

LABORATORY WORK BOOK

EL-103 Basic Electronics



Name: _____

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Year: _____

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LABORATORY WORK BOOK

EL-103 Basic Electronics

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

Basic Electronic Laboratory CONTENTS

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1.		P3	3	To learn about the Electrical & Electronic Symbols and Laboratory	
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LAB SESSION 01

Objective

To learn about the electrical symbols and laboratory equipments like, Multimeter, Oscilloscope, Function Generator, Power Supplies.

Theory

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 the

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 5Ω 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 Ω**) the more it fights. Most resistors you'll see range between 1 ohm and 1 mega ohm (1.0 M Ω) 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 k Ω 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 flow, 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 Ω when really you're in M Ω . This is a big problem for beginners so be careful!

Lab Procedure

Look for an ohm (Ω) 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 Ω symbol and then 7 submodes, ranging from 200 Ω to 2000M Ω .

Example1. Testing a resistor

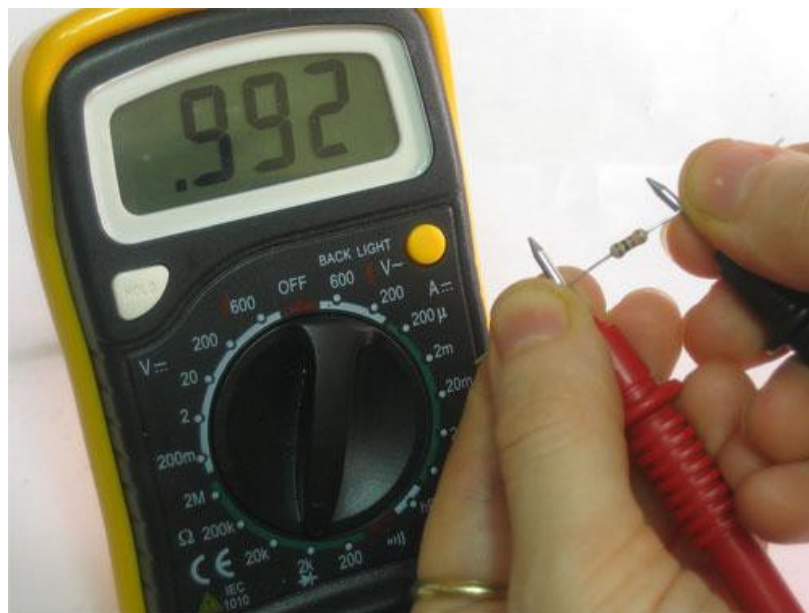
With an auto-ranging meter, just put the two probes across the resistor and read the number. For example, this 1K Ω 5% resistor is actually 0.988 K ohm. And this 10K Ω is really 9.80K Ω .

Note that the numbers look similar but the decimal point has moved.

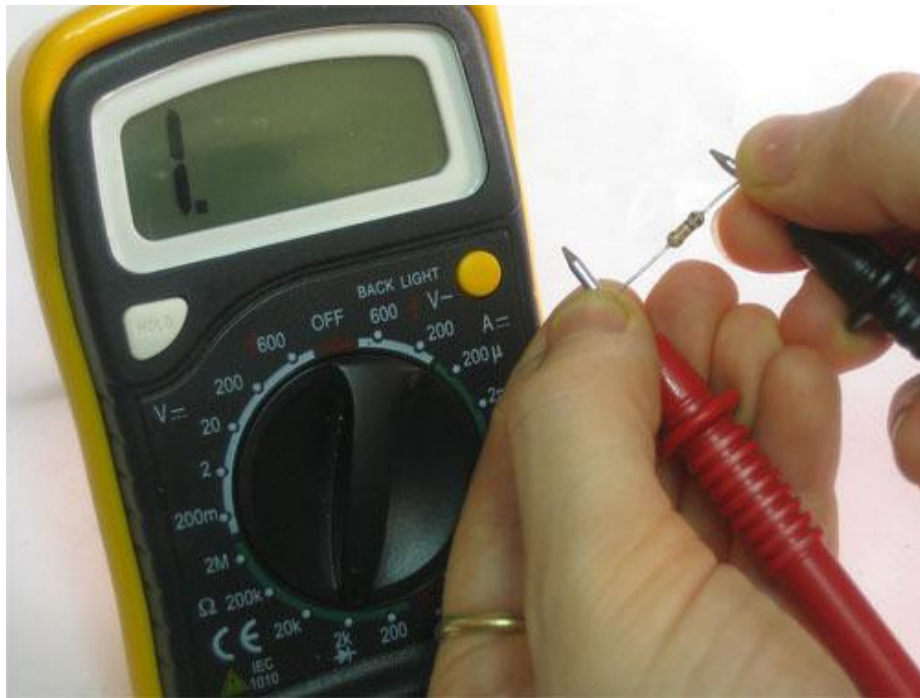




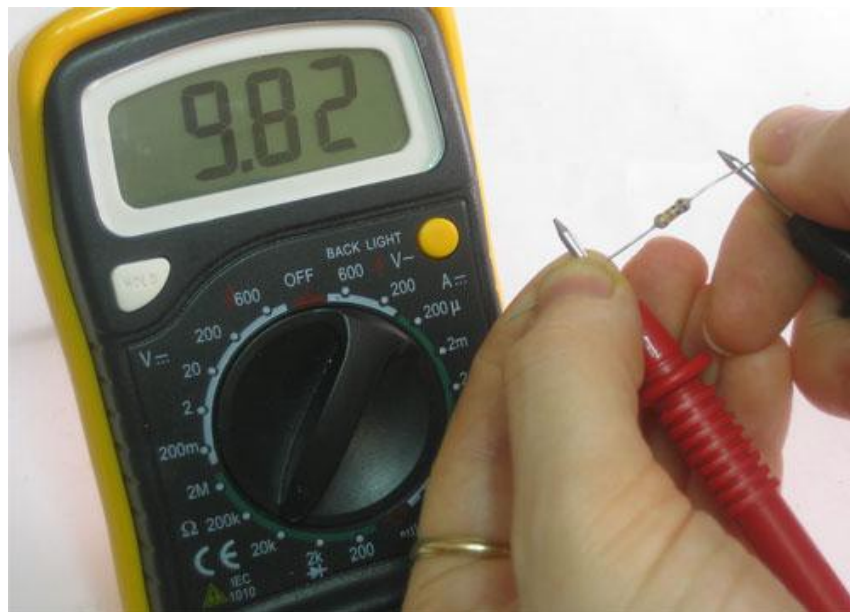
This ranged meter requires that you dial in the range. We'll guess that this resistor is under $2\text{K}\Omega$ then measure it. We get 0.992 which means its 0.992 $\text{K}\Omega$ (or, a $1\text{K}\Omega$ resistor)



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".



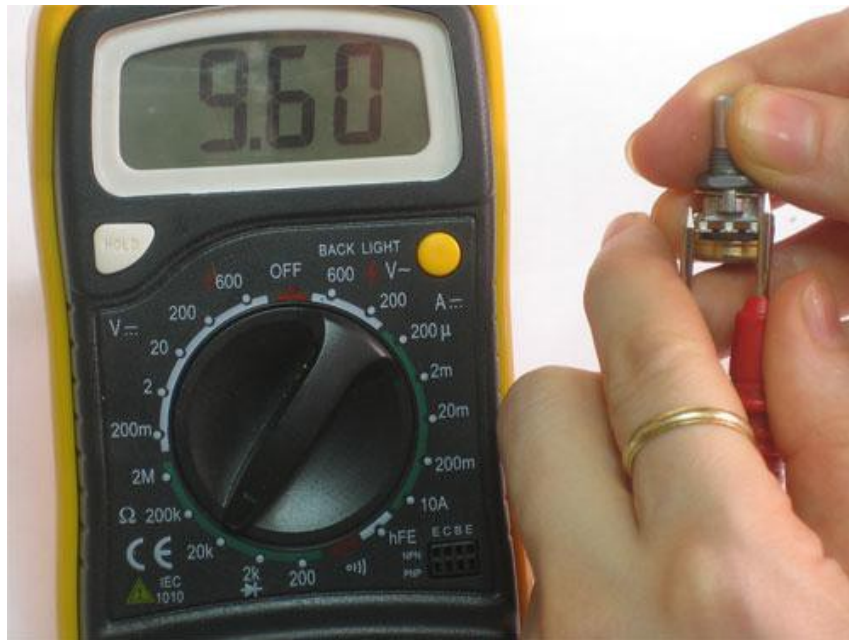
We try again, changing the range to 20KΩ.



It is a 9.82 KΩ resistor (10KΩ)

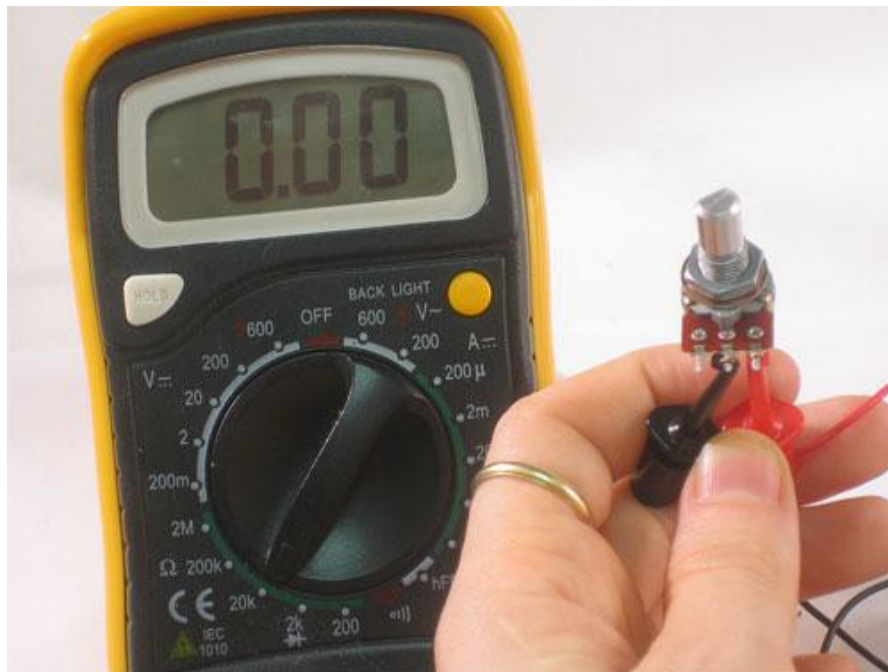
Example 2. Testing a potentiometer

You can test the max-value of a potentiometer by measuring across the two 'ends' as shown here with a rotational 10KΩ 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.

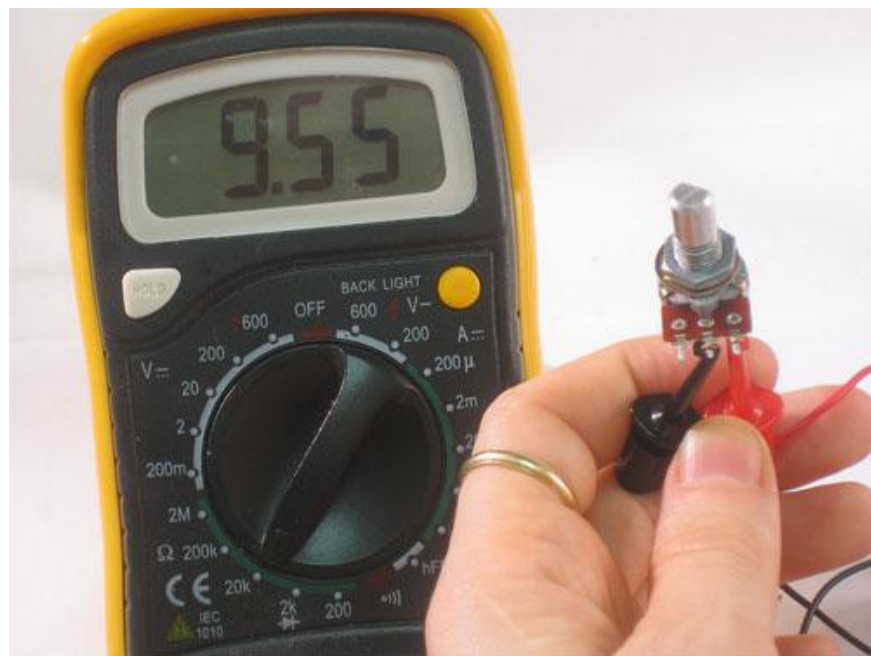
This is a 10KΩ linear potentiometer



The minimum resistance of the pot, 0Ω (a short) as expected



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

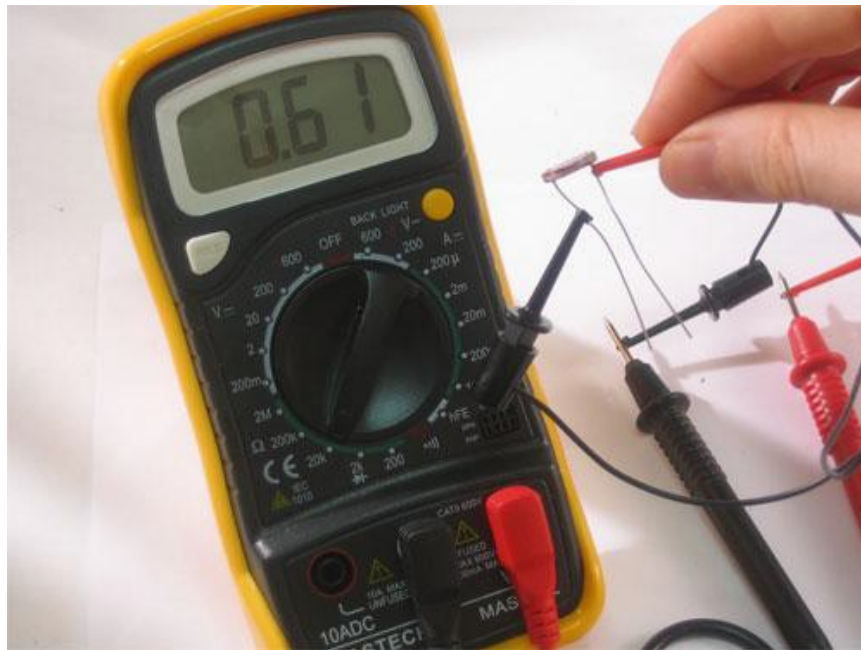


Maximum value is $9.5\text{K}\Omega$ (it should be around
 $10\text{K}\Omega$)

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 20K max.

First, set the range, in this case 20K Ω seems pretty good. In bright light, it measures about 610 Ω . Slightly shaded it's 5.84K Ω (remember this is still a well-lit photo)



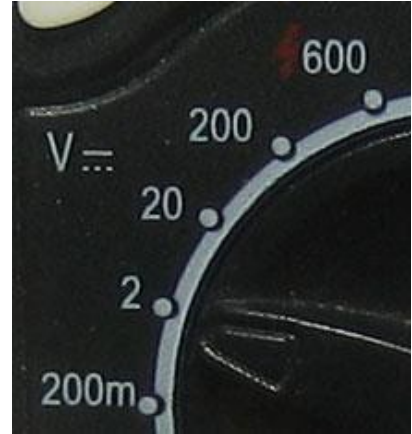
Lab Procedure

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 have a wave next to it (AC).

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

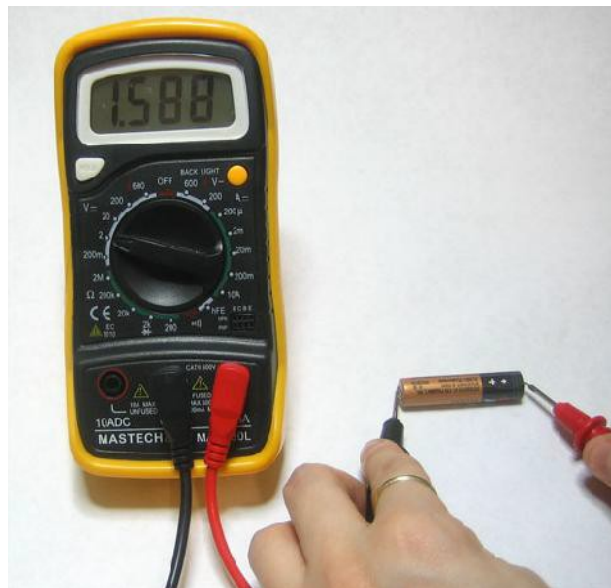
This ranged meter has 5 ranges, the top range is 750 VAC or 1000 VDC, to switch between DC and AC you need to press the DC/AC button on the upper right.

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**.

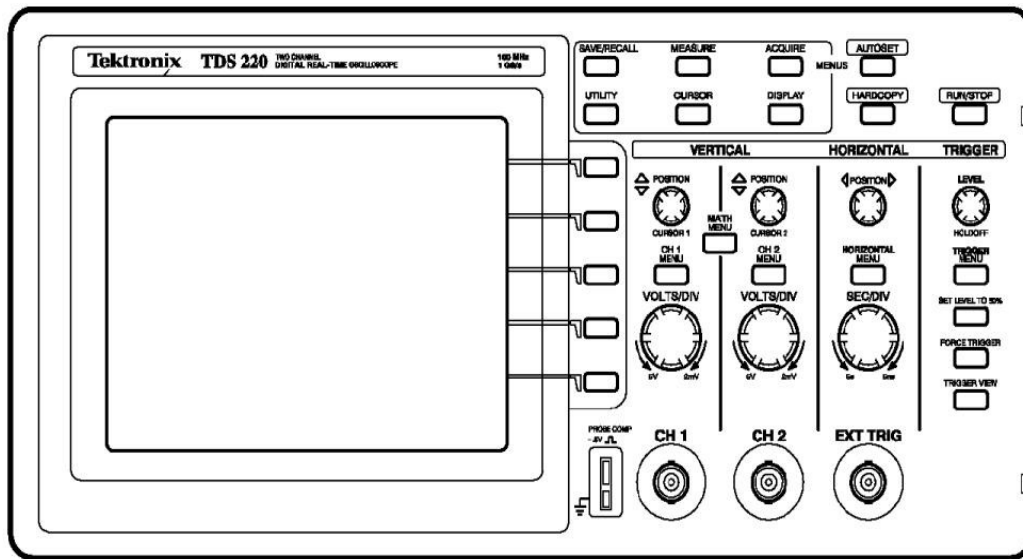


Post Lab

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?

Oscilloscopes

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



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.

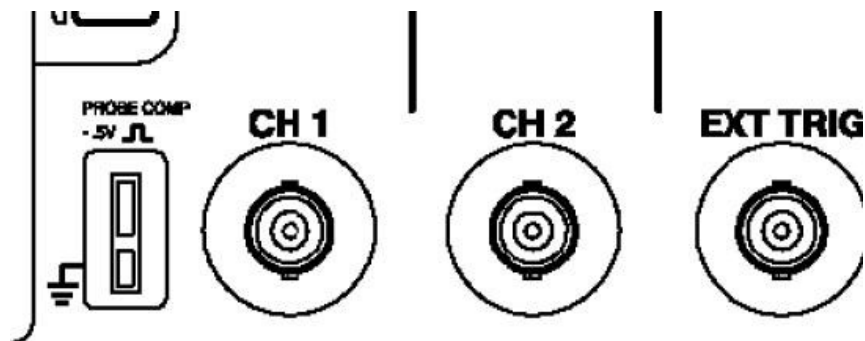
3. Be sure that Setups is highlighted (in inverse video) and press the button beside "Recall Factory."

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.



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.

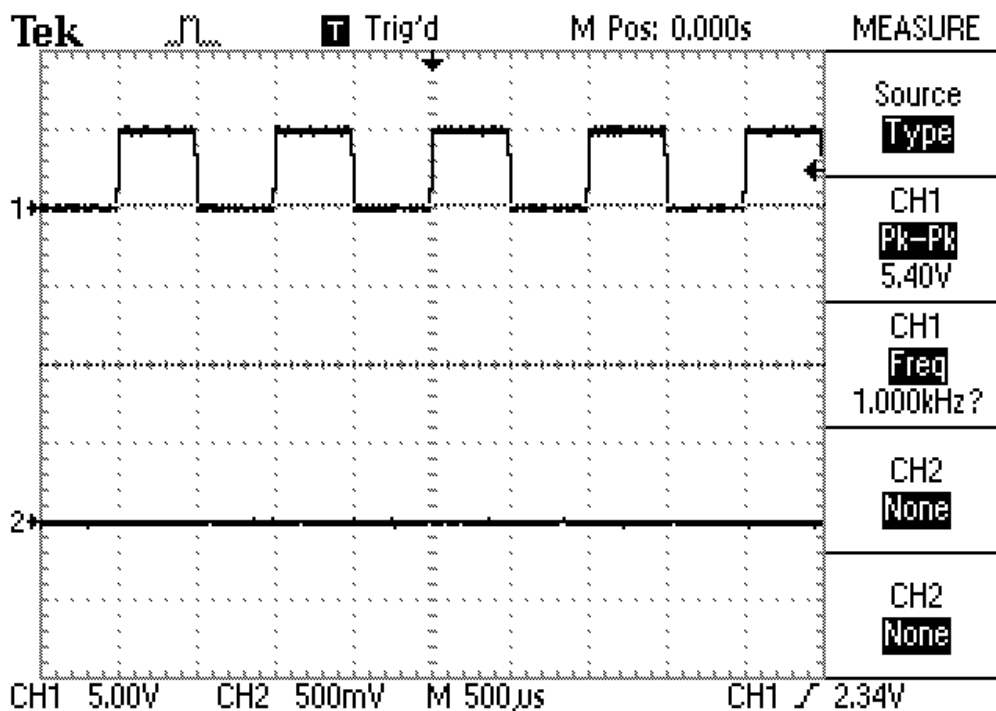
5. Press the AUTOSET button near the top right corner on the front-panel. The oscilloscope sets the vertical, horizontal, and trigger controls automatically which usually results in a usable display. These settings are adequate in this and many other situations. Be aware that the oscilloscope also sets 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.

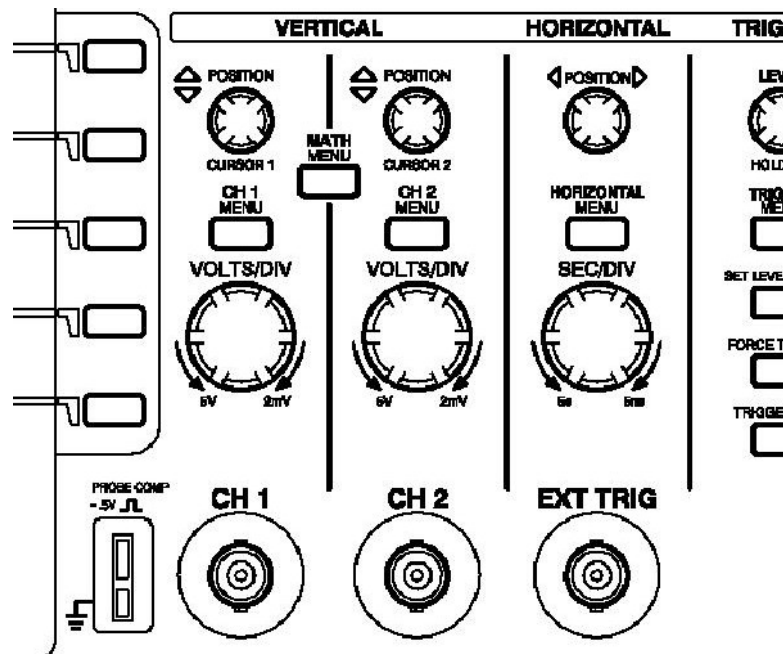


To demonstrate the downside of using Autoset, follow these steps:

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

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 ($1/f$).

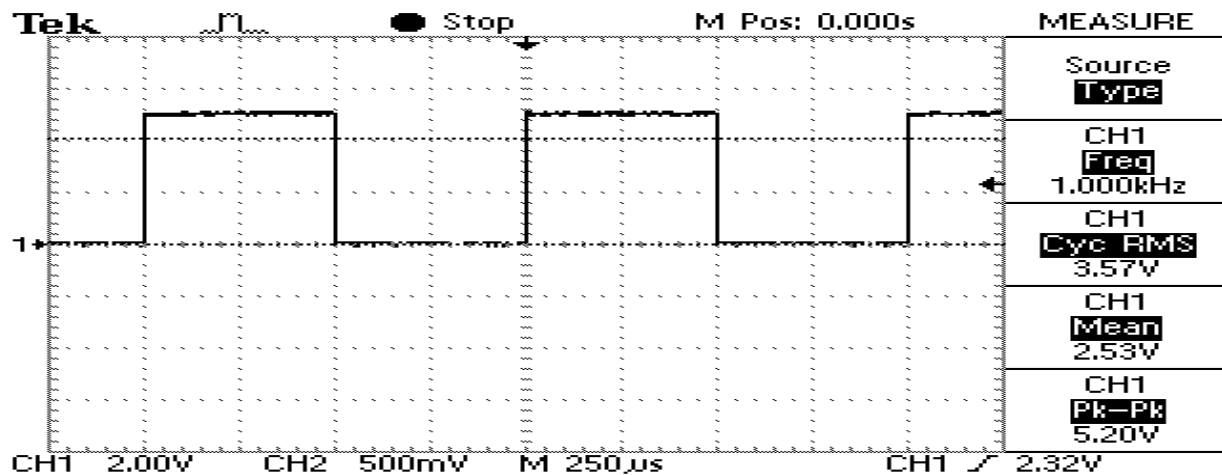
4) Press the fourth button until Mean appears. The oscilloscope displays the mean voltage.

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.

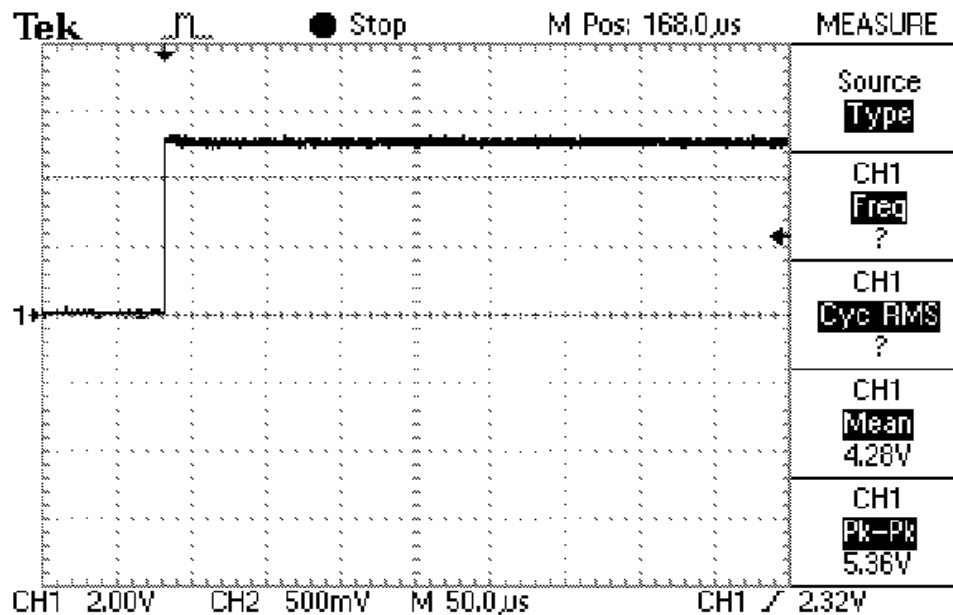
7) Press the appropriate channel menu front-panel button, such as CH 1 MENU.

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 μ 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

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.
2. Use multisim to implement task performed in post lab.



Psychomotor Domain Assessment Rubric-Level P3					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
<u>Equipment Identification</u> Sensory skill to <i>identify</i> equipment and/or its component for a lab work.	Not able to identify the equipment.	--	--	--	Able to identify equipment as well as its components.
<u>Equipment Use</u> Sensory skills to <i>demonstrate</i> the use of the equipment for the lab work.	Doesn't demonstrate the use of equipment.	Slightly demonstrates the use of equipment.	Somewhat demonstrates the use of equipment.	Moderately demonstrates the use of equipment.	Fully demonstrates the use of equipment.
<u>Procedural Skills</u> <i>Displays</i> skills to act upon sequence of steps in lab work.	Not able 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.	Able to fully understand lab work procedure and perform lab work.
<u>Response</u> Ability to <i>imitate</i> the lab work on his/her own.	Not able 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.	Able to fully imitate the lab work.
<u>Observation's Use</u> <i>Displays</i> skills to use the observations from lab work for experimental verifications and illustrations.	Not able to use the observations from lab work for experimental verifications and illustrations.	Slightly able to use the observations from lab work for experimental verifications and illustrations.	Somewhat able to use the observations from lab work for experimental verifications and illustrations.	Moderately able to use the observations from lab work for experimental verifications and illustrations.	Fully able to use the observations from lab work for experimental verifications and illustrations.
<u>Safety Adherence</u> Adherence to <i>safety</i> procedures.	Doesn't adhere to safety procedures.	Slightly adheres to safety procedures.	Somewhat adheres to safety procedures.	Moderately adheres to safety procedures.	Fully adheres to safety procedures.
<u>Equipment Handling</u> <i>Equipment care</i> 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.
<u>Group Work</u> <i>Contributes</i> in a group based lab work.	Doesn't participate and contribute.	Slightly participates and contributes.	Somewhat participates and contributes.	Moderately participates and contributes.	Fully participates and contributes.

Laboratory Session No. _____

Date: _____

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LAB SESSION 2

OBJECTIVE

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

Theory

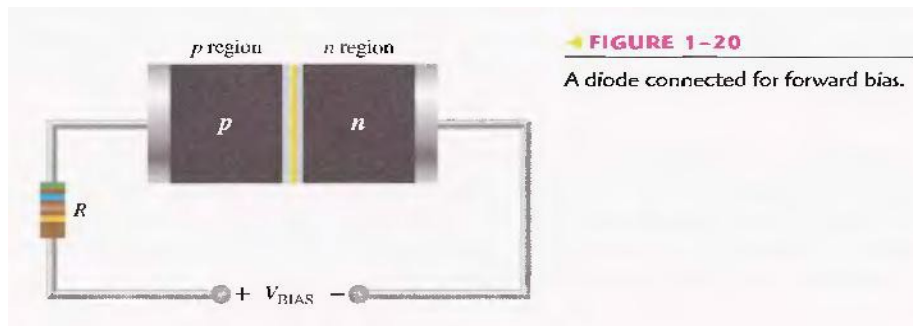
Introduction

Biasing 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.

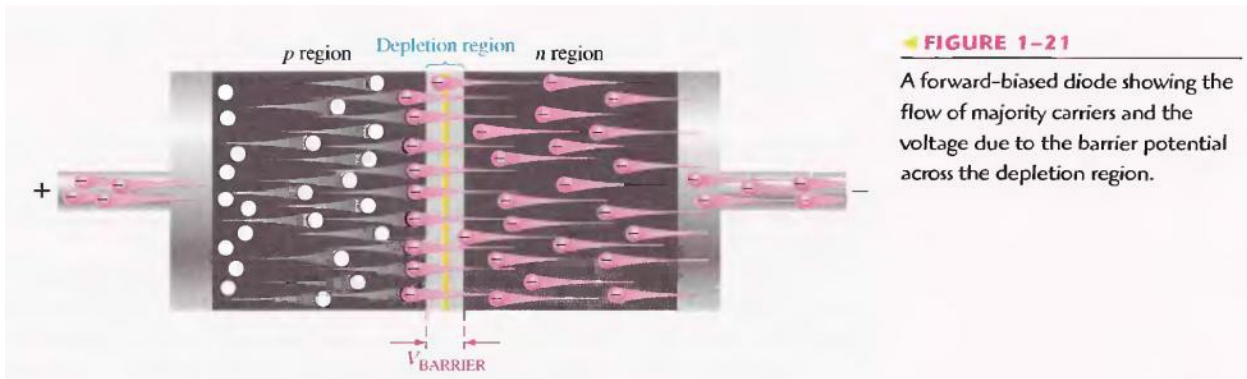
Forward Bias

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.



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.

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.

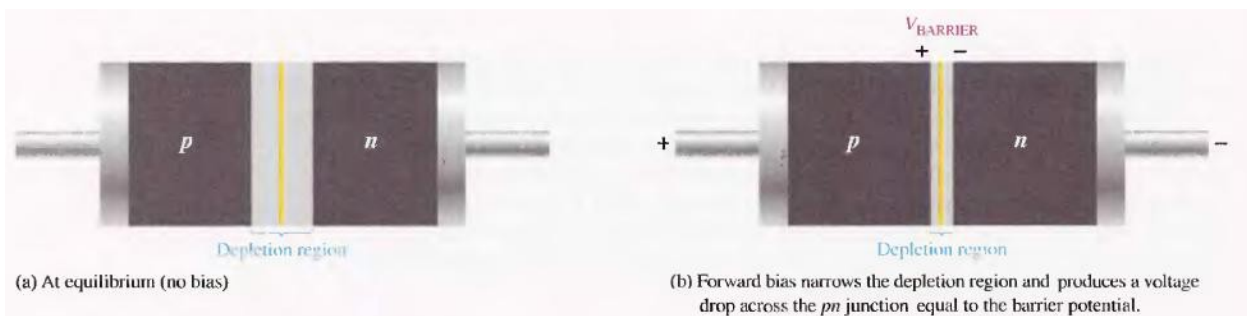


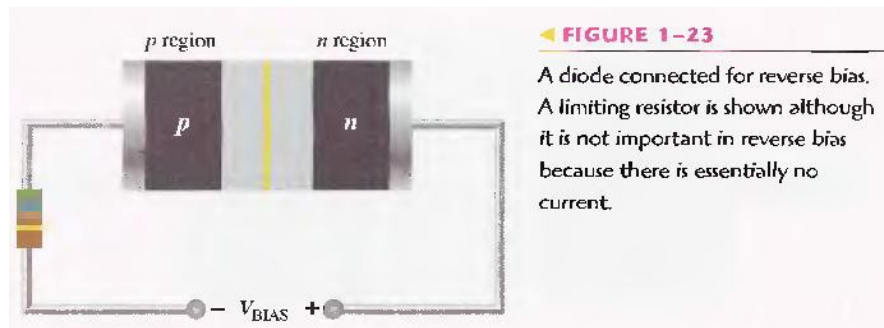
FIGURE 1-22

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.

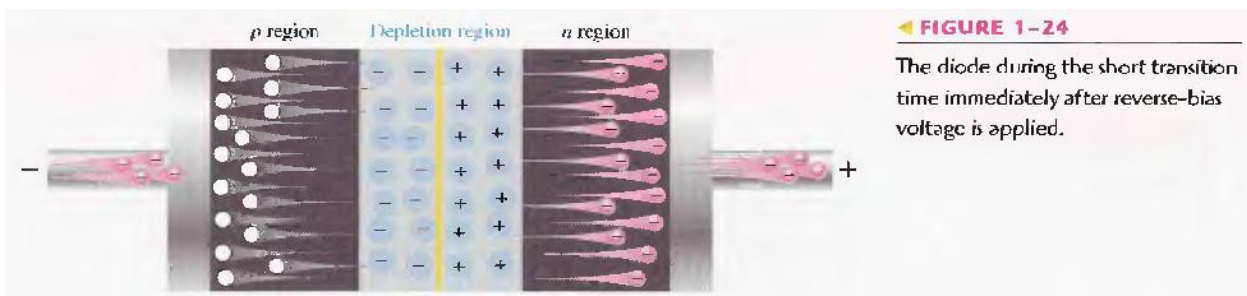
Reverse Bias

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_{bias} just as it was for forward bias. Notice that the positive side of V_{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.



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 n region, away from the pn junction. As the electrons flow toward the positive

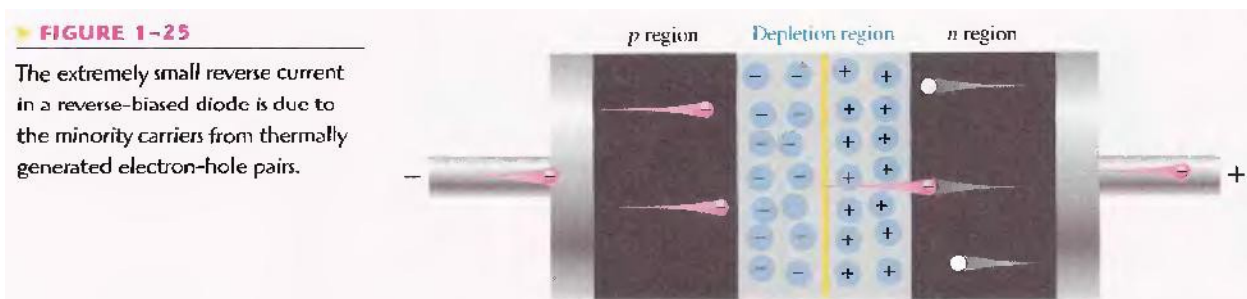
side of the voltage source, additional positive ions are created. This results in a widening of the depletion region and a depletion of majority carriers.



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.



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

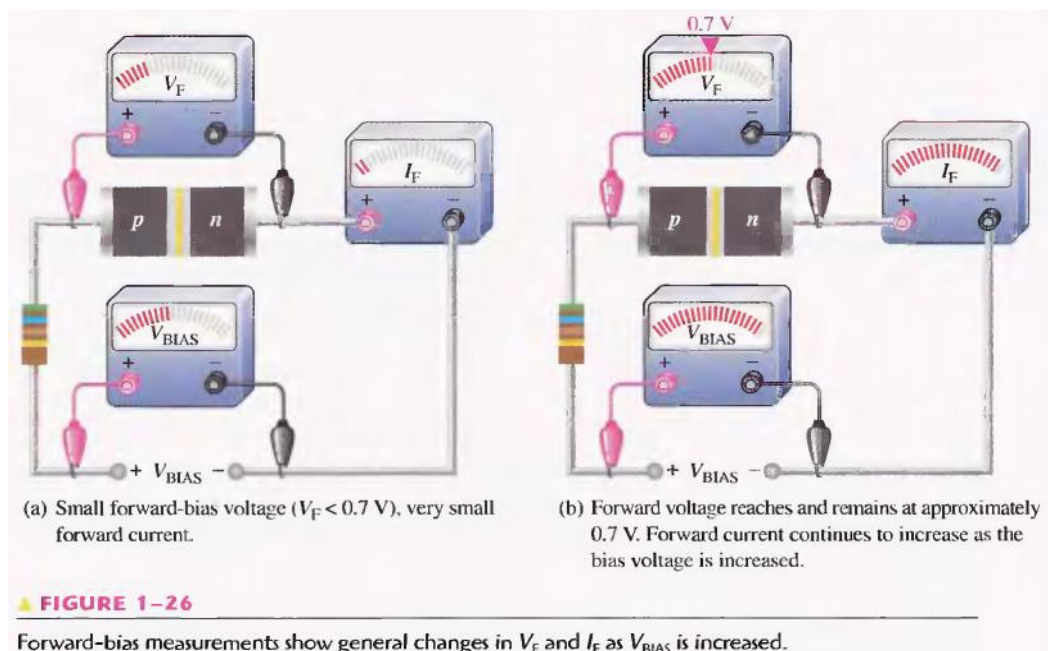
energy to knock valence electrons out of orbit and into the conduction band. The newly created conduction electrons are also high in energy and repeat the process. If one electron knocks only two others out of their valence orbit during its travel through the p region. The numbers quickly multiply. As 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.



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.

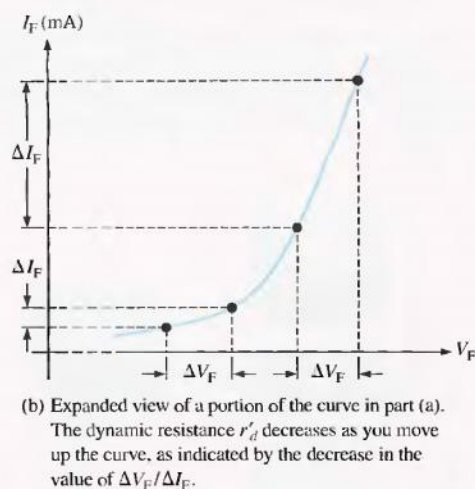
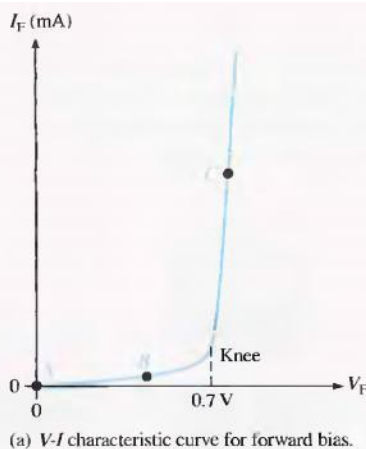
Graphing the V-I Curve

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

FIGURE 1-27

Relationship of voltage and current in a forward-biased diode.



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.

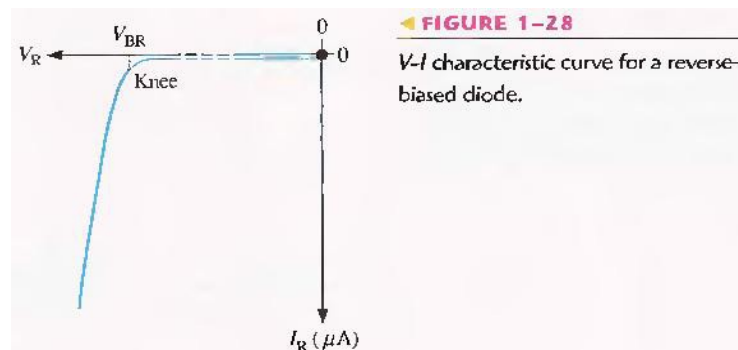
Dynamic Resistance Figure 1-27(b) is an expanded view of the V-I characteristic curve in part (a) and illustrates dynamic resistance. Unlike a linear resistance, the resistance of the forward-biased diode is not constant over the entire curve. Because the resistance changes as you move along the V-I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

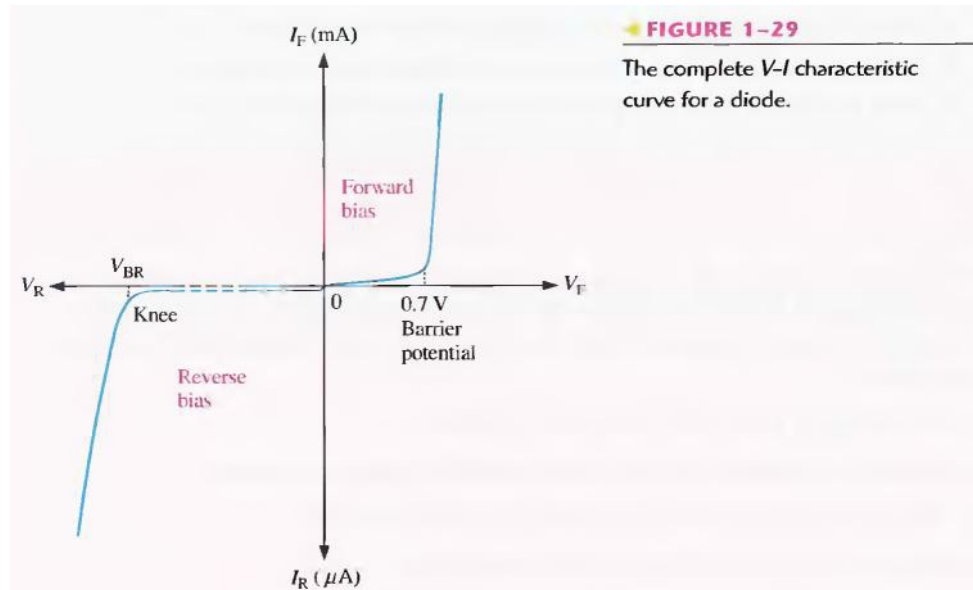
When a reverse-bias voltage is applied across a diode, there is only an extremely small reverse current (I_R) through the pn junction. With 0 V across the diode, there is no reverse current. As you gradually increase the reverse-bias voltage, there is a very small reverse current and the voltage across 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.



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 I_F scale is in mA compared to the I_R scale in μA .

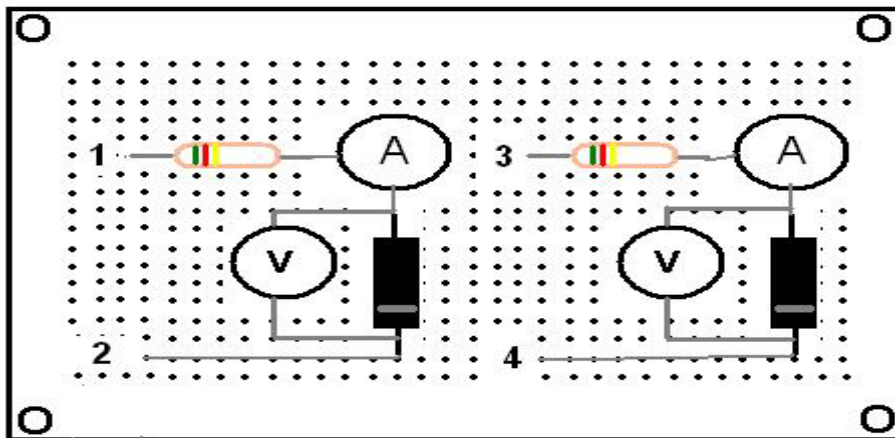


Required components

- 1) Bread-board
- 2) Silicon diode
- 3) Germanium diode
- 4) 2 Resistors (10KΩ each)

Procedure

Make the circuit as shown.



- 1- Apply positive supply across terminal 1 & 2. (Terminal 1 being positive)
- 2- Connect a voltmeter across 1st 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.

Graph:

Attach both graphs here.

Post lab

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

Observations

Forward bias mode

SILICON

Voltage	Current

GERMANIUM

Voltage	Current

REVERSE BIAS MODE

SILICON

Voltage	Current

GERMANIUM

Voltage	Current



Psychomotor Domain Assessment Rubric-Level P3					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
<u>Equipment Identification</u> Sensory skill to <i>identify</i> equipment and/or its component for a lab work.	Not able to identify the equipment.	--	--	--	Able to identify equipment as well as its components.
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<u>Response</u> Ability to <i>imitate</i> the lab work on his/her own.	Not able 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.	Able to fully imitate the lab work.
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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 3.1. 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 3.2. 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, as shown in Fig. 3.1

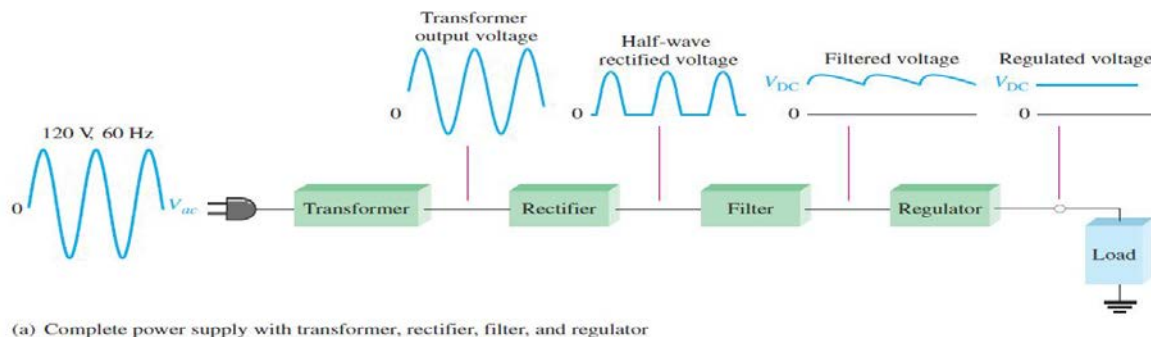
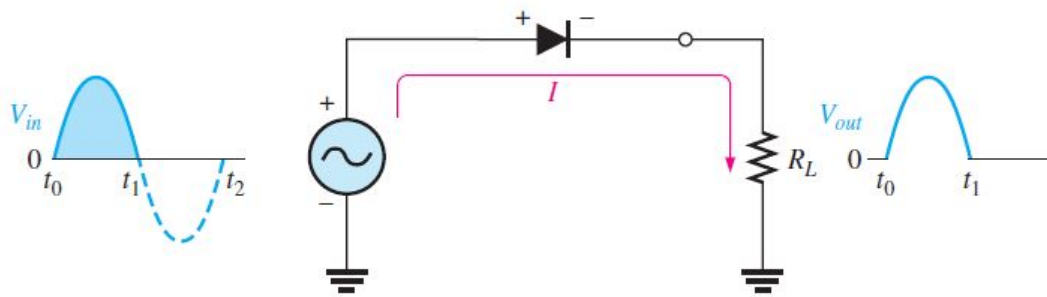
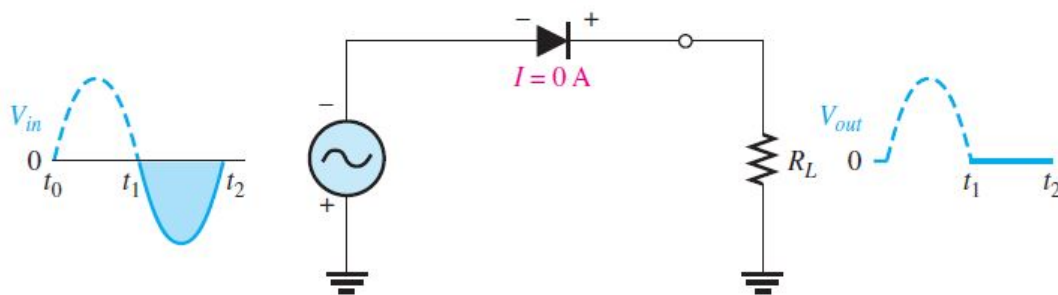


Figure 3.1: Half wave rectifier



(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

Figure 3.2: Function of half wave

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 below. The expression for the peak output voltage is:

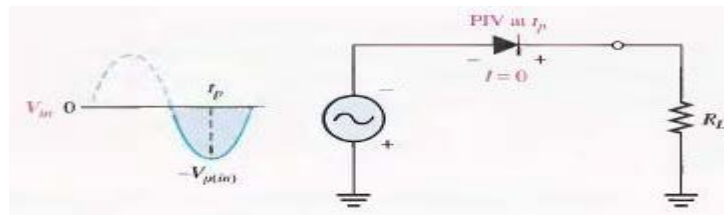
$$VP(out) = VP(in) - 0.7$$

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)

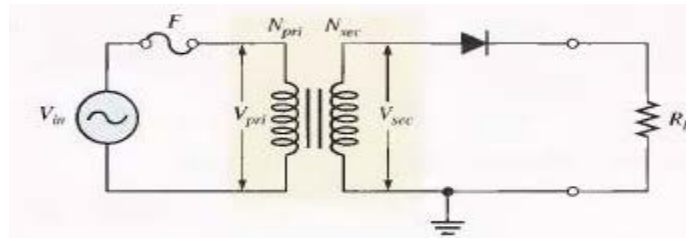
The peak inverse voltage (PIV) equals the peak value of the input voltage, and the diode must be capable of withstanding this amount of repetitive reverse voltage. For the diode in Figure below, the maximum value of reverse voltage, designated as PIV occurs at the peak of each negative alternation of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

$$PIV = V_P(in)$$



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 below. 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.



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 below. We will define the turns ratio as the ratio of secondary turns, N_{sec} to the primary turns, N_{pri} : $n = N_{sec} / N_{pri}$

$$V_{sec} = n V_{pri}$$

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 $V_{sec} = V_{pri}$.

The peak secondary voltage, $V_{P(sec)}$ in a transformer-coupled half-wave rectifier is the same as $V_{P(in)}$ in

Equation 2-2. Therefore, Equation below written in terms of $V_{P(sec)}$ is:

$$V_{P(out)} = V_{P(sec)} - 0.7$$

and the Equation below in terms of $V_{p(sec)}$ is:

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

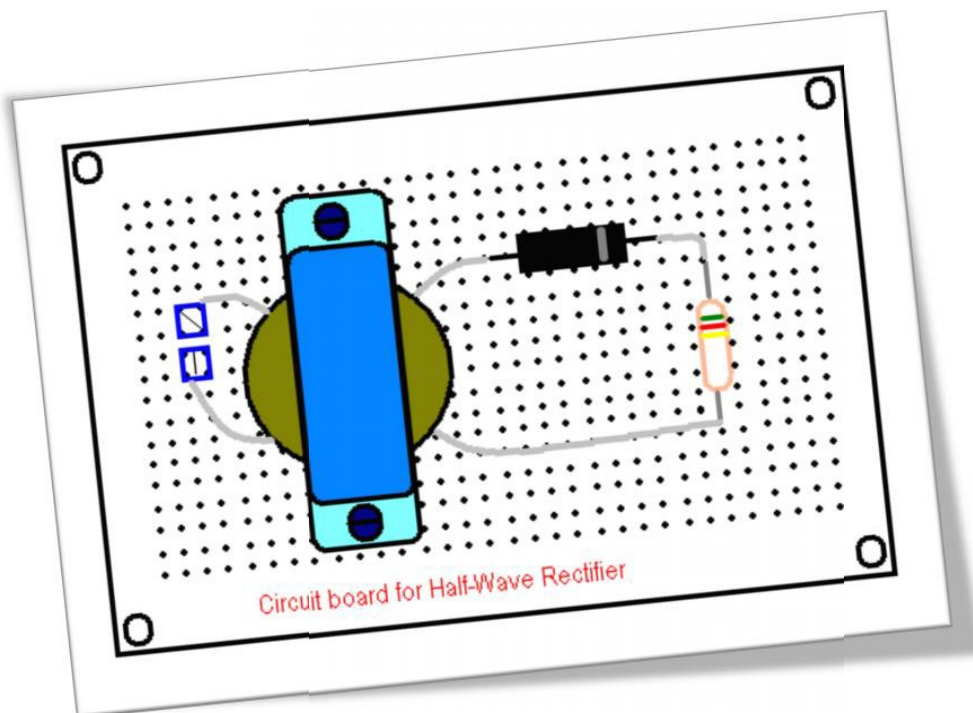
Pre-lab

Equipment required

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

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
Input to transformer				
Transformer output				
Circuit output				

Post lab

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

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	V _{peak-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.



Psychomotor Domain Assessment Rubric-Level P3					
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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 4.1.

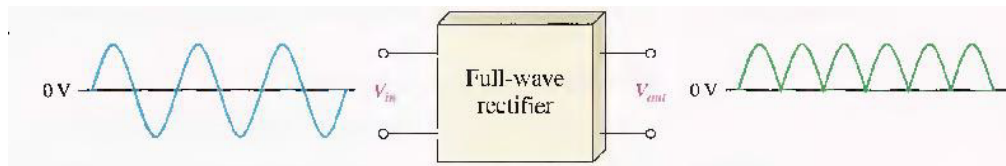


Figure 4.1: Full Wave rectification

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:

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

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 4.2 , 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.

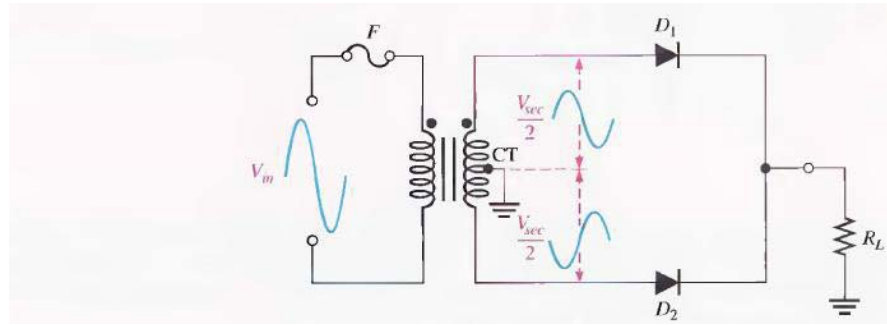


Figure 4.2: A Center Tape Full Wave rectification

For a positive half-cycle of the input voltage, the polarities of the secondary voltages are as shown in Figure 4.3(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 4.3(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.

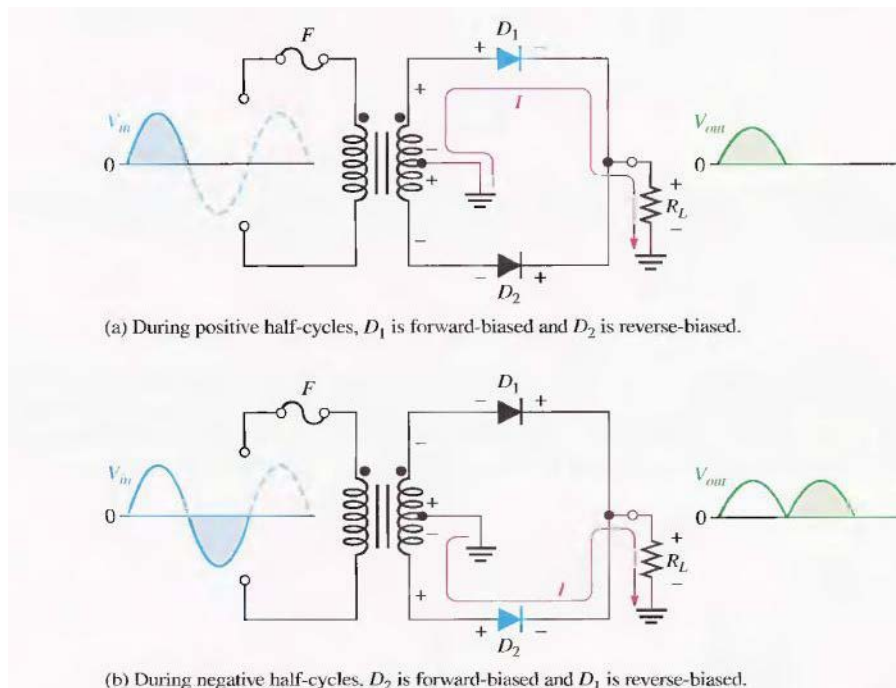


Figure 4.3: Center Tape operation

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 4.4 (a). 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.

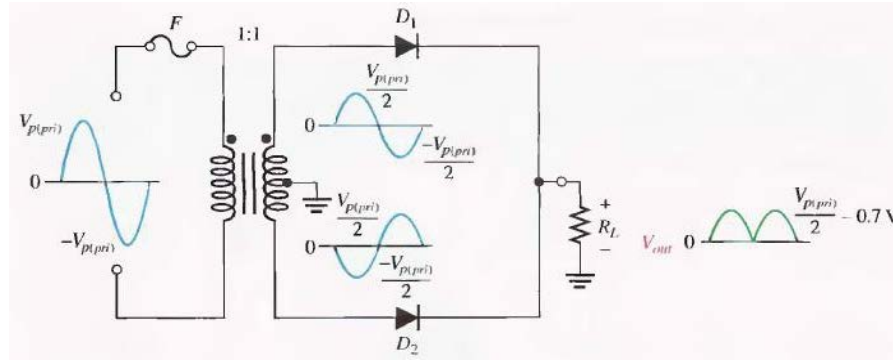


Figure 4.4 (a): Center tape Full Wave rectification

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 4.4 (b). 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} .

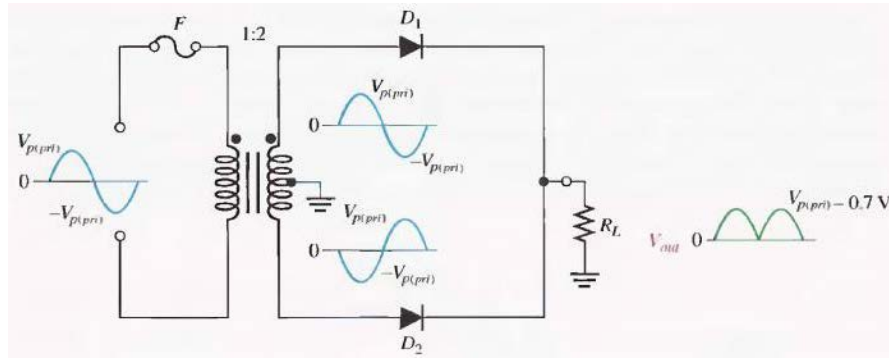


Figure 4.4 (b): Center tape Full Wave rectification with transformer

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.

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

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 4.4 where D_2 is assumed to be reverse-biased and D_1 is assumed to be forward-biased to illustrate the concept.

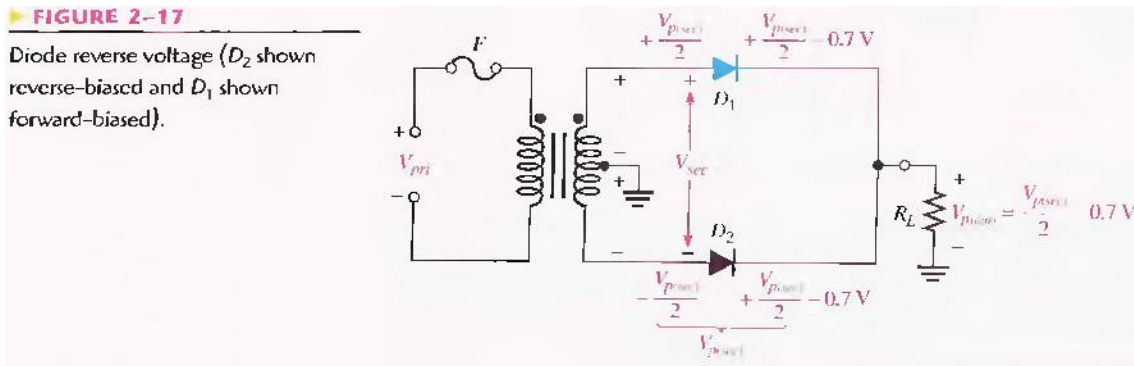


Figure 4.5: Diodes in reverse / forward mode

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

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

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:

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

Pre-lab

Objective

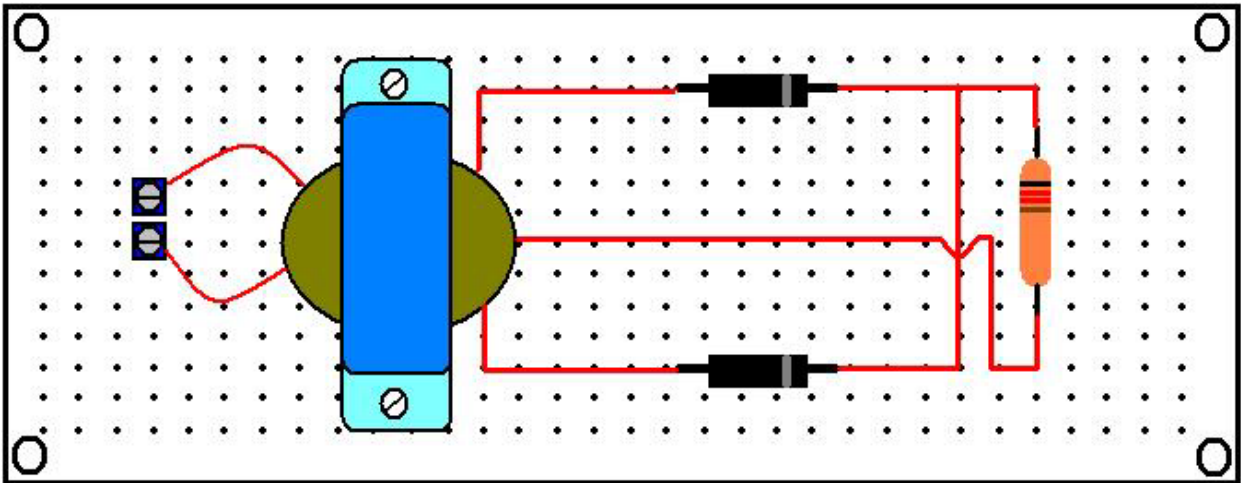
To construct a Full-Wave rectifier on a bread-board.

Equipment required

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

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. Observe the output using Oscilloscope & note down V_{peak-peak}, Frequency, rms value & average value.
2. Observe the output of transformer & note down all values.
3. Now observe the output across resistor using oscilloscope & note down same values as mentioned in above step.

Observations

Readings	V _{peak-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	V _{peak-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	V _{peak-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.



Psychomotor Domain Assessment Rubric-Level P3					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
<u>Equipment Identification</u> Sensory skill to <i>identify</i> equipment and/or its component for a lab work.	Not able to identify the equipment.	--	--	--	Able to identify equipment as well as its components.
<u>Equipment Use</u> Sensory skills to <i>demonstrate</i> the use of the equipment for the lab work.	Doesn't demonstrate the use of equipment.	Slightly demonstrates the use of equipment.	Somewhat demonstrates the use of equipment.	Moderately demonstrates the use of equipment.	Fully demonstrates the use of equipment.
<u>Procedural Skills</u> <i>Displays</i> skills to act upon sequence of steps in lab work.	Not able 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.	Able to fully understand lab work procedure and perform lab work.
<u>Response</u> Ability to <i>imitate</i> the lab work on his/her own.	Not able 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.	Able to fully imitate the lab work.
<u>Observation's Use</u> <i>Displays</i> skills to use the observations from lab work for experimental verifications and illustrations.	Not able to use the observations from lab work for experimental verifications and illustrations.	Slightly able to use the observations from lab work for experimental verifications and illustrations.	Somewhat able to use the observations from lab work for experimental verifications and illustrations.	Moderately able to use the observations from lab work for experimental verifications and illustrations.	Fully able to use the observations from lab work for experimental verifications and illustrations.
<u>Safety Adherence</u> Adherence to <i>safety</i> procedures.	Doesn't adhere to safety procedures.	Slightly adheres to safety procedures.	Somewhat adheres to safety procedures.	Moderately adheres to safety procedures.	Fully adheres to safety procedures.
<u>Equipment Handling</u> <i>Equipment care</i> 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.
<u>Group Work</u> <i>Contributes</i> in a group based lab work.	Doesn't participate and contribute.	Slightly participates and contributes.	Somewhat participates and contributes.	Moderately participates and contributes.	Fully participates and contributes.

Laboratory Session No. _____

Date: _____

Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with 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 5.1. When the input cycle is positive as in part (a), diodes D_1 and D_2 are forward-biased and conduct current in the direction shown. A voltage is developed across R_L that looks like the positive half of the input cycle. During this time, diodes D_3 and D_4 are reverse-biased.

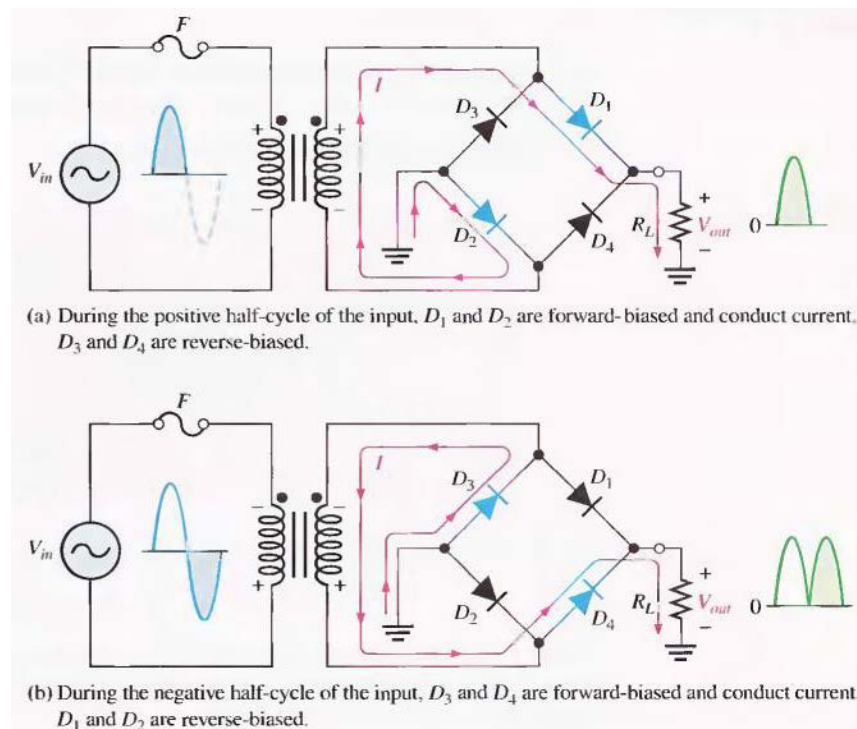


Figure 5.1: Operation of bridge rectifier

When the input cycle is negative as in Figure 5.1(b), diodes D_3 and D_4 are forward-biased and conduct current in the same direction through R_L as during the positive half-cycle. During the negative half-cycle, D_1 and D_2 are reverse-biased. A full-wave rectified output voltage appears across R_L as a result of this action.

Bridge Output Voltage: A bridge rectifier with a transformer-coupled input is shown in Figure 5.2 (a). During the positive half-cycle of the total secondary voltage, diodes D_1 and D_2 are

forward-biased. Neglecting the diode drops, the secondary voltage appears across the load resistor. The same is true when D3 and D4 are forward-biased during the negative half-cycle.

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

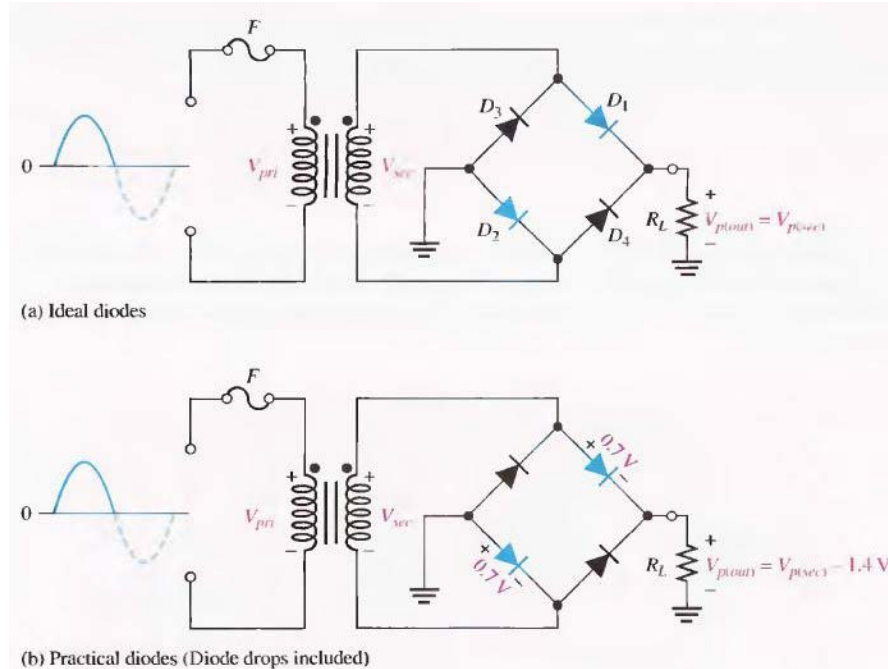


Figure 5.2: Operation during a positive half of primary and secondary voltages

As you can see in Figure 5.2(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

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

Peak Inverse Voltage: Let's assume that D1 and D2 are forward-biased and examine the reverse voltage across D3 and D4. Visualizing D1 and D2 as shorts (ideal model), as in Figure 2-22(a), you can see that D3 and D4, have a peak inverse voltage equal to the peak secondary voltage. Since the output voltage is ideally equal to the secondary voltage,

$$PIV = V_{p(out)}$$

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

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

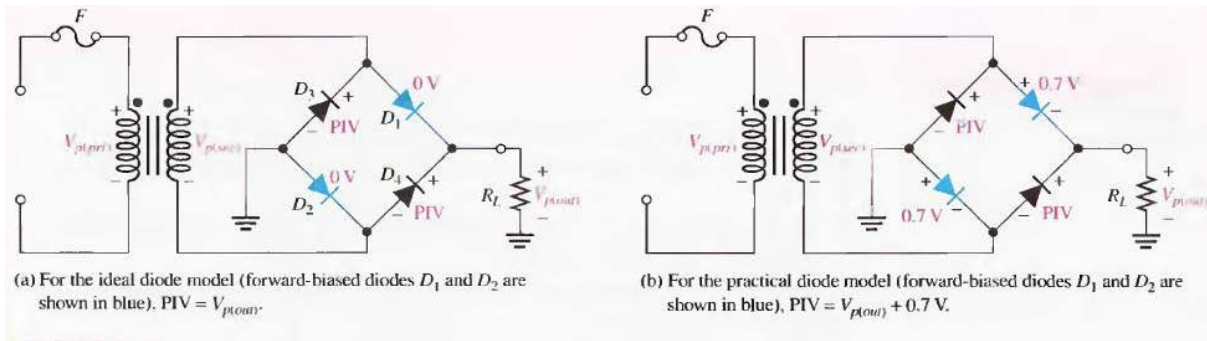


Figure 5.3: Peak voltages during positive half cycle

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

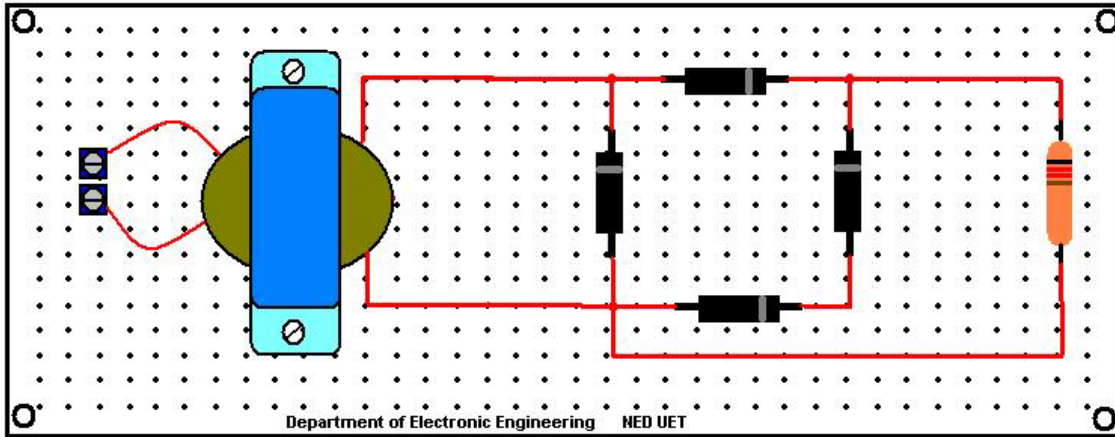
To construct a Full-Wave Bridge rectifier on a bread-board

Equipment required

- 1- Bread-board
- 2- Four silicon diodes (1N4001)
- 3- Transformer (220V – 12V)
- 4- Resistor (10k Ω)
- 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 $V_{\text{peak-peak}}$, 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	$V_{\text{peak-peak}}$	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 $1K\Omega$, $100K\Omega$ & $1M\Omega$ & write the change in output values in the following table.

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

- 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.

5- 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?

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



Psychomotor Domain Assessment Rubric-Level P3					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
<u>Equipment Identification</u> Sensory skill to <i>identify</i> equipment and/or its component for a lab work.	Not able to identify the equipment.	--	--	--	Able to identify equipment as well as its components.
<u>Equipment Use</u> Sensory skills to <i>demonstrate</i> the use of the equipment for the lab work.	Doesn't demonstrate the use of equipment.	Slightly demonstrates the use of equipment.	Somewhat demonstrates the use of equipment.	Moderately demonstrates the use of equipment.	Fully demonstrates the use of equipment.
<u>Procedural Skills</u> <i>Displays</i> skills to act upon sequence of steps in lab work.	Not able 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.	Able to fully understand lab work procedure and perform lab work.
<u>Response</u> Ability to <i>imitate</i> the lab work on his/her own.	Not able 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.	Able to fully imitate the lab work.
<u>Observation's Use</u> <i>Displays</i> skills to use the observations from lab work for experimental verifications and illustrations.	Not able to use the observations from lab work for experimental verifications and illustrations.	Slightly able to use the observations from lab work for experimental verifications and illustrations.	Somewhat able to use the observations from lab work for experimental verifications and illustrations.	Moderately able to use the observations from lab work for experimental verifications and illustrations.	Fully able to use the observations from lab work for experimental verifications and illustrations.
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Laboratory Session No. _____

Date: _____

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

LAB SESSION 06

Objective

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

Introduction

A 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 6.1 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.

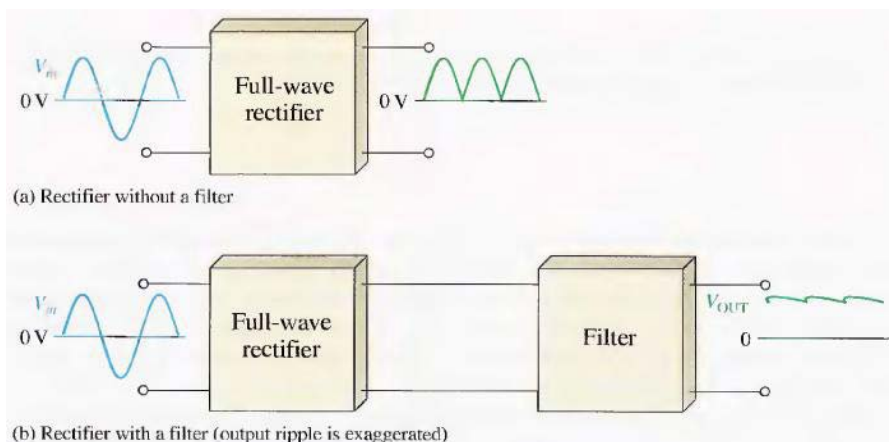


Figure 6.1: Working of filter

Capacitor-Input filter: A half-wave rectifier with a capacitor-input filter is shown in Figure 6.2. 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.

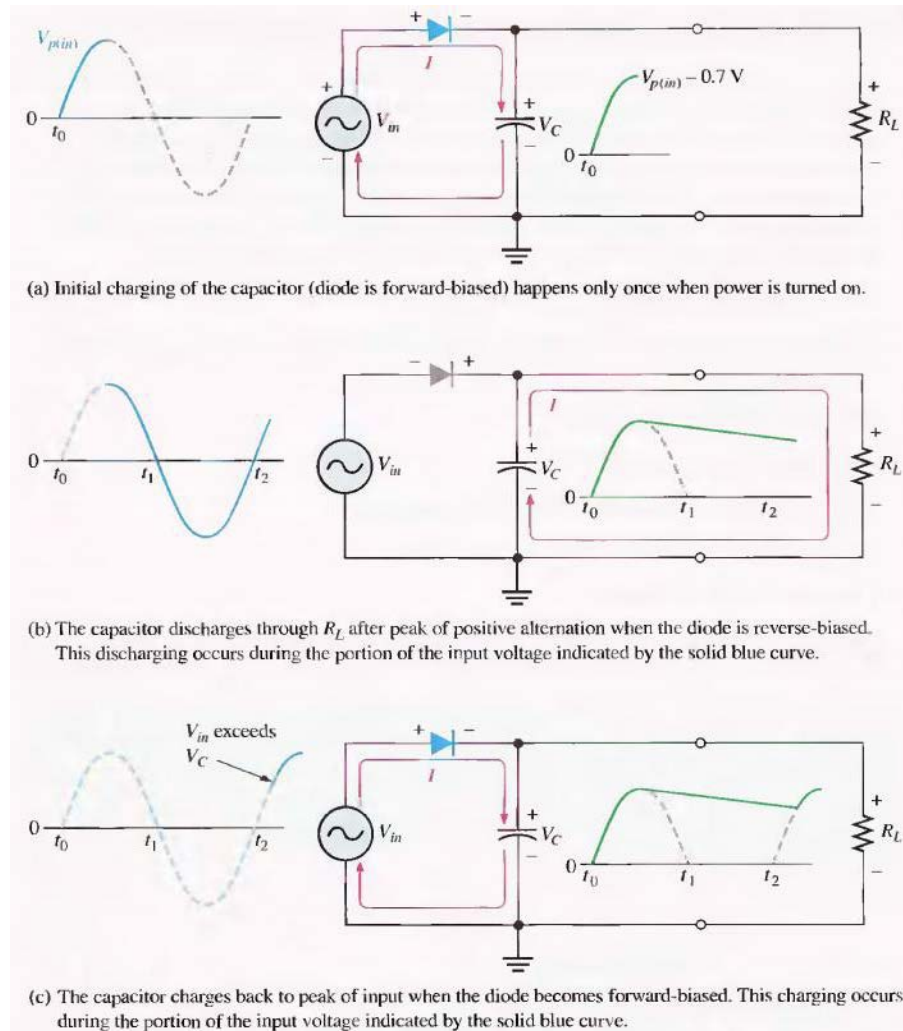
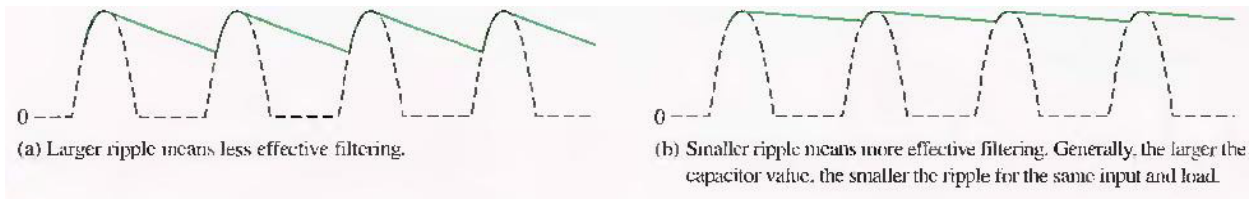


Figure 6.2: Operation of half-wave rectifier with capacitor input filter

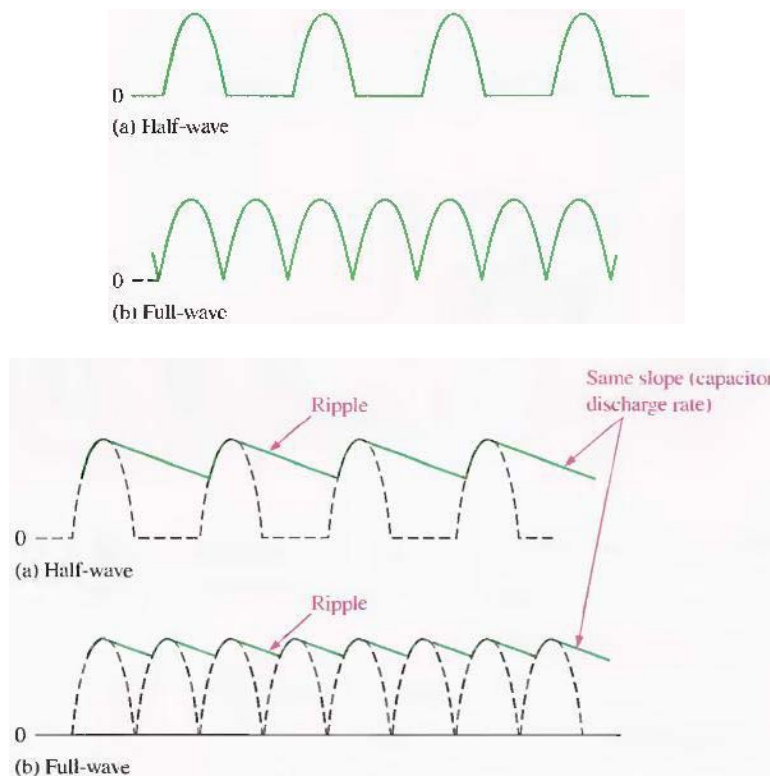
During the positive first quarter-cycle of the input, the diode is forward-biased, allowing the capacitor to charge to within 0.7 V of the input peak, as illustrated in Figure 6.2(a). When the input begins to decrease below its peak, as shown in part (b), the capacitor retains its charge and the diode 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 below.



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 below

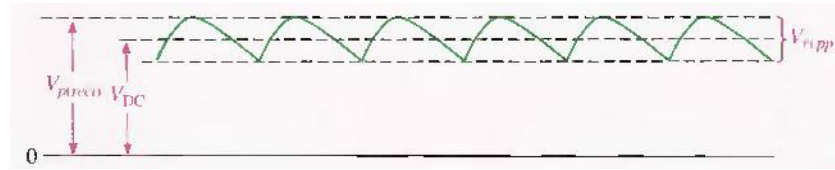


Ripple Factor: The ripple factor (r) is an indication of the effectiveness of the filter and is defined as:

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

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 below. 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.

$$V_{r(pp)} \cong \left(\frac{1}{fR_L C} \right) V_{p(rect)}$$

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

Surge Current in the Capacitor-Input Filter: Before the switch in Figure 6.3(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.

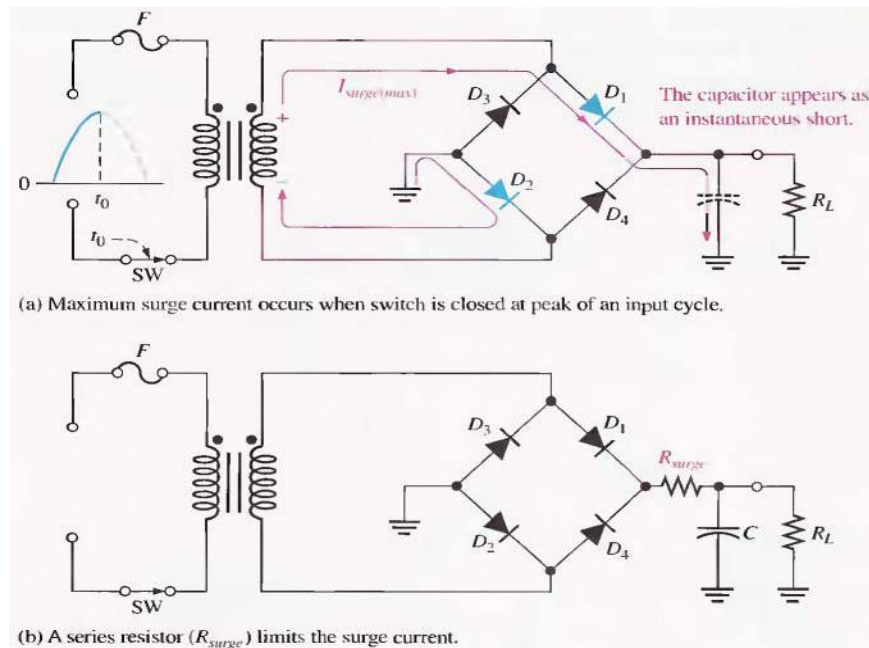


Figure 6.3: Surge current

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 6.3(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:

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

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 6.4.

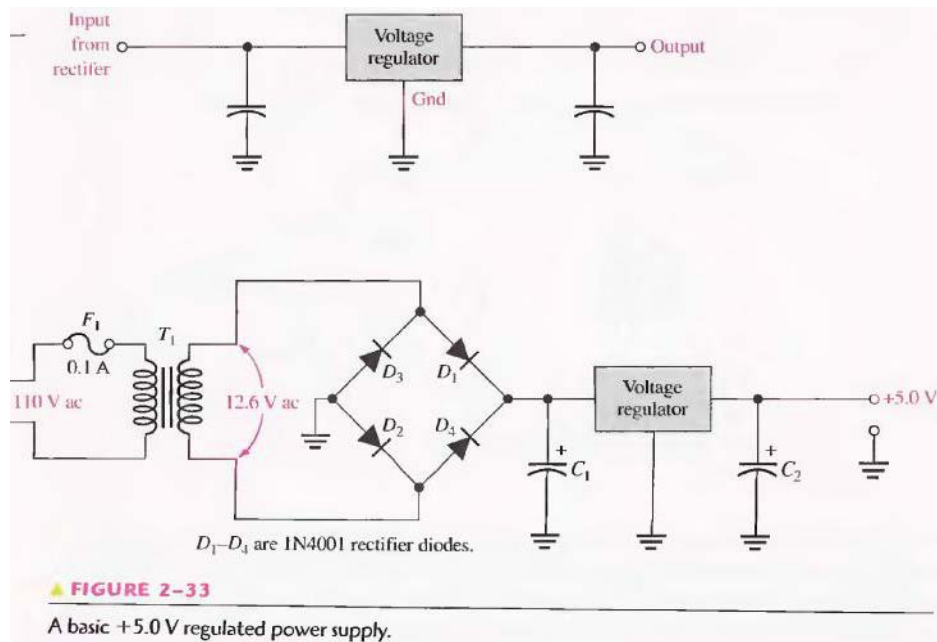


Figure 6.4: Voltage Regulator

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.

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

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:

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

where V_{NL} is the output voltage with no load and V_{FL} is the output voltage with full (maximum)

load.

Pre-lab

Objective

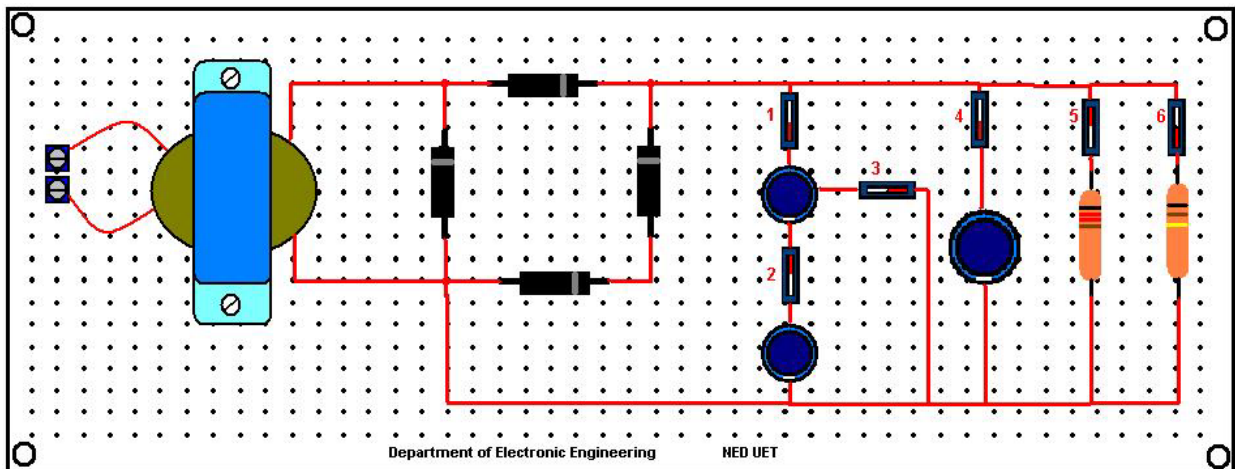
To insert capacitive filter in the circuit of half wave rectifier.

Equipment required

- 1- Above three circuits on bread-board
- 2- Polar capacitors ($4.7\ \mu\text{F}$, $47\ \mu\text{F}$, $470\ \mu\text{F}$)
- 3- Transformer (220V – 12V)
- 4- Resistor ($10\text{k}\Omega$)
- 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 V_{peak-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	V _{peak-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 $R = 200\Omega$, $C = 10\mu\text{F}$		
With $R = 3\text{k}\Omega$, $C = 10\mu\text{F}$		
With $R = 200\Omega$, $C = 470\mu\text{F}$		

Post lab

Calculations

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

Readings	V _{peak-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.



Psychomotor Domain Assessment Rubric-Level P3					
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Laboratory Session No. _____

Date: _____

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

LAB SESSION 7

Objective

To design, analyze and measure the output of diode limiters

Introduction

Figure 7.1(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_1 and the load resistor, R_L , as follows:

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

If R_1 is small compared to R_L , then $V_{out} = V_{in}$.

If the diode is turned around, as in Figure 7.1(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_L proportional to the input voltage.

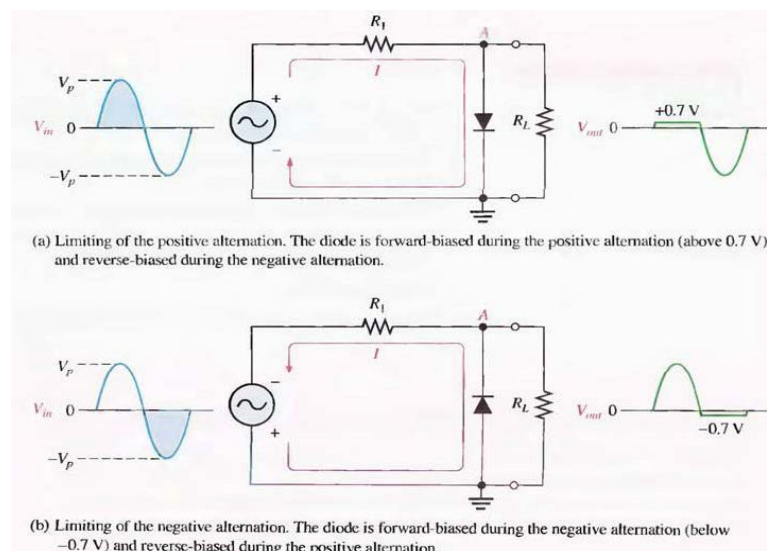


Figure 7.1: Diode as Clippers/limiters

Pre-lab

Objective

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

Laboratory procedure

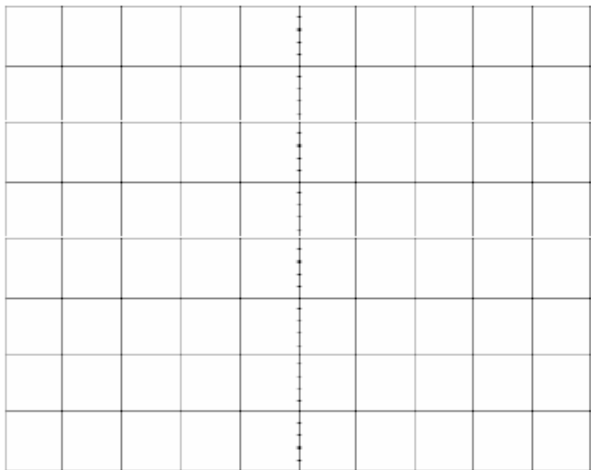
Objective

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

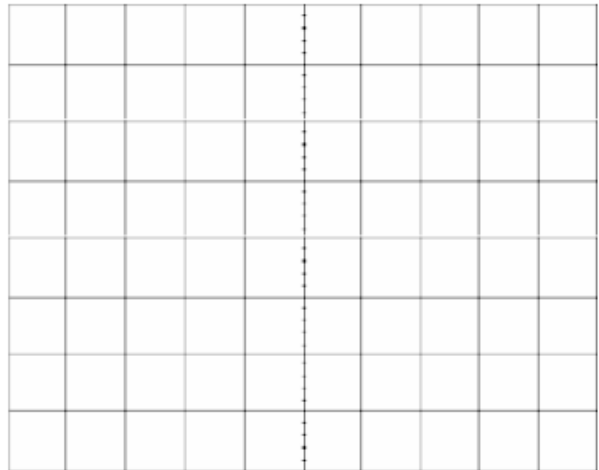
Procedure

- 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.



Psychomotor Domain Assessment Rubric-Level P3					
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Remarks	
Instructor's Signature with Date:	

LAB SESSION 8

Objective

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

Theory

Diode Clampers

A clamper adds a dc level to an ac voltage. Clampers are sometimes known as dc restorers. Figure 2-45 shows a diode clamper 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 ($V_{p(in)} - 0.7\text{ V}$), as shown in Figure 8.1(a). Just after the negative peak, the diode is reverse-biased. This is because the cathode is held near $V_{p(in)} - 0.7\text{ V}$ 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.

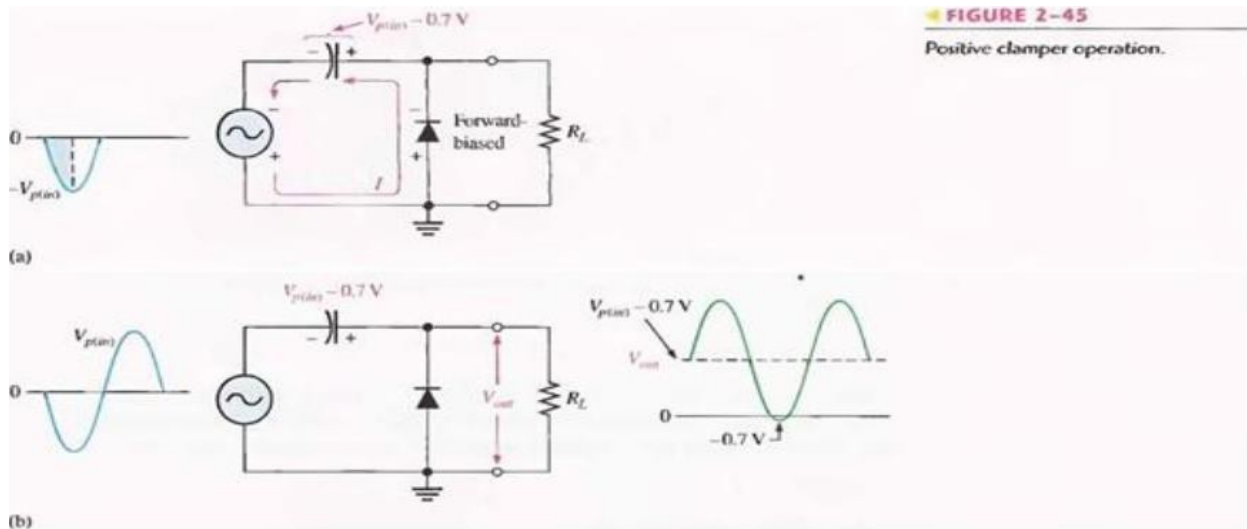


Figure 8.1: Positive Clamper

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 8.2.

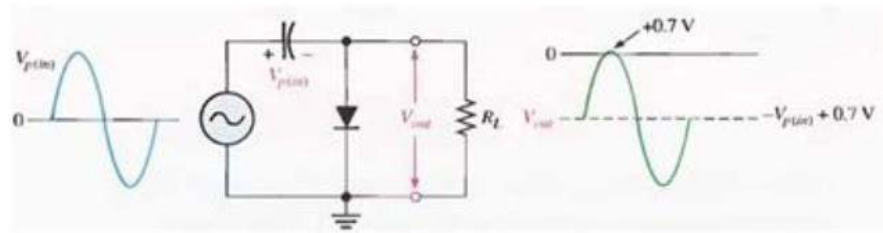


Figure 8.2: Negative Clamper

Pre-lab

Objective

To the 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=
Negative peak V =

Positive 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.



Psychomotor Domain Assessment Rubric-Level P3					
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Laboratory Session No. _____

Date: _____

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

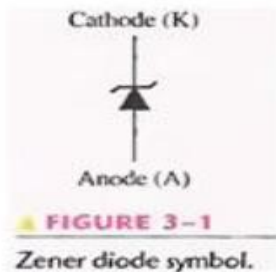
LAB SESSION 9

Objective

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

Theory

ZENER IODES



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, a zener diode is a silicon pn junction device that is designed for operation in the reverse breakdown 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 9.1 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.

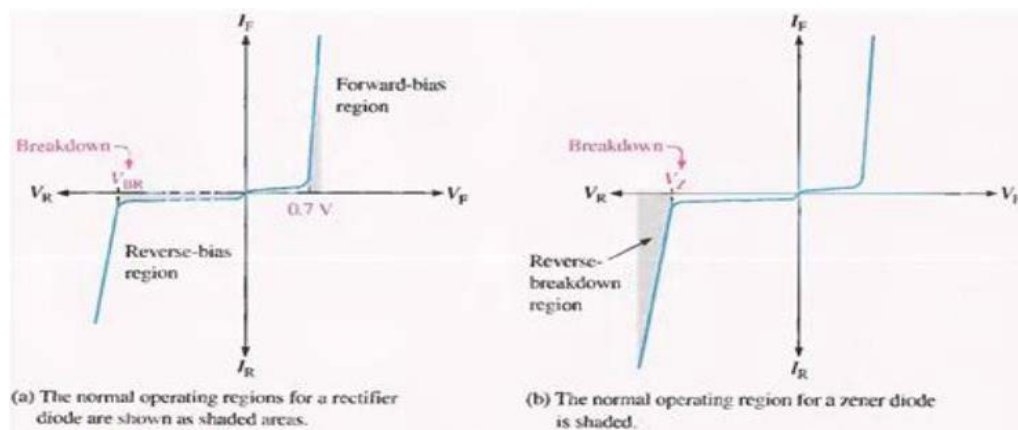


Figure 9.1: Characteristics of diode

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.

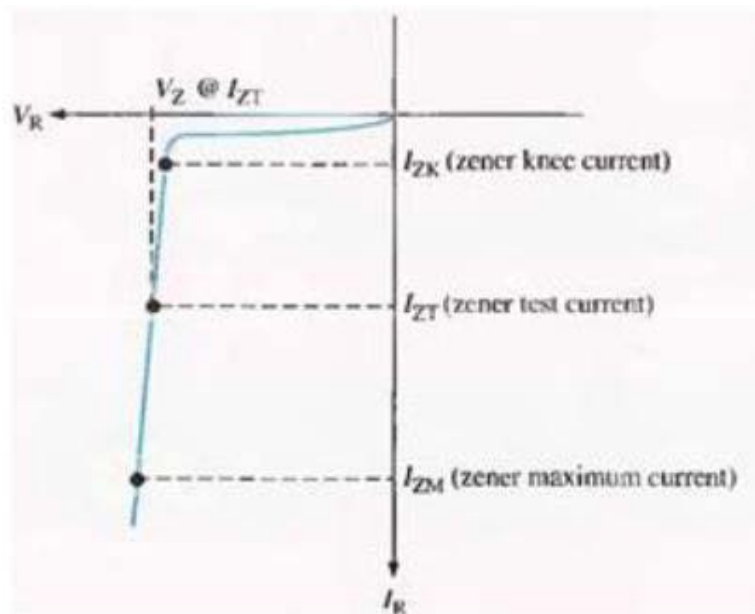


Figure 9.2: Reverse characteristics of Zener Diode

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 below 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.

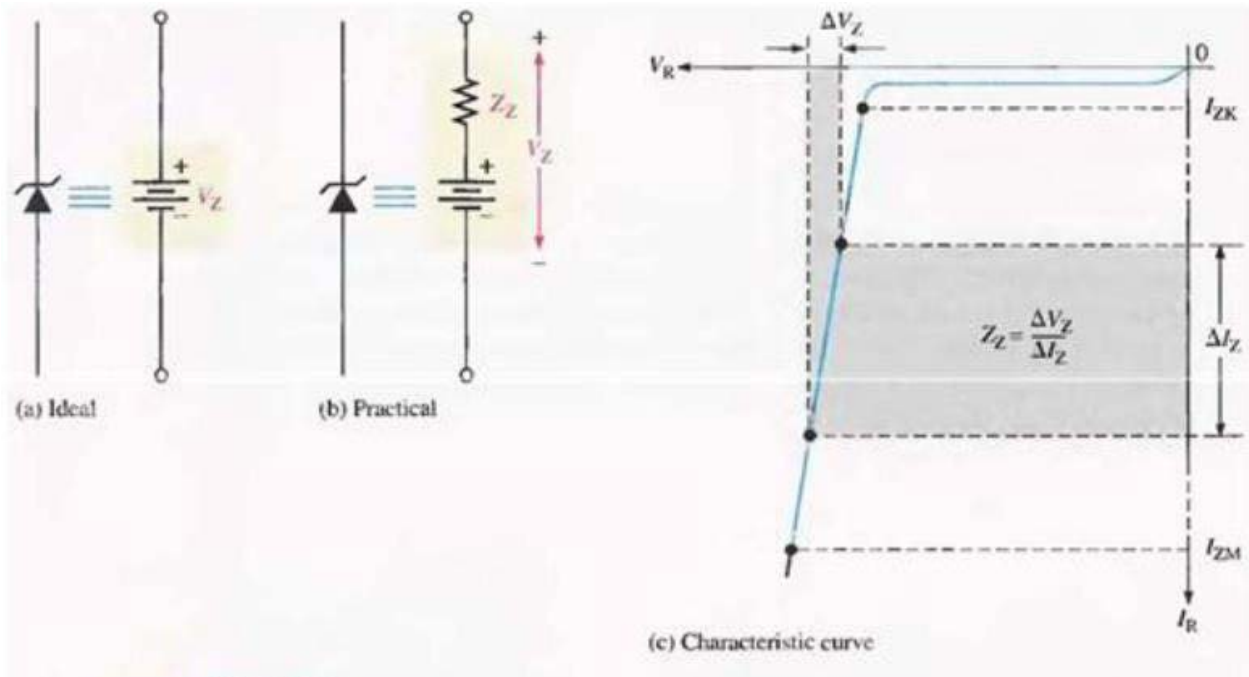


Figure above represents the practical model of a zener diode, where the zener impedance (Z_Z) is included. Since the actual voltage curve is not ideally vertical, a change in zener current (ΔI_Z) produces a small change in zener voltage (ΔV_Z), as illustrated in Figure above(c). By Ohm's law, the ratio of ΔV_Z to ΔI_Z is the impedance, as expressed in the following equation:

$$Z_Z = \frac{\Delta V_Z}{\Delta I_Z}$$

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.

Pre-lab

Objective

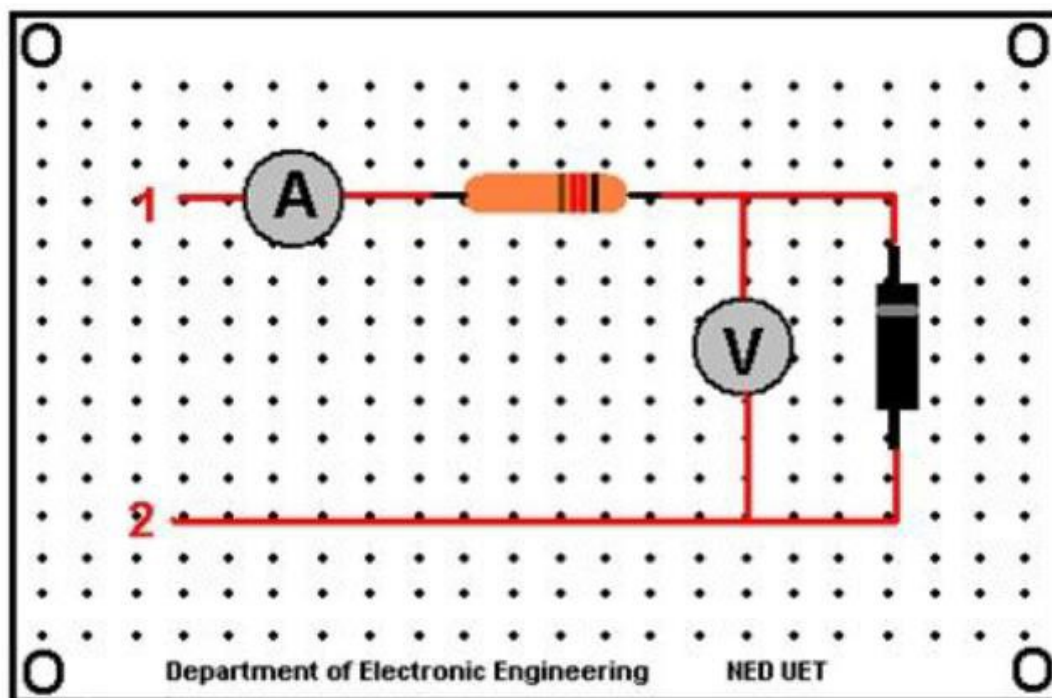
Construct the following circuit & Test for continuity.

Required components

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

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

Voltage	Current

REVERSE BIAS MODE

Voltage	Current

GRAPH

Attach both graphs here.

Post lab

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



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Remarks	
Instructor's Signature with Date:	

LAB SESSION 10

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.

Theory

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 voltage 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 $-R_f/R$ 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 $-R_f/R$.

Case-3: By setting the ratio 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

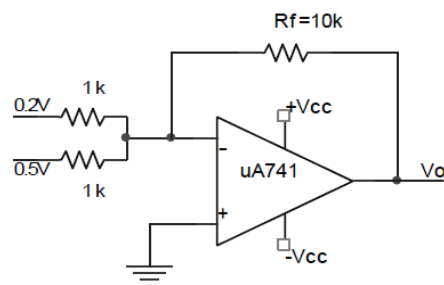
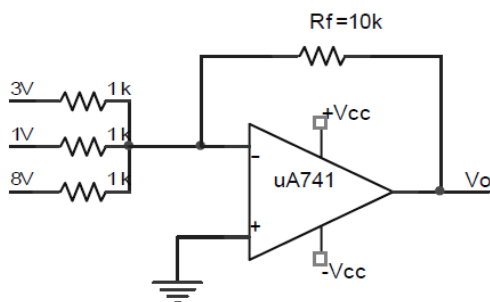
1. Assemble an adder circuit with $R_f = R_1 = 10k$ and $R_2 = 47k$ as shown in task2 of post lab exercise.
2. Feed sinusoidal input of amplitude 100mv and frequency 1 KHz to each input.
3. Observe the input voltages and output voltage on a CRO Find the magnitude of the output voltage and tabulate the reading in Table 2-1-2.
4. 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

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





Psychomotor Domain Assessment Rubric-Level P3					
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<u>Observation's Use</u> <i>Displays</i> skills to use the observations from lab work for experimental verifications and illustrations.	Not able to use the observations from lab work for experimental verifications and illustrations.	Slightly able to use the observations from lab work for experimental verifications and illustrations.	Somewhat able to use the observations from lab work for experimental verifications and illustrations.	Moderately able to use the observations from lab work for experimental verifications and illustrations.	Fully able to use the observations from lab work for experimental verifications and illustrations.
<u>Safety Adherence</u> Adherence to <i>safety</i> procedures.	Doesn't adhere to safety procedures.	Slightly adheres to safety procedures.	Somewhat adheres to safety procedures.	Moderately adheres to safety procedures.	Fully adheres to safety procedures.
<u>Equipment Handling</u> <i>Equipment care</i> 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.
<u>Group Work</u> <i>Contributes</i> in a group based lab work.	Doesn't participate and contribute.	Slightly participates and contributes.	Somewhat participates and contributes.	Moderately participates and contributes.	Fully participates and contributes.

Laboratory Session No. _____

Date: _____

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

LAB SESSION 11

Objective

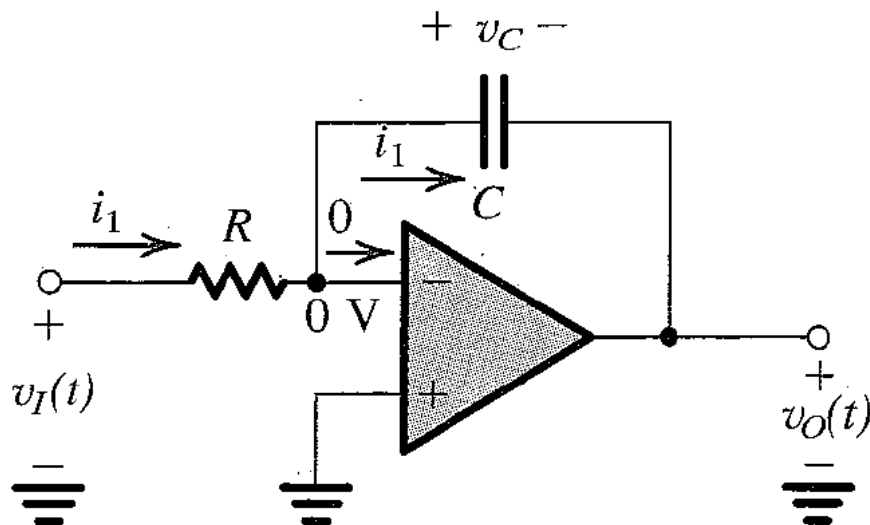
To design and versify the Operation of Inverting Integrator.

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)				



Psychomotor Domain Assessment Rubric-Level P3					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
<u>Equipment Identification</u> Sensory skill to <i>identify</i> equipment and/or its component for a lab work.	Not able to identify the equipment.	--	--	--	Able to identify equipment as well as its components.
<u>Equipment Use</u> Sensory skills to <i>demonstrate</i> the use of the equipment for the lab work.	Doesn't demonstrate the use of equipment.	Slightly demonstrates the use of equipment.	Somewhat demonstrates the use of equipment.	Moderately demonstrates the use of equipment.	Fully demonstrates the use of equipment.
<u>Procedural Skills</u> <i>Displays</i> skills to act upon sequence of steps in lab work.	Not able 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.	Able to fully understand lab work procedure and perform lab work.
<u>Response</u> Ability to <i>imitate</i> the lab work on his/her own.	Not able 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.	Able to fully imitate the lab work.
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Laboratory Session No. _____

Date: _____

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

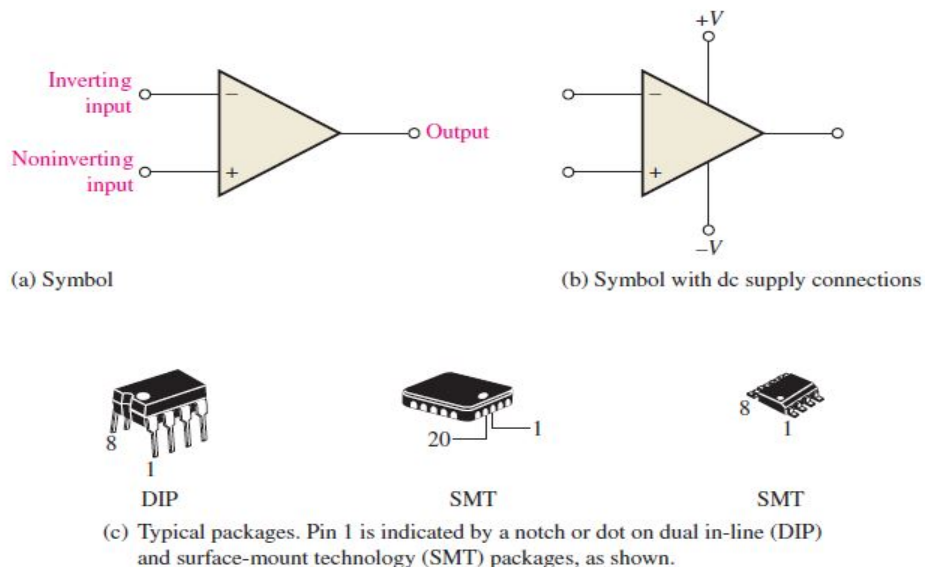
LAB SESSION 12

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

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).

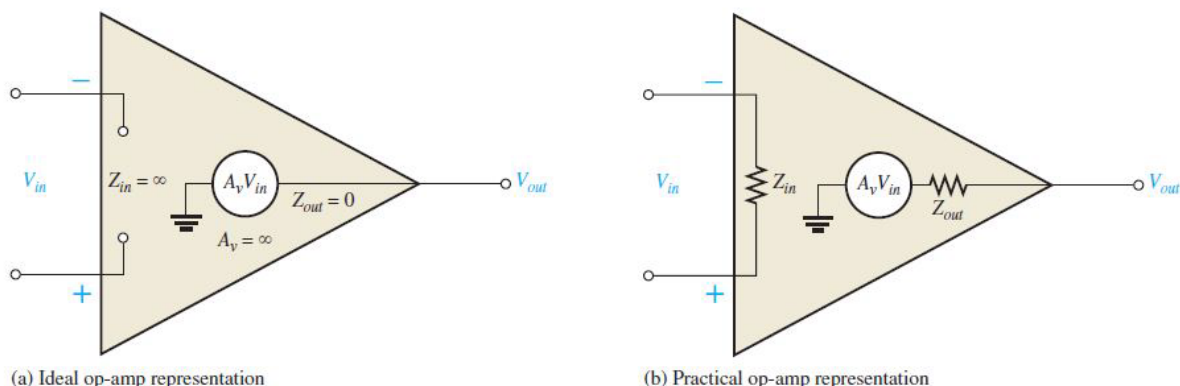


The Ideal Op-Amp

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

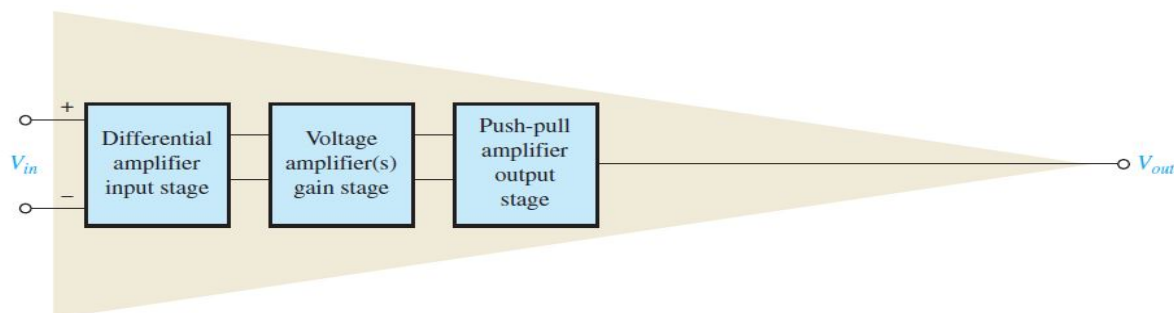
Basic op-amp representations.

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.

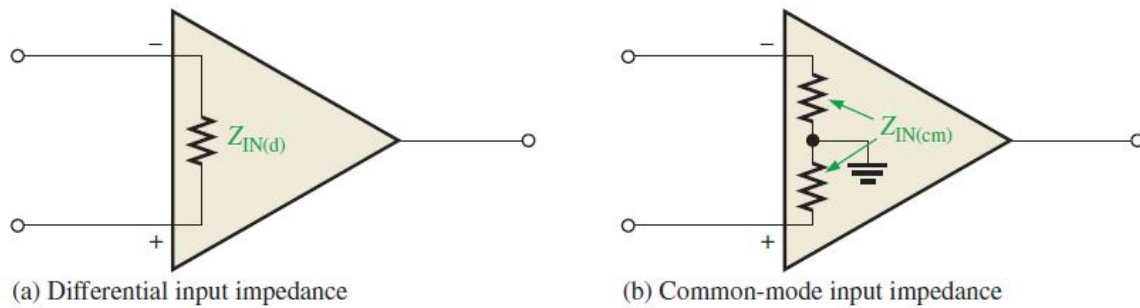
The CMRR is often expressed in decibels (dB) as

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

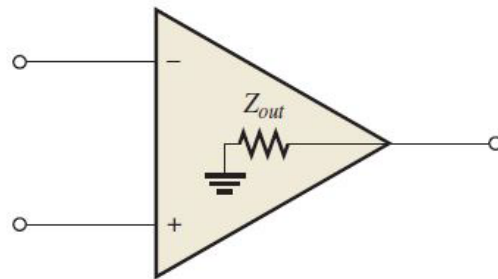
The **open-loop voltage gain**, A_{ol} , of an op-amp is the internal voltage gain of the device and represents the ratio of output voltage to input voltage when there are no external components. The open-loop voltage gain is set entirely by the internal design. Open-loop voltage gain can range up to 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).

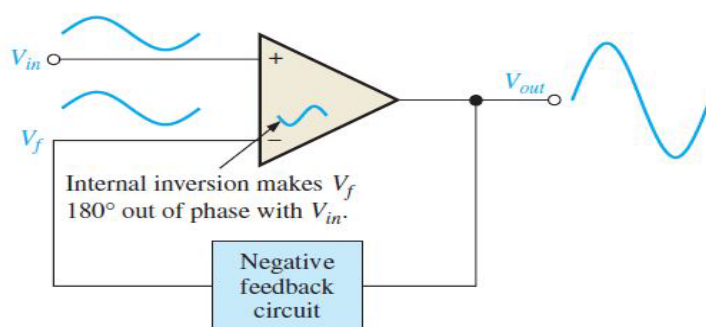


Output Impedance The *output impedance* is the resistance viewed from the output terminal of the op-amp, as indicated in Figure 12–10.



◀ **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,

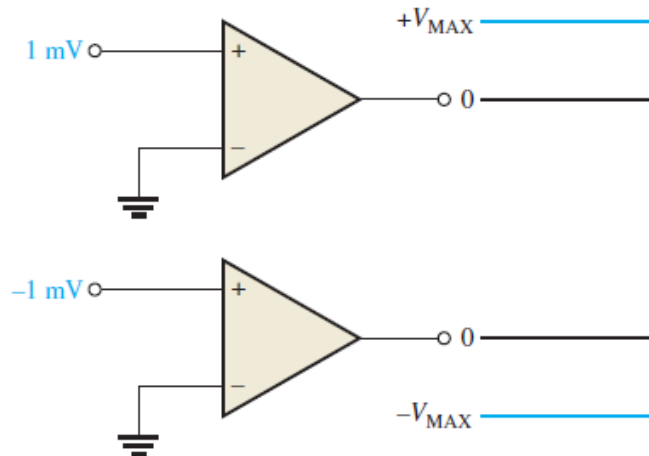
$$V_{IN}A_{ol} = (1 \text{ mV})(100,000) = 100 \text{ V}$$

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_{cl}) 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_d

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

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

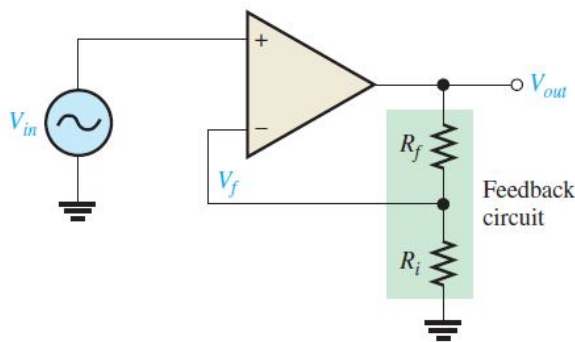


FIGURE 12–16
Noninverting amplifier.

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

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

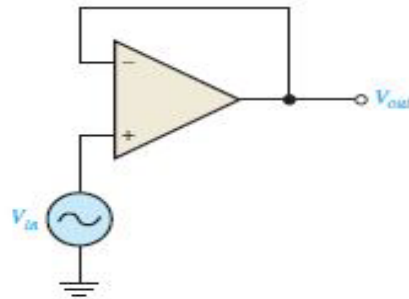
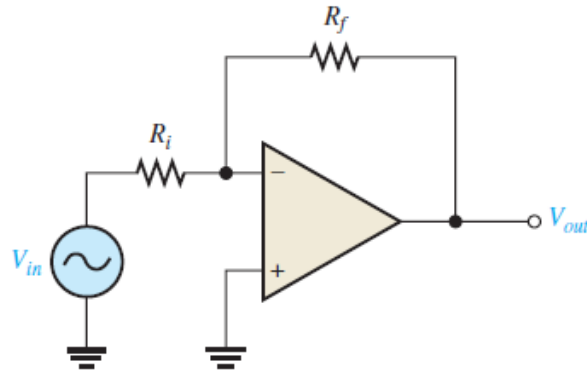


FIGURE 12-19
Op-amp voltage-follower.

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.

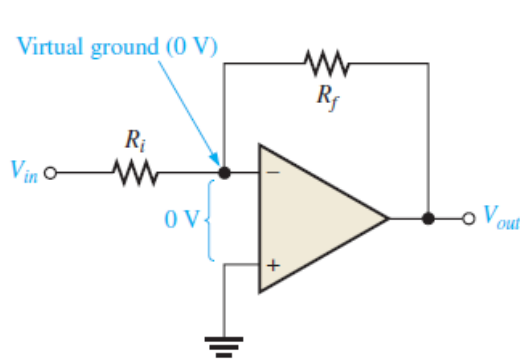


◀ **FIGURE 12–20**
Inverting amplifier.

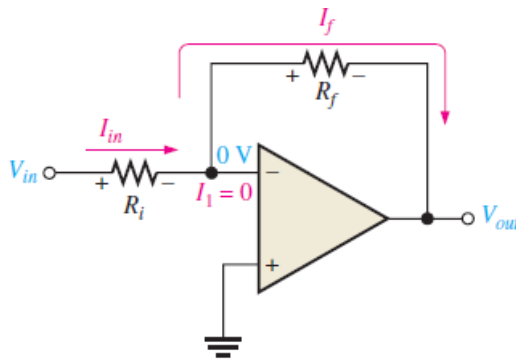
At this point, the ideal op-amp parameters mentioned earlier are useful in simplifying the analysis of this circuit. In particular, the concept of infinite input impedance is of great value. An infinite input impedance implies zero current at the inverting input. If there is zero current through the 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'

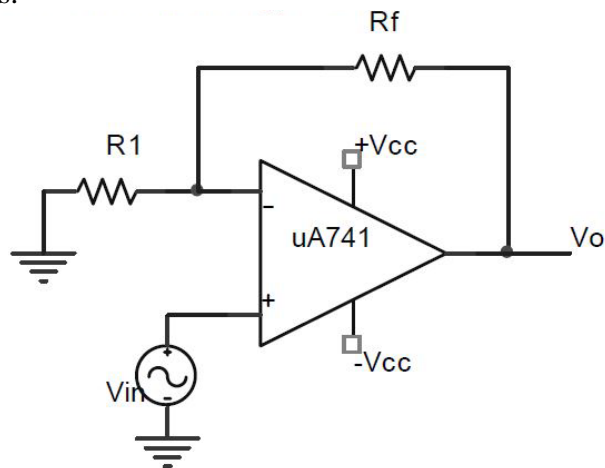
Lab procedure

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

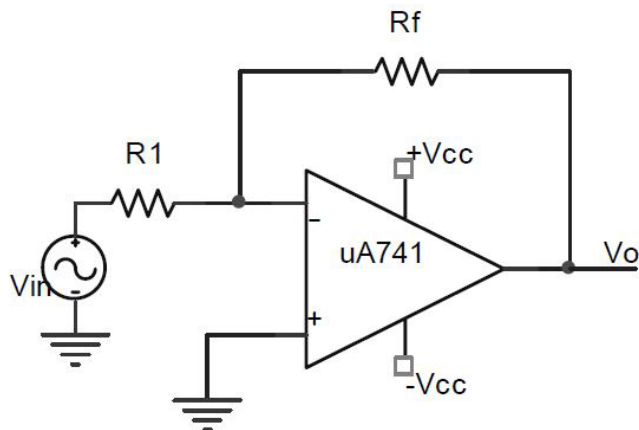
Inverting amplifier

4.1 Design an inverting amplifier for the gain of 15. Let $R_1=1.5k\Omega$. 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.



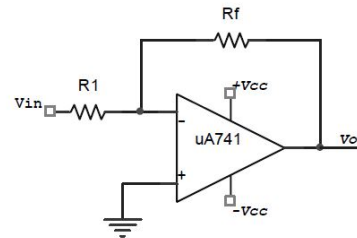
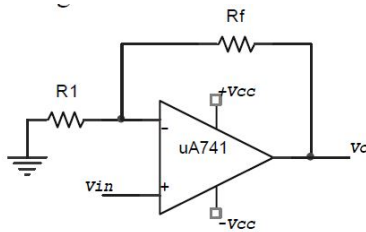
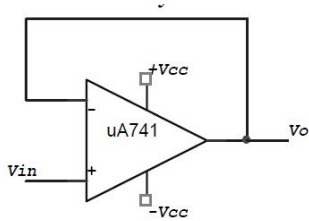
Inverting amplifier

Observations

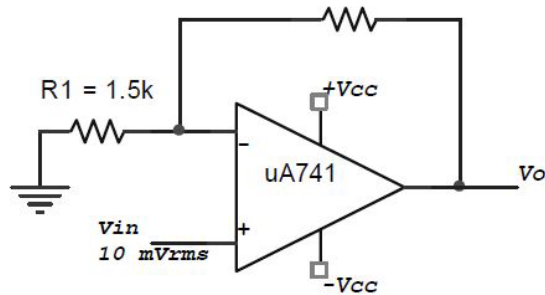
Parameter	Inverting Amplifier	Non- Inverting
V_{in}		
Frequency		
V_{out}		

Post lab

1. Identify each of the op-amp configurations.



2. For the amplifier determine the following: (a) ACL(NI) (b) VO
 $R_f = 560k$





Psychomotor Domain Assessment Rubric-Level P3					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
<u>Equipment Identification</u> Sensory skill to <i>identify</i> equipment and/or its component for a lab work.	Not able to identify the equipment.	--	--	--	Able to identify equipment as well as its components.
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Laboratory Session No. _____

Date: _____

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

OPEN ENDED LAB

To design and verify the operation of a common source amplifier using vero board

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

Common source amplifier with source degeneration

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

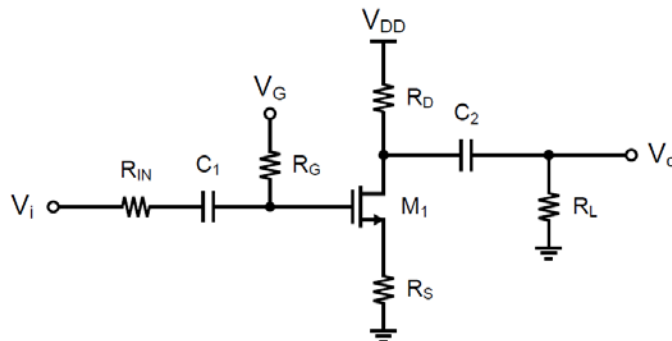


Fig. 12.1 Common source amplifier with source degeneration

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 R_G in Fig. above. To analyze the operating point of the MOSFET, we can overlay the I-V characteristic of the MOSFET- R_S 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.

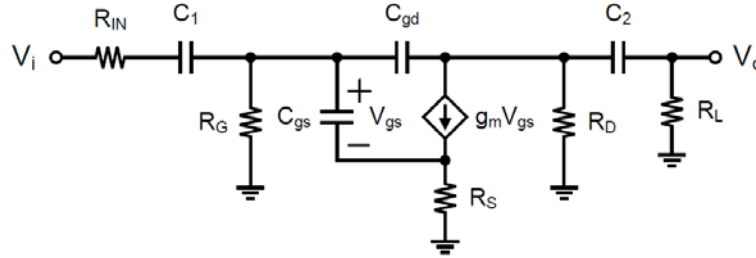


Fig. 12.2 AC equivalent circuit of the amplifier

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.

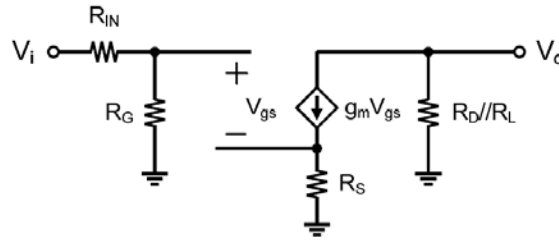


Fig. 12.3 Mid-band AC equivalent circuit of the amplifier

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	
G_m	
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.
2. Implement this circuit on veroboard



Psychomotor Domain Assessment Rubric-Level P3					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
<u>Equipment Identification</u> Sensory skill to <i>identify</i> equipment and/or its component for a lab work.	Not able to identify the equipment.	--	--	--	Able to identify equipment as well as its components.
<u>Equipment Use</u> Sensory skills to <i>demonstrate</i> the use of the equipment for the lab work.	Doesn't demonstrate the use of equipment.	Slightly demonstrates the use of equipment.	Somewhat demonstrates the use of equipment.	Moderately demonstrates the use of equipment.	Fully demonstrates the use of equipment.
<u>Procedural Skills</u> <i>Displays</i> skills to act upon sequence of steps in lab work.	Not able 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.	Able to fully understand lab work procedure and perform lab work.
<u>Response</u> Ability to <i>imitate</i> the lab work on his/her own.	Not able 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.	Able to fully imitate the lab work.
<u>Observation's Use</u> <i>Displays</i> skills to use the observations from lab work for experimental verifications and illustrations.	Not able to use the observations from lab work for experimental verifications and illustrations.	Slightly able to use the observations from lab work for experimental verifications and illustrations.	Somewhat able to use the observations from lab work for experimental verifications and illustrations.	Moderately able to use the observations from lab work for experimental verifications and illustrations.	Fully able to use the observations from lab work for experimental verifications and illustrations.
<u>Safety Adherence</u> Adherence to <i>safety</i> procedures.	Doesn't adhere to safety procedures.	Slightly adheres to safety procedures.	Somewhat adheres to safety procedures.	Moderately adheres to safety procedures.	Fully adheres to safety procedures.
<u>Equipment Handling</u> <i>Equipment care</i> 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.
<u>Group Work</u> <i>Contributes</i> in a group based lab work.	Doesn't participate and contribute.	Slightly participates and contributes.	Somewhat participates and contributes.	Moderately participates and contributes.	Fully participates and contributes.

Laboratory Session No. _____

Date: _____

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