Department of Electronic Engineering
NED University of Engineering & Technology

PRACTICAL WORK BOOK

For the course

ELECTRONICS
(EL-232) For FE (FD)/ SS (AP)

Instructor's Name:___________________________
Student Name: ____________________________
Roll No.:______________Batch: ________________
Semester :____________ Year:_________________
Department: _________________________________

LABORATORY WORK BOOK
FOR THE COURSE

ELECTRONICS (EL-232)

Prepared By:
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Reviewed By:
Dr. Amna Shabbir (Assistant Professor)

Approved By:
The Board of Studies of Department of Electronic Engineering

Electronic Laboratory
CONTENTS

Lab Session 01

OBJECTIVE

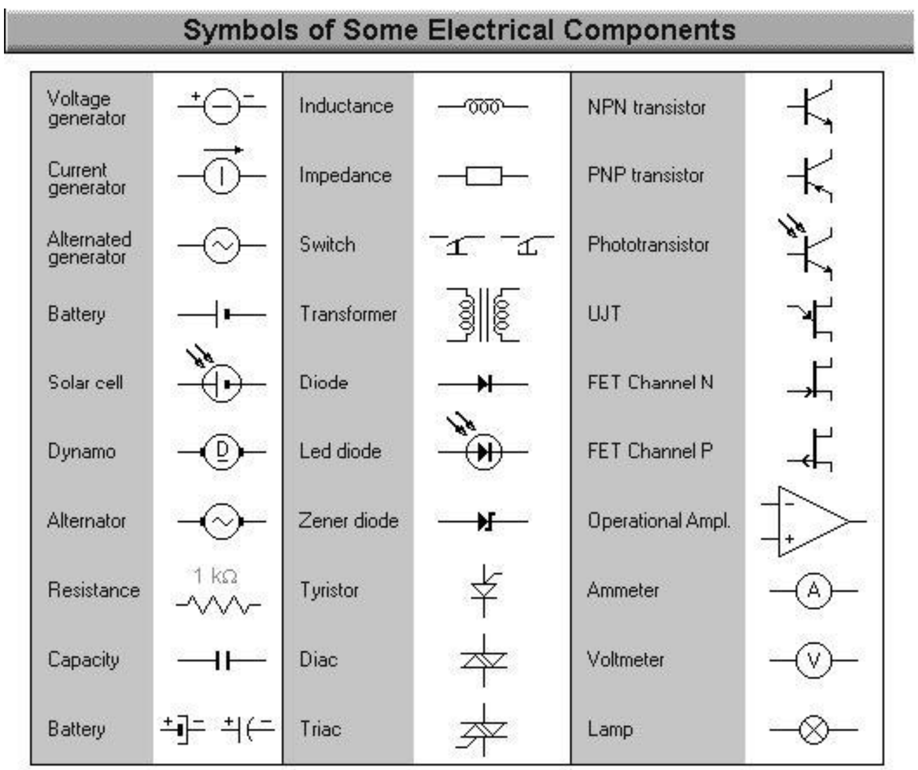
To PRACTICE the electrical symbols and laboratory equipments.

APPARATUS

- Digital Multimeter.
- Digital Oscilloscope. TDS-210
- Function Generator.
- Power supply unit mod. PS1-PSU/EV.

THEORY

Electrical Symbols



Electrical Variables

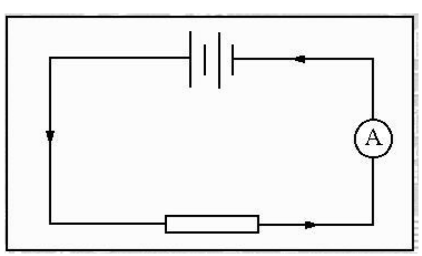
Variables		Measurement Unit	Symbol
Current intensity	I	Ampere	A
Voltage o e.m.f.	V	Volt	V
Power	P	Watt	W
Frequency	f	Hertz	Hz
Pulse	w	Radiant / s	rd / s
Period	T	Second	s
Phase	ϕ	Degree or radiant	° or rd
Impedance	Z	Ohm	Ω
Admittance	Y	Ohm^{-1} or Mho	Ω^{-1}
Resistence	R	Ohm	Ω
Capacitance	C	Farad	F
Inductance	L	Henry	H

Digital Multimeter

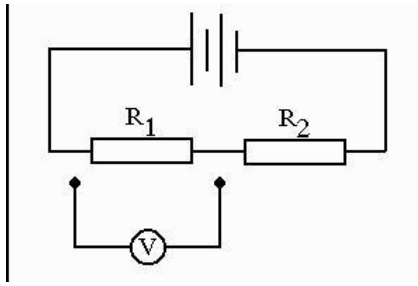
Multimeter is the measuring instrument use to measure voltage, current and resistance of the electronics and electrical circuit. Multimeter is basically an integration of Ammeter, Voltmeter and Ohm-meter. Some of the modern digital Multimeter also contains Frequency meter.

Ammeter is used to measure the current. Since current flows through the component, the ammeter must go in series with the component. This makes sure the same current flows through the meter. Current is measured in Amperes (A). Often in electronics we use large resistors which only allow very small current to pass. Therefore we used two other small units.

mA (milliamperes)
µA (microamperes)



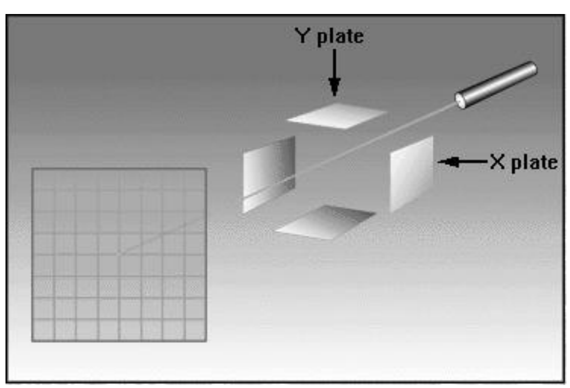
Voltmeter is used to measure the voltage and potential difference across the component. Therefore the voltmeter must go in parallel. If the internal resistance of voltmeter is quite small then the loading effect causes the problem.



The unit for measuring the voltage is volt. Small signals such as bio-signals are generally measure in millivolts (mV).

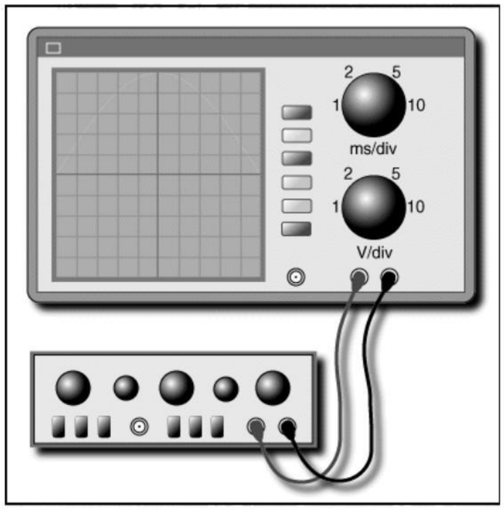
The Cathode Ray Oscilloscope

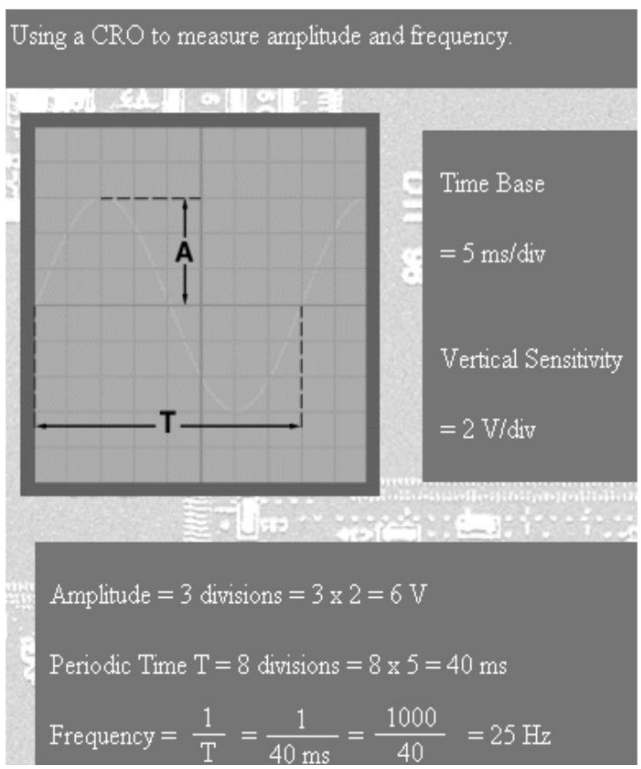
We use CRO to visualize at the voltages that changes with the time such as AC voltages and signal waveforms from amplifiers. The voltage on the X-plate makes the electron beam sweep across the screen. This sets the time base. The spot on the screen shows how the Y-voltage varies with the time.



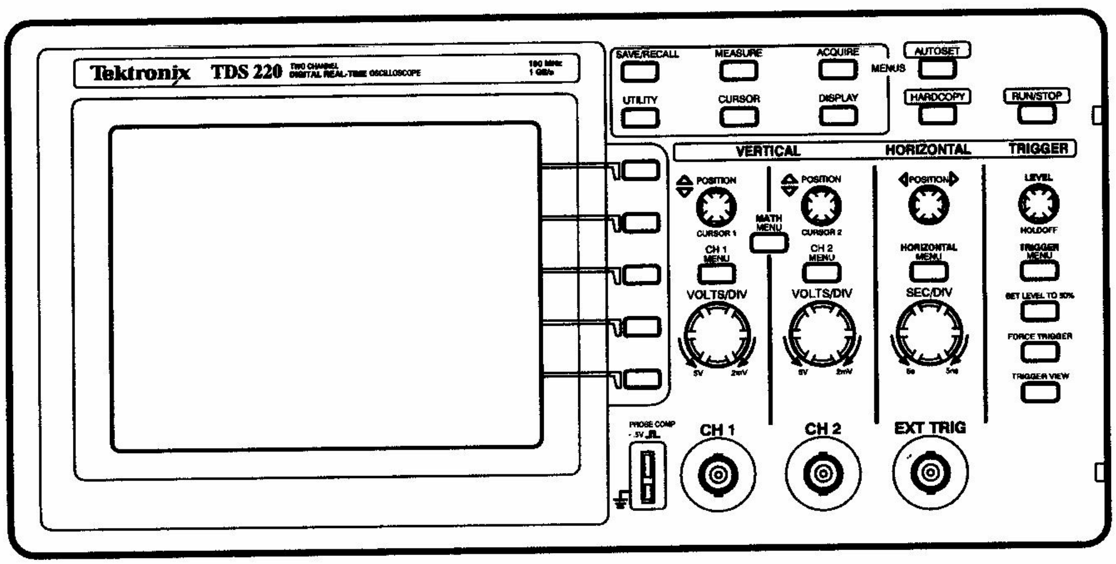
In this example the oscilloscope measures the sine wave with the peak amplitude of 5V and the frequency of 50 Hz. The two properties we need to know about the sine wave is its amplitude and frequency.

Here we are using Digital Oscilloscope with LCD (Liquid Crystal Display) panel. Volts/div. and Time/div. are controlled digitally through Autoset button. Even other electrical calculations are done directly through this oscilloscope. There are several controlling knobs and buttons that are quite user friendly.





Digital Real-Time Oscilloscope



General Features

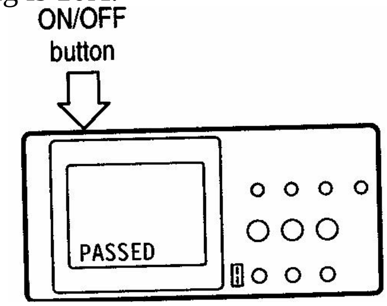
- 100 MHz (TDS 220 or TDS 224) or 60 MHz (TDS 210) bandwidth with selectable 20 MHz bandwidth limit
- 1GS/s sample rate and 2,500 point record length for each channel
- Cursors with readout
- Five automated measurements
- High-resolution, high-contrast LCD display with temperature compensation and replaceable back light
- Setup and waveform storage
- Autoset for quick setup
- Waveform averaging and peak detection
- Digital real-time oscilloscope
- Dual time base
- Video trigger capability
- RS-232, GPIB, and Centronics communication ports easily added with optional extension modules
- Variable persistence display
- User interface available in ten user-selectable languages

Functional Check

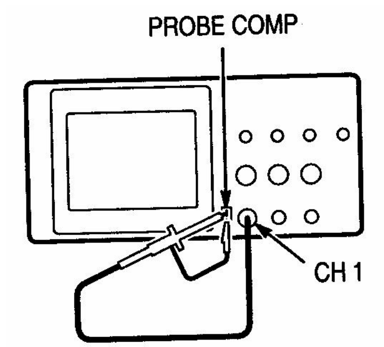
Perform this quick functional check to verify that your instrument is I operating correctly.

1. Turn on the instrument.

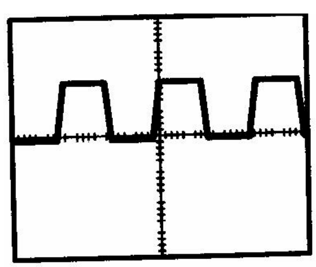
Wait until the display shows that all self tests passed. Push the SAVE/RECALL button, select Setups in the top menu box and push the Recall Factory menu box. The default Probe menu attenuation setting is 10X.



2. Set the switch to 10X on the P2100 probe and connect the probe to channel 1 on the oscilloscope. To do this, align the slot in probe connector with the key on the CH 1 BNC, push to connect, and twist to the right to lock the probe in place. Attach the probe tip and reference lead to the PROBE COMP connectors.



3. Push the AUTOSET button. Within a few seconds, you should see a square wave in the display (approximately 5 V at 1 kHz peak-to-peak). Push the CH 1 MENU button twice to turn off channel, push the CH 2 MENU button to turn on channel 2, repeat steps 2 .and 3. For TDS 224, repeat for CH 3 and CH 4.

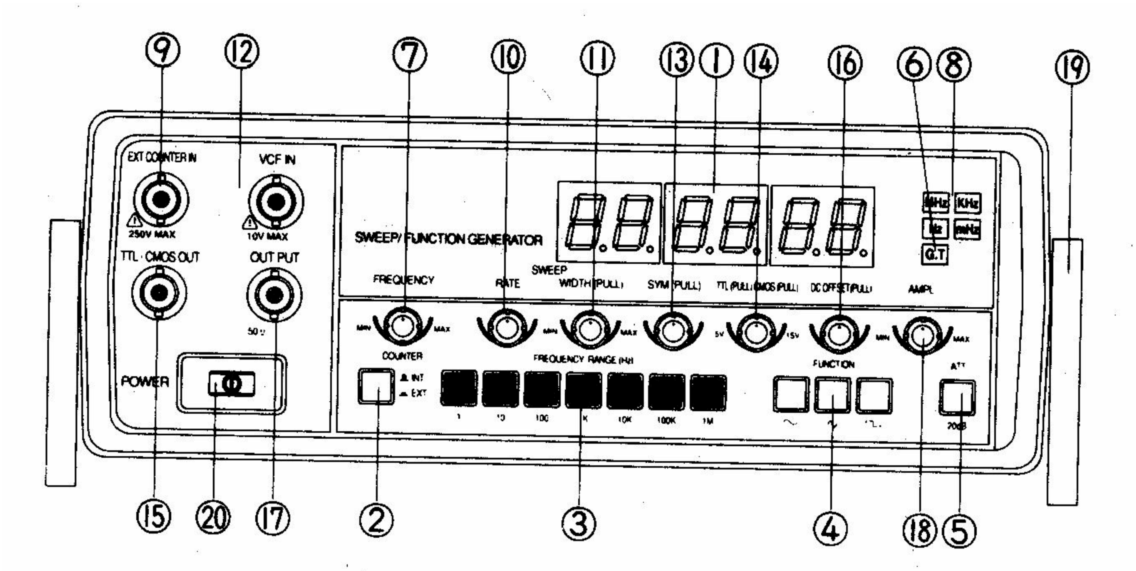


Using Autoset

The Autoset function obtains a stable waveform display for you. It automatically adjusts the vertical and horizontal scaling, as well as the trigger coupling, type, and position, slope, level and mode settings.

The Function Generator

This instrument is basically the frequency generator that can generate signals of different frequency, amplitude and shape. It is known as variable frequency source.



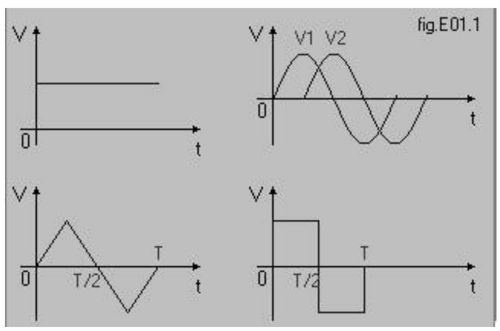
1. LED DISPLAY. — Displays internal or external frequency.
2. INTERNAUEXTERNAL SWITCH. — PUSH IN : External Frequency Counter. PUSH OUT: Internal Frequency Counter.
3. RANGE SWITCHES. — Frequency range Selector.
4. FUNCTION SWITCHES. — Select Sine wave, Triangle wave or Square wave output.
5. ATTENUATOR. — Selects Output Level by -20 dB.
6. GATE TIME INDICATOR. — Gate Time Is selected automatically by input signal.
7. FREQUENCY DIAL. — Controls Output frequency in selected range.
8. MHz, KHz, Hz, mHz INDICATOR. — Indicates unit of frequency.
9. EXTERNAL COUNTER INPUT BNC. — Used as an External Frequency Counter.
10. SWEEP RATE CONTROL. — On/Off Switch for Internal Sweep Generator, adjusts Sweep rate of Internal Sweep Generator.
11. SWEEP WIDTH CONTROL. — Pull out 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 1:1to 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.	PullOut to adjust tilt.
20. POWER SWITCH.	Push type switch. turning on the power when pressed.
21. FUSE HOLDER.	Replacing fuse with unscrewing
22. AC INLET.	For connection of the supplied AC power

Usually these are the shapes of the signal that can be generated using Function Generator.



POST- LAB

1. **Set the Function Generator to the value 1Vp-p sinusoid and 5Vp-p square wave?**
2. **Use dual channel of the oscilloscope to measure the signal from Function Generator?**
3. **Write down peak to peak, average and RMS values of the incoming signal?**

   _______________ _______________ _______________

4. **Use dual channel of the oscilloscope to measure the positive and negative DC voltages from Power supply unit?**
5. **Measure the mean and ripple content values of the incoming DC voltages?**

   _______________ _______________

F/OBEM 01/05/00

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Department of ____**ELECTRONIC**__ Engineering
Course Code and Title: ____**EL-232 ELECTRONICS**______

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Laboratory Session No. ____01_______ Date: ______________________

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

Lab Session 02

OBJECTIVE

To OPERATE under supervision the characteristic curve of Silicon diode.

INTRODUCTION

Although the diode is a simple device, it forms the basis for an entire branch of electronics. Transistors, integrated circuits, and microprocessors are all based on its theory and technology. In today's world, semiconductors are found all around us. Cars, telephones, consumer electronics, and more depend upon solid state devices for proper operation.

PN Junction

Now, we are ready to build a diode. To do this, we need two blocks of material, one N type and one P type.

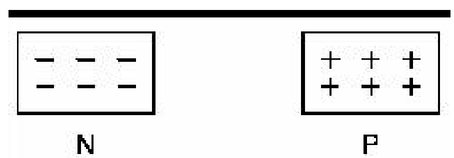


Figure 1. N and P Material

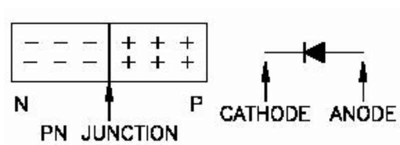


Figure 2. Diode

The resulting block of material is a diode. At the instant the two blocks are fused, their point of contact becomes the PN junction. Some of the electrons on the N side are attracted to the P side, while at the same time, an equal number of hole charges are attracted to the N side.

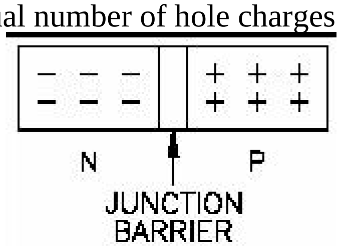


Figure 3. PN Junction Diode

As a result, the PN junction becomes electrically neutral. The barrier in Figure 3 is greatly exaggerated. In some semiconductor devices, the PN junction barrier may only be a few atoms thick. The PN junction is an electrical condition, rather than a physical one. The junction has no charge; it is depleted of charges. Thus, another name for it is the **depletion zone**. Because of the existence of the depletion zone, there is no static current flow from the N material to the P material.

The diode consists of two parts or elements, the N material and the P material. Their proper names are cathode and anode. The cathode is the N material and the anode is the P material. Electron current flow is from the cathode to the anode. Figure 4 illustrates a PN junction diode.

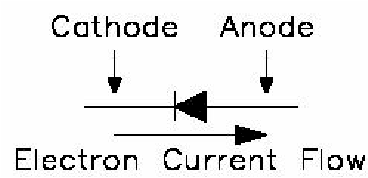


Figure 4. The Diode

Bias

Average DC level of current to set operating characteristics.

There are two types of bias in semiconductors, forward and reverse. Forward bias will eliminate the depletion zone and cause a diode to pass current. Reverse bias will increase the size of the depletion zone and in turn, block current. Figure 6 and 7 illustrates forward and reverse bias.

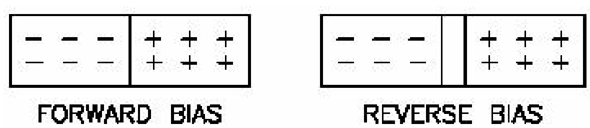
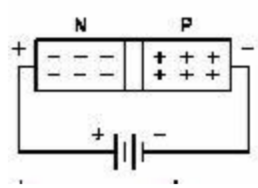


Figure 5. Bias

A diode is biased by placing a difference in potential across it. Figure 7 illustrates a forward biased diode. Because of the positive potential applied to the anode and the negative potential applied to the cathode, the depletion zone disappears. Current flows from the negative terminal of the battery through the N region, across the non-existent depletion zone, and through the P region to the positive terminal of the battery. It takes a specific value of voltage for a diode to begin conduction. Approximately .3 volts across a germanium diode or .7 volts across a silicon diode are necessary to provide forward bias and conduction. A germanium diode requires a lower voltage due to its higher atomic number, which makes it more unstable. Silicon is used far more extensively than germanium in solid state devices because of its stability.



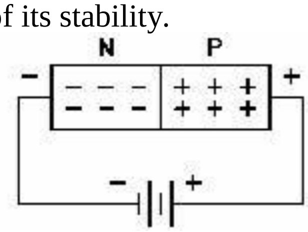


Figure 6. Reversed Biased Diode **Figure 7. Forward Biased Diode**

Reverse bias is accomplished by applying a positive potential to the cathode and a negative potential to the anode as shown in Figure 6. The positive potential on the cathode will attract electrons from the depletion zone. At the same time, the negative potential on the anode will attract holes. The net result is that the depletion zone will increase in size.

A forward biased diode will conduct, with only a small voltage drop over it. The voltage drop for a forward biased germanium diode is .3 volts, while .7 volts is normal for a silicon diode. We can say that a forward biased conducting diode is almost a short. A reversed biased diode will not conduct. Therefore, it can be considered an open circuit. We call a reversed biased diode **cut off**. Cut off refers to the current flow through the diode being blocked, or cut off.

Diode characteristics

The diode consists of two elements, the anode and the cathode. The anode corresponds to the P material and the cathode to the N material. Current flow is from the cathode to the anode.

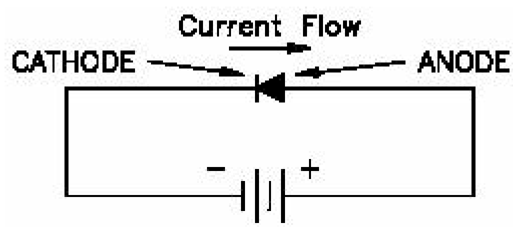


Figure 8. Forward Biased Diode

Figure 8 illustrates a forward biased diode with current flow and the diode elements labeled. The graph in Figure 9 depicts current flow through a diode with different values of forward and reverse bias.

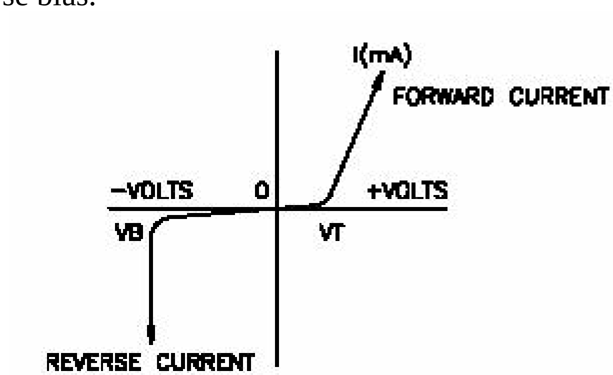


Figure 9. Forward and Reverse Currents of a Semiconductor Diode

Let's examine forward bias first.

As the forward bias is gradually increased, current through the diode will increase. A small forward voltage (forward bias) will generate a very large forward current (cathode to anode). Typical values of forward current are in the range of .2 to 20 amps. Of course, every diode has a maximum value of forward current that can be passed without damage. Typical low power diode current characteristics are:

I_f - the maximum forward current (up to 1 amp)

I_{fm} - maximum peak forward current (up to 5 amps, repetitive)

I_{fs} - maximum peak surge current (up to 35 amps, non-repetitive)

Reverse bias will affect diodes in a different manner. Figure 9 illustrates the point. As the reverse bias or voltage is increased, there will be a very small reverse current (anode to cathode). It will be in the range of 1 milliamp for a germanium (Ge) diode and 1 microampere for silicon (Si) diode. As the reverse voltage is gradually increased, the reverse current will stay at a constant low level until the junction breakdown voltage V_B is reached. At that point, the junction will cease to exist and the diode will conduct. As you can see in Figure 9, the current flow will be massive. Reverse current flow is so heavy that it is called **avalanche conduction**. When the diode is operated in the avalanche region, current flow becomes independent of voltage, and that point is called **avalanche breakdown**. Due to the massive electron flow, normal PN junction diodes are destroyed when operated in this manner.

The forward and reverse biased states of a diode can be compared to a variable resistor. Figure 10 illustrates the concept. A forward biased diode will drop only .3 or .7 V. That corresponds to an internal resistance in the anode that drops from several Kilo-ohms at the point where conduction begins to several ohms where a diode is conducting heavily. In the reverse bias state, resistance will be in the Mega-ohms until breakdown voltage is reached. At that point, internal resistance will drop rapidly.

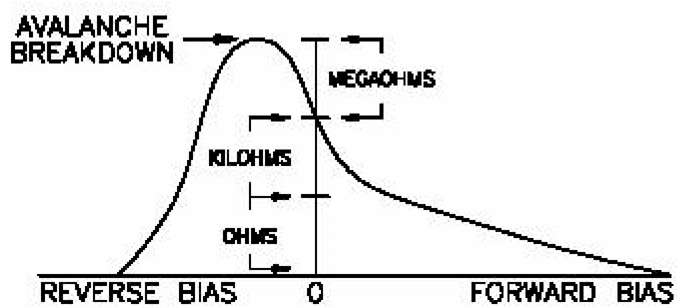


Figure 10. Diode Characteristics Expressed as a Resistance

The stripe on the body of the diode indicates the cathode. To test a diode, you will measure the resistance of the barrier junction.

PRE- LAB

OBJECTIVE

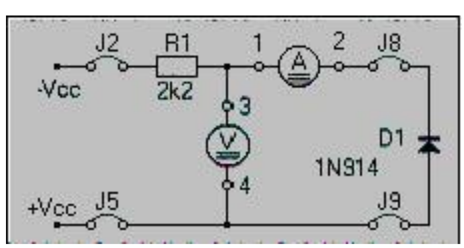
- IDENTIFY diode schematic symbols.
- DESCRIBE Silicon based diode operating characteristics.
- IDENTIFY diode construction characteristics.
- OBSERVE normal operations in a diode circuit.

EQUIPMENTS REQUIRED

- Power supply
- Breadboard
- Silicon diode
- Resistor (10 KΩ)
- Multimeter

PROCEDURE

1. Connect jumpers J2, J8, J9 and J5 to produce the circuit shown in the figure.
2. Steadily increase the supply voltage and measure the voltage across the silicon diode D1.
3. Remove all the jumpers from the module.
4. With the result obtained plot the voltage current curves for D1.



OBSERVATIONS

FORWARD BIAS MODE

SILICON DIODE

Voltage	Current

REVERSE BIAS MODE

SILICON DIODE

Voltage	Current

Current through Silicon based diode starts increasingly exponentially when potential across diode is approximately ______________ millivolts (Cut-in Voltage).

POST-LAB

- Attach both graphs here
- Make both circuits on multisim &attach the print out of simulated circuits

F/OBEM 01/05/00

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Laboratory Session No. ____01_______ Date: ______________________

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Remarks	
Instructor's Signature with Date:	

Lab Session 03

OBJECTIVE

To MANIPULATE with guidance the characteristic curve of Germanium diode.

INTRODUCTION

A germanium diode requires a lower voltage due to its higher atomic number, which makes it more unstable. Silicon is used far more extensively than germanium in solid state devices because of its stability.

PRE- LAB

OBJECTIVE

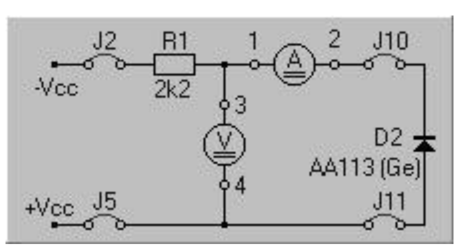
- IDENTIFY diode schematic symbols.
- DESCRIBE Germanium based diode operating characteristics.
- IDENTIFY diode construction characteristics.
- OBSERVE normal operations in a diode circuit.

EQUIPMENTS REQUIRED

- Power supply
- Breadboard
- Germanium diode
- Resistor (10 KΩ)
- Multimeter

PROCEDURE

1. Connect jumpers J2, J10, J11 and J5 to produce the circuit shown in the figure.
2. Steadily increase the supply voltage and measure the voltage across the silicon diode D2.
3. Remove all the jumpers from the module.
4. With the result obtained plot the voltage current curves for D2.



OBSERVATIONS

FORWARD BIAS MODE

GERMANIUM DIODE

Voltage	Current

REVERSE BIAS MODE

GERMANIUM DIODE

Voltage	Current

Current through Germanium based diode starts increasingly exponentially when potential across diode is approximately ______________ millivolts (Cut-in Voltage).

POST-LAB

- Attach both graphs here
- Make both circuits on multisim & attach the print out of simulated circuits

EXERCISES

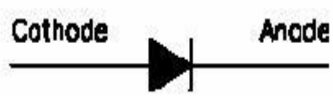
1. What are the 3 classifications of elements in electronics?
   a. Solid, liquid, gas
   b. Conductor, insulator, semiconductor
   c. Earth, wind, fire
   d. Semiconductor, insulator, conduit

2. What are the most common semiconductors in electronics?
   a. Silicon, gallium
   b. N and P
   c. Silver, aluminum
   d. Silicon, germanium

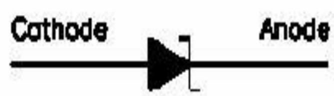
3. P material has majority ________ and N material has majority ______ .
   a. holes, electrons
   b. electrons, holes
   c. electrons, electrons
   d. holes, holes

4. Which is the correctly labeled schematic symbol of a diode?

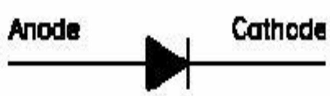
a.



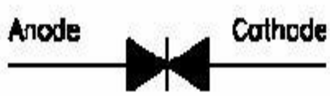
b.



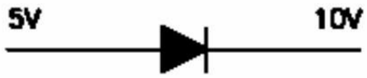
c.



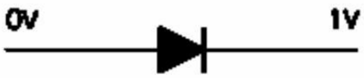
d.



5. Which diode is forward biased?

a.


b.


c.


d.


6. Which diode is forward biased?

a.


b.


c.


d.


7. Which diode is reverse biased?

a.

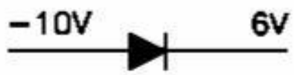

b.


c.


d.


8. Which diode is not reverse biased?

a.



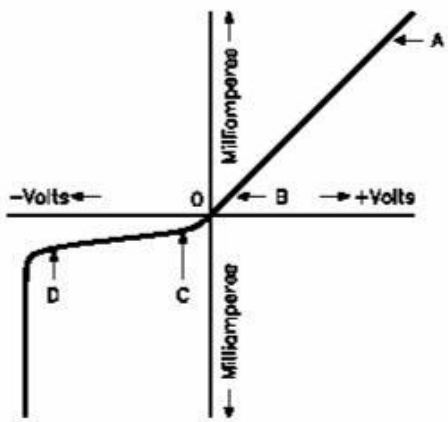
b.

c.

d.

9. Which arrow points to the avalanche region?

a. (A)
b. (B)
c. (C)
d. (D)



10. The diode's anode is made of ________ material and the cathode is made of ________ material.

a. P, P
b. P, N
c. N, P
d. N, N

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

Lab Session 04

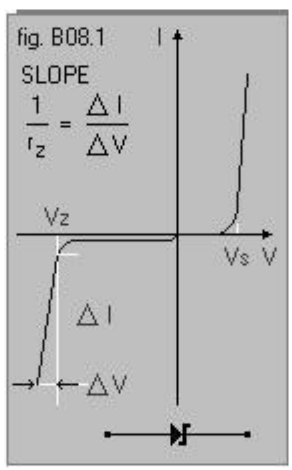
OBJECTIVE

To OPERATE under supervision the characteristic curve of Zener Diode.

BASIC THEORY

The Zener diode is a diode which is designed to be used in reverse bias, in the «breakdown» region. The Zener diode operates basically as follows:

- in FORWARD bias it behaves like a normal diode.
- in REVERSE bias it behaves like a normal diode until the «breakdown» voltage is reached (normally called the Zener voltage, Vz). At this point, the reverse current rapidly increases, while the voltage across it remains almost constant. (The term «breakdown» is not really appropriate for this type of diode: the diode is designed (originally by Zener) to work continually in this region, without any damage at all to the diode.)



Differential resistance

In a real Zener the voltage in the Breakdown region is not quite constant, but it increases slightly, as the current increases. The slope is almost vertical, and has the inverse dimensions of a resistance, known as the "differential resistance r_Z".

The Zener diode can be represented, when biased in this normal region of operation, by a battery Vz (the Zener voltage) in series with the resistance r_Z (fig.B08.2). In this region of operation the Zener resistance r_Z is only a few ohms.

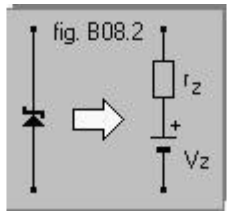


fig. B08.2

Voltage stabilizer

The basic stabilizer circuit using a Zener diode is shown in fig.B08.3. The Zener is reverse biased in the breakdown zone by the voltage Vi through the resistance R. For an ideal Zener, the voltage Vo across the load RL does not vary, and is the same as the Zener voltage, Vz. The main points of the stabilizer operation are:

- if the load current I_L increases, the current Iz through the Zener drops.
- if I_L drops, Iz increases
- if the input voltage Vi increases, Iz also increases.
- if Vi decreases, Iz also decreases.

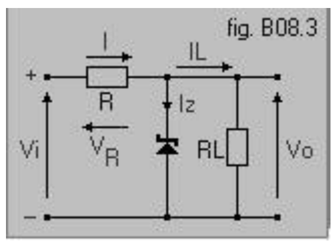


fig. B08.3

Voltage stability with change of load

Refer to fig.B08.4, and assume that the Zener is ideal. The voltage V_0 across the load is constant, so the supply current I is constant and is equal to:

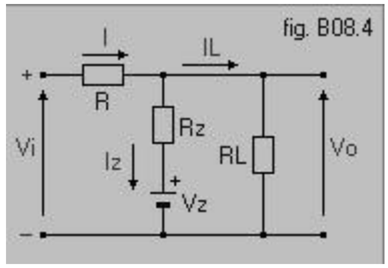
$$I = (Vi - Vo) / R$$

A change in the load current I_L causes an equal, but opposite change in the Zener current Iz: (the supply current I is constant, to a first approximation)

$$\Delta I_L = -\Delta I_z$$

For a real Zener, this current change causes a small change in output voltage due to the effect of r_Z:

$$\Delta Vo = r_z \, \Delta I_z = - r_z \, \Delta I_L$$



Voltage stability with change of input voltage

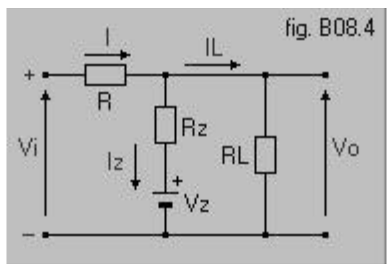
Refer to fig.B08.4. For an ideal Zener, as the input voltage Vi varies, the output voltage V_0 stays constant, and so does the current I_L through the load.

A change in Vi causes a change in the supply current I, and consequently a change in Iz:

$$\Delta I = \Delta Vi / R = \Delta Iz$$

And the change in the output voltage is :

$$\Delta Vo = r_z \, \Delta I_z = (r_z / R) \, \Delta Vi$$



PRE- LAB

OBJECTIVE

- IDENTIFY diode schematic symbols.
- DESCRIBE Zener based diode operating characteristics.
- IDENTIFY diode construction characteristics.
- OBSERVE normal operations in a diode circuit.

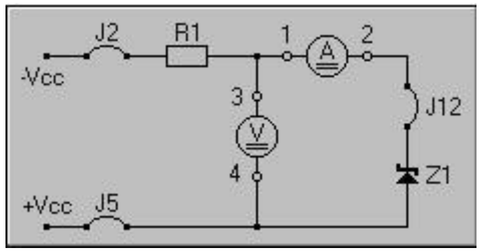
EQUIPMENTS REQUIRED

- Power supply
- Breadboard
- Zener diode (1N4736)
- Resistor (10 KΩ)
- Multimeter

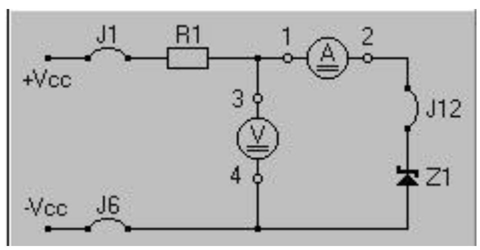
PROCEDURE

- ***Measurement of the Zener current as a function of the input supply voltage***

1. Connect jumpers J2, J12, J5, the ammeter and the voltmeter to produce the circuit of figure B08.5.



2. In forward bias, measure the current through the Zener diode Z 1 as function of the voltage across it.
3. Now reverse bias the diode by removing jumpers J2 and J5 and connecting J1 and J6.



4. Measure (in reverse bias) the voltage across the diode as the supply voltage Vcc is varied.

OBSERVATIONS

FORWARD BIAS MODE

ZENER DIODE

Voltage	Current

REVERSE BAIS MODE

ZENER DIODE

Voltage	Current

POST-LAB

- ATTACH both graphs here
- MAKE both circuits on multisim & attach the print out of simulated circuits

EXERCISES

1. A zener diode is a type of junction diode that is normally used in ____________ .
   a. current regulator circuits
   b. voltage divider circuits
   c. voltage regulator circuits
   d. voltage multiplier circuits

2. To increase their breakdown voltage, zener diodes are connected ____________ .
   a. back-to-back
   b. in series
   c. in parallel
   d. in series parallel

3. A 9-volt zener diode regulator has an output voltage of 5.6 V. This may indicate that ____________ .
   a. the zener diode is defective
   b. load current is excessive
   c. the zener diode is open
   d. load current is too low

4. Two 3.6 V zener diodes are connected back-to-back in an AC circuit. The output signal ____________ .
   a. has a maximum amplitude of 7.2 volts peak-to-peak
   b. cannot exceed 7.2 V peak
   c. will be limited to 4.2 V peak
   d. cannot be less than 3.6 V peak

5. In a zener diode voltage regulator circuit, ____________ .
   a. as the load current increases, zener resistance increases
   b. as the applied voltage increases, zener resistance increases
   c. as the load current decreases, zener resistance increases
   d. None of the above.

6. The zener diode is a linear device that follows Ohm's Law.

   a. The statement is true.
   b. This is true for a Zener diode providing a reference voltage.
   c. This is true for a Zener diode connected as a regulator.
   d. The statement is never true.

7. The purpose of the current limiting resistor in a zener diode circuit is to ________________ .

   a. maintain a constant current through the load resistor
   b. maintain a constant voltage across the zener diode
   c. maintain a constant current through the zener diode
   d. drop the additional voltage from the power supply in order to maintain a constant voltage across the zener diode

8. If a zener diode has 15 volts across it and 20 mA of current flowing through it, what is the zener power dissipation?

   ____

9. A zener diode has a zener resistance of 5 Ω. If the current changes from 10 mA to 20 mA, what is the voltage change across the zener diode?

   ____

10. A current change of 2 mA through a zener diode produces a voltage change of 15 mV. What does the zener resistance equal?

   ____

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Laboratory Session No. _____01________ Date: ________________________

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

Lab Session 05

OBJECTIVE

To IMITATE the the Half-wave rectifier.

BASIC THEORY

The rectifier circuit converts the AC voltage furnished by the utilities company into the DC voltage required to operate electronic equipment. Many common electrical products use voltages provided by a rectifier. Without the rectifier to convert the AC voltage to the DC voltage required to operate these electrical units, it would be virtually impossible to have the conveniences that we enjoy today. A television without a rectifier would require several extremely large batteries. These batteries would have to be large because of the current that is required. In other words, a television without the rectifier would be so large that it would occupy an entire room. The rectifier is the heart of the electronic unit.

Introduction

A rectifier system can be divided into five sections, each performing a separate function. Figure 1 is a block diagram of a rectifier system. This lesson deals with the input, rectifier, and filter sections.

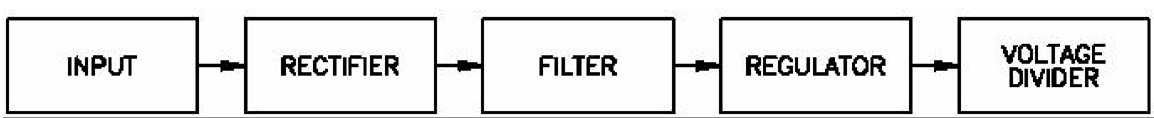


Figure 1. Rectifier System

Input Block

The input block consists of a transformer, normally a power transformer that receives the AC input signal from some power source. The transformer transfers the electrical energy received to the rectifier section by electromagnetic induction or mutual inductance. The transformer performs the transfer of energy without any change in frequency, but it is able to change the voltage and current from the input source to the voltage and current required by the rectifier section. The phase relationship of the current in the secondary of the transformer is dependent upon the phase of the voltage in the primary winding and the direction of the winding in the secondary. If the secondary windings are wound in the same direction as the primary windings, the phase between the input signal and the output signal will be the same. If the secondary windings are wound in the opposite direction of the primary windings, the phase between the input signal and the output signal will be 180 degrees out of phase. The schematic drawings of a transformer indicate the phase relationship between the primary and secondary with the use of dots.

The dots on a schematic diagram indicate which windings are in phase. Figure 2 illustrates this relationship.

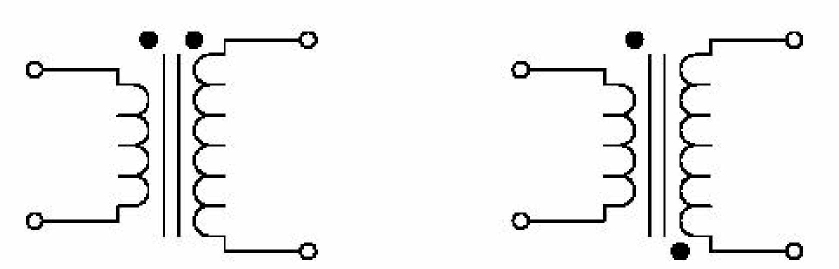


Figure 2. Transformer

Rectifier Block

The rectifier circuit is the most important part in the rectifier system. The rectifier circuit converts the AC waveform from the input block into a pulsating DC waveform. One of several different rectifier circuits may be utilized to perform this function. These circuits are the half-wave rectifier, the full-wave rectifier, the full-wave bridge rectifier, and the voltage doubler.

Half-Wave Rectifier

Figure 3 shows the schematic diagram for a half-wave rectifier. The half-wave rectifier is the simplest type of rectifier; it consists of only one diode. For explanation purposes, a load resistance must be placed in the circuit to complete the path for current flow and to develop the output signal.

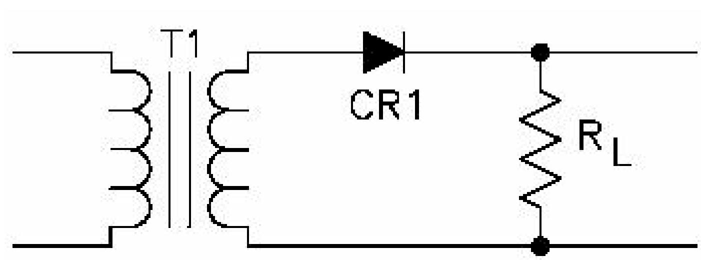


Figure 3. Half-Wave Rectifier

The half-wave rectifier in Figure 3 is a positive half-wave rectifier. It is called a positive half-wave rectifier because it only uses the positive portion of the input sine wave and produces a positive pulsating DC signal. During the positive alternation of the input voltage, the positive alternation of the sine wave causes the anode of the diode to become positive with respect to the cathode. The diode is now forward-biased and will conduct. Current will flow from the negative side of the transformer secondary, through the load resistor, through the diode, to the positive side of the transformer secondary. This path for current flow will exist during the complete positive alternation of the input waveform because the diode will remain forward-biased as long as the positive signal is applied to the anode. The resulting output of the rectifier will be developed across the load resistor and will be a positive pulse very similar to the positive alternation of the input waveform. Figure 4 illustrates the output waveform across the load resistor. During the negative alternation of the input sine wave, the anode is negative with respect to the cathode and the diode will become reverse-biased. As long as this condition exists, no current will flow in the circuit and an output signal cannot be developed across the load. The circuit gives the appearance of producing a series of positive pulses. A negative half-wave rectifier operates very similar to a positive half-wave rectifier, except the output will be a series of negative pulses. (Refer to Figure 5.)

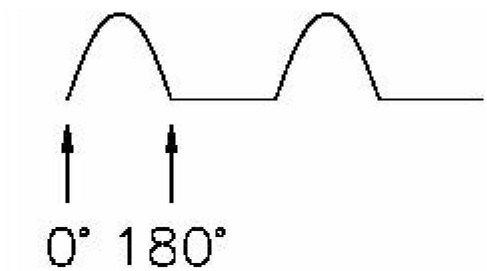


Figure 4. Output Waveform of a Positive Half-Wave Rectifier

During the positive alternation, the diode is reverse-biased; no current will flow through the circuit, and no signal will be developed across the load. This condition will exist any time a positive alternation is present on the cathode. When the negative alternation is present on the cathode, the diode is forward-biased; current flows from the negative side of the secondary through the diode, through the load resistance, to the positive side of the secondary. This condition allows a negative pulse to be developed across the load resistance and continues until the negative cycle is removed from the cathode. The output of a negative half-wave rectifier will be a series of negative pulses. The amplitude of the output is approximately the same as the peak voltage of the input signal if measured with the oscilloscope. If a multimeter is used to measure the pulsating DC voltage, it will indicate the average voltage. The average voltage of a sine wave is zero volts; however, if the negative portion of a sine wave is clipped off, the average value changes to some positive value. Since the waveform swings positive but never goes negative, the average voltage will be positive. To determine the average value of a pulsating DC signal using a half-wave rectifier, multiply the peak voltage by .318.

Example: Input peak value = 10 volts AC
10 volts AC X .318 = 3.18 volts AC
$E_{AVG} = E_{PEAK} \times .318$

The average value of a signal is the average of all the instantaneous values during one alternation. For one positive alternation, the voltage value increases from 0 volts to some maximum peak value and decreases back to 0 volts; the average value would be some value between the two limits. The instantaneous value of an alternating voltage or current is the value of voltage or current at one particular instant. The value may be zero if the particular instant is the time in the cycle at which the polarity is changing. It may also be the same as the peak value if the selected instant is the time in the cycle at which the voltage or current stops increasing and starts decreasing. There are actually an infinite number of instantaneous values between zero and peak value.The current flows in the circuit during the half cycle (duration of a half- wave) and produce a positive half-wave voltage across the load. The average value V_m of the rectified voltage is:

$$V_m = V_M / \pi = 0.318 \cdot V_M$$

The rms voltage is:

$$V_{rms} = V_M / 2$$

Ripple Frequency

The half-wave rectifier gets its name from the fact that it conducts during only half the input cycle. Its output is a series of pulses with a frequency that is the same as the input frequency. Thus, when operation is from a 60 hertz line source, the frequency of the pulses is 60 hertz. The frequency at which the pulses appear is called ripple frequency.

Peak Inverse Voltage (PIV)

The largest reverse voltage that the diode must be able to withstand without breakdown is known as PIV. It is the largest reverse voltage that is expected to appear across the diode.

$$\textbf{PIV} = \textbf{V}_\textbf{M}$$

PRE-LAB

OBJECTIVE

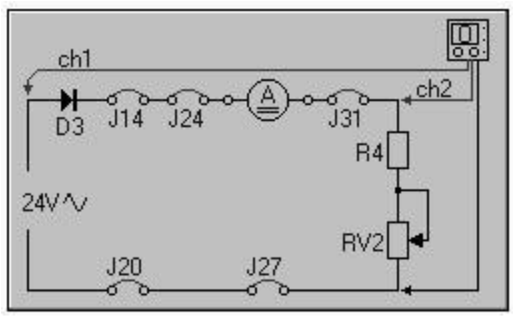
- To CONSTRUCT the half-wave rectifier on breadboard

EQUIPMENT REQUIRED

- Breadboard
- Silicon Diode (1N4001)
- Centre tapped transformer (220V-12V)
- Resistor (10kΩ)
- Oscilloscope

PROCEDURE

- Connect jumpers J14, J24, J31, J27, J20 and the ammeter to produce the circuit shown below.
- Adjust RV_2 to obtain the minimum current in the circuit.
- Connect the Oscilloscope to display both the input voltage and the voltage across the load.
- Compare the two waveforms and determine at which time the diode conducts.



OBSERVATIONS

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

POST-LAB

CALCULATIONS

- Using the formulas given in introduction of this lab, fill out the following readings:

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

- Make the same circuit on Multisim & attach the print out of observed output
- Make the same circuit on breadboard with output resistance 1KΩ, 100Ω & 1MΩ & write the change in output values in the following table

Readings	Vpeak-peak	Frequency	Rms Value	Average Value
1KΩ				
100kΩ				
1MΩ				

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Laboratory Session No. _____01________ Date: ________________________

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

Lab Session 06

OBJECTIVE

To PRACTICE the Full-wave rectifier.

BASIC THEORY

Conventional Full-Wave Rectifier

A full-wave rectifier uses two diodes and a center-tapped transformer. Before we discuss a full-wave rectifier, let's consider these points about a center-tapped transformer. Refer to Figure 1. A center-tapped transformer is composed of two windings, one primary winding and one secondary winding which is divided by a ground connected to the center of the secondary winding. When a center tap of a transformer is grounded, the voltages at the opposite side of the secondary windings are 180 degrees out of phase. The amplitude of these two signals will be the same, because there is the same number of windings above the ground as there is below the ground. When the voltage at point A is positive with respect to the ground, the voltage at point B is negative with respect to the ground.

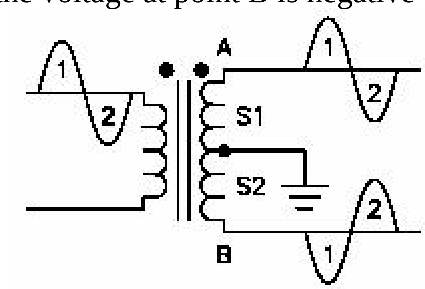


Figure 1. Center-tapped Transformer

Theory Of Operation Of A Full-Wave Rectifier

During the first half cycle, the anode of CR1 is positive with respect to the cathode, while the anode of CR2 is negative with respect to the cathode. Refer to Figure 2. Thus, CR1 is forward-biased, while CR2 is reverse-biased. During the second half cycle, the anode of CR1 is negative with respect to the cathode, while the anode of CR2 is positive with respect to the cathode, causing CR1 to be reversed-biased and CR2 to be forward-biased.

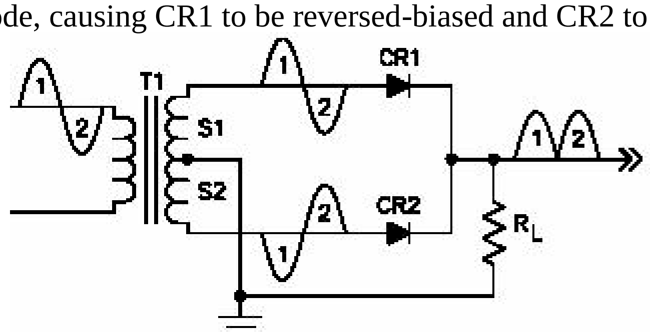


Figure 2. Full Wave Rectifier

When CR1 is forward-biased, current will flow from ground through the load resistor, through the diode CR1, to the upper half of T1, through T1 to the center tap, and back to the ground. As current flows through the load resistor, a positive signal is developed at the junction of RL and CR1. This signal is a positive DC pulse with amplitude approximately the same as the input signal. This signal is developed during the first half of the input cycle only. Refer to Figure 3.

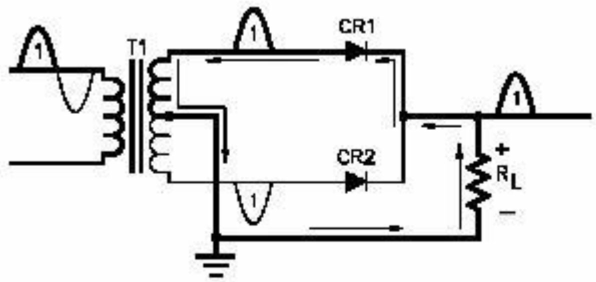


Figure 3. First Half Cycle Rectifier

During the second half cycle of the input signal, CR2 is forward-biased and will allow current to flow. CR1 is reversed -biased during this half cycle. Current will now flow from the ground through the load resistor, through CR2, up through the lower half of the transformer, to the center tap, and back to the ground. Current is still flowing in the same direction across the load resistor so that a positive signal will be developed at the junction of CR2 and RL. Refer to Figure 4.

During this one cycle of the input sine wave, two positive DC pulses have been developed. With this condition, the output frequency has doubled. If the input frequency is 60 hertz, the positive alternation will be present 60 times. After the full-wave rectification, there will be 120 positive pulses at the output. The amplitude, if measured with an oscilloscope, will be approximately the same as the peak input signal. If the DC output signal is measured with a multimeter, the indication will be the average value of the peak signal. To determine the average value of a full-wave rectified signal, multiply the peak value by .636.

Example: $E_{AVG} = E_{PEAK} \times .636$

Input peak value = 10 V AC

10 V AC x .636 = 6.36 V DC

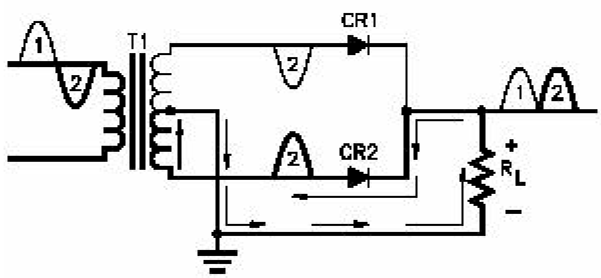
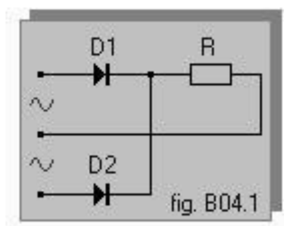


Figure 4. Second Half Cycle Rectifier

Advantage of Full Wave Rectifier

The Half wave rectifier has too low an average (or rms) value of output voltage, as it uses only half the input cycle. This is inconvenient, especially if the load requires a lot of power. There are two alternatives to the simple rectifier, which rectify the whole of the input cycle, and so increase the average and rms value of the rectified voltage.

One circuit – the full-wave rectifier, uses two diodes, as seen in figure



This dual diode rectifier requires two equal voltages, but 180' apart, on the anodes. The average value V_m of the rectified voltage is:

$$V_m = 2 \cdot V_M / \pi = 0.636 \cdot V_M$$

The rms voltage V_{eff} is:

$$V_{eff} = V_M / \sqrt{2} = 0.707 \cdot V_M$$

Peak Inverse Voltage (PIV)

The largest reverse voltage that the diode must be able to withstand without breakdown is known as PIV. It is the largest reverse voltage that is expected to appear across the diode. During the positive half cycle D1 is conducting and D2 is cut off. The voltage at the cathode of D2 is $V_O = V_M – 2V_{DO}$ and that at its anode is $-V_M$. Therefore,

$$\mathbf{PIV = 2V_M - V_{DO}}$$

It is approximately for the case of half-wave rectifier.

PRE-LAB

OBJECTIVE

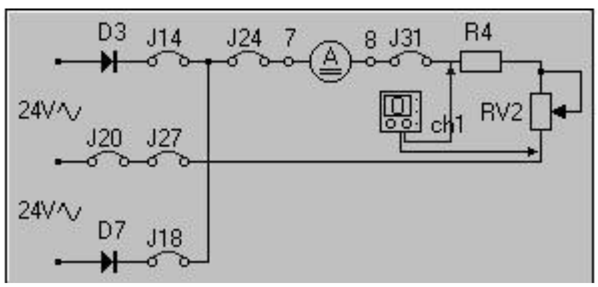
- To CONSTRUCT the full-wave rectifier on breadboard

EQUIPMENT REQUIRED

- Breadboard
- Two Silicon Diodes (1N4001)
- Centre tapped transformer (220V-12V)
- Resistor (10kΩ)
- Oscilloscope

PROCEDURE

- Connect jumpers J14, J18, J24, J31, J27, J20 and the ammeter to produce the circuit shown below.
- Connect the ground of the oscilloscope to the common point of the two ac input voltages. Connect the probes to display the voltage across the load and alternatively on the anodes of diodes D3 and D7.
- Adjust RV_2 to obtain the maximum load current through the circuit.
- Set the ammeter to dc, disconnect jumper J18 and measure the current.



OBSERVATIONS

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

POST-LAB

CALCULATIONS

- Using the formulas given in introduction of this lab, fill out the following readings:

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

- Make the same circuit on Multisim & attach the print out of observed output
- Make the same circuit on breadboard with output resistance 1KΩ, 100Ω & 1MΩ & write the change in output values in the following table

Readings	Vpeak-peak	Frequency	Rms Value	Average Value
1KΩ				
100kΩ				
1MΩ				

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Psychomotor Domain Assessment Rubric-Level P3					
Skill Sets	Extent of Achievement				
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Equipment Identification Sensory skill to ***identify*** equipment and/or its component for a lab work.	Not able to identify the equipment.	--	--	--	Able to identify equipment as well as its components.
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Response Ability to ***imitate*** the lab work on his/her own.	Not able to imitate the lab work.	Able to slightly imitate the lab work.	Able to somewhat imitate the lab work.	Able to moderately imitate the lab work.	Able to fully imitate the lab work.
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Safety Adherence Adherence to ***safety*** procedures.	Doesn't adhere to safety procedures.	Slightly adheres to safety procedures.	Somewhat adheres to safety procedures.	Moderately adheres to safety procedures.	Fully adheres to safety procedures.
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Laboratory Session No. ____01_______ Date: ______________________

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

Lab Session 07

OBJECTIVE

To OPERATE under supervision the Bridge rectifier.

BASIC THEORY

The Full-Wave Bridge Rectifier

A basic full-wave bridge rectifier is illustrated in Figure 1.

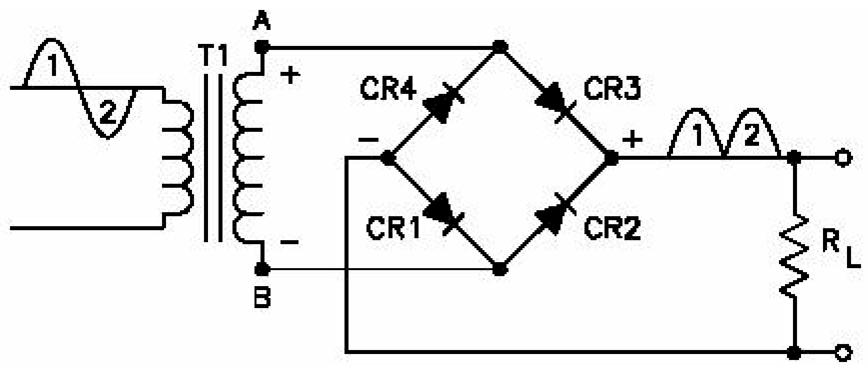


Figure 1. Basic Full-Wave Bridge Rectifier

A full wave bridge rectifier has one advantage over the conventional full-wave rectifier: the amplitude of the output signal. The frequency of the positive pulses will be the same in either rectifier. When the output signal is taken from a bridge rectifier, it is taken across the entire potential of the transformer; thus, the output signal will be twice the amplitude of a conventional full-wave rectifier. For the first half cycle of a bridge rectifier, refer to Figure 2.

During the first half cycle of the input signal, a positive potential is felt at Point A and a negative potential is felt at Point B. Under this condition, a positive potential is felt on the anode of CR3 and on the cathode of CR4. CR3 will be forward-biased, while CR4 will be reverse-biased. Also, a negative potential will be placed on the cathode of CR1 and the anode of CR2. CR1 will be forward- biased, while CR2 will be reverse biased. With CR1 and CR3 forward-biased, a path for current flow has been developed. The current will flow from the lower side of the transformer to Point D. CR1 is forward-biased, so current will flow through CR1 to Point E, from Point E to the bottom of the load resistor, and up to Point F. R3 is forward-biased, so current will flow through CR3, to Point C, and to Point A. The difference of potential across the secondary of the transformer causes the current to flow.

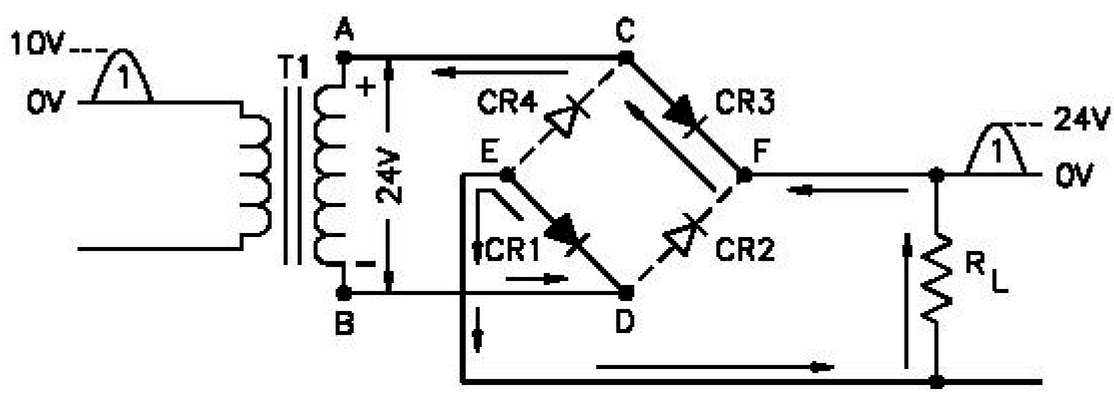


Figure 2. Full Wave Bridge Rectifier (First Half-Wave Cycle Operation)

Diodes CR1 and CR3 are forward-biased, so very little resistance is offered to the current flow by these components. Also, the resistance of the transformer is very small, so approximately all the applied potential will be developed across the load resistor. If the potential from Point A to Point B of the transformer is 24 volts, the output developed across the load resistor will be a positive pulse approximately 24 volts in amplitude.

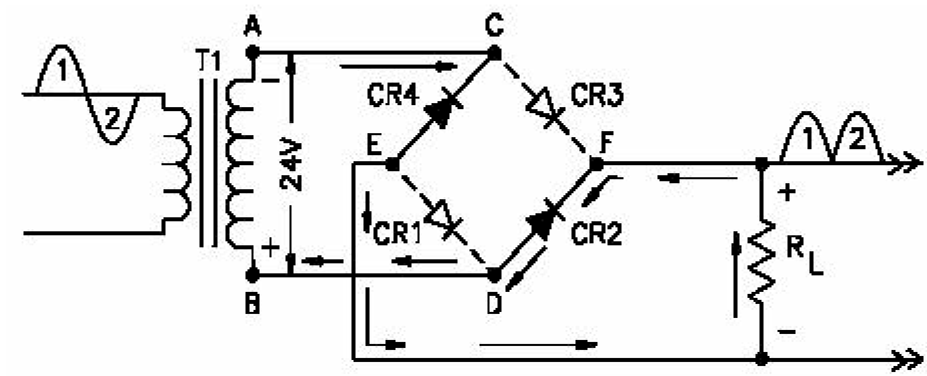


Figure 3. Full-Wave Bridge Rectifier (Second Cycle Operation)

When the next alternation of the input is felt (Figure 3), the potential across the transformer reverses polarity. Now, a negative potential is felt at Point A and a positive potential is felt at Point B. With a negative felt at Point C, CR4 will have a negative on the cathode and CR3 will have a negative on the anode. A positive at Point D will be felt on the anode of CR2 and the cathode of CR1. CR4 and CR2 will be forward-biased and will create a path for current flow. CR1 and CR3 will be reverse-biased, so no current will flow. The path for current flow is from Point A to Point C, through CR4 to Point E, to the lower side of the load resistor, through the load resistor to Point F, through CR2 to Point D, and to the lower side of T1. Current flows because of the full potential being present across the entire transformer; therefore, the current through the load resistor will develop the complete voltage potential. The frequency of the output pulses will be twice that of the input pulses because both cycles of the input AC voltage are being used to produce an output. The average value V_m of the rectified voltage is:

$$V_m = 2 \cdot V_M / \pi = 0.636 \cdot V_M$$

The rms voltage V_{eff} is:

$$V_{eff} = V_M / \sqrt{2} = 0.707 \cdot V_M$$

Peak Inverse Voltage (PIV)

Consider the circuit during the positive half cycles. The reverse voltage across CR2 can be determined from the loop formed by CR2, CR1 and R_L as

$$V_{D2} \text{ (reverse)} = V_O + V_{D1} \text{ (forward)}$$

$$PIV = V_M - 2V_{DO} + V_{DO} = V_M - V_{DO}$$

PIV is about half the value for the full wave rectifier with a center-tapped transformer. This is one of the advantages of bridge rectifier.

PRE-LAB

OBJECTIVE

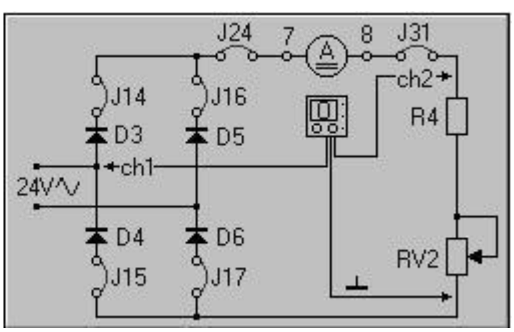
- To CONSTRUCT the full-wave rectifier on breadboard

EQUIPMENT REQUIRED

- Breadboard
- Four Silicon Diodes (1N4001)
- Centre tapped transformer (220V-12V)
- Resistor (10kΩ)
- Oscilloscope

PROCEDURE

- Connect jumpers J14, J16, J24, J31, J17, J15 and the ammeter to produce the circuit shown below.
- Adjust RV_2 to obtain the maximum current in the circuit.
- Connect the ground of the oscilloscope to the anode of D4 and probe 1 to the cathode of the D4 and probe 2 across the load.



OBSERVATIONS

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

POST-LAB

CALCULATIONS

- Using the formulas given in introduction of this lab, fill out the following readings:

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

- Make the same circuit on Multisim & attach the print out of observed output
- Make the same circuit on breadboard with output resistance 1KΩ, 100Ω & 1MΩ & write the change in output values in the following table

Readings	Vpeak-peak	Frequency	Rms Value	Average Value
1KΩ				
100kΩ				
1MΩ				

EXERCISES

1. What is the output frequency of a bridge rectifier?
   a. One-half the input
   b. Twice the input
   c. The same as the input
   d. One-fourth the input

2. What type of rectifier is the bridge rectifier?
   a. Full-wave rectifier
   b. Half-wave rectifier
   c. No waveform, pure DC only
   d. None of the above.

3. In reference to the bridge rectifier, during the first cycle of the AC pulse, how many diodes are forward biased?
   a. Two
   b. Three
   c. One
   d. Four

4. In reference to the bridge rectifier, during the second pulse of the first AC cycle, how many diodes are reverse biased?
   a. One
   b. Three
   c. Two
   d. Four

5. The average value of the output of a full-wave rectifier is equal to ________________________ .
   a. The RMS value of the peak output value
   b. The peak value of the output voltage
   c. 0.318 of the peak output voltage
   d. 0.636 of the peak output voltage

6. The main advantage of a bridge rectifier using the same input transformer as a full-wave rectifier is that ______________________ .

   a. it will double the output voltage
   b. less current is required for the diodes to conduct
   c. the ripple frequency is two times that of the full-wave rectifier
   d. the ripple frequency is one-half that of the full-wave rectifier

7. Which of the three rectifiers produces the maximum average DC output voltage when using the same transformer?

   ____

8. The frequency of the variations in the DC output voltage of a rectifier is called ______________________ frequency.

9. In a diode, electrons flow from ___________________ .

   a. anode to cathode when the anode is positive with respect to the cathode
   b. anode to cathode when the anode is negative with respect to the cathode
   c. cathode to anode when the anode is positive with respect to the cathode
   d. cathode to anode when the anode is negative with respect to the cathode

10. The process of changing an AC voltage to a pulsating DC voltage is called ______________________ .

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Laboratory Session No. _____01________ Date: ________________________

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

Lab Session 08

OBJECTIVE

To MANIPULATE with guidance the operation of filters for smooth DC supply.

BASIC THEORY

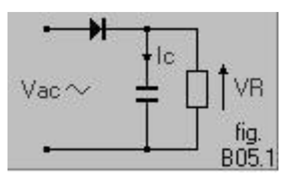
Filter Block

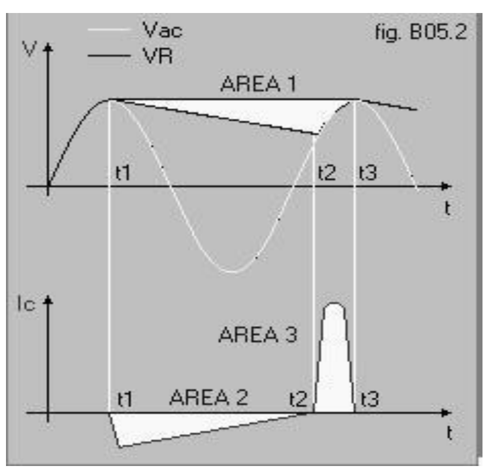
The output from the rectifier circuit is a pulsating DC. This pulsating DC cannot be utilized in most electronic circuits because of the fluctuation of the output voltage. To make this output voltage usable, it must be smoothed out to a steady DC output with very little fluctuation. To perform this, a filter circuit is utilized. The filter circuit is placed between the rectifier and the output load; it uses capacitors, resistors and inductors to smooth or decrease the ripple voltage. There are four basic types of filter circuits used in basic electronics. These are:

1. Basic capacitor filter
2. LC (choke-input) filter
3. LC (capacitor input) filter
4. RC (capacitor input) filter

Capacitive Filter

This can be achieved by connecting a capacitor across the load, as shown in the figure. The behavior of the smoothed voltage, and the current, with the capacitor are also shown in figures.



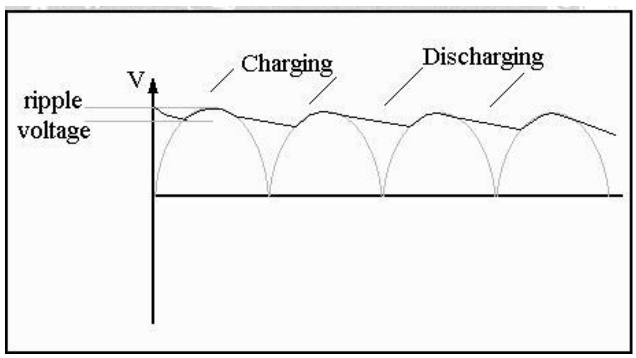


The capacitor charges up while the diode is conducting, until it reaches the maximum value of the rectified voltage. When the supply voltage to the anode is less than the voltage on the cathode, (i.e. the max. voltage of the capacitor), the diode is cut off.

The capacitor will then supply current to the load. This discharge current is shown as area 2 of figure B05.2. The capacitor discharges during the time interval (t_2-t_1). If the capacitor is small, and/or the resistance of the load is low, the capacitor will discharge very quickly, and the smoothing will not be very good.

When the input voltage to the anode, is higher than the voltage left across the capacitor, the capacitor charges up again (during interval t_3- t_2). The diode provides a current pulse to replace the charge lost by the capacitor. During the time t_3-t_2 the capacitor must restore the quantity of charge lost during t_2-t_1.

The voltage across the load looks like this;



The time taken by capacitor to discharge depends on the time constant of the circuit.

T = RC

Vr = Vp / (fCR)

The capacitor input filter is the most basic type of filter, and its use is very limited. It can be used in circuits that require extremely high voltage and low current, such as power supplies for cathode-ray tubes or electron-tube circuits which require very little load current from the power supply. This type of filter is also used where the power supply ripple frequency is not critical and has minimum effect on the operation of the circuit. Refer to Figure 1.

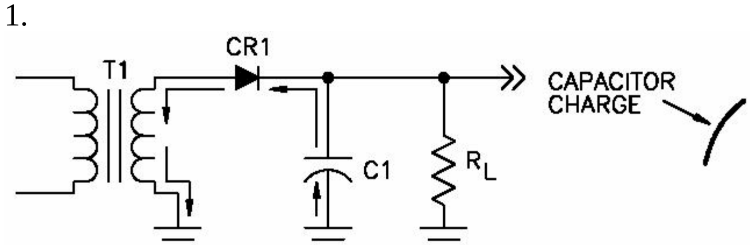


Figure 1. Capacitor Input Filter (Capacitor Charge)

When a positive potential is felt at the top of T1, CR1 will be forward-biased and will allow current to flow from the bottom of T1 to the bottom of C1 and from the top of C1 through CR1 to the top of T1. With this path for current flow, C1 will charge to some positive potential. This positive potential will be less than the peak value induced across the transformer because of the voltage drop of C1. The charge time of C1 will be extremely short because of the RC time constant of CR1 (which is forward-biased and with a low resistance) and C1.

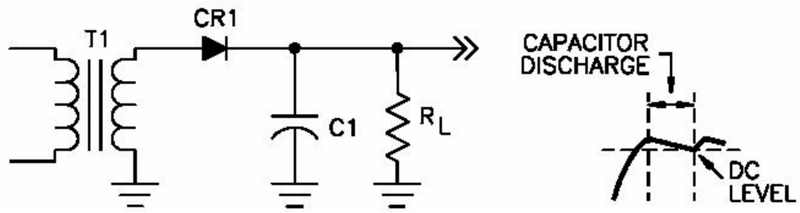


Figure 2. Capacitor Input Filter (Capacitor Discharge)

When the next alternation of the input is felt on the secondary of T1, the top of T1 will be negative. With the negative on the anode of CR1, it will become reverse-biased and will not allow current to flow through it. Now that C1 has a chance to discharge, it will discharge through the load resistor. The RC time constant of RL and C1 should be very long; with this long TC, C1 will discharge very slowly. Due to this slow discharge time, C1 will not be allowed to discharge completely and will retain most of the charge that as placed there during the first alternation. This establishes a high DC level for the output and reduces the output ripple. Refer to Figure 2.

LC Choke-Input Filter

This filter is used in power supplies where voltage regulation is important and current output is relatively high. It is used in radar and communication transmitters. Refer to Figure 3.

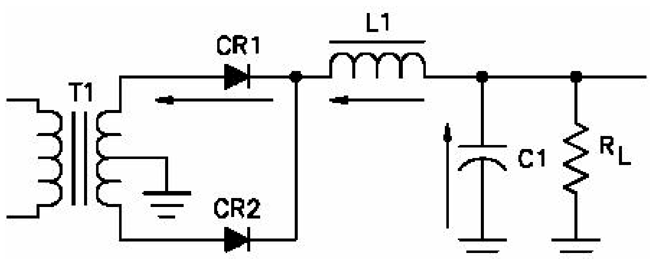


Figure 3. LC Choke-Input Filter (Capacitor Charge Path)

L1 placed in series with the output of the rectifier attempts to keep the current through the load flowing at a constant rate. Figure 3 shows the charge path for C1. Any time the current starts to decrease in this circuit, the magnetic field of L1 will begin to collapse and will attempt to keep current moving at a constant rate. Refer to Figure 4.

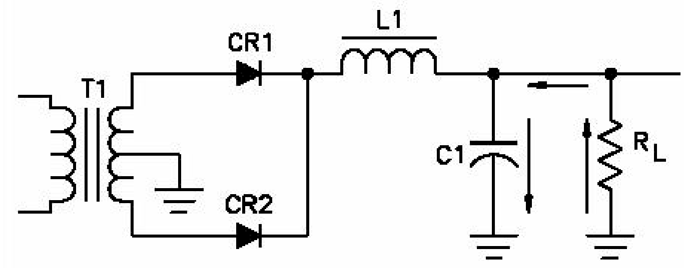


Figure 4. LC Choke-Input Filter (Capacitor Discharge Path)

Figure 4 shows the discharge path for C1. Again, the charge time is short so that C1 can charge rapidly, and the discharge time is extremely long to prevent the capacitor from discharging completely.

LC Capacitor Input Filter

This is one of the most commonly used filters. It is used in circuits that require a low current output and a load current that must be relatively constant, such as those for radio receivers and small audio power supplies. Refer to Figure 5.

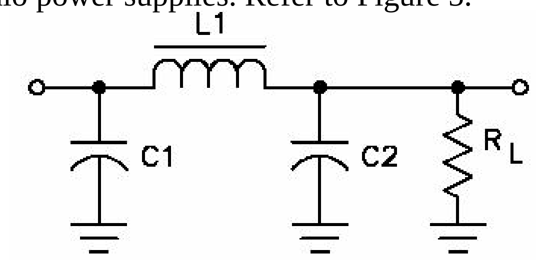


Figure 5. LC Capacitor Input Filter

The purpose of C1 is to reduce the ripple to a relatively low level and, at the same time, to establish the DC level for the output. C1 will charge to the maximum peak value of the input signal. Also, C1 will charge very rapidly but will discharge extremely slowly. With this slow discharge time, the voltage on C1 will not discharge back to zero before the next pulse is felt on C1 and recharges it. L1 and C2 form the LC filter and reduce the ripple even further. L1 has a high value of inductance and a high value of inductive reactance to the ripple frequency. C2 offers a low reactance to the ripple. L1 and C2 form a voltage divider; because of the reactance offered by each component, most of the ripple is dropped across L1 and very little ripple is felt across C2 and the load. L1 and C2 have very little effect on the DC voltage, because the only opposition to current flow is the internal resistance of the wire of L1. The LC filter provides good filtering action over a wide range of currents. C1 filters best when the load is drawing very little current. L1 filters best when the current is highest. The complementary nature of these two components ensures that good filtering will occur over a wide range of frequencies. The LC filter has two disadvantages: it is more expensive to build, and the inductor is heavy and bulky. The combination of rectifier and filter comprises what is normally called the **power supply**. The power supply, as designed for the application, provides the required voltages to satisfy the equipment operation.

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

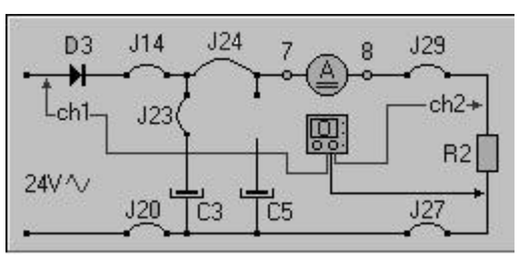
EQUIPMENT REQUIRED

- Above three circuits on breadboard
- Capacitors (4.7μF, 47μF, 470μF)
- Centre tapped transformer (220V-12V)
- Resistors (10kΩ, 100 kΩ)
- Oscilloscope

PROCEDURE

Analysis Capacitive Filter

1. Connect jumpers J14, J24, J29, J27, J20 and the ammeter, for dc current measurements, to produce the circuit of figure B05.9.
2. Connect the oscilloscope to display the ac input voltage on channel, and the voltage across the load (resistor R2) on channel.
3. Observe the voltage across the load on the oscilloscope, and measure the current through the circuit.
4. Connect jumper J23 to produce a capacitive filter with C3.
5. Measure the current through the load; observe and measure the peak-to-peak voltage of the ripple on the load.
6. Disconnect jumper J29 and connect jumper J30, so increasing the load resistance.
7. Take the circuit back to the last configuration, i.e. disconnect J30 and connect J29. Disconnect J23 and connect J25 to increase the capacitance of the filter.
8. Measure the current through the circuit, observe and measure the peak-to-peak voltage of the ripple on the load.



OBSERVATIONS

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

POST-LAB

CALCULATIONS

- Using the formulas given in introduction of this lab, fill out:

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

- Make the same circuit on multisim & attach the print out of observed outputs

EXERCISES

. Select the statement that BEST describes the effect of capacitor filtering on the output of a rectifier.

a. It increases the peak output voltage.
b. It increases the ripple amplitude.
c. It increases the average output voltage.
d. It decreases the frequency of the ripple voltage.

. Increasing the capacitance of the filter capacitor will have what effect on the ripple amplitude?

a. Ripple will increase.
b. Ripple will remain the same.
c. Ripple will double.
d. Ripple will decrease.

. How many diodes are required for a full-wave rectifier?

a. 3
b. 4
c. 2
d. 1

. How often does current flow in a half wave rectifier with reference to the AC input?

a. During the entire AC input
b. Only during half of the AC input
c. When both of the diodes are forward bias
d. When both of the diodes are reverse-biased

. In reference to a full-wave rectifier, ______________________.

a. the output is a pure DC voltage
b. only the positive half of the input cycle is used
c. only the negative half of the input cycle is used
d. the complete input cycle is used

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NED University of Engineering & Technology
Department of ____**ELECTRONIC**__ Engineering
Course Code and Title: ____**EL-232 ELECTRONICS**______

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

Laboratory Session No. ____01_______ Date: _______________________

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

Lab Session 09

OBJECTIVE

To OPERATE under supervision the operation of Diode Limiters.

INTRODUCTION

In power supplies, a device called a rectifier uses a diode limiter. The input voltage to the power supply is a 115 V AC sine wave. The output is a DC voltage. This would be impossible without the simple, yet vital, diode. In this lesson, you will explore how a diode can customize waveforms for you. In order for a complex piece of electronic equipment to function, it requires different shaped signals and triggers. By using limiters and other types of circuits, sine waves and square waves can be converted to practically any shape the circuit requires. The diode limiter is the simplest wave shaping circuit yet designed.

Diode Limiter

The diode limiter can also be called a diode clipper. The definition of a limiter is:

DEFINITION

LIMITER - A device which clips or removes all or part of an existing waveform, above or below a specified bias level.

A basic diode limiter circuit is composed of a diode and a resistor. Depending upon the circuit configuration and bias, the circuit may clip or eliminate all or part of an input waveform. Limiter circuits, which are used for wave shaping and circuit protection, are very simple circuits. The phenomenon that allows a limiter to work is diode biasing. A forward-biased diode conducts, acting almost like a short circuit. It will have a very small voltage drop due to the barrier junction. If the diode is germanium, the drop will be .3 V. If it is a silicon diode, the drop will be .7 V. A reversed biased diode, being cut off, acts as an open circuit. By controlling the cut-off and conduction states of a diode, input waveforms can be customized, or wave shaped. Though this sounds complex, all you do is use biasing to control a diode. The square wave and the sine wave are the most common signals used in electronics. As many electronic applications require different wave shapes, circuits have been developed to alter wave shape. Figure 1 illustrates some typical wave shapes that some applications require and that can be developed by simple limiter circuits.

Figure 1. Wave Shapes

Depending upon how the wave shape is to be altered, one of five simple diode limiter circuits can be used.

1. Series Positive Limiter
2. Series Negative Limiter
3. Parallel Positive Limiter
4. Parallel Negative Limiter

Now, let's examine each diode limiter circuit in detail. Even though any wave shape can be limited, sine waves have been used throughout the discussion for simplicity.

Series Positive Limiter

Figure 2 illustrates a typical series positive limiter circuit. The reasons it is called a series positive limiter are:

- The diode is in series with the output, and
- The circuit eliminates the positive alternation of the input waveform.

When the input waveform goes positive, the diode is reverse biased. A reversed biased diode acts as an open circuit, blocking current flow to the output. Since a forward biased diode acts like a short circuit, the negative alternation of the input signal is developed over R1 without any changes.

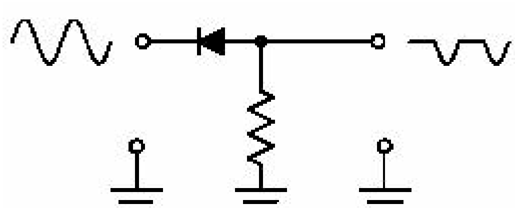


Figure 2. Series Positive Limiter

Series Negative Limiter

Figure 3 illustrates a typical series negative limiter circuit. It is called a series negative limiter circuit because:

- The diode is in series with the output, and
- The circuit eliminates the negative alternation of the input waveform.

When the input waveform goes negative, the diode is reversed biased. A reversed biased diode acts as an open circuit, blocking current flow to the output. Therefore, the negative alternation of the signal is not developed over R1. When the input waveform goes positive, the diode is forward biased. Since a forward biased diode acts like a short circuit, the positive alternation of the input signal is developed over R1, without any changes. Note that a positive limiter eliminates the positive alternation and the negative limiter eliminates the negative alternation. The way to convert from a positive limiter to a negative limiter is to reverse the diode.

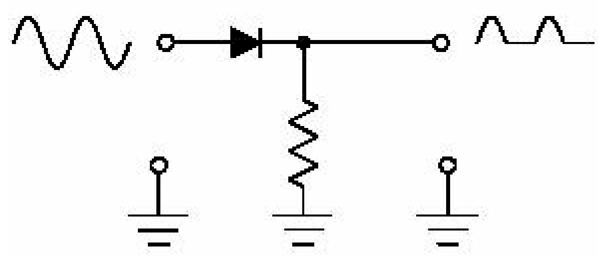


Figure 3. Series Negative Limiter

Parallel Positive Limiter

The limiter circuit depicted in Figure 4 illustrates a typical parallel positive limiter circuit. It is classified as a parallel positive limiter circuit for two reasons:

- The diode is in parallel with the output, and
- The circuit eliminates the positive alternation of the input waveform.

When the input signal goes positive, the diode is forward biased. As a forward biased diode conducts, the positive portion of the input signal is shunted to ground, preventing any signal from being passed out of the circuit. A negative input signal reverse biases the diode. As you remember, a reversed biased diode acts as an open circuit. Therefore, the negative alternation of the input signal is passed to the output.

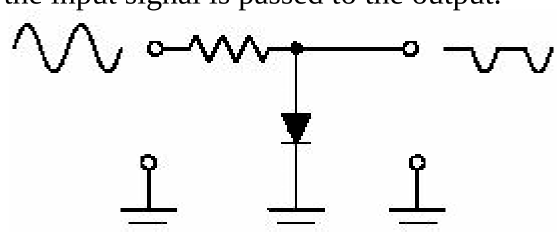


Figure 4. Parallel Positive Limiter

Parallel Negative Limiter

The circuit depicted in Figure 5 illustrates a typical parallel negative limiter circuit. It is classified as a parallel negative limiter circuit for two reasons:

- The diode is in parallel with the output, and
- The circuit eliminates the negative alternation of the input waveform.

When the input signal goes negative, the diode is forward biased. As a forward biased diode conducts, the negative alternation of the input signal is shunted to ground, preventing any signal from being passed out of the circuit output.

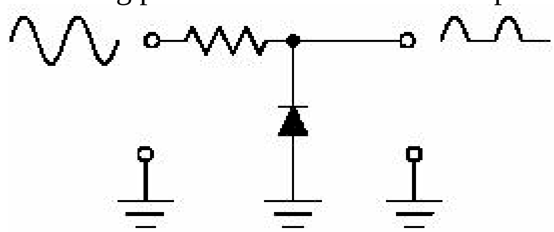


Figure 5. Parallel Negative Limiter

PRE-LAB

OBJECTIVE

To CONSTRUCT the circuits of fig-2-5 on bread board, apply input to the above-mentioned circuits & find out outputs.

EQUIPMENT REQUIRED

- Breadboard
- Silicon Diodes (1N4001)
- Centre tapped transformer (220V-12V)
- Resistor (10kΩ)
- Oscilloscope

OBSERVATIONS

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

POST-LAB

Make the circuit of Fig. fig-2-5 on Multisim & attach the print out of observed outputs

EXERCISES

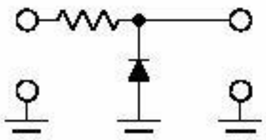
_______ 1. What is the function of a limiter circuit?

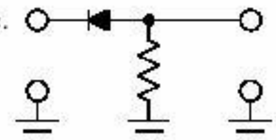
a. Regulate the DC Voltage output level
b. Limit the amplitude of any waveform to a predetermined level
c. Maintain the reference level at a constant value
d. Limit the frequency to a predetermined value

_______ 2. What component is the basis of a limiter circuit?

a. Resistor
b. Capacitor
c. Diode
d. Inductor

_______ 3. From the illustrations below, select the series negative limiter.

a.


c.


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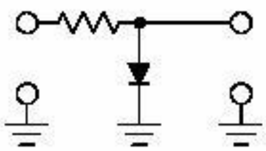
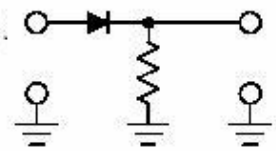
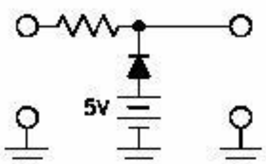
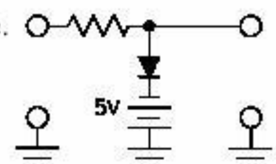
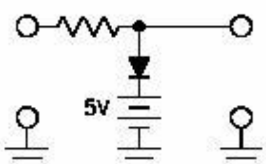


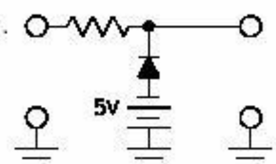
d.


_______ 4. From the illustrations below, select the parallel negative limiter with positive bias.

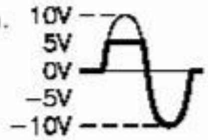
a.


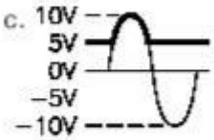
c.


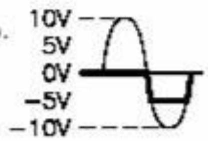
b.


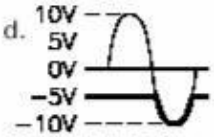
d.


______ 5. Using the illustrations in Question 4, select the correct output waveform for a parallel negative limiter with positive bias.

a. 

c. 

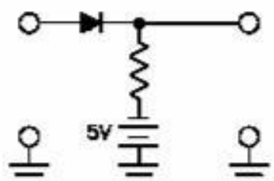
b. 

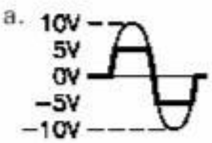
d. 

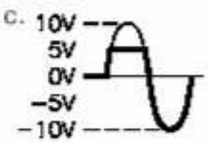
______ 6. What characteristic of a diode makes it useful as a limiter?

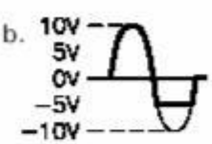
a. Its ability to block current flow
b. Its acting like a short when forward biased and an open when reversed biased
c. Its barrier junction
d. Its being constructed from two dissimilar materials

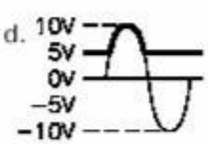
______ 7. Match the limiter circuit to the correct output waveform.



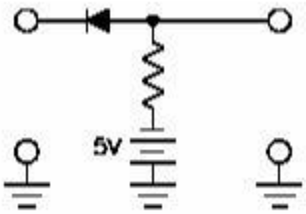
a. 

c. 

b. 

d. 

________ 8. Match the limiter circuit to the correct output waveform.



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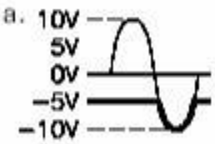

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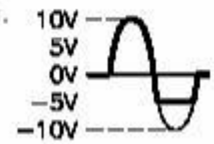

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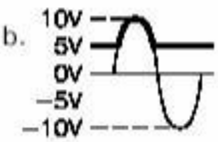

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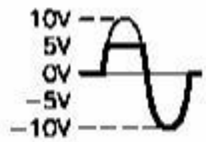
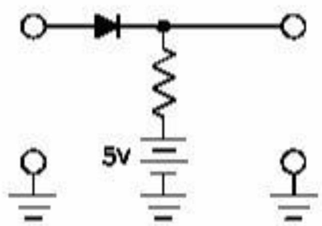
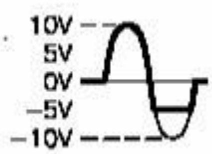
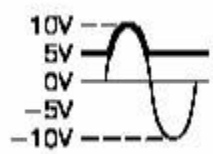


________ 9. Match the limiter circuit to the correct output waveform.



a.


c.


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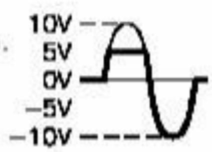
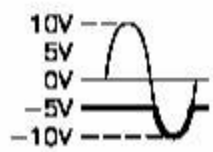


d.


F/OBEM 01/05/00

NED University of Engineering & Technology
Department of ____**ELECTRONIC**__ Engineering
Course Code and Title: ____**EL-232 ELECTRONICS**______

Psychomotor Domain Assessment Rubric-Level P3					
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Equipment Handling ***Equipment care*** during the use.	Doesn't handle equipment with required care.	Rarely handles equipment with required care.	Occasionally handles equipment with required care.	Often handles equipment with required care.	Handles equipment with required care.
Group Work ***Contributes*** in a group based lab work.	Doesn't participate and contribute.	Slightly participates and contributes.	Somewhat participates and contributes.	Moderately participates and contributes.	Fully participates and contributes.

Laboratory Session No. ____01_______ Date: _______________________

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

Lab Session 10

OBJECTIVE

To PRACTICE the operation of Diode Biased Limiters.

Biased Limiters

By the addition of circuit bias, waveforms can be truly customized. Up until now, either the positive or negative alternation of the input waveform could be eliminated. Controlled application of bias enables the partial elimination of a signal. What these simple circuits can do is very interesting.

Biased Negative Series Limiter

Figure 7 illustrates a typical negative limiter circuit with bias applied. The bias is provided by the –5 volt battery in series with R1. As you remember, a negative limiter clips the negative alternation of the input signal and passes the positive alternation to the output. Where this circuit is different from a negative limiter is the application of bias.

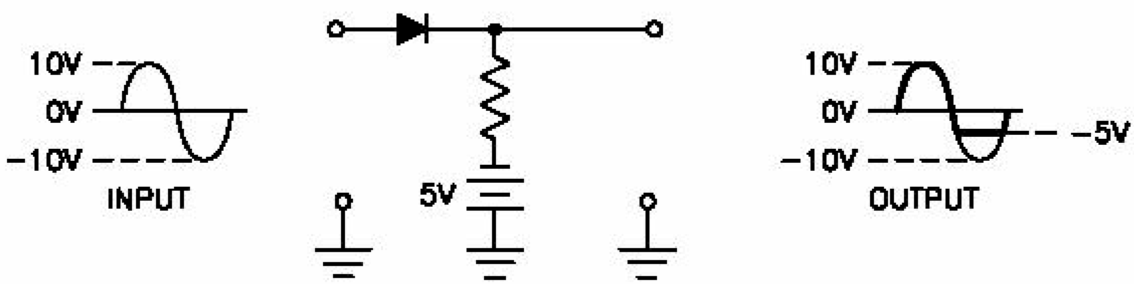

Figure 1. Series Negative with Negative Bias

Due to the applied bias on the cathode, the diode remains in the forward biased state until the signal on the anode drops below –5 volts. That is why the negative alternation of the signal is clipped, or limited, from –5 volts to –10 volts. If positive bias is used, as in Figure 8, the biased negative limiter gives a different output. The diode remains in the cut-off state until the voltage on the anode exceeds +5 volts. As the input is a 20 volts peak-to-peak sine wave, the output from the limiter is less than one half cycle.

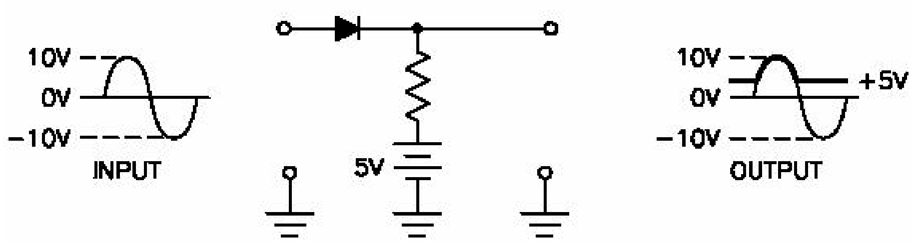

Figure 2. Negative Limiter with Positive Bias

Biased Positive Series Limiter

From its name, you know that this circuit limits the positive alternation of the output signal. Figure 9 depicts a positive series limiter with positive bias. As the anode has +5 volts bias on it, the only time the diode is reversed biased is when the cathode voltage exceeds +5 volts. If negative bias is used, the waveform is altered. In Figure 10, the series positive limiter has a negative bias applied to the anode. That means the diode is reversed biased unless the cathode voltage is less than –5 volts. As a result, the output of the limiter circuit never exceeds –5 volts.

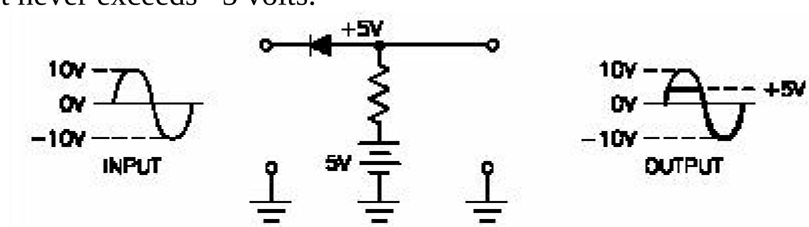

Figure 3. Series Positive Limiter with Positive Bias

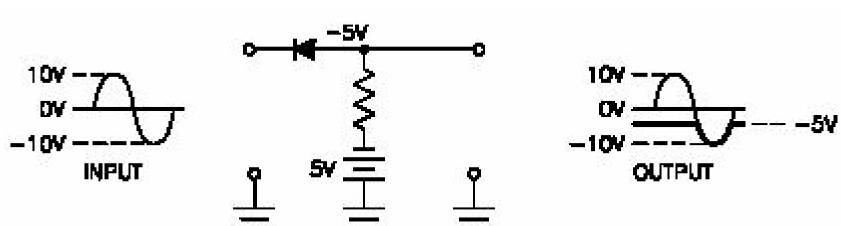

Figure 4. Series Positive Limiter with Negative Bias

Biased Parallel Limiters

With the parallel limiters, remember that if the diode is forward biased, the alternation of the input signal is eliminated by being shunted to ground. By adding bias, the output waveform is a portion of the input waveform. The circuit illustrated in Figure 11 is a parallel positive limiter with positive bias. As the input waveform is 20 volts peak-to-peak and the limiter has +5 volts of bias applied to the cathode, the only time the diode is forward biased is when the input waveform exceeds 5 volts.

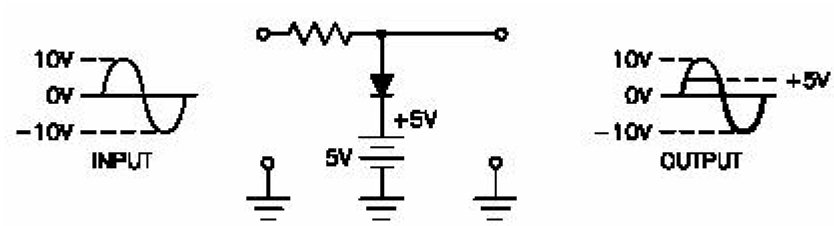

Figure 5. Parallel Positive Limiter with Positive Bias

Changing the bias changes the output waveform. Figure 12 is a parallel positive limiter with negative bias. The only time the limiter is forward biased is when the input signal exceeds –5 volts. When the diode is forward biased, it conducts, and that part of the signal is shunted to ground.

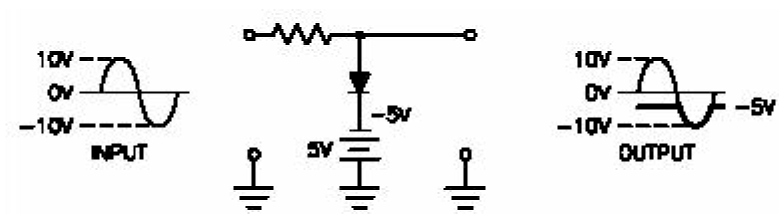

Figure 6. Parallel Positive Limiter with Negative Bias

Negative biased parallel limiters function in just the opposite way. First, let's investigate the negative limiter with positive bias, pictured in Figure 13. Limiting occurs only when the diode is forward biased. The diode remains cut off until the cathode voltage drops below +5 volts. The signal from the limiter is just the positive peak of the input waveform on a +5 volt baseline.

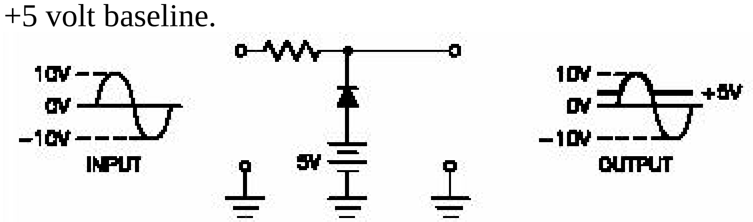

Figure 7. Parallel Negative Limiter with Positive Bias

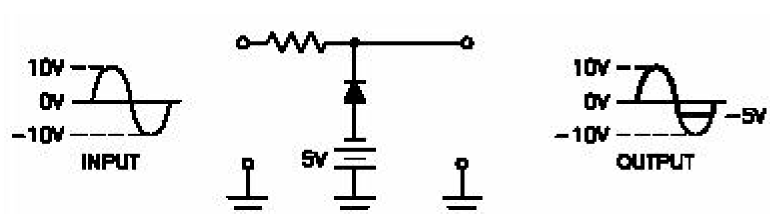

Figure 8. Parallel Negative Limiter with Negative Bias

The final parallel negative limiter uses negative bias. In order for limiting action to occur, the diode must be forward biased. Due to the negative bias on the anode, the diode does not conduct until the signal on the cathode drops below –5 volts. Figure 14 illustrates the circuit and waveform.

PRE-LAB

OBJECTIVE

To CONSTRUCT the circuits of fig-1-8 on bread board, apply input to the above-mentioned circuits & find out outputs.

EQUIPMENT REQUIRED

- Breadboard
- Silicon Diodes (1N4001)
- Centre tapped transformer (220V-12V)
- Resistor (10kΩ)
- Oscilloscope
- DC Power Supply

OBSERVATIONS

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

POST-LAB

Make the circuit of Fig. fig-1-8 on Multisim & attach the print out of observed outputs

F/OBEM 01/05/00

NED University of Engineering & Technology
Department of ____**ELECTRONIC**__ Engineering
Course Code and Title: ____**EL-232 ELECTRONICS**______

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

Laboratory Session No. ____01_______ Date: _______________________

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

Lab Session 11

OBJECTIVE

To MANIPULATE with guidance the operation of Diode Clampers.

INTRODUCTION

Certain applications of electronics require that a signal or waveform be fixed to a specific voltage level. In such situations, a clamper is used to clamp, or restrain, either the upper or lower peak value of a waveform to a fixed DC potential. A DC clamper can also be called a DC Restorer or Baseline Stabilizer. Clamper circuits are found in many advanced applications such as test equipment, instruments, video, radar, and sonar.

The study of the clamper brings together theories from several preceding lessons. You will use information that you learned in your study of capacitors, RC time constants, diodes, and biasing. As you can readily see, each lesson is important, as it is the foundation for succeeding lessons.

What Is A Clamper?

The best way to begin is with the definition.

DEFINITION

DC CLAMPER - A circuit in which either the upper or lower peak of a waveform is fixed to a predetermined level.

As an example, an incoming waveform is a square wave that varies from –15 volts to +15 volts. A positive DC clamper can produce an output that varies from 0 to +30 volts. There are also negative and biased clampers.

RC Time Constant

Since you have previously studied RC time constants, you need only a short review before beginning the discussion of clampers. An RC time constant is the measure of the amount of time required to fully charge or discharge a capacitor. The required time is a function of the value of the resistance and capacitance. The value of one-time constant is calculated by multiplying the resistance by the capacitance. Diode clamping circuit operation is based on the principle of RC time constants.

Positive Diode Clamper

Figure 1 illustrates a positive clamper circuit. The purpose of the circuit is to clamp or reference an input signal to ground (0 volts) with the entire waveform above ground. R1 provides a discharge path for C1. The value of R1 is large so that the discharge time of C1 is very large when compared to the pulse width of the input signal. The purpose of the diode is to provide a fast charge path for C1. After C1 becomes fully charged, it acts as a voltage source. If you compare the input and output waveforms, it is easy to see how a clamper functions. The illustrated circuit uses T1 through T6. T represents time. In the illustration, the input is compared to the output whenever the input changes. By using the T, we have a reference with which to compare events.

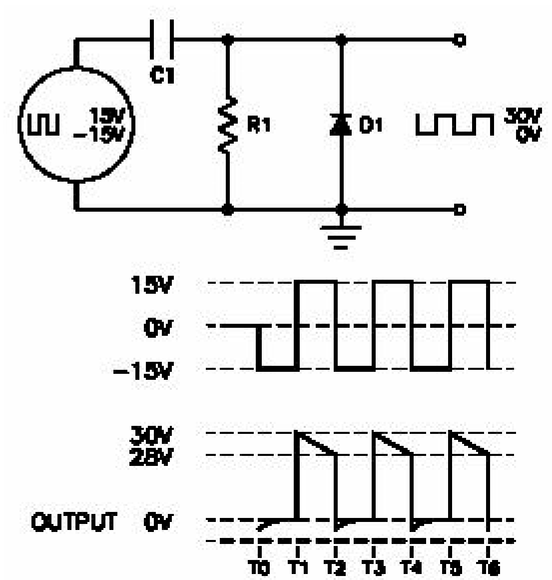

Figure 1. Positive Clamper and Waveform

At T0, the –15 volt input signal appears across the diode and resistor. That is because, at the first instant, the forward biased diode places ground on the right side of the capacitor. The initial voltage across D1 and R1 causes a voltage spike in the output. Because D1 is forward biased, it has a very small resistance, resulting in C1's charge time being almost instantaneous. The –15 volts felt on the cathode of D1 and ground on the anode provides that forward bias. When the voltage drop across C1 reaches –15 volts, the value of the output voltage is 0 volts. At T1, the +15 volt input signal and the –15 volt charge of C1 are in series and aid each other. As a result, +30 volts appears across R1 and D1. The +30 volts on the cathode of D1 provides reverse bias, pushing it into cut-off. From T1 to T2, C1 discharges to about 13 volts because of the large value of R1. That causes the output to decrease to about +28 volts. At time T2, the input signal changes from +15 volts to –15 volts. The –15 volt input is now series opposing with the 13 volts across C1. That leaves about –2 volts on the cathode D1, and it goes into conduction. From T2 to T3, D1 conduction rapidly charges C1 to +15 volts, and the output changes from –2 volts to 0 volts. At T3, the charge on C1 and the input signal are again series aiding. As a result, the output voltage is +30 volts. From T3 to T4, C1 again discharges to 13 volts through R1

At this point, T3 to T4 is the same as T1 to T2. The operation of the circuit for each 360o cycle of the input square wave is identical. The input waveform has been changed from varying from –15 volts to +15 to varying from 0 volts to +30 volts. Except for the reference level being changed, the output is almost identical to the input. If you compare the input and output waveforms in Figure 1, you will notice several important facts.

- The peak-to-peak amplitude of the input signal is not changed by the clamper circuit.
- The shape of the output waveform is almost identical to the input waveform.
- The output waveform is referenced to, or clamped to, ground rather than appearing above and below ground.

If the input signal amplitude changes, the negative peak remains clamped to ground. If the input amplitude decreases, the charge on C1 decreases, decreasing the output. If the input amplitude increases, C1's charge increases, increasing the output. The charge on the capacitor is dependent upon the size of the input signal.

Negative Diode Clamper

The negative clamper illustrated in Figure 2 is identical to the positive clamper, except the positive peak value of the waveform is clamped to ground, resulting in the entire waveform being negative. The components in the negative clamper circuit are identical to the positive clamper, except the diode is reversed. As can be seen from the illustration, a 50 volt peak-to-peak square wave varying around 0 volts (+25 volts to –25 volts) is applied to a negative diode clamper. The output from the circuit is a –50 volt square wave with the peak positive point referenced to 0 volts.

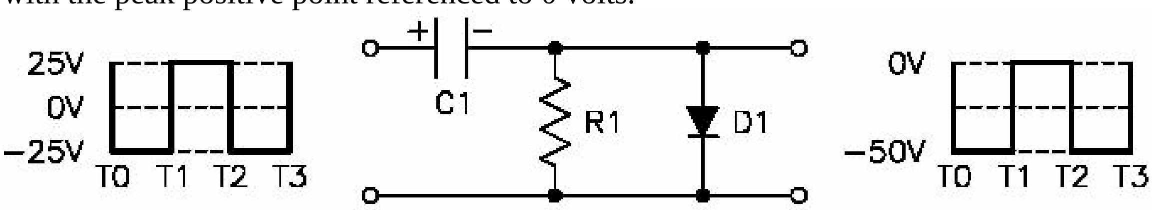

Figure 2. Negative Clamper Circuit

One point you may have noticed is that the arrow of the diode points in the direction of the circuit reference. If the arrow of the diode points up, the circuit is a positive clamper. If the arrow points down, the circuit is a negative clamper.

PRE-LAB

OBJECTIVE

To CONSTRUCT the circuits of fig-1-2 on bread board, apply input to the above-mentioned circuits & find out outputs.

EQUIPMENT REQUIRED

- Breadboard
- Silicon Diode (1N4001)
- Capacitor (4.7μF)
- Centre tapped transformer (220V-12V)
- Resistor (10kΩ)
- Oscilloscope

OBSERVATIONS

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

POST-LAB

Make the circuit of Fig. fig-1-2 on Multisim & attach the print out of observed outputs

F/OBEM 01/05/00

NED University of Engineering & Technology
Department of ____**ELECTRONIC**__ Engineering
Course Code and Title: ____**EL-232 ELECTRONICS**______

Psychomotor Domain Assessment Rubric-Level P3					
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Laboratory Session No. ____01_______ Date: ________________________

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

Lab Session 12

OBJECT

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.)

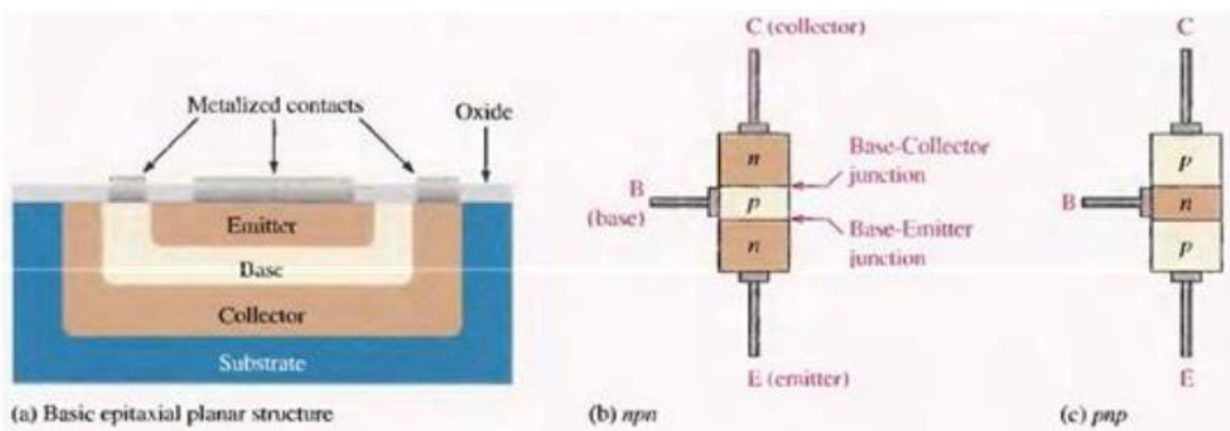


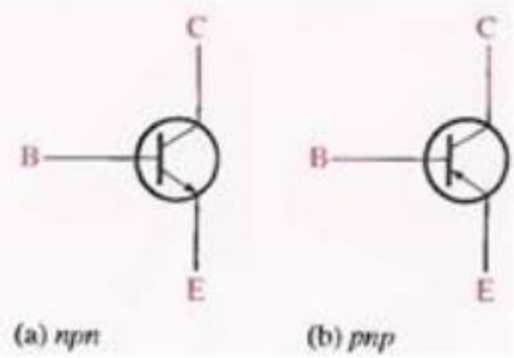
FIGURE 4-1

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.



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.

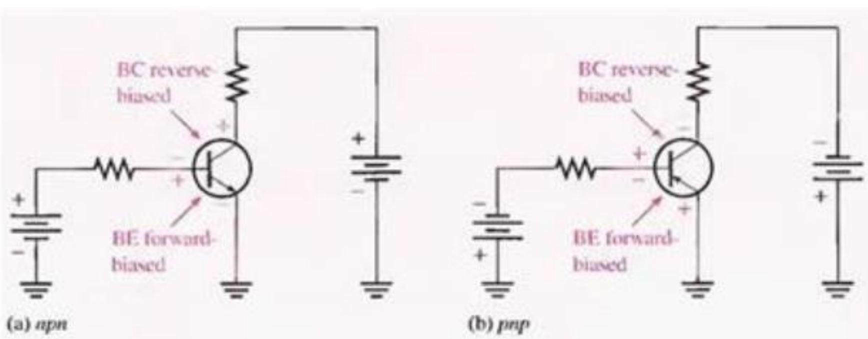


FIGURE 4–3

Forward-reverse bias of a BJT.

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.

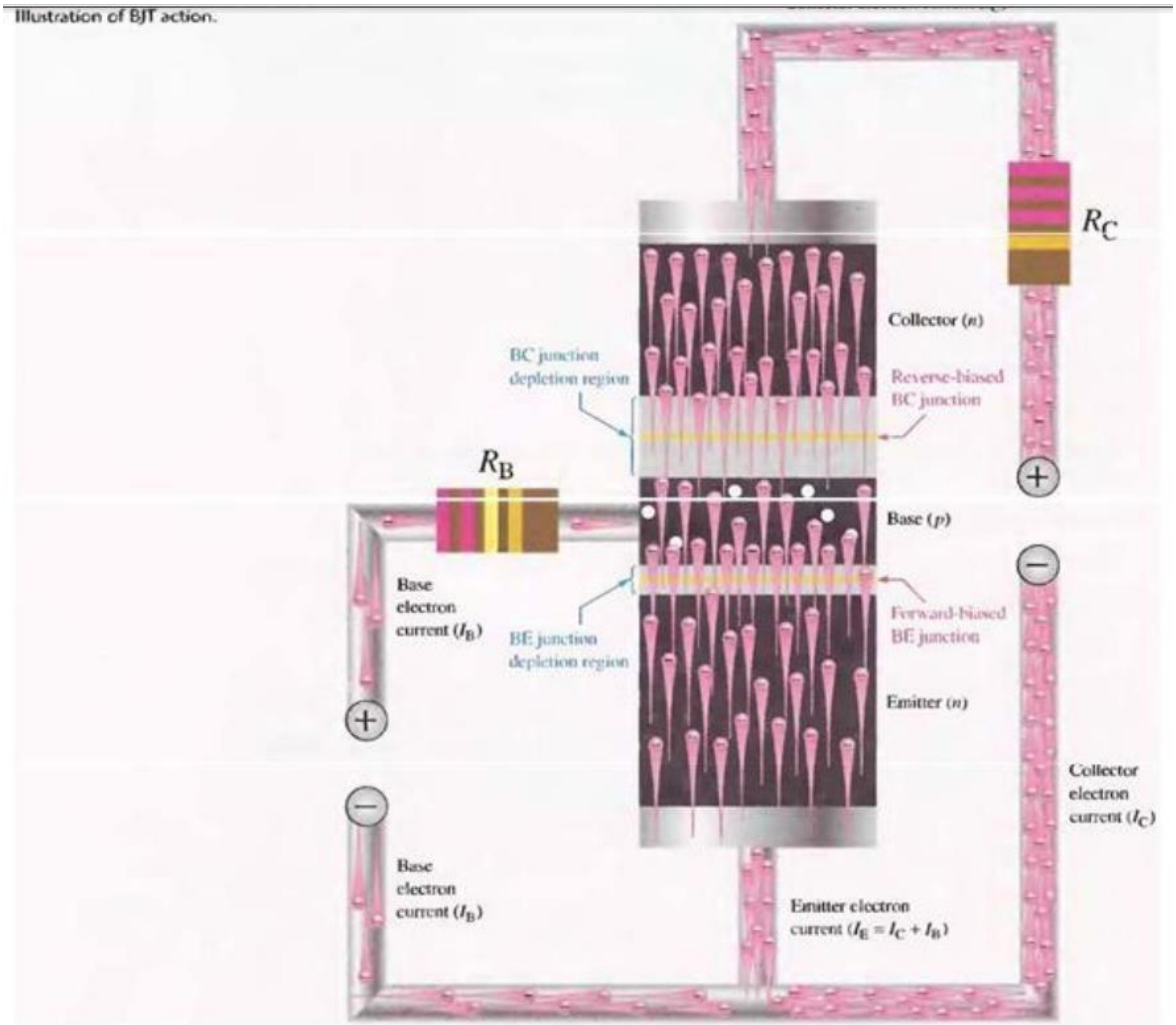


Fig. 4-4

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.

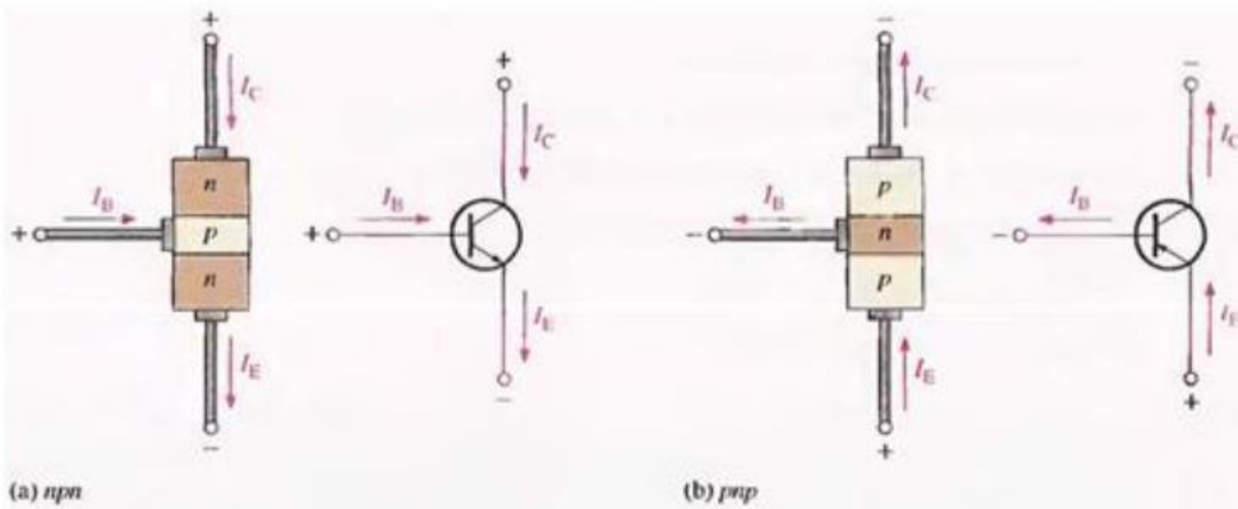


FIGURE 4–5

Transistor currents.

These diagrams show that the emitter current (I_E) is the sum of the collector current (Ic) 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 Vcc 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, Vcc is normally taken directly from the power supply output and V_{BB} (which is smaller) can be produced with a voltage divider.

DC Beta (β_{DC}) and DC Alpha (α_{DC})

The ratio of the dc collector current (Ic) to the dc base current (I_B) is the dc beta (β_{DC}), which is the dc current gain of a transistor.

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

Typical values of β_{DC} range from less than 20 to 200 or higher. β_{DC} is usually designated as an equivalent hybrid (h) parameter, h_{FE} , on transistor data sheets.

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

The ratio of the dc collector current (Ic) to the dc emitter current (I_E) is the dc alpha (α_{DC}). The alpha is a less-used parameter than beta in transistor circuits.

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

Typically, values of α_{DC} range from 0.95 to 0.99 or greater, but α_{DC} is always less than 1. The reason is that I_C is always slightly less than I_E by the amount of I_B. For example, if I_E = 100 mA and I_B = 1 mA, then I_C = 99 mA and α_{DC} = 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

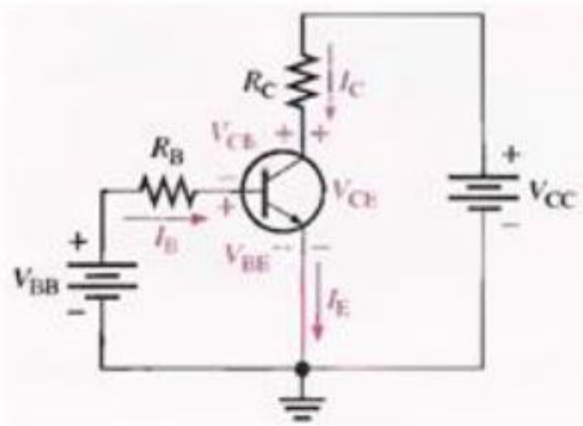


FIGURE 4–7

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

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

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, V_{CE} for specified values of base current, I_B. Notice in the circuit diagram that both V_{BB} and Vcc are variable sources of voltage.

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

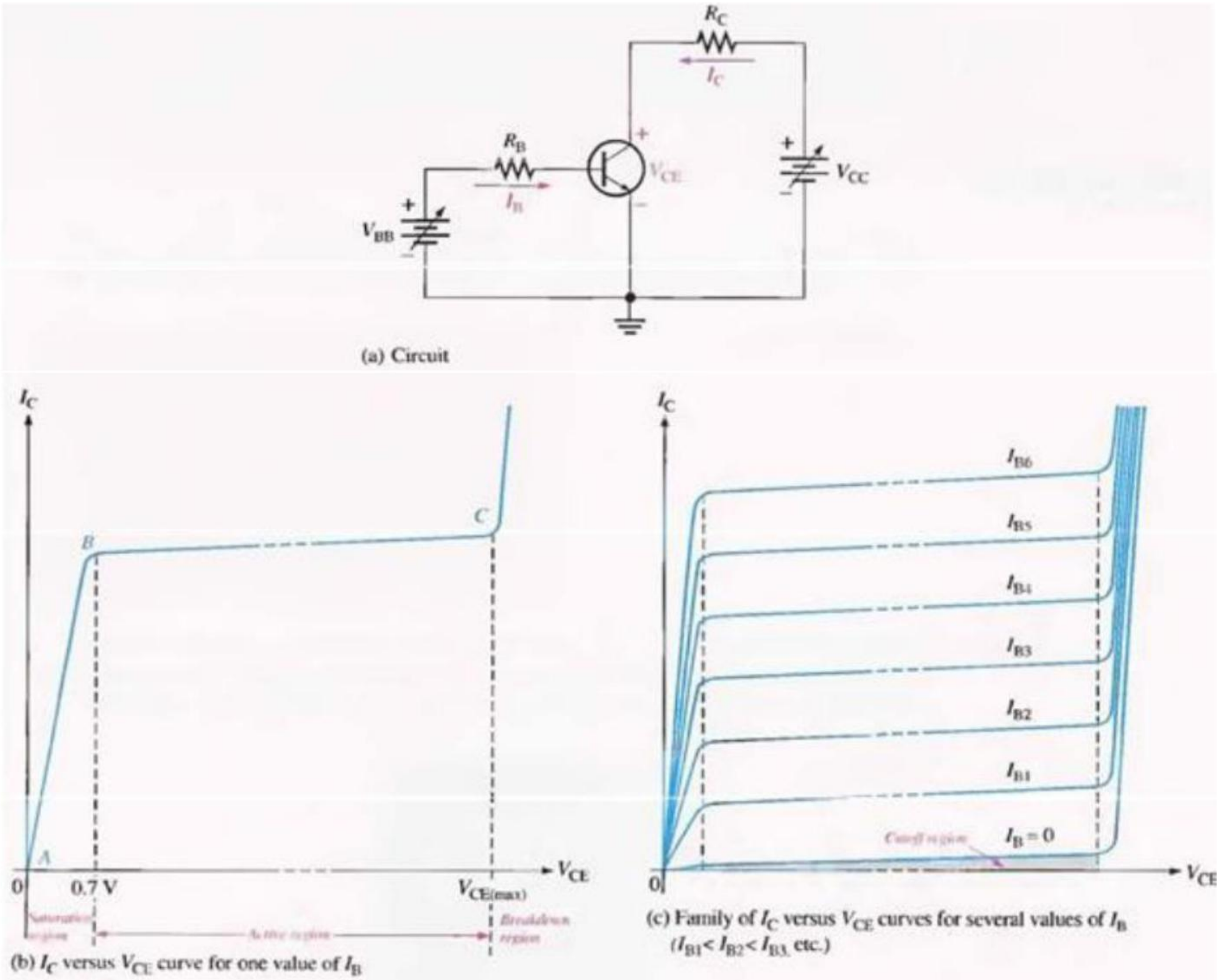


FIGURE 4–9

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 $I_c = \beta_{DC} I_B$. 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.

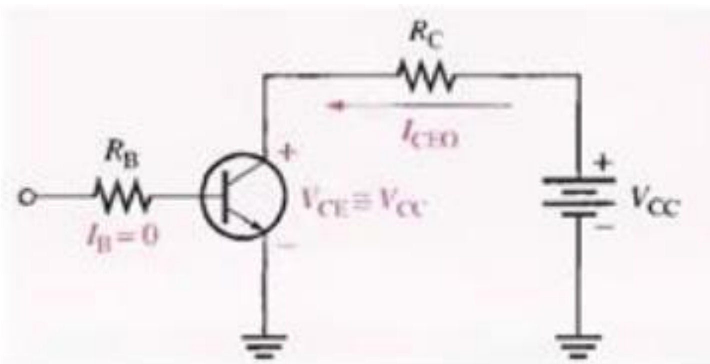


FIGURE 4–12

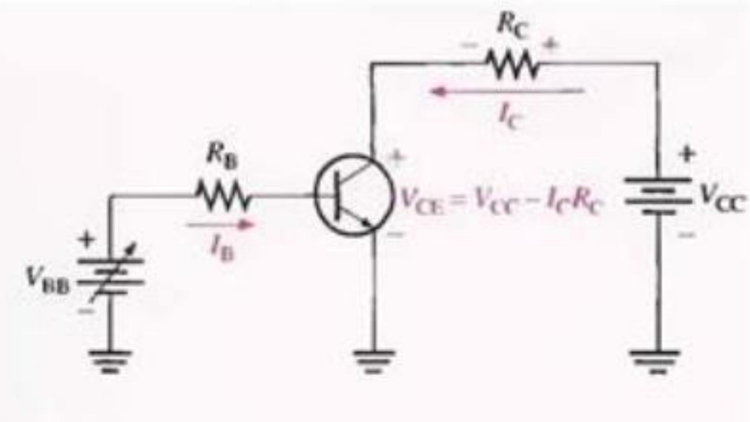
Cutoff: Collector leakage current (I_{CEO}) is extremely small and is usually neglected. Base-emitter and base-collector junctions are reverse-biased.

Saturation

When the base-emitter junction becomes forward-biased and the base current is increased, the collector current also increases ($I_c = \beta_{DC} I_B$) 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 $I_c = \beta_{DC} I_B$ 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.

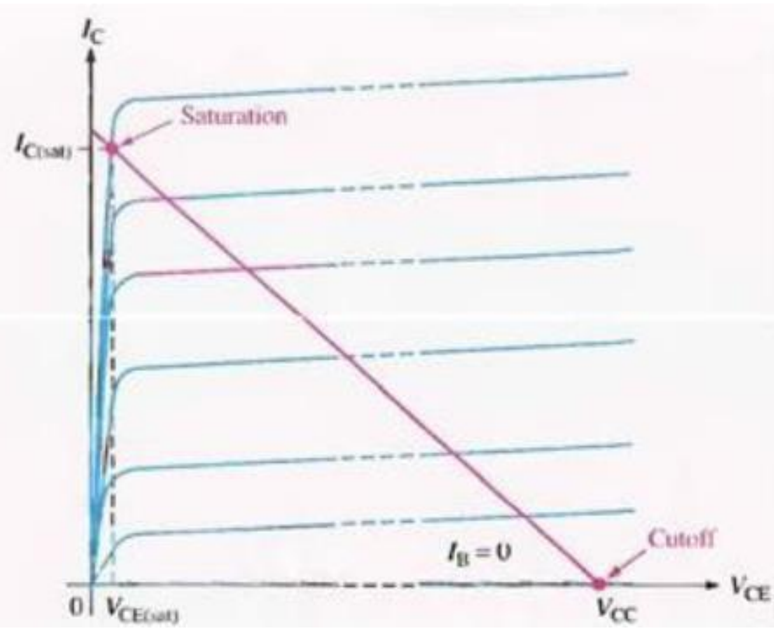


DC load line

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.



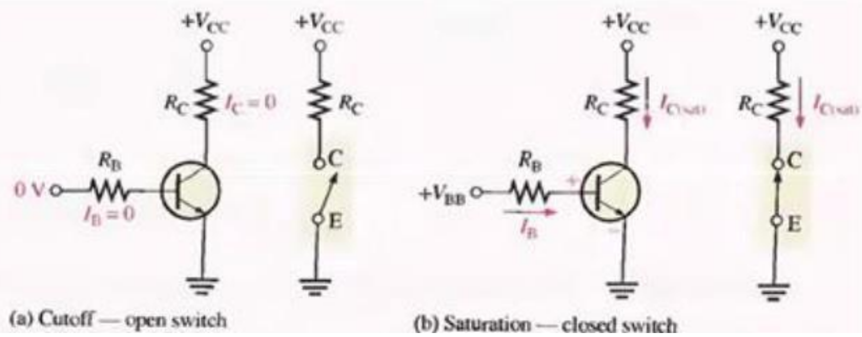
THE TRANSISTOR AS A SWITCH

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.

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.



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}.

$$V_{CE(cutoff)} = V_{CC} \qquad \text{Equation 4–9}$$

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:

$$I_{C(sat)} = \frac{V_{CC} - V_{CE(sat)}}{R_C} \qquad \text{Equation 4–10}$$

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

$$I_{B(min)} = \frac{I_{C(sat)}}{\beta_{DC}} \qquad \text{Equation 4–11}$$

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.

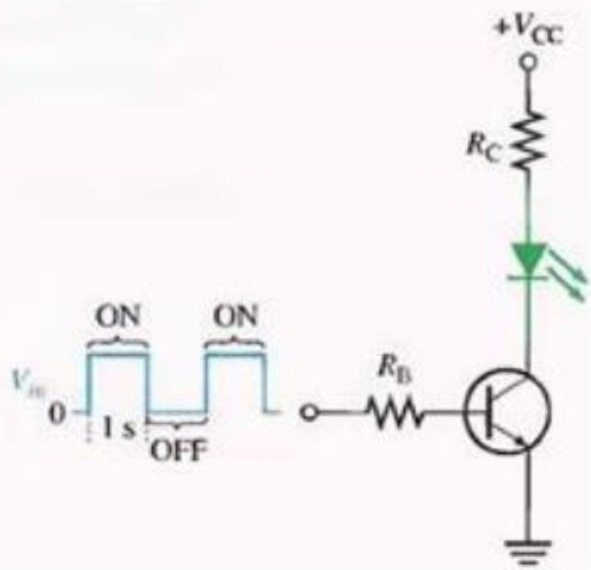


FIGURE 4-24

A transistor used to switch an LED on and off.

PRE-LAB

OBJECTIVE

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

EQUIPMENTS REQUIRED

- Breadboard
- PNP & NPN transistors (2N222, 2N3904 etc)
- Resistors
- DC Power Supply
- Multimeter

PROCEDURE

- First check the transistors for their pin configuration.
- 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).
- Now check this same circuit with resistor values found from above simulation on bread board.
- Plot the curve on graph paper.
- Now from the graph, try to set a suitable value of Vcc such that the transistor is in middle of saturation region.
- 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).
- Again from the graph, try to set a suitable value of Vcc such that the transistor is in middle of active region.
- Note down all the values of current & voltages using digital multimeter. Find VC, VB, VE with respect to ground & IC, IE, IB.
- To experience cut off region, just put VBB < 0.5 V find out all values of currents & voltages.
- Place all the values of currents & voltages in following chart.
- 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			
IE			
IC			
VB			
VE			
VC			

CALCULATIONS

Cutoff Region:	Saturation Region:	Active Region:

POST-LAB

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)

IC	VCE

IC	VCE

EXERCISES

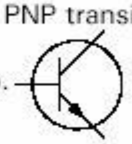
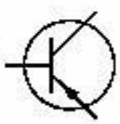
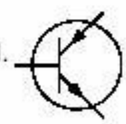
1. A transistor consists of __________ PN junctions and __________ elements.

   a. 3, 2
   b. 2, 2
   c. 3, 3
   d. 2, 3

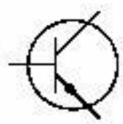
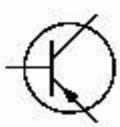
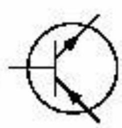
2. The names of a transistor's elements are _____________ .

   a. anode, cathode
   b. emitter, base, collector
   c. emitter, base, anode
   d. collector, base, cathode

3. Choose the correct symbol for a PNP transistor.

   a. 
   b. 
   c. 
   d. 

4. Choose the correct symbol for an NPN transistor.

   a. 
   b. 
   c. 
   d. 

5. What is the thinnest element of a transistor?

   a. Emitter
   b. Base
   c. Collector
   d. All are the same size.

6. The total current flowing through a transistor passes through the ________________ .

   a. emitter
   b. base
   c. collector
   d. emitter and base

7. What is the primary difference between NPN and PNP transistors?

   a. Quantity of materials used in construction
   b. Polarity of voltage
   c. Number of elements
   d. Number of junctions

8. For an NPN transistor to conduct, ____________________________.

   a. the base must be more positive than the collector, but negative compared to the emitter
   b. the emitter must be the most positive, the base the least positive
   c. the collector must be the least positive, the base more positive than the collector, and the emitter the most positive
   d. the emitter must be the least positive, the base more positive than the emitter, and the collector the most positive

9. What component allows the transistor to amplify?

   a. R_L
   b. R_B
   c. C_C
   d. Q_1

10. What is the difference between the schematic symbols for an NPN transistor and a PNP transistor?

   a. The direction of the arrow on the collector
   b. The element with the arrow
   c. The direction of the arrow on the emitter
   d. The number of elements

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

Laboratory Session No. ____01_______ Date: _______________________

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

OPEN ENDED LAB

OBJECTIVE

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

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

- Depletion Type
- Enhancement

The symbols for both configurations of MOSFETs are shown below in Fig. oel.1.

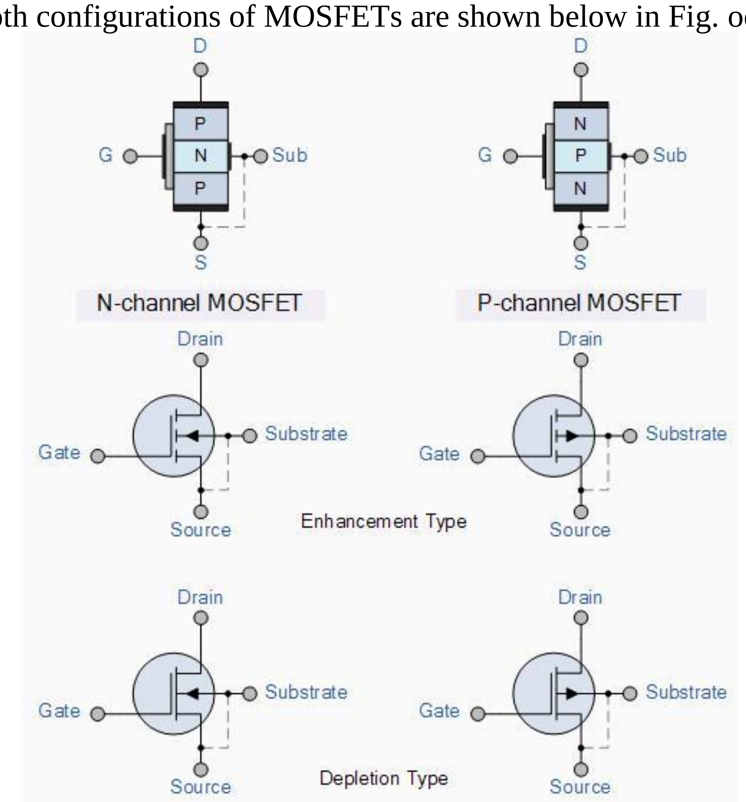

Fig.1 Open Ended Lab regarding symbols

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.

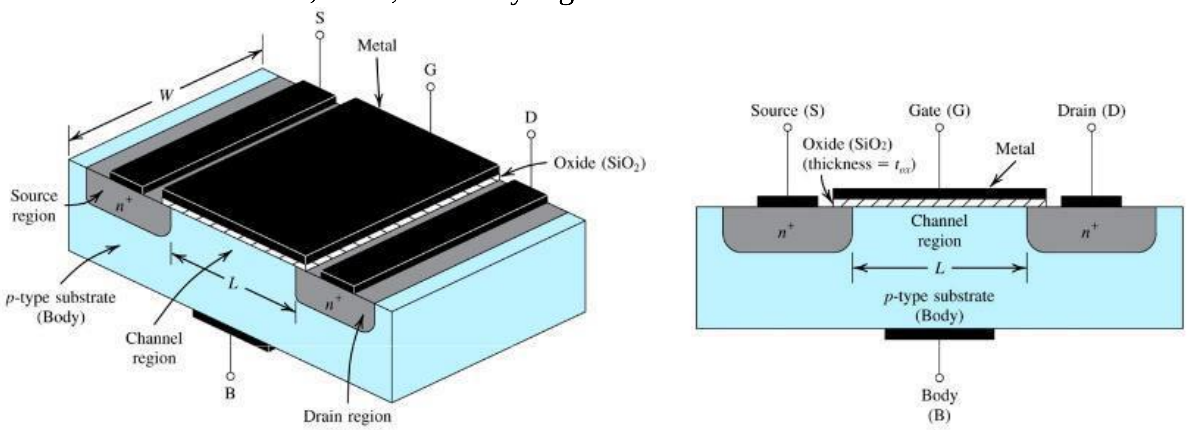

Fig.2 Open Ended Lab regarding MOSFET

Modes of operation

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

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

PRE-LAB

OBJECTIVE

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

EQUIPMENT REQUIRED

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

PROCEDURE

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

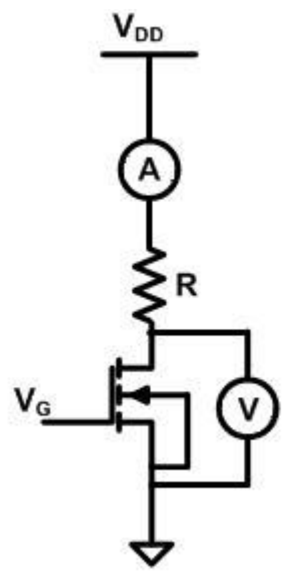

Fig.3 Open Ended Lab regarding procedure

OBJECTIVE

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

PROCEDURE

- Apply appropriate values of V_G and V_{DD}
- Connect a voltmeter across the drain source terminal of NMOS to determine the value of V_{DS}
- Connect ammeter to determine drain current (I_D)
- 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			

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

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