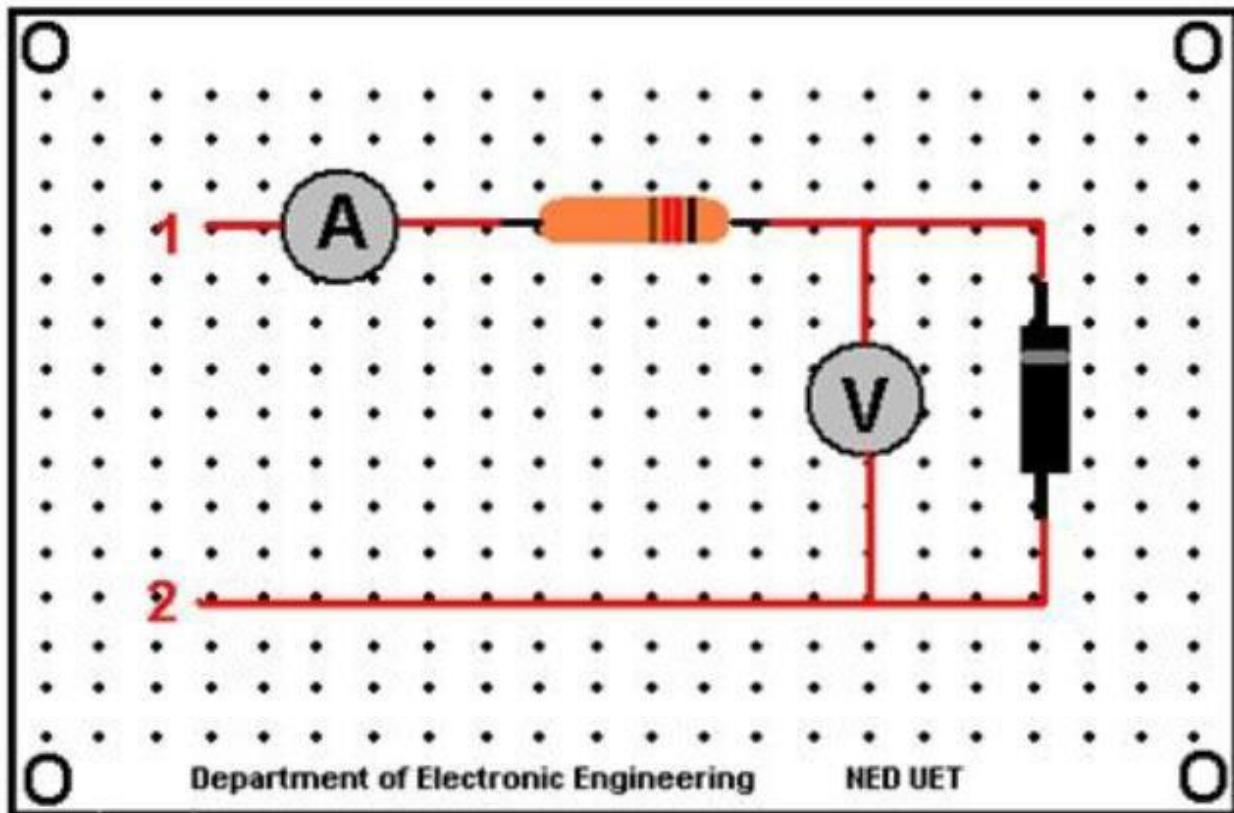
Construct the following circuit & Test for continuity.

### Required components

- 1) Vero board
- 2) A zener diode (1N4736)
- 3) Resistor (10KΩ)

### Procedure

Solder the circuit as shown.



## Laboratory procedure

### Objective

To plot the V-I curve of zener diode.

### Procedure

- 1- Apply positive supply across terminal 1 & 2. (Terminal 1 being positive) Connect a voltmeter across the drain source terminal of NMOS to determine the value of  $V_{DS}$ .
- 2- Connect variable voltage source & start varying the variable supply voltages.
- 3- For each division of voltages, note the corresponding current & voltage across the diode.
- 4- Take at least nine readings & then reverse the supply voltages across terminal 1 & 2.  
(This time terminal 2 being positive)
- 5- Repeat the same procedure for negative voltages
- 6- After getting all the readings, plot the V-I curve for both diodes.

## Observations

## **Forward bias mode**

## **REVERSE BIAS MODE**

## GRAPH

Attach both graphs here.

## Post lab

1. Make both circuits on multisim & attach the print out of simulated circuits.

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**Department of Electronic Engineering**

Course Code: \_\_\_\_\_ Course Name: \_\_\_\_\_

Laboratory Session No. \_\_\_\_\_ Date: \_\_\_\_\_

Skill Sets	Psychomotor Domain Assessment Rubric-Level P3				
	0	1	2	3	4
<b>Equipment Identification</b> Sensual ability to identify equipment and/or its component for a lab work	Unable to identify the equipment	Able to identify very few equipment and components to be used in lab work	Able to identify some of the equipment and components to be used in lab work	Able to identify most of the equipment and components to be used in lab work	Able to identify all of the equipment as well as its components
<b>Procedural Skills</b> Displays skills to act upon sequence of steps in lab work	Unable to either learn or perform lab work procedure	Able to slightly understand lab work procedure and perform lab work	Able to somewhat understand lab work procedure and perform lab work	Able to moderately understand lab work procedure and perform lab work	Fully understands lab work procedure and perform lab work
<b>Response</b> Capability to initiate the lab work on his/her own	Unable to initiate the lab work	Able to slightly initiate the lab work	Able to somewhat initiate the lab work	Able to moderately initiate the lab work	Fully initiates lab work
<b>Observation's Use</b> Displays skills to perform related mathematical calculations using the observations from lab work	Unable to use lab work observations for mathematical calculations	Able to slightly use lab work observations for mathematical calculations	Able to somewhat use lab work Observations for mathematical calculations	Able to moderately use lab work Observations for mathematical calculations	Fully use lab work Observations for mathematical calculations
<b>Equipment Use</b> Sensory skills to describe the use of the equipment for the lab work	Unable to describe the use of equipment	Rarely able to describe the use of equipment	Occasionally describe the use of equipment	Often able to describe the use of equipment	Regularly able to describe the use of equipment
<b>Equipment Handling</b> Equipment care during the use	Doesn't handle Equipment with required care	Rarely handles equipment with required care	Occasionally handles Equipment with required care	Often handles Equipment with required care	Handles equipment with required care
Ability to troubleshoot errors and try to resolve with/without the supervision or guidance	Unable to troubleshoot experimentation errors and resolve them	Able to troubleshoot experimentation errors but cannot resolve them	Able to troubleshoot experimentation errors and resolve them under supervision	Able to troubleshoot experimentation errors independently but need guidance in resolving them	Able to troubleshoot experimentation errors and resolve them without supervision or guidance

Weighted CLO (Psychomotor Score)	_____
Remarks	_____
Instructor's Signature with Date:	_____

## **LAB SESSION 10**

To design and verify following basic op-amp circuits and explain the operation of each:

- a. Inverting amplifier
- b. Non-inverting amplifier

2. To analyze and design circuits of the type listed in item 1 above for voltage gain.

**Student Name:**

**Roll no.:                          Batch:**

**Semester :                          Year:**

<b>Total Marks</b>	<b>Marks Obtained</b>

**Remarks (if any) :**

**Instructor Name:**

**Instructor Signature:**                                    **Date:**

# LAB SESSION 10

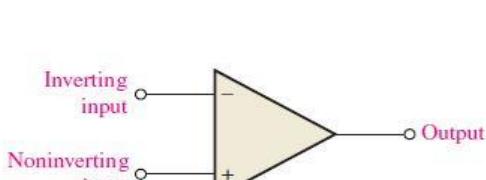
## OBJECTIVE

1. To design and verify following basic op-amp circuits and explain the operation of each:
  - a. Inverting amplifier
  - b. Non-inverting amplifier
2. To analyze and design circuits of the type listed in item 1 above for voltage gain.

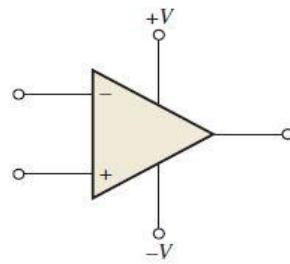
## Theory

### Introduction

The standard **operational amplifier (op-amp)** symbol is shown in Figure 12–1(a). It has two input terminals, the inverting (–) input and the noninverting (+) input, and one output terminal. Most op-amps operate with two dc supply voltages, one positive and the other negative, as shown in Figure 12–1(b), although some have a single dc supply. Usually these dc voltage terminals are left off the schematic symbol for simplicity but are understood to be there. Some typical op-amp IC packages are shown in Figure 12–1(c).



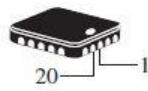
(a) Symbol



(b) Symbol with dc supply connections



DIP



SMT



SMT

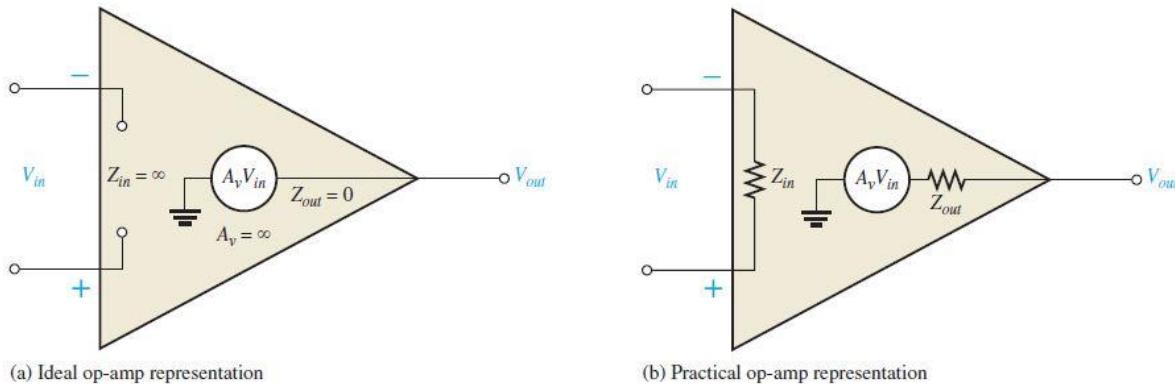
(c) Typical packages. Pin 1 is indicated by a notch or dot on dual in-line (DIP) and surface-mount technology (SMT) packages, as shown.

## **The Ideal Op-Amp**

To illustrate what an op-amp is, let's consider its ideal characteristics. A practical op-amp, of course, falls short of these ideal standards, but it is much easier to understand and analyze the device from an ideal point of view.

First, the ideal op-amp has *infinite voltage gain* and *infinite bandwidth*. Also, it has an *infinite input impedance* (open) so that it does not load the driving source. Finally, it has a *zero output impedance*. Op-amp characteristics are illustrated in Figure 12–2(a). The input voltage,  $V_{in}$ , appears between the two input terminals, and the output voltage is  $A_v V_{in}$ , as indicated by the internal voltage source symbol. The concept of infinite input impedance is

a particularly valuable analysis tool for the various op-amp configurations, which will be discussed in Section 12–4.



**▲ FIGURE 12-2**

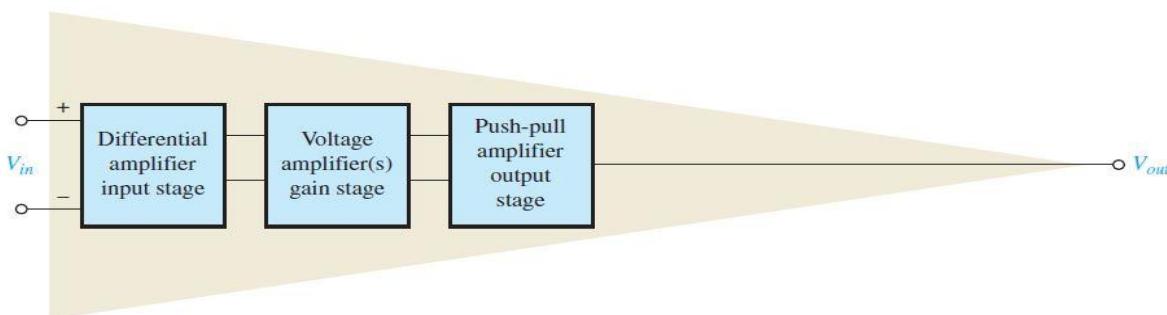
Basic op-amp representations.

### The Practical Op-Amp

Although integrated circuit (IC) op-amps approach parameter values that can be treated as ideal in many cases, the ideal device can never be made. Any device has limitations, and the IC op-amp is no exception. Op-amps have both voltage and current limitations. Peak-to-peak output voltage, for example, is usually limited to slightly less than the two supply voltages. Output current is also limited by internal restrictions such as power dissipation and component ratings.

Characteristics of a practical op-amp are *very high voltage gain, very high input impedance, and very low output impedance*. These are labelled in Figure 12-2(b). Another practical consideration is that there is always noise generated within the op-amp. Noise is an undesired signal that affects the quality of a desired signal. Today, circuit designers are using smaller voltages that require high accuracy, so low-noise components are in greater demand. All circuits generate noise; op-amps are no exception, but the amount can be minimized.

**Internal Block Diagram of an Op-Amp** A typical op-amp is made up of three types of amplifier circuits: a differential amplifier, a voltage amplifier, and a push-pull amplifier, as shown in Figure 12-3. The **differential amplifier** is the input stage for the op-amp. It provides amplification of the difference voltage between the two inputs. The second stage is usually a class A amplifier that provides additional gain. Some op-amps may have more than one voltage amplifier stage. A push-pull class B amplifier is typically used for the output stage.



**▲ FIGURE 12-3**

Basic internal arrangement of an op-amp.

The differential amplifier was introduced in Chapter 6. The term *differential* comes from the amplifier's ability to amplify the difference of two input signals applied to its inputs. Only the difference in the two signals is amplified; if there is no difference, the output is zero. The differential amplifier exhibits two modes of operation based on the type of input signals. These modes are *differential* and *common*, which are described in the next section. Since the differential amplifier is the input stage of the op-amp, the op-amp exhibits the same modes.

## Op-Amp Parameters

**Common-Mode Rejection Ratio** Desired signals can appear on only one input or with opposite polarities on both input lines. These desired signals are amplified and appear on the output as previously discussed. Unwanted signals (noise) appearing with the same polarity on both input lines are essentially cancelled by the op-amp and do not appear on the output. The measure of an amplifier's ability to reject common-mode signals is a parameter called the **CMRR (common-mode rejection ratio)**.

Ideally, an op-amp provides a very high gain for differential-mode signals and zero gain for common-mode signals. Practical op-amps, however, do exhibit a very small common-mode gain (usually much less than 1), while providing a high open-loop differential voltage gain (usually several thousand). The higher the open-loop gain with respect to the common-mode gain, the better the performance of the op-amp in terms of rejection of common-mode signals. This suggests that a good measure of the op-amp's performance in rejecting unwanted common-mode signals is the ratio of the open-loop differential voltage gain,  $A_{ol}$ , to the common-mode gain,  $A_{cm}$ . This ratio is the common-mode rejection ratio, CMRR.

$$\text{CMRR} = \frac{A_{ol}}{A_{cm}}$$

The higher the CMRR, the better. A very high value of CMRR means that the open-loop gain,  $A_{ol}$ , is high and the common-mode gain,  $A_{cm}$ , is low.

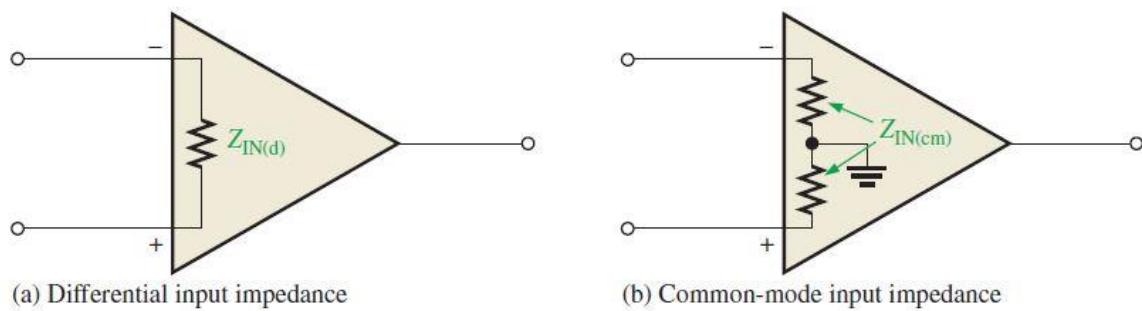
The CMRR is often expressed in decibels (dB) as

$$\text{CMRR} = 20 \log \left( \frac{A_{ol}}{A_{cm}} \right)$$

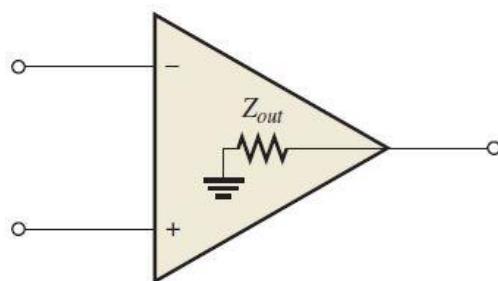
The **open-loop voltage gain**,  $A_{ol}$ , of an op-amp is the internal voltage gain of the device and represents the ratio of output voltage to input voltage when there are no external components. The open-loop voltage gain is set entirely by the internal design. Open-loop voltage gain can range up to 200,000 (106 dB) and is not a well-controlled parameter. Datasheets often refer to the open-loop voltage gain as the *large-signal voltage gain*.

A CMRR of 100,000, for example, means that the desired input signal (differential) is amplified 100,000 times more than the unwanted noise (common-mode). If the amplitudes of the differential input signal and the common-mode noise are equal, the desired signal will appear on the output 100,000 times greater in amplitude than the noise. Thus, the noise or interference has been essentially eliminated.

**Input Impedance** Two basic ways of specifying the input impedance of an op-amp are the differential and the common mode. The *differential input impedance* is the total resistance between the inverting and the noninverting inputs, as illustrated in Figure 12–8(a). Differential impedance is measured by determining the change in bias current for a given change in differential input voltage. The *common-mode input impedance* is the resistance between each input and ground and is measured by determining the change in bias current for a given change in common-mode input voltage. It is depicted in Figure 12–8(b).



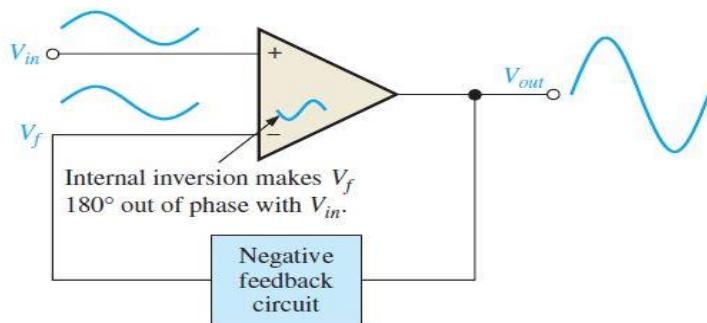
**Output Impedance** The *output impedance* is the resistance viewed from the output terminal of the op-amp, as indicated in Figure 12–10.



◀ FIGURE 12-10

Op-amp output impedance.

Negative feedback is illustrated in Figure 12–14. The inverting (–) input effectively makes the feedback signal 180° out of phase with the input signal.



◀ FIGURE 12-14

Illustration of negative feedback.

## Why Use Negative Feedback?

As you can see in Table 12–1, the inherent open-loop voltage gain of a typical op-amp is very high (usually greater than 100,000). Therefore, an extremely small input voltage drives the op-amp into its saturated output states. In fact, even the input offset voltage of the op-amp can drive it into saturation. For example, assume  $V_{IN} = 1 \text{ mV}$  and  $A_{ol} = 100,000$ . Then,

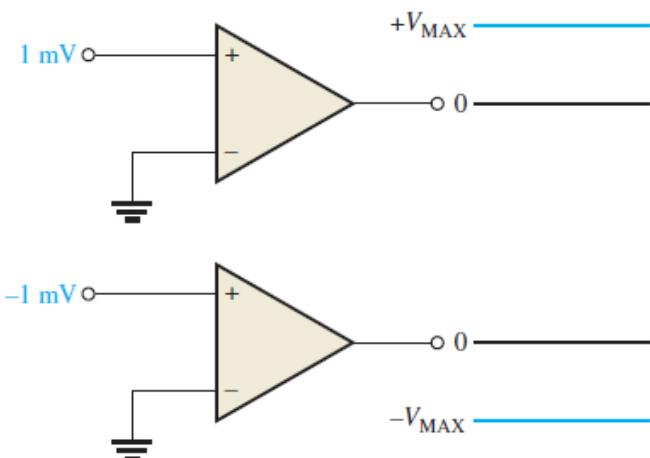
$$V_{IN}A_{ol} = (1 \text{ mV})(100,000) = 100 \text{ V}$$

Since the output level of an op-amp can never reach 100 V, it is driven deep into saturation and the output is limited to its maximum output levels, as illustrated in Figure 12–15 for both a positive and a negative input voltage of 1 mV.

The usefulness of an op-amp operated without negative feedback is generally limited to comparator applications (to be studied in Chapter 13). With negative feedback, the closed-loop voltage gain ( $A_c$ ) can be reduced and controlled so that the op-amp can function as a

► FIGURE 12–15

Without negative feedback, a small input voltage drives the op-amp to its output limits and it becomes nonlinear.



linear amplifier. In addition to providing a controlled, stable voltage gain, negative feedback also provides for control of the input and output impedances and amplifier bandwidth. Table 12–2 summarizes the general effects of negative feedback on op-amp performance.

## OP-AMPS WITH NEGATIVE FEEDBACK

An op-amp can be connected using negative feedback to stabilize the gain and increase frequency response. Negative feedback takes a portion of the output and applies it back out of phase with the input, creating an effective reduction in gain. This closed loop gain is usually much less than the open-loop gain and independent of it.

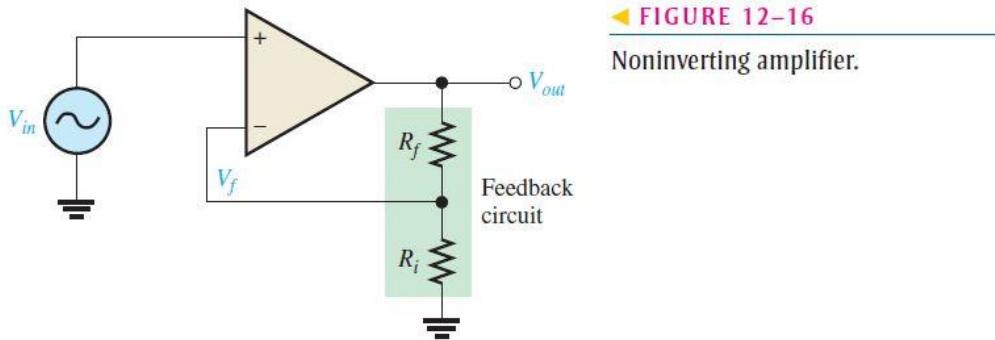
## Closed-Loop Voltage Gain, $A_{cl}$

The **closed-loop voltage gain** is the voltage gain of an op-amp with external feedback. The amplifier configuration consists of the op-amp and an external negative feedback circuit that connects the output to the inverting input. The closed-loop voltage gain is determined by the external component values and can be precisely controlled by them.

### Noninverting Amplifier

An op-amp connected in a **closed-loop** configuration as a **noninverting amplifier** with a controlled amount of voltage gain is shown in Figure 12–16. The input signal is applied to the noninverting (+) input. The output is applied back to the inverting (−) input through the feedback circuit (closed loop) formed by the input resistor  $R_i$  and the feedback resistor  $R_f$ . This creates negative feedback as follows. Resistors  $R_i$  and  $R_f$  form a voltage-divider circuit, which reduces  $V_{out}$  and connects the reduced voltage  $V_f$  to the inverting input. The feedback voltage is expressed as

$$V_f = \left( \frac{R_i}{R_i + R_f} \right) V_{out}$$



Then applying basic algebra,

$$\begin{aligned} V_{out} &= A_{ol}V_{in} - A_{ol}BV_{out} \\ V_{out} + A_{ol}BV_{out} &= A_{ol}V_{in} \\ V_{out}(1 + A_{ol}B) &= A_{ol}V_{in} \end{aligned}$$

Since the overall voltage gain of the amplifier in Figure 12–16 is  $V_{out}/V_{in}$ , it can be expressed as

$$\frac{V_{out}}{V_{in}} = \frac{A_{ol}}{1 + A_{ol}B}$$

The product  $A_{ol}B$  is typically much greater than 1, so the equation simplifies to

$$\frac{V_{out}}{V_{in}} \cong \frac{A_{ol}}{A_{ol}B} = \frac{1}{B}$$

The closed-loop gain of the noninverting (NI) amplifier is the reciprocal of the attenuation ( $B$ ) of the feedback circuit (voltage-divider).

$$A_{cl(NI)} = \frac{V_{out}}{V_{in}} \cong \frac{1}{B} = \frac{R_i + R_f}{R_i}$$

Therefore,

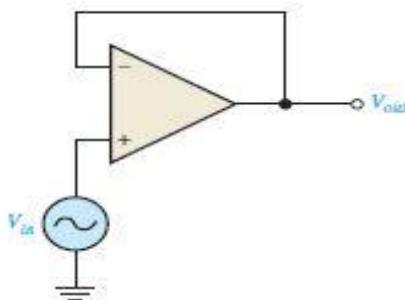
$$A_{cl(NI)} = 1 + \frac{R_f}{R_i}$$

Notice that the closed-loop voltage gain is not at all dependent on the op-amp's open-loop voltage gain under the condition  $A_{ol}B \gg 1$ . The closed-loop gain can be set by selecting values of  $R_i$  and  $R_f$ .

## Voltage-Follower

The **voltage-follower** configuration is a special case of the noninverting amplifier where all of the output voltage is fed back to the inverting (−) input by a straight connection, as shown in Figure 12–19. As you can see, the straight feedback connection has a voltage gain of 1 (which means there is no gain). The closed-loop voltage gain of a noninverting amplifier is  $1/B$  as previously derived. Since  $B = 1$  for a voltage-follower, the closed-loop voltage gain of the voltage-follower is

$$A_{cl(VF)} = 1$$



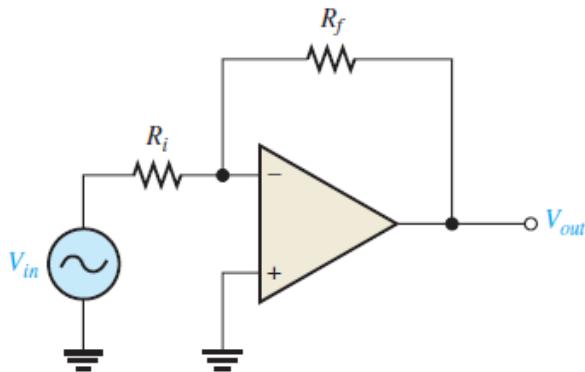
**FIGURE 12–19**  
Op-amp voltage-follower.

The most important features of the voltage-follower configuration are its very high input impedance and its very low output impedance. These features make it a nearly ideal buffer amplifier for interfacing high-impedance sources and low-impedance loads. This is discussed further in Section 12–5.

## Inverting Amplifier

An op-amp connected as an **inverting amplifier** with a controlled amount of voltage gain is shown in Figure 12–20. The input signal is applied through a series input resistor  $R_i$  to the inverting (−) input. Also, the output is fed back through  $R_f$  to the same input. The non-inverting (+) input is grounded.

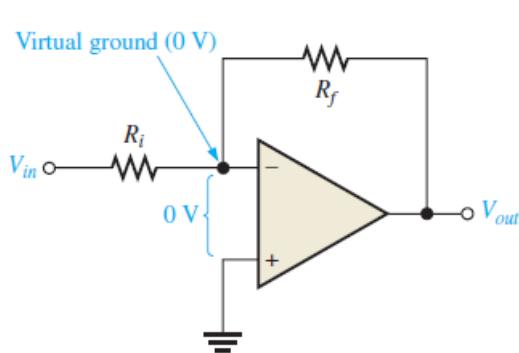
**◀ FIGURE 12–20**  
Inverting amplifier.



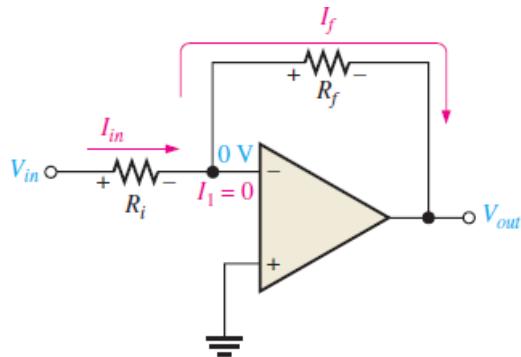
At this point, the ideal op-amp parameters mentioned earlier are useful in simplifying the analysis of this circuit. In particular, the concept of infinite input impedance is of great value. An infinite input impedance implies zero current at the inverting input. If there is zero current through the input impedance, then there must be *no* voltage drop between the inverting and noninverting inputs. This means that the voltage at the inverting (−) input is zero because the noninverting (+) input is grounded. This zero voltage at the inverting input terminal is referred to as *virtual ground*. This condition is illustrated in Figure 12–21(a).

Since there is no current at the inverting input, the current through  $R_i$  and the current through  $R_f$  are equal, as shown in Figure 12–21(b).

$$I_{in} = I_f$$



(a) Virtual ground



(b)  $I_{in} = I_f$  and current at the inverting input ( $I_1$ ) is 0.

The voltage across  $R_i$  equals  $V_{in}$  because the resistor is connected to virtual ground at the inverting input of the op-amp. Therefore,

$$I_{in} = \frac{V_{in}}{R_i}$$

Also, the voltage across  $R_f$  equals  $-V_{out}$  because of virtual ground, and therefore,

$$I_f = \frac{-V_{out}}{R_f}$$

Since  $I_f = I_{in}$ ,

$$\frac{-V_{out}}{R_f} = \frac{V_{in}}{R_i}$$

Rearranging the terms,

$$\frac{V_{out}}{V_{in}} = -\frac{R_f}{R_i}$$

Of course,  $V_{out}/V_{in}$  is the overall gain of the inverting (I) amplifier.

$$A_{cl(I)} = -\frac{R_f}{R_i}$$

Equation 12–10 shows that the closed-loop voltage gain of the inverting amplifier ( $A_{cl(I)}$ ) is the ratio of the feedback resistance ( $R_f$ ) to the input resistance ( $R_i$ ). *The closed-loop gain is independent of the op-amp's internal open-loop gain.* Thus, the negative feedback stabilizes the voltage gain. The negative sign indicates inversion.

## Prelab

### Objective

Construct the inverting and non inverting amplifier circuits on bread board & Test for continuity.

### Required components

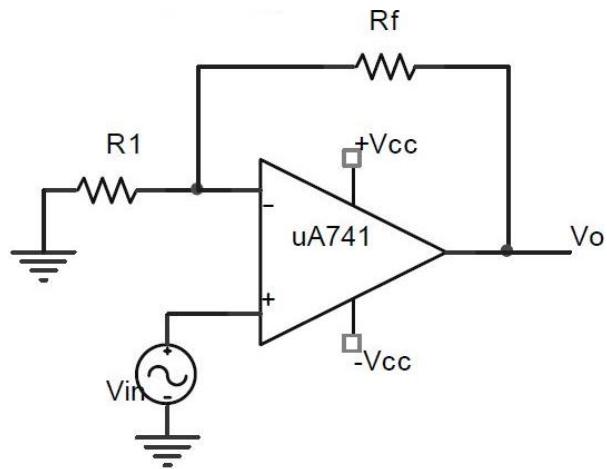
1. Power supply : variable regulated low voltage dc source
2. Equipments : AFO, CRO, DMM
3. Resistors
4. Capacitors
5. Semiconductors : IC 741 op-amp
6. Miscellaneous : Bread board and wires'

### Lab procedure

Make the circuit as shown.

#### **Non-Inverting amplifier**

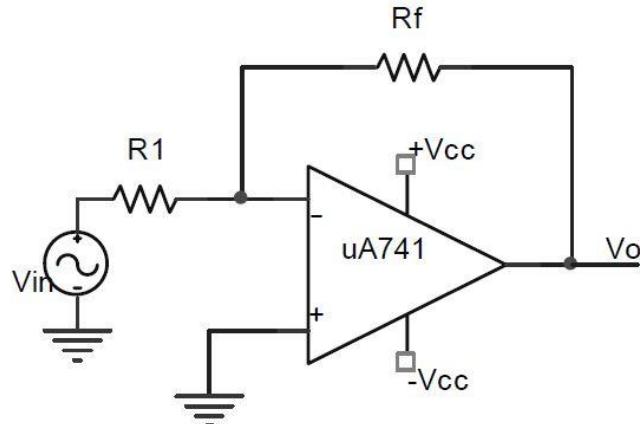
- 1.1 Design a non-inverting amplifier for the gain of 15. Let  $R_1=1.5k$  Assemble the circuit.
- 1.2 Feed sinusoidal input of amplitude 100mV and frequency 1KHz
- 1.3 Observe the input voltages and output voltage on a CRO.
- 1.4 Calculate closed-loop gain (ACL). Compare the experimental results with the theoretical values.



**Non- inverting amplifier**

### Inverting amplifier

- 4.1 Design an inverting amplifier for the gain of 15. Let  $R_1=1.5\text{k}\Omega$ . Assemble the circuit.
- 4.2 Feed sinusoidal input of amplitude 100mv and frequency 1KHz.
- 4.3 Observe the input and output voltages on a CRO.
- 4.4 Calculate ACL. Compare the experimental results with the theoretical values.



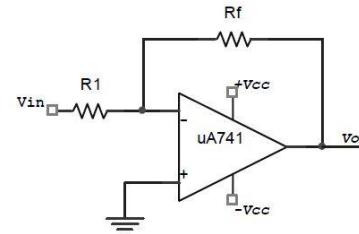
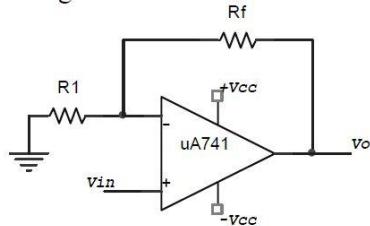
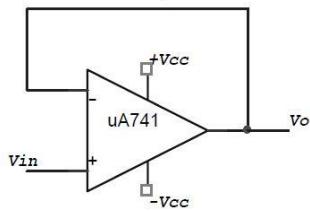
**Inverting amplifier**

### Observations

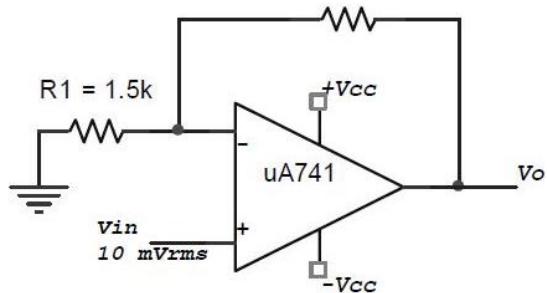
Parameter	Inverting Amplifier	Non- Inverting
Vin		
Frequency		
Vout		

## Post lab

1. Identify each of the op-amp configurations.



2. For the amplifier determine the following: (a)  $A_{CL(NI)}$  (b)  $V_o$   
 $R_f = 560k$



**NED University of Engineering and Technology, Karachi**  
**Department of Electronic Engineering**

Course Code: \_\_\_\_\_ Course Name: \_\_\_\_\_

Laboratory Session No. \_\_\_\_\_ Date: \_\_\_\_\_

Skill Sets	Psychomotor Domain Assessment Rubric-Level P3			
	Extent of Achievement			
	0	1	2	3
<b>Equipment Identification</b> Sensual ability to identify equipment and/or its component for a lab work	Unable to identify the equipment	Able to identify very few equipment and components to be used in lab work	Able to identify some of the equipment and components to be used in lab work	Able to identify most of the equipment and components to be used in lab work
<b>Procedural Skills</b> Displays skills to act upon sequence of steps in lab work	Unable to either learn or perform lab work procedure	Able to slightly understand lab work procedure and perform lab work	Able to somewhat understand lab work procedure and perform lab work	Able to moderately understand lab work procedure and perform lab work
<b>Response</b> Capability to imitate the lab work on his/her own	Unable to imitate the lab work	Able to slightly imitate the lab work	Able to somewhat imitate the lab work	Able to moderately imitate the lab work
<b>Observation's Use</b> Displays skills to perform related mathematical calculations using the observations from lab work	Unable to use lab work observations for mathematical calculations	Able to slightly use lab work observations for mathematical calculations	Able to somewhat use lab work Observations for mathematical calculations	Able to moderately use lab work Observations for mathematical calculations
<b>Equipment Use</b> Sensory skills to describe the use of the equipment for the lab work	Unable to describe the use of equipment	Rarely able to describe the use of equipment	Occasionally describe the use of equipment	Often able to describe the use of equipment
<b>Equipment Handling</b> Equipment care during the use	Doesn't handle Equipment with required care	Rarely handles equipment with required care	Occasionally handles Equipment with required care	Often handles Equipment with required care
Ability to troubleshoot errors and try to resolve with/without the supervision or guidance	Unable to troubleshoot experimentation errors and resolve them	Able to troubleshoot experimentation errors but cannot resolve them	Able to troubleshoot experimentation errors independently but need guidance in resolving them	Able to troubleshoot experimentation errors and resolve them without supervision or guidance

Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

## **LAB SESSION 11**

**To design and verify the basic summing amplifier op-amp circuits and explain its operation.**

**Student Name:**

**Roll no.:**

**Batch:**

**Semester :**

**Year:**

<b>Total Marks</b>	<b>Marks Obtained</b>

**Remarks (if any) :**

**Instructor Name:**

**Instructor Signature:**

**Date:**

# LAB SESSION 11

## OBJECTIVE

1. To design and verify the basic summing amplifier op-amp circuits and explain its operation.
2. To analyze and design circuits of the type listed in item 1 above for voltage gain.

## INTRODUCTION

### **Summing amplifier**

The summing amplifier is an application of the inverting op-amp configuration. The summing amplifier has two or more inputs, and its output age is proportional to the algebraic sum of its input voltages. Fig. 2-1-4 shows a two-input inverting summing amplifier.

**Case-1:** If all the three resistors are equal ( $R_1=R_2=R_f=R$ ) then

$$V_o = - (V_{in1} + V_{in2})$$

The above equation shows that the output voltage has the same magnitude as the sum of two input voltages but with a –ve sign indicating inversion.

**Case-2:** When  $R_f$  is larger than the input resistors, the amplifier has a gain of  $-\frac{R_f}{R}$

where  $R$  is the value of each equal value input resistor ( $R_1=R_2=R$ ). The general expression for the output is

$$V_o = - \frac{R_f}{R} (V_{in1} + V_{in2})$$

The above equation shows that the output voltage has the same magnitude as the sum of all the input voltages multiplied by a constant determined by the ratio  $-\frac{R_f}{R}$ .

**Case-3:** By setting the ration  $R_f/R$  equal to the reciprocal of the number of inputs ( $n$ ), ie.,  $\frac{R_f}{R} = \frac{1}{n}$  summing amplifier can be made to produce the mathematical average of the input voltages.

**Case-4:** A different weight can be assigned to each input of a summing amplifier by simply adjusting the values of the input resistors. In this case, the output voltage can be expressed as

$$V_o = - \left( \frac{R_f}{R_1} V_{in1} + \frac{R_f}{R_2} V_{in2} \right)$$

The weight of a particular input is set by the ratio of  $R_f$  to  $R_x$  for the input ( $R_x = R_1, R_2, \dots$ )

## Procedure

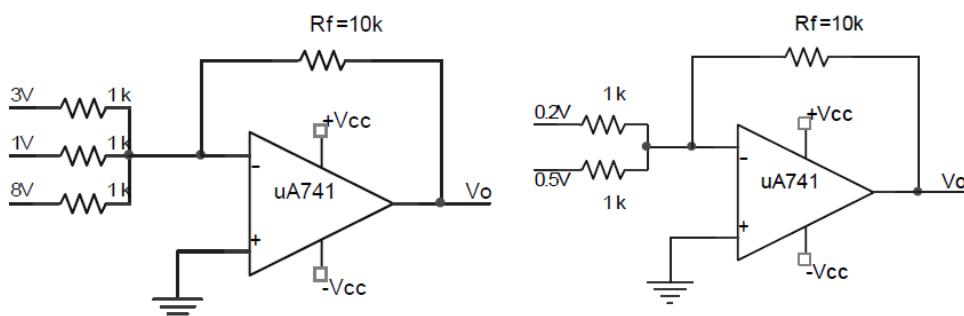
- Assemble an adder circuit with  $R_f = R_1 = 10k$  and  $R_2 = 47k$  as shown in task2 of post lab exercise.
- Feed sinusoidal input of amplitude 100mv and frequency 1 KHz to each input.
- Observe the input voltages and output voltage on a CRO Find the magnitude of the output voltage and tabulate the reading in Table 2-1-2.
- Compare the experimental results with the theoretical values.

## Observations

Op amp Circuit	Input Signal V1	Input Signal V2	Output Designed value	Output Observed value
Summing amplifier				

## Post lab

- On Multisim, design a 3-stage amplifier using 741 op-amp with gains of +10, -18 and -27. Use a  $270K\Omega$  feedback resistor for all three stages. What output voltage will result for an input of  $150\mu V$ ?
- Determine the output voltage of each amplifier in Figure below.



## **LAB SESSION 12**

**To design and verify the Operation of Inverting Integrator.**

**Student Name:**

**Roll no.:**

**Batch:**

**Semester :**

**Year:**

<b>Total Marks</b>	<b>Marks Obtained</b>

**Remarks (if any) :**

**Instructor Name:**

**Instructor Signature:**

**Date:**

**NED University of Engineering and Technology, Karachi**  
**Department of Electronic Engineering**

Course Code: \_\_\_\_\_ Course Name: \_\_\_\_\_

Laboratory Session No. \_\_\_\_\_ Date: \_\_\_\_\_

Skill Sets	Psychomotor Domain Assessment Rubric-Level P3				
	0	1	2	3	4
Equipment Identification Sensual ability to identify equipment and/or its component for a lab work	Unable to identify the equipment	Able to identify very few equipment and components to be used in lab work	Able to identify some of the equipment and components to be used in lab work	Able to identify most of the equipment and components to be used in lab work	Able to identify all of the equipment as well as its components
Procedural Skills Displays skills to act upon sequence of steps in lab work	Unable to either learn or perform lab work procedure	Able to slightly understand lab work procedure and perform lab work	Able to somewhat understand lab work procedure and perform lab work	Able to moderately understand lab work procedure and perform lab work	Fully understands lab work procedure and perform lab work
Response Capability to initiate the lab work on his/her own	Unable to initiate the lab work	Able to slightly initiate the lab work	Able to somewhat initiate the lab work	Able to moderately initiate the lab work	Fully initiates lab work
Observation's Use Displays skills to perform related mathematical calculations using the observations from lab work	Unable to use lab work observations for mathematical calculations	Able to slightly use lab work observations for mathematical calculations	Able to somewhat use lab work Observations for mathematical calculations	Able to moderately use lab work Observations for mathematical calculations	Fully use lab work Observations for mathematical calculations
Equipment Use Sensory skills to describe the use of the equipment for the lab work	Unable to describe the use of equipment	Rarely able to describe the use of equipment	Occasionally describe the use of equipment	Often able to describe the use of equipment	Regularly able to describe the use of equipment
Equipment Handling Equipment care during the use	Doesn't handle Equipment with required care	Rarely handles equipment with required care	Occasionally handles Equipment with required care	Often handles Equipment with required care	Handles equipment with required care
Ability to troubleshoot errors and try to resolve with/without the supervision or guidance	Unable to troubleshoot experimentation errors and resolve them	Able to troubleshoot experimentation errors but cannot resolve them	Able to troubleshoot experimentation errors and resolve them under supervision	Able to troubleshoot experimentation errors independently but need guidance in resolving them	Able to troubleshoot experimentation errors and resolve them without supervision or guidance

Weighted CLO (Psychomotor Score)	_____
Remarks	_____
Instructor's Signature with Date:	_____

## LAB SESSION 12

### Objective

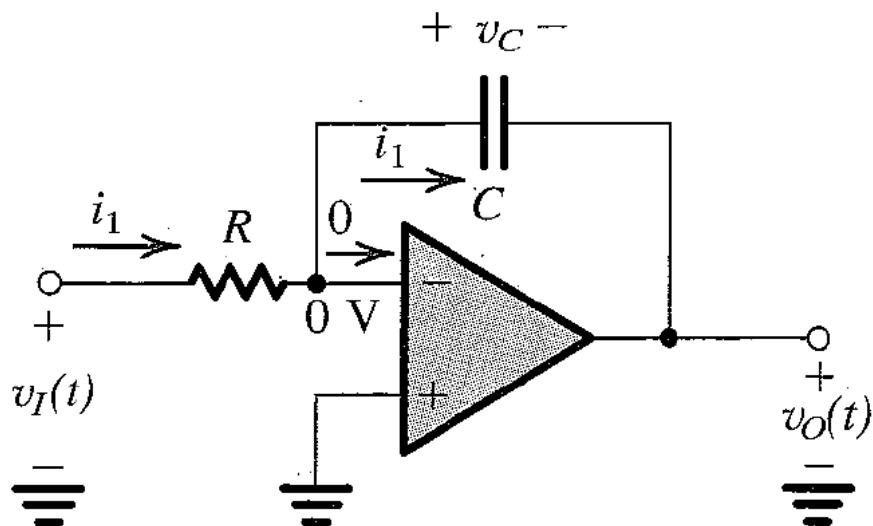
To design and verify the Operation of Inverting Integrator.

### Equipment required

Protoboard  
741 Opamps  
Resistors, Capacitors  
Digital Multimeter  
Function Generator  
Oscilloscope

### Theory

By placing the capacitor in the feedback path, and resistor at the input realizes the mathematical operation of integration.



## **Observations and calculations**

S. No.	Frequency	Input (p-p) V	Output(p-p) V	Gain
1.(1k)				
2.				
3.				
4.(10k)				
5.				
6.				
7.				
8.(100k)				

**NED University of Engineering and Technology, Karachi**  
**Department of Electronic Engineering**

Course Code: \_\_\_\_\_ Course Name: \_\_\_\_\_

Laboratory Session No. \_\_\_\_\_ Date: \_\_\_\_\_

Skill Sets	Psychomotor Domain Assessment Rubric-Level P3			
	Extent of Achievement			
	0	1	2	3
<b>Equipment Identification</b> Sensory ability to identify equipment and/or its component for a lab work	Unable to identify the equipment	Able to identify very few equipment and components to be used in lab work	Able to identify some of the equipment and components to be used in lab work	Able to identify most of the equipment and components to be used in lab work
<b>Procedural Skills</b> Displays skills to act upon sequence of steps in lab work	Unable to either learn or perform lab work procedure	Able to slightly understand lab work procedure and perform lab work	Able to somewhat understand lab work procedure and perform lab work	Able to moderately understand lab work procedure and perform lab work
<b>Response</b> Capability to imitate the lab work on his/her own	Unable to imitate the lab work	Able to slightly imitate the lab work	Able to somewhat imitate the lab work	Able to moderately imitate the lab work
<b>Observation's Use</b> Displays skills to perform related mathematical calculations using the observations from lab work	Unable to use lab work observations for mathematical calculations	Able to slightly use lab work observations for mathematical calculations	Able to somewhat use lab work Observations for mathematical calculations	Able to moderately use lab work Observations for mathematical calculations
<b>Equipment Use</b> Sensory skills to describe the use of the equipment for the lab work	Unable to describe the use of equipment	Rarely able to describe the use of equipment	Occasionally describes the use of equipment	Often able to describe the use of equipment
<b>Equipment Handling</b> Equipment care during the use	Doesn't handle Equipment with required care	Rarely handles equipment with required care	Occasionally handles Equipment with required care	Often handles Equipment with required care
Ability to troubleshoot errors and try to resolve with/without the supervision or guidance	Unable to troubleshoot experimentation errors and resolve them	Able to troubleshoot experimentation errors but cannot resolve them	Able to troubleshoot experimentation errors and resolve them under supervision	Able to troubleshoot experimentation errors independently but need guidance in resolving them

Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

## **LAB SESSION 13**

**To determine source, drain and gate terminals and investigate the different modes of operation of an enhancement type n-channel MOSFET**

**Student Name:**

**Roll no.:                          Batch:**

**Semester :                          Year:**

<b>Total Marks</b>	<b>Marks Obtained</b>

**Remarks (if any) :**

**Instructor Name:**

**Instructor Signature:**                                    **Date:**

# LAB SESSION 13

## Objective

To determine source, drain and gate terminals and investigate the different modes of operation of an enhancement type n-channel MOSFET.

## Theory

### Introduction

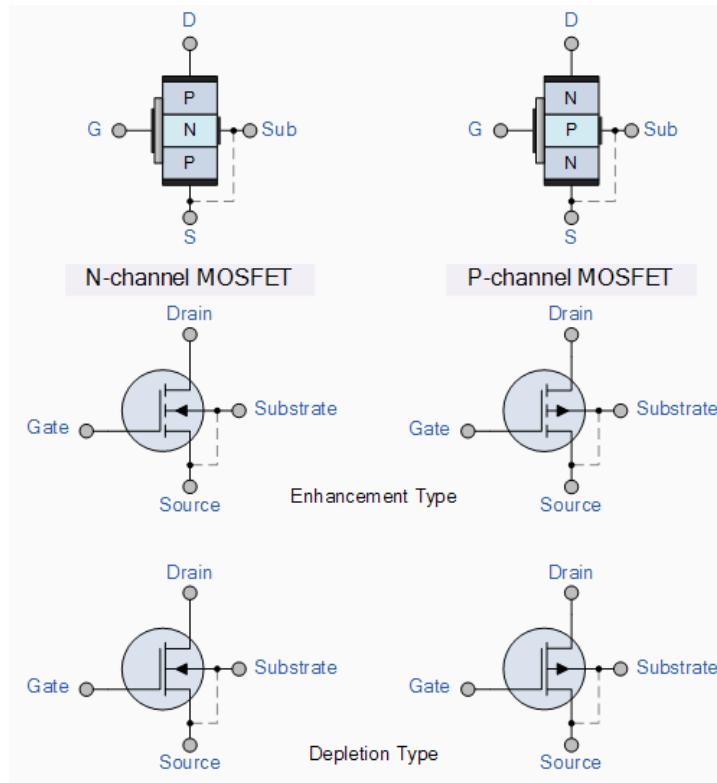
A field effect transistor (FET) operates as a conducting semiconductor channel with two ohmic contacts – the *source* and the *drain* – where the number of charge carriers in the channel is controlled by a third contact – the *gate*. The most popular amongst the FETs are the MOSFETs (metal-oxide semiconductor field effect transistors).

There are two major types of MOSFETs, called the enhancement type and depletion type. Each of these types can be manufactured with a so-called n channel or p channel

1. Depletion Type

2. Enhancement

The symbols for both configurations of MOSFETs are shown below in Fig. 14.1.



## Enhancement-mode N-Channel MOSFET (NMOS)

The physical structure of a n-Channel Enhancement-Type MOSFET (NMOS) is shown. The device is fabricated on a p-type substrate (or Body). Two heavily doped n-type regions (Source and Drain) are created in the substrate. A thin (fraction of micron) layer of SiO<sub>2</sub>, which is an excellent electrical insulator, is deposited between source and drain region. Metal is deposited on the insulator to form the Gate of the device (thus, metal-oxide semiconductor). Metal contacts are also made to the source, drain, and body region.

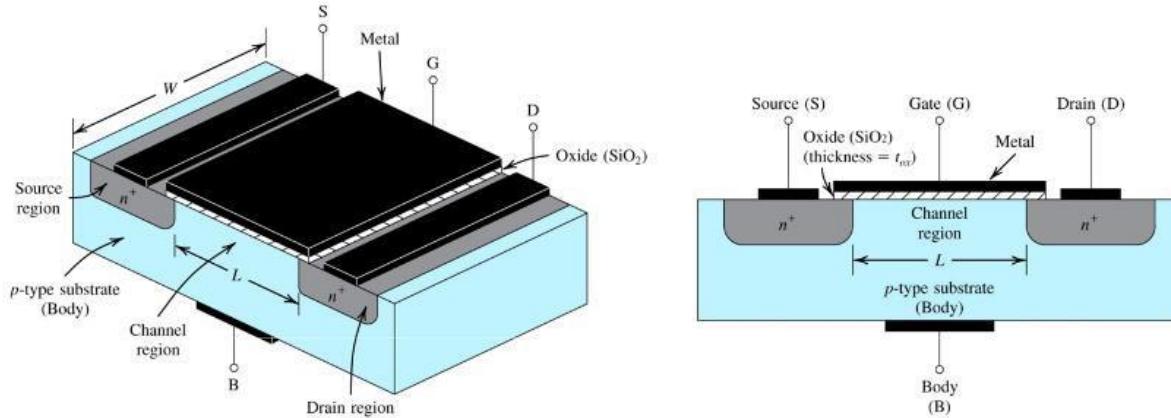


Fig. 14.2

## Modes of operation

There are three distinct channel conditions for NMOS operation called the modes of operation:

1. Cutoff - When  $V_{GS} < V_{th}$ , no channel is induced (no inversion layer is created), and so  $I_D=0$ . We call this mode Cutoff.
2. Triode - When an induced channel is present (i.e.  $V_{GS} > V_{th}$ ), but the value of  $V_{DS}$  is not large enough to pinch-off this channel (i.e.  $V_{DS} < V_{GS}-V_{th}$ ), the NMOS is said to be in Triode mode.
3. Saturation - When an induced channel is present (i.e.,  $V_{DS} \geq V_{GS}-V_{th}$ ), and the value of  $V_{DS}$  is large enough to pinchoff this channel, the NMOS is said to be in Saturation mode.

## Pre-lab

### Objective

To construct transistor biasing circuit and determine the  $V_{th}$  from datasheet.

### Equipment required

- 1- Bread-board
- 2- NMOS transistor (2N7000)
- 3- Jumpers (If required)
- 4- Resistors ( $1\text{k}\Omega$ ,  $100\text{k}\Omega$ ,  $1\text{M}\Omega$ )

## **Procedure**

- 1- Make the circuit shown in fig 14.3 on bread-board.
- 2- Test the continuity of all connections.
- 3- Determine the value of  $V_{th}$  from datasheet.

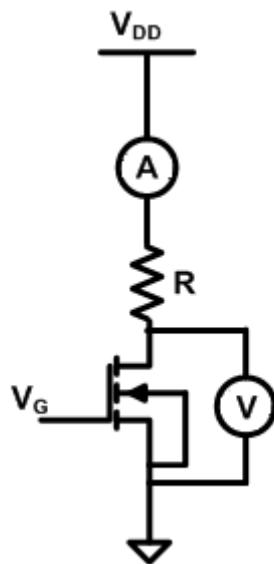


Fig. 14.3

## **Laboratory procedure**

### **Objective**

To determine source, drain and gate terminals and the modes of operation of NMOS.

## **Procedure**

- 1- Apply appropriate values of  $V_G$  and  $V_{DD}$ .
- 2- Connect a voltmeter across the drain source terminal of NMOS to determine the value of  $V_{DS}$ .
- 3- Connect ammeter to determine drain current ( $I_D$ ).
- 4- Repeat the same procedure for different values of resistances

## Observations

For  $V_{GS} = V$ ,  $V_{DD} = V$

$R (\Omega)$	$I_D (A)$	$V_{DS} (V)$
500		
2k		
1M		

## Post lab

## Calculations

$R (\Omega)$	$V_{DS} (V)$	$V_{GS}-V_{th}$	Mode of operation
1k			
100k			
1M			

## Task to be submitted

- 1- Using a similar transistor model, verify the results for each of the three circuits using Multisim.

**NED University of Engineering and Technology, Karachi**  
**Department of Electronic Engineering**

Course Code: \_\_\_\_\_ Course Name: \_\_\_\_\_  
 Laboratory Session No. \_\_\_\_\_ Date: \_\_\_\_\_

		Psychomotor Domain Assessment Rubric-Level P3				
		Extent of Achievement				
Skill Sets	0	1	2	3	4	
<b>Equipment Identification</b> Sensinal ability to identify equipment and/or its component for a lab work	Unable to identify the equipment	Able to identify very few equipment and components to be used in lab work	Able to identify some of the equipment and components to be used in lab work	Able to identify most of the equipment and components to be used in lab work	Able to identify all of the equipment as well as its components	
<b>Procedural Skills</b> Displays skills to act upon sequence of steps in lab work	Unable to either learn or perform lab work procedure	Able to slightly understand lab work procedure and perform lab work	Able to somewhat understand lab work procedure and perform lab work	Able to moderately understand lab work procedure and perform lab work	Fully understands lab work procedure and perform lab work	
<b>Response Capability to initiate the lab work on his/her own</b>	Unable to initiate the lab work	Able to slightly initiate the lab work	Able to somewhat initiate the lab work	Able to moderately initiate the lab work	Fully initiates lab work	
<b>Observation's Use</b> Displays skills to perform related mathematical calculations using the observations from lab work	Unable to use lab work observations for mathematical calculations	Able to slightly use lab work observations for mathematical calculations	Able to somewhat use lab work Observations for mathematical calculations	Able to moderately use lab work Observations for mathematical calculations	Fully use lab work Observations for mathematical calculations	
<b>Equipment Use</b> Sensory skills to describe the use of the equipment for the lab work	Unable to describe the use of equipment	Rarely able to describe the use of equipment	Occasionally describe the use of equipment	Often able to describe the use of equipment	Regularly able to describe the use of equipment	
<b>Equipment Handling</b> Equipment care during the use	Doesn't handle Equipment with required care	Rarely handles equipment with required care	Occasionally handles Equipment with required care	Often handles Equipment with required care	Handles equipment with required care	
Ability to troubleshoot errors and try to resolve with/without the supervision or guidance	Unable to troubleshoot experimentation errors and resolve them	Able to troubleshoot experimentation errors but cannot resolve them	Able to troubleshoot experimentation errors independently but need supervision	Able to troubleshoot experimentation errors independently but need guidance in resolving them	Able to troubleshoot experimentation errors independently but need supervision or guidance	

Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

## **LAB SESSION 14**

The objective of this MOSFET lab are:

1. To bias an NMOS transistor.
2. To design and verify the operation of NMOS transistor in a common-source amplifier configuration and to measure its amplification.

**Student Name:** \_\_\_\_\_

**Roll no.:** \_\_\_\_\_ **Batch:** \_\_\_\_\_

**Semester :** \_\_\_\_\_ **Year:** \_\_\_\_\_

Total Marks	Marks Obtained

**Remarks (if any) :** \_\_\_\_\_

**Instructor Name:** \_\_\_\_\_

**Instructor Signature:** \_\_\_\_\_ **Date:** \_\_\_\_\_

# LAB SESSION 14

## Objective

The objective of this MOSFET lab are:

1. To bias an NMOS transistor.
2. To design and verify the operation of NMOS transistor in a common-source amplifier configuration and to measure its amplification.

## Theory

### Introduction

For this lab we will be using the 2N7000 MOSFET. A model for this MOSFET can be obtained at the

following website: [www.fairchildsemi.com/models/PSPICE/Discrete/MOSFET.html](http://www.fairchildsemi.com/models/PSPICE/Discrete/MOSFET.html)

### **Common source amplifier with source degeneration**

We will perform DC and AC analyses for the CS amplifier shown in Fig. 12.1.

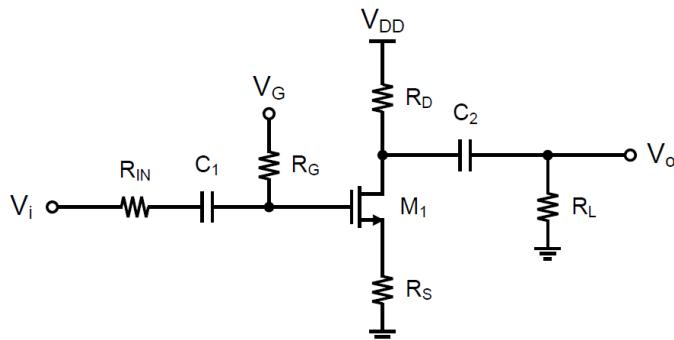


Fig. 12.1 Common source amplifier with source degeneration

### **DC Analysis**

To ensure that the circuit functions as an amplifier, we need to first make sure that the MOSFET is biased properly in the saturation region. This is accomplished with the resistor RG in Fig. above. To analyze the operating point of the MOSFET, we can overlay the I-V characteristic of the MOSFET-RS combo ( $I_D$  vs.  $V_D$  not  $V_{DS}$ ) with the load line of  $R_D$ . To obtain maximum output swing, the transistor is often biased at the Q (quiescent) bias point in the middle of the linear region of the transfer function. This usually leads to a drain voltage around  $V_{DD}/2$ . The drain current of the MOSFET at the Q point can be determined by solving

$$I_D = \frac{1}{2} k' (V_G - I_D R_S - V_{TH})^2$$

where  $V_{TH}$  is the threshold voltage of the MOSFET and  $k'$  is a device parameter.

### **AC Analysis**

AC analysis refers to the small-signal linear analysis of the amplifier equivalent circuit shown in Fig. 12.1.

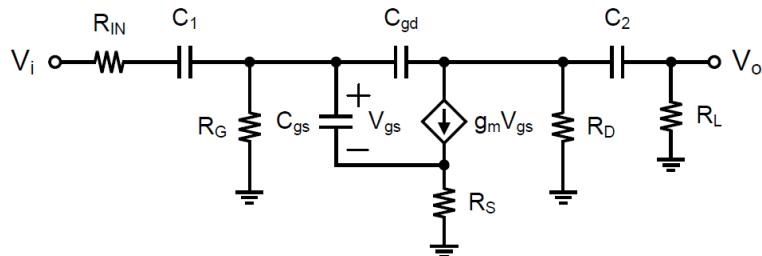


Fig. 12.2 AC equivalent circuit of the amplifier

Note that here the MOSFET symbol has been replaced by an equivalent model. We are interested in the mid-band gain of the CS amplifier. To determine this gain, we recognize  $C_1$  and  $C_2$  as the AC-coupling capacitors, while  $C_{gs}$  and  $C_{gd}$  are inherent capacitance of the MOSFET that will lead to high-frequency roll-offs of the amplifier gain. Since the mid-band gain is independent of frequency, we can short all AC-coupling capacitors ( $C_1$  and  $C_2$ ) and open all high frequency capacitors ( $C_{gs}$  and  $C_{gd}$ ) in the equivalent circuit and obtain the mid-band equivalent circuit shown in Fig. 12.1.

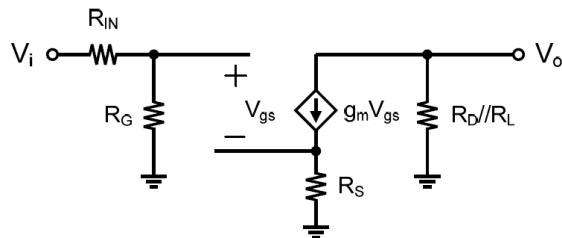


Fig. 12.3 Mid-band AC equivalent circuit of the amplifier

The mid-band gain thus can be determined as

$$A_{mid} = -\left(\frac{R_G}{R_{IN} + R_G}\right) \frac{g_m}{1 + g_m R_S} (R_D // R_L)$$

Here we assume that  $r_o \gg R_D$  and  $R_L$ . If  $g_m R_S \gg 1$ , above eqn. can be simplified as

$$A_{mid} \approx -\left(\frac{R_G}{R_{IN} + R_G}\right) \frac{1}{R_S} (R_D // R_L)$$

## Procedure

1. Set  $V_{DD} = 10V$ ,  $R_G = R_{IN} = R_S = 1k$ ,  $R_D = R_L = 20k$ , and  $C_1 = C_2 = 22\mu F$ .
2. Determine the gate bias  $V_G$  to set the drain voltage to roughly  $V_{DD}/2$ .
3. Determine  $I_D$ ,  $g_m$ , and  $r_o$  of the MOSFET at the operating point above.
4. Determine the small-signal (AC) gain of the amplifier at the operating point above.
5. Use the function generator as the input source, and set it up as follows
  - o Waveform: sinusoidal
  - o Offset: the  $V_G$  you found

o Amplitude: 0.1V

o Frequency: 1kHz

6. Use the oscilloscope to view the input and output waveforms. Record the small-signal (AC) voltage gain.

## **Observations**

	Values
$I_D$	
$gm$	
$r_o$	
Calculated Voltage gain	
$V_{in}$	
$V_o$	
Measured Voltage gain	

## **Post lab**

1. Using a similar transistor model verify the above results on multisim.

## **LAB SESSION 15**

**To design and verify the operation of a Common Gate Amplifier.**

**Student Name:**

**Roll no.:**                   **Batch:**

**Semester :**                   **Year:**

<b>Total Marks</b>	<b>Marks Obtained</b>

**Remarks (if any) :**

**Instructor Name:**

**Instructor Signature:**

**Date:**

## LAB SESSION 15

### Objective

To design and verify the operation of a Common Gate Amplifier.

### Equipment required

Protoboard

MOSFET

Resistors, Capacitors

Digital Multimeter

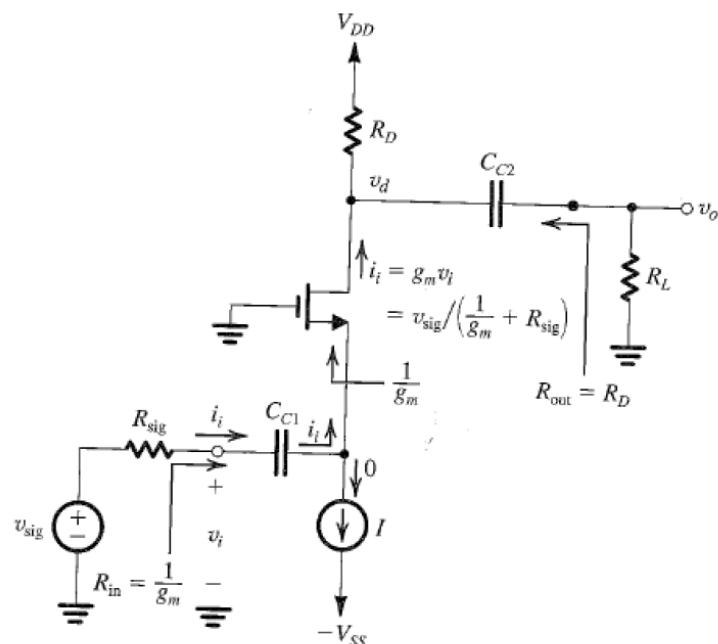
Function Generator

Oscilloscope

Connecting wires

### Theory

By establishing a signal ground on the MOSFET gate terminal, a circuit configuration called Common Gate is obtained. The input is applied to the source and output is taken at the drain terminal, with gate being the common terminal between input & output ports.



## **Observations and calculations**

S.No.	Frequency	Input (p-p) V	Output(p-p) V	Gain