PRACTICAL WORK BOOK

For Academic Session 2014

BASIC ELECTRONICS
(EL-102)
For F.E (EL & TC ONLY)

Name   : _____

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LABORATORY WORK BOOK

FOR THE COURSE

EL-102 BASIC ELECTRONICS

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Basic Electronic Laboratory Manual

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Lab Session 01

OBJECTIVE

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

MULTIMETERS

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

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

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

What is continuity?

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

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

Remember!

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

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

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

If you are testing two points in a circuit and there is a (big) capacitor between those points **you may hear a quick beep and then quiet**. That's because the voltage the meter is applying to 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 5 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**)
the more it fights. Most resistors you'll see range between 1 ohm and 1 mega ohm (1.0 M) 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 dont have to read any numbers and the stripes are visible no matter how it is rotated.

This image shows a 1.0 kΩ 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 KΩ when really you're in MΩ. This is a big problem for beginners so be careful!

Lab Procedure

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

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   5% resistor is actually
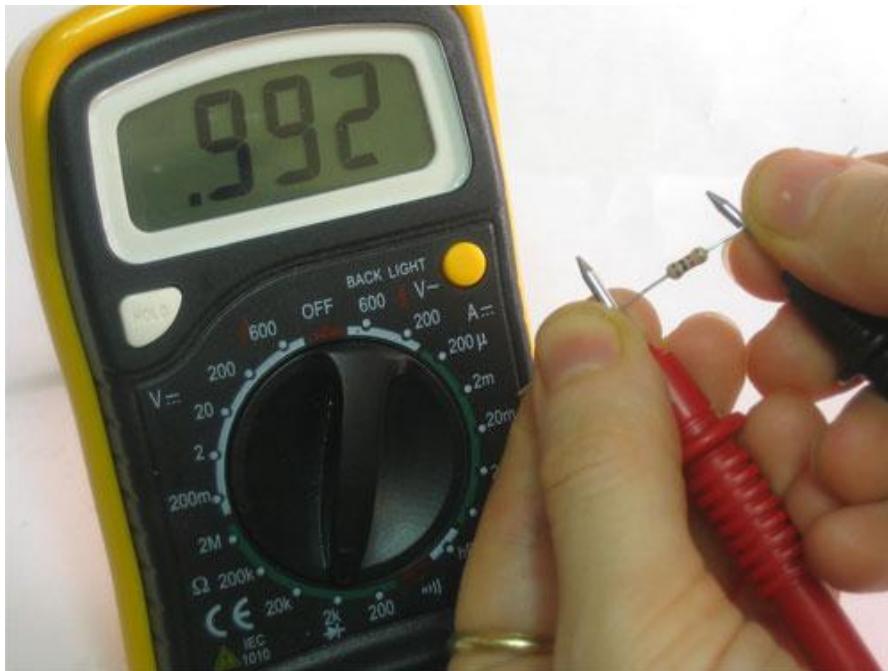
0.988 K ohm.

And this 10K   is really 9.80K   . Note that the numbers look similar but the decimal point has moved.
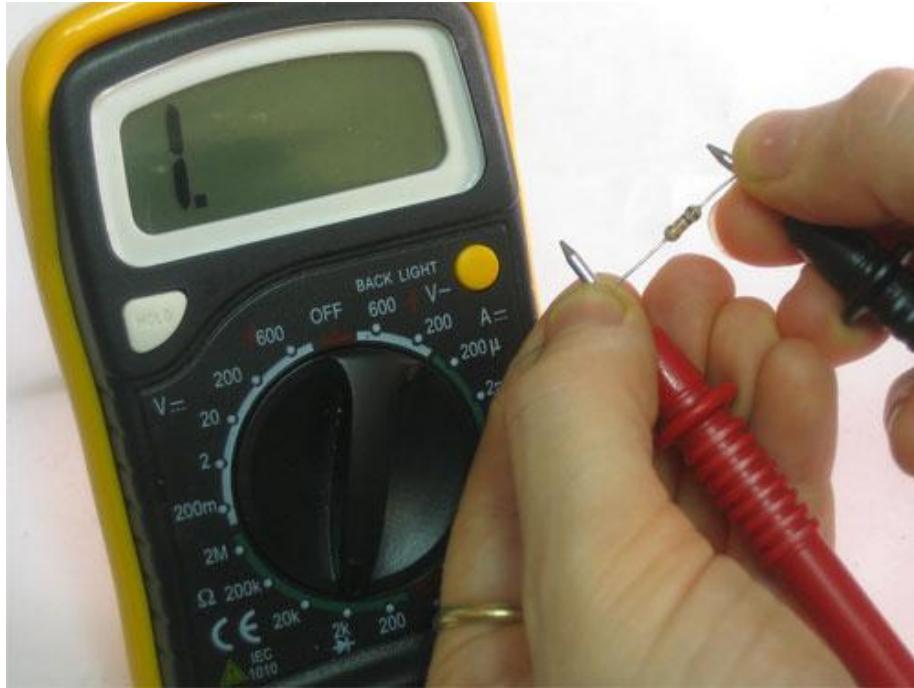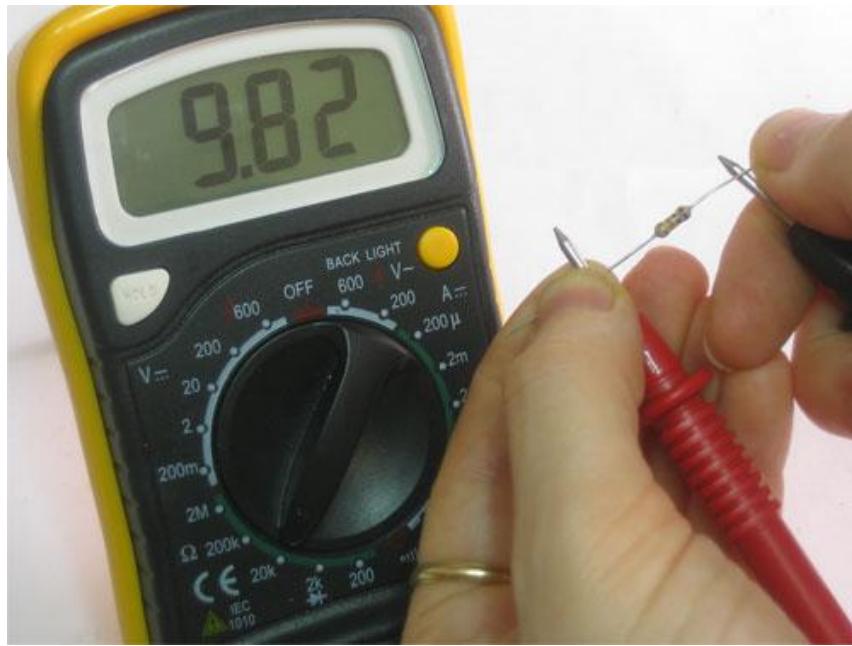
This ranged meter requires that you dial in the range. We'll guess that this resistor is under 2K then measure it. We get 0.992 which means its 0.992 K   (or, a 1K   resistor)

Now testing a different resistor, we will again guess its under 2K   . 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 secion as meaning "open loop" here it means "the measurement is higher than the range"
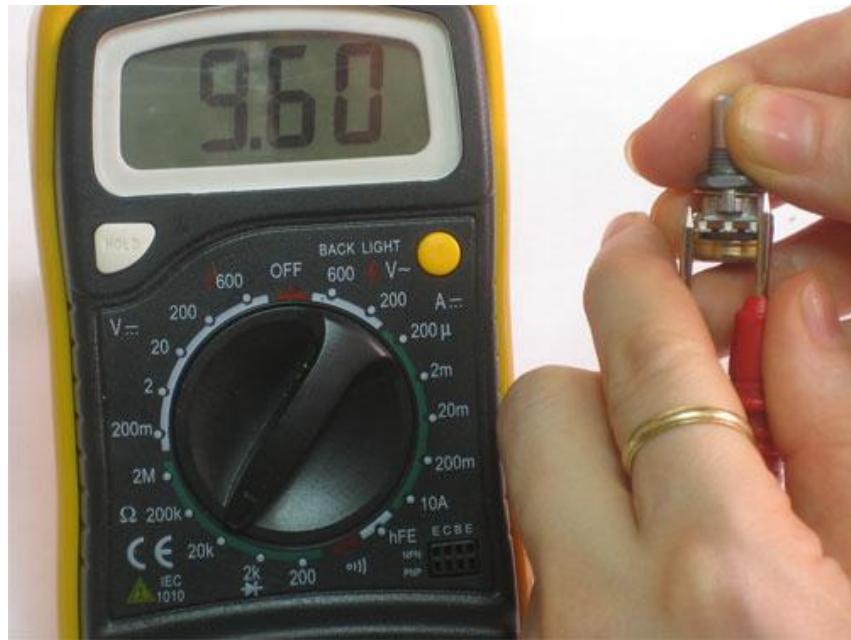
We try again, changing the range to 20K .

It is a 9.82 K resistor (10K)
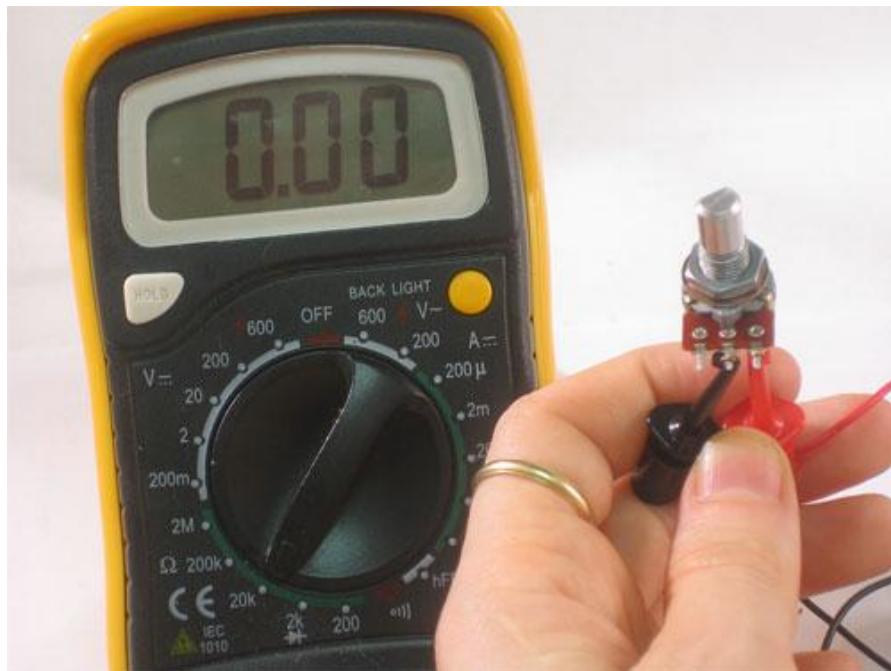
Example 2. Testing a potentiometer

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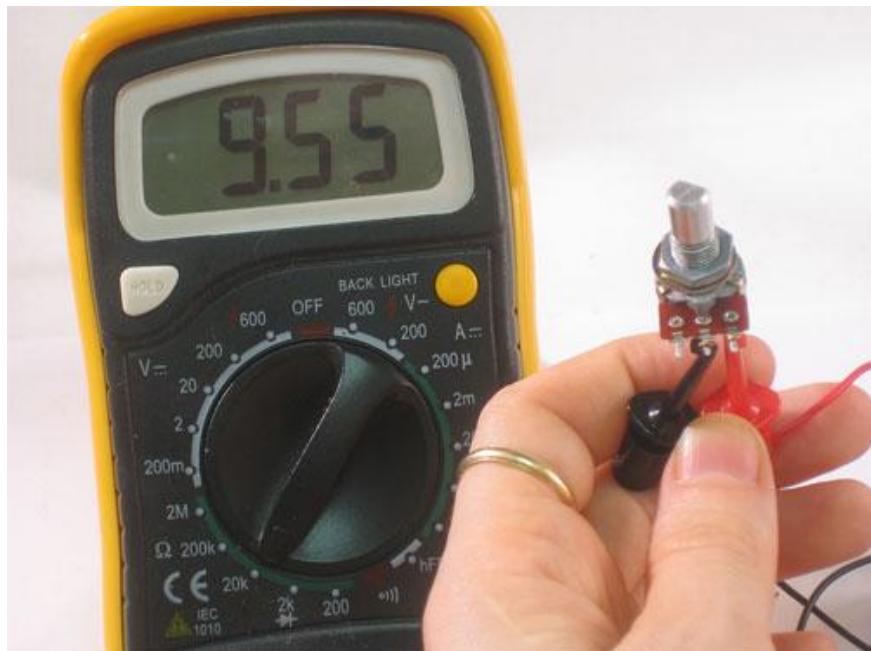
This is a 10K   linear potentiometer

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

Potentiometer centered, about 5K
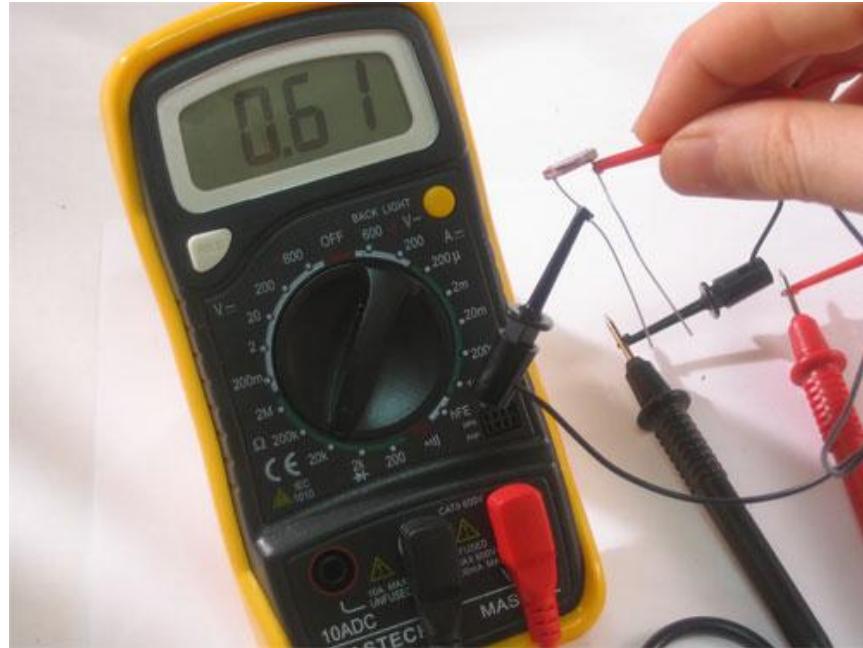
Maximum value is 9.5K   (it should be around 10K   )

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   seems pretty good. In bright light, it measures about 610

Slightly shaded it's 5.84K   (remember this is still a well-lit photo)

What is voltage?

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

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

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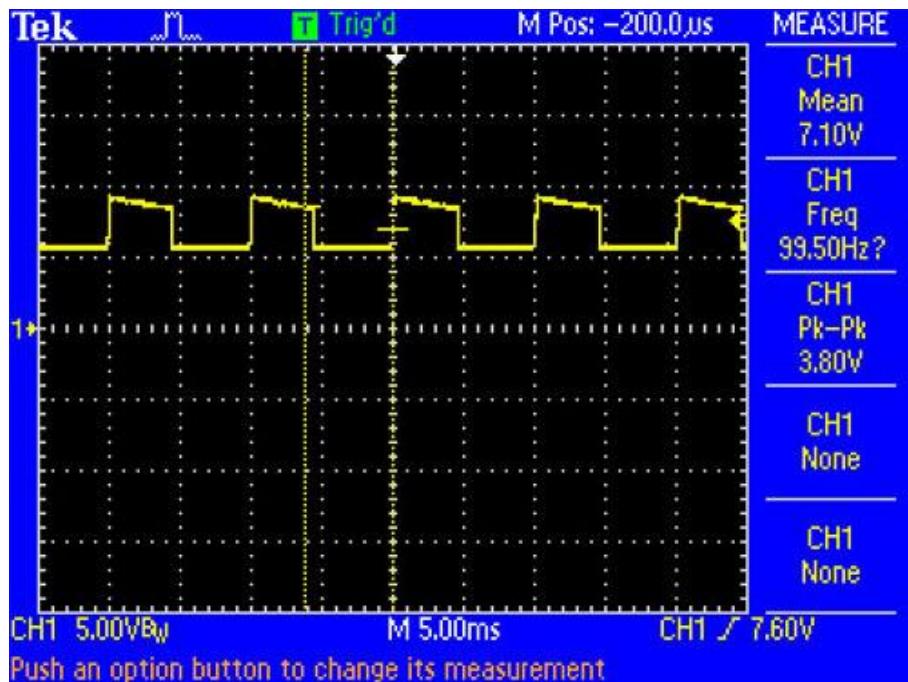
Direct current voltage is what comes out of batteries. The battery is at 9V, and it pretty much keeps that voltage constant, until it dies. The chemical reactions inside the battery create DC voltage. Most of the Electronic circuits work on DC voltage.

Alternating current voltage is what comes out of the wall socket. The generator at the US power plant creates a voltage that oscillates, going from -120V to 0 to +120V to 0 again, 60 times a second. At the European power plant its -240V to +240V at 50 times a second. (Note that those voltages are 'RMS' - Root Mean Square - which means that the peak voltage is actually about 1.4x higher, but since multimeters show RMS voltages, its easier to just use those)
AC voltage is great for power plants because its easy to transform AC voltages (using a transformer) up to 50KV for long distance travel and then down to 240V or 120V to safely power your home. Batteries only supply DC voltage and wall plugs only supply AC voltage. However, it is totally possible to have **both** AC and DC voltage at a certain point:
If an AC voltage is oscillating between -60V and +60V it has 120V AC and 0V DC because the **average** voltage of -60V and +60V is 0V.
If an AC voltage is oscilating between 0V and 120V then it has 120V AC and 60V DC because the average voltage of 0V and 120V is 60V.

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

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

Remember!

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

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

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

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

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

Lab Procedure

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

This meter has the double line for DC voltage, and 5 ranges, from 200mV to 600V.
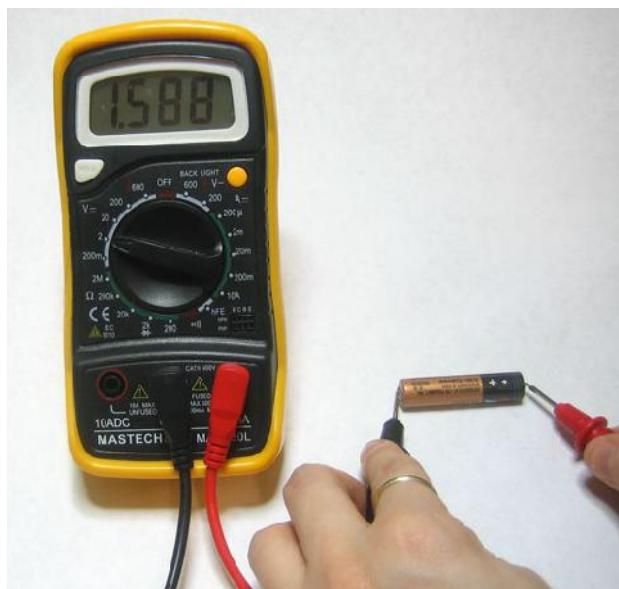
This ranged meter has 5 ranges, the top range is 750 VAC or 1000 VDC, to switch between DC and AC you need to press the DC/AC button on the upper right.

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).
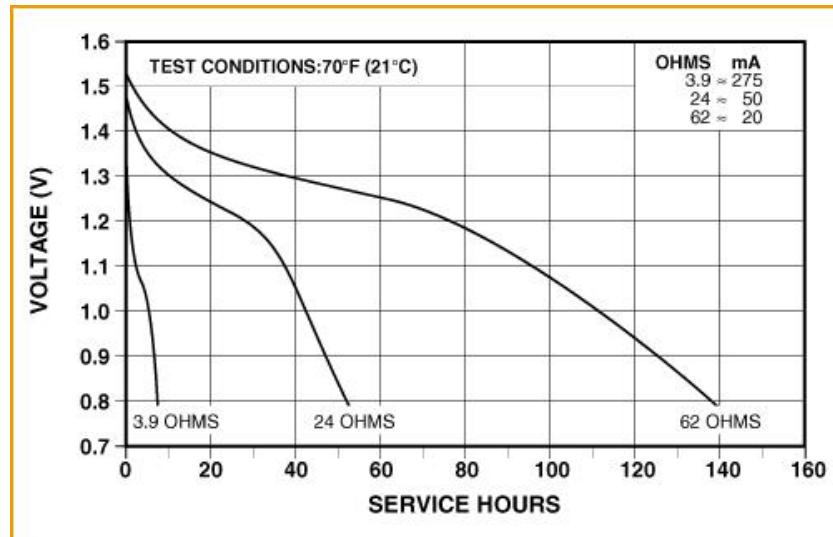

Example 1: Testing batteries

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**.

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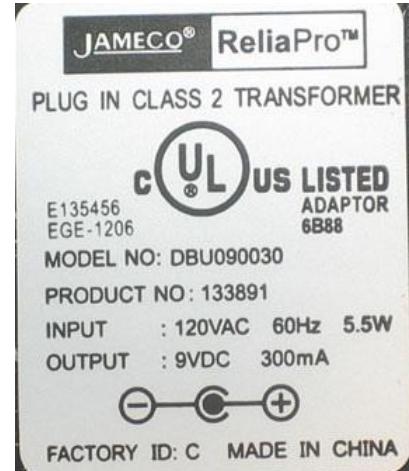

Using this graph you can easy tell how fresh your battery is and how long you can expect it to last.

Example 2: Testing wall wart (adapter) plugs

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

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

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

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

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

Example 3: Testing Wall output

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

About 220V, as expected

Post Lab

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

3. OPERATION

### 3-1. Controls, indicators and connectors
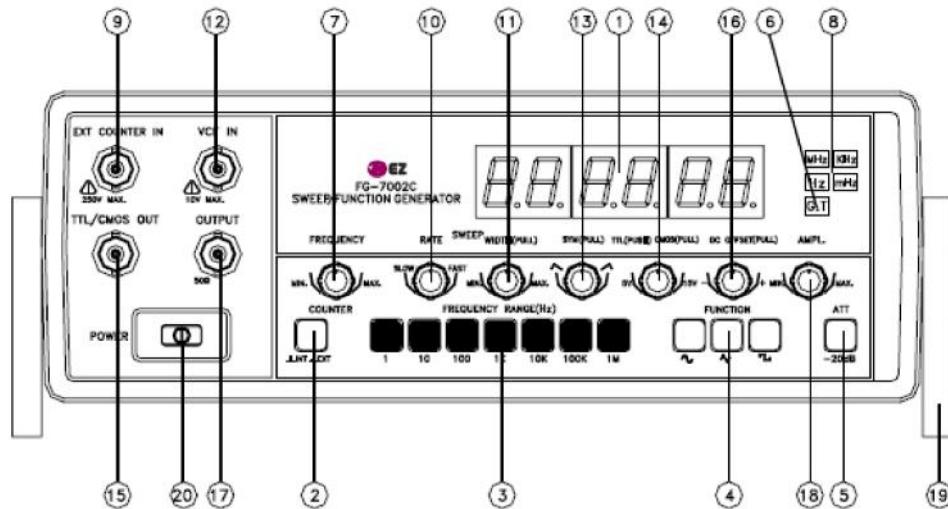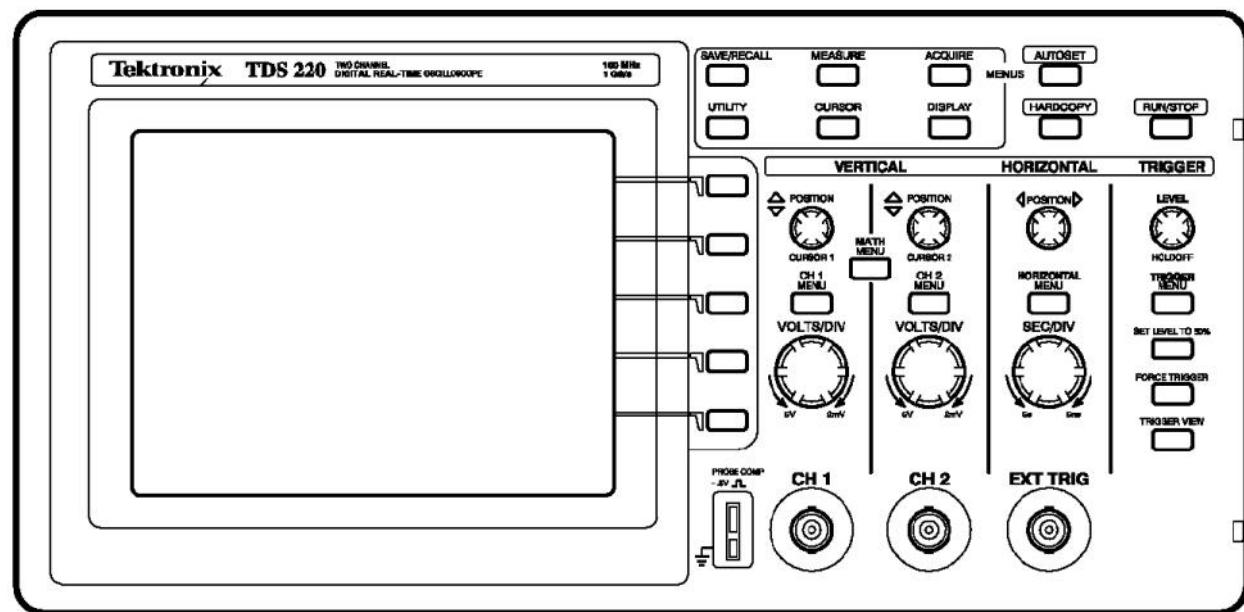
FIG 1. FRONT PANEL OPERATOR'S CONTROLS

① LED DISPLAY.	Displays Internal Or External Frequency.
② INTERNAL/EXTERNAL SWITCH.	PUSH IN : External Frequency Counter. PUSH OUT: Internal Frequency Counter.
③ RANGE SWITCHES.	Frequency Range Selector.
④ FUNCTION SWITCHES.	Select Sine wave, Triangle Wave Or Square Wave Output.
⑤ ATTENUATOR.	Selects Output Level By -20 dB.
⑥ GATE TIME INDICATOR.	Gate Time Is Selected Automatically E Input Signal.
⑦ FREQUENCY DIAL.	Controls Output Frequency In Selecte Range.
⑧ MHz, KHz , Hz, mHz INDICATOR.	Indicates Unit Of Frequency.
⑨ EXTERNAL COUNTER INPUT BNC.	Used As An External Frequency Counter.

⑪ SWEEP WIDTH CONTROL.   Pullout And Adjusts Magnitude Of
                                          Sweep.

⑫ VCF INPUT BNC.   Voltage Controlled Frequency Input
                                          Permits External Sweep.
                                          Frequency Control Sweep Rate Control
                                          Should Be Off When Applying External
                                          Voltage At This BNC.

⑬ SYMMETRY CONTROL.   Adjust Symmetry Of Output
                                          Waveform 1:1 to 10:1 With Push/Pull
                                          Switch On.

⑭ TTL/CMOS CONTROL.   Selects TTL Or CMOS Mode
                                          Pull-out : CMOS Level Control, Push-
                                          In: TTL Level.

⑮ TTL/CMOS OUTPUT BNC.   TTL/CMOS Level Output.

⑯ DC OFFSET CONTROLS.   Adds Positive Or Negative DC
                                          Component To Output Signal.

⑰ MAIN OUTPUT BNC.   Impedance 50 Ohm.

⑱ AMPLITUDE CONTROL.   Adjusts Output Level From 0 TO 20 dB.

⑲ TILT STAND.   Pull Out To Adjust Tilt.

⑳ POWER SWITCH.   Push type switch. turning on the power
                                          when pressed.

Oscilloscopes

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

Lab procedure 1 - Getting Started

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

1. Plug in the oscilloscope and apply power by pressing the POWER button on the top of the case.
Notice that when you apply power, the oscilloscope immediately performs a self-test.
2. Wait until the display shows that all self tests passed and press the SAVE/RECALL front-panel button (top left).
The SAVE/REC menu displays on the right of the screen. The top right bezel button toggles between two menus: Setups and Waveforms.
3. Be sure that Setups is highlighted (in inverse video) and press the button beside "Recall Factory."
The oscilloscope recalls the default factory settings to initialize the instrument to a known state, which eliminates any nasty surprises. If at any time you do not understand what the oscilloscope is displaying, you can repeat this step.
*The box at the end of this lesson also gives some suggestions for getting out of odd screen modes without resetting everything.*
The display that dominates the left side of the scope is a digital LCD screen. This means that displayed signals have visible pixel "jaggies." If you have used an analog scope, you will notice that the signals, especially sine waves, do not look as smooth and continuous on this screen. The digital display does, however, have some significant advantages, as you will discover. Some of the information around the edges of the display will be explained as we go along; the rest can be looked up in the Tektronix manuals. The large area down the right side of the screen is the menu. A large number of menus are available and are called up by pressing various buttons on the control panel. The buttons immediately to the right of the screen correspond to the menu items; their functions change depending on the menu displayed.
Take a close look at the probes that are provided with the scope. These are important to the performance of the oscilloscope and should be handled with care. The sprung hook tip is removable, revealing a point that can be used in tight locations. The short wire that terminates in an alligator clip is the ground connection. If both probes are connected to the scope, disconnect one of them by turning the connector to the left and pulling it straight toward you.

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

the scope are labelled CH 1 (for channel 1) and CH 2.
Usually you will connect the probes here, but you can also
use a coaxial cable with a BNC connector to connect the
scope to a function generator or other signal source. Immediately to the left of the inputs
is a pair of small metal tabs labelled PROBE COMP for probe compensation. This is an
internal source of a square wave at about 5 volts magnitude and 1KHz, used to adjust the
internal compensation of the probe.
4. Connect the probe on channel 1 of the scope to the top tab, and the ground clip of the
probe to the bottom tab.
5. Press the AUTOSET button near the top right corner on the front-panel.
The oscilloscope sets the vertical, horizontal, and trigger controls automatically which
usually results in a usable display. These settings are adequate in this and many other
situations. Be aware that the oscilloscope also sets a number of background functions that
might be not be desirable in some circumstances.
Depending on how the oscilloscope was being used when it was last turned off, you may
see one or more channels displayed. The trace labels on the left edge of the screen
correspond to the channel numbers on the front of the oscilloscope.
6. If only one channel appears, press the CH 2 MENU front-panel button to display
channel 2, and then press AUTOSET again.
Now both channels display even though there is nothing but noise on channel two. The
upper trace should show a steady square wave as depicted below. The wave is stationary
on the screen because AUTOSET has set the oscilloscope's trigger to channel 1 and the
trigger circuit causes successive similar waveforms to be superimposed on the screen.
For a complete discussion of trigger see the Tektronix manual.
If the top and bottom of the square waves are not straight, your probe needs to be
compensated, but you do not need to do it right now.
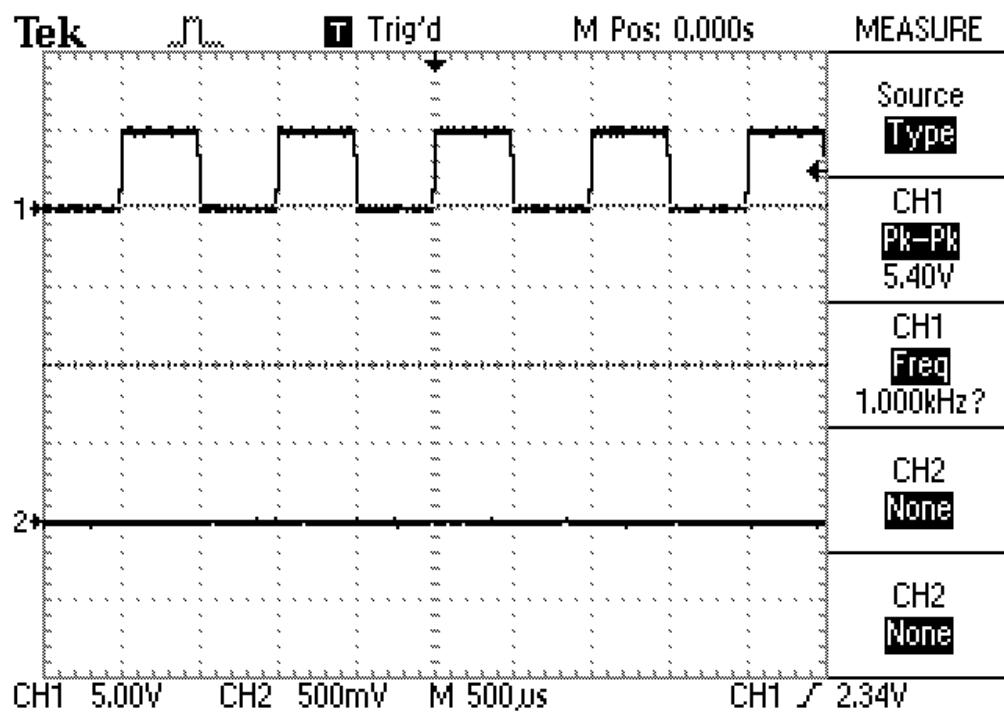
To demonstrate
the downside of
using Autoset,
follow these
steps:
a) Disconnect
the channel 1
probe from
PROBE COMP,
and connect
channel 2
instead.
Press
AUTOSET.
The wave is no
longer
stationary

because there is no signal on channel 1 to trigger the oscilloscope, which is now free-running.
b) Press the TRIGGER MENU button (near the right edge of the scope).The third menu item is the trigger source, which is currently set to CH1.
c) Press the button beside this menu item once to switch the source to CH2.The display should become stable.
d) Now press AUTOSET again. Once again the scope is free running because Autoset sets the trigger source to the lowest displayed channel. This is just one of many settings that Autoset changes – see the Tektronix manual for the complete list, and use Autoset wisely.
e) Before proceeding, switch the probe compensation waveform back to channel 1. Now let us get rid of the useless channel 2 display and expand the channel 1 presentation.
7. Press the CH 2 MENU front-panel button to remove the channel 2 waveform from the display. If that channel's menu is not already displayed, the first push of the button displays the menu (the top right corner of the screen will say CH1 or CH2). A second push turns off the channel. Do this and you should see that the channel 2 trace disappears. Now look at the channel 1 control area. In addition to the CH 1 MENU front-panel button, there are two knobs. The top one controls the vertical position.
8. Turn the POSITION knob to bring the displayed waveform down to the middle of the screen. Note that as soon as you start turning the knob, a line of text appears in the bottom left corner of the screen. This is telling you how far the zero level of this channel is from the vertical center of the screen. There are several reasons why you might want the display exactly centered, and this helps you to do that.
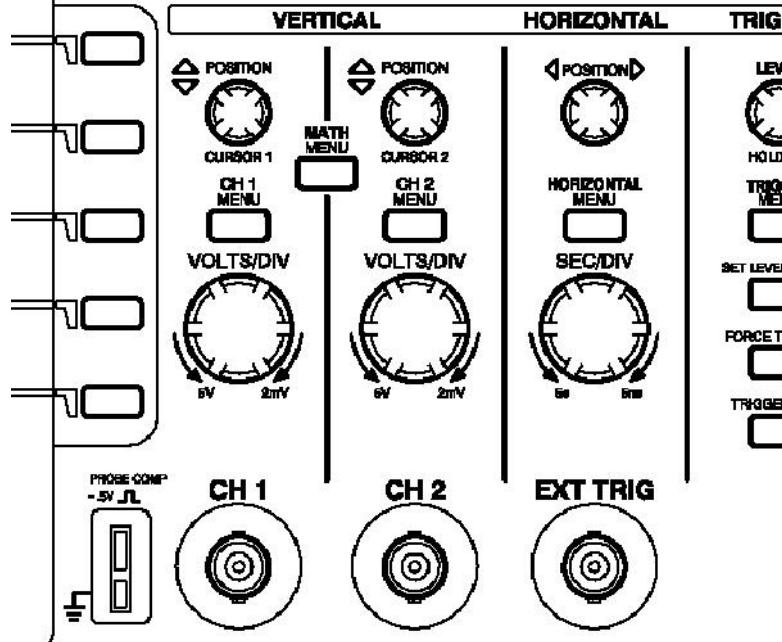
Once you have the trace centered you can expand it for a better view. The bottom knob of the channel, or vertical, controls is the volts per division range control. Turning the VOLTS/DIV knob to the right increases the sensitivity (decreases the volts per division, and expands the display vertically). One division is the distance between the grid lines on the screen, a bit less than one centimeter apart. Just to the right, on the other side of the channel 2 controls, is a similar knob labelled SEC/DIV that controls the time base resolution. Turning it to the right reduces the time per division and expands the display horizontally.

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

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

Lab Procedure 2 – Measurements

In general, you will use an oscilloscope to measure characteristics of a signal, such as magnitude or period of oscillation. You can look at the signal in relation to the screen grid or graticule to estimate the values of these characteristics, which was about one could do with early oscilloscopes. Modern oscilloscopes have much more powerful measurement capabilities.
In this lesson, you will learn about the following topics:
• How to use the Measure menu to define the source and type of measurement to take
• How to set the Probe menu item to match the probe in use
• The difference between measuring a signal and a displayed waveform
Lesson 2 begins where lesson 1 ended. If the oscilloscope has been turned off or the settings changed since lesson 1, you need to quickly redo lesson 1 to get back the centered square waveform that fills most of the screen with two or three full cycles displayed.
To perform the Measurements lesson, follow these steps:
1) Press the MEASURE front-panel button.
The word "MEASURE" appears above the menu area, Type is the active menu, CH1 is the source for four measurements and no measurements are selected (NONE).
The Measure menu is a Page Selection type of menu. The top menu displays two menu names: Source and Type. The active menu is highlighted in inverse video - white letters in a black box. When Source is highlighted, you can press each of the other four bezel buttons to switch between CH1 and CH2 as the measurement source. When Type is highlighted, you can press each of the other four buttons to select the type of measurement to take from the selected source.
2) Press the second button until Freq appears. A question mark appears momentarily until the oscilloscope measures the frequency of the signal connected to CH1.
3) Press the third button until Period appears. The oscilloscope displays the period of the signal (1/f).
4) Press the fourth button until Mean appears. The oscilloscope displays the mean voltage.
5) Press the fifth button until Pk-Pk appears. The oscilloscope displays the peak-to-peak voltage.
6) Press the third button until Cyc RMS appears. The oscilloscope displays the true RMS value of one cycle of the waveform.
The Freq, Period, Mean, Pk-Pk, and Cyc RMS measurements are always available. If you have a TDS2MM module in your oscilloscope, then there are some other measurements available that we will not cover here, such as rise time.
The next drawing shows how the oscilloscope display should now look. There may be
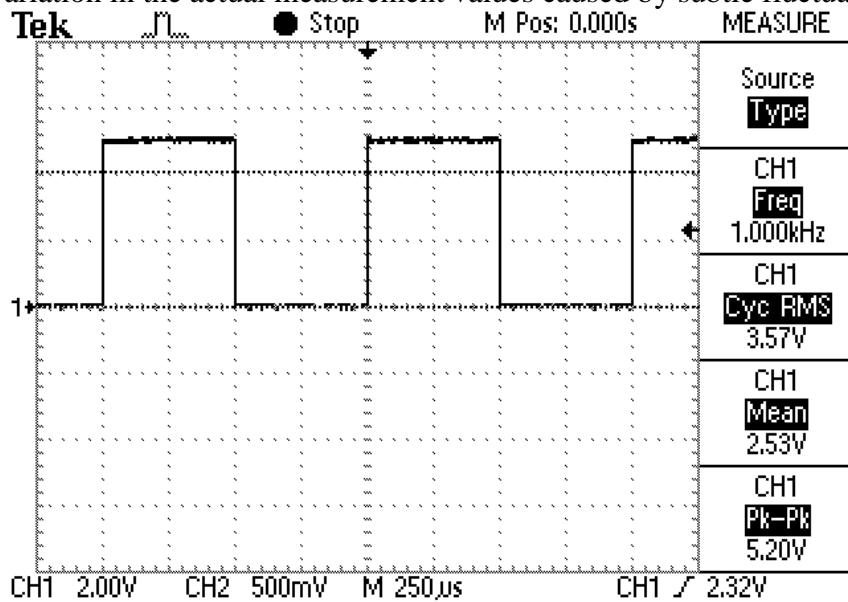
some variation in the actual measurement values caused by subtle fluctuations in the source

signal.

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

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

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

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

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

8) Press the MEASURE front-panel button.

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

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

is not at the centre, use the Horizontal POSITION knob to move it to the centre.
Read the mean voltage. The value should be approximately half the peak voltage; it may
actually be a bit less because the peak voltage includes any overshoot – something to
remember for the future when interpreting peak-to-peak values. Now we are going to
deliberately cause an erroneous
reading.
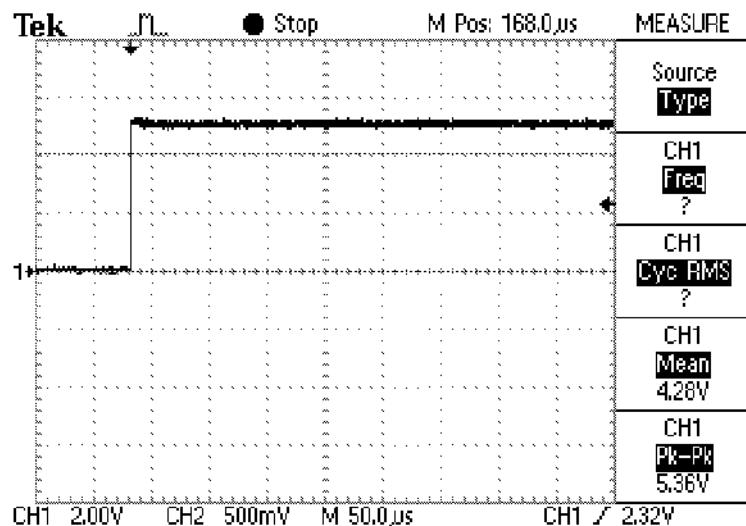
9) Turn the Horizontal SEC/DIV
knob
(time base control) until the time
per division reads M 50.0 μs.
The oscilloscope no longer displays
values for frequency or RMS voltage
because there is not a full cycle to
measure on the screen, but the mean
voltage has not significantly changed.
10) Turn the Horizontal 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 yo u 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 labelled Contrast Increase and Contrast
Decrease but they actually lower and raise, respectively, the screen brightness. If the
screen is too dark you actually need to press the Contrast Decrease button to raise the
contrast.

POST LAB

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

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

TASK:

1. Find & list the application where different types of waveforms are used.

Lab Session 02

OBJECTIVE

To make a circuit on a bread-board & find different currents & voltages

PRE – LAB

Procedure

Simulation

Simulate the circuit using multisim and check whether the output is amplified version of input or not?

Wiring the circuit
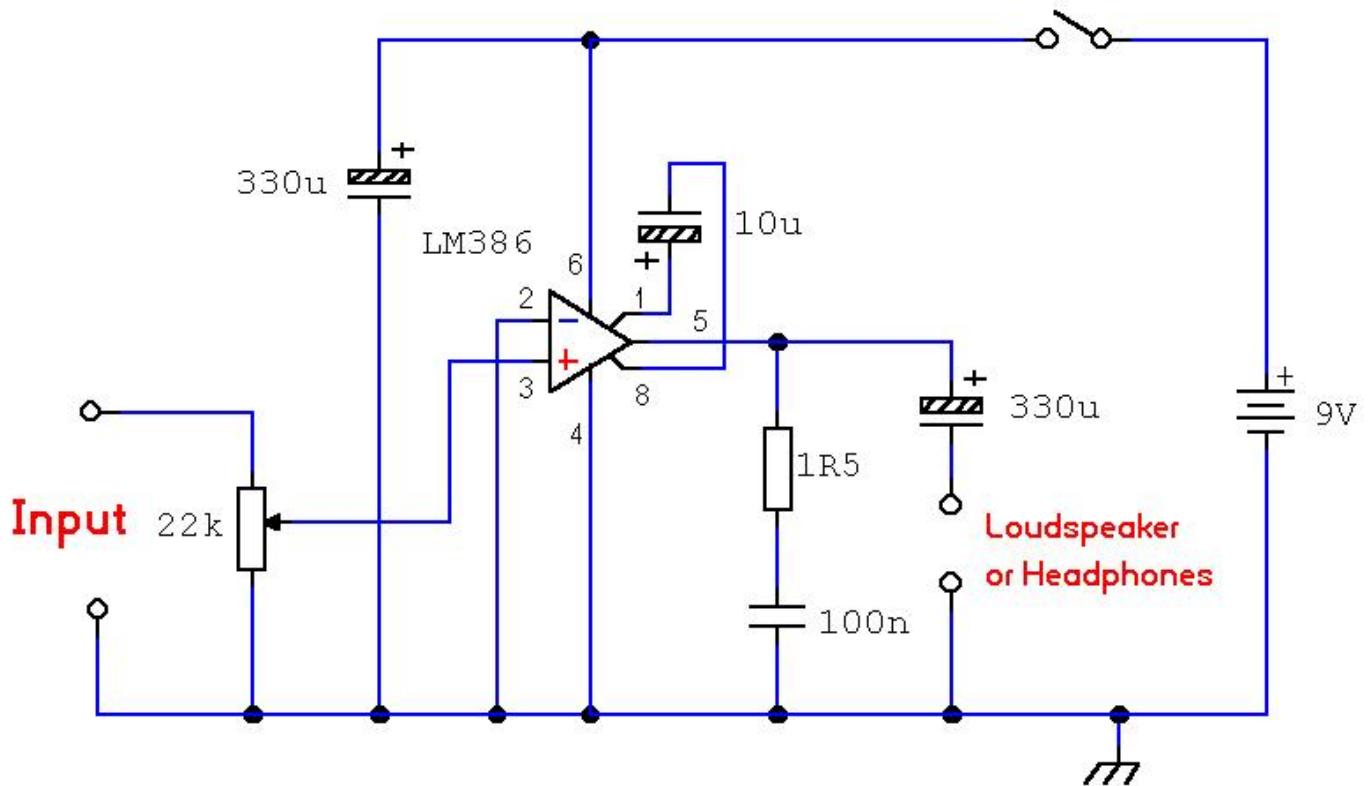
How to construct a circuit on veroboard by reading the schematic. If you're an experienced constructor, then you will just look at the schematic and start assembly. Experience tells you where to place components and use veroboard space to its best advantage. If you are a beginner, certain prerequisites are assumed. You need to be able to read the circuit diagram and relate to each component on the diagram, as it is wired onto the veroboard. You also need to be able to solder, and beware of the position and orientation of the board and components when working on it from the reverse side.

Notes: The circuit is based on the National Semiconductor LM386 amplifier. In the diagram above, the LM386 forms a complete non-inverting amplifier with voltage gain of x200.

A datasheet in PDF format can be downloaded from the National Semiconductor website. The IC is available in an 8 pin DIL package and several versions are available; the LM386N-1 which has 325mW output into an 8 ohm load, the Lm386N-3 which has 700mW output and the LM386N-4 which offers 1000mW output. all versions work in this circuit.

The gain of the Lm386 can be controlled by the capacitor across pins 1 and 8. With the 10u cap shown above, voltage gain is 200, omitting this capacitor and the gain of the amplifier is 20.

The IC works from 4 to 12Volts DC, 12Volt being the maximum recommended value. The internal input impedance of the amplifier is 50K, this is shunted with a 22k log potentiometer so input impedance in this circuit will be lower at about 15k. The input is DC coupled so care must be taken not to amplify any DC from the preceeding circuit, otherwise the loudspeaker may be damaged. A coupling capacitor may included in series with the 22k control to prevent this from happening.. The schematic is shown below:
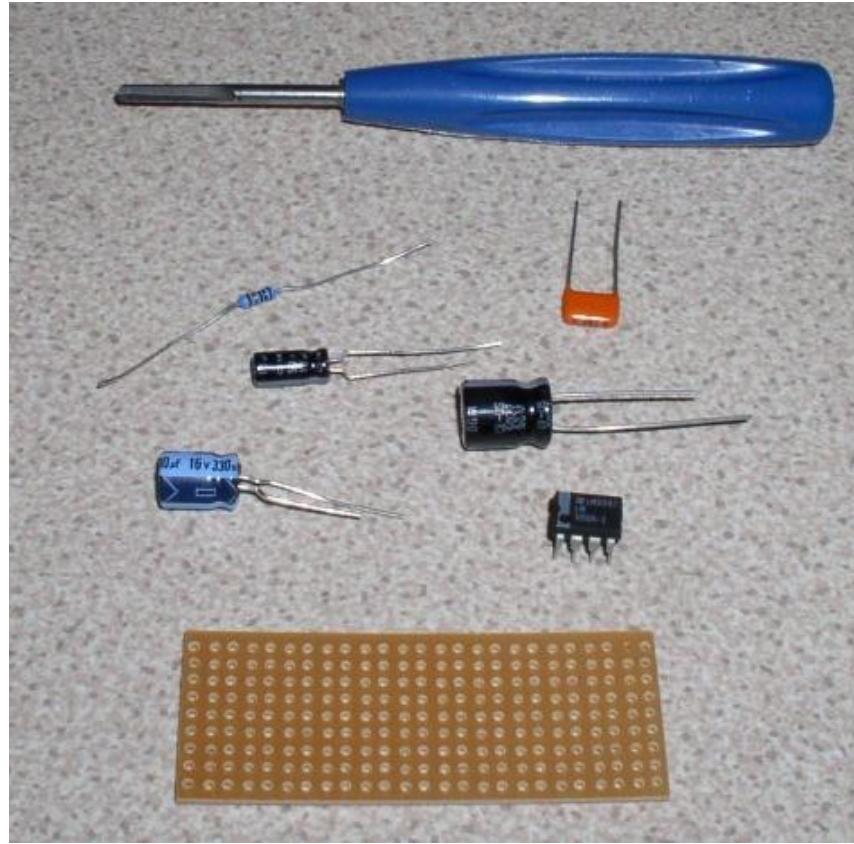
Below is the suggested parts list:

1 22k potentiometer (log)
1 1R5 ohm resistor 5% tolerance
1 10u 25WV electrolytic capacitor
2 330u 25WV electrolytic capacitors
1 100n ceramic capacitor 100V (these small capacitors are usually rated 100 or 2220 or 400V)
1 LM386 linear integrated circuit
1 8 Pin DIL socket (optional)
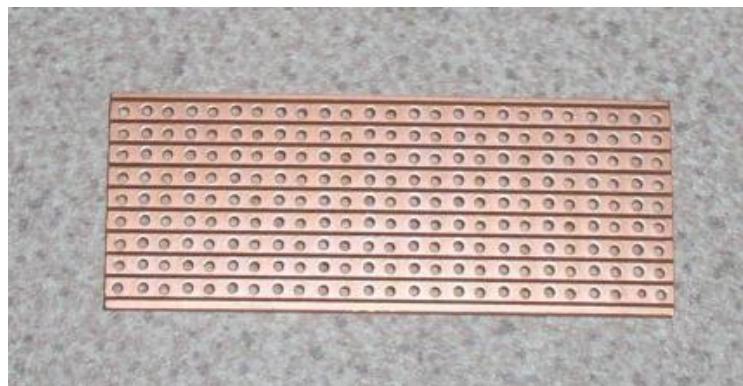
Step 1:
First the components are collected and laid out. The blue item is a veroboard track cutter
(Optional).

Step 2
A suitable piece of veroboard is used. This must be large enough to hold all the components of the circuit. They are available in standard sizes, the piece below is 9 holes wide by 25 holes long and approximate dimesions 1 by 2.5 inches. Each of the horizontal 9 strips is known as a "track". A track is the same as a single wire running from opposite ends of the board.
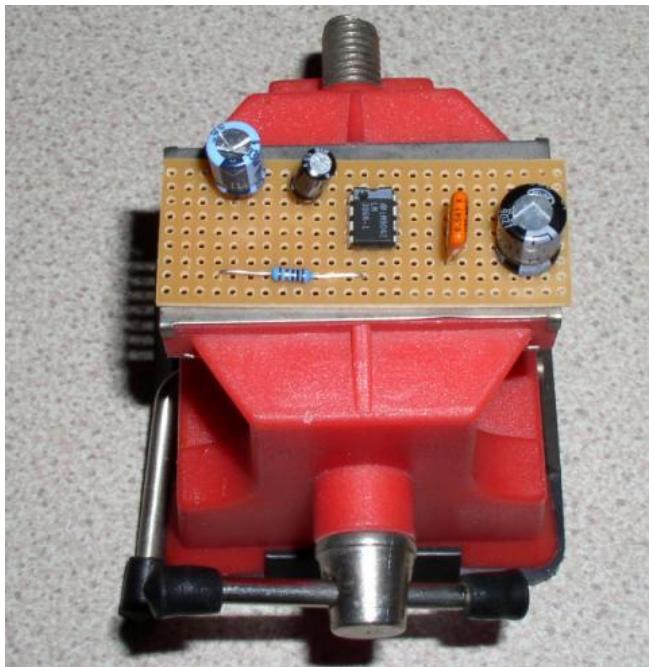
If a track is broken, with a veroboard cutter, then you have two non-connected wires on the same horizontal strip. Note that NO continuity exists across adjacent tracks. If this should happen, i.e. when cutting a track and a piece of copper "swarf" should accidentally bridge two tracks, then

the design would be compromised and probably not work at all. Therefore take care when breaking tracks and examine the board after making each break.

Step 3
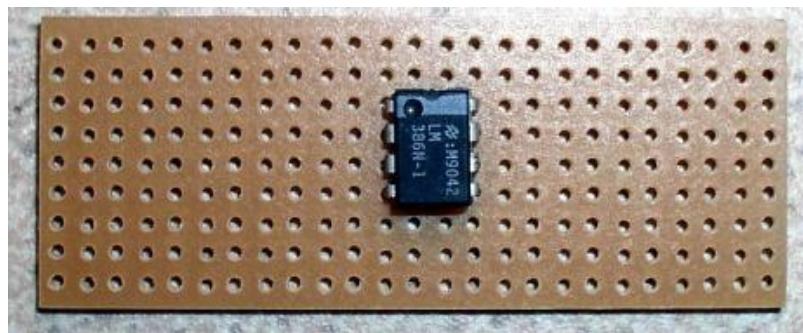
Check that the veroboard is large enough. Loosely push all components through the holes (in any order). Leave at least a space of 2 holes between components. This will allow room for wiring


and track breaks.
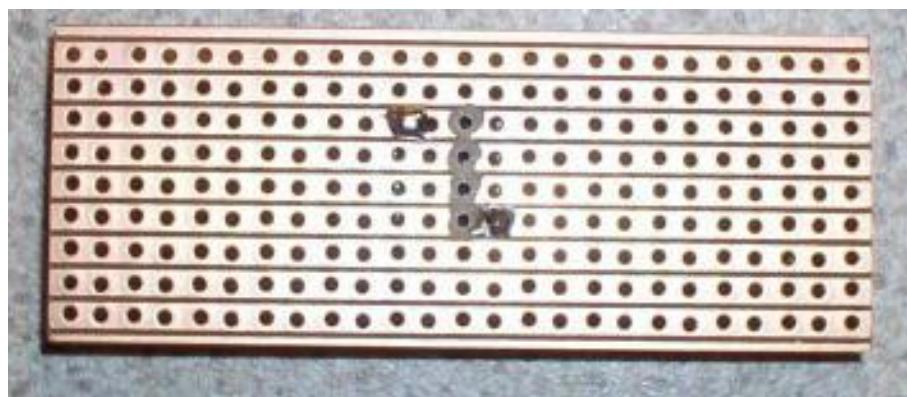
Step 4
Work begins! You do need to know how to read a schematic. The lines represent wires, the symbols are the components.

To help identify components, these are listed here. Look at the schematic. The triangle represents the LM386. As 7 connections are used it makes sense to place the IC somewhere central, (see above picture), as tracks above and below the IC will act as the wires for the power supply.

Step 5

Turn the board over, all component pins should poke through the shiny copper side of the board. All soldering and track cutting is also done on this side. You need a little soldering experience to begin with. If you are not used to soldering, then it is advisable to use a plastic IC socket. There are other advantages to using a socket, mainly if the IC should fail, it can be simply unplugged from the socket and replaced, no need to desolder and resolder. Remember that as the board is now upside down that the top and bottom tracks are reversed. If you turn it upside down and through 180 degrees then left and right are also interchanged. This must be born in mind throughout construction. If in doubt, turn the board back and forth and keep an eye on a reference point, say pin 1 of the IC, marked with a dimple or round spot.
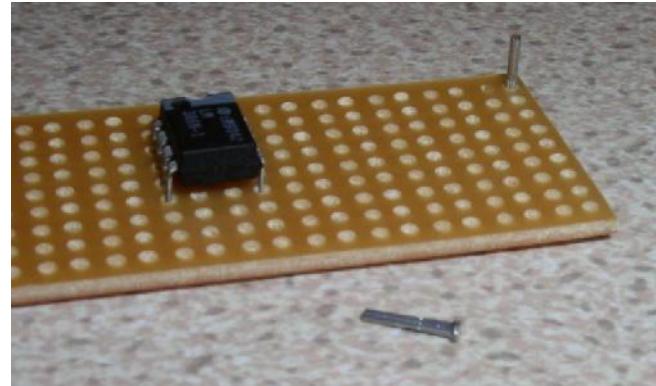

Here we have soldered diagonally opposite legs. This makes sure the IC is held firmly. Next the veroboard track cutter is used to break 4 holes in the centre of the IC (or IC socket). Without this pins 1and 8, 2 and 7, 3 and 6, 4 and 5 would be short-circuited. After breaking the tracks, solder the remaining pins on the IC or IC socket.
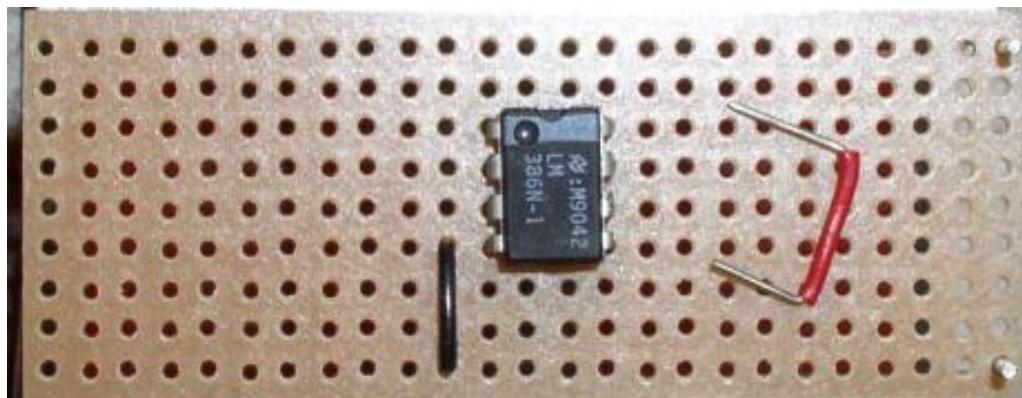
Step 6

Turn the board over and use two veropins for the power connectors. A veropin is a short piece of metal that makes contact with the copper side of the veroboard. It is rigid and allows a wire to be connected on the component side of the board. Veropins also make convenient test points as well.

A veropin is shown above (centre bottom). Push two veropins through the copper side at the right hand side on track extremities. It is a good idea to separate power supply rails by at least one vero track.
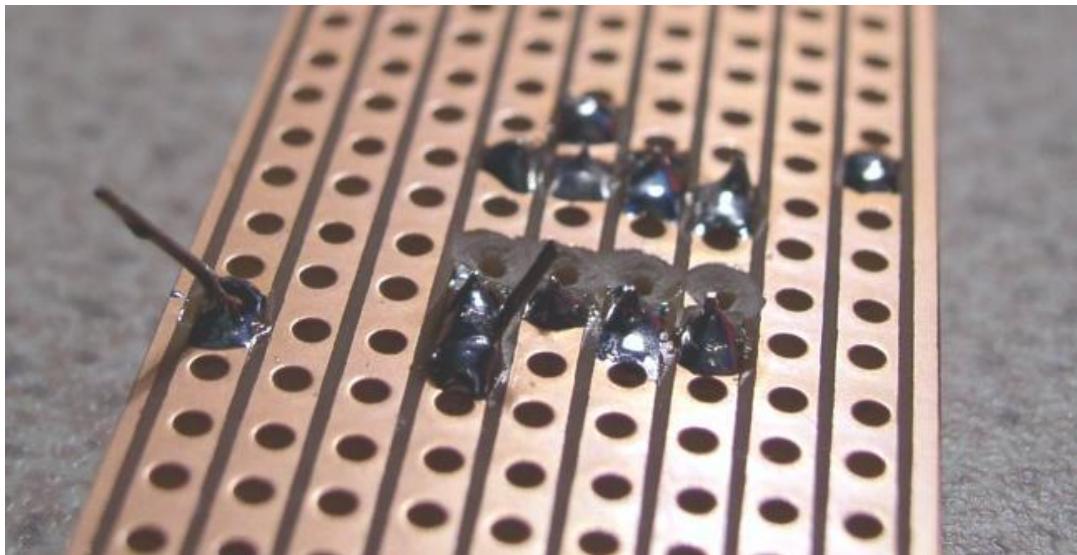
Step 7

Now the IC and power rails are ascertained, it is time to start wiring. Pin 4 is the ground connection, so a piece of wire is used to connect from the adjacent track next to pin 4 of the LM386 to the ground track (bottom track) with veropin. I use black for ground connections, and red wires for power.
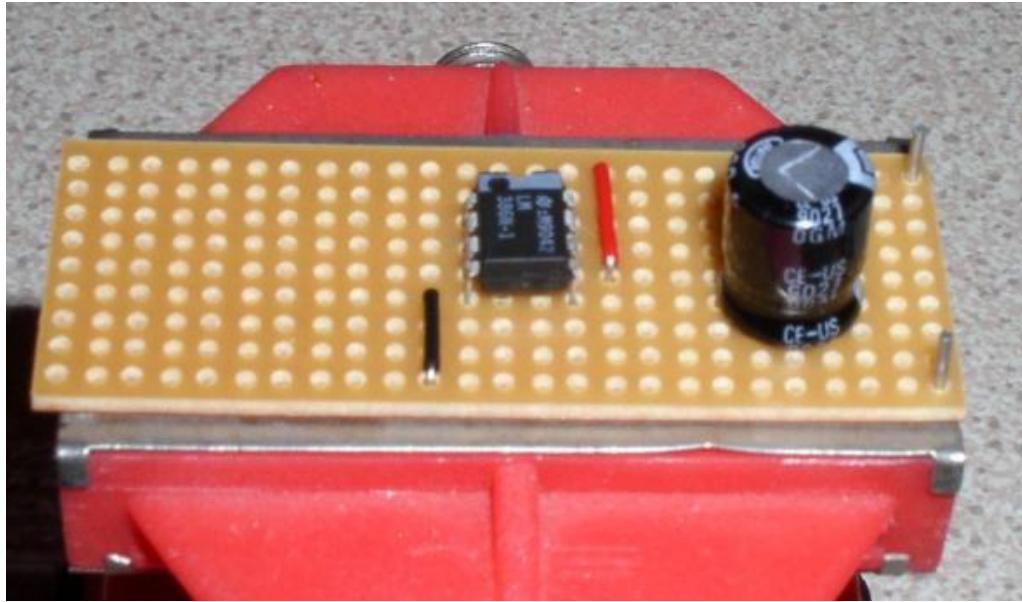

Step 8

The wire (also called a "jumper") because it bridges are spans several tracks is soldered on the copper side. After soldering the end wires are cut close to the board. The red jumper connects pin 6 of the IC to the top power rail and can be seen in the photo below already soldered.

Step 9
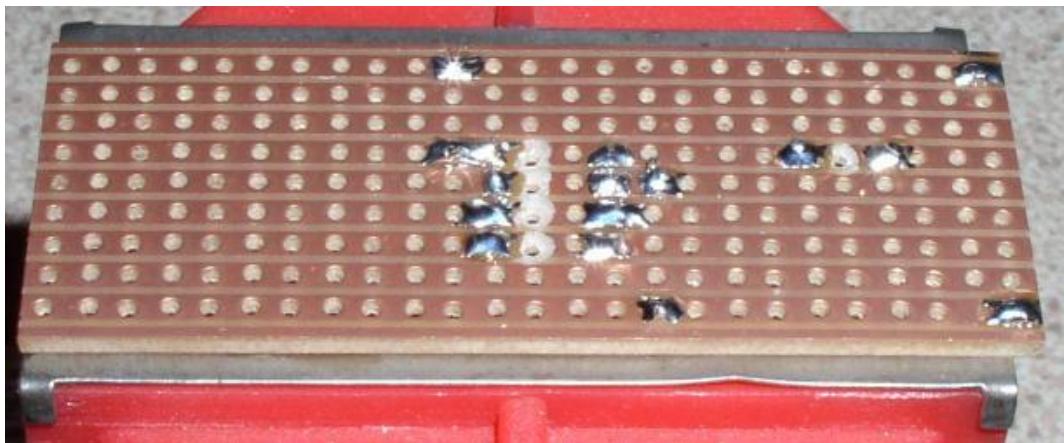
Components can be added in any order, I prefer to use the larger parts first, so I am aware of the physical space left on the board. It is however good practice to solder veropins, jumpers first, then passive components, resistors, capacitors, inductors, followed by active components such as diodes and transistors next. Finally IC's are added last, the reason for this order is that repeated soldering and excessive overheating of the board can destroy the sensitive components. If however, you are a competent at soldering, any order of assembly can take place.

The board is turned over and the 330u output capacitor put in place. From the schematic the "+" plate needs to connect to pin 5 of the IC. I place the component a few holes away on the same track as pin 5 of the IC in the same direction.
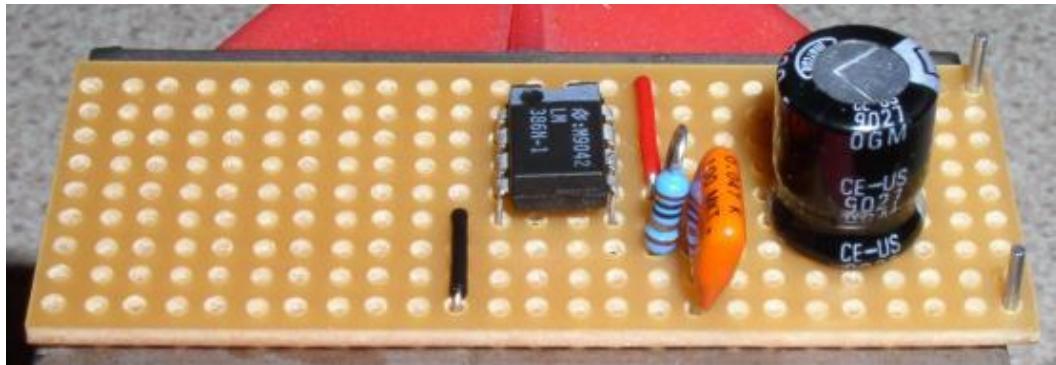
Step 10
As can be seen below, the 330u capacitor is now soldered a few holes away from pin 5 of the IC. Also note that the centre track of the capacitor is broken. If you forget to do this then the component is short circuited by the vero track itself. Components may be placed in line with the tracks, at right angles, or diagonally, there are no rules. However, if components are in line with a track, then the track must be broken, otherwise the component is short circuited. The output from the amplifier (see schematic) is the negative side of this capacitor. A veropin can also be used to make the external connection to a loudspeaker easier.
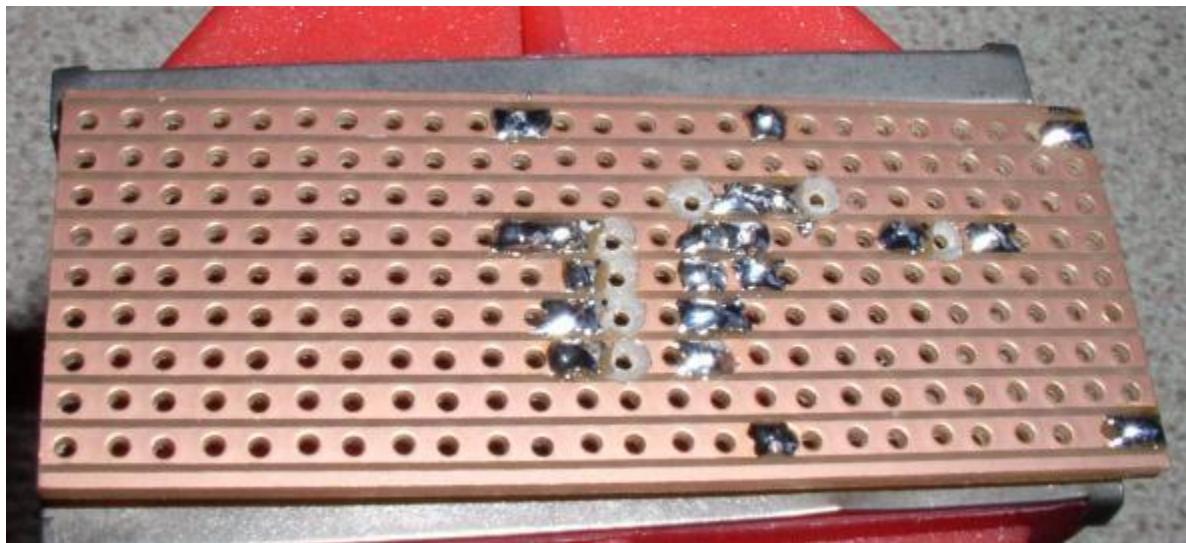
Step 11

As the output capacitor has been soldered, the zobel network comprising of the 1R5 resistor and 100n capacitor are wired up. Referring to the schematic, one end of the resistor is also connected to pin 5, one end of the capacitor goes to ground, and the free ends of these two components are wired together.

Step 12

This is the underside of the 1R5 resistor and 100n capacitor. The resistor is wired adjacent to pin5 of the IC and to the track immediately below the IC. The 100n capacitor is wired adjacent to the resistor and to ground.
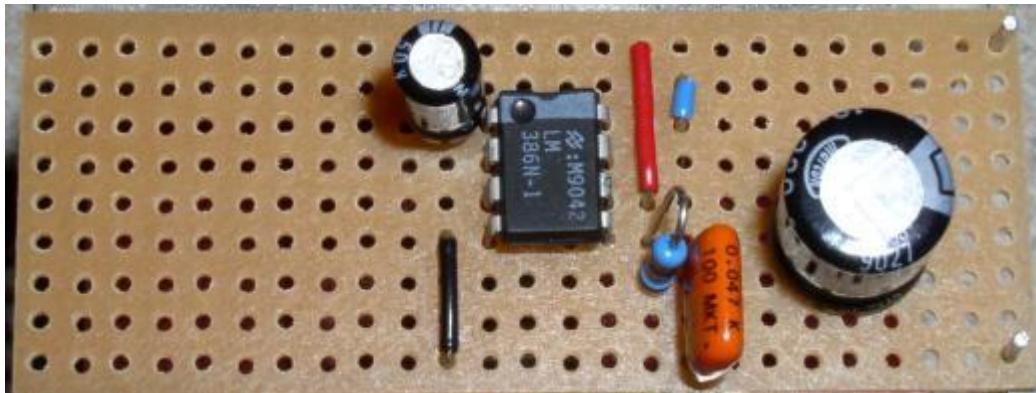
As no more connections are at the union of the resistor and capacitor, the tracks are cut either side. The track either side of the break is now free to be used, if required. The tiny piece of solder also on the same track as pin 5 of the IC is a solder splash. As long as the solder blob does not bridge adjacent tracks, it is nothing to worry about.

Step 13

Referring to the schematic, the output side of the amplifier is almost complete, apart from a 10u electrolytic capacitor connected to pins 1 and 8 of the IC. Note the polarity, the positive terminal

connect at pin 1, so the capacitor is pushed through a veroboard hole adjacent to pin 1 of the LM386, at right angles to the copper tracks on the reverse side.

As pin 8 is connected to the negative plate of the capacitor, a blue jumper wire is pushed through a hole near the IC on pin 8, the other end of the jumper wire is connected to the same track as the negative pin of the 10u capacitor. This is shown in the above picture.
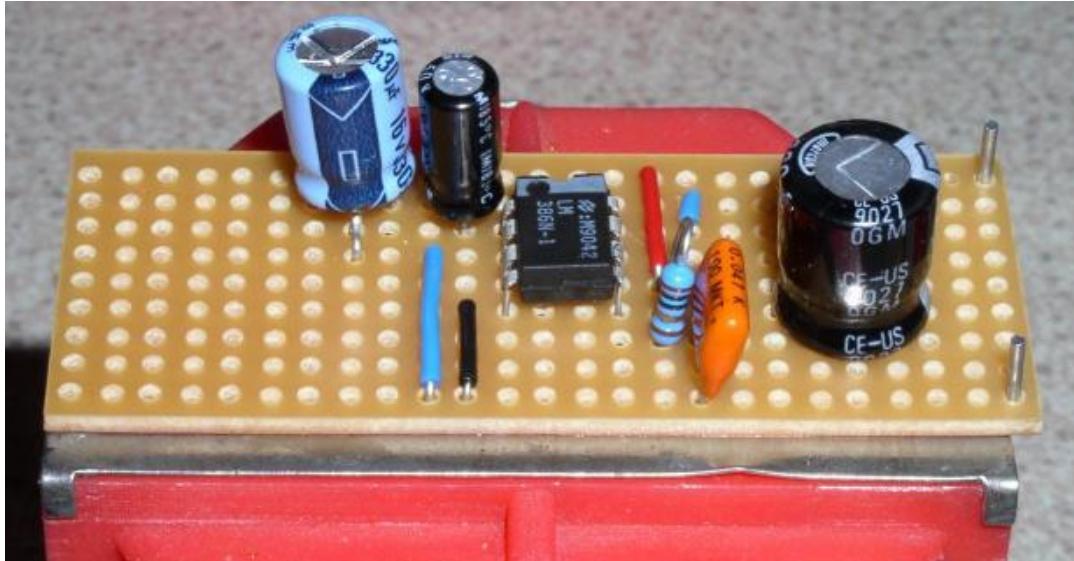
Step 14

The underside of the veroboard is shown below. Note that the right hand side of the picture shows the power supply veropins (top and bottom tracks).

Step 15

The final 330u electrolytic capacitor can be added. This is the leftmost capacitor in the schematic.

This capacitor is inserted so that the positive plate is on the positive power track and the negative plate reached to the same track as pin 2 of the LM386 which is also at ground potential. The final component is the volume control. As this is external all that remains is to solder a length of screened cable between the LM386 at pin 3 and ground.
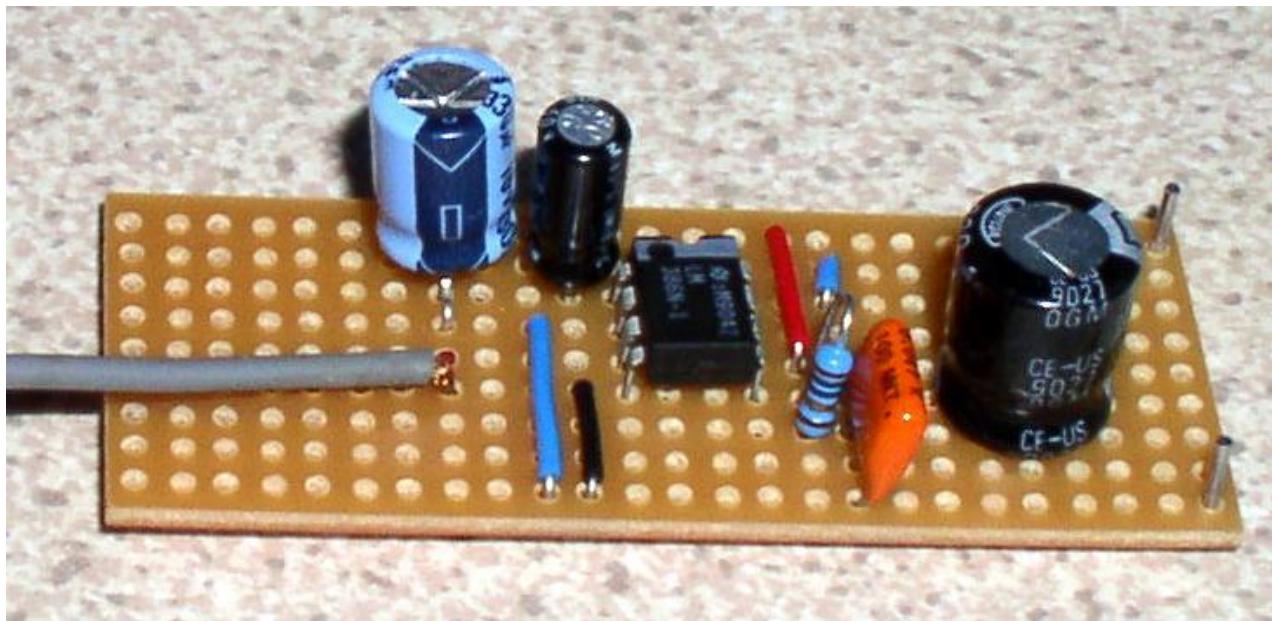
Step 16

Job complete. A final closeup inspection of the board is recommended. Pay particular attention to all areas where the tracks have been cut and also where there are any solder splashes. All soldered joints should appear shiny as in the picture below.

Step 17

The final completed amplifier circuit with a short length of screened cable (grey) leading off to the volume control.

Lab Procedure

OBJECTIVE

To apply DC biasing & ac signal & observe the output.

2.3   EQUIPMENT REQUIRED

1- Your circuit board
2- Function Generator
3- Oscilloscope
4- DC Supply
5- Multimeter

2.4   PROCEDURE

1- Check the continuity of all tracks using multimeter.
2- Apply the DC supply to the circuit.
3- Check the voltages across each component & write them in the following table.

Across:	Voltage (V)
1) 330uF capacitors	
2) Pin 6 & 4 of IC	
3) 10uF capacitor	

4) **R5**	
5) **Pin 3 & 4**	
6) **220k ohm potentiometer**	

4- Now apply a 100Hz, 1mVpk-pk sine wave from function generator to the circuit input (at potentiometer).
5- Check the output ac voltage across Pin 5 & 4 using oscilloscope.
6- Using following formulas & reading, fill the following table.

Vin (across Potentiometer)	
Vout (across pin 5 & 4)	
Gain (Gain = Vout/Vin)	

Post Lab

Task:

1- Calculate value of maximum input for which output is a sine wave.
2- Calculate the range of frequency for which output is a sine wave.
3- Attach the simulated version of the circuit.

Lab Session 3

OBJECTIVE

To study the characteristic curves of Silicon & Germanium diodes
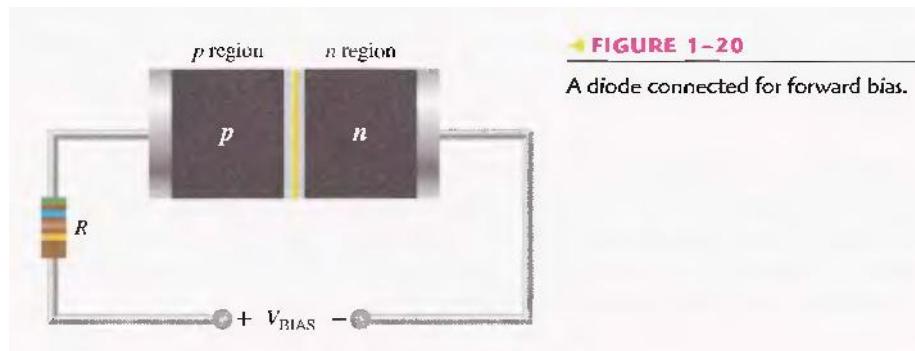
3.1   INTRODUCTION

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 de voltage of the proper polarity across the pn junction.
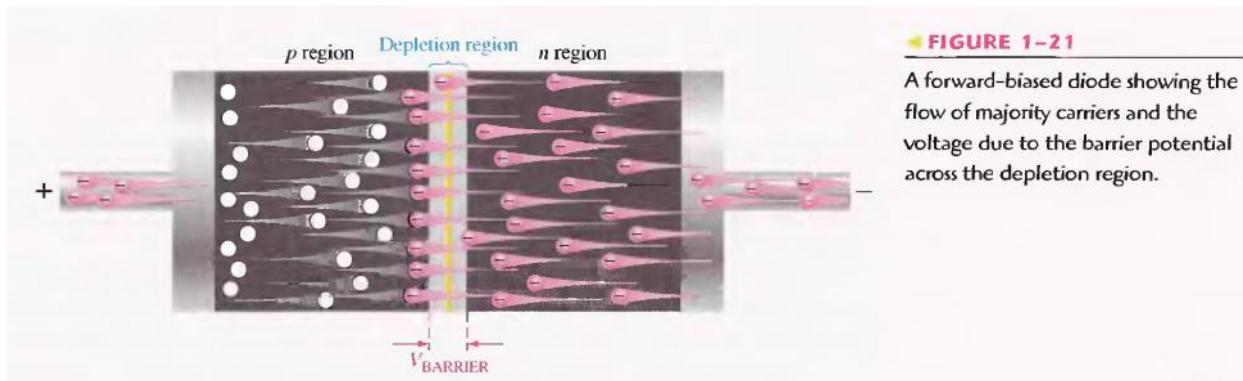
Forward Bias

To bias a diode, you apply a de 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.

◄ FIGURE 1-20

A diode connected for forward bias.

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

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

FIGURE 1-21

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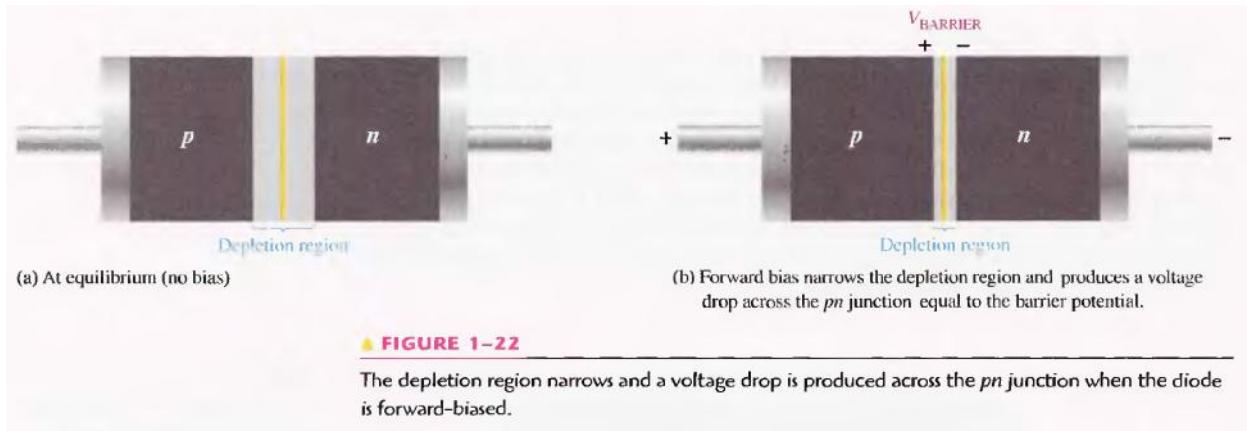
The bias-voltage source imparts sufficient energy to the free electrons for them to overcome the barrier potential of the depletion region and move on through into the p region. Once in the p region, these conduction electrons have lost enough energy to immediately combine with holes in the valence band.

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

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

As the electrons flow out of the p region through the external connection (conductor) and to the positive side of the bias-voltage source, they leave holes behind in the p region; at the same time, these electrons become conduction electrons in the metal conductor. Recall that the conduction band in a conductor overlaps the valence band so that it takes much less energy for an electron to be a free electron in a conductor than in a semiconductor. So there is a continuous availability of holes effectively moving toward the pn junction to combine with the continuous stream of electrons as they come across the junction into the p region.
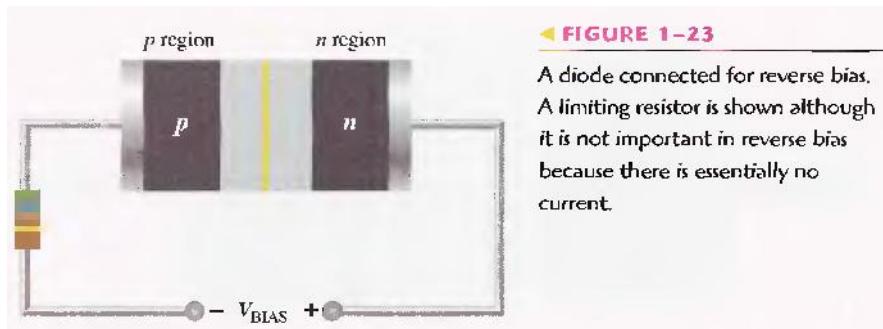
**The Effect of Forward Bias on the Depletion Region** As more electrons flow into the depletion region the number of positive ions is reduced. As more holes effectively flow into the depletion region on the other side of the p/1 junction, the number of negative ions is reduced. This reduction in positive and negative ions during forward bias causes the depletion region to narrow, as indicated in Figure 1-22.

(a) At equilibrium (no bias)

(b) Forward bias narrows the depletion region and produces a voltage drop across the *pn* junction equal to the barrier potential.

▲ 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.
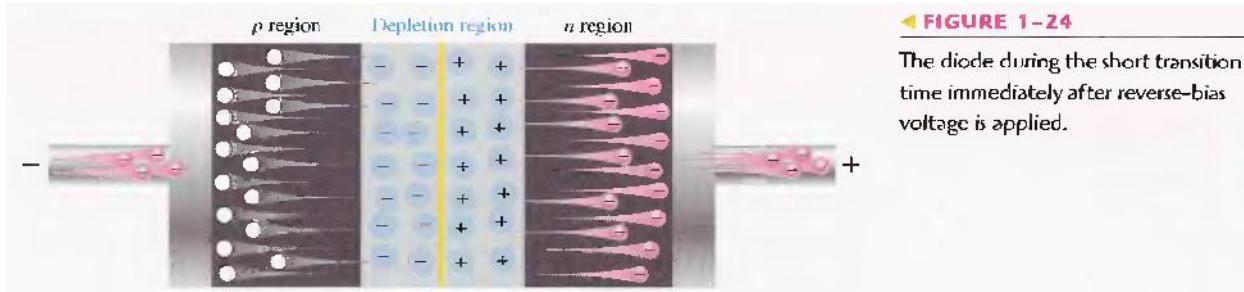
Reverse Bias

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 Vbias just as it was for forward bias. Notice that the positive side of Vbias is connected to the n region of the diode and the negative side is connected to the p region. Also note that the depletion region is shown much wider than in forward bias or equilibrium.

◄ FIGURE 1–23

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

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

side of the voltage source, additional positive ions are created. This results in a widening of the depletion region and a depletion of majority carriers.
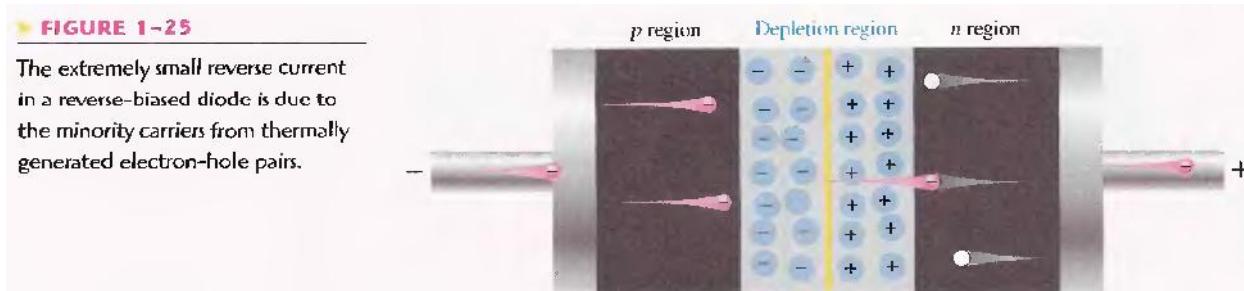
The diode during the short transition time immediately after reverse-bias voltage is applied.

In the p region, electrons from the negative side of the voltage source enter as valence electrons and move from hole to hole toward the depletion region where they create additional negative ions. This results in a widening of the depletion region and a depletion of majority carriers. The flow of valence electrons can be viewed as holes being "pulled" toward the positive side. The initial flow of charge carriers is transitional and lasts for only a very short time after the reverse-bias voltage is applied. As the depletion region widens, the availability of majority carriers decreases. As more of the n and p regions become depleted of majority carriers, the electric field between the positive and negative ions increases in strength until the potential across the depletion region equals the bias voltage, Vbias. 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 11 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 Norn1ally, 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.

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

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

electrons out of orbit and into the conduction band. The newly created conduction electrons are also high in energy and repeat the process. If one electron knocks only two others out of their valence orbit during its travel through the p region. The numbers quickly multiply. As these high-energy electrons go through the depletion region, they have enough energy to go through the 11 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 cunent 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 happen 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.

(a) Small forward-bias voltage ($V_F < 0.7$ V), very small forward current.

(b) Forward voltage reaches and remains at approximately 0.7 V. Forward current continues to increase as the bias voltage is increased.
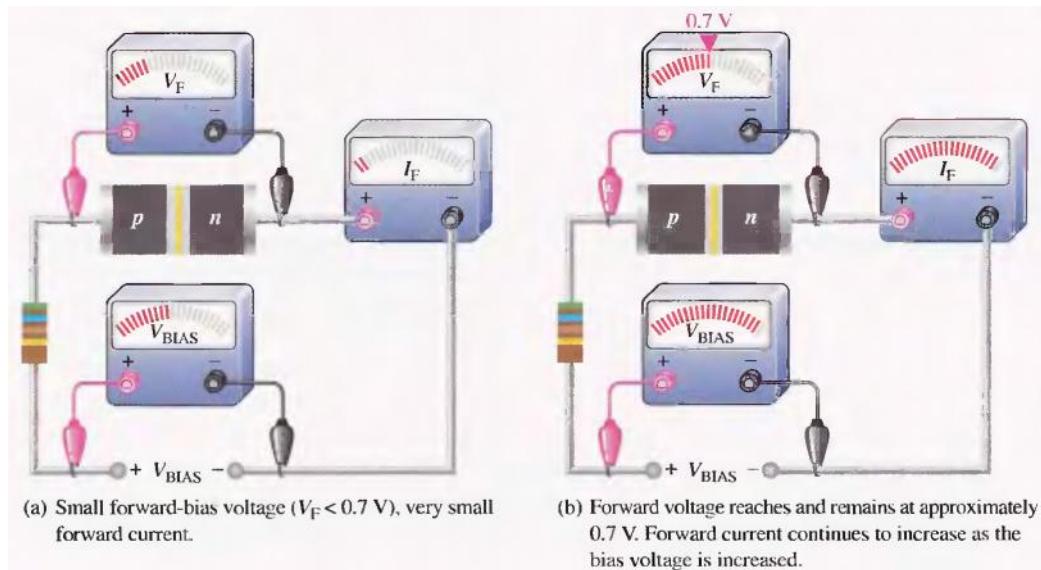
▲ FIGURE 1-26
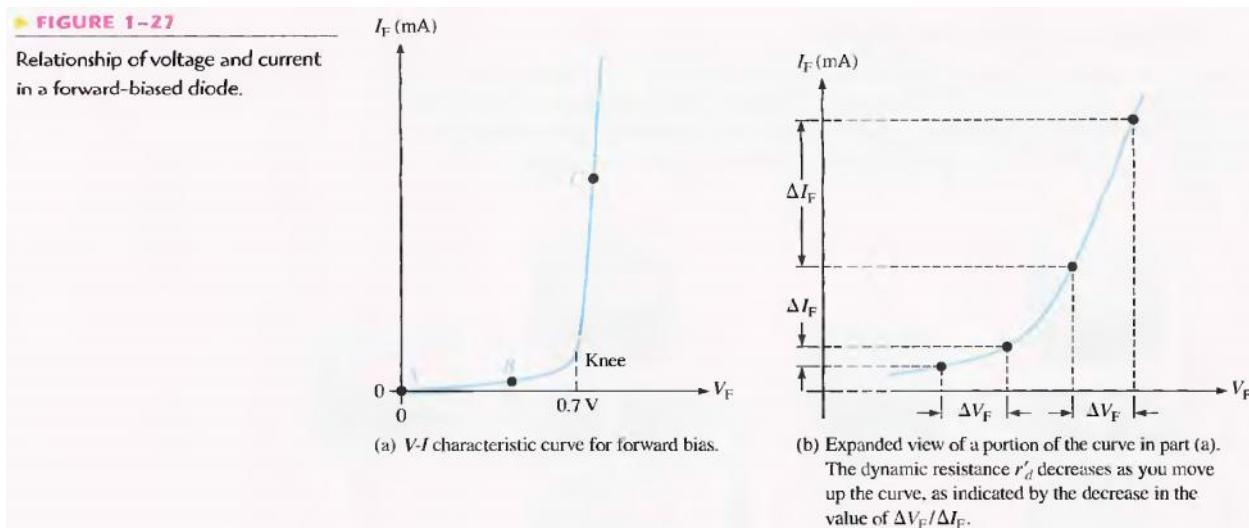
Forward-bias measurements show general changes in V_F and I_F as V_{BIAS} is increased.

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

(a) V-I characteristic curve for forward bias.

(b) Expanded view of a portion of the curve in part (a). The dynamic resistance r'_d decreases as you move up the curve, as indicated by the decrease in the value of $\Delta V_F / \Delta I_F$.

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 l' 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 ($r'_d = \ V_F / \ I_F$). The resistance begins to decrease in the region of the knee of the curve

and becomes smallest above the knee where there is a large change in current for a given change in voltage.
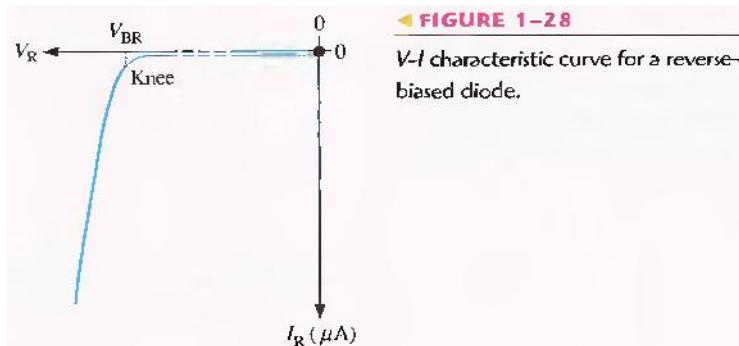
V-I Characteristic for Reverse Bias

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

As you continue to increase the bias voltage, the current continues to increase very rapidly, but the voltage across the diode increases very little above V_{BR}. Breakdown, with exceptions, is not a normal mode of operation for most pn junction devices.
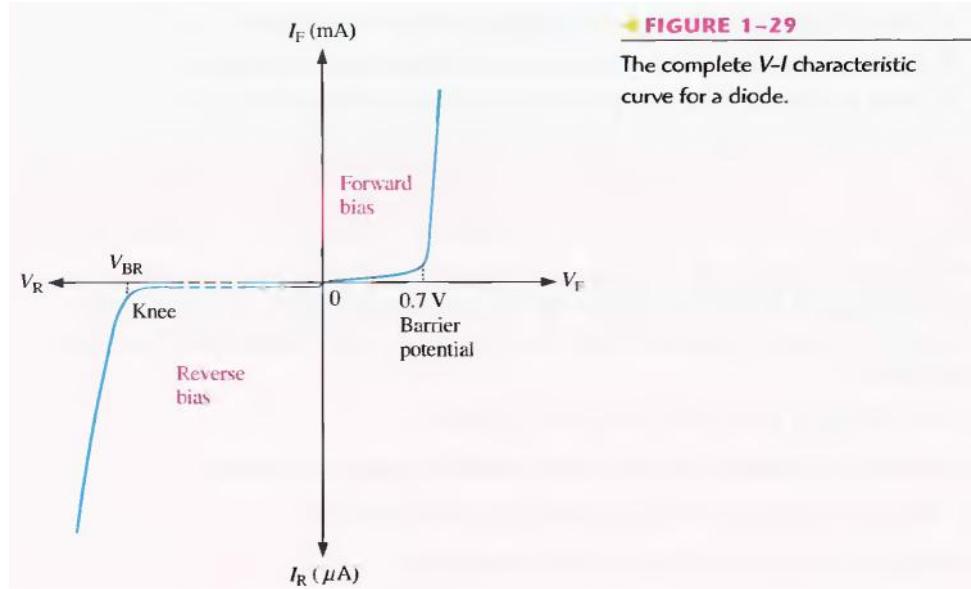
Graphing the V-I Curve If you plot the results of reverse-bias measurements on a graph, you get the V-I characteristic curve for a reverse-biased diode. A typical curve is shown in Figure 1-28. The diode reverse voltage (V_R) increases to the left along the horizontal axis and the reverse current (I_R) increases downward along the vertical axis.

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


◀ **FIGURE 1–28**

V-I characteristic curve for a reverse-biased diode.
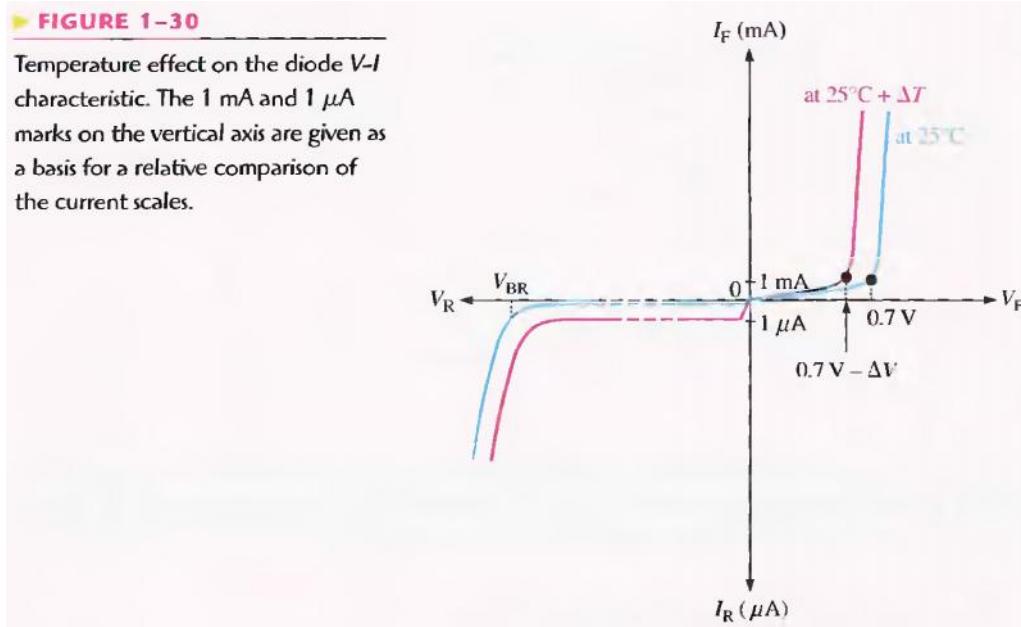
The Complete V-I Characteristic Curve

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

FIGURE 1-29

The complete V-I characteristic curve for a diode.

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

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

FIGURE 1-30

Temperature effect on the diode V-I characteristic. The 1 mA and 1 μA marks on the vertical axis are given as a basis for a relative comparison of the current scales.

Pre Lab
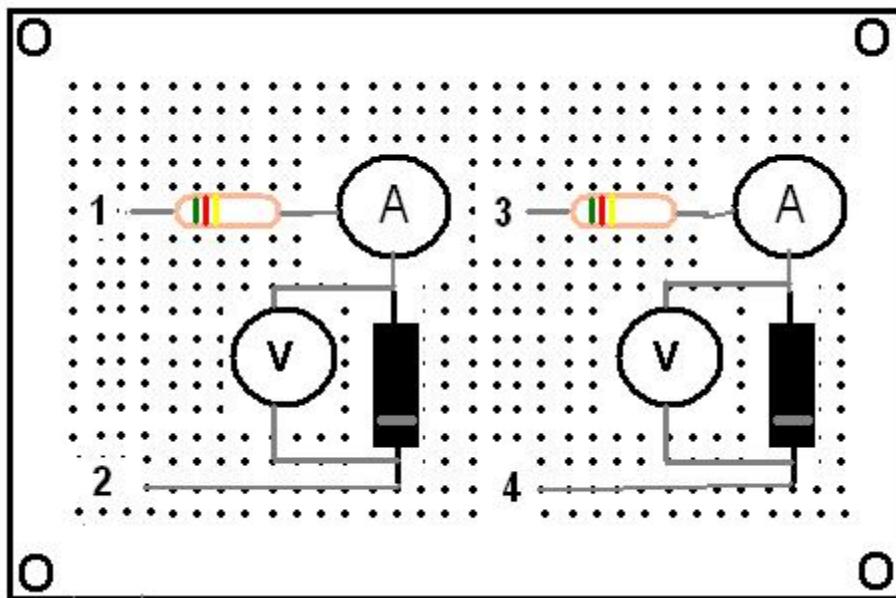
OBJECTIVE

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

REQUIRED COMPONENTS

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

PROCEDURE

Make the circuit as shown.

Lab Procedure

OBJECTIVE

To plot the V-I curve of Silicon & Germanium diodes.

PROCEDURE

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.

OBSERVATIONS

FORWARD BAIS MODE

SILICON DIODE   GERMANIUM DIODE

Voltage	Current

Voltage	Current

REVERSE BAIS MODE

SILICON DIODE   GERMANIUM DIODE

Voltage	Current

Voltage	Current

GRAPH:

Attach both graphs here.

POST LAB

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

Lab Session 04

OBJECTIVE
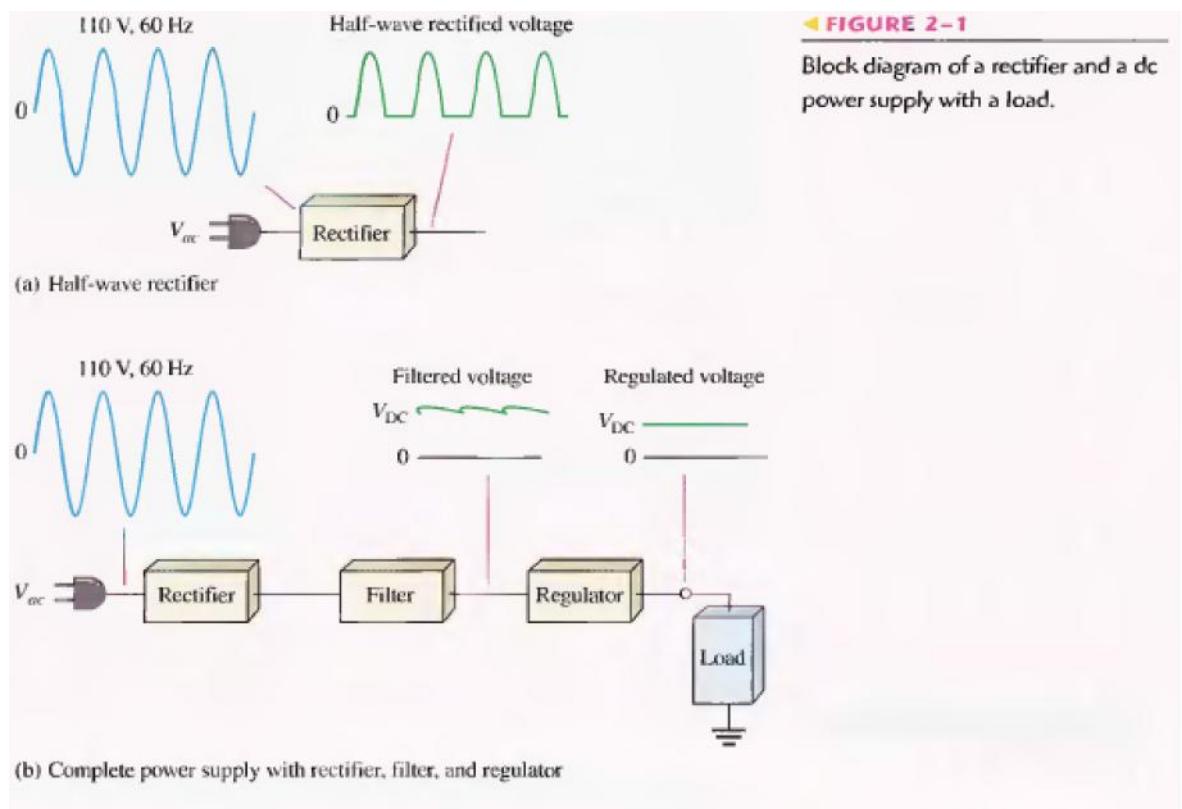
To study the half-wave rectifier

4.1   INTRODUCTION
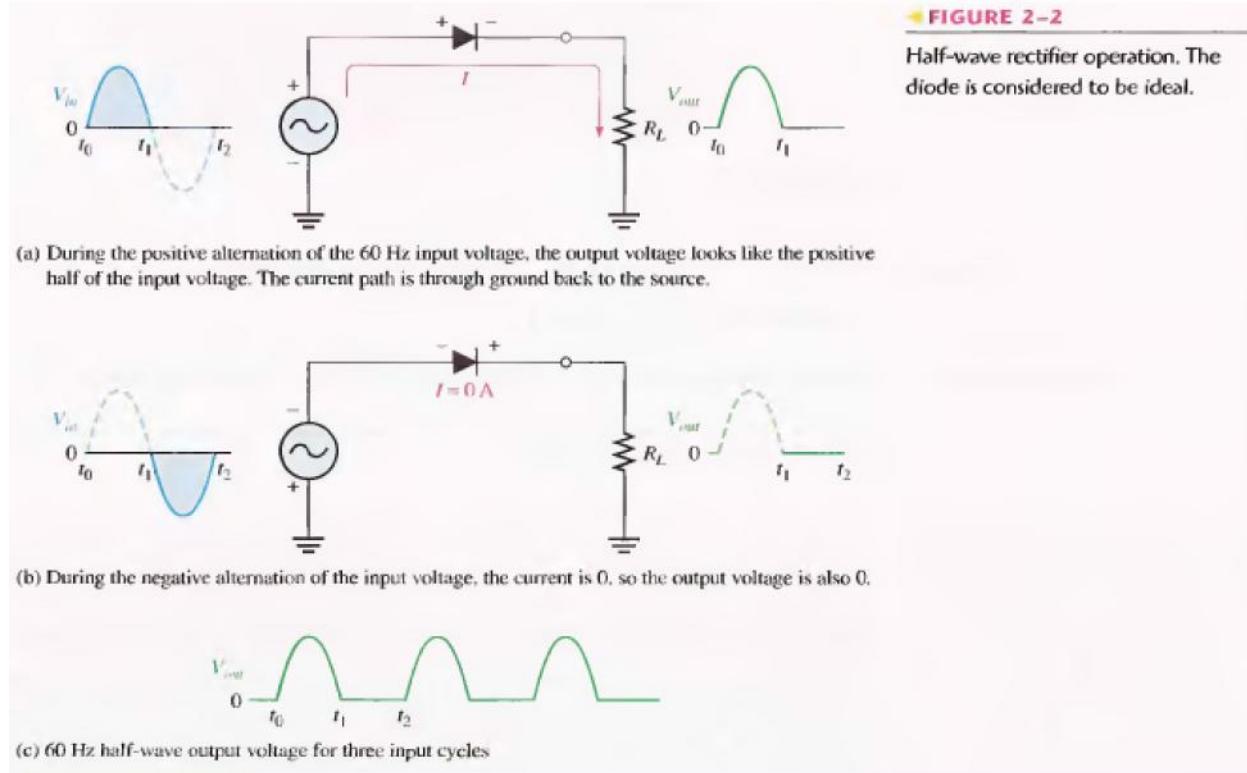
Because of their ability to conduct current in one direction and block current in other direction, diodes are used in circuits called rectifiers that convert ac voltage into dc voltage. Rectifiers are found in all dc power supplies that operate from an ac voltage source. A power supply is an essential 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.

### 4.1.1   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. Basic block diagrams for a rectifier and complete power supply are shown in Figure 2-1. The rectifier can be either a half-wave rectifier or a full-wave rectifier (covered in proceeding labs). The rectifier converts the ac input voltage to a pulsating dc voltage, which is half-wave rectified as shown in Figure 2-1(a). A block diagram for a complete power supply is shown in part (b). 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.

110 V, 60 Hz   Half-wave rectified voltage

(a) Half-wave rectifier

◄ FIGURE 2–1

Block diagram of a rectifier and a dc power supply with a load.

110 V, 60 Hz   Filtered voltage   Regulated voltage

(b) Complete power supply with rectifier, filter, and regulator
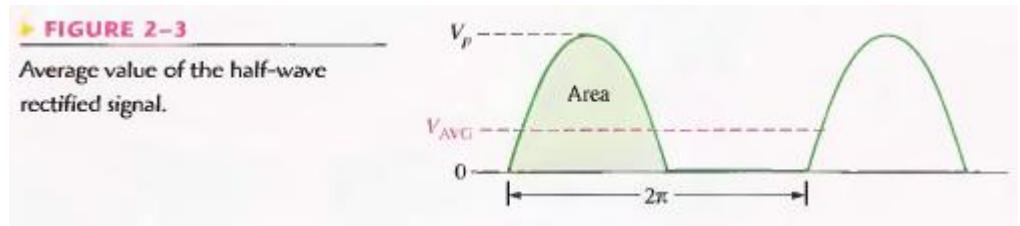
◄ FIGURE 2–2

Half-wave rectifier operation. The diode is considered to be ideal.

(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

4.1.2 Average Value of the Half-Wave Output Voltage

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

Equation 2-1 $\quad V_{AVG} = \dfrac{Vp}{\pi}$

▶ FIGURE 2-3

Average value of the half-wave rectified signal.
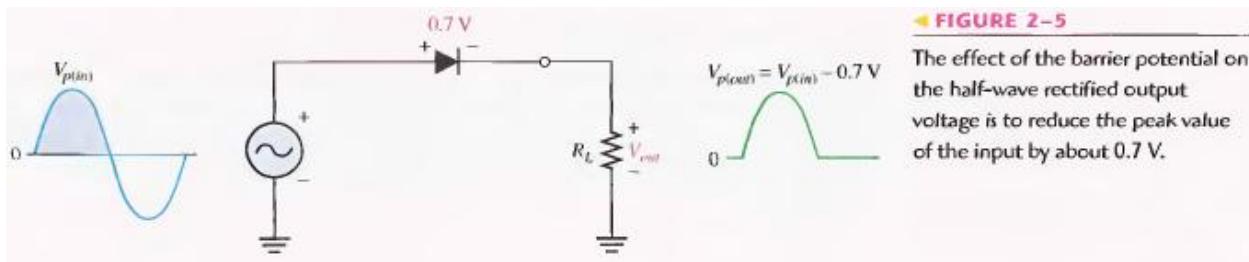
4.1.3 Effect of the Barrier Potential on the Half-Wave Rectifier Output

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

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

◀ FIGURE 2-5

The effect of the barrier potential on the half-wave rectified output voltage is to reduce the peak value of the input by about 0.7 V.

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).
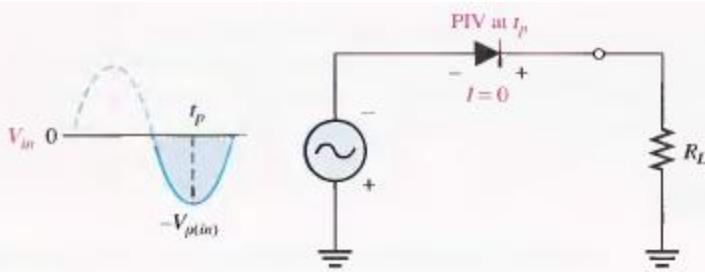
4.1.4 Peak Inverse Voltage (PIV)

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

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

FIGURE 2–8

The PIV occurs at the peak of each half-cycle of the input voltage when the diode is reverse-biased. In this circuit, the PIV occurs at the peak of each negative half-cycle.
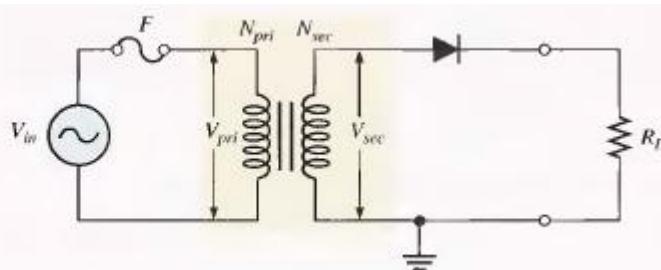
4.1.5   Half-Wave Rectifier with Transformer-Coupled Input Voltage

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

FIGURE 2–9

Half-wave rectifier with transformer-coupled input voltage.

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

> **Equation 2-4 $V_{sec} = n \, V_{pri}$**

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 2-2 written in terms of $V_{p(sec)}$ is:

> **Equation 2-5 $V_{P(out)} = V_{P(sec)} - 0.7$**

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

> **Equation 2-6 $PIV = V_{P(sec)}$**

PRE-LAB

OBJECTIVE
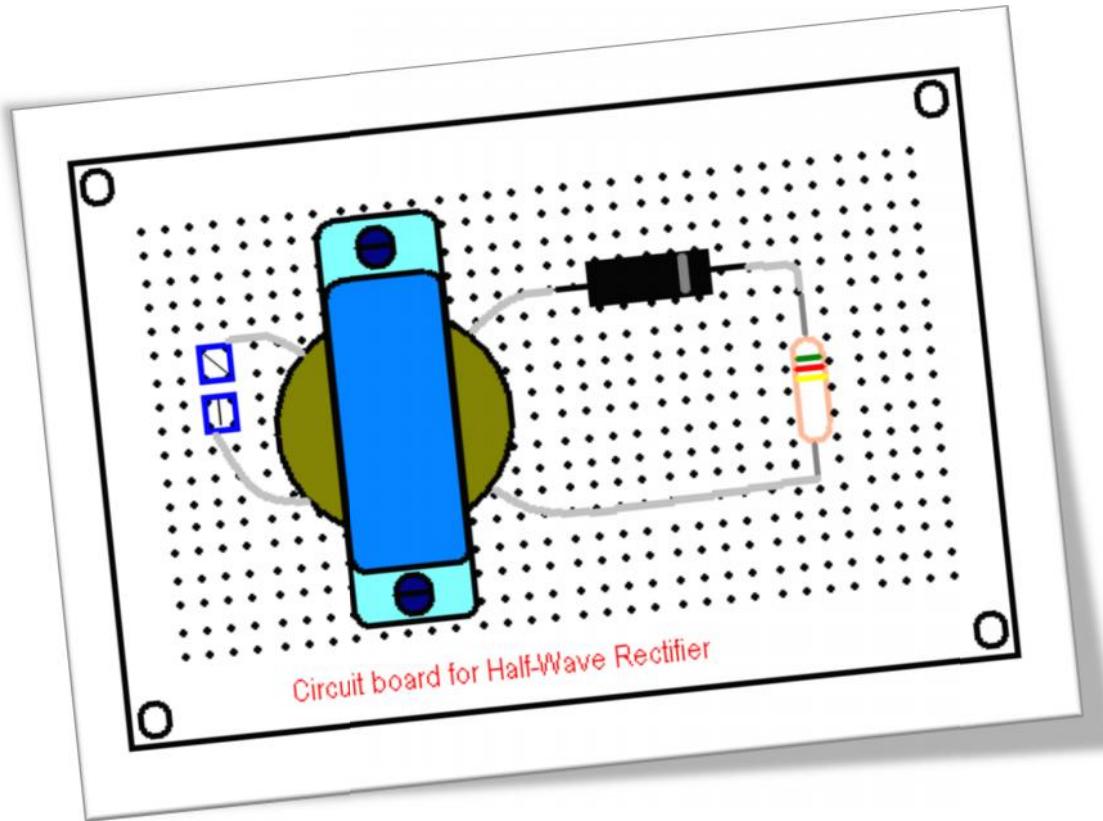
To construct a Half-Wave rectifier on a bread-board

4.3　EQUIPMENT REQUIRED

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

4.4　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.

Circuit board for Half-Wave Rectifier

LABORATORY PROCEDURE

OBJECTIVE

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

4.6   EQUIPMENT REQUIRED

1- Oscilloscope
2- Circuit constructed in PRE-LAB

4.7   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.

4.8   OBSERVATIONS

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

POST LAB

4.9   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 circuit				
Transformer output				
Circuit output				

4.10   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 , 100 & 1M & write the change in output values in the following table.

Readings	Vpeak-peak	Frequency	Rms Value	Average Value
1K				
100k				
1M				

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.

Lab Session 05
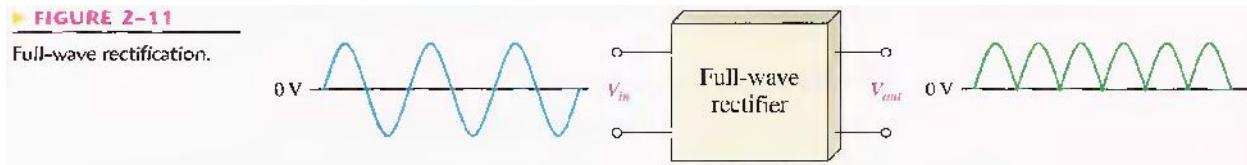
OBJECTIVE

To study the full-wave rectifier

INTRODUCTION

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

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

► FIGURE 2-11

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:

$$\text{Equation 2-5} \qquad V_{AVG} = \frac{2V_p}{\pi}$$

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

The Center-Tapped Full-Wave Rectifier

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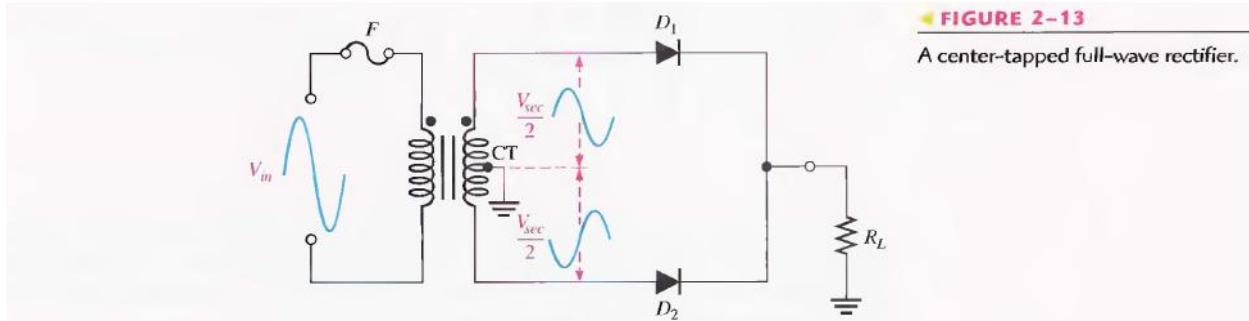
A center-tapped full-wave rectifier.

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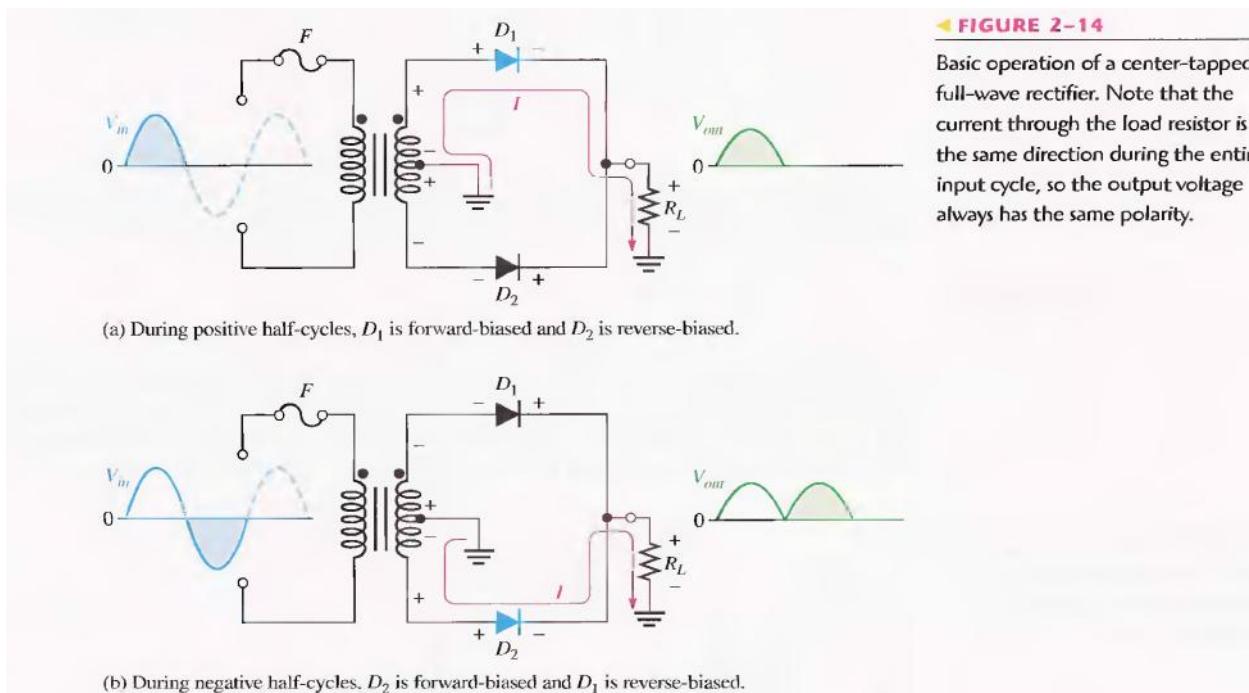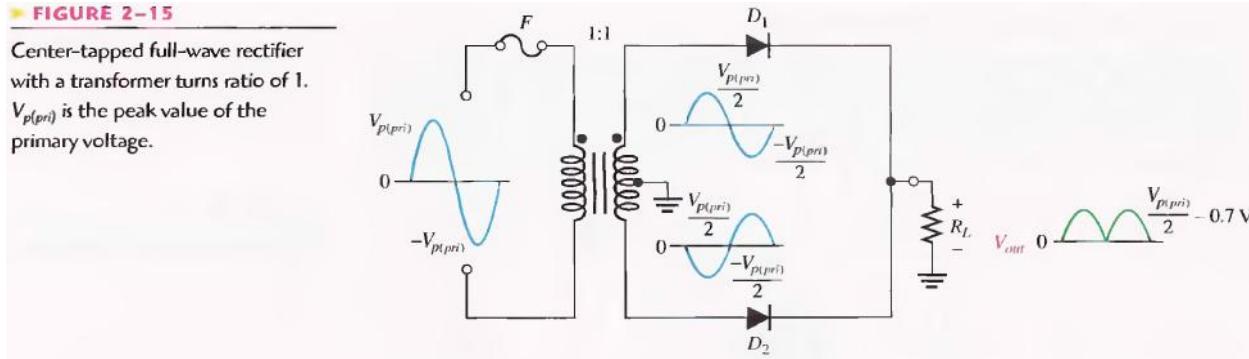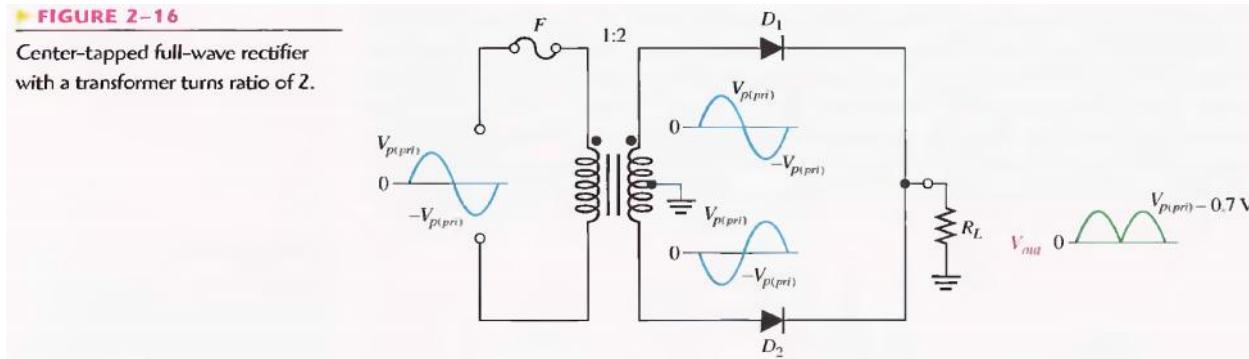
◄ FIGURE 2–14

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

(a) During positive half-cycles, D_1 is forward-biased and D_2 is reverse-biased.

(b) During negative half-cycles. D_2 is forward-biased and D_1 is reverse-biased.

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

▶ FIGURE 2–15

Center-tapped full-wave rectifier
with a transformer turns ratio of 1.
$V_{p(pri)}$ is the peak value of the
primary voltage.
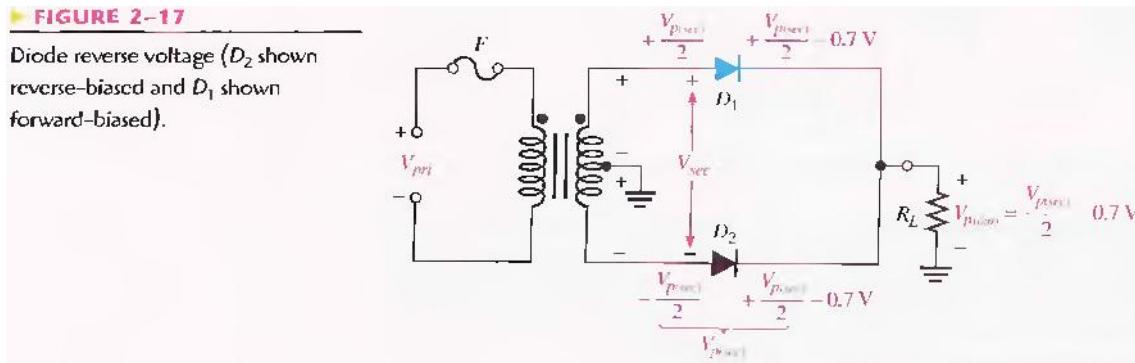
In order to obtain an output voltage with a peak equal to the input peak (less the diode drop), a step-up transformer with a turns ratio of n = 2 must be used, as shown in Figure 2-16. In this case, the total secondary voltage (V_{sec}) is twice the primary voltage ($2V_{pri}$), so the voltage across each half of the secondary is equal to V_{pri}.

▶ FIGURE 2–16

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

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

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

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

▶ FIGURE 2–17

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

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

The peak inverse voltage across D_2 is

$$PIV = \left(\frac{V_{p(sec)}}{2} - 0.7\,V \right) - \left(-\frac{V_{p(sec)}}{2} \right) = \frac{V_{p(sec)}}{2} + \frac{V_{p(sec)}}{2} - 0.7\,V$$
$$= V_{p(sec)} - 0.7\,V$$

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

$$V_{p(sec)} - 2V_{p(out)} + 1.4\,V$$

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

$$PIV = 2V_{p(out)} + 0.7\,V \qquad \text{Equation 2–7}$$

PRE-LAB

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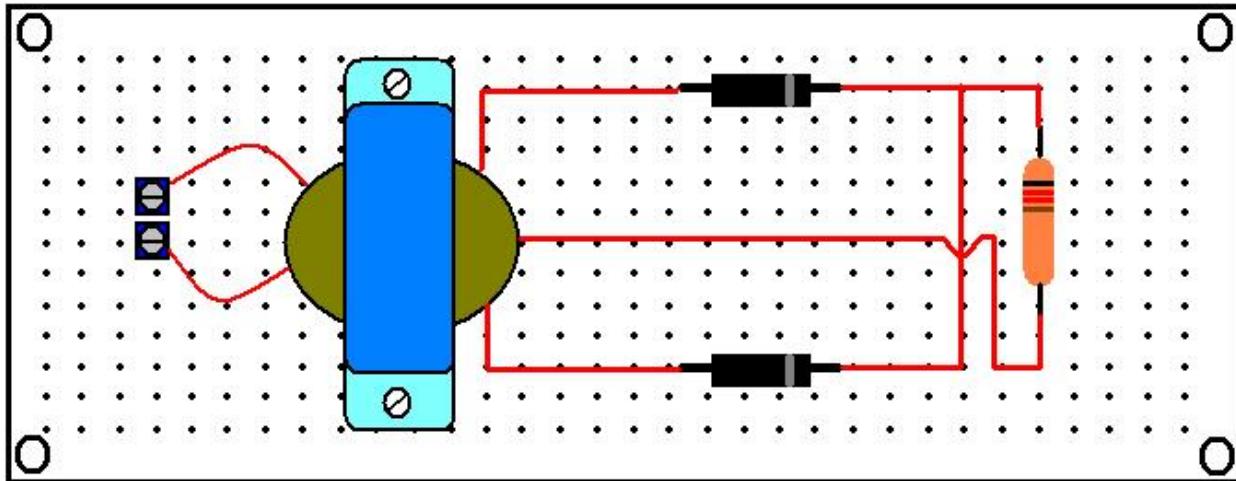
To construct a Full-Wave rectifier on a bread-board.

5.3   EQUIPMENT REQUIRED

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

5.4   PROCEDURE

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

LABORATORY PROCEDURE

OBJECTIVE

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

5.6   EQUIPMENT REQUIRED

3- Oscilloscope
4- Circuit constructed in PRE-LAB

5.7   PROCEDURE

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

5.8   OBSERVATIONS

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

POST LAB

5.9   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 circuit				
Transformer output				
Circuit output				

5.10   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 , 100K & 1M & write the change in output values in the following table.

Readings	Vpeak-peak	Frequency	Rms Value	Average Value
1K				
100k				
1M				

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.
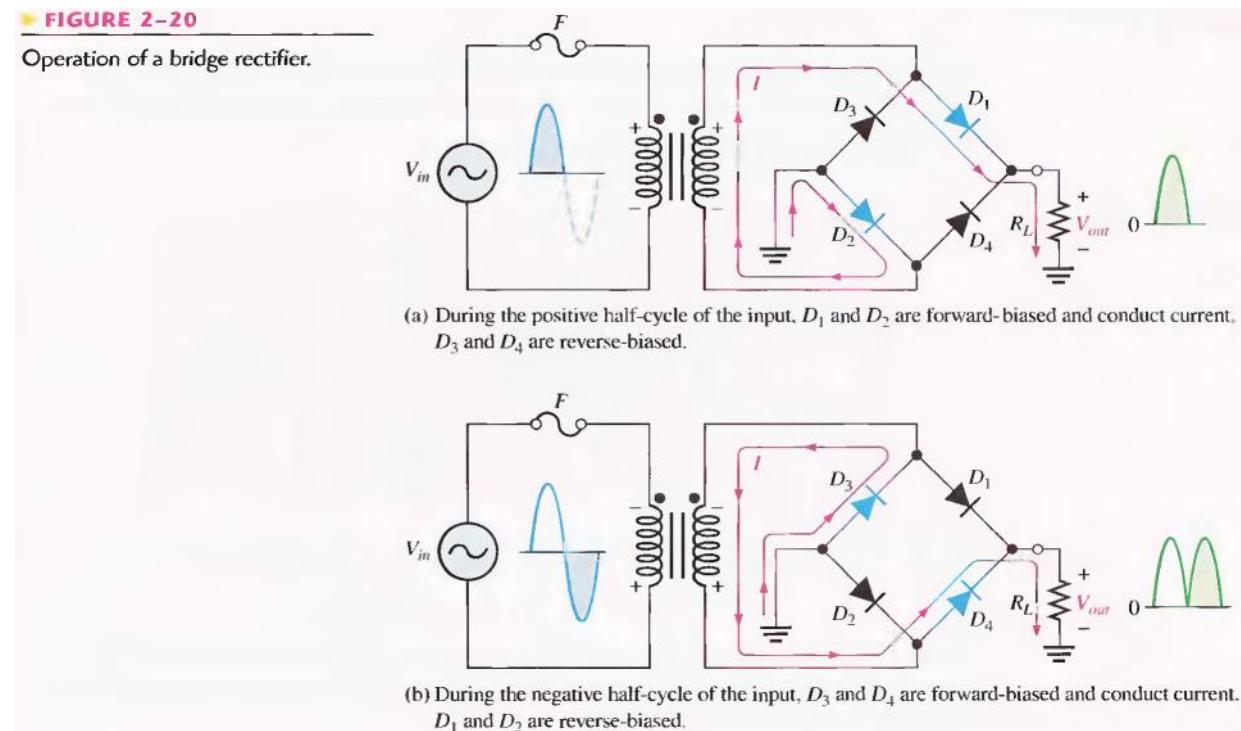
Lab Session 06

OBJECTIVE

To study the full-wave Bridge rectifier

INTRODUCTION
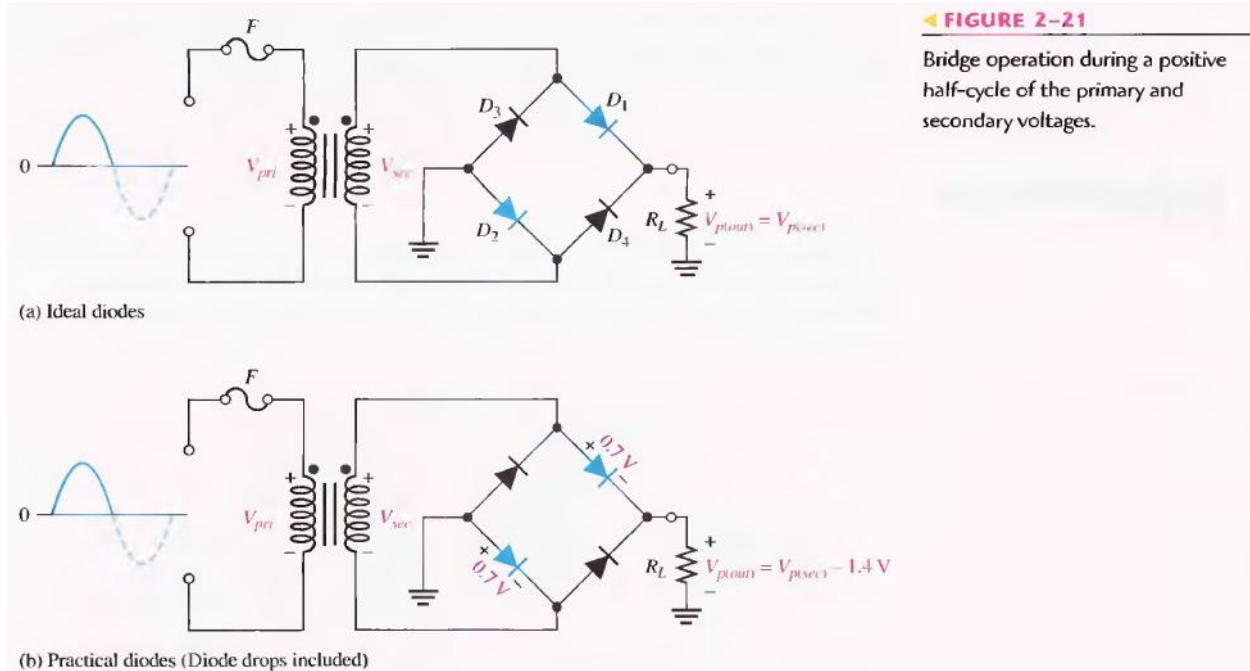
The bridge rectifier uses four diodes connected as shown in Figure 2-20. When the input cycle is positive as in part (a), diodes D_1 and D_2 are forward-biased and conduct current in the direction shown. A voltage is developed across R_L that looks like the positive half of the input cycle. During this time, diodes D_3 and D_4 are reverse-biased.


► FIGURE 2-20

Operation of a bridge rectifier.

(a) During the positive half-cycle of the input, D_1 and D_2 are forward-biased and conduct current. D_3 and D_4 are reverse-biased.

(b) During the negative half-cycle of the input, D_3 and D_4 are forward-biased and conduct current. D_1 and D_2 are reverse-biased.

When the input cycle is negative as in Figure 2-20(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 2-21 (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 D_3 and D_4 are forward-biased during the negative half-cycle.

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

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

(a) Ideal diodes

(b) Practical diodes (Diode drops included)

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

$V_{P(out)} = V_{P(sec)} - 1.4\ V$
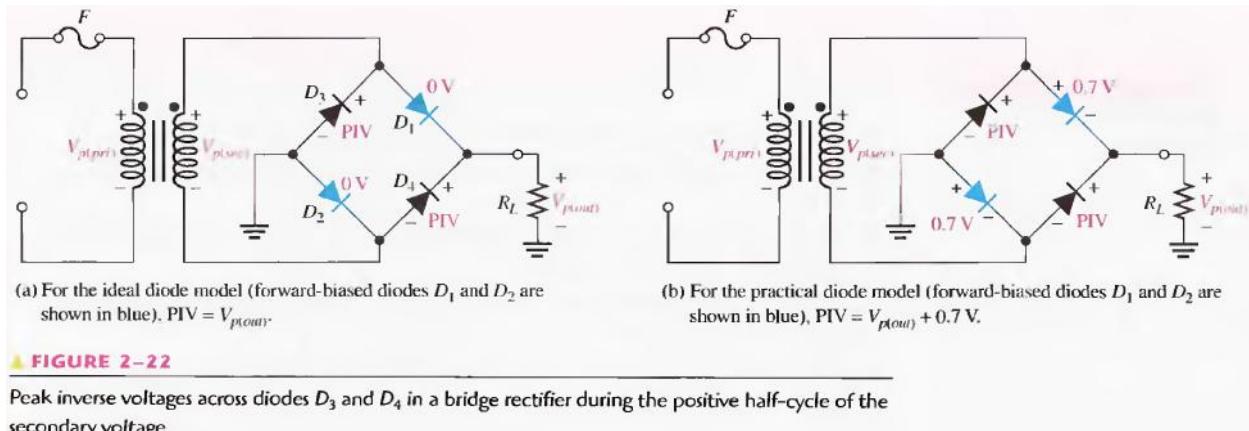
Peak Inverse Voltage: Let's assume that D_1 and D_2 are forward-biased and examine the reverse voltage across D_3 and D_4. Visualizing D_1 and D_2 as shorts (ideal model), as in Figure 2-22(a), you can see that D_3 and D_4, have a peak inverse voltage equal to the peak secondary voltage. Since the output voltage is ideally equal to the secondary voltage,

$PIV = Vp(out)$

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 Vp(out) is

$PIV = Vp(out) + 0.7\ V$ Equation 2–9

(a) For the ideal diode model (forward-biased diodes D_1 and D_2 are shown in blue). PIV = $V_{p(out)}$.

(b) For the practical diode model (forward-biased diodes D_1 and D_2 are shown in blue), PIV = $V_{p(out)} + 0.7$ V.

▲ FIGURE 2–22

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

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

PRE-LAB

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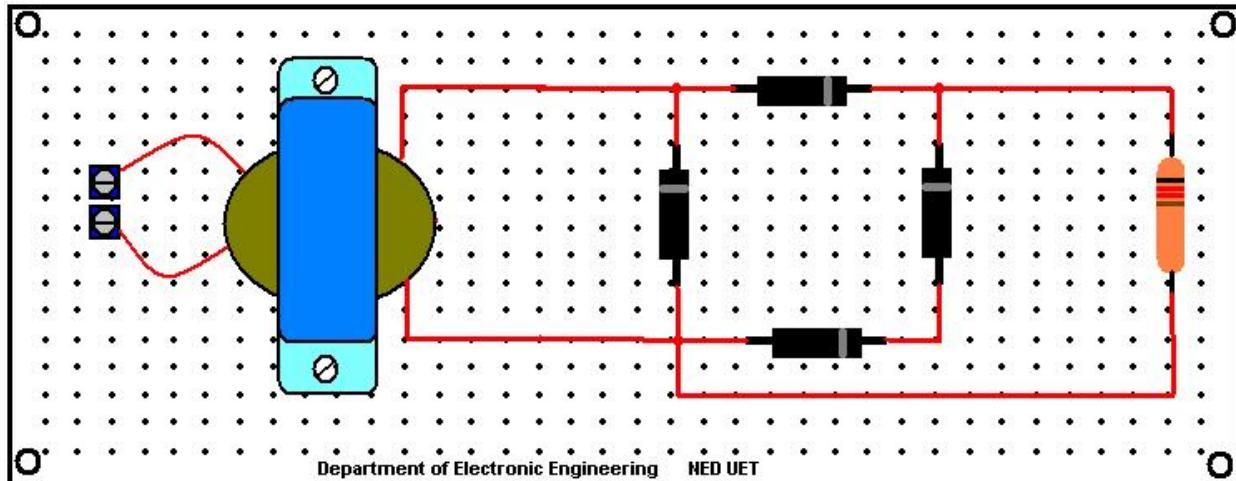
To construct a Full-Wave Bridge rectifier on a bread-board

6.3   EQUIPMENT REQUIRED

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

6.4   PROCEDURE

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

Department of Electronic Engineering   NED UET

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.

6.6   EQUIPMENT REQUIRED

1- Oscilloscope
2- Circuit constructed in PRE-LAB

6.7   PROCEDURE

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

6.8   OBSERVATIONS

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

POST LAB

6.9   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 circuit				
Transformer output				
Circuit output				

6.10   TASK TO BE SUBMITTED

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

Readings	Vpeak-peak	Frequency	Rms Value	Average Value
1K				
100k				
1M				

7- In multisim, reverse the direction of each diode one by one & write the output values in each case. Also provide the reason for each output.

8- In multisim, make the same circuit with one changing, i.e apply supply at the transformer secondary connect the rest circuit with transformer's primary, what happens at output??? Provide the reason also.

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

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

Lab Session 07

OBJECTIVE
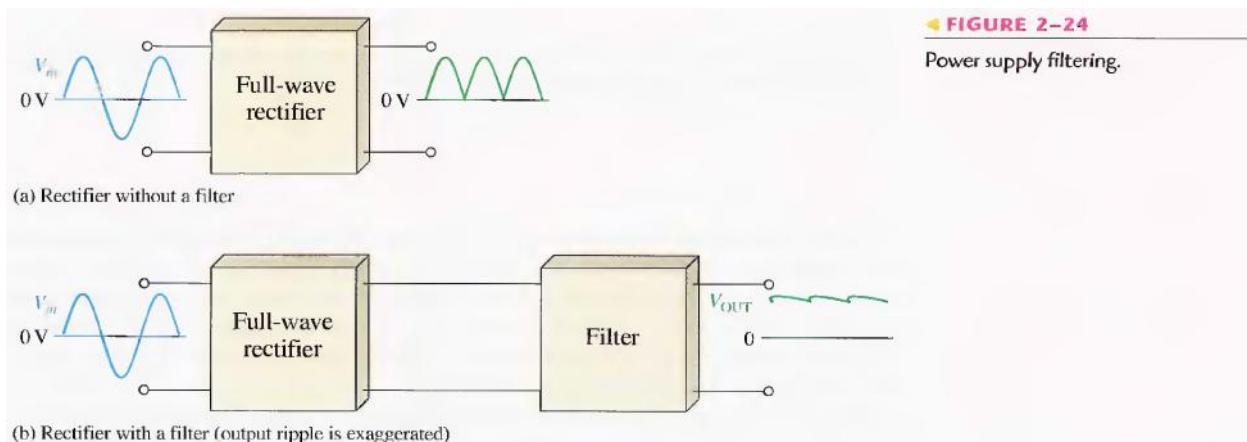
To study the operation of filters for smooth dc supply

INTRODUCTION

POWER SUPPLY FILTERS

A power supply filter ideally eliminates the fluctuations in the output voltage of a half- wave or full-wave rectifier and produces a constant-level dc voltage. Filtering is necessary because electronic circuits require a constant source of dc voltage and current to provide power and biasing for proper operation. Filters are implemented with capacitors, as you will see in this section. Voltage regulation in power supplies is usually done with integrated circuit voltage regulators. A voltage regulator prevents changes in the filtered dc voltage due to variations in input voltage or load.
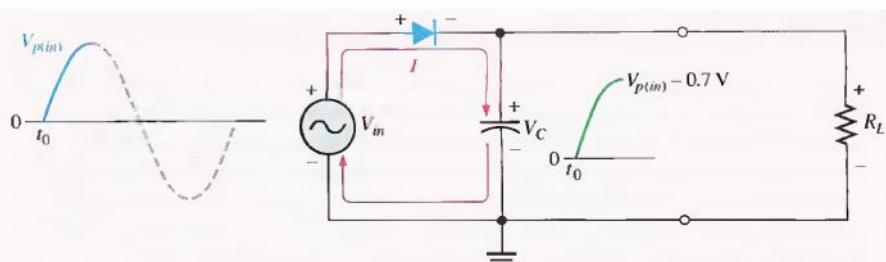
In most power supply applications, the standard 50 Hz ac power line voltage must be converted to an approximately constant dc voltage. The 50 Hz pulsating dc output of a half- wave rectifier or the 100 Hz pulsating output of a full-wave rectifier must be filtered to reduce the large voltage variations. Figure 2-24 illustrates the filtering concept showing a nearly smooth dc output voltage from the filter. The small amount of fluctuation in the filter output voltage is called ripple.

◀ FIGURE 2–24

Power supply filtering.

(a) Rectifier without a filter

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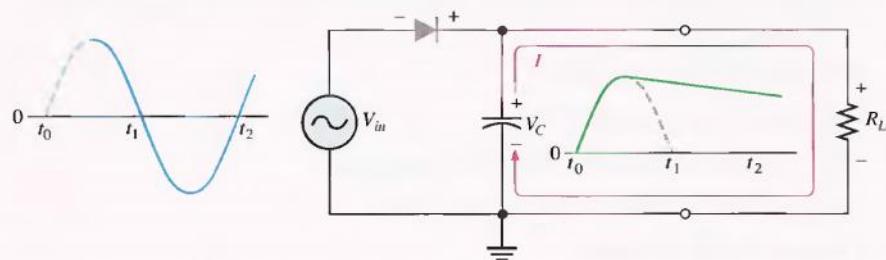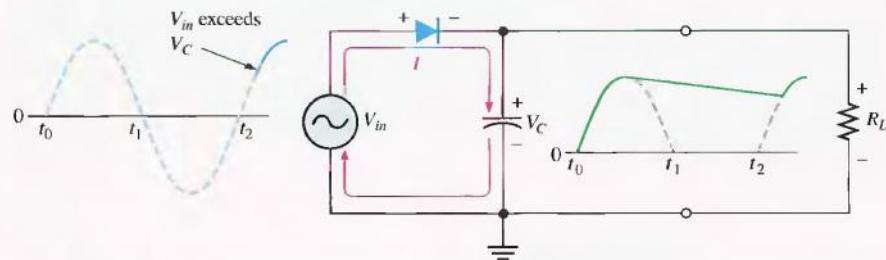
Capacitor-Input filter: A half-wave rectifier with a capacitor-input filter is shown in Figure 2-25. The filter is simply a capacitor connected from the rectifier output to ground. R_L represents the equivalent resistance of a load. We will use the half-wave rectifier to illustrate the basic principle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

▶ FIGURE 2–25

Operation of a half-wave rectifier with a capacitor-input filter. The current indicates charging or discharging of the capacitor.
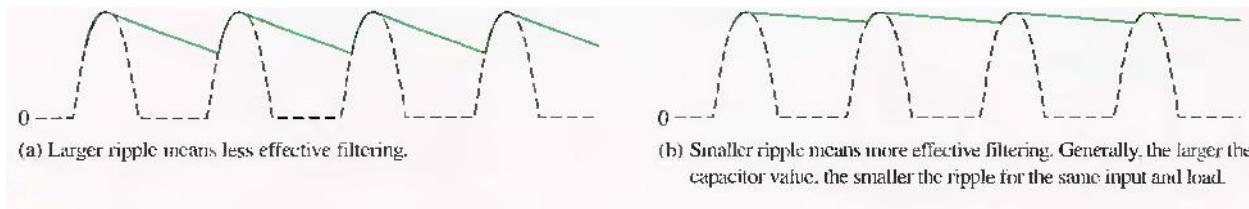
(a) Initial charging of the capacitor (diode is forward-biased) happens only once when power is turned on.

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


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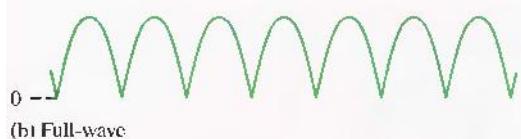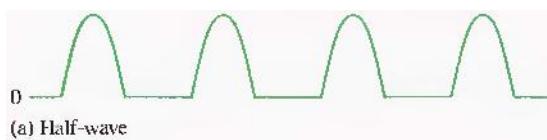
During the positive first quarter-cycle of the input, the diode is forward-biased, allowing the capacitor to charge to within 0.7 V of the input peak, as illustrated in Figure 2-25(a). When the input begins to decrease below its peak, as shown in part (b), the capacitor retains its charge and the diode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

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

(a) Larger ripple means less effective filtering.

(b) Smaller ripple means more effective filtering. Generally, the larger the capacitor value, the smaller the ripple for the same input and load.
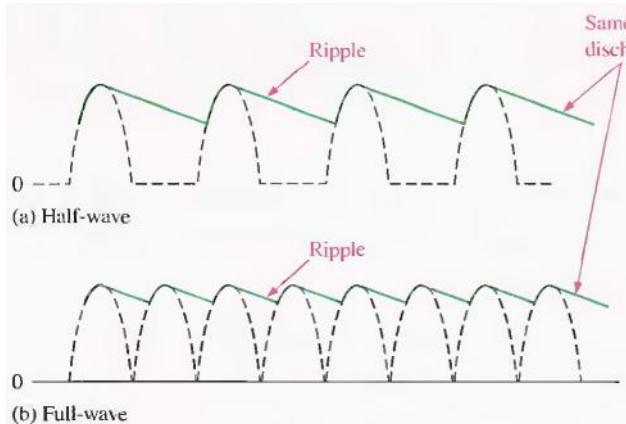
▲ **FIGURE 2–26**

Half-wave ripple voltage (green line).

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

(a) Half-wave

(b) Full-wave

◄ **FIGURE 2–27**

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

(a) Half-wave

(b) Full-wave

◄ **FIGURE 2–28**

Comparison of ripple voltages for half-wave and full-wave rectified voltages with the same filter capacitor and load and derived from the same sinusoidal input voltage.
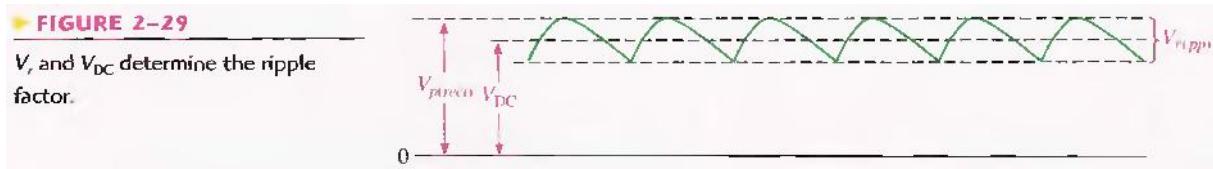
Ripple Factor: The ripple factor (r) is an indication of the effectiveness of the filter and is defined as:

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

Equation 2–10

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

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

► FIGURE 2-29

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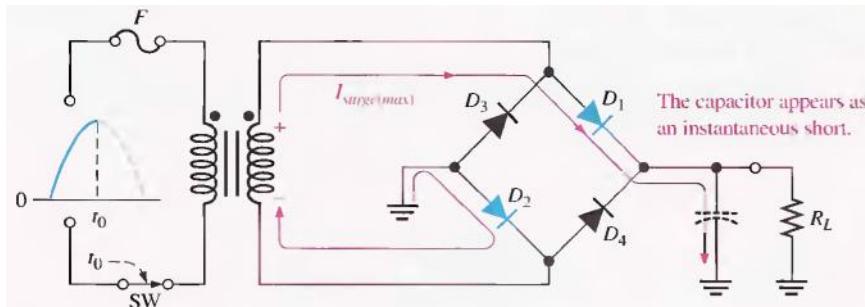
For a full-wave rectifier with a capacitor-input filter, approximations for the peak-to-peak ripple voltage, $V_{r(pp)}$ and the dc value of the filter output voltage, V_{DC}, are given in the following expressions. The variable $V_{p(rect)}$ is the unfiltered peak rectified voltage.

Equation 2-11

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

Equation 2-12

$$V_{DC} \cong \left(1 - \frac{1}{2fR_LC}\right)V_{p(rect)}$$
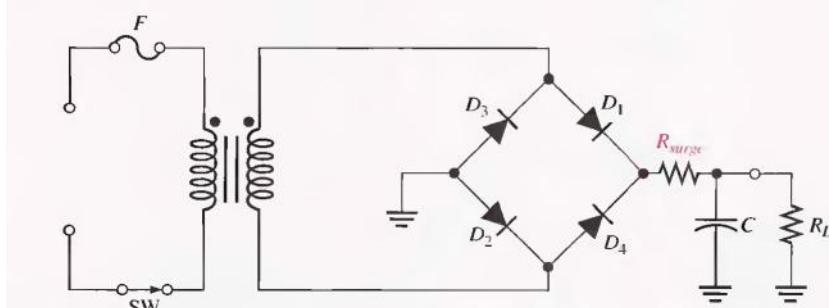
Surge Current in the Capacitor-Input Filter: Before the switch in Figure 2-31(a) is closed, the filter capacitor is uncharged. At the instant the switch is closed, voltage is connected to the bridge and the uncharged capacitor appears as a short, as shown. This produces an initial surge of current, I_{surge} through the two forward-biased diodes D_1 and D_2. The worst-case situation occurs when the switch is closed at a peak of the secondary voltage and a maximum surge current. $I_{surge(max)}$ is produced, as illustrated in the figure.

◄ FIGURE 2-31

Surge current in a capacitor-input filter.

The capacitor appears as an instantaneous short.

(a) Maximum surge current occurs when switch is closed at peak of an input cycle.

(b) A series resistor (R_{surge}) limits the 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 2-31(b). The value of this resistor must be small compared to R_L. Also, the diodes must have a maximum forward surge current rating such that they can withstand the momentary surge of current. This rating is specified on diode data sheets as I_{FSM}. The minimum surge resistor value can be calculated as follows:

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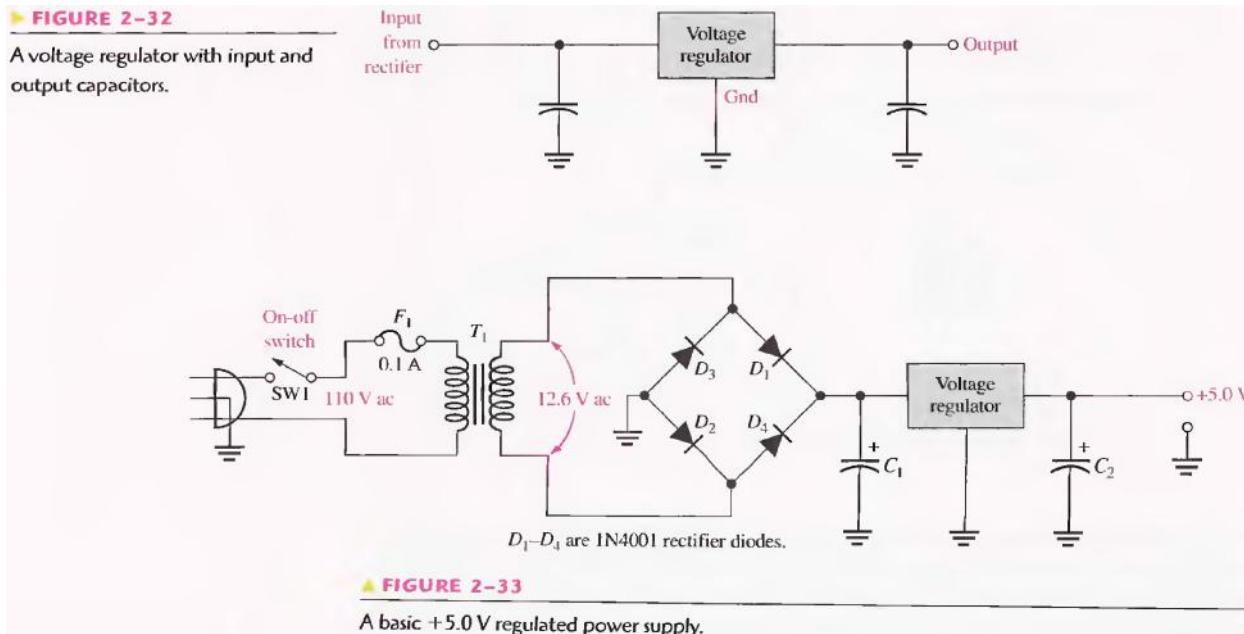
Voltage Regulators

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 µF to 1.0 µF) is connected from the output to ground to improve the transient response.

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

► FIGURE 2–32

A voltage regulator with input and output capacitors.

D_1–D_4 are 1N4001 rectifier diodes.

▲ FIGURE 2–33

A basic +5.0 V regulated power supply.

Percent Regulation

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

$$\text{Line regulation} = \left(\frac{\Delta V_{OUT}}{\Delta V_{IN}} \right) 100\% \qquad \text{Equation 2–14}$$

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

$$\text{Load regulation} = \left(\frac{V_{NL} - V_{FL}}{V_{FL}} \right) 100\% \qquad \text{Equation 2–15}$$

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

PRE-LAB

OBJECTIVE
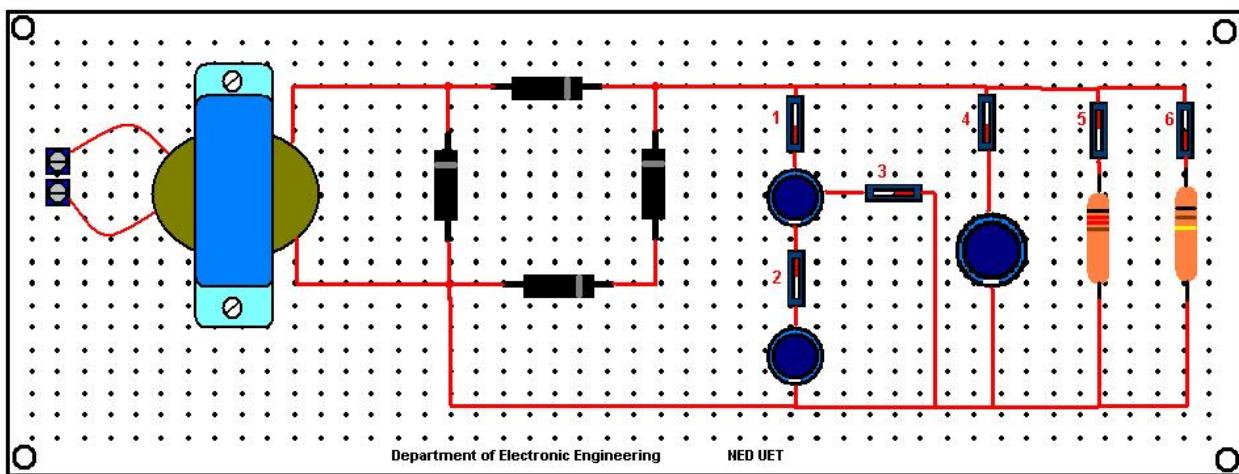
To insert capacitive filter in the circuits of half wave, Full-Wave with 2 diodes & Full-wave Bridge rectifier on a bread-board.

7.3   EQUIPMENT REQUIRED

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

7.4   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.

7.6   EQUIPMENT REQUIRED

1- Oscilloscope
2- Circuit constructed in PRE-LAB

7.7   PROCEDURE

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

2- Observe the output using Oscilloscope & note down Vpeak-peak, Frequency, rms value & average value.

3- Observe the output of transformer & note down all values.

4- Now observe the output across resistor using oscilloscope & note down same values as mentioned in above step.

5- Change the position of switches so as to make different RC combinations & observe the output & note down.

7.8   OBSERVATIONS

Readings	Vpeak-peak	Frequency	Rms Value	Average Value	Ripple Voltage
Input to circuit					
Transformer output					
Circuit output					
With 47µF & 10k					
With (47µF+4.7µF) & 10k					
With 47µF & 100k					
With 470µF & 10k					
With 470µF + 100k					
With (4.7µF+47µF+470µF) + (100k +10k					

POST LAB

7.9   CALCULATIONS

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

Readings	Vpeak-peak	Frequency	Rms Value	Average Value	Ripple Voltage
Input to circuit					
Transformer output					
Circuit output					
With 47µF & 10k					
With (47µF+4.7µF) & 10k					
With 47µF & 100k					
With 470µF & 10k					
With 470µF + 100k					

With (4.7μF+47μF+470μF) + (100k +10k					

7.10 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.

Lab Session 8

OBJECTIVE

To study the operation of diode limiters
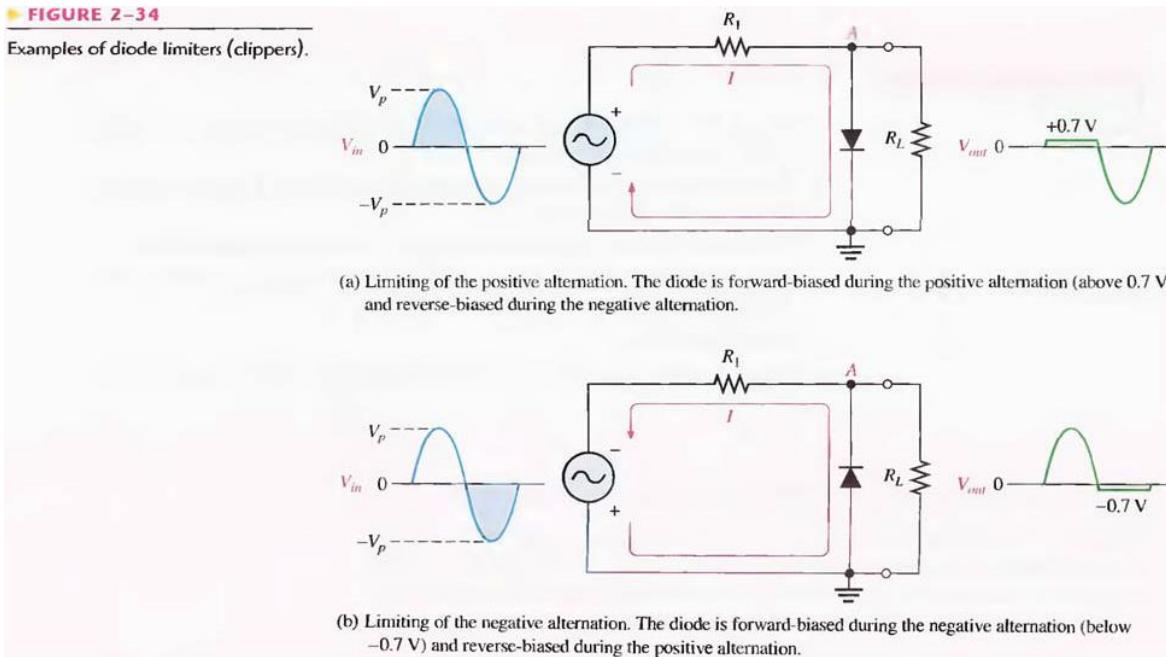
INTRODUCTION

Figure 2-34(a) shows a diode limiter (also called clipper) that limits or clips the positive part of the input voltage. As the input voltage goes positive, the diode becomes forward-biased and conducts current. Because, the cathode is at ground potential (0 V), the anode cannot exceed 0.7V (assuming silicon). So point A is limited to +0.7V when the input voltage exceeds this value. When the input voltage goes back below 0.7 V, the diode is reverse- biased and appears as an open. The output voltage looks like the negative part of the input voltage, but with a magnitude determined by the voltage divider formed by Rl and the load resistor, RL, as follows:

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

If R1 is small compared to RL, then Vout = Vin.

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

FIGURE 2-34

Examples of diode limiters (clippers).

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

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

PRE-LAB

OBJECTIVE

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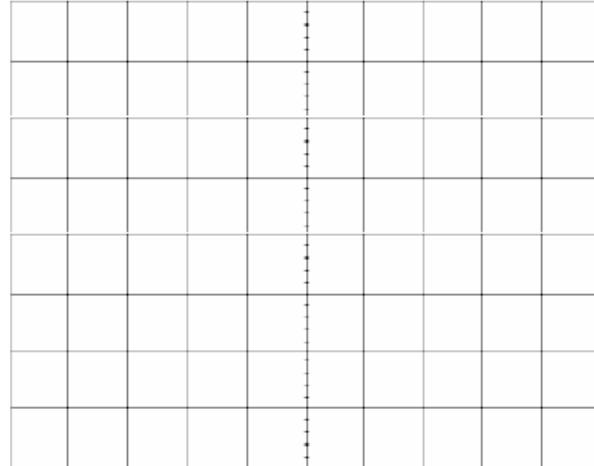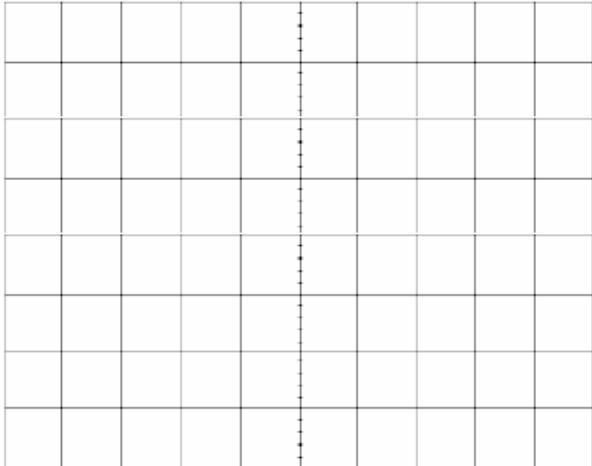
LABORATORY PROCEDURE

OBJECTIVE

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

PROCEDURE

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

OBSERVATIONS

1- SCALES: Vertical _____ V/Div, Horizontal _____ s/Div

2- SCALES: Vertical _____ V/Div, Horizontal _____ s/Div

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.
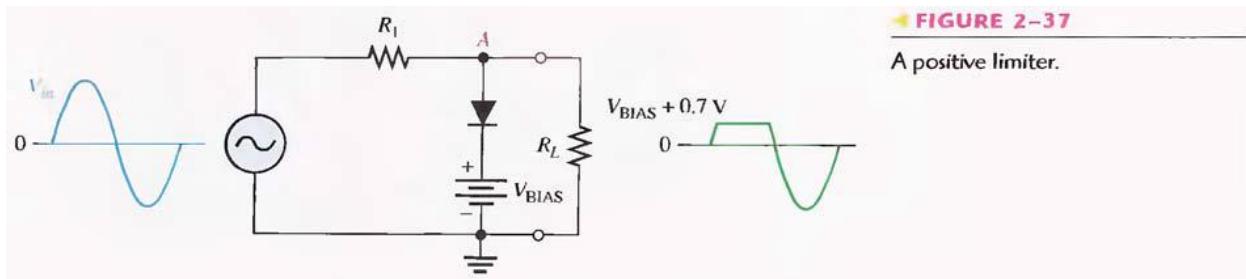
Lab Session 9

OBJECTIVE
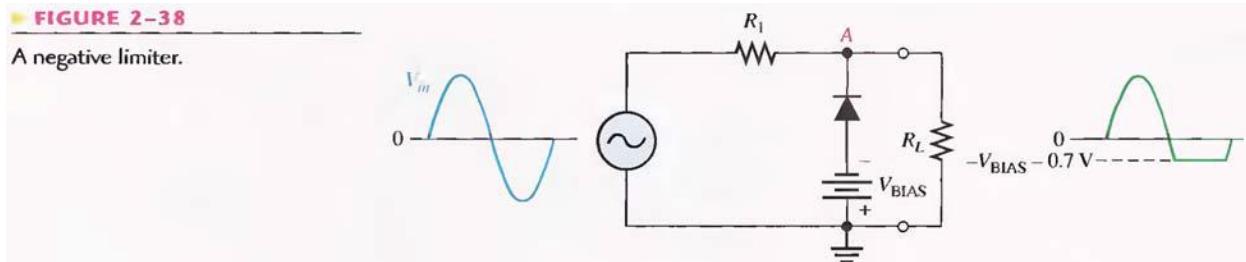
To study the operation of Biased Diode Limiters.

INTRODUCTION
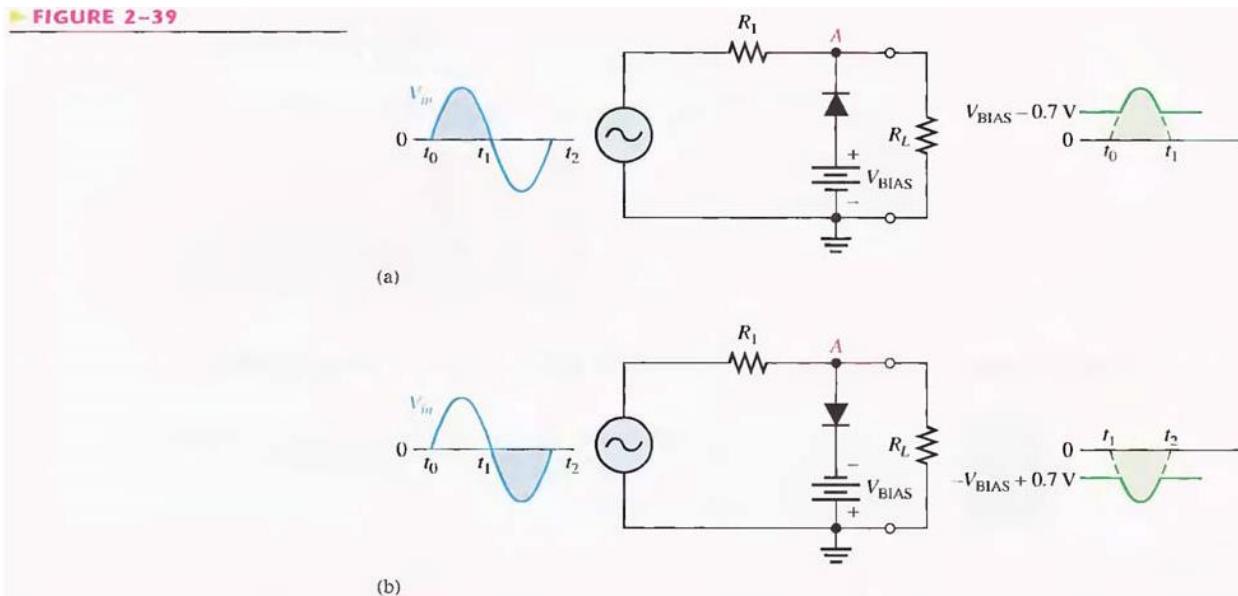
The level to which an AC voltage is limited can be adjusted by adding a bias voltage, VBIAS, in series with the diode, as shown in Figure 2-37. The voltage at point A must equal VBIAS + 0.7 V before the diode will become forward-biased and conduct. Once the diode begins to conduct, the voltage at point A is limited to VBIAS + 0.7 V so that all input voltage above this level is clipped off.

◄ FIGURE 2–37

A positive limiter.

To limit a voltage to a specified negative level, the diode and bias voltage must be connected as in Figure 2-38. In this case, the voltage at point A must go below -VBIAS - 0.7 V to forward-bias the diode and initiate limiting action as shown.

► FIGURE 2–38

A negative limiter.

By turning the diode around, the positive limiter can be modified to limit the output voltage to the portion of the input voltage waveform above VBIAS - 0.7 V, as shown by the output waveform in Figure 2-39(a). Similarly, the negative limiter can be modified to limit the output voltage to the portion of the input voltage waveform below -VBIAS + 0.7 V, as shown by the output waveform in part (b).

► FIGURE 2-39

PRE-LAB

OBJECTIVE

To construct the circuits of fig-2-37, 38 & 39 on bread board & test the continuity.

## LABORATORY PROCEDURE

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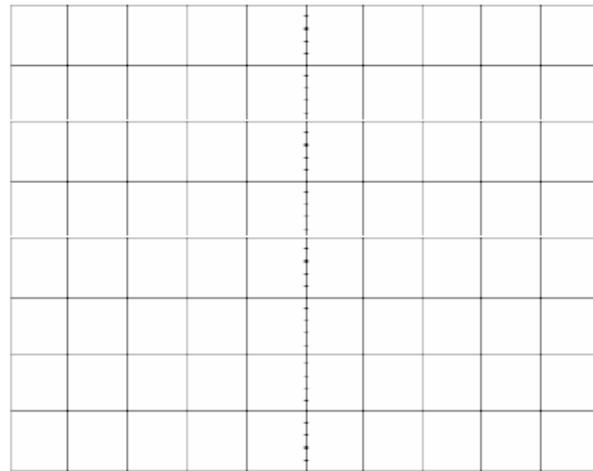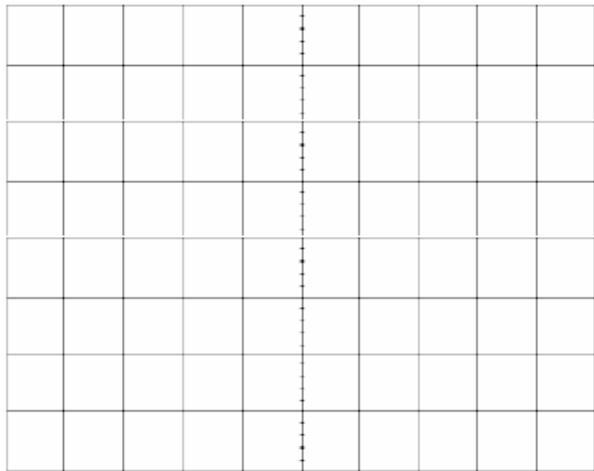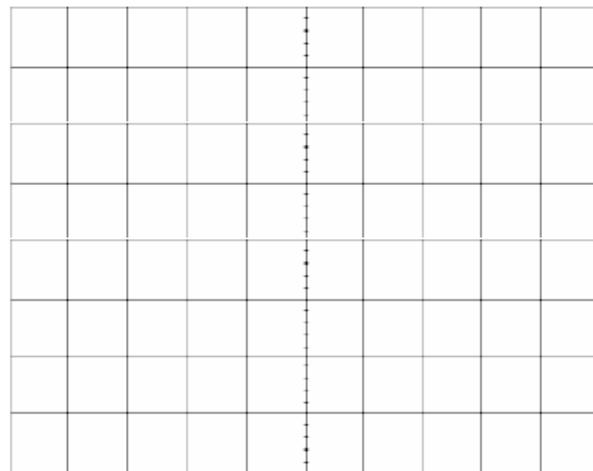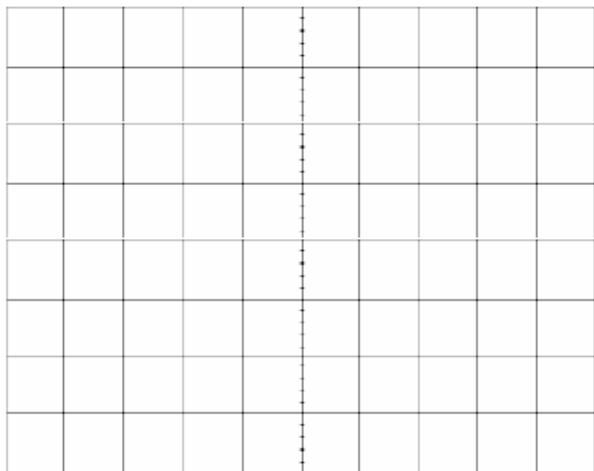
To apply input to the above mentioned circuits & find out outputs.

PROCEDURE

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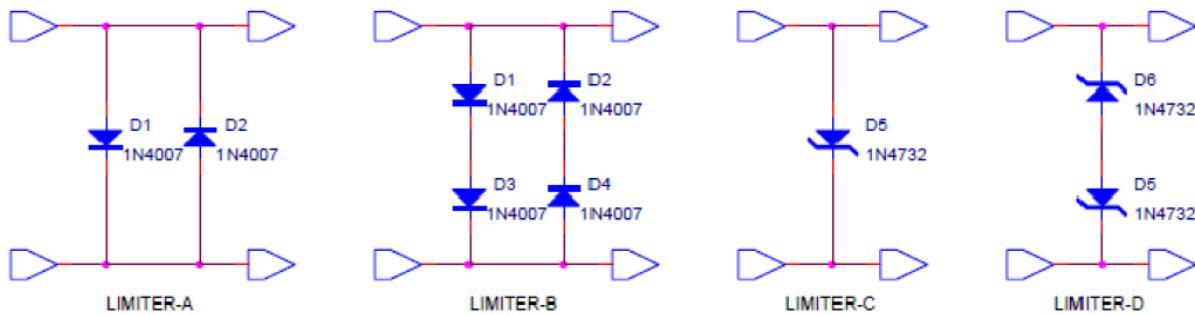
OBSERVATIONS

1- SCALES: Vertical _____ V/Div, Horizontal _____ s/Div

2- SCALES: Vertical _____ V/Div, Horizontal _____ s/Div

3- SCALES: Vertical _____ V/Div, Horizontal _____ s/Div

4- SCALES: Vertical _____ V/Div, Horizontal _____ s/Div

POST LAB

TASK TO BE SUBMITTED

1- Increase the frequency of the input waveform & find the frequency at which the output waveform starts to distort, write the frequency & the reason behind distortion.

2- The oscilloscope can also be used to directly display the voltage transfer characteristics (VTC) of this circuit. Simply reconfigure the oscilloscope to display Ch-1 versus Ch-2 in an X-Y mode. Ground the inputs to both channels by setting the coupling switches to GND, and then switch the oscilloscope into the X-Y mode. (On Tektronix oscilloscopes, all you need to do is push the X-Y button in; on Hewlett-Packard oscilloscopes, you will need to access the X-Y mode through the MATH function menu.) Use the position controls to move the dot onto the cross-hairs in the exact center of the screen. Change the input coupling on each of the two channels back to DC and the display should now show the VTC. Sketch the VTC shown on the oscilloscope screen on next page of workbook.

3- Sketch the VTC curve of the following circuits also.

4- Draw circuits in Multisim using triangular and square waves as the input supply and observe the output on Multisim.

Lab Session 10
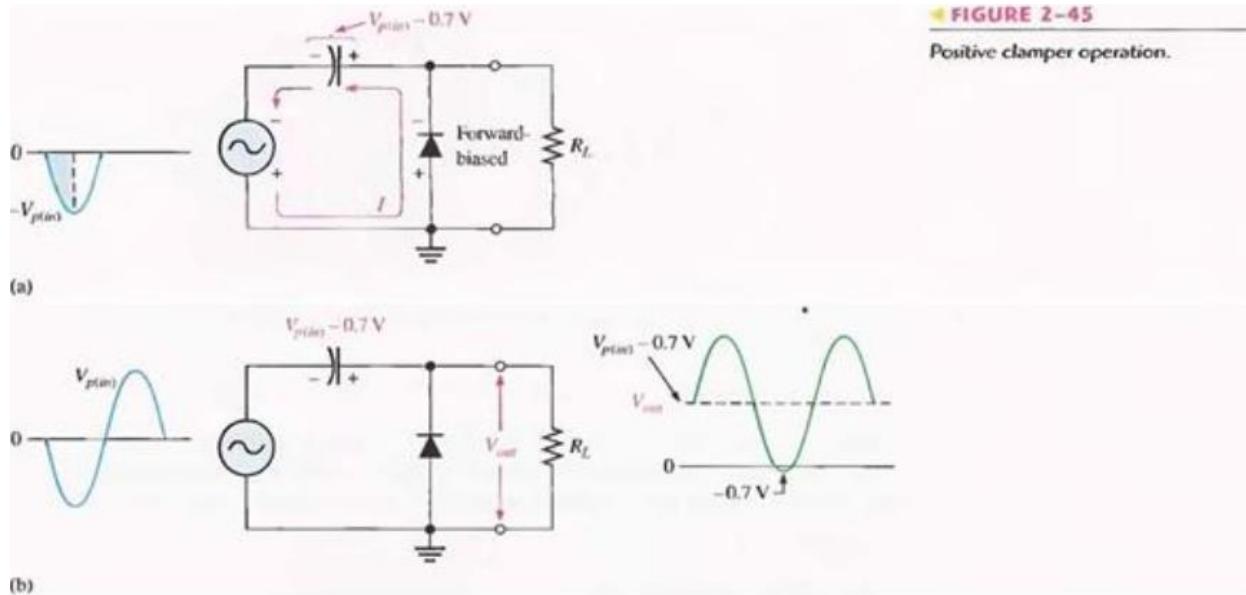
OBJECTIVE

To study the operation of diode clampers.
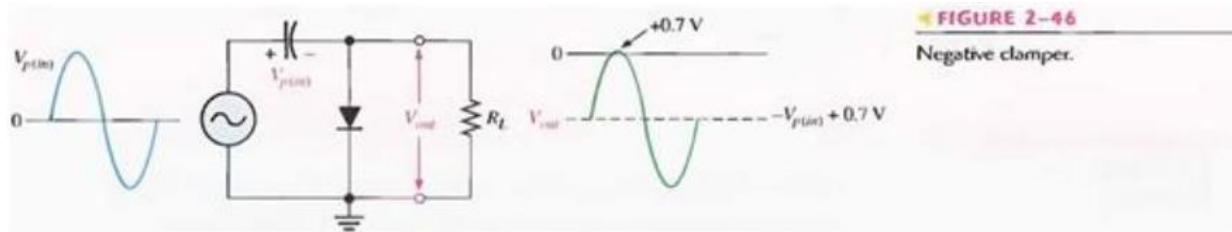
11.1   INTRODUCTION

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 (Vp(in) - 0.7 V), as shown in Figure 2-45(a). Just after the negative peak, the diode is reverse-biased. This is because the cathode is held near Vp(in) - 0.7 V by the charge on the capacitor. The capacitor can only discharge through the high resistance of RL. 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 RL. For good clamping action, the RC time constant should be at least ten times the period of the input frequency.

◄ FIGURE 2-45

Positive clamper operation.

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

FIGURE 2-46
Negative clamper.

PRE-LAB

OBJECTIVE

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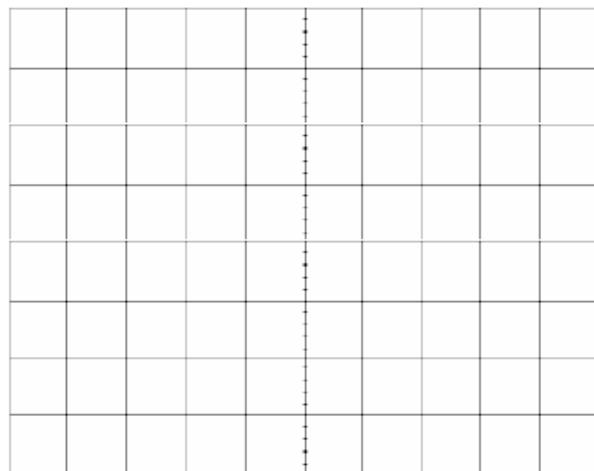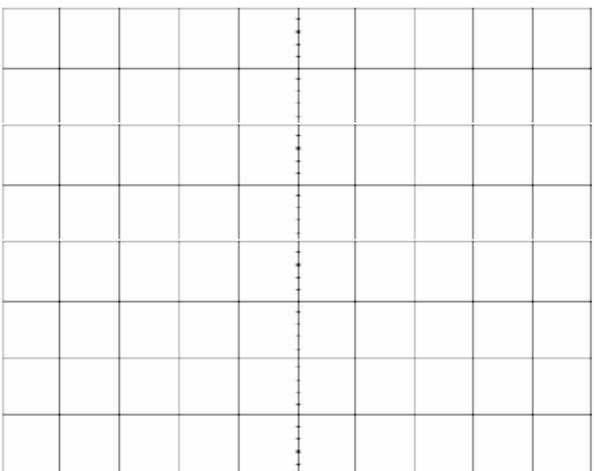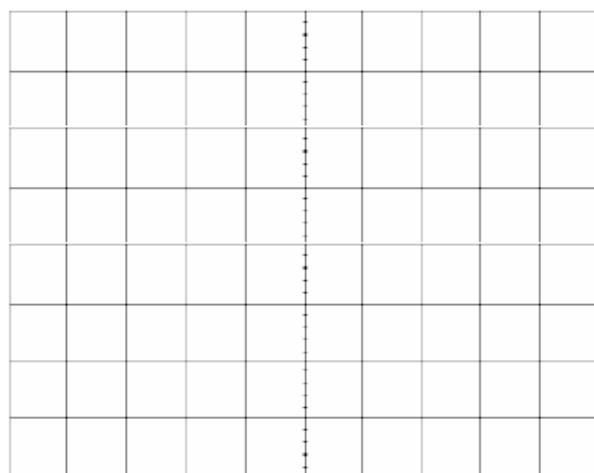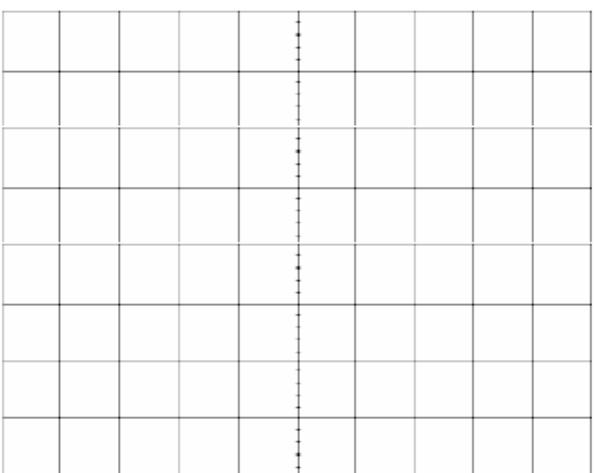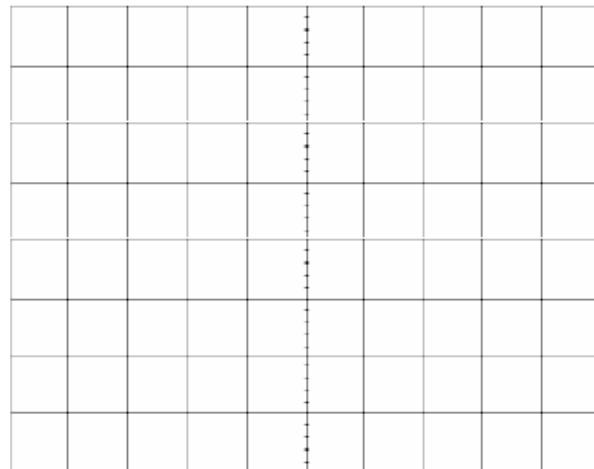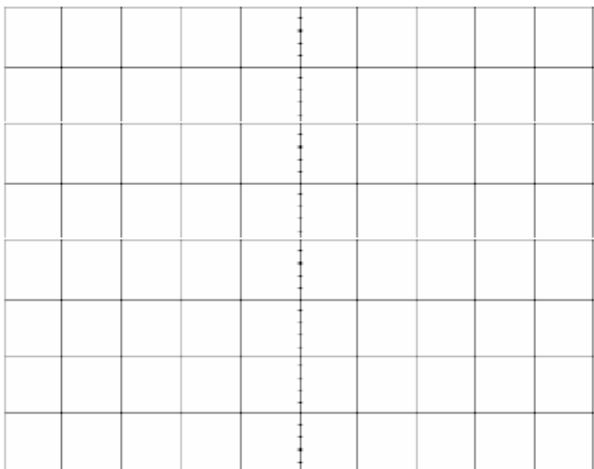
LABORATORY PROCEDURE

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.

11.6 OBSERVATIONS
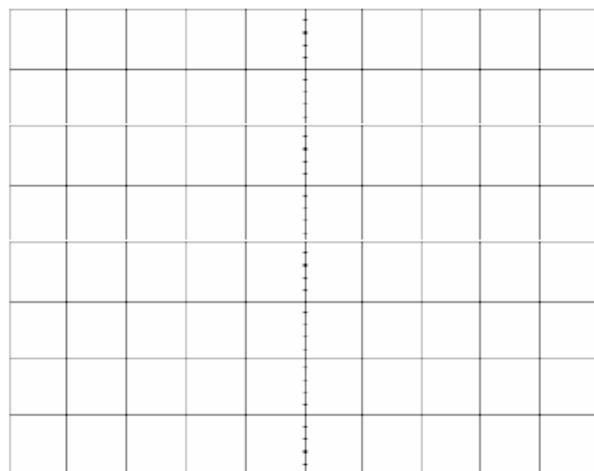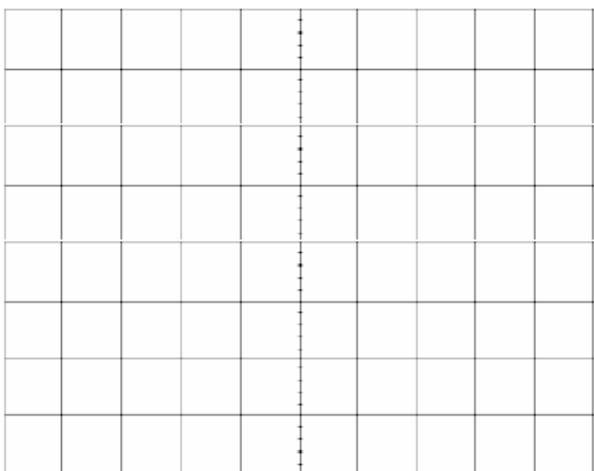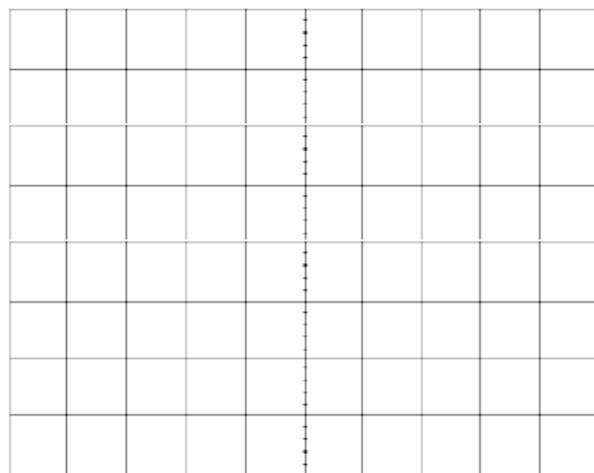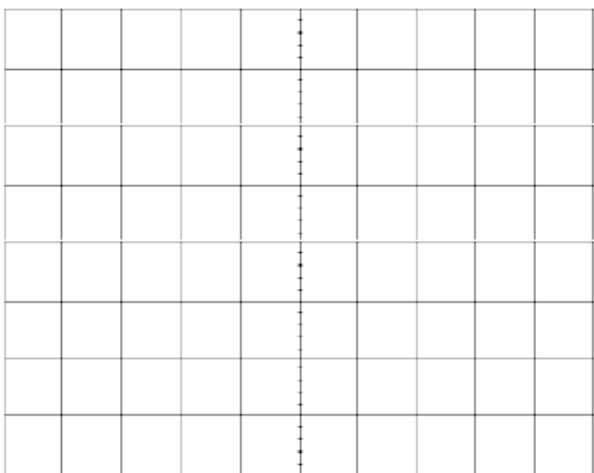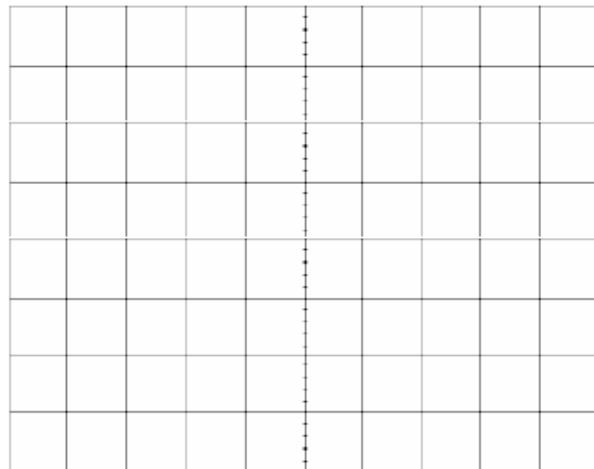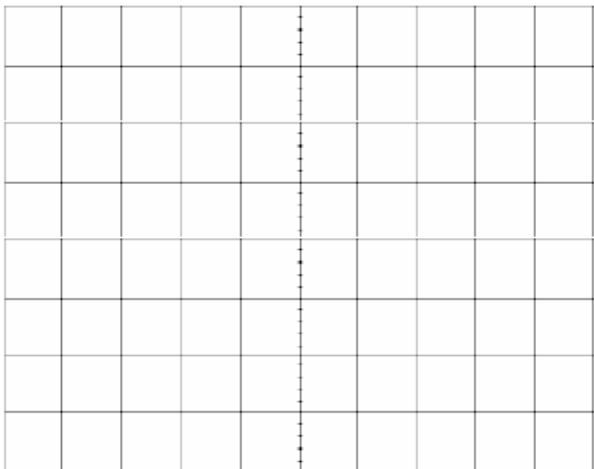
1- SCALES: Vertical _____ V/Div, Horizontal _____ s/Div

2- SCALES: Vertical _____ V/Div, Horizontal _____ s/Div

3- SCALES: Vertical _____ V/Div, Horizontal _____ s/Div

4- SCALES: Vertical _____ V/Div, Horizontal _____ s/Div

5- SCALES: Vertical _____ V/Div, Horizontal _____ s/Div

6- SCALES: Vertical _____ V/Div, Horizontal _____ s/Div

POST LAB

4.10   TASK TO BE SUBMITTED

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

2- The oscilloscope can also be used to directly display the voltage transfer characteristics (VTC) of this circuit. Simply reconfigure the oscilloscope to display Ch-1 versus Ch-2 in an X-Y mode. Ground the inputs to both channels by setting the coupling switches to GND, and then switch the oscilloscope into the X-Y mode. (On Tektronix oscilloscopes, all you need to do is push the X-Y button in; on Hewlett-Packard oscilloscopes, you will need to access the X-Y mode through the MATH function menu.) Use the position controls to move the dot onto the cross-hairs in the exact center of the screen. Change the input coupling on each of the two channels back to DC and the display should now show the VTC. Sketch the VTC shown on the oscilloscope screen on next page of workbook.

3- Write the application of Clampers in electronics circuits.

Comment	Cascading voltage clamper circuits one after the other produces a very common circuit that can be used to multiply DC voltages. These circuits find extensive use in high-voltage and switch-mode power supplies.
Set-Up	Disconnect the Ch-2 oscilloscope probe from the breadboarded circuit of Procedure 7 and then remove resistor R1. The laboratory transformer inputs and the Ch-1 oscilloscope probe do not need to be moved.

Add additional diodes and capacitors to the breadboard to produce the circuit shown in Fig. E2.8 below. Be very careful to install each diode and each capacitor in the correct polarity. The parts used in this circuit are:

  D1, D2, D3, D4 = 1N4007
  C1, C2, C3, C4 = 10 µF 25 V electrolytic
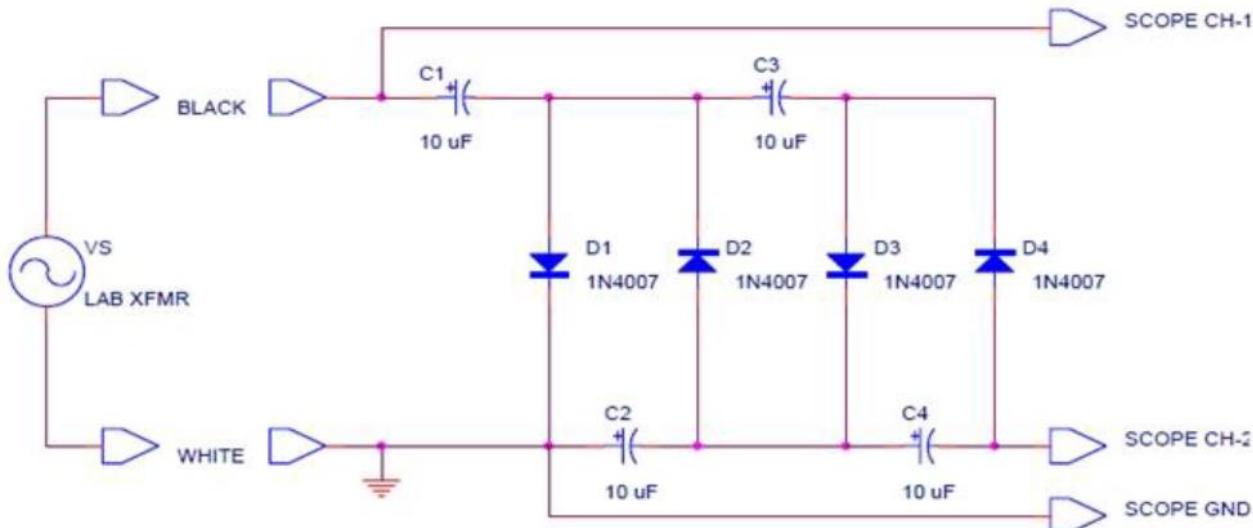
Figure E2.8

Measurement-8	Adjust the vertical position of both oscilloscope channels so that the zero voltage level is aligned to the center cross hair on the screen. Draw a schematic of the multiplier circuit in your notebook, and then place a little sketch of the voltage waveform existing at each end of each diode (8 nodes total) beside each of the nodes in your schematic. Use the Ch-2 oscilloscope probe to sample each of these waveforms. Measure the DC output voltage that appears at the node between D4 and C4, as shown in Fig. E2.8. This is the actual output terminal of the multiplier. Use the bench DMM to measure the voltage existing across each capacitor and record these values and their polarities on the schematic in your notebook.

Lab Session 11

OBJECTIVE

To study the operation of Voltage Doubler.

11.1 INTRODUCTION

Voltage multipliers rectify low voltage AC to high voltage DC (pulsed). It is a specialized rectifier circuit producing an output which is theoretically an integer times the AC peak input, for example, 2, 3, or 4 times the AC peak input. Thus, it is possible to get 200 VDC from a 100 V peak AC source using a doubler, 400 VDC from a quadrupler and so on. Although it is usual to use a transformer to increase the voltage, sometimes a suitable step-up transformer or a specially insulated transformer required for high voltage applications may not be available. An alternative approach is to use a voltage multiplier circuit.

11.1.1 Voltage Doubler

The Voltage Doubler circuit shown in Fig. 11.1 (a) consists of only two diodes, two capacitors and an ac input voltage. This simple gives a DC output voltage equal to the peak-to-peak value of the input. In other words, double the peak voltage value.

The half-wave voltage doubler in Figure 11.1 (a) shown below is composed of two circuits: a clamper at (b) and a peak detector (half-wave rectifier), shown in modified form in Figure 11.1 (c). C2 has been added to a peak detector (half-wave rectifier).
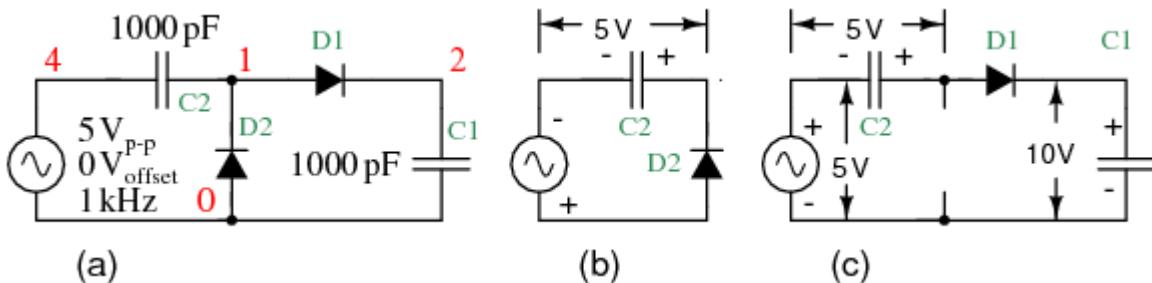
Figure 11.1

Referring to Figure above (b), C2 charges to 5 V (4.3 V considering the diode drop) on the negative half cycle of AC input. The right end is grounded by the conducting D2. The left end is charged at the negative peak of the AC input. This is the operation of the clamper.

During the positive half cycle, the half-wave rectifier comes into play at Figure above (c). Diode D2 is out of the circuit since it is reverse biased. C2 is now in series with the voltage source. Note the polarities of the generator and C2, series aiding. Thus, rectifier D1 sees a total of 10 V at the peak of the sinewave, 5 V from generator and 5 V from C2. D1 conducts waveform v(1) (Figure below), charging C1

to the peak of the sine wave riding on 5 V DC (Figure below v(2)). Waveform v(2) is the output of the doubler, which stabilizes at 10 V (8.6 V with diode drops) after a few cycles of sinewave input.

PRE-LAB

OBJECTIVE

To construct a Half Wave Voltage Doubler on a bread-board

11.2 EQUIPMENT REQUIRED

1- Bread-board
2- Two silicon diodes (1N4001)
3- Two capacitors (1000 pF)
4- Jumpers (If required)

11.3 PROCEDURE

1- Test the diode using diode tester in multimeter.
2- Make the circuit shown in fig 11.1on bread-board.
3- Test the continuity of all connections.

LABORATORY PROCEDURE

OBJECTIVE

To apply a Sine wave input to the Voltage Doubler circuit & observe the output waveform & parameters.

11.4 EQUIPMENT REQUIRED
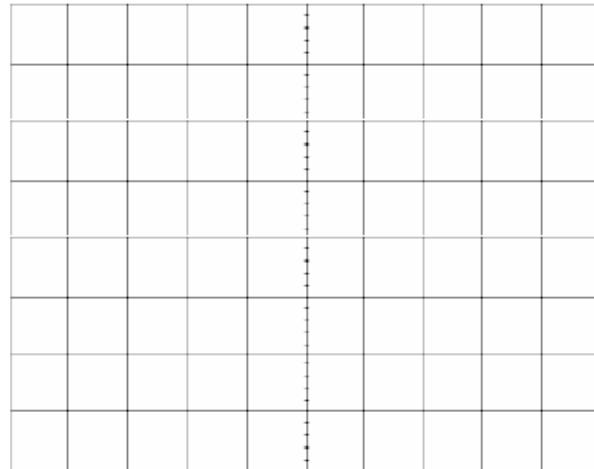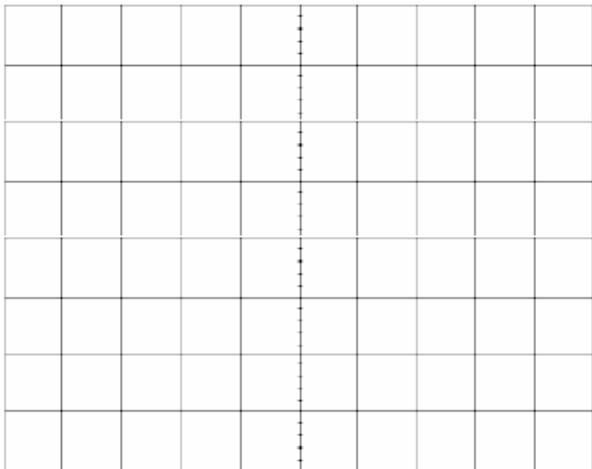
1- Function Generator
2- Oscilloscope
3- Circuit constructed in PRE-LAB

11.5 PROCEDURE

4- Set the function generator to 1KHz, 5Vpk-pk sine wave using oscilloscope.
5- Now apply the input to the circuit & observe the output using oscilloscope.

11.6 OBSERVATIONS

Draw the Output wave forms appearing at node 1 and 2.

POST LAB

4.10   TASK TO BE SUBMITTED

1- Make the same circuit on Multisim & attach the print out of observed outputs.
2- Make the circuit of a full-wave voltage doubler on Multisim & attach the print out of observed outputs.
3- What is the difference between a full-wave and a half wave voltage doubler. Which is better in your opinion?

Lab Session 12

OBJECTIVE

To study the characteristic curve of Zener Diode & find the Zener Voltage Vz.

14.1 INTRODUCTION

ZENER DIODES
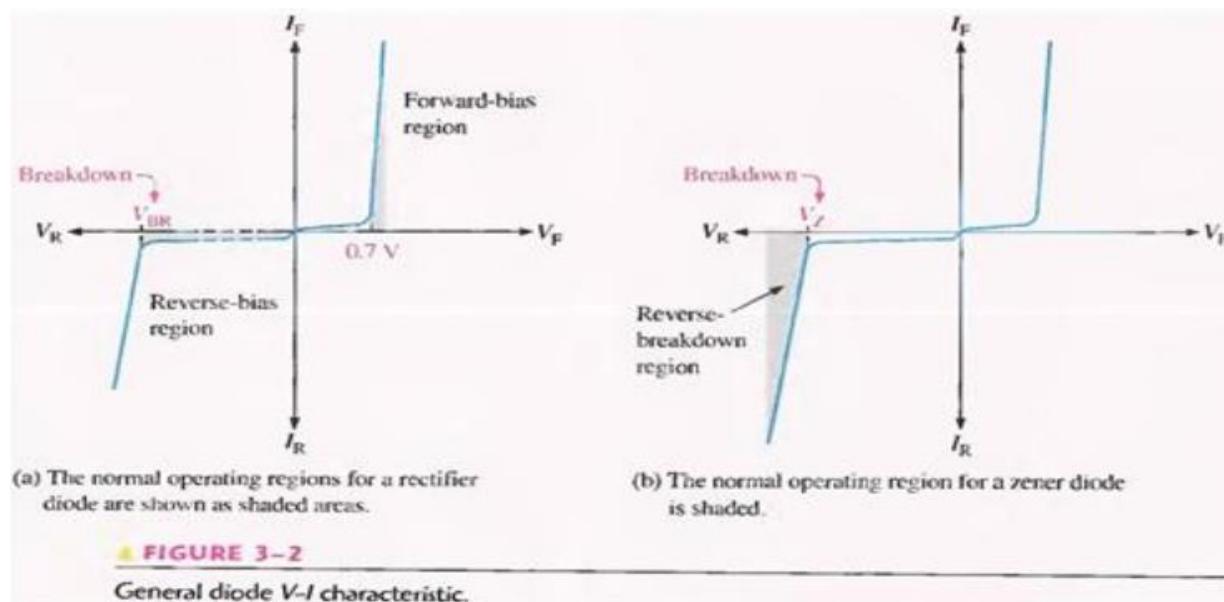
FIGURE 3-1
Zener diode symbol.

A major application for zener diode is as a type of voltage regulator for providing stable reference voltages for use in power supplies, voltmeters and other instruments. In this section, you will see how the zener diode maintains a nearly constant dc voltage under the proper operating conditions. You will learn the conditions and limitations for properly using the zener diode and the factors that affect its performance.
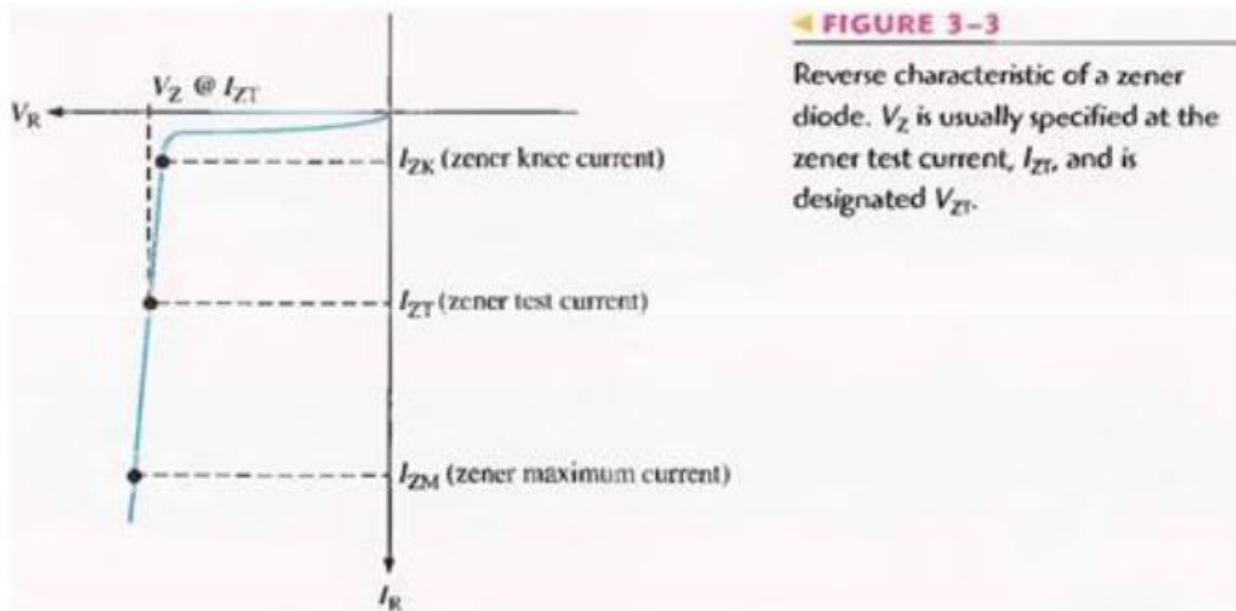
The symbol for a zener diode is shown in Figure 3-1. A zener diode is a silicon pn junction device that is designed for operation in the reversebreakdown region. The breakdown voltage of a zener diode is set by carefully controlling the doping level during manufacture.

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

(a) The normal operating regions for a rectifier diode are shown as shaded areas.

(b) The normal operating region for a zener diode is shaded.

FIGURE 3-2
General diode V-I characteristic.

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 (Vz), 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 (VR) is increased, the reverse Current (IR) remains extremely small up to the "knee" of the curve. The reverse current is also called the zener current, Iz. At this point, the breakdown effect begins: the internal zener resistance, also called zener impedance (Zz), begins to decrease as the reverse current increases rapidly. From the bottom of the knee, the zener breakdown voltage (Vz) remains essentially constant although it increases slightly as the zener current, Iz, increase.

◄ FIGURE 3-3

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

Zener Regulation The ability to keep the reverse voltage across its terminals essentially constant is the key feature of the zener diode. A zener diode operating in breakdown acts as a voltage regulator because it maintains a nearly constant voltage across its terminals over a specified range of reverse-current values. A minimum value of reverse current, IZK 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, IZM 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 IZK.

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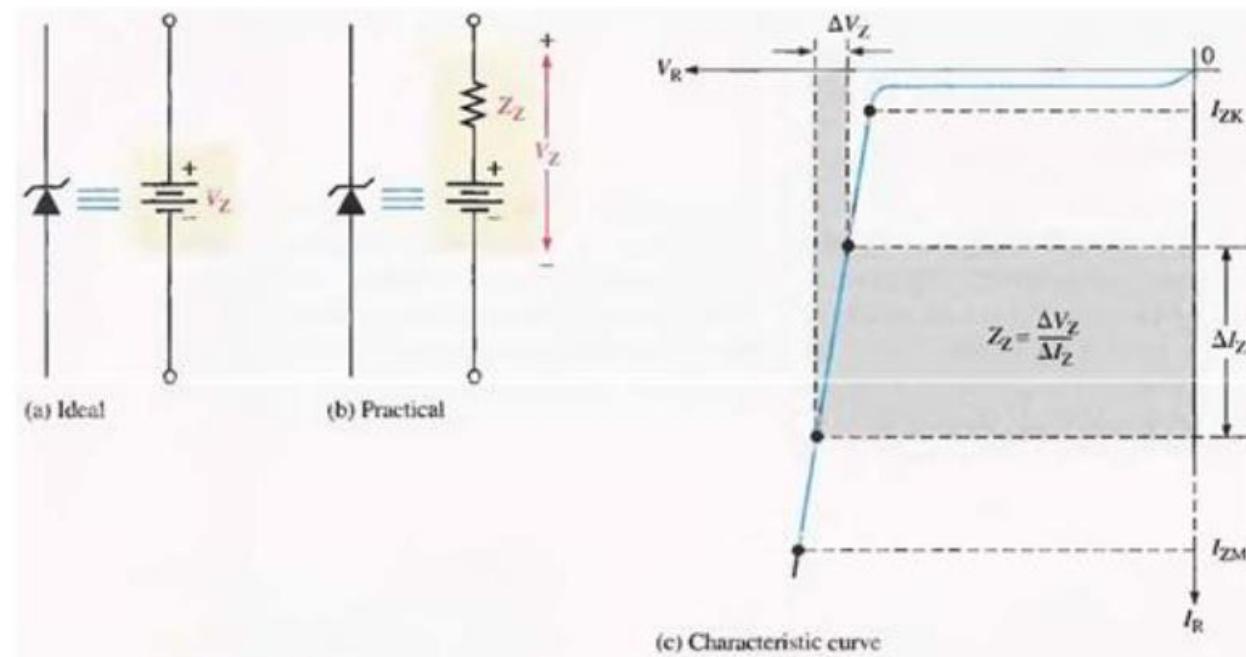
▲ FIGURE 3-4

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

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

Equation 3-1 $$Z_z = \frac{\Delta V_z}{\Delta I_z}$$

Normally, Zz is specified at IZT, the zener test current, and is designated ZZT. In most cases, you can assume that Zz is constant over the full linear range of zener current values and is purely resistive.

Temperature Coefficient

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

Equation 3–2 $$\Delta V_z = V_z \times TC \times \Delta T$$

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

Equation 3–3 $$\Delta V_z = TC \times \Delta T$$

PRE-LAB

OBJECTIVE
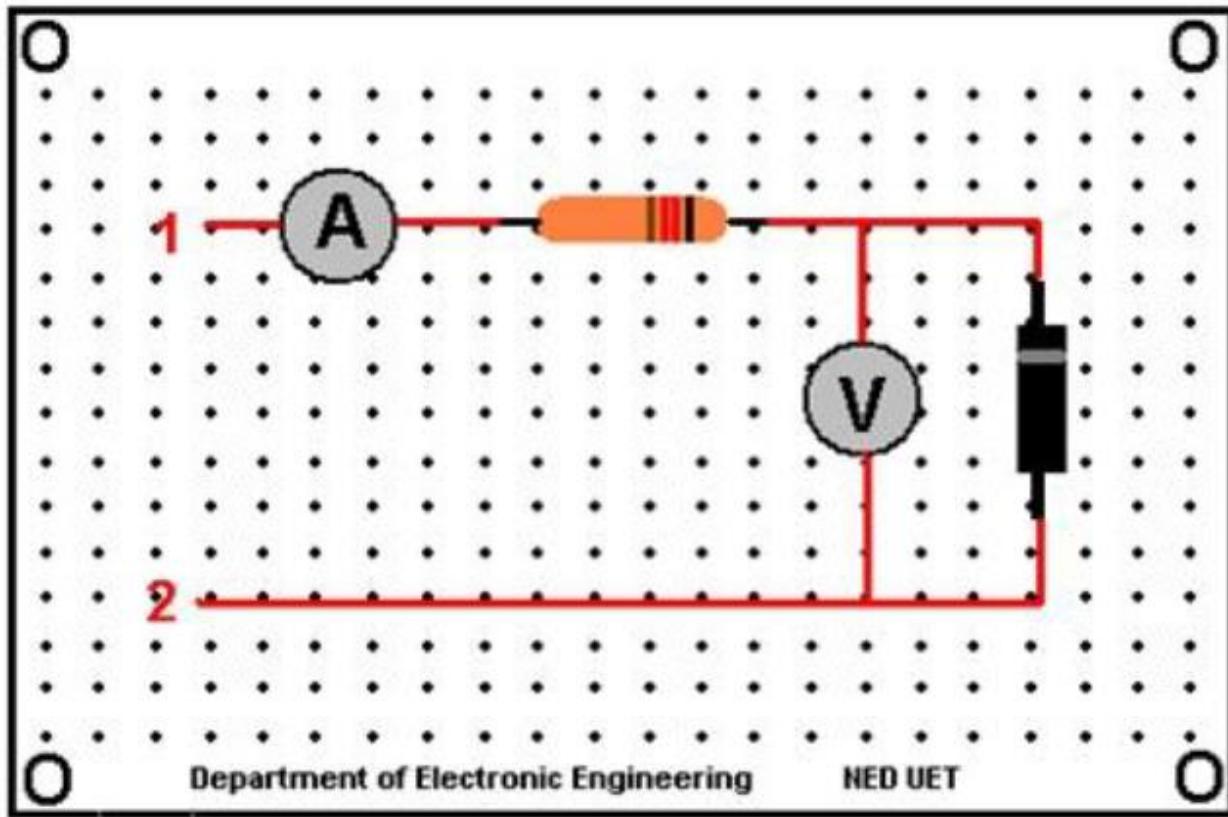
Construct the following circuit & Test for continuity.

REQUIRED COMPONENTS

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

PROCEDURE

Solder the circuit as shown.

Department of Electronic Engineering   NED UET

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.
2. Find the voltage regulation of your circuit. (Hint Voltage regulation = (No load Voltage - Full
3. load voltage)/No load voltage x 100)

Lab Session 13

PRE-LAB

OBJECTIVE:

To identify the type of transistor (NPN & PNP) & find its mode of operation on different values of Vcc by calculating its base, collector & emitter voltage & currents.

INTRODUCTION:

The BJT (bipolar junction transistor) is constructed with three doped semiconductor regions separated by two pn junctions, as shown in the epitaxial planar structure in Figure 4-1(a). The three regions are called emitter, base, and collector. Physical representations of the two types of BJTs are shown in Figure 4-l(b) and (c). One type consists of two n regions separated by a p region (npn), and the other type consists of two p regions separated by an n region (pnp). The pn junction joining the base region and the emitter region is called the base-emitter junction. The pn junction joining the base region and the collector region is called the base-collector junction, as indicated in Figure 4-1(b). A wire lead connects to each of the three regions, as shown. These leads are labeled E, B. and C for emitter, base, and collector, respectively. The base region is lightly doped and very thin compared to the heavily doped emitter and the moderately doped collector regions. (The reason for this is discussed in the next section.)

(a) Basic epitaxial planar structure   (b) npn   (c) pnp

▲ FIGURE 4-1

Basic BJT construction.
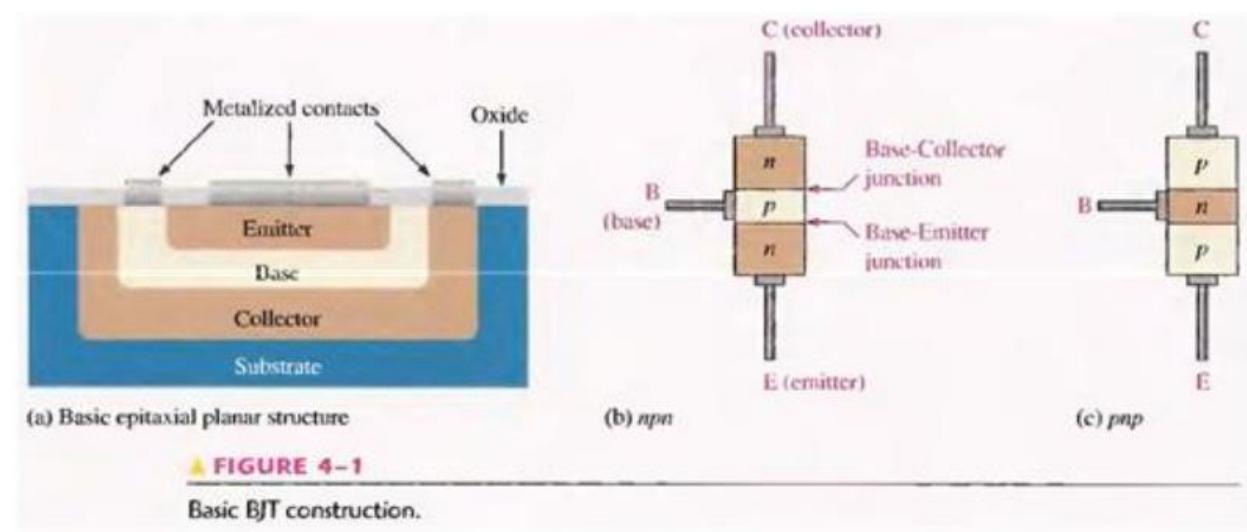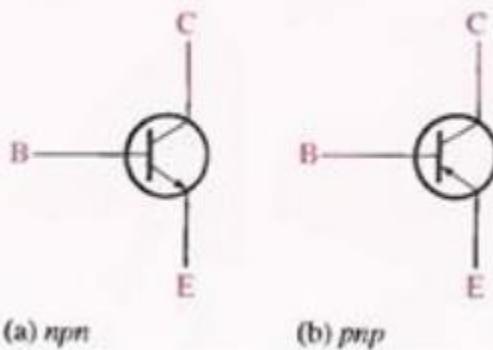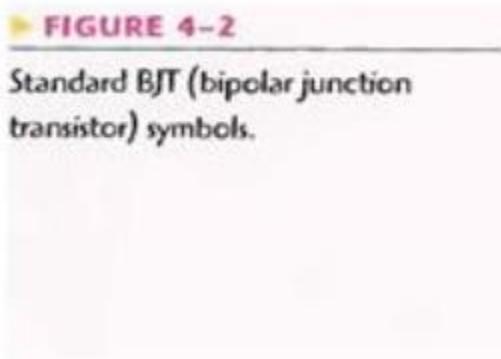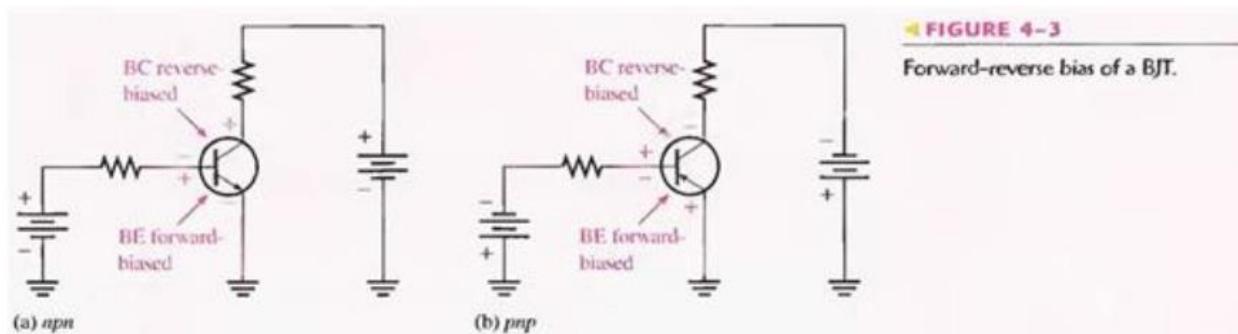
Figure 4-2 shows the schematic symbols for the npn and pnp bipolar junction transistors. The term bipolar refers to the use of both holes and electrons as carriers in the transistor structure.

▶ FIGURE 4-2

Standard BJT (bipolar junction transistor) symbols.

(a) *npn*   (b) *pnp*

BASIC TRANSISTOR OPERATION

In order for the transistor to operate properly as an amplifier, the two pn junctions must be correctly biased with external dc voltages. In this section, we use the npn transistor for illustration. The operation of the pnp is the same as for the npn except that the roles of the electrons and holes, the bias voltage polarities, and the current directions are all reversed. Figure 4-3 shows the proper bias arrangement for both npn and pnp transistors for active operation as an amplifier. Notice that in both cases the base-emitter (BE) junction is forward biased and the base-collector (BC) junction is reverse-biased.

◀ FIGURE 4-3

Forward–reverse bias of a BJT.

(a) *npn*   (b) *pnp*

To illustrate transistor action, let's examine what happens inside the npn transistor. The forward bias from base to emitter narrows the BE depletion region, and the reverse bias from base to collector widens the BC depletion region, as depicted in Figure 4-4. The heavily doped n-type emitter region is teeming with conduction-band (free) electrons that easily diffuse through the forward-biased BE junction into the p-type base region where they become minority carriers, just as in a forward-biased diode. The base region is lightly doped and very thin so that it has a limited number of holes. Thus, only a small percentage of all the electrons flowing through the BE junction can combine with the available holes in the base. These relatively few recombined

electrons flow out of the base lead as valence electrons, forming the small base electron current, as shown in Figure 4-4.
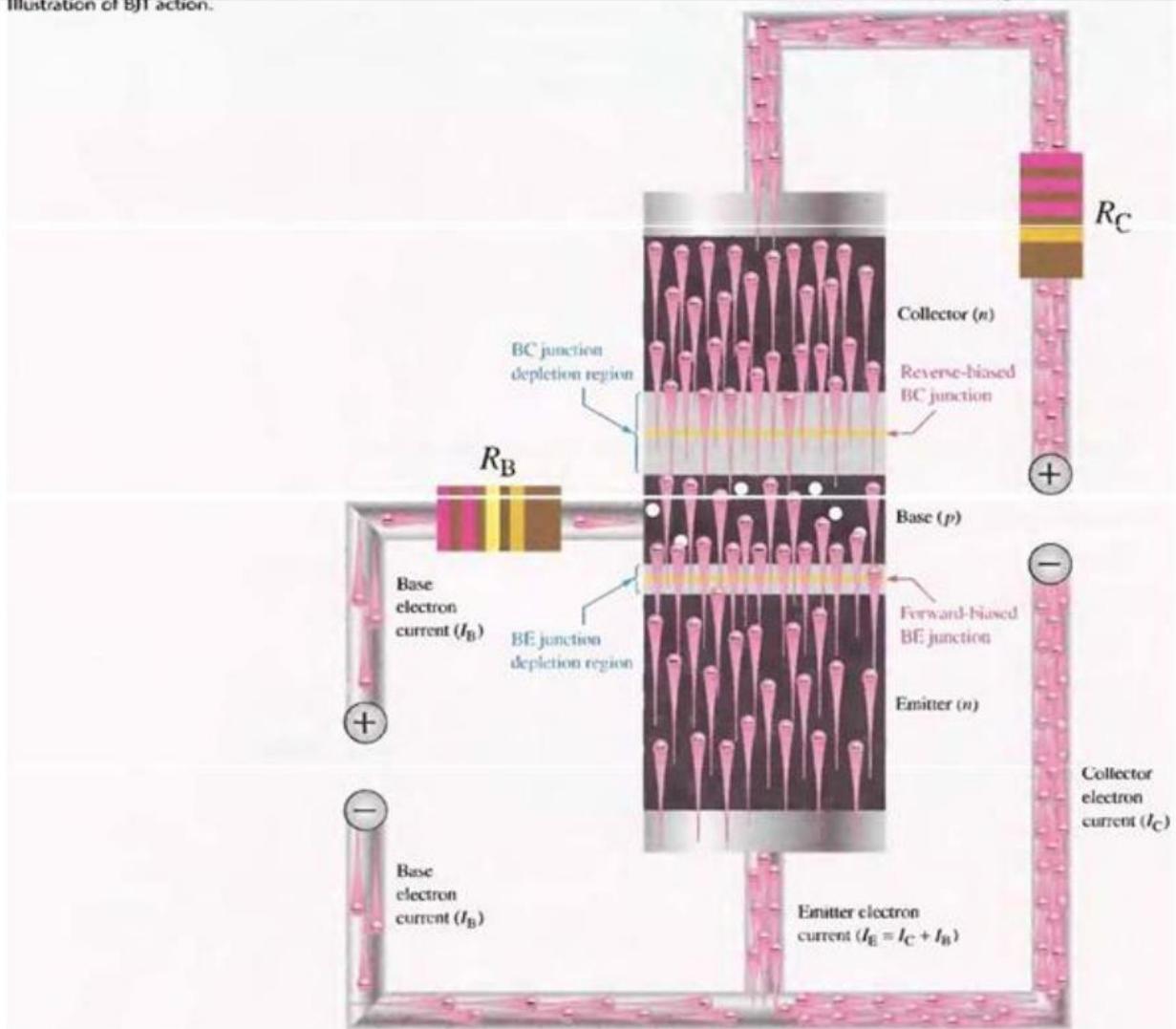
Fig. 4-4

Most of the electrons flowing from the emitter into the thin, lightly doped base region do not recombine but diffuse into the BC depletion region. Once in this region they are pulled through the reverse-biased BC junction by the electric field set up by the force of attraction between the positive and negative ions. Actually, you can think of the electrons as being pulled across the reverse-biased BC junction by the attraction of the collector supply voltage. The electrons now move through the collector region, out through the collector lead, and into the positive terminal of the collector voltage source. This forms the collector electron current, as shown in Figure 4-4. The collector current is much larger than the base current. This is the reason transistors exhibit current gain.

Transistor Currents

The directions of the currents in an npn transistor and its schematic symbol are as shown in Figure 4-5(a); those for a pnp transistor are shown in Figure 4-5(b). Notice that the arrow on the emitter of the transistor symbols points in the direction of conventional current.
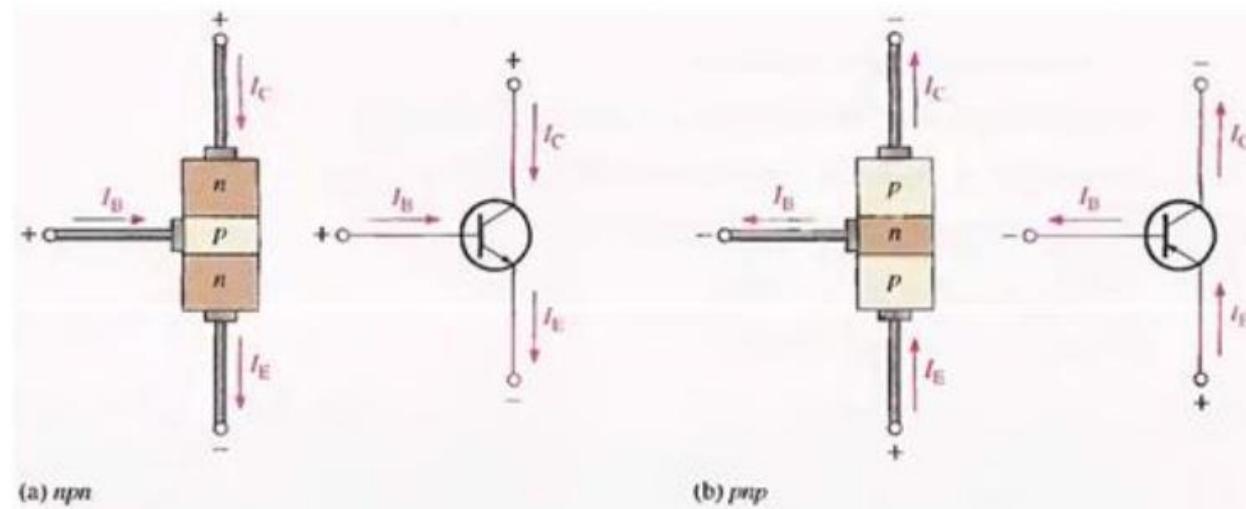
▲ FIGURE 4–5

Transistor currents.

These diagrams show that the emitter current (I_E) is the sum of the collector current (I_C) and the base current (I_B), expressed as follows:

$$I_E = I_C + I_B$$

Equation 4–1

As mentioned before, I_B is very small compared to I_E or I_C. The capital-letter subscripts indicate dc values.

TRANSISTOR CHARACTERISTICS AND PARAMETERS

Two important parameters, β_{DC} (dc current gain) and α_{DC} are introduced and used to analyze a transistor circuit. Also, transistor characteristic curves are covered, and you will learn how a transistor's operation can be determined from these curves. Finally, maximum ratings of a transistor are discussed.

As discussed in the last section, when a transistor is connected to dc bias voltages, as shown in Figure 4-6 for both npn and pnp types. V_{BB} forward-biases the base-emitter junction and V_{CC} reverse-biases the base-collector junction. Although in this chapter we are using battery symbols to represent the bias voltages, in practice the voltages are often derived from a dc power supply. For example, V_{CC} is normally taken directly from the power supply output and V_{BB} (which is smaller) can be produced with a voltage divider.

DC Beta (βDC) and DC Alpha (αDC)

The ratio of the dc collector current (Ic) to the dc base current (IB) is the dc beta (βDC), which is the dc current gain of a transistor.

Equation 4–2 $$\beta_{DC} = \frac{I_C}{I_B}$$

Typical values of βDC range from less than 20 to 200 or higher. βDC is usually designated as an equivalent hybrid (h) parameter, hFE, on transistor data sheets.

$$h_{FE} = \beta_{DC}$$

The ratio of the dc collector current (Ic) to the dc emitter current (IE) is the dc alpha (αDC). The alpha is a less-used parameter than beta in transistor circuits.

$$\alpha_{DC} = \frac{I_C}{I_E}$$

Typically, values of αDC range from 0.95 to 0.99 or greater, but αDC is always less than 1. The reason is that Ic is always slightly less than IE by the amount of IB. For example, if IE = 100 mA and IB = 1 mA, then Ic = 99 mA and αDC = 0.99,

Current and Voltage Analysis

Consider the basic transistor bias circuit configuration in Figure 4-7. Three transistor dc currents and three dc voltages can be identified.

IB: dc base current
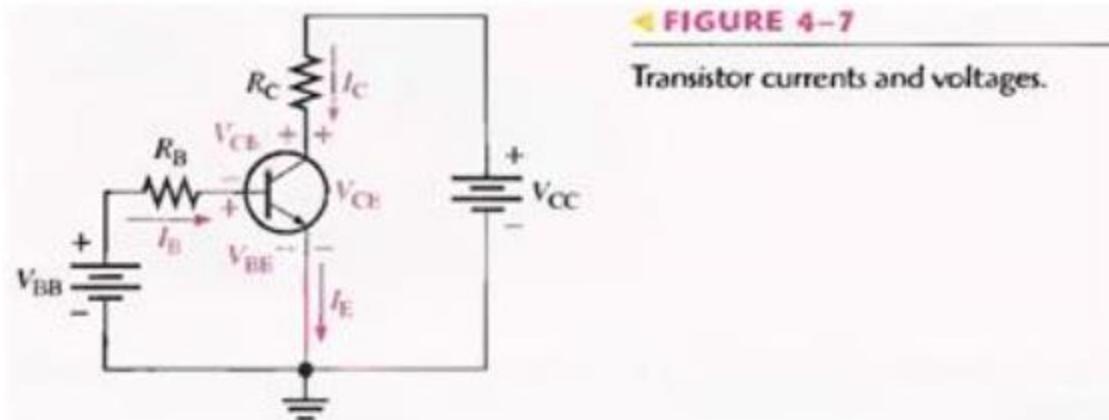
IE: dc emitter current

IC: dc collector current

VBE: dc voltage at base with respect to emitter

VCB: dc voltage at collector with respect to base

VCE: dc voltage at collector with respect to emitter

◄ FIGURE 4–7

Transistor currents and voltages.

VBB forward-biases the base-emitter junction and VCC reverse-biases the base-collector junction. When the base-emitter junction is forward-biased, it is like a forward-biased diode and has a nominal forward voltage drop of

$$V_{BE} \cong 0.7 \text{ V}$$ **Equation 4–3**

Although in an actual transistor VBE can be as high as 0.9 V and is dependent on current, we will use 0.7 V throughout this text in order to simplify the analysis of the basic concepts. Since the emitter is at ground (0 V), by Kirchhoff's voltage law, the voltage across RB is

$$V_{R_B} = V_{BB} - V_{BE}$$

Also, by Ohm's law,

$$V_{R_B} = I_B R_B$$

Substituting for V_{R_B} yields

$$I_B R_B = V_{BB} - V_{BE}$$

Solving for I_B,

Equation 4–4
$$I_B = \frac{V_{BB} - V_{BE}}{R_B}$$

The voltage at the collector with respect to the grounded emitter is

$$V_{CE} = V_{CC} - V_{R_C}$$

Since the drop across R_C is

$$V_{R_C} = I_C R_C$$

the voltage at the collector can be written as

Equation 4–5
$$V_{CE} = V_{CC} - I_C R_C$$

where $I_C = \beta_{DC} I_B$.

The voltage across the reverse-biased collector-base junction is

Equation 4–6
$$V_{CB} = V_{CE} - V_{BE}$$

Collector Characteristic Curves

Using a circuit like that shown in Figure 4-9(a), you can generate a set of collector characteristic curves that show how the collector current, Ic varies with the collector-to-emitter voltage, VCE for specified values of base current, IB. Notice in the circuit diagram that both VBB and Vcc are variable sources of voltage.

Assume that VBB is set to produce a certain value of IB and Vcc is zero. For this condition, both the base-emitter junction and the base-collector junction are forward-biased

(a) Circuit

(b) I_C versus V_{CE} curve for one value of I_B

(c) Family of I_C versus V_{CE} curves for several values of I_B ($I_{B1} < I_{B2} < I_{B3}$ etc.)
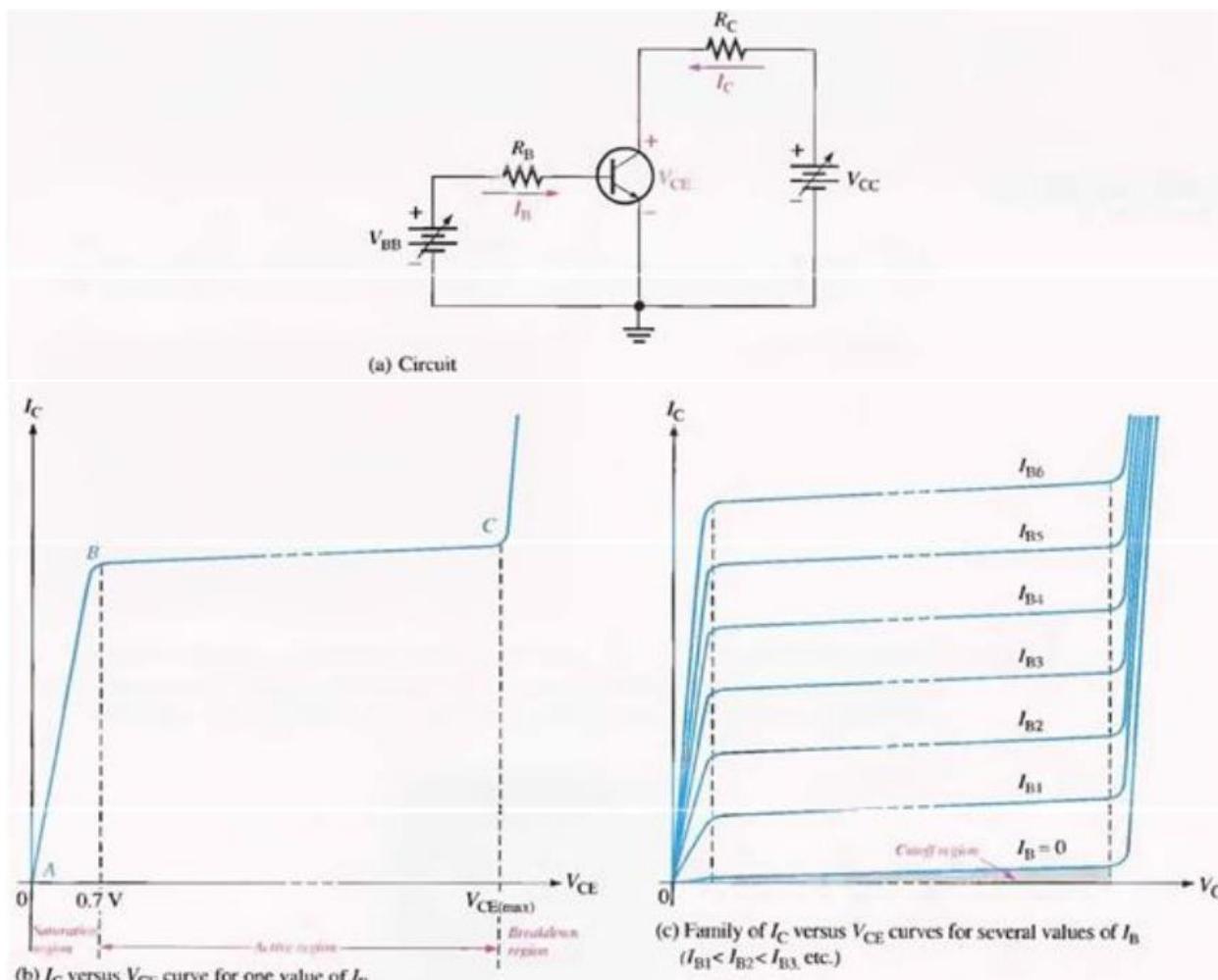
FIGURE 4-9

Collector characteristic curves.

This is because the base is at approximately 0.7 V while the emitter and the collector are at 0 V. The base current is through the base-emitter junction because of the low impedance path to ground and, therefore, Ic is zero. When both junctions are forward-biased, the transistor is in the saturation region of its operation. As Vcc is increased, V_{CE} increases gradually as the collector current increases. This is indicated by the portion of the characteristic curve between points A and B in Figure 4-9(b). Ic increases as Vcc is increased because V_{CE} remains less than 0.7 V due to the forward- biased base-collector junction. Ideally, when V_{CE} exceeds 0.7 V, the basecollector junction becomes reverse-biased and the transistor goes into the active or linear region of its operation. Once the base-collector junction is reverse-biased, Ic levels off and remains essentially constant for a given value of I_B as V_{CE} continues to increase. Actually, Ic increases very slightly as V_{CE} increases due to widening of the base-collector depletion region. This results in fewer holes for recombination in the base region which effectively causes a slight increase in β_{DC}. This is shown by the portion of the characteristic curve between points B and C in Figure 4- 9(b).

For this portion of the characteristic curve, the value of Ic is determined only by the relationship expressed as Ic = β_{DC} I$_B$. When V$_{CE}$ reaches a sufficiently high voltage, the reverse-biased base-collector junction goes into breakdown; and the collector current increases rapidly as indicated by the part of the curve to the right of point C in Figure 4-9(b). A transistor should never be operated in this breakdown region. A family of collector characteristic curves is produced when Ic versus V$_{CE}$ is plotted for several values of I$_B$, as illustrated in Figure4-9(c). When I$_B$ = 0, the transistor is in the cutoff region although there is a very small collector leakage current as indicated. The amount of collector leakage current for I$_B$ = 0 is exaggerated on the graph for illustration.

Cutoff

As previously mentioned, when I$_B$ = 0, the transistor is in the cutoff region of its operation. This is shown in Figure 4-12 with the base lead open, resulting in a base current of zero. Under this condition, there is a very small amount of collector leakage current, I$_{CEO}$, due mainly to thermally produced carriers. Because I$_{CEO}$ is extremely small, it will usually be neglected in circuit analysis so that V$_{CE}$ = Vcc. In cutoff, both the base-emitter and the base-collector junctions are reverse-biased.
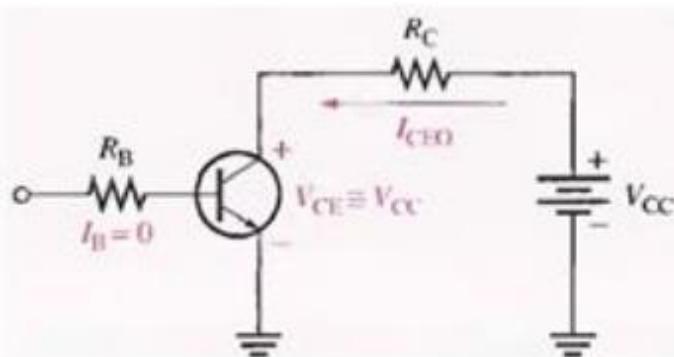
◄ FIGURE 4-12
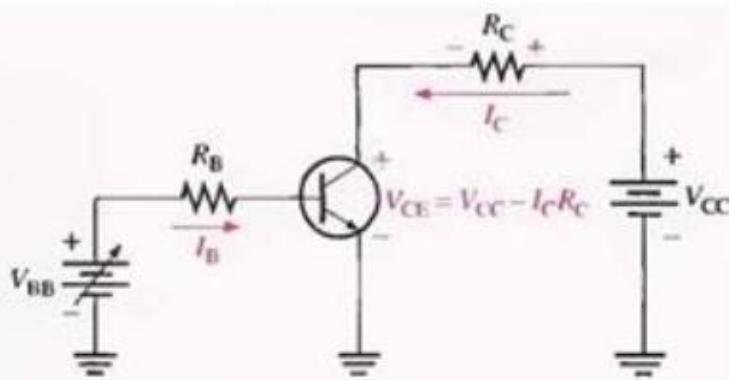
Cutoff: Collector leakage current (I_{CEO}) is extremely small and is usually neglected. Base-emitter and base-collector junctions are reverse-biased.

Saturation

When the base-emitter junction becomes forward-biased and the base current is increased, the collector current also increases (Ic = β_{DC}I$_B$) and V$_{CE}$ decreases as a result of more drop across the collector resistor (V$_{CE}$ = V cc - IcRc). This is illustrated in Figure 4-13. When V$_{CE}$ reaches its saturation value, V$_{CEsat}$, the base-collector junction becomes forward-biased and Ic can increase no further even with a continued increase in I$_B$. At the point of saturation, the relation Ic = β_{DC} I$_B$ is no longer valid. V$_{CE(sat)}$ for a transistor occurs somewhere below the knee of the collector curves, and it is usually only a few tenths of a volt for silicon transistors.

▶ **FIGURE 4–13**

Saturation: As I_B increases due to increasing V_{BB}, I_C also increases and V_{CE} decreases due to the increased voltage drop across R_C. When the transistor reaches saturation, I_C can increase no further regardless of further increase in I_B. Base-emitter and base-collector junctions are forward-biased.

$$V_{CE} = V_{CC} - I_C R_C$$
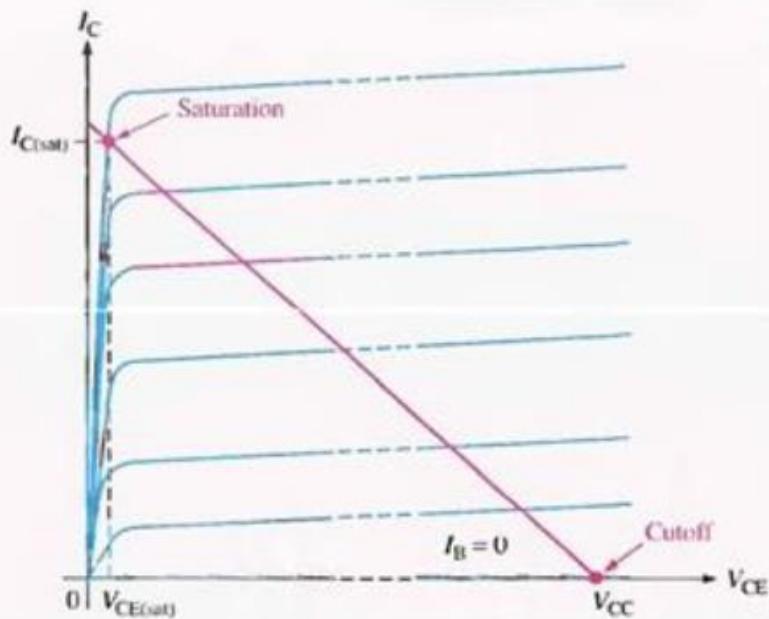
DC load line

Cutoff and saturation can be illustrated in relation to the collector characteristic curves by the use of a load line. Figure 4-14 shows a de load line drawn on a family of curves connecting the cutoff point and the saturation point. The bottom of the load line is at ideal cut-off where $I_C = 0$ and $V_{CE} = V_{CC}$. The top of the load line is at saturation where $I_C = I_{C(sat)}$ and $V_{CE} = V_{CE(sat)}$. In between cutoff and saturation along the load line is the active region of the transistor's operation.

▶ **FIGURE 4–14**
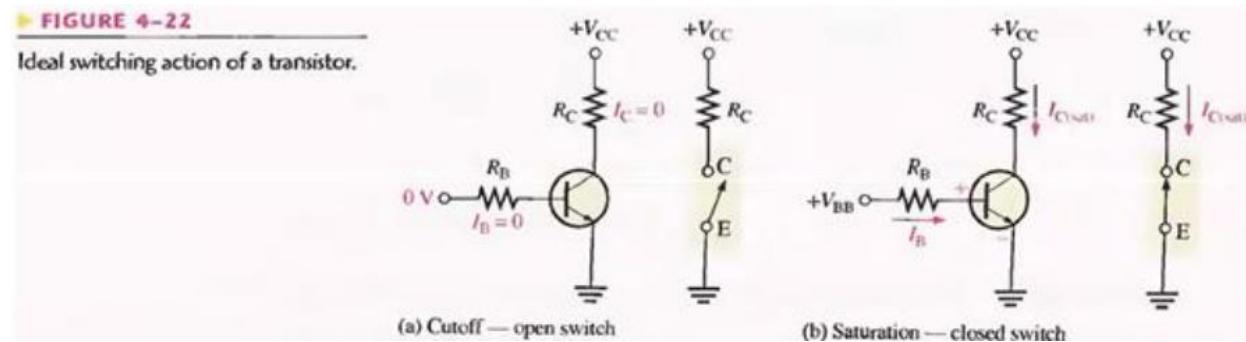
DC load line on a family of collector characteristic curves illustrating the cutoff and saturation conditions.

THE TRANSISTOR AS A SWITCH

In the previous section, you saw how the transistor can be used as a linear amplifier. The second major application area is switching applications. When used as an electronic switch, a transistor is normally operated alternately in cutoff and saturation Digital circuits make use of the switching characteristics of transistors.

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Figure 4-22 illustrates the basic operation of the transistor as a switching device. In part (a), the transistor is in the cutoff region because the base-emitter junction is not forward-biased. In this condition, there is, ideally, an open between collector and emitter, as indicated by the switch equivalent. In part (b), the transistor is in the saturation region because the base-emitter junction and the base-collector junction are forward-biased and the base current is made large enough to cause the collector current to reach its saturation value. In this condition, there is, ideally, a short between collector and emitter, as indicated by the switch equivalent. Actually, a voltage drop of up to a few tenths of a volt normally occurs, which is the saturation voltage. $V_{CE(SAT)}$.

▶ FIGURE 4-22
Ideal switching action of a transistor.

(a) Cutoff — open switch   (b) Saturation — closed switch

Conditions in Cutoff

As mentioned before, a transistor is in the cutoff region when the base-emitter junction is not forward-biased. Neglecting leakage current, all of the currents are zero, and V_{CE} is equal to V_{CC}.

$$V_{CE(cutoff)} = V_{CC}$$

Equation 4–9

Conditions in Saturation

As you have learned, when the base-emitter junction is forward-biased and there is enough base current to produce a maximum collector current, the transistor is saturated. The formula for collector saturation current is:

$$I_{C(sat)} = \frac{V_{CC} - V_{CE(sat)}}{R_C}$$

Equation 4–10

Since $V_{CE(SAT)}$ is very small compared to V_{CC}, it can usually be neglected. The minimum value of base current needed to produce saturation is

$$I_{B(min)} = \frac{I_{C(sat)}}{\beta_{DC}}$$

Equation 4–11
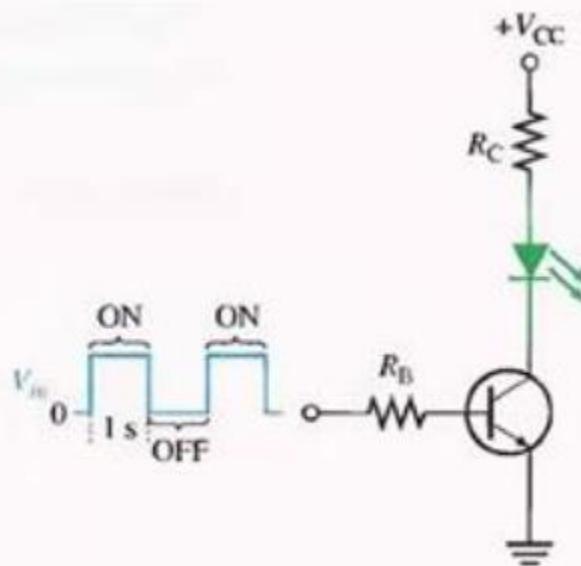
I_B should be significantly greater than $I_{B(min)}$ to keep the transistor well into saturation.

A Simple Application of a Transistor Switch

The transistor in Figure 4-24 is used as a switch to turn the LED on and off. For example, a square wave input voltage with a period of 2 s is applied to the input as indicated. When the square wave is at 0 V, the transistor is in cutoff; and since there is no collector current, the LED does not emit light. When the square wave goes to its high level, the transistor saturates. This forward-biases the LED, and the resulting collector current through the LED causes it to emit light. Thus, the LED is on for 1 s and off for 1 s.

► FIGURE 4-24

A transistor used to switch an LED on and off.

LABORATORY PROCEDURE

OBJECTIVE

To test the transistors, find there EBC pins using DMM & construct transistor biasing circuit & plot its I_C vs V_{CE} curve.

REQUIRED COMPONENTS

1- Breadboard (for testing) & Vero board (for implementation)
2- PNP & NPN transistors (2N222, 2N3904 etc)
3- Resistors
4- Variable voltage supplys

PROCEDURE

1- First check the transistors for there pin configuration.
2- Check the circuit of figure 4-13 on Multisim first & calculate the suitable values for all resistors, such that the circuit operates in saturation & cut-off mode for an input square waveform of 1V pk-pk (1Hz frequency)(i.e output is also a square wave of 1Hz frequency with magnitude equal or greater than 1V pk-pk).
3- Now check this same circuit with resistor values found from above simulation on bread board.
4- If the circuit is working fine then implement the same circuit on wire o board.
5- Plot the curve on graph paper.
6- Now from the graph, try to set a suitable value of Vcc such that the transistor is in middle of saturation region.
7- Note down all the values of current & voltages using digital multimeter. Find VC, VB, VE with respect to ground & IC, IE, IB (Hint : Voltmeter is always connected in parallel & ammeter connected in series).
8- Again from the graph, try to set a suitable value of Vcc such that the transistor is in middle of active region.
9- Note down all the values of current & voltages using digital multimeter. Find VC, VB, VE with respect to ground & IC, IE, IB.
10- To experience cut off region, just put VBB < 0.5 V find out all values of currents & voltages.
11- Place all the values of currents & voltages in following chart.
12- After observing all the values, prove the mode of operations using your own calculations.

OBSERVATIONS

Keeping VBB & RB constant:

I_C	V_{CE}

	Saturation	Active	Cutoff
IB			
IC			
IE			
VB			
VE			
VC			

CALCULATIONS

Cutoff Region:	Saturation Region:	Active Region:

POST LAB

1- Apply a square wave at the base of transistor & increase the frequency using function generator. Find the value of frequency at which the output waveform starts distorting.

Sketch the I_C-V_{CE} curve for different values of I_B (by changing R_B or V_{BB}). (Keeping V_{CC} & R_C constant)

I_C	V_{CE}

I_C	V_{CE}

Lab Session 14

OBJECTIVE

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

14.1 INTRODUCTION

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

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

1. Depletion Type

2. Enhancement

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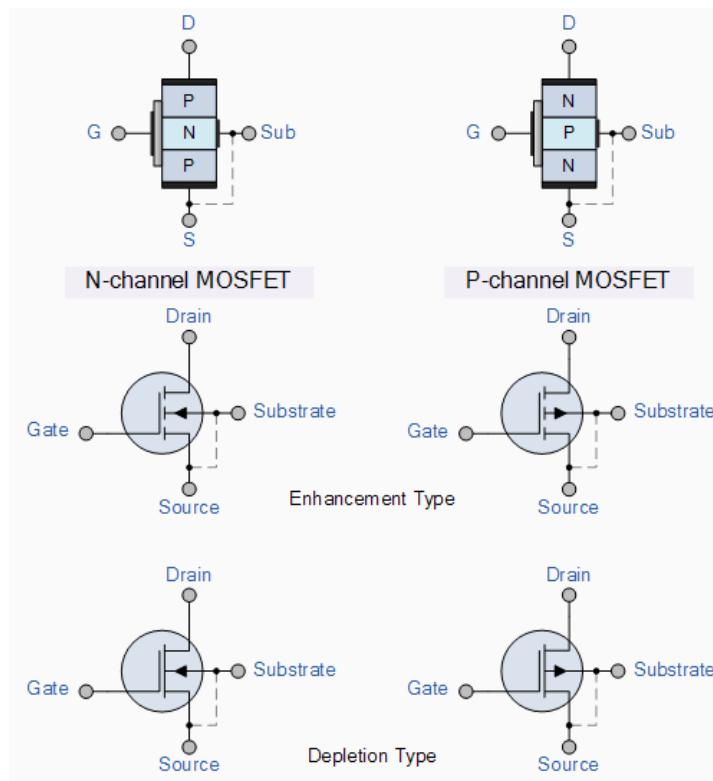

Fig. 14.1

14.1.1 Enhancement-mode N-Channel MOSFET (NMOS)

The physical structure of a n-Channel Enhancement-Type MOSFET (NMOS) is shown. The device is fabricated on a p-type substrate (or Body). Two heavily doped n-type regions (Source and Drain) are created in the substrate. A thin (fraction of micron) layer of SiO2, which is an excellent electrical insulator, is deposited between source and drain region. Metal is deposited on the insulator to form the Gate of the device (thus, metal-oxide semiconductor). Metal contacts are also made to the source, drain, and body region.
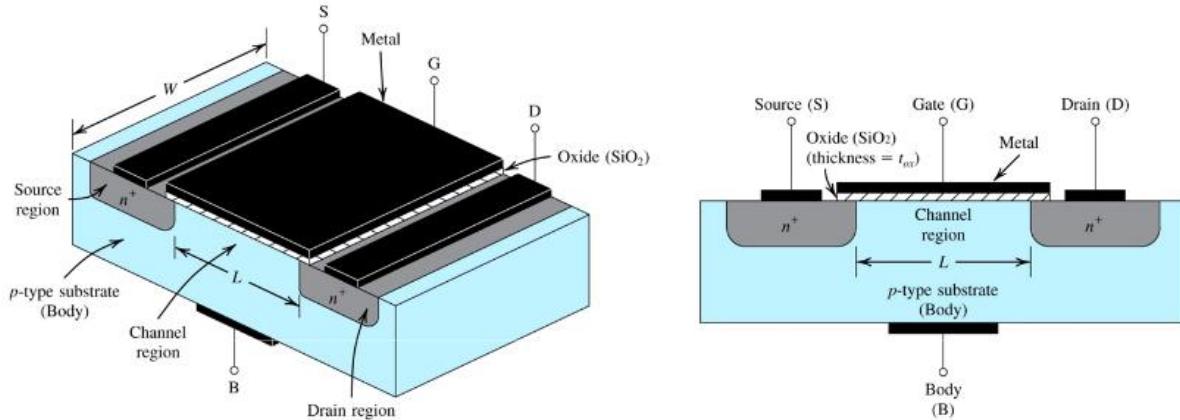

Fig. 14.2

14.1.2 Modes of operation

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

1. Cutoff - When $V_{GS} < V_{th}$, no channel is induced (no inversion layer is created), and so $I_D=0$. We call this mode Cutoff.

2. Triode - When an induced channel is present (i.e. $V_{GS} > V_{th}$,), but the value of V_{DS} is not large enough to pinch-off this channel (i.e. $V_{DS} < V_{GS}-V_{th}$), the NMOS is said to be in Triode mode.

3. Saturation - When an induced channel is present (i.e., $V_{DS} \geq V_{GS}-V_{th}$), and the value of V_{DS} is large enough to pinchoff this channel, the NMOS is said to be in Saturation mode.

PRE-LAB

OBJECTIVE

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

14.2 EQUIPMENT REQUIRED

1- Bread-board
2- NMOS transistor (2N7000)
3- Jumpers (If required)
4- Resistors (1kΩ, 100kΩ, 1MΩ)

14.3 PROCEDURE

1- Make the circuit shown in fig 14.3 on bread-board.
2- Test the continuity of all connections.
3- Determine the value of Vth from datasheet.
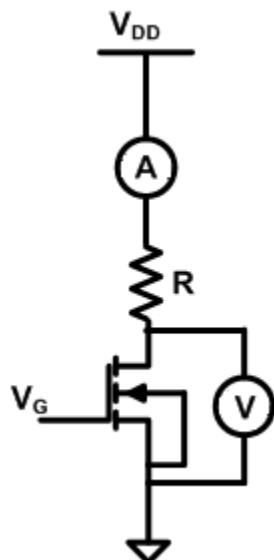
Fig. 14.3

LABORATORY PROCEDURE

OBJECTIVE

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

PROCEDURE

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

OBSERVATIONS

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

R (Ω)	I_D (A)	V_{DS} (V)
1k		
100k		
1M		

POST LAB

CALCULATIONS

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

14.4   TASK TO BE SUBMITTED

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